AKADEMIE DER WISSENSCHAFTEN DER DDR
Forschungsbereich Geo- und Kosmoswissenschaften
ZENTRALINSTITUT FUR PHYSIK DER ERDE

Veröffentlichungen des Zentralinstituts für Physik der Erde
Nr. 66

Tectonic Regime of Molasse Epochs

Comparative Analysis of the Formation of Paleozoic and Cenozoic Molasses in Central and South-East Europe and Some Regions of U.S.S.R.

Report on Activities of Working Group 3.3
Multilateral Cooperation of the Academies of Sciences
of the Socialist Countries, Problem Commission IX

Compiled by
H. LÜTZNER, G. SCHWAB
by Order of the Members of Working Group 3.3

Editor: The Director of the Central Earth Physics Institute Potsdam
Potsdam 1982

Wissenschaftliche Redaktion: Dr. sc. H. Lützner

F 267/82 P 204/81

Contents

V o r w o r t

Der Sammelband "Tectonic Regime of Molasse Epochs" faßt Forschungsergebnisse in einer ersten Etappe zusammen, die durch die Mitglieder der Arbeitsgruppe 3.3 "Tektonisches Regime der Epochen der Molassebildung" der Problemkommission IX der multilateralen Zusammenarbeit der Akademien sozialistischer Länder zum Thema "Geosynklinalprozeß und Entwicklung der Erdkruste" während der Jahre 1975 - 1980 erarbeitet wurden.

Die damit verbundene wissenschaftliche Zielstellung -- Klärung der endogenen und auch exogenen Gesetzmäßigkeiten der Krustenentwicklung während der Molasseetappen -- ist integrierter Bestandteil der Gesamtaufgabenstellung der Problemkommission IX in bezug auf die Krustengenese. Denn die Molasseetappe charakterisiert in der Krustenentwicklung einen markanten Abschnitt des Wechsels von der Mobil-(Geosynklinal-) zur Stabil-(Tafel-)Etappe. Entsprechend sind die Bewegungsvorgänge dieses Zeitabschnittes im Sediment der Becken als "Beckenfüllungen" besonders deutlich materialisiert. Charakteristisch sind Bruchvorgänge, die noch von postumen großwelligen Deformationsvorgängen der vorausgegangenen Faltungsepoche (Tektogenese), wie sie in synsedimentären Strukturen zum Ausdruck kommen, überlagert werden. Die Deformationsintensität nimmt entsprechend zum Hangenden ab, wie die zunehmende Korrelierbarkeit der Sedimente in der gleichen Richtung zeigt.

Generell ist daher die spezielle Untersuchung des Abschnittes der Molasseetappe mit lithologischen Methoden in mehrfacher Hinsicht von grundlegender Bedeutung:

(1) zum Nachweis der vertikalen Änderung der Deformationsintensität des Krustenregimes, insbesondere unter Einbeziehung des Magmatismus dieser Etappe,

(2) zur Analyse der lateralen Beziehungen zwischen Tektogen (Mobilzonen) und Vorland (Kraton, Tafel), da die Molassesedimente und z.T. auch Magmatite (subsequenter Vulkanismus) beide geotektonische Strukturbereiche gemeinsam überdecken.

Die Klärung dieses grundlegenden Problems der Molasseetappe ist ident mit der Fragestellung nach dem "break-up" von Platten und der Wechselwirkung von Subduktionszonen (einschließlich ihres Magmatismus) mit der Intraplattentektonik im Sinne der modernen Plattentektonik (Mobilismus).

Diese integrierte Aufgabe wurde seitens der Arbeitsgruppe 3.3 der Problemkommission IX systematisch und daher auch in zeitlicher Hinsicht mittel- und langfristig in Angriff genommen. Als erster Schritt zur Lösung der gemeinsamen Aufgabe durch die in der Arbeitsgruppe kooperierenden Geologen aus sieben sozialistischen Ländern wurden zunächst lithologisch-tektonische Typusprofile nach einheitlicher Legende einer größeren Anzahl von Molassebecken zusammengestellt, deren Dokumentation und Erläuterung den Hauptteil des vorliegenden Bandes einnimmt. Dadurch wurde erreicht, daß die Aufnahme- und Darstellungsmethodik erstmalig zwischen den beteiligten Ländern für Aspekte der Grundlagenforschung nach inhaltlichen Aspekten vereinheitlicht wurde; die erzielten Ergebnisse sind somit untereinander vergleichbar.

DOI:https://doi.org/10.2312/zipe.1982.066

Durch die zusammenfassende Darstellung sedimentologischer, fazieller und tektonischer Merkmale für fast 40 Abfolgen paläozoischer und känozoischer Molassen Mittel- und Südosteuropas sowie der UdSSR ließen sich auf diesem Wege vergleichende Aussagen erreichen, so z.B. zum lithologischen Aufbau, zu den Mächtigkeiten und Bildungsbedingungen, zur Dauer der Molassesedimentation und zur Größe der Akkumulationsraten verschiedener gebirgsbildender Epochen sowie zugleich auch Aussagen über die zeitliche und räumliche Korrelation der Molassebildungsstadien innerhalb der einzelnen tektonischen Ären. In methodologischer Hinsicht ist der überregionale Ansatz (Vergleich) der Typenprofile gleichbedeutend mit einem Verallgemeinerungseffekt zur Ableitung allgemeiner Gesetzmäßigkeiten der Molassengenese, da die Lokaleffekte auf diese Weise erfahrungsgemäß eliminiert wurden.

Die speziellen Untersuchungen der Arbeitsgruppe 3.3 sind vorrangig eingebunden in die wissenschaftlichen Zielstellungen der Unterkommission 3 der Problemkommission IX, die auf die Charakterisierung von tektonischen Bewegungen, sedimentären und magmatischen Prozessen der Flysch- und Molassestadien der Geosynklinalentwicklung orientiert sind. Hierin ist ein Hauptwert der durch die Arbeitsgruppe erarbeiteten Profildarstellungen zu sehen. Denn hierdurch wird die unmittelbare Verbindung der sedimentologischen Daten mit den magmatischen Prozessen und olisthostromaren Bildungen während der Epochen der Molassenbildung möglich, wie sie von anderen Arbeitsgruppen der Unterkommission beschrieben wurden. Durch eine komplexe Betrachtungsweise sind zukünftig vertiefte Einblicke in die ablaufenden tiefkrustalen Vorgänge und Informationen über die Intensität der vertikalen Krustenbewegungen am Ende der Mobiletappe zu erwarten. Liegt das Schwergewicht der vorliegenden Untersuchungen noch auf der beschreibenden Darstellung der geologischen Sachverhalte, so wird es die Aufgabe der weiteren Kooperation sein, durch eine geeignete Verknüpfung der Teilergebnisse der verschiedenen Arbeitsgruppen der PK IX zu einer Erweiterung der geologischen Kenntnisse über den Charakter der tektonischen Bewegungen kontinentaler Mobil- und Aktivitätszonen im Übergangsstadium zum tektonischen Tafelregime zu gelangen. Eine derartige Aussage ist gleichbedeutend mit vertieften Aussagen über die kontrollierenden Faktoren der Lagerstättenbildung und Akkumulation mineralischer Rohstoffe, so für die Kohlenwasserstofführung oder die Minerogenie von Schwermetallen und Kaustobiolithen.

Neben seinen inhaltlichen Aussagen verdient der vorliegende Band auch aus wissenschaftsorganisatorischen und methodischen Gründen besondere Beachtung. So gelang es den Mitarbeitern der internationalen Arbeitsgruppe durch die Erarbeitung der lithotektonischen Profile eine neue Arbeitsgrundlage und damit Ausgangsposition zu finden, durch die die internationale Kooperation im Rahmen der PK IX neue Impulse erhielt. Damit ist besonders die kollektive Erarbeitung einer übergeordneten Problemorientierung der lithologischen Forschungsarbeiten vieler Spezialisten der Teilnehmerländer in Richtung auf eine krustengenetische Aussage gemeint, die in der Regel für einen einzelnen Fachspezialisten nur sehr langfristig erreicht werden kann. Auch kann unter diesen neuen Bedingungen eine übergeordnete Fragestellung des Vergleiches von jungen und alten Molassen verschiedener Deformationszyklen (Alpiden, Varisziden) in Angriff genommen werden, nämlich die erkenntnistheoretische wichtige Frage nach der Evolution derartiger Krustenprozesse in Raum und Zeit.

DOI:https://doi.org/10.2312/zipe.1982.066

Der Vertiefung dieser internationalen Zusammenarbeit dient ebenfalls die Arbeit am internationalen Wörterbuch "Molasse", über dessen methodische Bearbeitung und Zusammenstellung in einem Beitrag dieses Bandes berichtet wird.

Als Ständiger Vertreter der Akademie der Wissenschaften der DDR für die PK IX, die mit der Leitung der Arbeitsgruppe 3.3 beauftragt ist, möchte ich allen Mitgliedern der Arbeitsgruppe, aber auch den zahlreichen an dieser Arbeit beteiligten Spezialisten der Teilnehmerländer für ihren aktiven Einsatz danken, den sie bei der Realisierung ihrer Aufgabe gezeigt haben. Mein besonderer Dank in diesem Zusammenhang gilt Herrn Dr. G. SCHWAB als Vorsitzenden der Arbeitsgruppe 3.3 und Herrn Dr. sc. H. LÜTZNER für die sehr sorgfältige wissenschaftliche Redaktion dieses Sammelbandes.

Der Akademie der Wissenschaften der DDR gebührt der Dank aller beteiligten Kollektive für die Bereitstellung der Mittel zur Durchführung von Geländearbeiten im Territorium der DDR sowie zur Drucklegung des vorliegenden Sammelbandes.

Prof. Dr. sc. K.-B. JUBITZ
Ständiger Vertreter der Akademie
der Wissenschaften der DDR in der
Problemkommission IX

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

On the activities of working group 3.3 "Tectonic regime of epochs of molasse formation" in the period 1975 - 1980

by

G. SCHWAB [1]

After founding the problem commission IX "Geosynclinal process and development of the Earth's crust" in 1974 the working group 3.3 was established as one of the first groups during a meeting at Berlin, G.D.R., in March 1975.

The main task of the group is to compare the formation of Paleozoic (Caledonian and Variscan) and Cenozoic (Alpidic) molasses and their domaines of occurrence (molasse basins in a broad sense) using lithological, facial, and tectonic criterions. The scope of the comparative researches, carried out in all member countries, is to get new ideas about the temporal, spatial, and substantial relations of sedimentary and volcanic molassic rocks and their regions to the tectonic activities in the mobile belts at the end of geosynclinal process. In this connection a number of scientific problems are waiting to be solved not at least with regard to origin and occurrence of mineral deposits.

Such problems are (1) the subdivision of molasse formation in periods and their comparison in the regions of mobile belts being in research by the members of the working group; (2) the characterization of tectonic impulses and of tectonic state of the Earth's crust during molasse formation by means of lithologic and tectonic analysis; and (3) the temporal correlation of tectonic movements proved in molasse basins, in morphogenous areas of uplift, and in neighbouring platform regions. A special problem is being expressed by the occurrence of olisthostromes as a sedimentation type which indicates a high grade of tectonic mobility.

To approach this questions we consider the molasse formation as an evolution stage between the geosynclinal process in a narrower sense and the stage of cratonization. Therefore the topics of working group 3.3 are comprised in the objects of view of subcommission 3 "Tectonic movements, sedimentary and magmatic processes" of problem

[1] Zentralinstitut für Physik der Erde AdW, Institutsteil Berlin; DDR, 1199 Berlin-Adlershof, Rudower Chaussee 5

DOI:https://doi.org/10.2312/zipe.1982.066

commission IX. Within the scope of the five working groups ("Flysch", "Olisthostromes", "Molasses", "Subsequent magmatites", "Carbonates") there are comparative investigations of flysch and molasse stages as an integrating essential part of geosynclinal processes of Central European Variscides, Carpathian Mountains, Balkans, and selected tectogenes and territories of the Soviet Union (Tjan-Shan, Central Kazakhstan, South Siberia, Caucasus, Afghano-Tajik Depression).

First results of such investigations were reported on a common colloquium of the working groups in Halle (G.D.R.) in 1978 and published as a publication of Central Institute of Physics of the Earth, Potsdam (1980).

The first approach of working group 3.3 is the idea of molasse as a stage reflecting a particular tectonic period at the end of geosynclinal process. The molasse evolution begins with the culmination of tectogenesis and is in direct spatial and temporal relation with morphological upheaval of the system of former geosynclinal troughs and the following denudation of the morphogene. Because of migration and propagation of tectogenesis the beginning and the end of molasse formation in the different zones of the tectogene did not happen simultaneously. With regard to temporal and spatial position in the tectogene we can distinguish different molasse types on the base of different criterions. They are summarized in Tab. 5 of the paper of E. GRUMBT in this volume (p. 26).

These ideas, starting from the classical concept of geosynclinal development, have been completed by the new ideas considering the processes of deeper parts of the Earth's crust (in sense of plate tectonics). Such investigations are possible in the field of the Alpidic molasses, because here are better dates to reconstruct the structure of crust (thicknesses, temperature regime), above all by the help of subsequent volcanism, investigated by the working group 3.4 "Magmatism and metallogenesis associated to the epochs of molasse formation". The results of first researches are discussed in the contribution on West Carpathian intramontane basins made by D. VASS (in this volume). At the base of analogous investigations it is necessary to draw conclusions about the crustal conditions at the termination of Variscan mountain building in the forthcoming work of both working groups.

In the researches of group 3.3, which are presided by the Academy of Sciences of G.D.R. (G. SCHWAB, chairman), there are taking part geologists from Bulgaria, Czechoslovakia, German Democratic Republic, Hungary, Poland, Romania, Soviet Union, and from Vietnam: P. BAKALOV, Sofia (since 1980); R. GRADZIŃSKI, Cracow; E. GRUMBT, Jena; K. HAJDU-MOLNÁR, Miskolc (since (1979); G. HÁMOR, Budapest (till 1977); Vl. HOLUB, Prague (since 1980); G. KATZUNG, Berlin; I. KRYSTEK, Brno; Yu. G. LEONOV, Moskva; H. LÜTZNER, Jena; M. MICU, Bucharest (since 1979); A.A. MOSSAKOVSKIJ, Moskva; N. OSZCZYPKO, Cracow; Sz. PORĘBSKI, Cracow (since 1979); M. SĂNDULESCU, Bucharest (till 1979); G. SCHWAB, Berlin; A.K. TEISSEYRE, Wroclaw (till 1978); Y. TENCHOV, Sofia; D. VASS, Bratislava; A. VOZÁROVÁ, Bratislava (since 1978); K.L. VOLOCHKOVICH, Moskva; Sl. YANEV, Sofia.

The members of the group held annual meetings under the above-said subject of molasse problems. The special way of approach during the period 1976 - 1981 was

DOI:https://doi.org/10.2312/zipe.1982.066

(1) to study special molasse basins in the host countries during the meetings,

(2) to compile selected case studies of molasse basins and to get them comparable by means of a uniform shape of representation,

(3) to find a common use of molasse terms by the elaboration of a molasse terms glossary.

Up to the present meetings with geological excursions and common field work took place in the following regions:

1976	Czechoslovakia,	Bratislava	West Carpathian Foredeep and Innercarpathian molasse basins (D. VASS, I. KRYSTEK)
1977	Soviet Union,	Dushanbe	Afghano-Tajik Depression (Darvaz region) (Yu.G. LEONOV, I.G. SHCHERBA)
1978	G.D.R.	Jena	Saale Depression (Halle-Hartz region; Thuringian Forest) (H. LÜTZNER, G. SCHWAB)
1979	Poland,	Cracov	West Carpathian Foredeep, Innercarpathian molasse basins, Upper-Silesian Basin. Intra-Sudetic Basin (R. GRADZIŃSKI, N. OSZCZYPKO)
1980	Romania,	Bucharest	Eastcarpathian Foredeep, Carpathian Marginal Folds (M. MICU M. SĂNDULESCU)
1981	Hungary,	Budapest	Pannonian Basin (K. HAJDU-MOLNÁR, A. JÁMBOR)

The members of group 3.3 gratefully acknowledge the contribution of numerous colleagues, who collaborated in sense of the objectives of the group, especially in field work and as leaders of excursions. The following specialists took part in the leadership of geological excursions: in Czechoslovakia E. BRESTENSKÁ, J. ČVERČKO, M. ELEČKO, B. GAŽA, R. JIŘIČEK, M. KALIČIAK, V. KONEČNÝ, R. RUDINEC, C. TERESKA, J. TÖSZÉR; in Soviet Union R.M. DAVIDSON, V.S. LUCHNIKOV, M.G. MELAMED, V.G. NIKOLAYEV; in the G.D.R. J. ELLENBERG, F. FALK, H. HAUBOLD, A.O. LUDWIG, J. MÄDLER, R. SIMON, H. VOIGT; in Poland S.W. ALEXANDROWICZ, K. BIRKENMAJER, M. DOKTOR, A. GARLICKI, W. NEMEC, M. OTFINOWSKI, J. PORZYCKI, J. RUTKOWSKI, A.K. TEISSEYRE: in Romania D.J. JIPA, N. MIHĂILESCU, M. STEFĂNESCU; in Hungary A. BARABAS, L. BARTKO, I. BÉRCZI, J. GEIGER, L. GODA, J. HAAS, J. HALMAI L. KORPÁS, M. MÁTYÁS, I. RÉVÉSZ.

In connection with field work the following guidebooks have been issued (manuscripts, reproduced in a limited number):

ВАШ, Д. и др.: Тектонические развитие молассовых впадин Западных Карпат.- Путеводитель экскурсии по неогенным бассейнам Западных Карпат по случаю заседания рабочей группы 3.3 "Тектонический режим молассообразующих эпох".
Geologický ústav "Dionýza Štúra", Bratislava 1976, 90 p., 23 Figs

DOI:https://doi.org/10.2312/zipe.1982.066

ЛЕОНОВ, Ю.Г.; МЕЛАМЕД, Я.Р.; ЩЕРБА, И.Г.: Материалы по геологии неогеновых отложений Афгано-Таджикской впадины.
Геологически Институт АН СССР, Москва-Душанбе 1977, 50 стр., 14 рис. 2)

BENEK, R.; KATZUNG, G.; RÖLLIG, G.; SCHWAB, G.; ELLENBERG, J.; FALK, F.; LÜTZNER, H.; MÄDLER, J.; VOIGT, H.; EIGENFELD, F.; HAUBOLD, H.; SCHWAB, M.; GLÄSSER, W.; LUDWIG, A.: Exkursionsführer zu den Geländearbeiten der Arbeitsgruppen 3.3 (Molasse) und 3.4 (Magmatismus der Molasseepoche) im Südteil der DDR vom 17. - 28. Mai 1978.
Zentralinstitut für Physik der Erde AdW DDR, Berlin, 1978, 60 p., 20 Figs (in Russian)

ALEXANDROWICZ, S.W.; BIRKENMAJER, K.; DOKTOR, M.; GARLICKI, A.; GRADZIŃSKI, R.; NEMEC, W.; OTFINOWSKI, M.; OSZCZYPKO, N.; PORĘBSKI, S.J.; PORZYCKI, J.; RUTKOWSKI, J.; TEISSEYRE, A.K.: Guide to Excursions - Miocene Molasse of the Carpathians, Variscan External Molasse of Upper Silesia, Variscan Internal Molasses of Central Sudetes.
Zakład Nauk Geologicznych PAN, Zespół Pracowni w Krakowie, Kraków 1979, 53 p., 22 Figs

SĂNDULESCU, M.; MICU, M.; STEFĂNESCU, M.; JIPA, D.; MIHĂILESCU, N.: Cretaceous and Tertiary Molasses in the Eastern Carpathians and Getic Depression.
Institute of Geology and Geophysics, Bucharest 1980, 79 p., 17 Figs

JÁMBOR, A. (ed.): Molasse formation in Hungary. Excursion Guide to the Meeting of the Academy of Sciences of Socialist Countries Multilateral Cooperation, Problem Commission IX. Working Group 3.3 in Hungary, 1981.
Budapest 1981, 185 p., 71 Figs

In order to compile a series of case studies the members agreed to use summarizing graphs of lithology and magmatic-tectonic data as a simple tool for comparison of different basins. Such lithotectonic profiles have been set up of some molasse basins and areas in Central and South-East Europe and of selected regions of the Soviet Union. The profiles elaborated up to the present are collected in this volume (Annex 1 - 39) and commented by the authors. The explanatory notes are an essential part of the case histories as they give additional verbal and graphic informations as well as genetic interpretations. The principles of the legend are explained by LÜTZNER (cf. p. 37 - 42). A major part of the graphs describes the sedimentary features and processes, including the interpretation of sedimentary environments. This is completed by a series of signs describing the magmatic activity as well as tectonic conditions and events. Concerning the regions with occurrence of volcanic rocks the members of working group "Magmatism and metallogenesis associated to the epochs of molasse formation" are compiling type-profiles in an analogous manner. In this profiles the emphasis is shifted to the description of volcanic, volcanotectonics, and metallogenetic features.

The lithotectonic profiles permit to compare the temporal relation of sedimentary, volcanic, and tectonic events. They give a summary of the lithologic content of the molasse sequences, also with regard to the evolution of molasse formation in course of different folding epochs, and form the base for separation of main types and main stages of molasse formation.

---

2) A report on field work of group 3.3 in Afghano-Tajik Depression was given by SCHWAB et al. 1980

DOI:https://doi.org/10.2312/zipe.1982.066

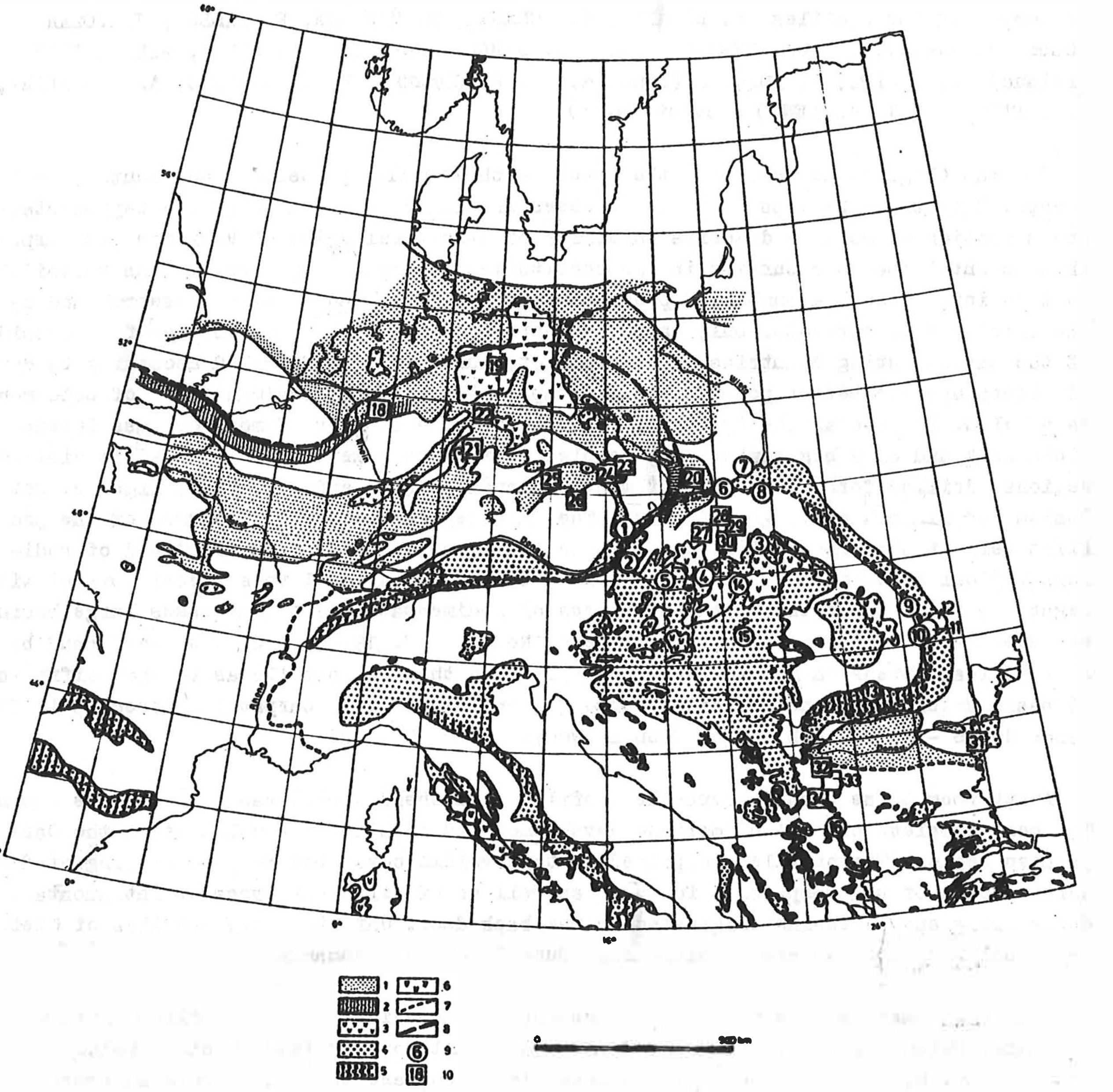


Fig. 1. Position of lithotectonic molasse profiles in Central and Southeast Europe
1 - Upper Paleozoic molasse, 2 - ditto, folded, 3- Upper Paleozoic volcanic rocks, 4 - Cenozoic molasse, 5 - ditto, folded, 6 - Cenozoic volcanic rocks, 7 - front of Alpidic fold belt, 8 - front of Variscan fold belt, 9 - lithotectonic profiles of Cenozoic molasses (Annex 1 - 16), 10 - lithotectonic profiles of Upper Paleozoic molasses (Annex 18 - 34)

DOI:https://doi.org/10.2312/zipe.1982.066

This volume comprises 22 profiles of Paleozoic and 17 profiles of Cenozoic molasse basins. Compiling the profiles a number of cooperating geologists aided the work of the group. The gratitude of working group belongs to the following colleagues who had hand in compiling the profiles: S. BAJANIK, V. KONEČNÝ, M. MARKOVÁ, R. TÁSLER, J. VOZÁR (Czechoslovakia); J. ELLENBERG (G.D.R.); A. JÁMBOR (Hungary); W. NEMEC, A.K. TEISSEYRE (Poland); D.C. JIPA, B. POPESCU (Romania); I. BORODAENKO, U. KLISHEVICH, A. RAZVALAEV, I.G. SHCHERBA, I. TESLENKO (Soviet Union).

The map (Fig. 1) demonstrates the sites of the profiles in Central and South-East Europe. Selecting the type areas the members of the group tried to give a representative cross section of molasse deposits in different structural units of Variscan and Carpathian mountain belts occurring in the territories of their countries. It was unavoidable to take into account a number of preconditions caused by the level of research and by the existence of outcrops. Only in one exceptional case a lithotectonic profile outside of the participating countries (Ruhr district, Annex 18) was compiled according to dates of literature for better possibility to compare the foredeep sedimentation of both mountain belts. In general the typeprofiles summarize the results of more or less intensive field work and of a big number of boreholes, which are however concentrated in distinct regions, drilled for exploration of mineral deposits (oil and gas, coal, lignite, potassium and mineral salt, ground water).The data represented in the columns of the profiles reflect the different level of investigations, especially in the field of sedimentological researches. Furthermore, the profiles are unequal to a certain extent with regard to the size of the represented area of sedimentation. In some cases large basins are demonstrated in an single profile (e.g. No. 15, 17, 19, 39). On the other hand basins of less extension may be represented by more than one profile as to show difference of basin development under variing tectonic conditions (e.g. Carpathian Foredeep in Poland: No. 6 - 8; Carpathian Foredeep in Romania: No. 9 - 12).

Apart from these restrictions the profiles comprehend a wide range of molasse basins. The most complete picture of molasse development is obtained for molasses in the Carpathian region. The profiles comprised in this volume cover the Neogene filling of different zones of the Carpathian foredeep as well as of different types of intramontane depressions and of basins originated in the back deep. Unfortunately profiles of Cretaceous molasse deposits are missing (e.g. Bucegi molasse, Romania).

The development of the Carpathian foredeep is summarized by the profiles of outer (Moravia, Poland, profiles No. 1 and 7) and internal zone (Poland, Central Moldavian, profiles No. 6, 10 - 12). Thus, it is possible to compare the pretectonic molasses in the outermost overthrusted units of Eastern Carpathians (Marginal fold units and Subcarpathian unit respectively, profiles No. 10 - 12) both with the folded Miocene molasses lying beneath the Carpathian thrustfault in the West Carpathians (profile No. 6) and with the molasses of the external part of the foredeep in front of the Carpathians overlying the consolidated regions of platform cover (Poland, profile No. 7) and Bohemian Massif (profile No. 1). In connection with the formation of foredeep molasses a special interest exists to compare the formation of outer molasse zones controlled by fault tectonics with inner molasse zones reflecting the tectonic mobility of fold belts.

DOI:https://doi.org/10.2312/zipe.1982.066

The filling of intramontane basins, overlying the Inner Carpathian units, started simultaneously with that of the foreland. The drawn up basins represent the type of longitudinal intramontane depressions (Vienna Basin, profile No. 2; East Slovakian Basin, profile No. 3; Nowy Sąoz Basin, profile No. 8), that means the filling of basins which are in accordance with the structural plan of a tectonically heterogenous basement. They were created with the beginning of the development of main molasse in the West Carpathians (Eggenburgian) and were intensively reoonstructed in the second period of main molasse formation in Badenian - Sarmatian time (cp. explanatory notes by D. VASS).

The profiles of Ipel' and Gabčikovo Basin (profiles No. 4 and 5) and of North Hungarian and Pannonian basin (profiles No. 14 and 15) permit a comparison between molasse formation within the backdeep. The paleotectonic history of back molasse, divided in four periods by VASS, comprehends the history of molasse from beginning with Early molasse (uppermost Cretaceous to Egerian) and to ending with the sedimentation of Late molasse (Pannon - Quarternary) as represented by the Gabčikovo and Pannonian Basin.

The tectonic position of the Getic Paleogene deposits (South Carpathians, profile No. 13), for whioh JIPA (this volume, p. 137 - 146) argues an attribution to a marginal geosynclinal facies, is not clear with regard to molasse or pre-molasse character of the sequence. - The only one profile of Cenozoic molasses of the Balkan region is that of the Blagoevgrad Graben (profile No. 16).

The position of profile No. 17 (Afghano-Tajik-Depression), which is situated outside of the map, Fig. 1, is indicated in a sketch map reproduced in the explanatory notes to this profile. It represents the molasse sequence of a Neogene tectonic activation zone.

The Variscan outer molasse is represented by two profiles of the foredeep (Ruhr district, profile No. 18; Upper Silesia, profile No. 20) and a synthetic profile of the foreland within the Central European Depression (profile No. 19). Among the inner molasse basins represented here, there are the longitudinal troughs within the fold belts (Saale Depression, profiles No. 21 and 22; Intra-Sudetic Basin (profiles No. 23 and 24) as well as the basins within the Bohemian Massif (Central Bohemian Region, profile No. 25; Blanioe Furrow, profile No. 26). The series of Variscan molasse profiles is continued with basins of the Ozeohoslovakian West Carpathians (profiles No. 27 - 30). Further profiles characterize the Variscan molasse of Bulgaria with one example from the foreland (Moesian Platform, profile No. 27) and three oases of inner molasse basins (profiles No. 32 - 34). The paleozoic molasse profiles of Central and South East Europe are completed by some profiles of Devonian and Lower Carboniferous molasse basins situated in the Asian part of Soviet Union (Alai Ridge, profiles No. 35 - 38; Minusinsk Basin, profile No. 39).

The examples of molasse sequences collected in this volume are by no means a complete representation even of the Central and South-East European regions. Some interesting basins had to be renounoed because no author was available. Among these are the Erzgebirge Depression, Świebodzice Depression, Trutnov Basin, Thracian Basin, Moesian Platform, Mecsek Mts.

An essential part of the group's effort was the clearing of geological terms connected with molasse problems. It was proposed to elaborate a glossary of molasse terms as to

DOI:https://doi.org/10.2312/zipe.1982.066

find a common basis for a unified use. A preliminary information on the state of work is given by E. GRUMBT in this volume (p. 21 - 36).

In the forthcoming work of group 3.3 it is provided to use the lithotectonic profiles as the basis of supraregional comparison of molasse formation both of the same and of different tectonic eras. An essential part of these activities will be the compilation of tectogenetic maps of the molassic regions in Central and South-East Europe during the next years.

Important aspects of this comparison will be (1) the tectonic position of molassic rocks as a part of the process of genesis of the Earth's crust, especially as an indicator of the late tectogenetic processes of mountain building. In connection with this aim the cooperation with working group 3.4 (Magmatism) will be important; and (2) the evolution of molasses in sense of A.A. MOSSAKOVSKIJ, that means to discuss the correspondence and the difference of lithologic and tectonic features as well as the kind of occurrence among molasses of different geotectonic cycles. Initial points of future work will be the relations between lithologic structure and tectonic setting of Middle and Upper Paleozoic molasses of the Tjan-Shan, the southern part of Sibiria, of the Upper Paleozoic molasses in Central and South-East Europe and the Cenozoic molasses of the Carpathian mountain system. On the base of this investigation it will be necessary to take in consideration also molasse profiles of other mountain belts.

Data and information comprised in the lithotectonic profiles raised the knowledge of molasses to a new qualitative level, based first of all upon a synthesizing supraregional view of the history and of the tectonic regime of molasses. The lithotectonic profiles confirmed the twofold polarity of the history of molasses, i.e. in time and space and facililated an adequate division. In this direction the considerations of MOASSAKOVSKIJ (1965), VASS (1980), KATZUNG (1977) and LÜTZNER et al. (1979) are to reconcile. A first step will be done in a common publication of VASS and LÜTZNER, which is in preparation.

The members of working group 3.3 are grateful to the Academies of Sciences of socialist countries, to the directors of academic and state Geological Institutes for granting the means to carry out the investigations. They especially return thanks to the council of problem commission No. IX for the knowing furtherance of the researches, and the director of Central Institute of Physics of Earth of Academy of Sciences of G.D.R., Prof. Dr. H. KAUTZLEBEN, and the permanent representative of Academy of Sciences of G.D.R. in the problem commission No. IX, Prof. Dr. K.-B. JUBITZ, for the possibility to publish their results in this volume. Finally, the editors are very thankful for the distinguished assistance of Mrs. Dr. T. BANDLOVA, Mrs. Dipl.-Min. G. BUDZINSKI, Mrs. Th. DIETRICH, Mrs. G. JAUCH, Mrs. H. SCHRÖDER, and Mrs. D. VIEHWEGER with the preparation of manuscripts for print.

DOI:https://doi.org/10.2312/zipe.1982.066

References

Autorenkollektiv: Tektonische Bewegungen, sedimentäre und magmatische Prozesse der Flysch- und Molasseetappen des variszischen und alpidischen Zyklus in Zentral- und Südosteuropa sowie in ausgewählten Gebieten der UdSSR.
Veröff. Zentralinst. Physik d. Erde, Potsdam 58 (1980) 304 p.

KATZUNG, G.: Die posttektonischen Molassen und Subsequentite am Außenrand und im nördlichen Vorland des variszischen Tektogens.
Z. angew. Geol., Berlin 23 (1977) 12, p. 597-602

LÜTZNER, H.; FALK, F.; ELLENBERG, J.; GRUMBT, E.; LUDWIG, A.O.: Übersicht über die variszische Molasseentwicklung in Mitteleuropa und am Ural.
Z. geol. Wiss., Berlin 7 (1979) 9, p. 1157-1167

MOSSAKOVSKIJ, A.A.: K voprosu ob orogennom etape razvitija geosinklinal'nych oblastej.
Geotektonika, Moskva 1965, 2, p. 3-16

SCHWAB, G.; KATZUNG, G.; LUDWIG, A.O.; LÜTZNER, H.: Neogene Molassesedimentation in der Tadžikischen Depression (Tadžikische SSR).
Z. angew. Geol., Berlin 26 (1980) 5, p. 229-241

VASS, D.: Principles of subdivision and principal types of the West Carpathian molasse basins and depressions.
Veröff. Zentralinst. Physik d. Erde, Potsdam 58 (1980), p. 155-176

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Tasks, structure and problems of the molasse terms glossary

by

EBERHARD GRUMBT[1)]

1. Intention

Working group 3.3. "Tectonic regime of epochs of molasse formation" which is subordinated to the problem commission IX of Multilateral Cooperation of the Academies of Sciences of socialist countries, has since the beginning of its activities in 1975 taken over the task to draw up a special glossary of molasse terms. This glossary is of general importance for determination and uniform use of terms of the molasse complex, especially within the international molasse working group.

The fact that specialists of seven countries - of the Socialist Republic of Czechoslovakia, of the G.D.R., of the Socialist Republic of Roumania, of the U.S.S.R., of the People's Republic of Hungary, of the People's Republic of Bulgaria and of the People's Republic of Poland - work together on common problems emphasizes the necessity of establishing uniform terms as a basic premise for mutual understanding.

In detail it was necessary to select important and less usual terms of the complex of problems "molasse" and to interpret them on the base of today's knowledge in most cases newly. Moreover, some terms are applied quite differently, caused by the historic development in the different countries. In this respect a unification became necessary. Furthermore, some terms are applied only in some countries. They had to be generalized in case they are of importance for the specialists of the other countries.

In its organization the molasse terms glossary follows special dictionaries already existing or being in preparation, but we had to take into account special interests of the working group 3.3. With regard to the volume, too, with only some more than 50 terms the glossary differs from most projects of similiar character.

1) Akademie der Wissenschaften der DDR, Zentralinstitut für Physik der Erde, Institutsteil Jena; DDR-6900 Jena, Burgweg 11

DOI:https://doi.org/10.2312/zipe.1982.066

Table 1. Outline of terms of the complex of problems "molasse" in genetic correspondence

General terms

22 molasse
- (external molasse)
- (interior molasse)
- (early molasse)
- (main molasse)
- (late molasse)
- (preorogenic molasse)
- (postorogenic molasse)

4 basin
41 depression
5 cover
27 orogen (= Morphogen)
29 mountain building
9 mountain building of epiplatform
46 orogen (= Tektogen)
47 orogeny (orogenesis)
38 rhythm
52 cycle
20 †magmatic cycle
18 lineament
50 deep fault
49 tectonic-magmatic activation

Types of molasse

15 continental molasse
21 marine molasse
40 sedimentary molasse
30 upper molasse
51 lower molasse
23 molasse complex
26 molassoid

Molasse environments

1 eolian environment
8 eluvial environment
7 deluvial environment
14 colluvial environment
36 proluvial environment
11 fluvial environment
17 lacustrine environment
31 palustrine environment
6 deltaic environment
19 littoral environment
16 coastal lagoonal environment
10 shallow marine environment

DOI:https://doi.org/10.2312/zipe.1982.066

Areas of molasse formation		Stages of molasse formation
24 molasse depression	(external depression)	25 molasse stage
37 foredeep	foreland)	28 mountain building (orogenic)stage
3 ↑outer zone of foredeep		35 postorogenic stage
13 ↑inner zone of foredeep		43 late orogenic stage
39 backdeep	(backland)	45 taphrogenic stage
12 interior (inner) depression	(intermontane basin) (intramontane basin) (interior basin)	44 platform stage
2 superimposed depression	(transmitted depression)	48 tectonic stage
32 periclinal depression		
33 pericratonal depression		
34 postorogenic depression		
42 late orogenic depression		

Explanations

22 molasse	term of 1st order
21 marine molasse	term of 2nd order
26 molassoid	term of 3rd order
3 ↑outer zone of foredeep	attributed term
(external depression)	attributed catchword

10 number of the term in alphabetical order of the German version

DOI:https://doi.org/10.2312/zipe.1982.066

The treatment of the terms is elaborated bilingually in Russian and German. The terms themselves are listed in eight further languages. First of all, the molasse terms glossary is provided for agreement among members of the group 3.3. But we hope that the glossary will be useful for all geologists working on molasse formations.

Tables 8 and 9 are worked out in cooperation with Yu. G. LEONOV (Moscow) who took also part in the editorial revision of the terms.

2. List of terms

A repeatedly revised list of molasse terms, which was set up by the members of the participating countries formed the starting point for further work. Altogether 52 terms of different meaning (1st - 3rd order) had been selected which can be attributed to four superordinate terms: General terms including molasse environments, types of molasse, areas of molasse formation, stages of molasse formation (Table 1). At the present time all terms are represented bilingually (German, Russian) in a manuscript. Members from Czechoslovakia, of the G.D.R., U.S.S.R., of Hungary and Bulgaria (Table 2) took part in this work. Editorial revision and assimilation of the bilingual texts was performed by E. GRUMBT and YU. G. LEONOV.

Table 2. Participation of the countries taking part in the treatment of molasse terms

Country	Treated terms
Czechoslovakia	7
G.D.R.	17
Roumania	-
U.S.S.R.	18
Hungary	1
Bulgaria	9
Poland	-
Altogether	52

3. Scheme of arrangement of terms

After selecting the terms and designating persons for treating them a uniform arrangement scheme for all terms was established. It consists of 9 items (Table 3). By this, the molasse terms glossary is referring to two patterns: the Deutsches Handwörterbuch der Tektonik (DHT) by H. MURAWSKI from 1968 on and the International Tectonic Lexicon by J. G. DENNIS, H. MURAWSKI and K. WEBER, published as a prodrome in 1979. However, some items of the molasse terms glossary exceed the dispositions of the above-mentioned special dictionaries or are related to the special tasks of working group 3.3. Therefore, in the head part the term is listed in 10 languages (Russian, German, English, French, Bulgarian, Polish, Roumanian, Slovakian, Czech, Hungarian). The references will be added for all terms commonly at the end of the glossary.

DOI:https://doi.org/10.2312/zipe.1982.066

4. Main groups of terms

As already pointed out, the selected terms of the complex of problems "molasse" can be divided into 4 main groups:

- General terms incl. molasse environment
- types of molasse
- areas of molasse formation
- stages of molasse formation

General terms

In this group a greater number of tectonic, some lithologic and also magmatic terms have been gathered up. The set of problems concerning application especially of some tectonic terms will be discussed in chapter 5. Here, only some aspects of the environment shall follow.

Table 3. Comparison of subdivision schemes of the terms in different special dictionaries

Deutsches Handwörterbuch der Tektonik ed. H. MURAWSKI 1968-1976	International Tectonic Lexicon ed. J.G. DENNIS, H. MURAWSKI and K. WEBER 1979	Molasse Terms Glossary
1. Etymology	1. Derivation	1. Derivation
2. First definition	2. Definition	2. Definition
3. Present usage	3. Current usage	3. Synonyms
4. Notes	4. History	4. Hierarchically attributed terms
5. References to catchwords	5. Special notes	5. Special cases of application of a term in the friendly countries
6. References	6. Tables, graphs	6. Proposing a uniform use of the term
7. Illustrations		7. Historical notes
		8. Notes
		9. Tables, figures

Molasse environments

The majority of sedimentary environments found in molasse formations are confined to the continental region. Only few touch the transition and marine region (Table 4). The depositing medium in consideration is predominantly water. Moreover, in some environments a more or less heavy influence of wind may be observed, as e.g. during the generation of coastal dunes or in the eluvium. In the eolian environments, of course, wind deposits are

DOI:https://doi.org/10.2312/zipe.1982.066

Table 4. Survey on molasse environments (after SELLEY 1976, RUCHIN 1958 et al.)

Region	Depositional medium	Environment
continental	wind	eolian
	water	eluvial
		deluvial
		colluvial
		proluvial
		fluvial
		lacustrine
		palustrine
transitional area		deltaic
		coastal lagoonal
		littoral
marine		shallow-marine

Table 5. Types of molasse according to temporal, spatial and compositionel aspects

Temporal position within geologic history	Temporal position within one orogenesis	Temporal position to orogenesis	Spatial-temporal position within one orogen	Spatial position to the orogen	Spatial-facial position	Composition
sub-Alpine molasse	late molasse	postorogenic molasse	upper molasse	external molasse	continental molasse	sedimentary molasse
sub-Variscan molasse	main molasse	preorogenic molasse	lower molasse	internal molasse	marine molasse	volcanogenic molasse
sub-Caledonian molasse	early molasse					

DOI:https://doi.org/10.2312/zipe.1982.066

dominating.

In the environments quoted in Table 4 the types which are of greatest importance for the formations of molasse are underlined. The terms for these environments and also those for the shallow marine and transition region are in general use in the Anglo-American and German special literature. Added to this there are several terms being used mainly in Soviet literature (RUCHIN 1958). These are the eluvial (environment of weathering residuals), the deluvial (environment of slope erosion), the colluvial (environment of talus deposits) and the proluvial (environment of alluvial fans). All types of environments mentioned are spread in arid and semiarid climates. Thus, they are of importance for formations of molasse, too.

Types of molasse

The multiplicity of designations of molasse types is derived from different aspects. Subdividing the terms according to their temporal, spatial and material aspect, a comprehensive picture on the meaning of the terms will arise (Table 5). Hereby one can notice that relations of terms among one another are scarcely existing.

Areas of molasse formation

Depositional areas of molasse, too, can be subdivided similiarly to types of molasse. The temporal and spatial relations to the orogene are in the foreground (Table 6).

Stages of molasse formation

Considering molasses as a period within the history of a mobile belt the stages of molasse formation are to be inserted between the geosynclinal stage s. s. and the platform stage (Table 7). Thereby the boundaries of the different stages are overlapping, especially those of orogenic stage and stage of mountain building.

5. Problems with regard to content

5.1. Differences in use of essential terms

Special literature, own conceptions, German, Russian, English and polyglot special dictionaries represented fundamentals for the treatment of terms concerning the content (Entwicklungsgeschichte der Erde 1970; Геологический словарь 1978; GARY et al. 1972; MURAWSKI 1968-1976, 1977; NEEF 1980; TESCHKE 1964, 1968; ŻYKŁA 1970). These reference books as well as the use of terms in the participating countries are not without contradictions. As already mentioned, the intention of the glossary is, however, unification and understanding of the terms in the different countries. Therefore we had to make compromises in the editorial treatment of some terms or to clear them up to

DOI:https://doi.org/10.2312/zipe.1982.066

Table 6. Subdivision of areas of molasse formation

Temporal position to orogenesis	Temporal-spatial position to orogen	Spatial position to orogen: within	Spatial position to orogen: without	Spatial position to orogen: peripheral	Material position
late orogenic depression	superimposed depression	interior depression (intermontane depression, intramontane basin, interior basin)	foredeep (inner zone of foredeep; outer zone of foredeep)	pericratonal depression	molasse depression
postorogenic depression	periclinal depression				

Table 7. Subdivision of stages of molasse formation

Geosynclinal stage s.s. \ orogenic stage \ stage of mountain building (molasse stage) \ taphrogenic stage \ platform stage

l a t e - — — post-

orogenetic stage

DOI:https://doi.org/10.2312/zipe.1982.066

reach the aim aspired to. This will be explained with some examples.

Orogenesis, tectogenesis, morphogenesis

The meaning of the term "orogenesis" changed several times in the history of geology. Since the middle of the 19th century especially in Europe the term "orogenetic" has several times been used in genetic meaning (GRESSLY 1840 et al.). Later GILBERT (1890), going out from the conditions in the west of the North American continent, called "orogeny" the phenomena of mountain building, and that in morphological meaning. He opposed those the wide span bending of epeirogeny, resulting among others in the formation of continental and oceanic basins. UPHAM (1894, p. 383) mentioned the use of "orogeny" for processes of structural changes of mountain building. Also STILLE (1924, p. 11) considered first of all tectonic movements with irreversible change of structure and the episodicity of these processes essential. But uplift of mountains was for him of no or of only secondary importance. KRAUS (1926, 1935, p. 461) pleaded for a unity of the orogenic process which can be recognized in the processes of structural formation and uplift (that means relief formation) of mountains.

HAARMANN (1927, p. 106) restricted the term "orogenesis" to morphologic mountain building and separated from it clearly the term "tectogenesis" = formation of tectonic structure (German: Gefügebildung). v. BUBNOFF (1949) used only the term "tectogenesis" (German: Strukturbildung). KHAIN and MURATOV (1968) and other authors restricted the term "orogenesis" to relief generating mountain building - like before HAARMANN (1927) or GILBERT (1890) - and opposed it to the formation of geosynclines.

SCHROEDER (1979, p. 1050) uses "tectogenesis" when he stresses the process of structural formation and "morphogenesis" when he considers the process of relief formation. SCHROEDER now wants to avoid the term orogenesis in German usage completely, having first granted it still a superordinate meaning (SCHROEDER 1973, p. 275).

In Soviet special literature, however, "orogen" or "orogenesis" now as ever are used for the (period of) relief generating mountain building. On the other hand application of morphogen(esis) causes difficulties in Russian terminology. In Anglo-American special literature "orogenesis" is mostly used in the sense of UPHAM (1894) and STILLE (1924), that means for processes of formation of structures (GARY et al. 1972).

In the molasse terms glossary it is tried to take into account the described different meaning of the terms orogenesis and tectogenesis. For German usage it is therefore proposed to designate "Tektogen" (Orogen s.l.) as a mobile belt of the Earth's crust which underwent a uniform history of geosynclinal basin development and concluding tectonic deformations which may be connected with magmatic and metamorphic processes. The process of forming regional structure is to be designated "Tektogenese" (Orogenese s.l.). A mountain belt in morphological sense is to be denoted in German "Morphogen" (Orogen s.s.), the relief generating process of mountain building as "Morphogenese" (Orogenese s.s.).

Therewith in German usage it is possible to use - in addition to the denotation "Tektogen(ese)" and "Morphogen(ese)" applied by SCHROEDER (1973, 1979) - the terms "Orogen-(ese)" with addendum s.l. (sensu latiori = in a broader sense of the word) or s.s. (sensu

DOI:https://doi.org/10.2312/zipe.1982.066

strictiori = in a narrower sense of the word). The corresponding terms of Anglo-American and Russian usage are compared with the German ones in Table 8.

Table 8. Comparison of present use of the terms orogen(esis), tektogen(esis) in Anglo-American, German and Russian usage

English	German	Russian
orogen(e)	Tektogen (Orogen s.l.)	складчатая (геосинклинальная) область
orogeny, orogenesis	Tektogenese (Orogenese s.l.)	геосинклинальное развитие, геосинклинальный цикл
(orogen(e))	Morphogen (Orogen s.s.)	ороген (горное сооружение)
(orogeny), mountain building	Morphogenese (Orogenese s.s.)	орогенез (горообразование)

Basins

Basin in tectonic sense is in the glossary defined as a more or less isometric subsidence of the Earth's crust being filled with sediments, partly with volcanic rock and volcanoclastic rock, too. Besides, there is the basin in geographic sense, a more or less closed topographic low of the continent or sea floor.

These definitions are decided in German usage. In Soviet geologic literature there are, however, different terms for the German word "Becken" (English: basin, French: bassin, the meaning of which must be known (Table 9):

- in geologic-tectonic sense

Syneclise (Russian: синеклиза) is in Soviet literature applied only for bigger platform structures (e.g. Moscow syneclise). But the Russian word бассейн (French: bassin) is used in Soviet special language for corresponding tectonic elements only if these structures had been taken over from foreign languages (especially from English or French languages), e.g. Parisian basin. in Russian Парижский бассейн.

DOI:https://doi.org/10.2312/zipe.1982.066

Table 9. Survey on different meanings of the German term "Becken" in Soviet geological literature

Range of application	Russian synonym	Example
geologic - tectonically: платформа = Tafel (platform)	синеклиза = Syneclise (syneclise)	- Московская синеклиза = Moskauer Syneclise (Moscow syneclise) in Russian original literature
geologic - tectonically: платформа = Tafel (platform)	бассейн = Bassin (basin)	- Парижский бассейн = Pariser Becken (Parisian basin) in translations of foreign (especially English and French) special literature
geologic - tectonically: структуры посторогенные = posttektogenetisch (postorogenic)	впадина = Becken (basin)	- молассовая впадина = Molassebecken (molasse basin) - Венский бассейн, Венская впадина = Wiener Becken (Vienna basin) - впадина (трог) Саар-Наэ (Саарская) = Saar-Nahe-Becken, Saar-Nahe-Trog (Saar-Nahe-basin, trough,
in the point of science of mineral deposits	бассейн = (kohle-, ölführendes usw.) Becken (coal basin, oil basin)	- Донецкий бассейн = Donezk-Becken (Donez basin)
geographically	бассейн, впадина = Meeresbecken (sea basin)	- Южно-Каспийский бассейн (впадина) = Südkaspisches Meeresbecken (South Caspian sea basin)
geographically	депрессия = Festlandsbecken (continental basin)	- ферганский юрский бассейн = Fergana-Becken (im Jura) (Jurassic Ferghana basin)
geographically	Таджикская депрессия = Tadshikische Depression (Tadshikian depresson)	

DOI:https://doi.org/10.2312/zipe.1982.066

The Russian term впадина is very often applied for tectonic basins, especially for superimposed, orogenic structural elements, e.g. Pannonian basin = Паннонская впадина, Wiener Becken = Венская впадина (but also Венский бассейн!).

- in the sense of economic geology

Here, in Russian language always бассейн is used for basin, e.g. Donezk basin = Донецкий бассейн

- in geographic sense

Basin is translated into Russian with бассейн for recent or fossil sea basins, and with депрессия, if continental basins are denoted.

Depression

The German term "Senke" is mainly used for a more or less pan-shaped regional depression of the Earth's crust, in most cases caused tectonically and filled with sediments, with transitions to basins or troughs (furrows). Secondly, "Senke" denotes local depressions over cavities in the underground (e.g. subrosion depression).

In Russian, depression can be translated as прогиб in the sense of long stretched structures of platform and geosynclinal stages, e.g. marginal deep, foredeep. The term впадина, however, is used in Russian language if more or less isometric structures, predominantly of the platform and mountain building stage, are to be denoted.

Interior (inner) depression

Interior (inner) depression as a subordinated term of depression forms for its part again a superordinated term for several further special depositional areas of interior molasse which can be denoted intermontane depression (basin), intramontane depression (basin) or interior basin (Table 1). Generally, in the molasse terms glossary all areas of molasse deposition situated in inner zones of an orogene are denoted interior (inner) depressions.

With respect to the Variscan inner molasses of Central Europe in German usage there has not been made a difference between intermontane and intramontane basins. The same is valid for Anglo-American and French special literature.

For the younger molasses or the Carpathians, however, a more distinct division of basins has been proposed by D. VASS in accordance with MAHEL' and BUDAY (1968):

- intermontane basins (Latin: inter....between):
  Basins, basin systems at the back side (in the backland, back chain area) of an orogen.
  synonyms: intermediate depression, intermountain depression, back-arc basin, backdeep.
  e.g. Panonian basin.

DOI:https://doi.org/10.2312/zipe.1982.066

- intramontane basins (Latin: intra... inside, within the mountain range): long-stretched depressions in an orogen.
  e.g. West Carpathian basin.
- interior basin: as a special case of inner basins, for the most part relatively small, isolated basins in the interior of an orogen.

Fig. 1 schematically shows the position of the interior (inner) depressions defined by D. VASS in their relation to the orogen of the Carpathians.

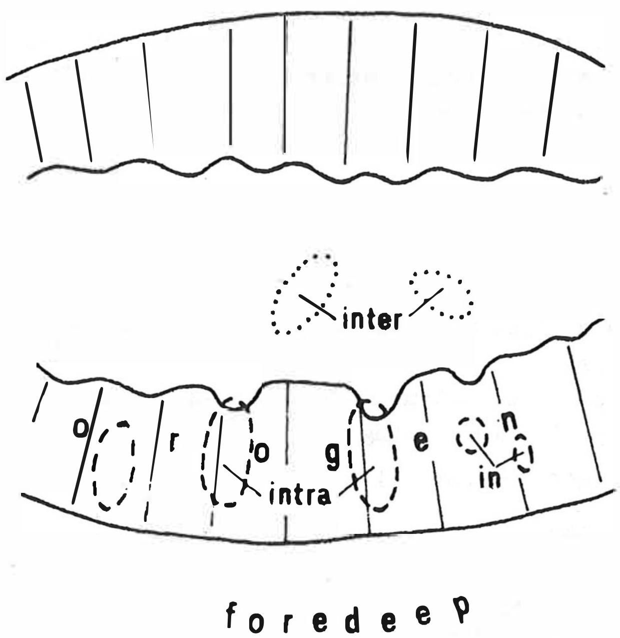


Fig. 1. Schematic position of the interior (inner) depressions of the Carpathian orogen according to D. VASS
inter - intermontane basin, intra - intramontane basin, in - interior basin

5.2. <u>Comparison of several definitions of one term</u>

For some of the terms treated so far it turned out necessary to admit several definitions if reasonable arguments existed. There are e.g. a geologic and a pedological interpretation of the term eluvial environment. And the palustrine environment does not only include peat formations in continental depressions and basins (lakes, pools) but also swamps in the tidal region.

DOI:https://doi.org/10.2312/zipe.1982.066

Concerning depressions, we differ between local subrosion depressions and regional, tectonically caused subsidences of the Earth's crust. Similiar relations exist with basins where more or less isometric, tectónic depressions of geographic basins, i.e. topographic lows of the mainland or sea floor are differed.

Still more distinct is the ambiguity of the term cycle even if it is confined to geologic phenomena. Sedimentary cycles are defined as repeating sedimentary sequences with a systematic time-trend of features or processes, respectively. Analogously also directed geotectonic processes and connected with them magmatic processes are denoted cyclic. With rhythms, too, one can differ between sedimentary and tectonic (magmatic) rhythms.

In all other cases in the glossary there is given only one definition for each term.

This is even then the case if a second variant could have characterized the phenomenon or the process in question from another point of view. If additional variants of definition turned out important their representation was carried out under point 7 (history).

6. Conclusions

In the present state a first phase of work on the molasse terms glossary has been reached. Further tasks are:

- Final evaluation of both variants of the terms by responsible members of the countries participating in working group 3.3.
- Working out of a uniform, for all terms comprised bibliography.
- Final editorial works.

According to the plan editorial works of the molasse terms glossary must be finished up to 1983. Printing is designed as a monograph.

Summary

The present paper informs on intention, subdivision, present phase of work and resulting problems of the molasse terms glossary. This glossary, containing more than 50 terms of molasse problems and adjoining fields, is to serve for clearing up and understanding among members of the international working group "Tectonic regime of epochs of molasse formation". At present the terms of the intended glossary are editorially revised in German and Russian language. A uniform literature list is in preparation.

The terms can be classified into 4 main groups: general terms incl. molasse environments, types of molasse, areas of molasse formation and stages of molasse formation, the meaning and further subdivision of which is commented and summarized in tables. A more detailled discussion is made for problems which had occured in interpretation of some important terms. For instance concerning the use of terms orogenesis - tectogenesis -

DOI:https://doi.org/10.2312/zipe.1982.066

morphogenesis or the use of subordinated terms of interior depression, especially with the intermontane and intramontane basin, the participants of the working group were proposed compromise solutions by the special commission for editorial work. In other cases, e.g. with basins and depressions, a comparison of different meaning and use of the terms in the languages was sufficient. Sometimes an ambiguity of terms (e.g. eluvial environment, basin, cycle etc.) is occuring. In such cases two or more definitions are justifiable. In all other cases different variants of definition were resigned.

References

BUBNOFF, S.v.: Grundprobleme der Geologie, 2. Aufl., 246 S.
Halle (S.): Mitteldeutsche Druckerei u. Verlagsanst. 1949

DENNIS, J.G.; MURAWSKI, H.; WEBER, K. (ed.): International Tectonic Lexicon. A Prodrome. 153 p.
Stuttgart: Schweizerbart 1979

GARY, M.; McAFEE, R.; WOLF, C.L.: Glossary of Geology, 3. Aufl., 857 p.
Washington D.C.: Amer. Geol. Inst. 1972

GILBERT, G.K.: Lake Bonneville.
Monogr. U.S. geol. Surv., Washington 1 (1890)

GRESSLY, A.: Observations géologiques sur le Jura soleurois.
Nouv. Mém. Soc. Helvét Sci. Natur., 2 (1840), p. 1838-1839

HAARMANN, E.: "Tektogenese" oder "Gefügebildung" statt "Orogenese" oder "Gebirgsbildung".
Z. deutsch. geol. Ges., Stuttgart 78 (1927) Mber. 3-5, p. 105-107

KHAIN, V.E.; MURATOV, M.V.: Geosynclinal belts, orogenic belts, folded belts and their relation in time and space.
Intern. Geol. Congr., 23. Sess., Prague 3 (1968), p. 9-13

KRAUS, E.: Der geomechanische Typus der Mittelrheinischen Masse und der orogene Cyclus.
C.R. Congr. géol. int., 14. Sess., Madrid 3 (1926), p. 1031-1076

KRAUS, E.: Die Einheit der Erdinnenkräfte.
N. Jb. Mineral. etc., B. Stuttgart 73 (1935), p. 404-464

MAHEL, M.; BUDAY, T.: Regional Geology of Czechoslovakia, 2, West Carpathians, 723 p.
Praha: Academia 1968

MURAWSKI, H. (Hrsg.): Deutsches Handwörterbuch der Tektonik, 1. - 6. Liefg.
Hannover: 1968-1976

MURAWSKI, H.: Geologisches Wörterbuch, 7. Aufl., 280 p.
Stuttgart: Enke 1977

NEEF, E. (Hrsg.): Das Gesicht der Erde, 5. Aufl., 627 p.
Leipzig: Brockhaus-Verlag 1980

RUCHIN, L.B.: Grundzüge der Lithologie. 806 p.
Berlin: Akademie-Verlag 1958

SCHROEDER, E.: Probleme tektonischer Untersuchungen im Orogen, speziell in den Varisziden.
Veröff. Zentralinst. Phys. Erde, Potsdam 14 (1973) 2, p. 273-302

SCHROEDER, E.: Zur Entwicklung der mitteleuropäischen Varisziden unter Berücksichtigung ihrer Position im paläozoischen Tektogengürtel Eurasiens.
Z. geol. Wiss., Berlin 7 (1979) 9, p. 1043-1055

SELLEY, R.C.: An introduction to Sedimentology. 408 p.
London usw.: Academic Press 1976.

DOI:https://doi.org/10.2312/zipe.1982.066

STILLE, H.: Grundfragen der vergleichenden Tektonik. 443 p.
Berlin: Borntraeger 1924

TESCHKE, H.-J.: Wörterbuch der Geowissenschaften, Russisch - Deutsch. 424 S.
Berlin: Akademie-Verlag 1964

TESCHKE, H.-J.: Wörterbuch der Geowissenschaften, Deutsch - Russisch. 508 S.
Berlin: Akademie-Verlag 1968

UPHAM, W.: Wave-like progress of an epeirogenic uplift.
J. Geol., 2 (1894), p. 380-395

ŻYKŁA, R.: Geological Dictionary - Słownik geologiczny - Geologičeskij slovar -
Dictionnaire de Géologie - Geologisches Wörterbuch. 1439 p.
Warszawa: Wydawn. geol. 1970

Autorenkollektiv: Entwicklungsgeschichte der Erde, 4. Aufl., 2.
Leipzig: Brockhaus Verlag 1970, p. 541-888

Геологический словарь вдвух томах, изд. второе, 456 с., 484 с.
Москва: издат. Недра 1978

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

General comments to organization and legend of the lithotectonic molasse profiles

by

HARALD LÜTZNER[1)]

Drawing up the lithotectonic profiles collected in this volume the authors followed the idea to compile descriptions of typical areas of molasse sedimentation under a unitary form of representation. To set up a lithologic column of the sedimentary sequences appeared to be the simplest way to get a base for comparing basins and areas of different size, especially as the representation should point out the general development of the lithologies, their thicknesses, and their relations to tectonic processes in a broad sense. For this it was necessary to emphasize several significant features of molasses as well as sedimentological interpretations, like the sedimentary environments. Finally, the main magmatic and tectonic events were to be demonstrated, as far as they affected the development of the molasse sequence. Thus, the lithologic column in the proper sense was supplemented by a series of further columns. The whole profile is organized into a number of data groups which may be designated as

- stratigraphy
- lithology
- additional information on sedimentation
- additional information on magmatism
- tectonics.

Each group is subdivided into several columns, which are commented below.

As intended on purpose the profiles have a uniform scale of thickness. The profiles have been drafted in the scale of 1 : 5 000 and were reduced to 1 : 12 500. The sedimentary sequences are represented in their natural succession, i.e. without regard to gaps in the stratigraphic record. In the lithologic column interruptions of sedimentation, unconformities and disconformities are uniformly indicated by a wavy line which is explained more precisely in the last column as a tectonic event.

[1)] Akademie der Wissenschaften der DDR, Zentralinstitut für Physik der Erde, Institutsteil Jena; DDR - 69 Jena, Burgweg 11

DOI:https://doi.org/10.2312/zipe.1982.066

Vertically, the profiles are divided into lithostratigraphic units. For better survey the limiting lines between units defined in the stratigraphic group are passed through all other columns. This is also necessary to limit the validity of seperately put symbols (for instance state of deformation). These lines do not necessarily imply a general change of features or conditions.

As variability of thickness is a common attribute of sedimentary units, especially of molasse sequences, it is clear that in the profiles the units are plotted with a medium or representative thickness. In many profiles the represented thicknesses do not occur one above the other strictly in one place. This holds true, for instance, for all basins with migrating depocentres. Thus not in all cases the whole vertical extension of a profile coincides with the real thickness of the total basin filling. It is for this reason that the scale line (left margin) has been restricted to about 500 m.

Stratigraphy

Starting from the left the first columns describe the stratigraphical position and subdivision of the sequence referring to international and regional stratigraphic standards. In molasse deposits stratigraphic dating is sometimes uncertain and stratigraphic boundaries are often difficult to fix. The legend provides signs for different degrees of reliability in finding (chrono-)stratigraphic boundaries. A few profiles have a special column for isotopic ages, too.

Molasse deposits usually display a rich diversity of lithofacies. This led to a setting up of an immense number of lithostratigraphical names which, dealing with comparative studies, must be overlooked easily. The profiles comprise the current lithostratigraphical names in the column lithostratigraphy. Here the authors follow the national standards of their countries or regional literature, respectively. The national lithostratigraphical nomenclature is not in all cases strictly identical with the guiding principles according to HEDBERG (1972). This refers also to the usage of "formation" and "member" which are used in many profiles to characterize a two-level hierarchical subdivision into lithostratigraphic units.

In a special column the range of thickness is given numerically for each unit.

Lithology

Lithology is represented bipartite: the left side shows the sedimentary record, the right side presents the volcanic rocks and tuffs. The interfingering relation between the two components is schematically indicated in the middle part.

For s e d i m e n t s a series of basic signs (e.g. sand, silt, dolomite) is used from which single signs can be mixed to illustrate the diversity of sedimentary rocks composing the molasse deposits. Horizontal changes of facies are represented in a schematized manner as far as possible.

DOI:https://doi.org/10.2312/zipe.1982.066

The classification of the volcanic rocks is founded on STRECKEISEN (1967) with some simplifications according to PÄLCHEN & SCHIRMER (1972). This coarse subdivision is sufficient for the purpose followed here[2]. As the selected type areas are sedimentary molasse basins the volcanic sequences make up only intercalations of lower or higher thickness. Intrusive bodies are not represented in the lithological column but are indicated in the columns of magmatism according to their geological age.

The r o c k c o l o u r s which may be rather variegated in molasse sediments are summarized into broad groups. Red colours are especially important in terrestrial deposits of Upper Paleozoic molasses. On the other hand, the red beds may tightly interfinger with grey and black sediments. Mixed signs of colour figure spotted, variegated or closely alternating patterns. Laterally adjoining signs refer to facies changes.

Sedimentary features and processes

Under this heading a series of further columns informs on composition, structures and genesis of the sediments. Left hand the representation of s e d i m e n t a r y c y c l e s completes the lithological column bringing out the general trends of sedimentation. The following columns hold particulars on the c o m p o s i t i o n o f t h e g r a v e l , s a n d a n d c l a y g r a d e . The occurrence of coarse clastic deposits is one of the typical features of molasses. In most cases the pebbles were transported only a rather short distance. Therefore, the composition of the gravel grade supplies an important clue to the petrographic composition or to the geological structure of the source areas from which the pebbles are derived. For figuring, only a few petrographic groups are distinguished which are thought to characterize the source areas according to their level of erosion in the emerged tectonic units of the crust. References to regional units are given by letters (e.g. pl - from platform, or - from orogene). The clastic grains of sandstones may have a short or long history of transport. This is reflected by low or high maturity of composition, respectively. Therefore, the legend provides a grouping of constituents which refers to the maturity of the sand grade.

Figuring the percentage of composition the authors choose a variant appropriate to their data: general or (indicated by arrow) distinct level circular diagrams, strip diagrams representing average values or an estimated range of percentage. The content of clay minerals is quoted qualitatively in most cases. As the clay minerals are subjected to strong diagenetic alterations these constituents give only limited evidence of the primary conditions of sedimentation. The presence of kaolinite may be used as an indicator of special conditions of weathering, especially in Upper Paleozoic molasse. Montmorillonite is connected with tuffaceous components of Cenozoic deposits.

---

[2] The useful help of Dr. R. BENEK in providing the classification and coordinating it with working group 3.4 "Magmatism and metallogenesis associated to the epochs of molasse formation" is gratefully acknowledged.

DOI:https://doi.org/10.2312/zipe.1982.066

In sedimentary basins with dominating clastic deposits the knowledge of the p a l e o c u r r e n t d i r e c t i o n s is important in order to understand the development of paleogeography and paleotectonics. In the profiles the pattern of paleocurrents can be figured only insufficiently. However, the authors treat this topic in the explanatory notes which are illustrated by paleocurrent maps in some cases, too. From the profile, besides a general information on transport direction, the changes of paleocurrents are easily surveyed. Abrupt changes, together with other features, are marking significant cuts in the basin development. They indicate paleotectonic processes which modify the basin configuration or the relative significance of surrounding source areas controlling the basin and/or range relief.

Figuring the l e n g t h o f t r a n s p o r t the authors summarize their interpretations of source and maturity of the clastic sediments. The scale is tripartite and logarithmic in rank, as for accentuating the contrast between close and long distant source areas.

The following column records s e d i m e n t a r y f e a t u r e s which the authors wish to emphasize for lithological characterization or genetic interpretation. Among these there are special constituents: intraformational pebbles prove processes of reworking; pyrite, other ore minerals and bituminous shales indicate reduced environmental conditions, etc. Another group of features concerns sedimentary structures. Cross-bedding of different type and size is very typical for molasse sandstones. Thick beds or graded bedding indicate special processes of sedimentation, too. Markings and deformational structures provide various genetic evidence.

The notation in the column f a u n a a n d f l o r a gives a first impression whether the sediments are rich or poor in fossils. Distinguishing only large systematic groups the signs are thought as a survey over the kind of fossils which are available for biostratigraphy and ecologic evidence. With a view to this, several signs are used which describe the status of preservation, especially of plants. By additional signs the fossils may be characterized as fresh-water, brackish or marine forms.

The s e d i m e n t a r y e n v i r o n m e n t s are an important aspect in comparing molasse deposits because their formation occurs in a broad diversity of conditions between neritic and intramountain. The authors subdivide this heading according to the special situation in the sedimentary basins described. The general order is from terrestrial on the left to marine on the right. The environments are designated as a two letter symbol which is easily understood as an abbreviation of the English term. Under a one letter symbol the environments may be grouped (or spezialized) as continental, brackish or marine. A strong line indicates the period of the profile in which the environment occurs.

Magmatism

In the field of magmatism the mainly petrographic representation of the volcanic rocks which is shown in the lithological column is completed by other features. In a first column this concerns s t r u c t u r a l f e a t u r e s of volcanic rocks

DOI:https://doi.org/10.2312/zipe.1982.066

and tuffs. Another column demonstrates the g e o m e t r y o f m a g m a t i c b o d i e s by a series of simplifying signs. Tuffs are characterized according to their occurrence in thin, single layers, big accumulations, and ignimbritic eruptions. This reflects different processes of out-burst and/or the distance of the centre of eruption. In a few profiles of well-preserved Cenozoic molasses paleovolcanologic evidences are available (agglomerate conus, stratovolcano, dome, etc.).

It must be mentioned that magmatic intrusions, too, are represented in this column. As intrusive bodies subvolcanic intrusions, dikes and plutonites are distinguished. To characterize the petrography of the intrusive rocks the legend provides additional signs for plutonic rocks which are inscribed into the signs of magmatic rock geometry. The intrusions are represented according to the geological age, not in the level of intrusion.

The right column had been reserved for other features of igneous rocks. After all, the column was exclusively used to demonstrate p o s t m a g m a t i c a l t e r a t i o n s . This is a useful information in respect to the modern state of the rocks. Furthermore, it permits conclusions to the thermal-geochemical regime during and after the molasse formation or to processes of paleoweathering, respectively.

Tectonics

The tectonical statements are set up in two columns on the right side of the profile. The first column describes the modern s t a t e o f d e f o r m a t i o n . The signs depict widely defined categories of the tectonic style. Further the degree of metamorphosis may be signified by a letter. The modern state of deformation results from the tectonic history during and after the molasse formation. In several profiles it is visible that the degree of deformation changes in a definite level. There the tectonic processes certainly took place during the molasse epoch. Many deformational processes however, happened in the postmolasse history, especially faulting and flat, brachyanticlinal folding which are typical in platform regions. Where Upper Paleozoic molasses have been involved in the alpidic tectogenesis the post-molasse deformation may be increased up to nappe tectonics and epizonal metamorphosis.

The t e c t o n i c e v e n t s a n d p r o c e s s e s , represented in the last column, are of special interest for the development of the molasse sequence. The basic events figured by signs are processes of folding, thrusting and nappe formation as well as faulting. Long-termed, synsedimentary processes are indicated separately.

Important information can be obtained, too, from the nature of contacts between lithostratigraphic units. Under the column of tectonic events there is explained what has been uniformly marked in the lithological column as a wavy line:disconformity over a substratum with different state of deformation, high angle disconformity, low angle unconformity, gaps of sedimentation with transgressive or regressive trend between above and below, complemented by significant levels of erosion or soil formation. Furthermore, two signs point to processes in the surrounding uplands the knowledge of

DOI:https://doi.org/10.2312/zipe.1982.066

whioh is derived from the totality of sedimentary features: strong elevation and formation of olisthostromes as an expression of periods with strong relief intensity.

Several authors have inscribed names of tectonic events into the profiles (e.g. tectonic phases). At any rate, in the commentary notes the tectonic processes are commented in detail what is in accordanoe with the design of the working group 3.3.

Summary

The organization and the legend of the lithotectonic profiles have been carried out under the scope of obtaining a better oomparison of type sections from molasse basins with a broad variety of size and lithological content. Sedimentary features and processes as well as informations on magmatism and tectonios are represented in a series of columns by means of symbols and signatures. The diversity of details imply the necessity of simplification which may obliterate some individual characteristics and peculiarities of the basins. On the other hand, a flexible handling of the appointed organization and the legend had to be tolerated as to find out the best fitting to the individual basins.

References

HEDBERG, H.D. (Edit.): An international guide to stratigraphic classifioation, terminology, and usage.
International Suboommission on Stratigraphic Classification, rep. 7. 1972

PÄLCHEN, E.; SCHIRMER, B.: Zur petrographischen Nomenklatur magmatischer Gesteine.
Geologie, Berlin 21 (1972), p. 536-553

STRECKEISEN, A.L.: Classifioation and nomenolature of igneous rocks.
N. Jb. Miner. Abh., Stuttgart 107 (1967), p. 144-240

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW, Potsdam (1982) 66

Explanatory Notes to the Lithotectonic Molasse Profile of the Carpathian Foredeep in Moravia (Czechoslovakia) (Comment to Annex 1)

by

IVAN KRYSTEK[1]

1. Introduction

The outer foredeep of the West Carpathian Mountains in Moravia represents a Neogene sedimentary area stretching along the outer part of these mountains and situated upon the slopes of the Bohemian Massif. No exhaustive data could be obtained on the SE margin of the older developmental stages of the foredeep, because it underlies the Flysch nappes. The present NW margin, formed by the Bohemian Massif, extends more or less linearily following the Carpathian direction (SW--NE) in accordance with the axis of the Central depression of the youngest development stage of the foredeep. However, Neogens sedimentation repeatedly extended beyond this line, as has been evidenced by the denudation remnants of the Ottnangian, Karpatian, and Badenian stages frequently found rather deeply within the Bohemian Massif. On the southwest, the outer foredeep of the West Carpathian Mts. passes into the outer Alpine foredeep of Austria and, on the northeast in Poland, it gradually passes into the foredeep of the Central Carpathian Mountains.

The literature concerning the Moravian part of the Carpathian foredeep is indeed abundant. In addition to previous authors, as are RZEHAK, PROCHÁZKA, HÖRNES, etc. whose works date back to 1850 - 1900 but have lost nothing of their importance, other geologists, mainly ADAM, BUDAY, DLABAČ, DORNIČ, JURKOVÁ, HOMOLA, CHMELÍK, MOŘKOVSKÝ, ADÁMEK etc., laid the foundations of the recognition of the detailed geological conditions. The papers by CICHA, ČTYROKÝ, BRZOBOHATÝ, GANNSS, POKORNÝ, HOLZKNECHT, MOLČÍKOVÁ, TEJKAL, and ZAPLETALOVÁ are of primary importance for the stratigraphy of the region. Paleogeographical and sedimentological problems have been studied, among others, by JURKOVÁ, CICHA, KRYSTEK, SENEŠ, and TEJKAL. The most essential works are quoted in the text.

1) Katedra Geologie a Paleontologie přírodovědecké fakulty University J.E. Purkyně; ČSSR, 61137 Brno, Kotlářská 2

DOI:https://doi.org/10.2312/zipe.1982.066

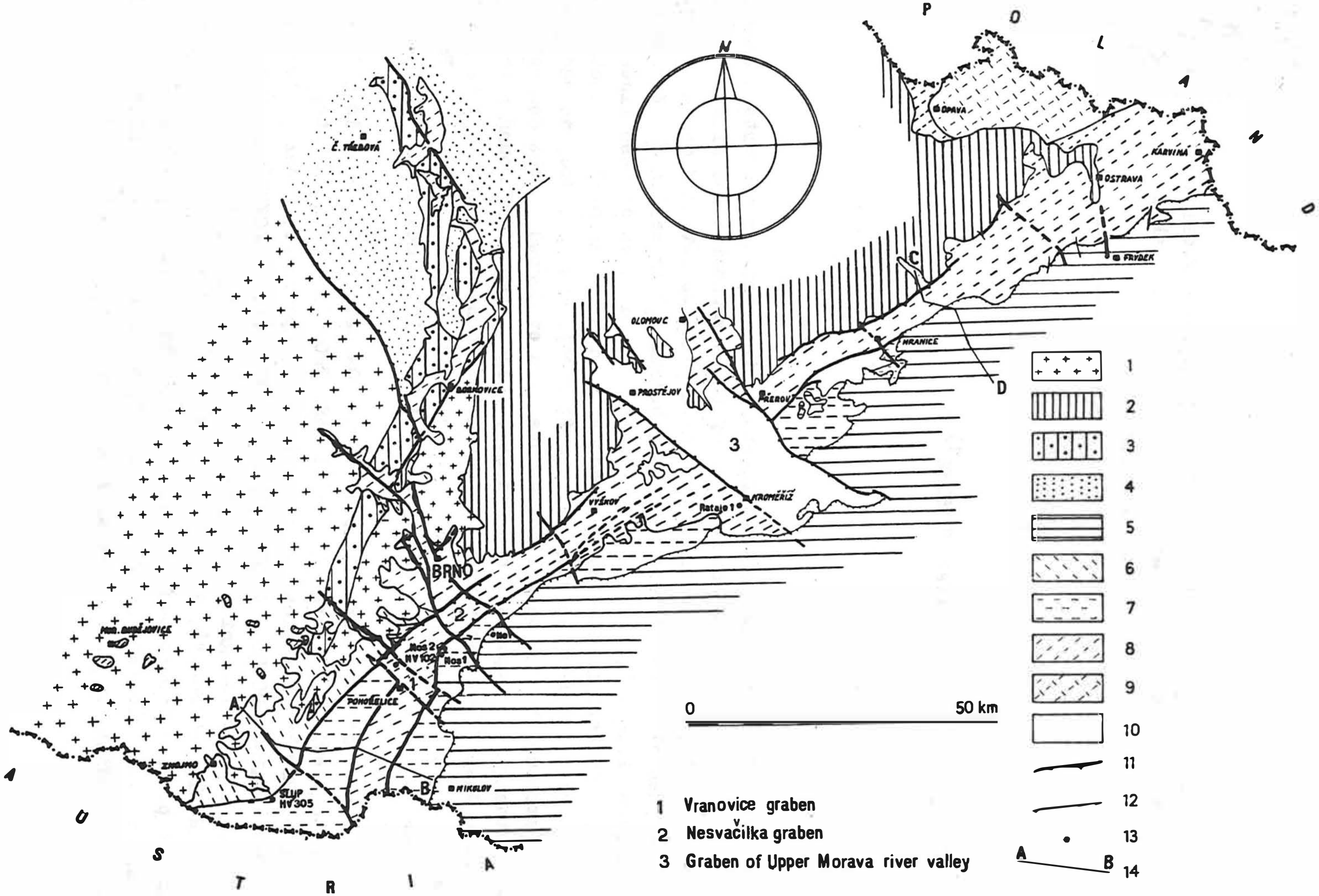


Fig. 1. Outer Carpathian Foredeep in Moravia (CSSR)

1 - plutonic and metamorphic rocks of the Bohemian Massif, 2...4 - sediments of the Bohemian Massif, 2 - Devonian and Lower Carboniferous, 3 - Permian, 4 - Cretaceous, 5 - flysch nappes, 6...9 - sediments of the Carpathian Foredeep, 6 - Eggenburgian and Ottnangian, 7 - Karpatian, 8 - Lower Badenian, 9 - Middle and Upper Badenian, 10 - Pliocene, 11 - faults, 12 - front of overtrust nappes, 13 - boreholes, 14 - profile lines

DOI:https://doi.org/10.2312/zipe.1982.066

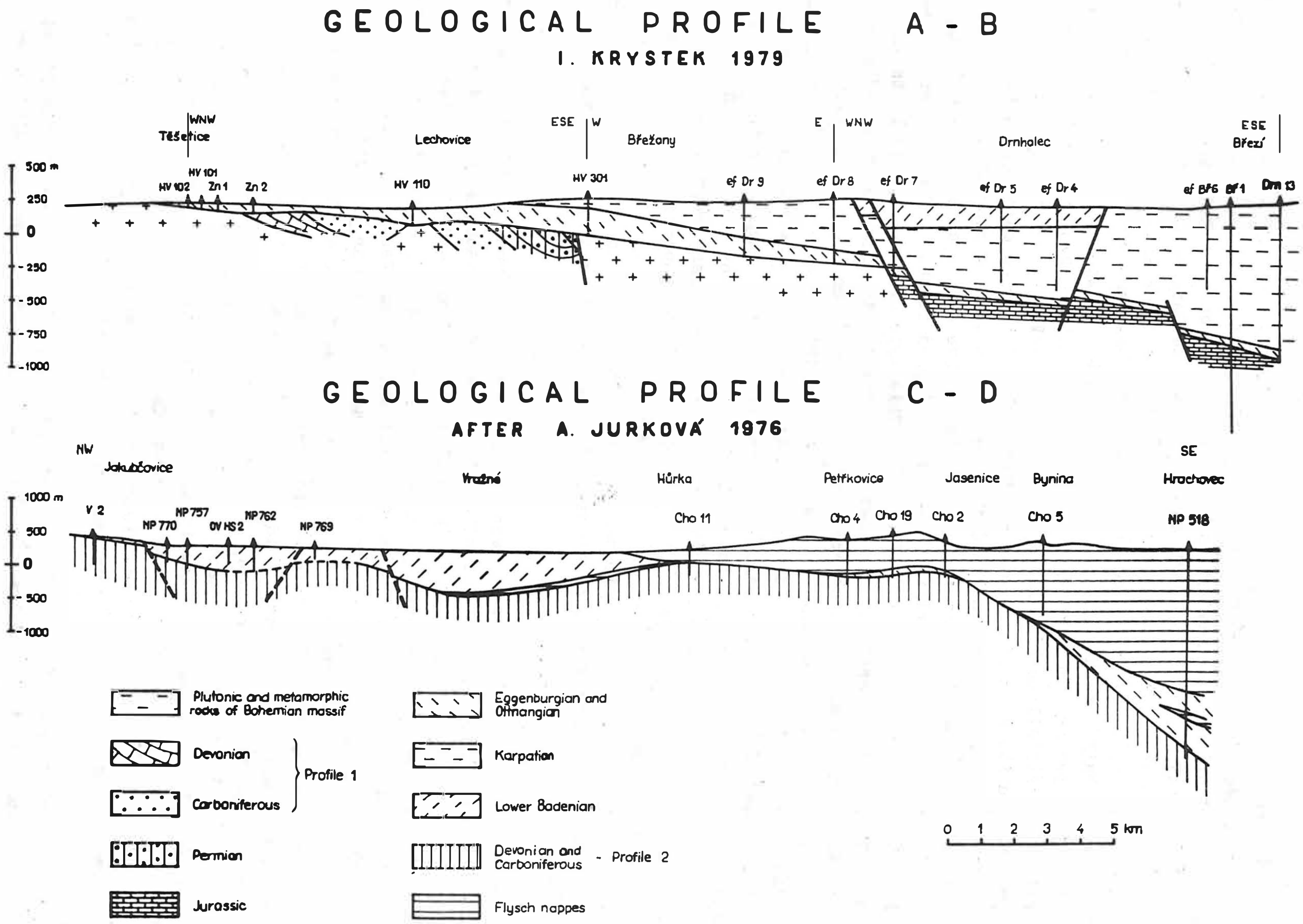


Fig. 2. Cross-sections of the outer Carpathian foredeep in Moravia (Czechoslovakia)

DOI:https://doi.org/10.2312/zipe.1982.066

2. General statements

In the outer part of the West Carpathian Mts., molasse sedimentation started as early as in the late Paleogene, but, with regard to denoting this area as the outer Carpathian foredeep, the beginnings of sedimentation have been placed only to the Eggenburgian or Egerian stages. BUDAY (1961, 1965, 1967) characterizes the Carpathian foredeep as a system of parallel, locally overlapping foredeeps of different age situated in front of the Flysch nappes and, partially, also underlying them. The basement of the sedimentary fill of the foredeep is built of the Bohemian Massif - from the viewpoint of geotectonics, of the Moravian and Silesian blocks forming part of the Bohemian megablock (in the sense of WEISS 1977). This crystalline basement is composed of pre-Variscan metamorphites and granitoides and, in its main part, it is covered with a Paleozoic cover (Devonian, Lower and Upper Carboniferous, and Permian) and with Mesozoic sediments most of the Jurassic period. The Moravian block is characterized by disjunctive tectonics of the individual blocks; the fault systems of the rigid basement are copied in the surface and even subsurface levels of the Earth's crust (WEISS 1977). This type of tectonics reflects in protracted active tectonic sectors, for instance in the longitudinal Slavkov-Těšín ridge (DLABAČ and MENČÍK 1964) or the transverse Nesvačilka and Vranovice grabens (Fig. 1). In addition to the Neogene sediments of the outer Carpathian foredeep, the fills of the above grabens consist also of the sediments of the autochthonous Paleogene, that means of sediments placed to the early development stage of the outer Carpathian molasse that were not included into the nappes of the Ždánice or the Pouzdřany units. DLABAČ and MENČÍK (1964) studied in detail the morphology of the pre-Tertiary basement delineating a number of morphologic elevations and depressions of various importance. Even though the role of some of the longitudinal ridges, mainly that of the partial elevations of the Slavkov-Těšín ridge, was overestimated by the authors mentioned, it reflects in the thicknesses and in the lithofacies development during the course of sedimentation in the foredeep.

The shape, the size and the development of the Carpathian foredeep in Moravia depend upon the intensity and the time distribution of the tectonic movements in the West Carpathians, but they are limited by the high consolidation of the underlying Bohemian megablock. For this reason, the development of the outer foredeep of the West Carpathians is rudimentary, in essence, in this area. The sediments of the West Carpathian foredeep are relatively slightly disturbed due to tectonic activity. We can recognize a system of transverse and longitudinal radial faults; the transverse faults striking NW—SE, mainly, are copied from the pre-Tertiary basement and their continuation in the uncovered part of the Bohemian Massif is frequently evident. In common with the (longitudinal) faults following the Carpathian direction they participate, to a high degree, in forming the morphology of the pre-Tertiary basement. Evidently, most of these faults are of synsedimentary origin, some of them pronouncedly manifesting themselves even during the subsequent tectonic reconstruction of several areas. The faults bounding the graben of the Upper Morava river valley filled with Pliocene sediments can serve as an illustrative example. Some of these faults have been active up to recent time.

Another type of tectonic deformation is related to the overthrusting of the Flysch nappes. The nappes were thrusted over the foredeep fill to distances exceeding 20 km, they are predominantly flat, but with considerably varying dip angles. The deformation

DOI:https://doi.org/10.2312/zipe.1982.066

of the Neogene sediments resulting from the overthrusting nappes is of varying intensity, ranging from almost minimum to intensive kneading of the nappe rocks with the Karpatian or Lower Badenian sediments. Locally slicing takes place, resulting in tectonic doubling of the thicknesses, mainly of those of the Karpatian sediments. Dislocated tectonic slices of the Karpatian in front of the Ždánice unit were encountered, for instance, in the Rataje-1 and Nítkovice 2 and 3 boreholes. Overthrusting of nappes took place in the time span between the Karpatian and the Lower Badenian stages as well as in the Badenian, particularly in the NE part of the West Carpathian foredeep.

3. Development of sedimentation and tectonics

Egerian

In the area of the outer Carpathian foredeep of the West Carpathian Mountains, Neogene sedimentation seems to have started in the Egerian, as can be concluded from the single occurence of Egerian sandy clays in the Malešovice HV-102 borehole (fide CICHA) situated about 25 km SW of Brno (Fig. 1). There, the Egerian sediments seem to from part of the older sedimentary fill of the Vranovice graben.

Eggenburgian

The transgression of the Eggenburgian (in the sense of the stratotype according to STEINIGER and SENĚS et al. 1971) has been proved without doubt. The marine Eggenburgian has been known mainly from the SW part of the outer West Carpathian foredeep. It was evidenced by macropaleontology in the surface exposures near Chvalovice and Šatov at the Austrian/Czechoslovak border line (TEJKAL 1958); a similar fauna was also observed in the Slup HV-305 borehole (KRYSTKOVÁ 1978, MS). Micropaleontological studies have evidenced marine Eggenburgian formations up to 80 m thick in other boreholes drilled in this area (MOLČÍKOVÁ 1976). The Eggenburgian sediments transgress over the metamorphites or over the greywacke and shale of the Lower Carboniferous. The lithological development varies with predominating fine-grained to coarse-grained sands and interbedded green-grey or grey-brown clays. In the uppermost part of the series the sands pass into dark green-grey sandy clays or clays the Eggenburgian age of which, however, cannot be proved.

Further evidence of occuring Eggenburgian sediments comes from the petroleum exploration wells of the Musov - Dolní Dunajovice - Březí region situated along the front of the nappe of the Ždanice unit (ZAPLETALOVÁ 1977). Eggenburgian sediments were found up to 100 m thick in a number of boreholes. Basal clastics characterized by the presence of green glauconitic and chlorite-glauconite sandstones with interbedded greenish-grey, grey to black-grey claystones were deposited at the base. This series shows an upward transition into grey or greenish grey claystones containing abundant fish remnants and Eggenburgian microfaunas. Other autochthonous Eggenburgian sediments were found only in the NE part of the foredeep at the Jaklovec hill in the Ostrava region. Bryozoan limestones and basaltic conglomerates with interbedded coarse-grained sandstones and mollusc faunas corresponding to the Eggenburgian region in Austria (GANNSS 1936; ČTYROKÝ 1958) were observed there. The connection of the Eggenburgian occurences in the SW and NE

DOI:https://doi.org/10.2312/zipe.1982.066

parts of the foredeep could not be reconstructed up to this time, but folded fragments of Eggenburgian sediments have been known from the front of the Flysch nappes.

Ottnangian

The relation between the Eggenburgian and the Ottnangian stages represented in the area of the Carpathian foredeep in Moravia could not be adequately explained for the present. No paleontologically unboubtedly proved Ottnangian sediments overlying the evidenced Eggenburgian sediments were found there. It cannot be excluded, however, that a part of the pelitic sediments containing redeposited Cretaceous microfaunas or lacking any faunas belong to the Ottnangian stage in the Slup, Chvalovice and Šatov regions. The investigations of the Lower Miocene sediments have shown that a similar situation exists in the petroleum prospecting areas of Musov and Drnholec (and, probably, also southward along the front of the Ždánice nappe). In this region, no criteria allowing to separate the Eggenburgian and the Ottnangian sediments have been known. The two stages form a single depositional cycle there, of course, in case that both stages are present.

Marine Ottnangian formations (clays and sandy clays) were described by CICHA et al. (1955) from the Nosislav No 1 and 2 boreholes (Fig. 1). The lower section of the series ranging from 160 to 180 m in thickness has been parallelized to the Robulus schlier from the Austrian molasse. Upwards, the series passes into a facies more brackish in character and, gradually, into the so-called fish schlier. The facies development of the Ottnangian considerably changes to the east and the north-east. Marine Ottnangian sediments were also described from the Nesvačilka-1 borehole (Fig. 1) situated about 19 km SE of Brno (core No. 11 in the hole interval from 395,4 to 400 m) in the pelitic intercalation of the basal clastic series. The latter is overlain by 100 m thick brackish mainly clay sediments including sandy intercalations. The latter series containing inconclusive microfaunas is overlain by mostly sandy sediments about 50 m thick that were parallelized (HOMOLA 1961) to the so-called Žatčany beds, mainly due to their facies development. With respect to the microfauna contained, the upper part of this horizon has been related to the overlying Karpatian formation, while the lower part (comprising also red-brown interbedded clays) has been compared to the Rzehakia beds by the author. Rzehakia specimens, known from a similar position in the oil-bearing sands of an oil pit near Telnice, were not found in the Nesvačilka-1 borehole, however.

Marine Ottnangian beds are no longer known eastward, lacking also northwestward in the area of the Žatčany oil field. Lithologically rather varying sediments are present there, ranging from coarse-grained sands and gravels to pure pelite zones. The correct parallelization of the latter is rather difficult, because it can base only on the results of previous exploratory drilling, the material allowing a micropaleontological revision being no longer available. Only the upper parts of the profiles of the Ottnangian in the Nosislav-1 and 2 and Nesvačilka-1 boreholes seem to be developed both to the east and to the northwest towards Brno.

The Ottnangian sedimentation is not believed to continue eastward and northeastward towards Slavkov and Výškov, but, beginning with the Brno region, it occurs almost continuously along the whole western margin of the foredeep as far as to the Znojmo re-

DOI:https://doi.org/10.2312/zipe.1982.066

gion. There, only the uppermost part of the Ottnangian seems to be present showing a lithologically rather variegated severely freshened development. The variegated (red-brown, carmine, intensely green, mottled) uncalcareous clays known from the Brno region (Brno freshwater clays), from the Ivančice region, and from the Znojmo region (Vitonice clays or the so-called Žerotice beds) are most typical. The variegated beds including also variegated sandstones and conglomerates at their bases, mainly northeast of Znojmo, often show the characteristic features of proluvial deposits. They occur at the base or alternate with sediments comprising macrofauna associations with Rzehakia socialis (RZEHAK) or a rather similar assemblage with the lack of this typical fossil. As a rule, the proper Rzehakia beds are sandy, locally with gravel horizons or, on the contrary, with interbedded clays. Rzehakia socialis (RZEHAK) have been also known from the pelitic sediments, however. The series can range from 100 to 150 m in thickness. Northeast of Znojmo, in the region where the Żerotice beds occur, the variegated sediments interfinger with a grey clayey and sandy series abundant in freshened and fresh-water macro- and microfaunas and remnants of water and land plants. Eastward, the grey series increases in thickness towards the deeper parts of the basin, while the variegated sediments gradually disappear at the same time. Acid vitric tuffites were observed at the base of the above series near Znojmo. The grey series and the proper Rzehakia beds can be considered to be sediments of the highly freshened marine bay (of the type of the Finnish Bay); the uniformity in some marks of the sandy sediments in the whole region and, particularly, the characteristic uniform association of heavy minerals with a high staurolite concentration throughout the region exclude the sedimentation in isolated limnic basins.

The problems associated with the Ottnangian stage in the Carpathian fore-deep in Moravia have not yet been resolved.

Karpatian

The appearance of Karpatian formations in that part of the Carpathian foredeep in Moravia where Ottnangian and Eggenburgian sediments are developed can be evidenced due to the presence of marine faunas (mainly microfaunas), due to a pronounced change in the carbonate contents or due to the changes in the heavy mineral associations (KRYSTEK 1967; KRYSTEK and TEJKAL 1968). However, a marked lithological boundary showing up by a striking change in the sediment type cannot be observed in most cases. Thus, water of higher salinity seems to have entered the Ottnangian freshened bay during the fundamental tectonic reconstruction in the foreland of the front of the Flysch nappes where, prior to this, no complete regression had taken place. A foredeep of Carpathian direction was formed stretching from the outer Alpine foredeep across Znojmo - Brno to the Ostrava region but, probably, it did not extend far into Poland. The central depression of the Carpathian foredeep was situated in an area more or less underlying the Flysch nappes at present and extending northeast of Brno at the southeast side of the Slavkov - Těšín ridge. The Karpatian sea extended beyond this ridge in places reaching, probably, through the transverse depressions far into the Bohemian Massif beyond the later Lower Badenian central depression. The depth of the Karpatian transgression over the Bohemian Massif is evidenced by denudation relicts newly found at a number of sites and by the occurence of Karpatian sediments at the base of the Lower Badenian in the Bučovice - Rousínov depression (the borehole near Čechyně, DORNIČ, MS, 1975).

DOI:https://doi.org/10.2312/zipe.1982.066

In the southwest part, the Karpatian formations transgress over the sediments of the Ottnangian - Eggenburgian sedimentary cycle and also directly over the crystalline basement of the Bohemian Massif.

From Brno to the northeast towards the Ostrava region, the Karpatian directly transgresses over the pre-Tertiary crystalline basement, but, mostly, over Paleozoic sediments (Devonian, Lower Carboniferous, and the coal-bearing Carboniferous in the Ostrava region). The schlier facies with typical grey calcareous clays comprising a silt component mostly concentrated at the surfaces of indistinct lamination is the most common lithofacies of the Karpatian stage. Larger or smaller intercalations of fine-grained sands or silts appear locally in this facies; in places, mainly in the southwest region, the sandy sediments form discontinuous bodies up to several ten metres thick and up to several kilometres long. Coarser-grained clastics only seldom appear in this facies. They occur at the base of the Karpatian in the central part of the Carpathian foredeep in Moravia and in the northeast part of the foredeep in the Ostrava region. Clastics of the "variegated facies" appear again in the central part of the foredeep (KREJČÍ and ŠPIČKA 1970). The surface occurences of Karpatian clastics in the area of the Litenčice hills (the Nítkovice gravels) and those in the Holešov region, probably, can also be assigned to the clastics mentioned above. CHMELÍK and DORNIČ (1969) suppose that the clastics appearing in the upper Karpatian sections of this region are due to the revival of the tectonic movements in the Carpathian Mountains.

The clastics contained in the uppermost section of the Karpatian stage in northeast Moravia (JURKOVÁ and NOVOTNÁ 1974), that means the variegated series including gypsum, are of different facies development. Two other types of lithofacies specific of this area are inserted between the basal clastics and the schlier development in northeast Moravia, one of them being the variegated basal siltstones (JURKOVÁ and NOVOTNÁ 1974) occuring with the absence of coarse-grained basal clastics, locally, at the base of the Karpatian formation. Like the basal clastics, they are sterile in faunas or comprise freshwater fauna and flora. Their character reminds of the variegated proluvial sediments associated with the Rzehakia beds in the southwest part of the foredeep. The so-called brown, mostly pelitic beds, named after the predominating pelites of various brown shades, are another specific lithofacies in NE Moravia. Locally, they contain laminae or thin layers of coal up to 20 cm thick. These beds can directly overlie the Carboniferous basement, but, according to JURKOVÁ and NOVOTNÁ (1974), they also overlie the basal clastics or the variegated basal siltstones. They are 60 m thick at maximum, upwards gradually passing into the schlier facies. Compared to other types of facies, the paleontological composition is rich in foraminifers and molluscs appearing in beds with coal lamination.

It can be stated in view of the microfauna that, in the major part of the outer foredeep of the West Carpathians in Moravia, the sedimentary basin attained its bathymetrically greatest depth in the central part of the Karpatian formations having, there, its most important communication with the open sea. By the late Karpatian stage, flattening and freshening of the sea gradually took place again. Maximum thicknesses of the Karpatian formations, exceeding 1100 m, were observed in the central depression in the southwest part of the foredeep. The maximum thicknesses observed, up to now, in the central part of the foredeep amount to about 750 m and to about 300 m in its northeast part.

DOI:https://doi.org/10.2312/zipe.1982.066

The deposition of the Karpatian sediments was terminated by thrusting the Flysch nappes (during the late Styrian movements) over the whole width of the central depression and, in places, almost over the whole width of the Carpathian foredeep (in its northeast part). These tectonic movements gave rise to a new outer foredeep preceded, probably, by a prolonged period of denudation that had affected a considerable part of the Karpatian sediments occuring at the previous margin of the basin along the Bohemian Massif. The subsequent Lower Badenian sediments overlie not only the Karpatian formations, but also the Ottnangian and, to a less degree, the Eggenburgian formations, mainly in the southwest part of the foredeep. They were deposited upon the crystalline basement of the Bohemian Massif or on its Paleozoic cover at the margin of the basin. Sediments of the Ždánice unit thrusted over the autochthonous Miocene formations that are lithologically identical with the Karpatian rocks found beneath the Lower Badenian in the boreholes drilled in the northeast part of the Carpathian foredeep in Moravia (JURKOVÁ 1971).

Badenian

The Lower Badenian transgression seems to have taken place in several stages. It proceeded, probably, from the southwest from the Alpine foredeep towards Brno and Výškov and, also, from the northeast from Poland across Ostrava and the so-called Moravian Gate towards the southwest. The later central depression had not yet been formed at that time and we are not sure whether the two flooded regions had joined completely. Basal clastica, well developed in the Ostrava region (Ostrava detritus), in the Brno region (Brno sands), and in the area southwest of Brno towards the borderline with Austria, were deposited during the first stage of the transgression. They are up to 200 m thick. The deposition of the basal clastics was terminated by a partial regression, as evidenced by the soil profile described by PELÍŠEK (1944) from the uppermost part of the Brno sands from Brno that underlie the Lower Badenian calcareous clays. A new transgression of the Lower Badenian sea proceeded, probably, across Brno eastward when a pronounced central depression was forming. The latter was bounded by the Lower Carboniferous of the Drahany plateau and the Nízký Jeseník Mountains on the northwest (in the area northeast of Brno) and by the Slavkov-Těšín ridge on the southeast.

After the transgression, the whole sedimentary area was interconnected across the upper Morava river valley, extending as far as to Ostrava and Poland. This younger stage can also be divided into two partial stages. The first of them was first distinguished by a faster subsidence of the central depression. Nearly pure pelites were deposited in its centre, while marginal clastics of varying thickness were formed at the margins. At that time, the Lower Badenian sea extended into the Bohemian Massif flooding the depressions of its dissected relief and depositing, in places, sands and sandy gravels of considerable thickness. The following development stage of the Badenian foredeep is characterized by the advancement of the transgression into the Bohemian Massif. Owing to the remnants of denudation - mostly Lower Badenian clays - the transgression can be evidenced deeply within the Paleozoic of the Nízký Jeseník Mountains, the Drahany plateau, the Moravian karst, and above the west Moravian crystalline basement. Simultaneously with the deposition of pelitic sediments or marginal clastics, bodies of algal limestones formed in various places of the Lower Badenian foredeep (most abundantly in

DOI:https://doi.org/10.2312/zipe.1982.066

the central part of the foredeep). The sediments originated in the relatively flat sea and their repeated occurrence in the profile evidences equilibrium conditions between subsidence and deposition for a long period of time. The limestone bodies are several tenths of metres up to several metres thick.

Acid vitric tuffites have been known from a number of boreholes drilled in various parts of the foredeep in the calcareous Lower Badenian clays. These clays, the so-called "tegels", are about 400 m thick in the midpart of the central Badenian depression. Maximum thicknesses about 1000 m were observed in the area of the Bludovice and Dětmarovice wash-out in the Ostrava region and in the NP-767 borehole near Přerov (JURKOVÁ and HUFOVÁ 1973). The width of the sedimentary area highly differed in the various regions and periods of time. The smallest width amounting to 6 km was observed between the towns of Přerov and Suchdol n.O., while the width is as much as 30 km near Karviná. The area flooded during the culminating Lower Badenian transgression measured about 60 km in width.

In the major part of the Carpathian foredeep in Moravia, the Lower Badenian sediments are disturbed only by radial faults, except for the northwest part of the foredeep where the Flysch nappes were overthrusted during the young Styrian movements. This overthrust beginning beyond the highest transverse uplift of the Slavkov-Těšín ridge (the Malenik hill) gradually increases eastward up to 8 km near Český Těšín (JURKOVÁ 1976). The Lower Badenian sediments underlying the nappes are slightly folded. Movements associated with the final overthrusting of the Flysch nappes resulted in the regression of the sea almost throughout the Carpathian foredeep in Moravia, terminating, thus, the Neogene sedimentation. Typical regression sediments have not been known in this area.

During the Middle and the Upper Badenian, sedimentation continued only in the Opava area that formed part of the new Middle and Upper Badenian foredeep situated in the territory of Poland. In the region between the towns of Opava and Hlučín, the Lower Badenian sediments are overlain by a pelite series containing gypsum and, further upwards, by a series of alternating grey calcareous sandy clays, sands and sandstones. The highest thickness of the later Badenian does not exceed 350 m there.

Pliocene

The youngest sediments of the Carpathian foredeep in Moravia are those of the Dacian and Romanian stages that were deposited in the transverse graben of the Upper Morava river valley. They are composed, mainly, of varicoloured sands with interbedded uncalcareous clays that are sterile in faunas in most cases.

4. Comments on the lithotectonic profile (Annex 1)

The profile was constructed on the basis of extensive field work and the results of the about 1000 boreholes drilled in the Carpathian foredeep in Moravia. The boreholes, however, are not equally distributed. Good evidence has been obtained of the lithofa-

DOI:https://doi.org/10.2312/zipe.1982.066

cies conditions, the thickness of the sediments, and tectonic development. However, there are some problems related to the stratigraphy of the Eggenburgian - Karpatian and much work is being conducted in order to solve them. The sedimentological investigations are nearly complete; they were terminated for the Lower Badenian sediments up to this time. When necessary, new research results were included into the profile. Radiometric chronometric data are lacking for the whole foredeep up to now. The lithostratigraphical division was not applied in its full range in the profile, because many unnecessary terms have been used for the region. The sedimentary cycles were not denoted in the profile, the sedimentation not being a typically cyclic one in the foredeep.

Data on the composition of the coarse-grained clastic sediments and those on granulometry are available only uncompletely. The source areas, with several exceptions, are supposed not to have been rather distant, as has been evidenced by the pebbles in the rocks of the Bohemian Massif and by the material from the Carpathian Mountains. The development of the character of the sedimentary area is well evidenced by the fauna and flora in most cases. Along with the tectonic development, the deformations of the sediments, and with the sequence of transgressions and regressions it is commented in detail in the text presented.

References

BUDAY, T.: Der tektonische Werdegang der Neogenbecken der Westkarpaten und ihr Baustil. Geol. Práce Zoš., Bratislava 60 (1961), p. 87-106

BUDAY, T.; CICHA, I.; SENEŠ, J.: Miozän der Westkarpaten. Bratislava: Geol. Úst. D.Š. 1965

BUDAY, T. et al: Regionální geologie ČSSR. Praha: Ústr. Úst. Geol., Academia Praha 1967

CICHA, I.; PAULÍK, J.; TEJKAL, J.: Stručné shrnutí výsledků geologických a paleontologických praci v miocénu jz. části vněkarpatské pánve na Moravě. Zpr. geol. výzk., Praha 1955 (1956), p. 13-15

ČTYROKÝ, P.: Předběžná zpráva o revizním paleontologickém výzkumu na Jaklovici v Ostravě. Vest. Ústr. Úst. geol., Praha 33 (1958), p. 71-74

ČTYROKÝ, P.: Interregional correlation of Rzehakia (Oncophora) Series in Euroasia. Comm. Mediterran. Neogene Stratigr. Proc. IV. Sess. Giorn. di Geol. 2, Bologna 35 (1967) 1, p. 273-287

DLABAČ, M.; MENČÍK, E.: Geologická stavba autochtonního podkladu západní části vnějších Karpat na území ČSSR. Rozpr. Čs. Akad. Věd, Ř. mat. přír. Věd, Praha 74 (1964) 1, p. 1-58

DORNIČ, J.: Vysvětlivky ke geologické mapě 1 : 50 000 - M-33-107-A. Praha: MS Geofond 1966

GANNSS, O.: Das Miozän des Jaklovec bei Mährisch Ostrau und dessen Bedeutung für die Stratigraphie des schlesischen Miozäns. Firgenwald, Reichenberg 9 (1936)

HOMOLA, V. et al: Opěrná vrtba Nesvačilka 1 v jihozápadní části vněkarpatské pánve na Moravě. Práce Úst. naft. výzk., Praha 17 (1961), p. 1-131

DOI:https://doi.org/10.2312/zipe.1982.066

CHMELÍK, F.; DORNIČ, J.: Nové poznatky o geologické stavbě střední části karpatské neogenní předhlubně na Moravě.
Zpr. geol. výzk., Praha 1967 (1969), p. 226-228

JURKOVÁ, A.: Vývoj badenské čelní hlubiny v Moravské bráně a na Ostravsku.
Geol. Práce Spr., Bratislava 57 (1969), p. 155-160

JURKOVÁ, A.: Stavba karpatské předhlubně a flyšových příkrovů na sv. Moravě.
Čas. Mineral. Geol., Praha 21 (1976) 4, p. 349-362

JURKOVÁ, A.; HUFOVÁ, E.: Předběžná zpráva o výsledcích hlubokého hydrogeologického vrtu Radslavice NP 767.
Sborník GPO, Ostrava 3 (1973), p. 143-146

JURKOVÁ, A.; NOVOTNÁ, E.: Facies a stavba karpatu na sv. Moravě.
Sborník GPO, Ostrava 7 (1974), p. 73-88

KREJČÍ, J.; ŠPIČKA, V.: Předběžná zpráva o výsledcích strukturně stratigrafieckého vrtu Rataje 1.
Praha: MS Geofond 1970

KRYSTEK, I.: Zur Paläogeographie des Neogens in der Karpatischen Vortiefe im Raum zwischen Brno und Znojmo.
Spisy přír. Fak. Univ. Purk., Brno 10 (1967) 4, 482, p. 166-168

KRYSTEK, I.: Výsledky sedimentologického výzkumu sedimentů spodního badenu v karpatské předhlubni (na Moravě).
Folia Facult. Sci. Natur. Univ. Purk. Brun., Brno 15 (1974) 8, Geol. 25, p. 1-32

KRYSTEK, I.: Ein Modell der Entwicklung der karpatischen Vortiefe in Mähren im unteren Badenien (Moravien).
Scripta Fac. Sci. Natur. Univ. Purk. Brun., Geologia, Brno 1 (1977) 7, p. 19-26

KRYSTEK, I.; TEJKAL, J.: K litologie a stratigrafii miocénu jihozápadní části karpatské předhlubne na Moravě.
Folia Facult. Sci. Natur. Univ. Purk. Brun., Brno 9 (1968) 7, Geol. 16, p. 1-31

MOLČÍKOVÁ, V.: Nové nálezy miocenní mikrofauny v oblasti styku karpatské předhlubně s Českým masívem.
Výzk. Práce Ústr. Úst. geol., Praha 13 (1976), p. 23-31

PELÍŠEK, J.: Fosilní půdy na oncoforových (miocenních) pískách střední Moravy.
Příroda, Brno 36 (1944), p. 79-83

STEINIGER, F.; SENEŠ, J. et al: M_1 Eggenburgien. Die Eggenburger Schichtengruppe und ihr Stratotypus. Chronostratigraphie und Neostratotypen Miozän der zentralen Paratethys, 2.
Bratislava: 1971

TEJKAL, J.: Spodnomiocenní (?) písky mezi Šatovem a Chvalovicemi a jejich fauna.
Acta Mus. Morav., Brno 43 (1958), p. 85-94

WEISS, J.: Fundament moravského bloku stavbě evropské platformy.
Folia Fac. Sci. Natur. Univ. Purk. Brun., Brno 18 (1977) 13, Geol. 30, p. 1-64

ZAPLETALOVÁ, I.: Některé výsledky a problémy mikrobiostratigrafického výzkumu miocénu na jv. svazích Českého masívu.
Zemní plyn a nafta, Hodonín 22 (1977) 1, p. 19-23

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Explanatory Notes to Lithotectonic Molasse Profiles of Inner West Carpathian Basins in Czechoslovakia (Comment to Annex 2 - 5)

by

DIONÝZ VASS[1]

1. Vienna Basin (Annex 2)

1.1. General data

The Vienna Basin extends on Czechoslovak territory over 3026 km^2. Its total area (i.e. including its Austrian part) is approximately twice as large as that. The Czechoslovak part of the Vienna Basin is between the Ždánický Les and the Chřiby Mountains on the northwest, and the Malé and Biele Karpaty Mountains on the southwest.

There is plentiful literature on the Vienna Basin. Most complete bibliography is in a book by BUDAY et al. (1965). In the time between World Wars I and II the opinions about stratigraphy, paleogeography and tectonics of the Vienna Basin were decisively influenced by MATĚJKA and KODYM (1923), SCHAFFER (1927), ANDRUSOV (1937, 1938). New data on tectonics were published by BUDAY and URBAN (1941), VEIT (1943), URBAN (1946), BUDAY (1946), JANÁČEK (1954).

New opinions about stratigraphy of the Neogene were presented by BUDAY (1955), BUDAY and CICHA (1956). The basement of the Vienna Basin was treated by BUDAY, MENČÍK and ŠPIČKA (1965), NEMEC and KOCÁK (1976); thickness maps of molasse sediments were compiled by ŠPIČKA (1969); paleogeography was dealt with by ŠPIČKA (1972). A modern summary of knowledge about the Vienna Basin was presented by BUDAY et al. (1963; 1965; 1967, p. 409-425). Besides that, the problems of paleontology and biostratigraphy were treated by many authors.

The Vienna Basin is largely covered by Quaternary sediments. Older sediments (pre-Badenian) crop out mainly in the NE part of the basin. As for its position in the Car-

1) Geologický ústav Dionýza Štúra; Czechoslovakia, 80940 Bratislava, Mlynská dolina 1

DOI:https://doi.org/10.2312/zipe.1982.066

Fig. 1. Molasse basins and depressions of West Carpathians

1...6 - outer molasse

Early molasse: 1 - autochthonous Oligocene and lowermost Miocene buried by the nappes of Outer Carpathians and by the main molasse, 2 - molassoid complex in allochthonous position (Ždánice-Hustopeče beds in Ždánice-Subsilesian unit, Upper Eocene - Egerian, 3 - pre-main molasse molassoid complex (Egerian) and main molasse (Eggenburgian - Karpatian) incorperated in frontal part of Ždánice-Subsilesian nappe (Pouzdřany unit)

Main molasse: 4 - molasse in foredeep (Eggenburgian - Badenian), 5 - proved margin of the main molasse beneath the nappes of Outer Carpathians

Late molasse: 6 - superposed Pliocene depression (graben) in the valley of upper Morava river

7, 10...13 - inner molasse; 8-9, 14...16 - back molasse

Early molasse: 7a - relicts of the deposits of the initial period of early molasse on the surface (uppermost Cretaceous), 7b - buried relicts of the initial period of the early molasse (uppermost Cretaceous - Paleocene), 8 - basin of Buda Paleogene (Eocene - Egerian), 9 - recent extension of early molasse buried by main molasse in Danube Lowland and early with main molasse buried by Central Slovakian volcanic rocks

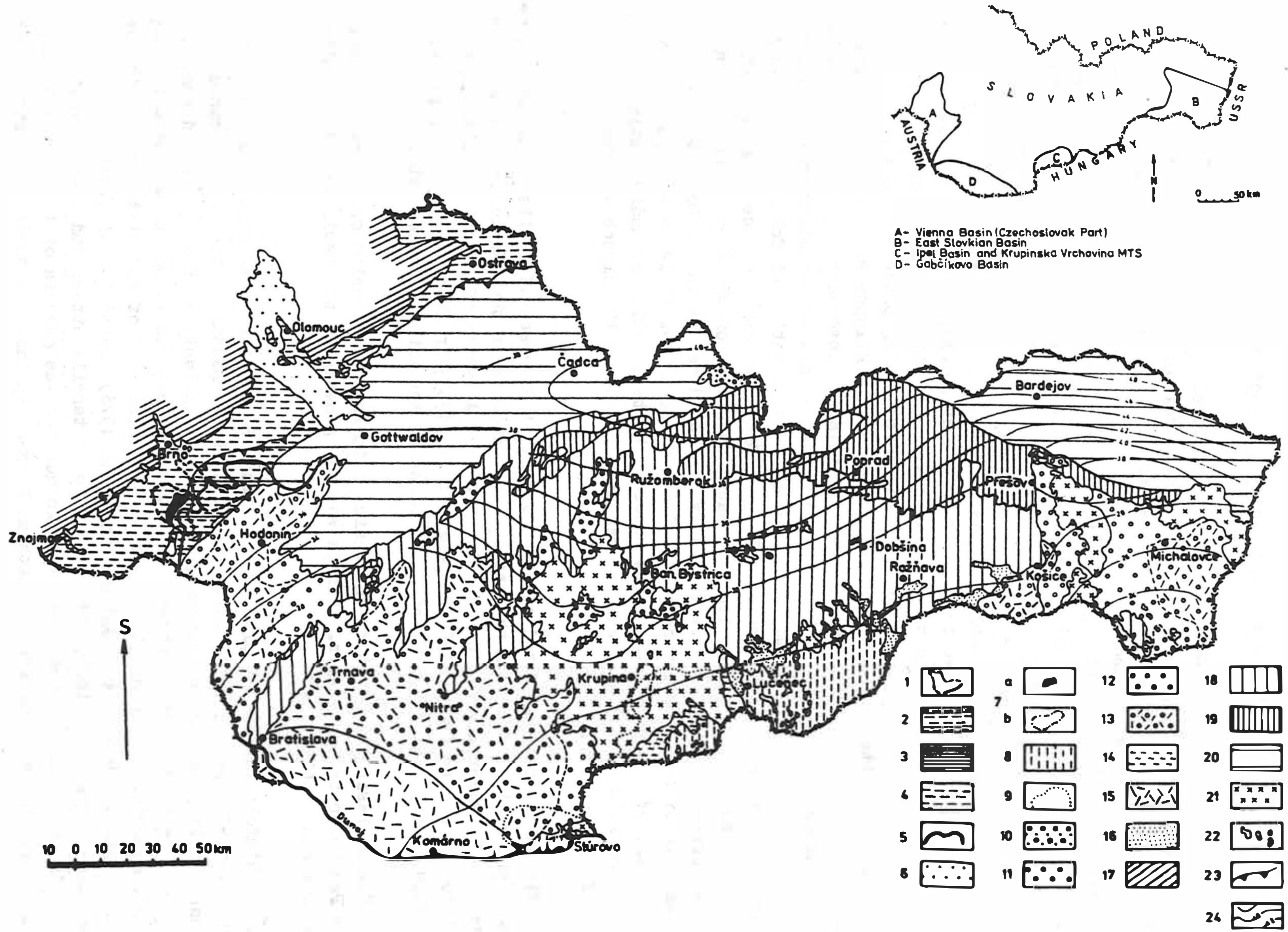
Main and late molasse inside the Carpathian mountains belt: 10 - intramontane depression with the recent thickened crust of continental type (Lower Miocene - Pliocene), 11 - intramontane depressions with the recent crust in the transition between normal continental crust and thinned continental crust (Eggenburgian - Pliocene), 12 - longitudinal intramontane basins (shelf basins, Eggenburgian - Sarmatian), 13 - longitudinal intramontane basins buried by the late molasse

Main molasse in the backdeep area: 14 - episodical basins and depressions (Eggenburgian - Badenian)

Late molasse: 15 - Pannonian basin (Pannonian - Pliocene), 16 - superposed shallow depressions

Other symbols: 17 - pre-Tertiary rocks of Bohemian massif, 18 - pre-Tertiary rocks of Inner West Carpathians, 19 - Paleogene and Gosau Cretaceous of Inner West Carpathians, 20 - Outer Flysch Carpathians, 21 - Neogene volcanic rocks undivided, 22 - Pliocene basalts in Southern Slovakia, 23 - front of the nappes of the Outer Flysch Carpathians, 24 - isopachs of the crust in km (according to PLANČAR in KVITKOVIČ and PLANČAR 1975)

DOI:https://doi.org/10.2312/zipe.1982.066



DOI:https://doi.org/10.2312/zipe.1982.066

pathian mountain system, the Vienna Basin is a longitudinal intramontane depression.

1.2. Tectonic structure and paleogeographic-paleotectonic history

The Vienna Basin rests unconformably on a tectonically heterogeneous basement. The position is, however, in accordance with structural plan of the basement or the basin is slightly diagonal to the basement. The eastern part of the Vienna Basin rests on Inner-Carpathian units formed tectonically by Upper Cretaceous (paleoalpine) folding, and on the Klippen Belt folded by Laramian later by mesoalpine movements (in the Eocene time) and accomplished by neoalpine movements (during the Neogene time). The western part of the Vienna Basin rests on the Magura flysch group, at the west of the town Břeclav on the Ždánice unit. These were folded mostly by neoalpine movements (Fig. 2). In relation to the evolution of molasse, the Vienna Basin was created at the beginning of formation of the main molasse in the West Carpathians (Eggenburgian) and was intensely reconstructed in the Badenian time. Regarding its relation to the basement, the formation and evolution of the basin followed the main folding process in the Inner Carpathians and were simultaneous with the re-folding of the Klippen Belt, folding of the Outer Flysch and/or with the tectonic transport of flysch nappes partly overlaid by the basin. Tectonic reconstruction of the basin in the Badenian and the culmination of subsidence in the Upper Badenian and Sarmatian followed the termination of folding processes in the Moravian part of the Outer Carpathian Flysch. Older sediments of the basin filling, at least in the western part (particularly where they rest on the Ždánice unit), must have been transported "en bloc" by tectonically displaced masses in the Lower Miocene to Badenian time of crust reduction in the Outer Carpathians. It is to be emphasized that the formation of the Vienna Basin was preceded by termination of sedimentation in flysch troughs, and that there is no gradual transition between the flysch and the molasse sediments of the basin filling.

The Vienna Basin is situated on the crossing of deep-seated faults (lineaments). The basement suture is a fault in the pre-alpine structure of the basement, i.e. the contact between the Bohemian Massif and the Slovak block. A system of Sudetian faults is transversal to the suture (BUDAY 1961 in BUDAY et al. 1965; in BUDAY et al. 1967, p. 409, 410). This configuration is regarded the cause of the origin of the basin.

The Vienna Basin is a part of the chain of intramontane basins confining the area of the Pannonian mantle diapir. This is why the genesis of the basin is related with the mantle diapir (VASS 1976).

The doublefold structural plan of the Vienna Basin (the lower structural horizon: Eggenburgian - Karpatian, eventually including Lower Badenian; the upper structural horizon: Middle Badenian to Pliocene; Fig. 3) is indicative of a doublefold genesis of the basin. The older horizon arose in the time of tectonic transport of the Outer Carpathians. According to newer literary data the subsidence of the platform beneath the Carpathian crustal block (e.g. GRECULA and ROTH 1978) caused the displacement of nappes. In the Inner-Carpathian block, subduction caused tensile stress and desintegration of the Earth's crust. Thus, conditions were formed for the genesis of the Vienna Basin, the East-Slovakian and the Transcarpathian Neogene Basins, and their lower structural horizon.

DOI:https://doi.org/10.2312/zipe.1982.066

The genesis of the upper structural horizon was decisively affected by another phenomenon - the active mantle diapir. On its periphery spreading took place as a result of pressure equilibration above the diapir (there were no conditions for subsidence).

The evolution of the Vienna Basin particularly in the Badenian and Sarmatian (16.5 - 10.5 m.y.) was markedly affected by synsedimentary movements along faults. At the same time subsidence culminated. In contrast to other basins of similar types (e.g. East-Slovakian Neogene Basin) there was no volcanic activity. In the final period of formation of molasses (since the Pannonian) in the Vienna Basin the activity of faults is fading out and the brackish environment is degraded to freshwater.

Paleogeographic evolution follows the paleotectonic. The structural plan in the pre-Middle Badenian period is at least partly controlled by E--W to ENE-striking faults (Fig. 4). The change of structural plan in the Badenian was followed by very active NE—SW to NNE-striking faults (Fig. 5 cf. Fig. 4). Whereas in the first period the basin expanded eastward or east-northeastward, in the next period the basin was reduced to its present area and expanded locally northward.

Besides the older (E—W, ENE) and younger (NE—SW, NNE) the structure of the basin is also affected by transversal faults. There are more faults in the area of the outer flysch basement of the basin. Movements along the faults were more intense and caused partial asymmetry of structure. This is indicative of a more mobile basement. In the area where the basement is built of the Inner-Carpathian units there are less faults with smaller vertical movements, forming symmetrical horsts and grabens. So the basement was more stable there (cf. BUDAY in BUDAY et al. 1967, p. 419). Another structural element, less significant though, are plicative structures (slight anticlines).

The Vienna Basin rests on normal or slightly thinned continental crust. There the Moho discontinuity is at depth 32 - 36 km (Fig. 1).

As regards tectonics of the Vienna Basin it should be emphasized that older molasse sediments (Eggenburgian - Lower Badenian) were mostly deformed by germanotype tectonics (faults and slight folding). The deformations reflect tectonic processes proceeding in the Lower Miocene time in adjacent and partly subjacent units of the Outer Flysch Carpathians. Tangential forces concentrated in shorter time intervals characterized by breaks in sedimentation. Spreading forces were active during sedimentation and caused subsidence of the basin. Later, in the reconstruction of the basin the spreading forces gave rise to and activated faults controlling subsidence of the Vienna Basin to a considerable extent and undermining the genesis of the present structural units of the basin. Synsedimentary vertical movements along some faults surpassed 1000 m.

In the Pannonian and Pliocene time, i.e. in the time of formation of late molasse, the fault tectonics faded out. The altitude of throw decreased radically (to tens of metres, scarcely 100 m).

DOI:https://doi.org/10.2312/zipe.1982.066

Fig. 2. Basement of Vienna Basin (according to ŠPIČKA 1969)

1 - Upper Cretaceous and Paleogene of the Inner Carpathians, 2 - Outer Flysch, Ždánice unit, 3 - Outer Flysch, Magura unit, 4 - Klippen Belt, 5 - Inner Carpathian units (Choč unit, Krížna unit, cover, crystalline complex, 6 - present margin of the basin, 7 - boundaries (mostly tectonic)of basement units

Fig. 3. Mutual relations between the lower and upper structural horizons of the main molasse in Vienna Basin

1 - crystalline complex of the Malé Karpaty Mts., 2 - Mesozoic of the Male Karpaty Mts., 3 - Mesozoic of Klippen Belt, 4 - Upper Cretaceous and Paleogene of the Inner Carpathians, 5 - Outer Flysch, Magura unit, 6 - Outer Flysch, Ždánice unit, 7 - lower structural level of the main molasse (Eggenburgian - Karpatian, 8 - upper structural horizon of the main molasse (Badenian - Sarmatian), 9 - axis of the Vienna Basin: A - lower structural level, B - upper structural level, 10 - present margin of the basin

Fig. 4. Extension, thickness, and significant faults of Karpatian stage in the Czechoslovak part of the Vienna Basin (thickness according to ŠPIČKA 1969; faults: according to BUDAY et al. 1967)

1 - thickness isopachs of the Karpatian (in m), 2 - significant faults, 3 - present margin of the basin

Fig. 5. Extension, thickness, and significant faults of the Sarmatian in the Czechoslovak part of the Vienna Basin (thickness: according to ŠPIČKA 1969; faults: according to BUDAY 1967

1 - thickness isopachs of the Sarmatian (in m), 2 - significant faults, 3 - present margin of the basin

DOI:https://doi.org/10.2312/zipe.1982.066

Fig. 2

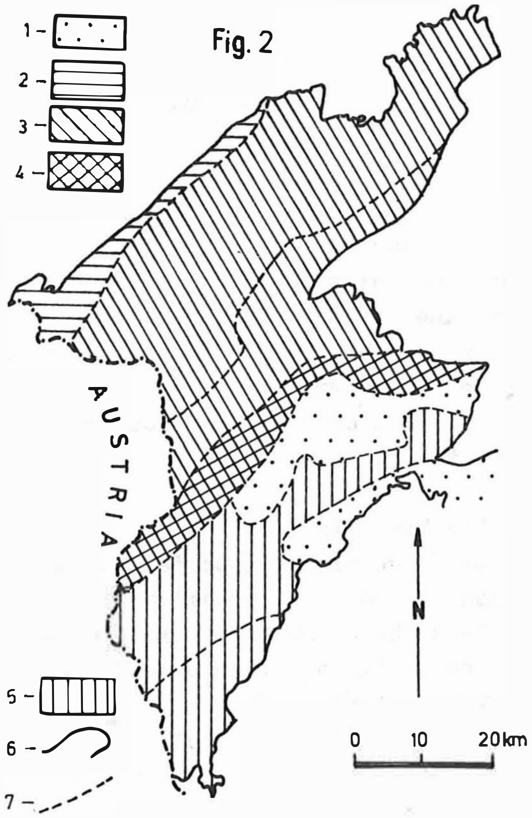


Fig. 3

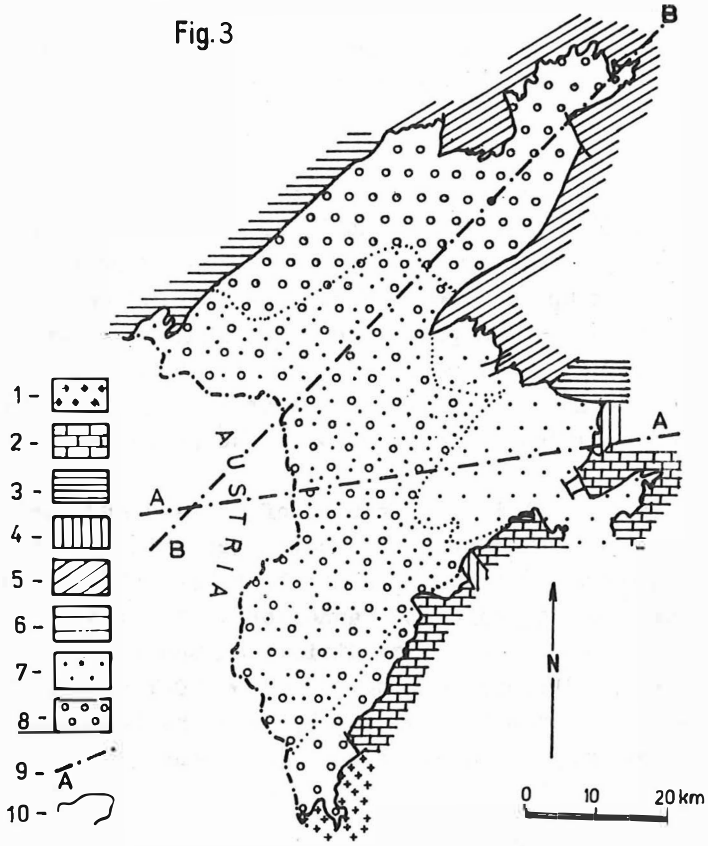


Fig. 4

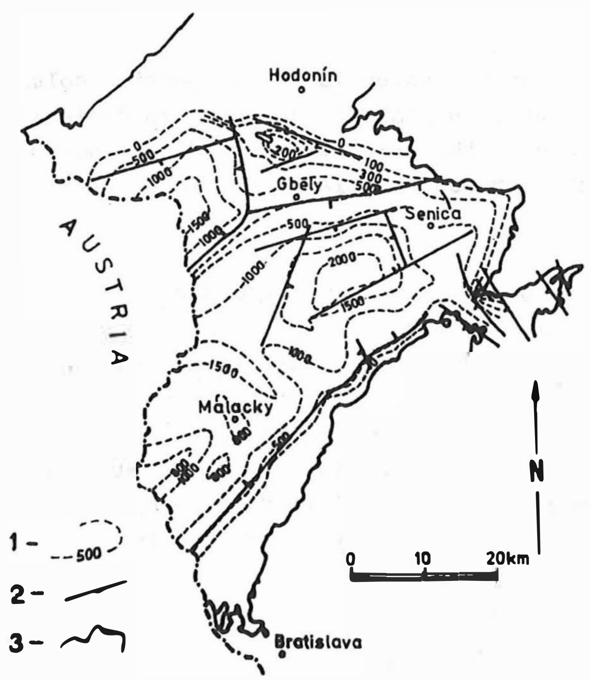
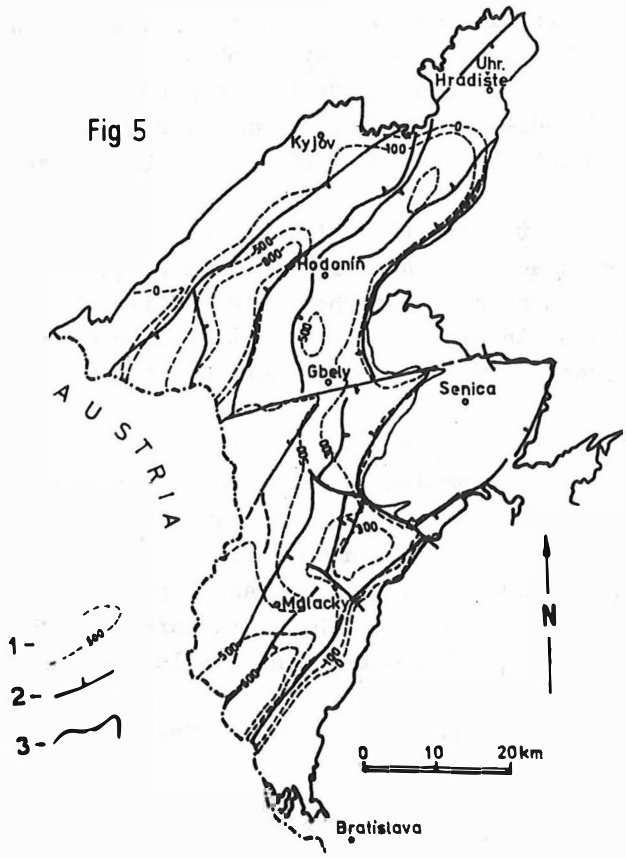


Fig 5



DOI:https://doi.org/10.2312/zipe.1982.066

1.3. Comments on the lithotectonic profile

The lithotectonic profile (Annex 2) was based on the results of several thousands of bore holes (exploratory bore holes for oil and gas) in the Czechoslovak part of the Vienna Basin.

The total of maximum thicknesses of Sediments in the profile is 6130 m which corresponds roughly to the estimation of the maximum of the basin filling. Thicknesses of the Badenian and Sarmatian exceed 2000 m; thickness of the Karpatian is up to 2000 m; i.e. about 2/3 of the total thickness of the basin filling correspond to the Karpatian to Sarmatian. Sedimentation rates (Table 1) are showing that the maximum rate of subsidence was in the Karpatian and Baden - Sarmatian. Prior to the Karpatian, i.e. in the Eggenburgian and Ottnangian, the rate of sedimentation was lower and subsidence slowed also in the Pannonian and the Pliocene.

Stratigraphy of molasse sediments in the basin is documented by plentiful fauna. The present biostratigraphic division is based mostly on microfauna. Marine sediments including the brackish Sarmatian are divided according to foraminifers, and now also according to nannoflora. Freshwater sediments or brackish mesohaline and oligohaline sediments are divided on the ground of ostracodes (information on biostratigraphic division may be found in BUDAY et al. 1965, BUDAY et al. 1967). The problem of biostratigraphic boundary between the Eggenburgian and Ottnangian, and reliable biostratigraphic correlation of sediments younger than Pannonian has not been solved as yet.

Radiometric chronometry of single stages is based on radiometric time scale of Paratethy Neogene (VASS and BAGDASARJAN 1978). Correlation with the international stratigraphic scale is made according to the same principle as in the case of the East-Slovakian Neogene Basin. Basical data for the correlation of Paratethys and Mediterranean stages may also be found in a prepared monograph on Neogene biozones of Central Paratethys (CICHA et al. in press).

Lithostratigraphic division as presented in the respective columns is in accordance with the division quoted in literature most frequently. The division is not current for the whole profile. Sequences or lithofacies typical of some parts of the basin with stable evolution on a certain area and correlable over a certain distance are presented as independent units.

In the lithological profile among clastic sediments pelites and psammites are dominant. In the lower part are thicker conglomerate layers (especially the Jablonica conglomerates in the NE part of the basin). Conglomerates are also in basal parts of new sedimentation macrocycles after all breaks in sedimentation, i.e. in basal horizons of a new transgression. They are, however, not significant - except clastic sediments at the base and marginal part of the Lower Badenian. In the Badenian, and scarcely in the Sarmatian, are lenses of organic algal and foraminiferal and/or organodetrital limestones. Among the clastic rocks are sporadical layers of acid tuffs or bentonites (Karpatian, Badenian, Sarmatian).

DOI:https://doi.org/10.2312/zipe.1982.066

In the Badenian, and especially in the Pannonian and Pontian there are in marginal facies thin seams or thicker seams of coal or lignite (economically significant is the Dubňany seam). Marine sediments are dominantly grey, green-grey, light-brown. Continental sediments or marginal marine facies are varicoloured including red layers.

S e d i m e n t a r y   c y c l e s were not studied in detail. Cyclic sedimentation may be observed on coarse-detrital marginal or basal sediments, in flyschoid sediments (alternation of pelites and sandstones in the Karpatian), and especially in Pannonian and Pontian coal facies.

C o m p o s i t i o n of the psephitic fraction changes in the profile. Conglomerates in the bottom part of the profile are monomict composed mostly of sedimentary rock pebbles of the immediate basement (Triassic carbonates in the Rozbehy conglomerates; and flysch sandstones in the Chropov conglomerates).

The Karpatian conglomerates (Jablonica) are polymict with predominant pebbles of sediments of pre-Tertiary basement (Triassic, Liassic, Lower Cretaceous carbonates, arcoses, quartzites, quartzose sandstones). In upper parts of the profile the ratio of pebbles of crystalline schists and quartz increases (to more than 50 %).

Vertical alternations are also observable in the composition of psammites. They become more mature from the base upward; quartz grains increase in amount and fragments of rocks and feldspars are less frequent.

Table 1. Velocity of subsidence in Vienna Basin

Age	age of boundary [m.y.]	max. thickness [m]	velocity of subsidence [cm/100 years]
	1.8		
Dacian - Romanian		180	
			0.6
Pontian		150	
	7.0		
Pannonian		550	1.6
	10.5		
Sarmatian		700	2.5
	13.3		
Badenian		1750	5.5
	16.5		
Karpatian		2000	8.0
	19.0		
Ottnangian - Eggenburgian		800	2.0
	23.0		

DOI:https://doi.org/10.2312/zipe.1982.066

Grain size of sedimentary rocks and their general trend are indicative of m a t e - r i a l t r a n s p o r t from comparatively distant areas. The distance cannot be determined exactly. It may be estimated reliably in the case of coarse clastic rocks. Poorly rounded and monomict clastic rocks were transported locally over a distance to 10 km; conglomerates with well rounded pebbles of polymict character were transported over distances up to 100 km.

S e d i m e n t a r y s t r u c t u r e s and other sedimentologic characters were studied only sporadically in the Vienna Basin. There are cross-bedding, erosive channels, graded bedding, and slump structures. There certainly are also other structures in molasse sediments and frequency of structures in the profile is greater. They can, however, not be studied in detail because of poorly exposed sedimentary rocks.

O r g a n i c r e m a i n s in molasse and particularly in marine sediments were extremely plentiful. There were studied in detail and described assemblages of molluscs, foraminifers, in some parts of the profile also calcareous nannoflora, in the upper desalinated part of the profile ostracods, molluscs, sporomorphs, leaf impressions and bones of mammals.

D e p o s i t i o n a l e n v i r o n m e n t of the lower part of filling of the Vienna Basin was marine. The sea had epicontinental character and its depth did not surpass 200 m; it most probably was smaller. In the uppermost Badenian and/or Sarmatian the sea started degrading and changing into brackish. Degradation of the environment culminated in the Pliocene and deposition in the Vienna Basin proceeded in a continental environment.

V o l c a n i c r o c k s are sporadic. They display a character of eolically transported ash from a greater distance. The source areas were most likely in the Central-Slovakian neovolcanic region (Badenian - Sarmatian) and in volcanic centres in Northern and Northeastern Hungary (Karpatian).

Intensity of t e c t o n i c d e f o r m a t i o n s in the lower part of the filling (up to the Lower Badenian inclusively) and in the upper part of the profile is different. The old part of the filling is dissected by faults and it is folded (germanotype deformation). Folds form gentle anticlines and synclines. Eggenburgian beds are dipping 15 - 25° in average, scarcely 45 - 60°. Karpatian and Lower Badenian beds show more gentle dip. The dips fade out toward the overlier; in the Pliocene they are lesser than 5° and they are evidently not controlled by folding. They are dips of blocks (BUDAY in BUDAY et al. 1967, p. 419). In the Middle Badenian and Sarmatian, and also in the Karpatian the fault tectonics was intensive. Some faults have synsedimentary character, In some cases the height of vertical movements is more than 1000 m. The fault activity faded out in the post-Sarmatian time. Tangential force caused occasional breaks in sedimentation and slight refolding of sedimentary rocks, as mentioned. Later on the folding processes proceeded in great distance (e.g. in the East Carpathians) and resulted only in regional regression and uplift of the sedimentation area without refolding of sedimentary rocks. Uplifts of source areas took place either in the immediate surroundings of the basin (Lower Miocene) or in a distant area. Regional uplifts resulted in significant psammite accumulation in the Vienna Basin.

DOI:https://doi.org/10.2312/zipe.1982.066

1.4. Conclusions

Most structural characters of the Vienna Basin are identic with those of the East-Slovakian Neogene Basin. Both basins belong to the same type of molasse basins.

The only substantial different character of the Vienna Basin is the absence of volcanic sources in the area of the basin or in its immediate surroundings. The absence of volcanism is not caused by the mechanism of faults; faults in the Vienna Basin have the same mechanism as faults in the East-Slovakian Neogene Basin. It is most likely that in the Earth's crust underlaying the Vienna Basin were no conditions favourable for the formation of magma chambers which is perhaps due to a comparatively greater thickness of the Earth's crust underlaying the basin.

Because of episodic occurrences of volcanic rocks in the Vienna Basin the Badenian and Sarmatian are comparatively less thick there than in the East-Slovakian Basin.

2. East-Slovakian Neogene Basin (Annex 3)

2.1. General data

The East-Slovakian Neogene basin extends over 4800 km^2 in the southern part of East Slovakia. Geologically it is a part of a larger molasse basin extending from East Slovakia into Transcarpathia (Soviet Union) and occupies the area between Košice on the west and the valley of the R. Teresva on the east. Molasse sediments filling the basin represent the main (the most part) and the late molasse.

The first comprehensive work on geology of the East-Slovakian Neogene Basin was published by SENEŠ and ŠVAGROVSKÝ (1957), followed by publications by JANÁČEK (1959), BUDAY in MATĚJKA et al.(1964), ČECHOVIČ et al. (1963), SENEŠ et al. (1963). Data are summarized by BUDAY (in BUDAY et al. 1967, p. 451-467). Volcanism in the East-Slovakian Neogene Basin was treated in a modern way by ORLICKÝ et al. (1970), and by SLÁVIK and TÖZSÉR (1973); radiometric ages of volcanic rocks are discussed in publications by BAGDASARJAN et al. (1971), ĎURICA et al. (1978), VASS et al. (1978).

Thicknesses of Neogene sediments were studied by JANÁČEK et al. (1969), RUDINEC and SLÁVIK (1972), paleogeography by RUDINEC (1978). The basement of molasse sediments were discussed by FUSÁN et al. (1971) and SLÁVIK (1976). The area of the basin except volcanic massifs is covered by Quaternary rocks. Numerous drill holes in the basin offered rich material from molasse sediments.

2.2. Tectonic structure and paleogeographic-paleotectonic history

The East-Slovakian Neogene Basin rests on Inner-Carpathian units including the Inner-Carpathian Flysch (Fig. 6), extending behind the Klippen Belt by a small projection to rest then on the Flysch of the Outer Carpathians. All units of the basement - except the Inner Carpathian Flysch - have a nappe structure. The basement of the most part of

DOI:https://doi.org/10.2312/zipe.1982.066

the East-Slovakian Neogene Basin tectonically formed by Upper Cretaceous (paleoalpine) folding that formed tectonically the Inner West Carpathians. The Klippen Belt was folded into nappes by Laramide and Mesoalpine processes (in the Eocene) and re-folded in the Miocene time. The Outer Flysch Carpathians were folded by the end of the Paleogene. In that time also the Inner Carpathian Flysch was folded but without nappes. Tectonic transport of Outer Flysch nappes was intensive in the Miocene (neoalpine folding).

The molasse basin proper began to develop with the onset of the main molasse (since the Eggenburgian). A deep drill hole (at Prešov) indicated possible initiation of molassoid sedimentation in the Egerian.

So the genesis of the molasse basin followed the main folding of the Inner West Carpathians and their refolding at the end of the Paleogene. During the evolution of the basin folding processes proceeded in the Outer Carpathians. Possibly the sediments of the initial stage of evolution of the basin were transported "en bloc" on the back of thrust masses in the time of the Lower Miocene reduction of the area in the Outer Carpathians. This may be said about that part of the East-Slovakian Neogene resting on the Outer Carpathians and having originally been larger. As regards flysch, the molasse sedimentation in the East-Slovakian Neogene Basin proceeded in the period when any sedimentation of the flysch type finished in the Carpathian region.

The basin is situated on the crossing of deep-seated faults of the basement (the Hornád fault, the Pecineaga line, the Szomos line, the Plešivec fault, the Košice and the Vihorlat faults) and so BUDAY (in BUDAY et al. 1967, p. 452-453) assumed that the faults gave rise to the basin. VASS (1976) regards it possible that the basin is genetically related with the active mantle diapir (the basin is included in a chain of basins

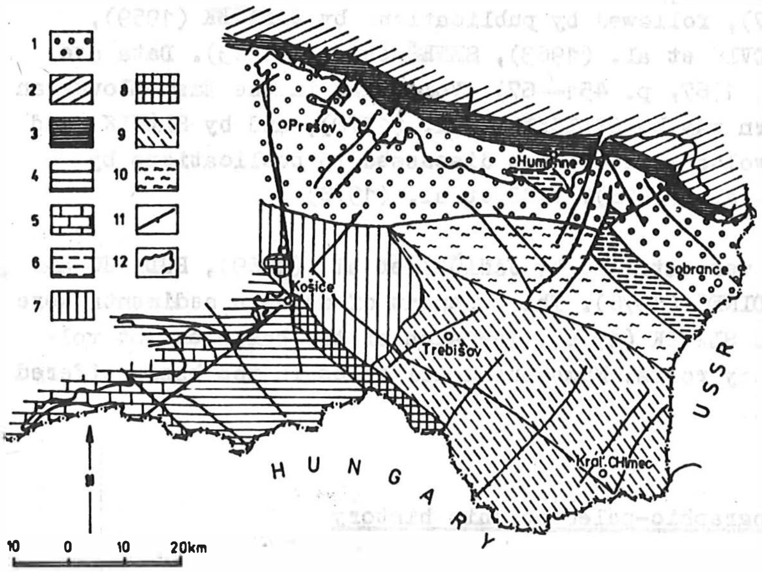


Fig. 6. Pre-molasse basement of the East-Slovakian Neogene Basin (according to SLÁVIK in FUSAN et al. 1971 and SLÁVIK 1976)

1 - Inner-Carpathian Flysch, 2 - Outer Flysch, 3 - Klippen Belt, 4 - Gemeride Paleozoic, 5 - Gemeride Mesozoic, 6 - Mesozoic of the Humenské pohorie mountains, 7 - Upper Paleozoic and Mesozoic of cover units of the West Carpathians, 8 - crystalline complexes of the West Carpathians, 9 - the Zemplín block, 10 - Pozdišovce-Inačov block, 11 - deep seated faults, 12 - present margin of the basin

DOI:https://doi.org/10.2312/zipe.1982.066

of similar type surrounding the area of activity of the Pannonian mantle diapir and differing in their evolution from molasse depressions in the central zone of the activity of the diapir).

The evolution of the molasse basin, particularly in the Badenian and Sarmatian times (16.5 - 10.5 m.y.) was associated with intensive synsedimentary movements along faults and with culminating subsidence and volcanism. In the late molasse period the fault activity and volcanism ended and marine molasses are definitely replaced by continental.

Paleogeographic evolution followed the paleotectonic history resulting in gradual expansion of the basin from NW to SE. The Eggenburgian (and/or Egerian) in the Czechoslovak part of the basin is limited to wider vicinity of Prešov (Fig. 7). The Ottnangian has not been proved in the East-Slovakian Neogene Basin so far. In the Karpatian the basin expanded considerably southeastward (Fig. 7). The expansion continued in the Badenian and culminated in the Sarmatian (Fig. 8) with intensive fault activity.

In the Eggenburgian to Karpatian time the faults of the Rankovce fault system (NW-striking) were synsedimentary and delimitated the areas of the maximum subsidence from SW and NE. In the same time also the Falkušovce fault system was active and delimitated the maximum subsidence on SE in the Karpatian.

In the Badenian - Sarmatian time the NW-striking synsedimentary Trebišov and Močarany fault systems were significant. They delimitated longitudinally the central (Čičarovce) depression (Fig. 8). The western margin of the subsidence area was controlled by the Hornád fault system (N--S striking). The inner subsidence area was dissected by faults of the N--S Albinov horst. Faults active in the Sarmatian delimitated the Sobrance elevation and the adjacent Choňkovce depression. The late molasse evolution starts from the Pannonian. The basin is getting reduced to fade out by the end of the Pliocene. Fault activity also ceased (Fig. 8).

The evolution of molasse in the East-Slovakian Neogene Basin was markedly affected by volcanism. In the Lower Miocene acid volcanism from distant or local centres was active with comparatively small content of igneous material (0.62 km^3). The centres cannot be identified accurately. In the Lower Badenian very intensive explosive rhyodacite volcanism produced approx. 578 km^3 of material. This was the beginning of culminating volcanic activity in the East-Slovakian Neogene Basin. In the Upper Badenian and Sarmatian the culmination of the volcanism continued dominantly in explosive andesite, less rhyolite volcanism. The total volume of volcanic material was about 920 km^3. Among Sarmatian and/or Badenian volcanic rocks also acid explosive and andesite rocks of Sarmatian - Pannonian age should partly be included (180 and 425 km^3; Tab. 2). The role of volcanism in molasse sedimentation of East-Slovakian Neogene Basin is well illustrated by a comparison of the total estimated volume of volcanic products (2136 km^3) with the total present volume of the basin filling (about 7000 km^3; SLÁVIK et al. 1968, p. 217-231).

The East-Slovakian Neogene Basin rests on thinned continental crust. On the ground of geophysical data the Moho discontinuity is presumably in the southern part of East Slovakia at a depth of about 24 km. The crust thickness increases northward and Moho discontinuity is sinking to 30 km (Fig. 1).

DOI:https://doi.org/10.2312/zipe.1982.066

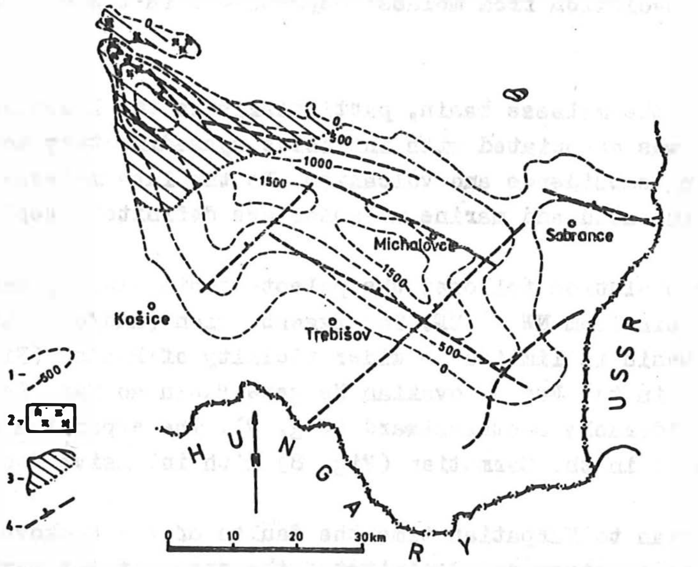


Fig. 7. Extension, thickness and basical features of tectonics of the lower structural horizon of the main molasse (Eggenburgian - Karpatian) in East-Slovakian Neogene Basin

1 - thickness isopachs in m, 2 - dispersed products of acid volcanism, 3 - extension of Eggenburgian, 4 - significant faults and fault zones

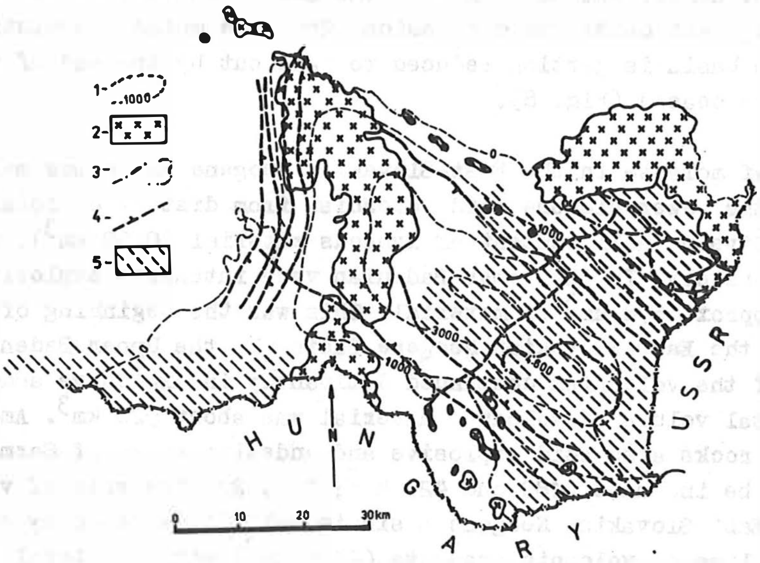


Fig. 8. Extension, thickness and basical features of tectonics of the upper structural horizon of the main molasse (Badenian - Sarmatian) in East-Slovakian Neogene Basin

1 - thickness isopachs in m, 2 - products of (mostly) andesite volcanism, cropping out, 3 - extension of buried products of volcanism of dominantly andesite character, 4 - significant faults and fault zones, 5 - extension of the late molasse covering the main molasse

DOI:https://doi.org/10.2312/zipe.1982.066

Older molasse sediments up to the Lower Badenian includingly are deformed by germanotype tectonics i.e. by faults and partly by folding. Older tectonic deformation caused by tangential forces were consequent to forces undermining the spatial shortening in the Outer Flysch Carpathians and refolding of the Klippen Belt (adjacent to East-Slovakian Neogene Basin) as shown by southvergent folds (ANDRUSOV in MAHEL' 1974, p. 154-156). It is most likely that the forces concentrated in the Ottnangian period (there was no sedimentation in the basin during the Ottnangian, i.e. the area was uplifted) and perhaps in the time between the Lower and Middle Badenian or Middle and Upper Badenian, since pre-Upper Badenian sedimentary rocks are slightly folded and deformed by overthrusts particularly in the northern part of the basin.

Table 2. Volume of volcanic rocks in East-Slovakian Neogene Basin (according to SLÁVIK et al. 1968, modified by VASS)

Age of volcanism	andesite [km^3]	rhyolite [km^3]	total [km^3]	
Pannonian, partly Upper Sarmatian	425	180	605	
Upper Sarmatian	95	5	100	culmination period of volcanic activity (Upper Sarmatian – Lower Badenian)
Lower Sarmatian	310	53	363	
Upper Badenian Lower Sarmatian	22.4	213	235.4	
Middle and Upper Badenian	119	135	254	
Lower Badenian		578	578	
Karpatian		0.42	0.42	
Eggenburgian		0.2	0.2	
Total	971.4	1164.6	2136.0	

Sedimentation of the Eggenburgian and especially Karpatian was not affected by tangential pressure. On the contrary: spreading resulted in faults controlling partly subsidence.

In the culmination stage of evolution of the main molasse, owing to decompressing forces, faults arose to control subsidence of East-Slovakian Neogene Basin and to cause its present intricate horst-graben structure. Vertical movements of some faults are higher than 1000 m. The faults had a comparatively great depth range since some of them served as ascending ways for calc-alcaline andesite magmas.

DOI:https://doi.org/10.2312/zipe.1982.066

In the Pannonian and Pliocene, i.e. in the time of formation of the late molasse, the fault tectonics was slowly fading out and the height of fault-throw decreased radically (to tens of metres, max. 100 m).

2.3. Comments on the lithotectonic profile

The lithotectonic profile (Annex 3) was mostly constructed on the basis of bore holes. Shallower bore holes with complete coring offered basical data about molasse sediments. Distribution of the sediments in greater depth and basical features of structure in deep parts of the basin were revealed by deep drilling with discontinuous coring and by geophysical measurements realized by several methods.

The total maximum t h i c k n e s s o f s e d i m e n t s presented in the profile is 10300 m. In respect to subsidence migration in time the stratigraphical complexes distinguished are not above one another in the maximum thicknesses in the central part of the basin, and so the maximal actual thickness is smaller. The deepest parts of the basin have not been penetrated by drilling so far but the maximum thickness of sediments is estimated to 7000 m. About 3/5 of this are Badenian and Sarmatian sediments, so the sedimentation must have culminated in that time. Sedimentation rates (Table 3) were increasing since the Eggenburgian to the Badenian. During Badenian and Sarmatian the rates of sedimentation culminated. The velocities markedly decreased during the deposition of late molasse (since the Pannonian time).

S t r a t i g r a p h y of East-Slovakian Neogene Basin is documented by marine fauna. In some cases the age is not proved reliably. For instance the Egerian is not proved sufficiently (atypical foraminiferal assemblages). Sediments referred to the Eggenburgian, Karpatian and Badenian contain plentiful marine fauna of molluscs and foraminifers. The Sarmatian beds are partly desalinated and difficult to differ from Pannonian sediments. Biostratigraphical division of progressively desalinated Pannonian and/or Pontian and Pliocene beds is somewhat difficult and was based on ostracods.

In many cases the age of volcanic rocks was determined radiometrically and paleomagnetically (BAGDASARJAN et al. 1971; SLÁVIK et al. 1976; ĎURICA et al. 1978; VASS et al. 1978). Radiometric calibration of individual stages is based on the radiometric time scale of Paratethys Neogene (VASS and BAGDASARJAN 1978).

Correlation of the Badenian with the international stratigraphical scale is based on planktonic foraminifers (base of Badenian = base of Langhian = N8p/N8p), calcareous nannoflora (Lower Badenian = NN5, Middle and Upper Badenian = NN5-6) and on radiometric ages. Correlation of the Lower and Upper Miocene is based on biostratigraphically less reliable groups of organisms. Correlation of the Pannonian and Pliocene with the Tortonian, Messinian and Mediterranean Pliocene is poorly documented.

L i t h o s t r a t i g r a p h i c a l d i v i s i o n of the whole profile of the East-Slovakian Neogene Basin is not used as a rule. Names were given only to some parts of the profile. Problematic Egerian is denoted as the Solivar beds, marine Eggenburgian beds as Prešov beds, brackish Eggenburgian beds as Čelovce beds and marginal

DOI:https://doi.org/10.2312/zipe.1982.066

brackish Upper Badenian and Sarmatian as Klčov beds; coarse-detrital Sarmatian (and/or Upper Badenian) to Pannonian beds (eventually Pliocene) are called the Košice formation; Middle Pannonian gravels such as the Pozdišovce formation and the Pannonian coal beds in the Pliocene are denoted as the Inačovce lignite formation.

Table 3. Velocity of subsidence in East-Slovakian basin

	age of boundary [m.y.]	max. thickness [m]	velocity of subsidence [cm/100 y.]
	1.8		
Pannonian-Pliocene		1200	1.4
	10.5		
Sarmatian		2400	8.6
	13.3		
Badenian		3500	10.9
	16.5		
Karpatian		1400	5.6
	19.0		
Ottnangian		-	
	20.5		
Eggenburgian		1000	4.6
	23.0		

In the lithological profile, pelitic sediments predominate but at margins they pass into sands to coarse-clastic rocks. The most significant horizons of coarse-clastic rocks are associated with the culminating molasse sedimentation, i.e. with the Badenian - Lower Sarmatian time (the Klčov beds). In the area around Košice there is a coarse-detrital marginal facies. It is partly equivalent to the Klčov beds and partly representative of the Upper Sarmatian, Pannonian, and eventually Pliocene. There is a thick horizon of coarse-clastic rocks at the base of the Karpatian and Pannonian. Coarse-clastic rocks also occur in the Eggenburgian.

In the early molasse basal beds are no significant conglomerate horizons (at least as proved by the drill hole Prešov-1). Generally the number of coarse-clastic horizons increases from the bottom upwards which is due to growing intensity of uplift of the source area of the basin and partly to intensified volcanism supplying detrital material.

In Eastern Slovakia, volcanic rocks form single complexes either buried (buried Zemplín volcanic mountain range, buried stratovolcanoes; SLÁVIK in MAHEL' 1974, p. 141) or building important morphostructures (the Slánske vrchy, the Vihorlat-Popričný mountain ranges). Volcanic products in the form of various volcanoclastics rocks enter the sedimentary filling of the basin to form there thicker horizons or whole volcano-sedimentary complexes. As already mentioned, the volcanogenic rocks hugely participate in the molasse filling of the basin.

DOI:https://doi.org/10.2312/zipe.1982.066

Another important element in the filling of the basin are evaporitic sediments associated with two critical periods of salinity of the marine environment in the basin (Karpatian and Middle Badenian).

As for c o l o u r o f s e d i m e n t s , the grey-blue and grey-green predominate, in the upper continental part of the profile brown, yellow-brown, and grey-brown dominate. Varicoloured sediments are scarce. Bright red and violet colours are practically absent (red-brown clays are in places in the Pozdišovce formation).

The problem of c y c l i c c h a r a c t e r o f s e d i m e n t a t i o n was not studied in detail because of the lack of surficial exposures, and because in the study of exploratory drill holes the question was not paid any attention. According to log profiles of deep drill holes there are indications of rhythmical (flyschoid) sedimentation in the Solivar beds and partly in the Prešov beds. Cyclical evolution may also be seen in the coal-bearing Čelovce beds in evaporite sediments, in the Klčov beds and in coarse-clastic marginal facies of the Upper Miocene.

In c o n g l o m e r a t e p e b b l e s the content of vein quartz increases upwards to disadventage of pebbles of pre-Neogene sedimentary rocks. In the time of culminating volcanism there are also pebbles of volcanic rocks but in a smaller amount as presumed according to the amount of volcanic material in the basin. The volcanic rocks are not rigid enough and fell out from the transport very soon. In the upper part of the profile the composition of coarse-clastic rocks depends mostly upon the local transport conditions.

In the sub-Vihorlat region are gravel horizons composed almost excludingly from andesite pebbles. In the time when the Pozdišovce formation arose, transport from the Outer Flysch was dominant, and gravels are composed from pebbles of sands and cherts only. In the Košické kotlina (depression) in the upper part of the profile are highly mature gravel horizons composed of pebbles of vein quartz and quartzite.

The picture of the p s a m m i t i c f r a c t i o n is only approximate. No planimetric analyses of loose sediments were done. The amount of quartz graine increases from the bottom upward. In the Badenian and Sarmatian sandy beds are plentiful feldspars and mica.

Character of roundness of the pebbly material and general lithological history show that the material was transported over 10 - 100 km to get into the basin. Current direction was only identified in one case namely in the Pozdišovce formation. There a complex of paleocurrent indications is characteristic of a transport from the north (VASS and ELEČKO 1977).

S e d i m e n t a r y s t r u c t u r e s and other sedimentologic characters were examined only sporadically in the East-Slovakian Neogene Basin (because of poor exposures). Mica aggregates are frequent on bedding surfaces. In pelitic marine beds are pyrite concretions and pyritized tests of foraminifers (poorly aerated environment). Concretions of gypsum or anhydrite occur in equivalents or in associated beds of evaporites. Carbonate and siderite concretions are in the upper part of the profile (in

DOI:https://doi.org/10.2312/zipe.1982.066

some areas they were mined for iron ore for a short time). Psammitic and psephitic horizons display also scarce cross-bedding. In pelitic horizons bedding is indistinct, frequently caused by irregular silt-sandy lamination. Flyschoid bedding was found in the Solivar, Prešov, Čelovce beds and in the lower part of the Karpatian.

F a u n a l   c o n t e n t of marine beds is very high. There were examined mostly molluscs, foraminifers, ostracods, pollen, spores and partly also nannoflora.

Molasse sedimentation in the East-Slovakian Neogene Basin proceeded in a marine e n v i r o n m e n t and in marginal marine environments (hypersaline and brackish) up to the Badenian time, inclusively. In the Uppermost Badenian and in the Lower Sarmatian the environment was brackish. In the course of the Sarmatian the brackish environment was being replaced by strongly desalinated brackish to freshwater environment lasting up to the end of sedimentation.

It may be stated that in the course of the evolution of the main molasse in the East-Slovakian Neogene Basin the marine environment is occasionally degrading to desalination or hypersalination but the sea regime is renewed after such an episode. Since the Upper Badenian the sea degradation got progressive not only in this basin but in the whole system of Carpathian molasse depressions and basins. The degradation culminated in freshwater sedimentation in lacustrine-fluvial environment during the Pliocene time.

M a g m a t i s m whose intensity increased in the time of formation of the main molasse was acid in the Lower Miocene as proved by eruptions of tuff material from local and distant centres. In the Badenian time, intensive andesitic and acid volcanism set on. The volcanic centres were in marginal parts of the basin and on horst within the basin. The volcanism manifested itself in varied forms (eruptions of ignimbrite, stratovolcanoes, domes, necks, and others).

T e c t o n i c   d e f o r m a t i o n s of molasse sediments in the East-Slovakian Neogene Basin are comparatively simple. Up to the Upper Badenian the deformation was germanotype (folds and faults), since then there were excludingly faults.

The t e c t o n i c   a c t i v i t y intensified in certain periods (phases of increased tectonomagmatic activity) and resulted in regressions and new transgressions. In the Lower Miocene the contact of the transgressive beds with the basement was disconformable, in the period after Middle Badenian it was hidden unconformable or unconformable on faults.

Synsedimentary movements along faults proceeded partly in the Eggenburgian and Karpatian, and particularly in the Badenian and Sarmatian. In the post-Sarmatian period epigenetic fault activity took place.

A large hiatus was revealed between the Eggenburgian and the Karpatian (in the Ottnangian).

DOI:https://doi.org/10.2312/zipe.1982.066

2.4. Conclusions

The East-Slovakian Neogene Basin is a typical representative of inner molasse basins in the West Carpathians. It represents the type of "longitudinal intramontane depression" (BUDAY 1961; BUDAY et al. 1965, 1967) or an intramontane depression with the structure of an intricate graben (VASS 1978). Similar basins are also called "shelf basins" in literature (SCHEIBNER 1976, p. 54).

The following features are typical for basins of this type:

- The basin is superposed mostly on Inner Carpathian partly on Outer Carpathian units and courses of its structure are parallel with the course of paleoalpine units of the basement or they are slightly diagonal to the units.
- Filling of the basin formed predominantly in the environment of a marine stable shelf with a tendency to degradation to a continental environment. Clastic sediments are dominant, evaporites are scarce. In the East-Slovakian Neogene Basin also volcanic rocks are frequent.
- Filling of the basin is divided into two structural horizons with varied structural plan and level, and type of tectonic deformations.
- Block faulting, typical of the upper structural level, is an intricate structure of graben and horsts. Movements along large faults were synsedimentary and the total height of throw was frequently more than 1000 m.
- In relation to molasse sedimentation areas the size of the basins is medium (about 5000 - 10000 km^2), accumulation of sediments and intensity of subsidence are great (6000 - 7000 m and up to 1 cm/100 years). Intensity of subsidence was greatest in the Badenian and Sarmatian.
- On the periphery of the basin or on the horst structures in the basin there volcanic centres were. Volcanism culminated in the same period as subsidence and synsedimentary fault activity.
- The basins are on the Earth's crust on transition from the normal continental to thinned continental crust.

3. The Ipel'ská kotlina (depression) and the Krupinská planina Mts. (Annex 4)

3.1. General data

The Ipel'ská kotlina (depression) is a part of the South-Slovakian depression and extends roughly between the towns Šahy and Lučenec at the foot of the Krupinská planina Mts. From geological viewpoint the Ipel'ská kotlina is only a part of a large sedimentation areas of the molasse backdeep. There the sedimentation of the early molasse (of the Budín Paleogene basin) proceeded and was followed by sedimentation of the main molasse in episodical depressions. Molasse sediments of episodical depressions are genetically related with volcanism of Central Slovakian region. Particularly close is the relation of volcanic rocks forming the Krupinská planina to the Ipel'ská kotlina.

DOI:https://doi.org/10.2312/zipe.1982.066

The Ipel'ská kotlina and the Krupinská planina belong to the best explored molasse complexes in the West-Carpathian region. Geologists paid a greater attention to the area by the end of the 19th and at the beginning of the 20th centuries, owing to occurrences of brown coal. Larger parts of this region were explored by BUDAY (1938), ČECHOVIČ (1952), and ČECHOVIČ et al. (1963); tectonics of the region was studied by PÁVAY VAJNA (1948), and the region was also commented by NOSZKY (1940). Results of work of more geologists - specialists on biostratigraphy, petrography, geophysics - and the results of our own investigations are summarized in a monography by VASS, KONEČNÝ and ŠEFARA (1979) including a detailed bibliography.

Sediments filling the Ipel'ská kotlina (depression), particularly sediments of the main molasse, are comperatively well exposed in natural exposures. Besides that the data on the sediments were obtained from many bore holes. Volcano-sedimentary formations are also well-exposed on the slopes of the Krupinská planina (plateau). Continuation of sediments of the Ipel'ská kotlina (depression) below the Krupinská planina were revealed by deep drilling.

3.2. Tectonic structure and paleogeographic-paleotectonic history

Molasse sediments of the Ipel'ská kotlina rest on the paleoalpine folded basement represented by Inner Carpathian units, especially by the Veporic, less by the Gemeric (Fig. 9). The structure of the units is nappe-like. Later they were refolded into megafolds.

Paleogeographic and paleotectonic history of molasse in the Ipel'ská kotlina and Krupinská planina may be divided into four periods. The first two periods are those of the early molasse, the next two correspond to the main molasse. In the backdeep and thus in the Ipel'ská kotlina the early molasse is more extensive and thicker than the main molasse (Fig. 10; inside the West Carpthian arc the relation of the two molasses is reverse). The evolution of the early molasse commenced in the Uppermost Cretaceous to Paleocene with deposition of clastic rocks and olistostromes in continental fluvial, later in the Eocene in lacustrine environments. Deposition proceeded in an areally limited depression controlled by meridional faults.

In the second period of the early molasse the sea got into the Ipel'ská kotlina. It was the culmination period of the early molasse (Rupelian and Egerian) in the backdeep. In the area under study two significant tectonic structures (Fig. 11) were decisive in that time. They also controlled the evolution of molasse sediments in later periods, i.e. in the time of formation of the main molasse up to the Badenian (16.5 m.y. B.P.). The two leading structures were the NE-striking Šahy elevation separating the area NW of the elevation from the open sea (Fig. 12), and the Dačov Lom graben controlling distribution of thickness of molasse sediments, distribution of coal seams in the Ottnangian and crossing transversaly the Šahy elevation. In the time of culminating marine transgressions the graben connected the open sea SE from the Šahy elevation with the area behind the elevation.

DOI:https://doi.org/10.2312/zipe.1982.066

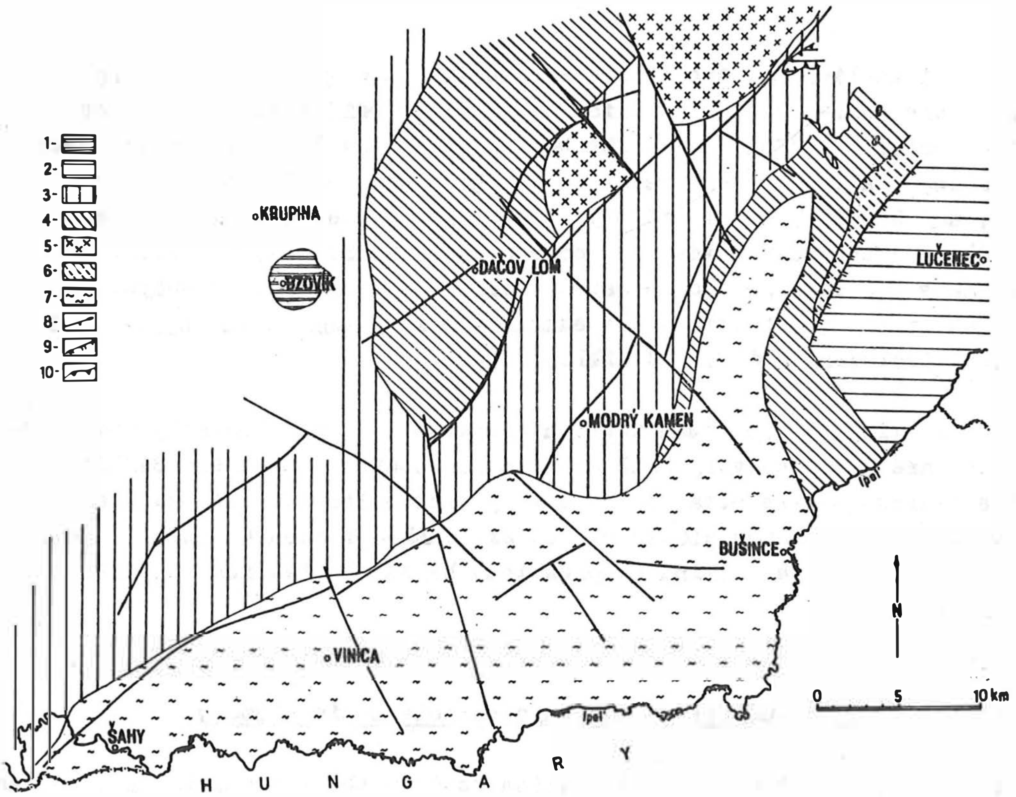


Fig. 9. Principal tectonic units of the pre-molasse basement of the Ipel'ská kotlina (depression) and the Krupinská planina Mts.

1 - higher tectonic units of the West Carpathians (the Choč or Gemeric nappe?), Jurassic, 2 - Gemeric, Upper Paleozoic, 3 - series of Veporic cover, Upper Paleozoic - Mesozoic, 4 - Veporic, the Kráľova Hoľa complex: crystalline schists with relicts of the Mesozoic cover, 5 - Veporic, the Kráľova Hoľa complex: granite rocks, 6 - Veporic, the Hladomorná dolina group: crystalline schists (Early Paleozoic), 7 - Veporic, the Hron complex: crystalline schists (Early Paleozoic), 8 - deep-seated faults and fault zones, 9 - thrusts, 10 - overthrusts and charriage lines

Since the Rupelian we may observe traces of synsedimentary fault tectonics (NW-striking fault system) in a limited extend. In the third evolutionary stage (Eggenburgian to Badenian) the main molasse formed and was affected by pulsation typical of episodical depressions of the backdeep. Molasse sedimentation was unstable both in time and space. Transgressions alternated with regressions, subsidence was limited. In the Ipel'ská kotlina the decisive influence of the Šahy elevation and of the Dačov Lom graben (Fig. 13) lasted up to the Badenian. The graben is associated with the activity of synsedimentary faults (NW-striking fault system). In the third period volcanism was significant. Its first manifestations - acid volcanism - are known from the Eggenburgian. Volcanic activity (andesite volcanism) culminated in the Badenian. Its ascending way was the volcanotectonic zone Šahy - Lysec crossing longitudinally the former Šahy elevation (Fig. 14). In the fourth and the last period (after the Badenian and up to the Recent) the volcanic activity ended and due to general uplift also the molasse sedimentation ended (in the Sarmatian) in the area under study. The following tectonic activity affected only epigenetically the sedimentary and volcano-sedimentary molasse complexes of the Ipel'ská kotlina and Krupinská planina. The tectonic activity was mainly represented by NNW-striking faults affecting epigenetically the complexes, and by the elevation of the central Ipel' valley controlling the denudation in the area studied.

DOI:https://doi.org/10.2312/zipe.1982.066

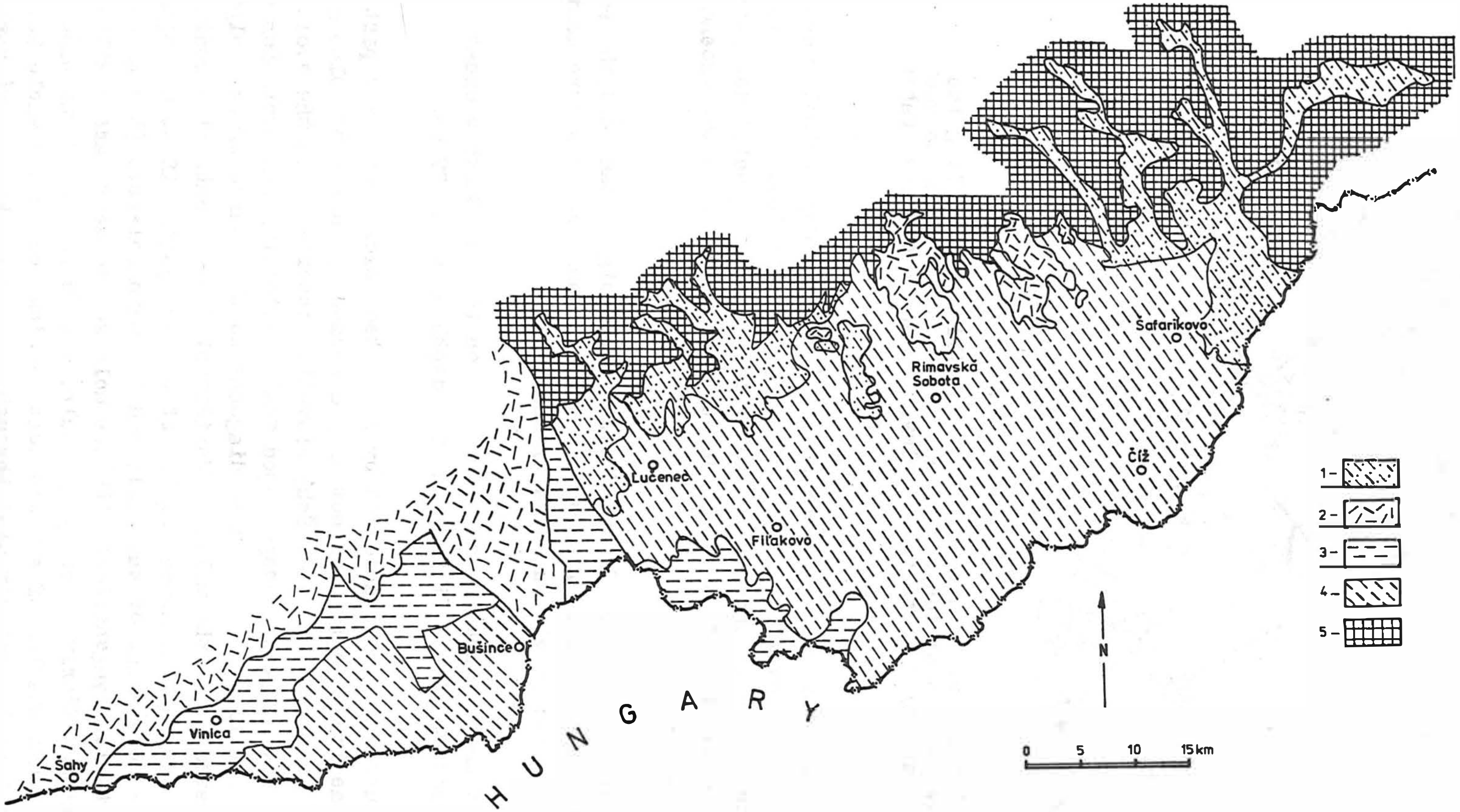


Fig. 10. Extension of early molasse, episodic evolution of the main molasse and the late molasse in South Slovakia

1 - late molasse (Dacian sediments), 2 - volcanic rock margins of the main molasse, 3 - episodic evolution of the main molasse (Eggenburgian to Karpatian), 4 - early molasse, 5 - pre-Tertiary rocks

DOI:https://doi.org/10.2312/zipe.1982.066

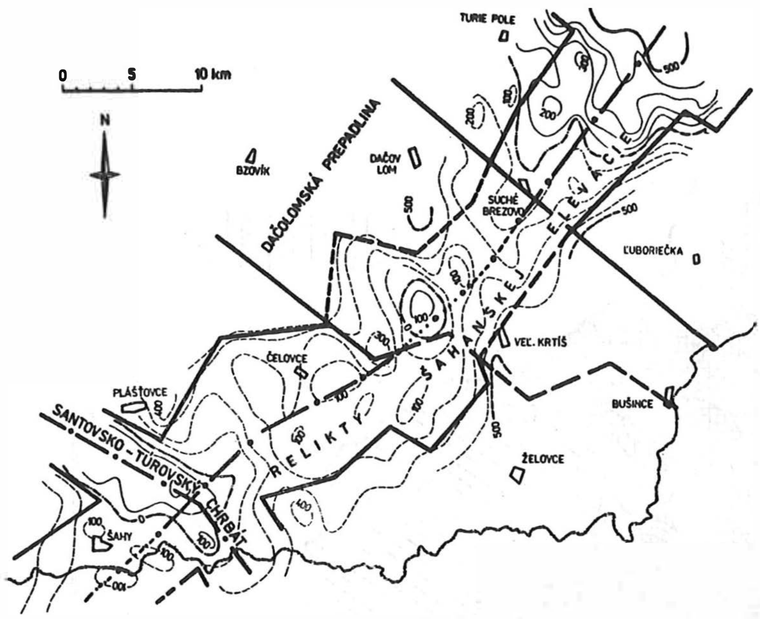


Fig. 11. Principal structures of Ipelská kotlina controlling the development of the early, partly of the main (up to the Karpatian) molasses: Šahy elevation and Dačov Lom graben

Further to the east (the Lučenská and the Rimavská kotlina depression) there is an area with resemblant molasse evolution like in the Ipelská kotlina. There in the Pliocene late molasse came into existence for a short time in a continental detrital facies. By the end of the Pliocene, deep fissures opened there and served as the ascending ways for basalt lava (Fig. 15).

In the Badenian time some faults of the NW system were significant and the activity of some ancient NE and meridional faults was renewed. Volcanic centres were mostly located on crossings of faults of various directions.

The Ipelská kotlina and the Krupinská planina are on thinned Earth's crust of continental type. The Mohorovičič discontinuity is at a depth of about 27 km.

The molasse sediments are mostly deformed by fault tectonios. The lower part of molasse (up to the Eocene includingly) was not only deformed by faults but also gently folded in the time of formation of the Šahy elevation observable in the evolution of sediments since the Rupelian. Among deep-seated faults affecting the evolution of molasse sediments most signifioant were faults diagonal to the course of paleoalpine structures of the folded basement of the molasse. Meridional faults controlled sedimentation in the first stage of the early molasse, faults of the NW system affected syngenetically the structure of the second stage of the early and the main molasses (the Dačov Lom graben). The meridional faults syngenetioal with the molasse sediments are auxiliary faults of the deepseated regional Zázrivá - Budapest fault. The NW faults of the Dačov Lom graben are surficial manifestation of a fault belt running aoross the whole West Carpathians from Trenčín (the Jastrabie fault) through Krupina to the Ipelská kotlina (depression) and through Sóshartyan - Szentkút to Szolnok in Hungary.

DOI:https://doi.org/10.2312/zipe.1982.066

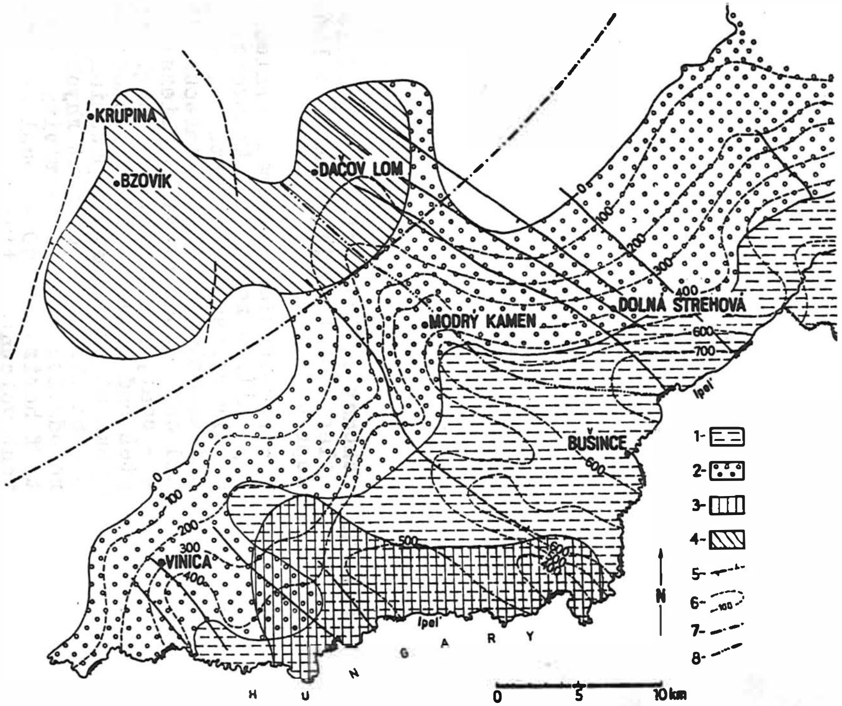


Fig. 12. Distribution of facies and thickness of early molasse (the Egerian part) in the Ipeľská Kotlina (depression) and the Krupinská planina Mts. The Šahy elevation confines the area of the saline lagoon on the NW, its occasional connection with the open sea was mediated by the Dačov Lom graben. The graben controlled the distribution of thickness of the molasse

1 - marine neritic facies, 2 - marine littoral and sublittoral facies, 3 - brackish facies of terminal beds of the Egerian, 4 - hypersaline facies (saline lagoon), 5 - faults, 6 - thickness isopachs in m, 7 - course of axis of the Šahy elevation, 8 - course of axis of the Dačov Lom graben

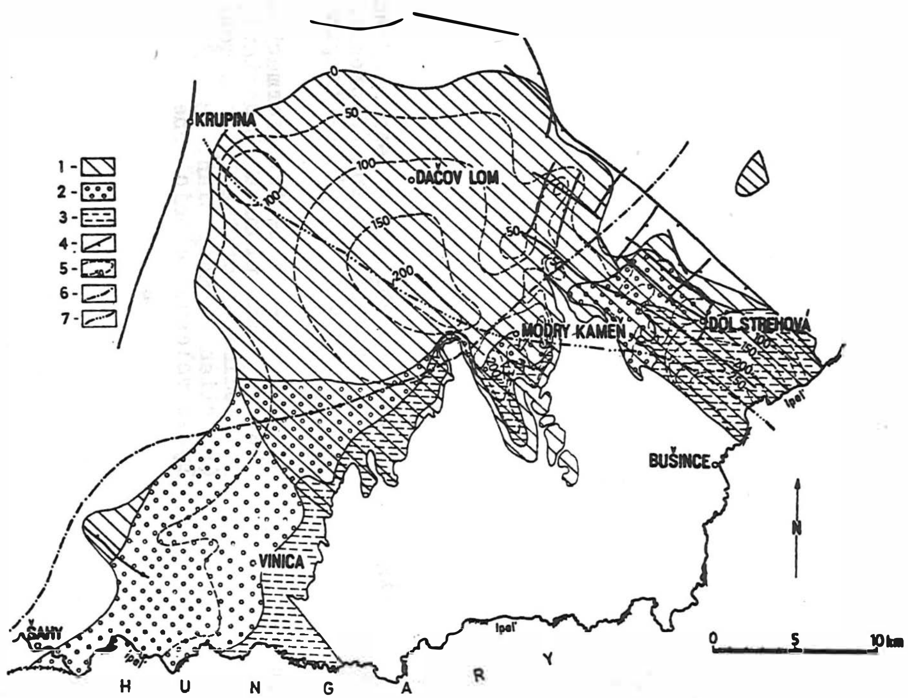


Fig. 13. Distribution of facies and thickness of the main molasse (the Karpatian part) in the Ipeľská Kotlina (depression) and the Krupinská planina Mts. The Šahy elevation confined the area of a brackish bay, and the Dačov Lom graben mediated occasional connection with the open sea and controlled the distribution of thicknesses

1 - marine neritic facies, 2 - marine littoral and sublittoral facies, 3 - brackish facies, 4 - significant faults, 5 - thickness isopachs in m, 6 - course of axis of the Šahy elevation, 7 - course of axis of the Dačov Lom graben

DOI:https://doi.org/10.2312/zipe.1982.066

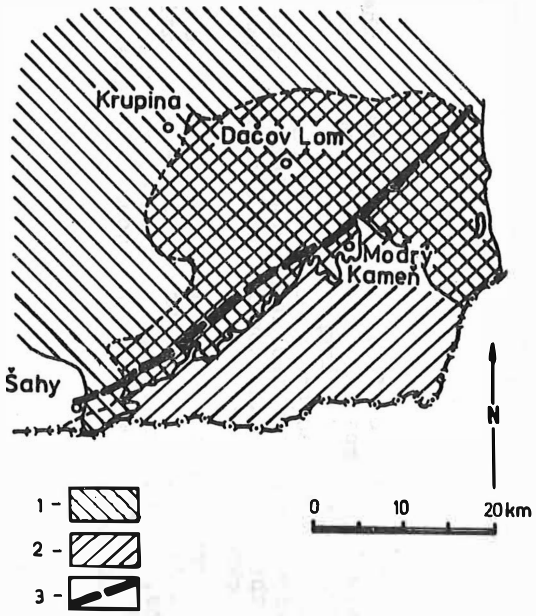


Fig. 14. Spatial relations between sediments of the Ipelská kotlina (depression) and volcanic rocks of the Krupinská planina Mts.

1 - volcano-sedimentary formations of the Krupinská planina (Badenian), 2 - sediments of the Ipelská kotlina (Rupelian to Karpatian), 3 - Šahy - Lysec volcanotectonic zone

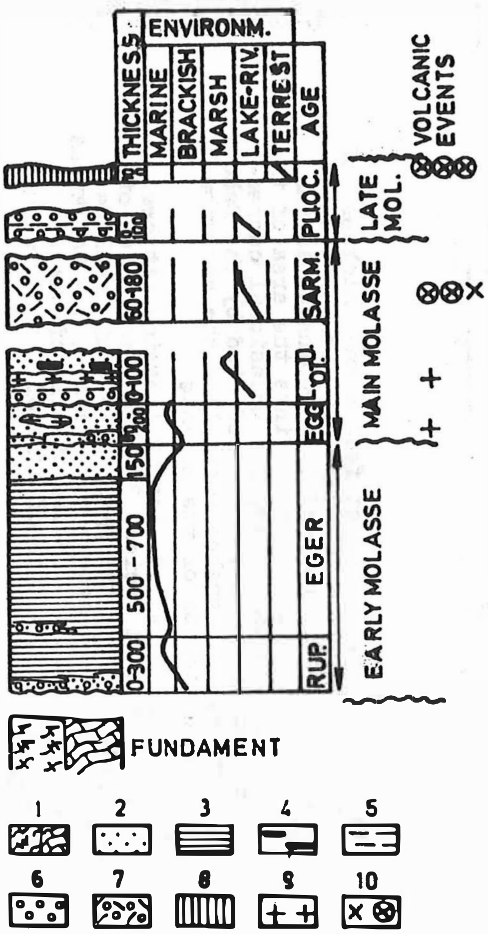


Fig. 15. Schematic lithotectonical profile of molasse of the Rimava and the Lučenec depressions

1 - pre-Tertiary basement (Paleozoic crystalline rocks, the Mesozoic, mainly Triassic sediments), 2 - sands and sandstones, 3 - calcareous silts and calcareous clays (schliers), 4 - coal, 5 - clays, 6 - conglomerates and gravels, 7 - volcanoclastic rocks of the Rimava depression, 8 - basalts, 9 - distant rhyolite and rhyodacite volcanic activity (acid tuff horizons), 10 - local and distant volcanic activity

DOI:https://doi.org/10.2312/zipe.1982.066

3.3. Notes on the lithotectonic profile

Molasse sediments depicted in the type profile of the Ipeľská kotlina and the Krupinska planina (Annex 4) were formed in the time interval between the uppermost Cretaceous and the Badenian inclusively. The genesis of the sediments lasted about 58 m.y. (approximately 70 - 13 m.y. B.P.). Sedimentation in such a great time interval was naturally not continuous and there must have been longer periods which are not represented by sediments.

Basing upon biostratigraphical data, the molasse sediments and volcanic rocks of the Ipeľská kotlina and the Krupinská planina were d i v i d e d as follows:

- The uppermost Cretaceous to Eocene. They form the lower part of the early molasse. Their biostratigraphical range was determined on the ground of palynomorphs.
- The Rupelian and the Egerian represent the culmination of the early molasse. Biostratigraphical range of sediments in these stages is mostly based on calcareous nannoflora, benthonic foraminifers and molluscs. For biostratigraphical interregional correlation, the calcareous nannoflora facilitating a correlation of the beds in question with the standard zones NP 24 and NP 25 is most significant.
- Sediments of the Eggenburgian and Ottnangian represent the first two "episodes" of the main molasses. They contain organic remains facilitating only an approximate biostratigraphical ranging (micro- and macroflora, bones of mammals, and also molluscs) and their stratigraphical range is documented by non-biostratigraphical evidence (superposition, lithological evolution a.o.). Radiometrical ages of rhyodacite tuffs from continental beds of Lower Ottnangian age (21 - 22 m.y., VASS et al. 1971, p. 322; BALOGH et al. in press) are rather indicative of Eggenburgian age of the beds.
- The Karpatian is a continuation of episodical evolution of the main molasse. In the Karpatian sediments there are plentiful marine fauna, molluscs, foraminifers, calcareous nannoflora. The calcareous nannoflora facilitates correlation of the Karpatian of the Ipeľská kotlina (depression) with the standard nannoplanktonic zone NN 4. Radiometric ages whose mean values vary between 18 and 19 m.y. (VASS and BAGDASARJAN 1978) do not exclude possible equivalency of these beds with the Ottnangian in Austria.
- In the Badenian, the sedimentation of the main molasse in the area studied culminated. The Badenian volcano-sedimentary formations contain sporadical horizons with marine fauna (and also micro- and macrofauna), molluscs and foraminifers facilitating the correlation with the Badenian, and also correlating the lower part of the Badenian with the standard planktonic zone N 9 on the ground of planktonic foraminifers. Radiometrical ages (around 15 - 16 m.y.) show that the biostratigraphical correlation is right (VASS et al. 1971, p. 322).

In the area studied only some l i t h o s t r a t i g r a p h i c units were distinguished:

- The Seľany beds are Rupelian lacustrine sediments replaced laterally by marine sediments and representing thus a continental Rupelian facies.

DOI:https://doi.org/10.2312/zipe.1982.066

- Upper Ottnangian productive beds are sands with coal seams. They are partly replaced by a facies of overlaying clays. These represent another lithostratigraphic unit and for the most part they overlay the productive beds. So they must be younger than the productive beds.
- The Rzehakia (oncophora) beds represent a Karpatian hyposaline facies well distinguishable both lithologically and biofacially. The Krtíš beds are partly equivalent in age and in facies to the Rzehakia beds. They are sandy shallow-water and beach sediments of the open sea.
- Badenian volcano-sedimentary bed sequences are divided into the Pribelce beds forming the base of the Badenian, the Vinica - Pribelce formation, the Opava formation and the Lysec formation. Each of the three formations is a complex of facies of one Badenian volcanic period (for example in the Opava formation are facies of the central intermediary and peripheral volcanic zones; KONEČNÝ in VASS et al. 1979).

M a x i m u m t h i c k n e s s of molasse sediments and of volcanoclastic rocks ranges up to 1600 m (bore hole GK-4). The total maximum thickness of molasse sediments of the single periods is greater owing to the fact that the maximum accumulations of sediments took place in different places. Thicknesses quoted in the respective columns represent either estimated average thickness and the present maximum thickness or the first value is zero, i.e. the given bed complex has a very irregular development, and there are considerable areas of the region studied without the complex. The maximum thicknesses were usually greater originally and then reduced during the intramolasse periods of denudation. The greater thickness - about 1100 m - was that of sediments of the culmination stage of evolution of the early molasse (Rupelian - Egerian). Sedimentation velocities calculated on the ground of the present maximum thicknesses and of radiometric ages, are in Table 4.

Among the t y p e s o f s e d i m e n t s pelites and sands and sandstones are predominant. In the lower part of the early molasse there are plentiful coarse-clastic rocks (conglomerates); in the upper part of the early molasse and in the main molasse the coarse clastic rocks are scarce. Another type of sediments are evaporitic sediments that formed in the culmination period of the early molasse but they are bound to the marginal parts of the sedimentation area. In the uppermost part of the main molasse, in the Badenian, various volcano-sedimentary and volcanic explosive rocks are practically the only types of rocks. Horizons of volcanoclastic rocks (tuffs) are also in the lower part of the main molasse. They occur sporadically in the upper part of the early molasse.

The sediments are mostly grey, only in continental parts of the profile they are variegated.

C y c l i c a l s e d i m e n t a t i o n in the area studied, generally regarded as typical of the molasse sediments, proceeded mainly in the period of continental sedimentation. The cycles are scarcely observable in marine sediments.

P e t r o g r a p h i c c o m p o s i t i o n of conglomerates, and composition of heavy fraction of sands and sandstones offers a very valuable information about the

DOI:https://doi.org/10.2312/zipe.1982.066

character of the source area. In conglomerates of the lower parts there is a dominance of pre-molasse sedimentary rocks. In upward direction, pebbles of the vein quartz increase in amount and pebbles of metamorphosed rocks appear as well. - In the upper part of the profile pebbles of syngenetic volcanic rocks are absolutely dominant.

In the lower part, minerals resedimented from pre-molasse sediments are dominating in heavy mineral associations. Higher up in the profile first of all the low-thermal, then high-thermal metamorphic minerals increase in amount. In the upper part of the profile, volcanogenic minerals are absolutely dominant. Vertical changes in the composition of conglomerates, of the heavy fraction of sandstones and of sands are due to progressive denudation in the source area. The denudation exposed even highly metamorphosed rocks prior to the Badenian. The post-denudation state of pre-molasse formations was preserved by the Badenian volcanism. The volcanism also covered the entire source area with its products.

Table 4. Velocity of subsidence in Ipelská kotlina (depression)

Age	age of boundary [m.y.]	max. thickness [m]	velocity of subsidence [cm/100 years]
	13.3		
Badenian		700	2.2
	15.5		
Karpatian		250	1.0
	19.0		
Eggenburgian - Ottnangian		450	1.1
	23.0		
Egerian		700	1.3
	27.0		
Rupelian		400	0.8
	33.0		
Uppermost Cretaceous -Eocene		540	0.2
	70.0		

In most cases we only determined the general course of the transport according to the source areas that were situated at the north of the depositional area, particularly as regards the main molasse. In the case of volcano-sedimentary Badenian formations the transport direction was derived from lateral alternations of facies. In the case of the Pribelce beds the current structures are indicators of paleocurrents.

Sedimentary structures in molasse sediments are comparatively scarce. In schliers which are a dominant type of sediments an irregular sandy lamination may be observed. Cross-beddings are scarce in sandy beds. The only exception are

DOI:https://doi.org/10.2312/zipe.1982.066

the Pribelce beds with variable structures (VASS 1977). Erosion structures are mainly in continental beds.

In continental beds of the profile as f o s s i l s there are plant remains, leaf impressions, sporomorphs, in the main molasse also occasional bones of mammals. In marine beds plentiful molluscs, foraminifers, and also calcareous nannoflora occur. In the lower and middle volcano-sedimentary formation are horizons with marine fauna and leaf impressions, in the upper formation are only leaf impressions.

Most molasse sediments formed in a marine e n v i r o n m e n t and in its marginal partial environments. Sedimentation in the initial stage of the evolution of the early molasse and at the end of the main molasse was continental in its nature. But between the two periods episodes of continental sedimentation were recorded amidst marine beds. Sedimentation proceeded mostly in a calm environment (few conglomerates). Transport of coarse clastic rocks is, however, typical of the initial sedimentation of the early molasse.

V o l c a n i s m was intensive in the time of degradation or even during the complete change of sedimentation in a marine environment to sedimentation in a continental environment. This in the profile described concerns both the Lower Ottnangian acid volcanism bound to continental beds, and the Badenian andesite volcanism. In the upper part of the early molasse (Rupelian - Egerian) and in the lower part of the main molasse (Eggenburgian - Ottnangian, Karpatian) a distant volcanic activity took place. It is documented by not too thick tuff horizons. In contrast, the Lower Ottnangian (Eggenburgian?) tuffs form thicker horizons and are partly welded.

In the Badenian time the volcanic centres were directly in the area under study. There were subaquatic eruptions associated with intrusions followed by formation of new extrusions and agglomerate cones. In the final stage volcanic domes and agglomerate cones formed (for details see KONEČNÝ in VASS et al. 1979).

T e c t o n i c d e f o r m a t i o n s were simple. In the pre-Rupelian part the deformations were caused by faults and the beds were gently folded. Younger beds were deformed mostly by faults, particularly by postsedimentary ones. There are some manifestations of synsedimentary activity but the faults were qualitatively different from recorded in the Vienna or East-Slovakian molasse basins. Intensive movements along the faults in the initial stage of the early molasse resulted in coarse-clastic rocks to olistostromes.

The t e c t o n i c m o v e m e n t s caused repeated breaks in sedimentation and new transgressions during the formation of molasse sediments. Breaks in sedimentation caused denudation and reduction of the original thickness of the sediments. There are longer hiatuses reliably proved on the Eggenburgian/Ottnangian and Karpatian/Badenian boundaries.

Extensive uplifts of the source area can be recorded mainly at the beginning of molasse sedimentation and in the time of volcanic activity when the steep relief is mostly due to growing volcanic apparatuses. All this happened on the background of a re-

DOI:https://doi.org/10.2312/zipe.1982.066

gional uplift which caused definitive retreat of the sea from the area studied in the Badenian time.

3.4. Conclusions

The Ipeľská kotlina (depression) is a part of the West Carpathian backdeep with a specific development of molasses. In the Ipeľská kotlina two types of molasse basins rest upon each other. The lower part of the filling forms a structural horizon belonging to the basin of the Buda Paleogene. The basin is a typical representative of basins of the early molasse in the backdeep. Typical features of the basin are as follows:

- The basin rests on the Pannonian block and extends to the Inner Carpathians, ignoring practically the structure of the basement. The extension of the basin is roughly controlled by the Balaton fault on the south and by the Muráň line or its analogues on the north.
- Sedimentation proceeded in the conditions of a stable shelf which were occasionally replaced by conditions of a continental environment. Typical sediments are schlier silty to sandy-pelitic beds but there are also coarse-clastic rocks and evaporites on the Hungarian territory also limestones in the Eocene.
- The structure of the basin is brachysynclinal, dish-like. The faults were less active, the steps range to several tens of metres in height, occasionally more than 100 m.
- The basin, including its extension on the Hungarian territory, is comparatively large (about 21 000 km^2 and only with medium-sized accumulations of sediments (to 3 000 m; maximum thicknesses are out of the Ipeľská kotlina in northern Hungary). Velocity of subsidence is comparatively small to medium: 0.8 - 1.3 cm/100 years, on the Hungarian territory perhaps even 2.5 cm/100 years. - The final stage of the existence of the basin was characterized by sudden areal expansion and culmination of subsidence.
- Volcanism is manifested sporadically.
- The basin rests on thinned continental crust.

The upper part of the filling of the Ipeľská kotlina and the Krupinská planina are composed of sediments and volcano-clastic rocks of episodic basins of the main molasse. Significant features of the basins are as follows:

- Sedimentation proceeded in the conditions of a stable shelf but also in continental conditions.
- The basins were stable neither in time nor in space.
- Structurally the basins are small depressions often superposed on ancient grabens. The faults are epigenetic, occasionally syngenetic, with low altitude of steps (tens of metres to 200 m).
- The basins occupy a small area (in Southern Slovakia only 1158 km^2) and comprise small accumulations of sediments (maximum several hundreds of metres). Subsidence is slow (0.2 - 1.1 cm/100 years).

DOI:https://doi.org/10.2312/zipe.1982.066

- The evolution of the basins was synchronous with intensive volcanic activity which proves that the faults - although without significant movements - extended to deeper parts of the Earth's crust and served as ascending ways for magma. Owing to volcanism there were local larger accumulations of volcanoclastic rocks (700 m in the Krupinská planina, more than 1000 m in NE Hungary).

4. The Gabčikovo Basin (Annex 5)

The Gabčikovo Basin represents the southern part of the region denoted in Czechoslovak geological literature as the Podunajská nížina (Danube lowland), the Danube lowland basin, the Danube basin (Podunajská panva) and otherwise.

4.1. General data

The Gabčikovo Basin is a prevalently plain area on the left bank of the Danube river between the Malé Karpaty Mts. and the town Komárno. Geologically it is a part of a large Pliocene basin extending on the Hungarian territory from the most part. The area of the whole basin is about 180 000 km^2 whereas its Slovak part is only about 10 000 km^2.

Tectonics of the area was treated in one of the first publications on this theme by ČEPEK (1938). Basical data on the structure of the basin and interpretation of the results of geophysical researches as well as basical division of the basin are presented in a publication by ADAM and DLABAČ (1961). The structure of the basin was also treated by BUDAY (1961, 1962) and in BUDAY et al. (1965, 1967). Thickness of filling of the basin was studied by ADAM and DLABAČ (1969), the structure of the pre-Tertiary basement by BUDAY and ŠPIČKA (1967) and by FUSÁN et al. (1971). The results of oil drilling are summarized by GAŽA (1974) and by GAŽA and BEINHAUEROVÁ (1976). A list of older bibliography was presented by BUDAY et al. (1965, p. 25-26).

The Gabčikovo Basin is completely covered by Quaternary sediments. All data on the structure, lithology, stratigraphy and tectonics are either from bore holes or resulted from interpretation of geophysical researches. As for its position in the Carpathian mountain system it is a molasse sedimentation area in the backdeep.

4.2. Tectonic structure and paleogeographic-paleotectonic history

The Gabčikovo Basin rests upon tectonically heterogeneous basement without respect to its structural plan. The basin rests from the most part on the crystalline complex of the Inner Carpathians and partly on the Mesozoic of the Pannonian block (Fig. 16). It is presumed that pre-Neogene basement was tectonically formed mainly by paleoalpine (Upper Cretaceous) folding, still its older (Variscan) structure cannot be excluded since the main component of the basement are pre-Mesozoic crystalline rocks. The basin arose at the beginning of the Pannonian and represents a late molasse basin. In the course of its evolution the Gabčikovo Basin annected also the areas of the older Galanta basin i.e. its part in the northern part of the Podunajská rovina (Danube

DOI:https://doi.org/10.2312/zipe.1982.066

plain), on the Podunajská pahorkatina (Upland) and in bays between the Malé Karpaty Mts., Inovec Mts. and Tribeč Mts. (Fig. 17). The existing information about the basin and its surroundings indicate a long emergence of the basin area. The area was devoid of the most part of Mesozoic rocks and denuded deep down to the level of highly metamorphosed rocks. It was partly activated to subsidence in the Badenian as a marginal area of subsidence centres situated on the N, NE and NW (Fig. 18), but it became the proper centre of subsidence as late as the Pannonian simultaneously with the regional uplift of the Carpathian region. Because of the regional uplift, the basin, originally flooded by brackish waters, degraded gradually to a freshwater basin and later to a system of lakes.

The main tectonic effect decisive for tectonic development and style of the basin was brachysynclinal bending. Sometimes, mainly at the margins, the basin was deformed by faults active in the Badenian and Sarmatian times. The height of fault vertical movements in the Pannonian and Pliocene were not large.

The formation of the basin and its tectonic style are regarded as a result of the crust collapse in the place of thinned crust due to subcrustal erosion by the mantle diapir. The collapse affected not only the Gabčikovo Basin but also a considerable part of the Pannonian block (STEGENA et al. 1975; VASS 1976). Volcanic activity preceded the development of the basin in the Badenian and Sarmatian in connection with the evolution of the main molasse (Fig. 19). The development of the basin was associated with basalt

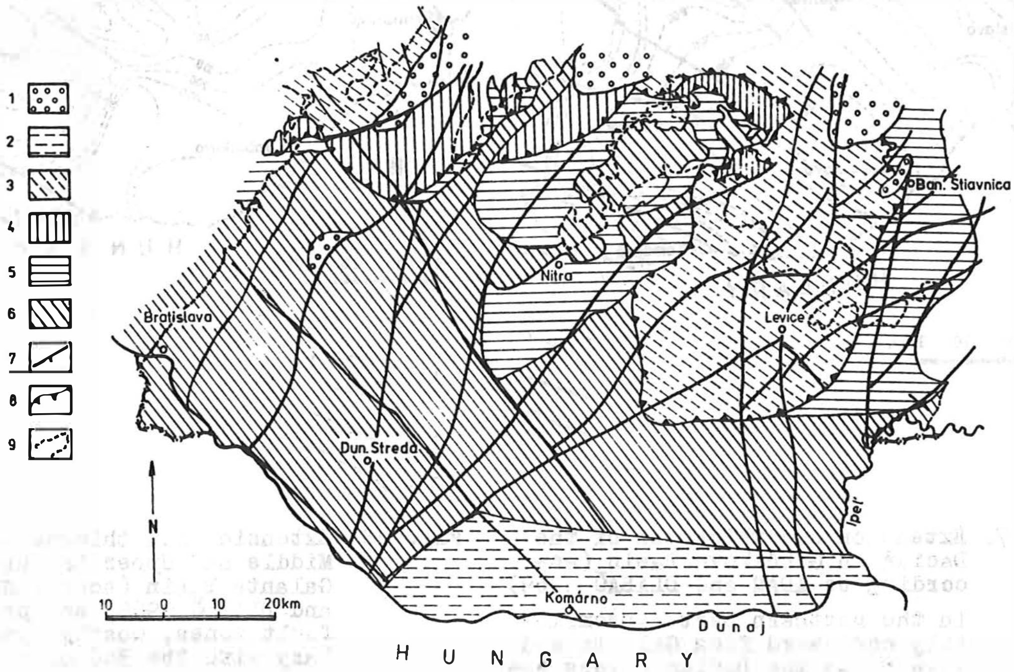


Fig. 16. Pre-molasse basement of the Gabčikovo Basin and its surroundings (according to FUSÁN et al. 1971)
1 - Inner-Carpathian Paleogene, 2 - Mesozoic of the Pannonian block, 3 - the Choč and the higher nappes of the West Carpathians, 4 - the Krížna nappe, 5 - Upper Paleozoic and Mesozoic of cover units of the West Carpathians, 6 - crystalline complexes of the West Carpathians, 7 - deep-seated blocks, 8 - nappe fronts, 9 - present margin of the basin

DOI:https://doi.org/10.2312/zipe.1982.066

volcanism active in the marginal parts or - like in the Gabčíkovo Basin - out of the subsidence area. The volcanism is an evidence of the existence of deep-seated faults serving as ascending ways for basalt magma. But no intensive vertical movements took place along these faults. The basalt volcanism indicates that the area was in the region with tectonic conditions of spreading (cf. DICKINSON 1970).

In the place of the basin the Earth's crust is continental but considerably thinned (because of subcrustal erosion of mantle diapir). In the Podunajská nížina (Danube lowland) the crust is about 28 km thick (Fig. 1). In Hungary the average thickness of the crust is about 24 - 26 km. The upper crust (granite layer) has normal thickness (16 - 19 km), the lower crust is comparatively thin (5 - 8 km; STEGENA et al. 1975, p. 76).

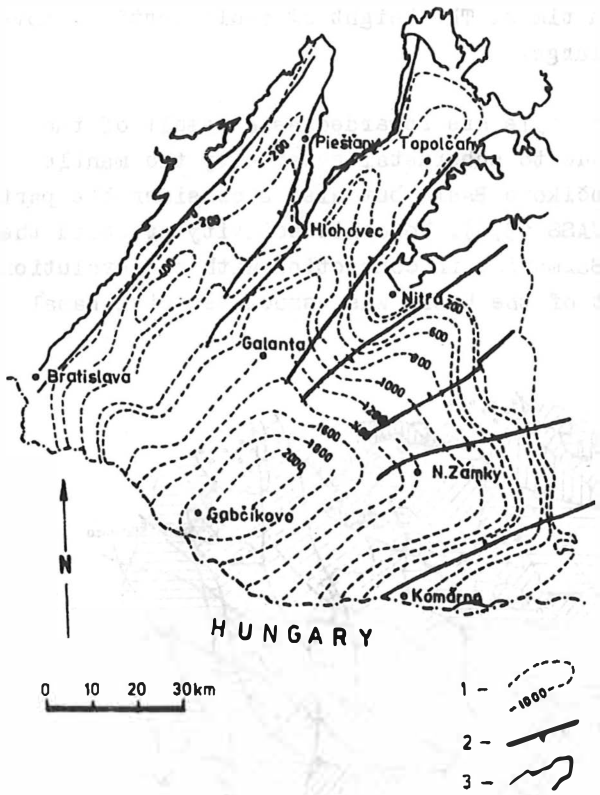


Fig. 17. Extension and thickness of the Dacian in Gabčíkovo Basin (according to ADAM and DLABAČ 1969)

In the northern part approximately northward from Galanta and Nové Zámky the Dacian covers the Galanta Basin of the main molasse. Fault activity faded out in the Dacian.

1 - thickness isopachs in m, 2 - significant faults and fault zones, 3 - present margin of the basin

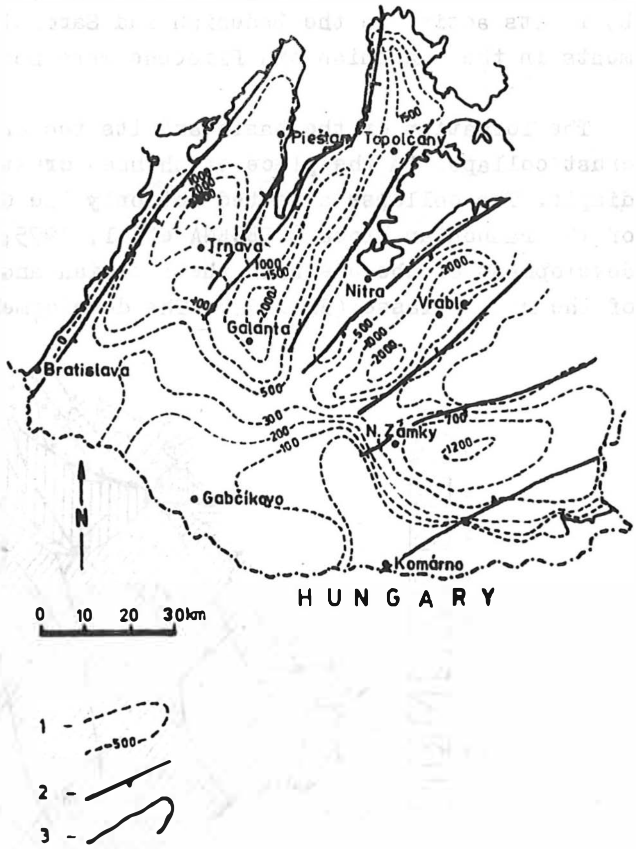


Fig. 18. Extension and thicknesses of the Middle and Upper Badenian in the Galanta Basin (according to ADAM and DLABAČ 1969) and principal fault zones, mostly synsedimentary with the Badenian

A comparison with Fig. 17 shows a spatial discordance between subsidence centres of the Galanta Basin (the main molasse) and the Gabčíkovo Basin (the late molasse)

1 - thickness isopachs in m, 2 - significant faults and fault zones, 3 - present margin of the basin

DOI:https://doi.org/10.2312/zipe.1982.066

These conclusions are based on seismic profiles, on a great geothermal anomaly and on high values of the heat flow. They are reasoning a supposition about subcrustal erosion of the Earth's crust.

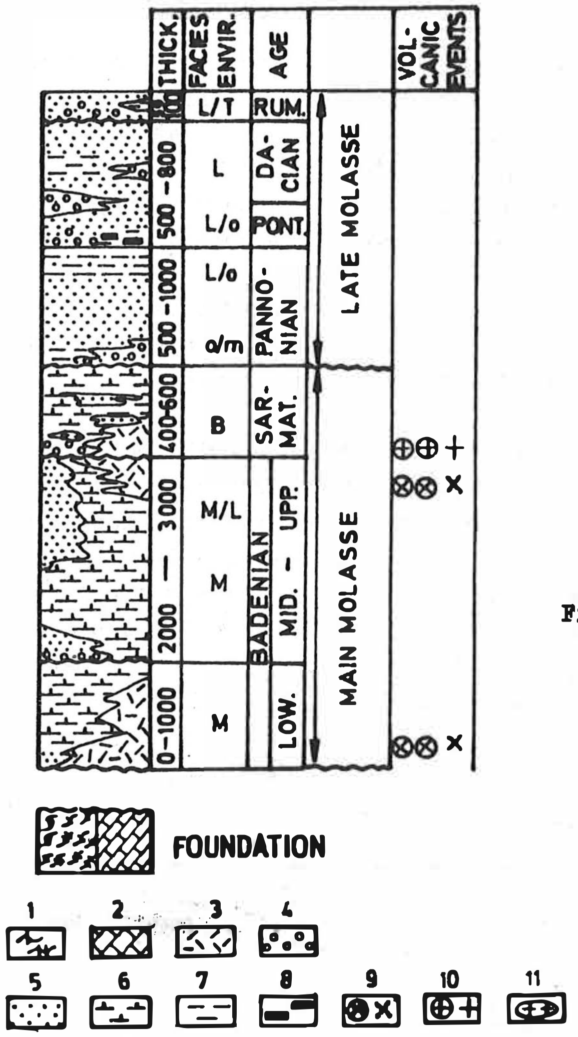


Fig. 19. Schematic lithotectonic profile of molasse of the Galanta Basin. The profile shows evident inversion between the thicknesses of the Badenian, Pannonian, Pliocene of the Galanta Basin and the Gabčíkovo Basin

1 - pre-Tertiary basement, Paleozoic crystalline rocks, 2 - pre-Tertiary basement, Mesozoic, 3 - andesite volcanoclastic rocks and lava flows, 4 - breccias and conglomerates, 5 - sands and sandstones, 6 - marls, marly clays, 7 - clays, 8 - lignite, 9 - distant and local volcanic activity, 10 - distant rhyolite volcanic activity, 11 - rhyolite volcanoclastics

4.3. Comments on the typical lithological-tectonical profile

S t r a t i g r a p h y   o f   s e d i m e n t s is based on microfauna, partly on foraminifers and mainly on ostracods. The division is regional but in the upper desalinated part of the profile (Dacian, Rumanian) are few fossils for reliable biostratigraphical division. Criteria for interregional biostratigraphical correlation are reliable and the correlation presented in the profile is only approximate and presumable. Some authors now correlate the Pontian/Dacian boundary with the Miocene/Pliocene boundary; others place the boundary in the middle of the Pontian. The survey of biostratigraphical division was published by BUDAY et al. (1965, 1967); newer views can be found, among others, in a work by JIŘÍČEK (1972).

DOI:https://doi.org/10.2312/zipe.1982.066

The total maximum thickness of filling of the basin is not known. Drill holes did not reach the deepest parts of the basin. A thickness of 3000 - 4000 m seems to be real. Subsidence velocity is about 4 cm/100 years (Fig. 16). The isotopical ages are inscribed after the radiometric time scale of the Paratethys Neogene (VASS and BAGDASARJAN 1978).

Lithological units - with the exception of the Kolárovo formation in the uppermost Pliocene - were not defined. The basin was only partly affected by the Badenian volcanism. Possible presence of volcanic rocks at the base of the molasse filling is indicated by magnetic anomalies extending from Hungary and from NE (PAGÁČ 1966) into the central part of the basin. The rocks are mostly grey, grey-green, scarcely varicoloured. Their colouring gets more varied in upward direction.

Cycles were not studied in detail because of poorly exposed beds and incontinuous coring of drill holes penetrating in greater depths. Cyclic development is presumed mainly in parts of the profile with lignite seams and fluvial sediments.

Composition of the psammitic fraction was studied in drill holes realized for the purpose of geothermal exploration. The results are orientational, and data from deeper parts of the profile concern the composition of the psammitic fraction in the marginal parts of the basin, not in its centre. Quartz grains are prevalent but not permanently. The amounts of other components are also variable. Transport directions cannot be determined directly. The material composition is indicative of the transport from the Inner Carpathians. Sandy and coarser materials are presumably transported over 10 - 100 km. Pelitic material may originate from more distant areas.

Table 5. Velocity of subsidence in the Gabcíkovo Basin

Age	age of boundary [m.y.]	max. thickness [m]	velocity of subsidence [cm/100 years]	average subsidence
Quaternary		400	2	4 cm/100 years
	1.8			
Dacian - Rumanian		2250	6	
	5.2			
Pontian		500	3	
	7.0			
Pannonian		1600	4	
	10.5			

Because of poor exposures, sedimentary structures could not be examined, with scarce exceptions. - Brackish fauna was recorded in Pannonian sediments. Its amounts decrease with decreasing salinity. Lignite seams are associated with carbonized wood fragments, leaf impressions and fossil soils, In Quaternary sediments there are mammalian remains. The environment shows slow degradation from marine

DOI:https://doi.org/10.2312/zipe.1982.066

beds extending there partly in the Badenian, through brackish to lacustrine and fluvial environments.

Tectonic deformations in the lower part which does not belong to the basin proper (the basin is superposed on it), have a fault character (Badenian and Sarmatian). The basin proper has a brachysynclinal structure which is deformed by subsidiary small faults. Signs of uplifts of the basin surrounding area are missing in the basin facies depicted by the profile, but they can be found in marginal facies superposed on a former basin of the main molasse. There are conglomerates comparatively frequent indicating uplifts of the West Carpathians.

4.4. Conclusions

The Gabčíkovo Basin is a type of late molasse basin of the West Carpathians. It has many structural features in common with the Buda Paleogene basin. Following are its different characters:

- The basin arose in an excludingly continental environment.
- The Gabčíkovo Basin is a partial basin of a large (178 099 km^2) Pliocene basin of the Pannonian block. Thicknesses of filling are medium in comparison with molasse basins but in some periods an intensive subsidence (6 cm/100 years) was recorded.

References

ADAM, Z.; DLABAČ, M.: Nové poznatky o tektonice Podunajské nížiny.
Věst. ústř. Úst. geol., Praha 36 (1961), p. 3, p. 189-198

ADAM, Z.; DLABAČ, M.: Vysvětlivky k mapám mocnosti a litofaciálního vývoje Podunajské nížiny.
Sb. geol. Věd, Záp. Karpaty, Bratislava 11 (1969), p. 156-171

ANDRUSOV, D.: O vzniku vnitoralpské pánve vídeňské.
Příroda, Brno 30 (1937)

ANDRUSOV, D.: Karpathen Miozän und Wiener Becken.
Petroleum, Berlin 34 (1938), p. 2-9

BALOGH, K.; ÁRVA-SOÓS, E.; RAVASZ-BARANYAI, L.: Potassium-argon dating of Mesozoic and Tertiary volcanics in Hungary.
(in press)

BAGDASARJAN, G.P.; SLÁVIK, J.; VASS, D.: Chronostratigrafický a biostratigrafický vek niektorých významných neovulkanitov východného Slovenska.
Geol. Práce, Spr., Bratislava 55 (1971), p. 87-96

BERÁNEK, B.; ADAM, Z.: Některé výsledky geofyzikálního výzkumu v oblasti styku Českého masívu a Karpat.
Sb. geol. Věd, ústř. Úst. geol., Užitá geofyzika, Praha 13 (1975), p. 65-72

BUDAY, T.: Geologické poměry okolí Šah na jižním Slovensku.
Rozpr. Čs. Acad. Věd, tř. 2 math., Příroda, Praha 47 (1938) 17, p. 1-23

BUDAY, T.: Několik poznámek ke stratigrafii a paleogeografii tortonu v západních částech Dolnomoravského úvalu.
Věst. Stát. geol. Úst., Praha 21 (1946)

DOI:https://doi.org/10.2312/zipe.1982.066

BUDAY, T.: Stratigrafie spodního a středního miocénu hlavních oblastí Dolnomoravského úvalu.
Praha: MS Geofond 1955

BUDAY, T.: Der tektonische Werdegang der Neogenbecken.
Geol. Práce, Zoš., Bratislava 60 (1961), p. 87-106

BUDAY, T.: Vysvetlivky k prehl'adnej geologickej mape ČSSR 1:200 000, Čalovo.
Bratislava: Geofond redakcia 1962

BUDAY, T.; CAMBEL, B.; MAHEL', M. et al: Vysvetlivky k prehl'adnej geologickej mape ČSSR 1:200 000, Wien-Bratislava, p. 5-247.
Bratislava: Geofond - vydavatel'stvo 1962

BUDAY, T.; URBAN, K.: Přehled geologie Jihomoravského neogénu.
Zprávy Stat. geol. Úst., Praha 17 (1941)

BUDAY, T.; CICHA, I.: Neue Ansichten über die Stratigraphie des unteren und mittleren Miozäns des inneralpinen Wiener Beckens und des Waagtales.
Geol. Práce, Zoš., Bratislava 43 (1956)

BUDAY, T.; ŠPIČKA, V.: Vliv podloží na stavbu a vývoj mezihorských depresí se zřetelem k poměrům v Podunajské pánvi.
Sb. geol. Věd, rad ZK, Bratislava 7 (1967), p. 153-187

BUDAY, T.; CICHA, J.; SENEŠ, J.: Miozän der Westkarpaten.
Bratislava: Geol. Úst. D.Š. 1965

BUDAY, T.; MENČÍK, E.; ŠPIČKA, V.: Geology of the Basement of some West Carpathian Neogene Basins.
Geol. Práce, Spr., Bratislava 37 (1965)

BUDAY, T. et al: Vysvetlivky k prehl'adnej geologickej mape ČSSR 1:200 000, Gottwaldov, p. 238
Praha: Geofond 1963

BUDAY, T. et al: Regionální geologie ČSSR II, Zv. 2, p. 1-651
Praha: Ústř. Úst. geol., Academia Praha 1967

CICHA, I. et al: Biozonal division of the upper tertiary basins of the eastern Alpe and West Carpathians.
(in press)

ČECHOVIČ, V.: Geologia juhoslovenskej pánvy.
Geol. Práce, Zoš., Bratislava 33 (1952), p. 1-53

ČECHOVIČ, V. et al: Vysvetlivky k prehl'adnej geologickej mape 1:200 000, Trebišov, p. 1-80
Bratislava: Geofond, redakcia 1963

ČEPEK, L.: Tektonika komárenské kotliny a vývoj podélneho profilu čsl. Dunaje.
Sb. ústř. Úst. geol., Praha 12 (1938), p. 33-64

DICKINSON, W.R.: Relation of andesites, granites and derivative sandstones to arctrench tectonics.
Rev. Geophys. & Space Phys., Washington 8 (1970), p. 813-860

ĎURICA, D.; KALIČIAK, M.; KREUZER, H.; MÜLLER, P.; SLÁVIK, J.; TÖZSÉR, J.; VASS, D.: Sequence of volcanic events in eastern Slovakia in the light of recent radiometric age determination.
Vest. ústř. Úst. geol., Praha 53 (1978), p. 75-88

FUSÁN, C.; IBRMAJER, J.; PLANČÁR, J.; SLÁVIK, J.; SMÍŠEK, M.: Geologická stavba podložia zakrytých oblastí juznej časti vnútorných Zapadných Karpát.
Zb. geol., Věd, ZK, Bratislava 15 (1971), p. 1-173

GAŽA, B.: Výsledky naftového prieskumu kolárovskej kladnej gravimetrickej anomálie.
Mineralia Slovaca, Spišská Nová Ves 6 (1974) 1, p. 23-39

GAŽA, B.; BEINHAUEROVÁ, M.: Príspevok ku geologii Zlatomoravského zálivu.
Mineralia Slovaca, Spišská Nová Ves 8 (1976), p. 221-240

DOI:https://doi.org/10.2312/zipe.1982.066

GRECULA, P.; ROTH, Z.: Kinematický model Západních Karpat.
Sb. geol. Věd, Ústř. Úst. geol., Praha 32 (1978), p. 49-70

JANÁČEK, J.: Předběžné výsledky studia paleogeografie a tektogenese staršího miocénu oblasti Láb-Malacky.
Sb. Ústř. Úst. geol., Praha 21 (1954)

JANÁČEK, J.: Nové tektonická a tektogenetické paznatky československá části vnitroalpské pánve.
Sb. Ústř. Úst. geol., Praha 21 (1954)

JANÁČEK, J.: Stratigrafie, tektonika a paleogeografie neogenu východního Slovenska.
Geol. Práce, Zoš. Bratislava 52 (1959)

JANÁČEK, J.; KOCÁK, A.; MOŘKOVSKÝ, M.: Rozšířená a vývoj neogénu východoslovenské pánve.
Zb. geol. Věd, ZK, Bratislava 11 (1969), p. 201-222

JIŘÍČEK, R.: Problém hranice sarmat/panon vo viedenskej, podunajskej a východoslovenskej pánve.
Mineralia Slovaca, Bratislava - Spišská Nová Ves 4 (1972) 14, p. 39-82

KUTHAN, M. et al: Vysvetlivky k prehl'adnej geologickej mape M-34-XXII, Zvolen, p. 1-132
Bratislava: Geofond redakcia 1963

KVITKOVIČ, J.; PLANČÁR, J.: Analýza morfoštruktúr z hl'adiska súčastnych pohybových tendencií vo vzťahu k hlbinnej geologickej stavbe Západných Karpat.
Geograf. čas. Slov. Akad. Vied, Bratislava 27 (1975) 4, p. 309-325

MATĚJKA, A.; KODYM, O.: Zpráva o geologii flyše v jihozápadním konci Bílých Karpat.
Sb. Stat. geol. Úst., Praha 3 (1923)

MATĚJKA, A. et al: Vysvetlivky k prehl'adnej geologickej mape ČSSR 1:200 000, Zborov-Košice, p. 1-254
Bratislava: Geofond - vydavatel'stvo 1964

MAHEL', M. (Edit.): Tectonics of the Carpathian Balkan regions.
p. 1-453
Bratislava: Geol. Inst. D.Št. 1974

NEMEC, F.; KOCÁK, A.: Predneogenní podloží Slovenské části viedenské pánvy.
Mineralia Slovaca, Bratislava - Spišská Nová Ves 8 (1976), p. 481-555

NOSKY, E.: Das Cserhát-Gebirge. Geologische Beschreibung ungarischer Landschaften.
Magyar. Kir. földtani Intézet Kiadása, Budapest (1940), p. 1-283

ORLICKÝ, O.; PAGÁČ, P.; SLÁVIK, J.: Paleomagnetism of volcanic rocks in Vihorlat Mts. and its geological interpretation.
Geol. Zb., Geologica Carpathica, Bratislava 21 (1970) 1, p. 153-166

PAGÁČ, I.: Poznámky k vzniku akumulácií neuhlovodíkových plynov v Podunajskej pánve.
Geol. Práce, Zpr., Bratislava 40 (1966), p. 71-78

PÁVAI VAJNA, F.: Bericht über die geologischen Aufnahmen längs des Mittellaufes der Ipoly.
Magyar állami földtani Intézet évi Jelentése, Budapest 2 (1939-40)

POSPÍŠIL, P.; VASS, D.; MERIORIS, L.; REPKA, T.: Neotektonická stavba Žitného ostrova a pril'ahlého územia Podunajskej nížiny.
Mineralia Slovaca, Bratislava 10 (1978) 5, p. 443-456

RUDINEC, R.; SLÁVIK, J.: Fázy vrásnenia a paleogeografický vývoj neogénu východného Slovenska.
Geol. Práce, Spr., Bratislava 60 (1972), p. 225-236

RUDINEC, R.: Paleogeographical, lithofacial and tectonogenetic development of the Neogene in Eastern Slovakia and its relation to volcanism and deep tectonic.
Geol. Zb., Geologica Carpathica, Bratislava 29 (1978) 2, p. 225-240

SENEŠ, J.; ŠVAGROVSKÝ, J.: Neogén východného Slovenska.
Geol. Práce, Zoš., Bratislava 46 (1957), p. 217-280

DOI:https://doi.org/10.2312/zipe.1982.066

SENEŠ, J. et al: Vysvetlivky k prehl'adnej geologickej mape 1:200 000 Čierna, p. 81-110. Bratislava: Geofond, redakcia 1963

SCHAFFER, F.X.: Der sogenannte Schlier des alpinen Wiener Beckens. Verh. geol. A.-R., Wien (1927)

SCHEIBNER, E.: Explanatory notes on the Tectonic map of New South Wales, p. 1-283 Sydney: Geol. Surv. of N.S.W., 1976

SLÁVIK, J.: Zemplinikum - možná nová tektonicka jednotka centrálnych Karpát. Geol. Práce, Spr., Bratislava 65 (1976), p. 7-19

SLÁVIK, J.; TÖZSÉR, J.: Geological structure of the Prešovské pohorie Mts. and its relation to the boundary of the West and East Carpathians. Geol. Zb., Geologica Carpathica, Bratislava 24 (1973) 1, p. 23-52

SLÁVIK, J.; ČVERČKO, J.; RUDINEC, R.: Geology of Neogene volcanism in East Slovakia. Geol. Práce, Spr., Bratislava 44-45 (1968), p. 215-239

SLÁVIK, J.; BAGDASARJAN, G.P.; KALIČIAK, M.; TÖZSÉR, J.; ORLICKÝ, O.; VASS, D.: Radiometricheskie vozrasty vulkanicheskich porod Vigorlata i Slanskych gor. Mineralia Slovaca, Bratislava 8 (1976) 4, p. 319-334

STEGENA, L.; GÉCZY, B.; HORVÁTH, F.: Late Cenozoic evolution of the Pannonian Basin. Tectonophysics, Amsterdam 26 (1975), p. 71-90

ŠPIČKA, V.: Rozbor mocností, rozšíření a vývoje neogénu v oblasti Vídeňské pánve. Zb. geol. Věd, Záp. Karpaty, Bratislava 11 (1969), p. 128-155

ŠPIČKA, V.: Paleogeografie neogenu československých Západních Karpát. Sb. geol. Věd, Geologie, Bratislava 22 (1972), p. 65-116

URBAN, K.: Příspěvek k poznání hlubšího miocénu v okolí Hodonína. Sb. Stat. geol. Úst., Praha 13 (1946)

VASS, D.: Molasové pánvy a globálno-tektonický model Karpát. (Molasse basins and global tectonic model of Carpathian). Zbornik referatov vedeckej konferencie: Ceskoslovenská geologia a globálna tektonika, p. 111-117. Smolenice: Edicne stredisko Geol. Úst. D.Š. 1976

VASS, D.: Príbelské vrstvy, ich sedimentárne textúry a genéza. Západné Karpaty, Sér. Geologie 2, Bratislava (1977), p. 145-198

VASS, D.: Principles of subdivision and principal types of the West Carpathians molasse basins and depressions. Veröff. Zentralinst. Physik d. Erde, Potsdam 58 (1980), p. 155-175

VASS, D.; ELEČKO, M.: Tvar valúnov a genéza pozdišovskej štrkovej formácie. Mineralia Slovaca, Bratislava 9 (1977) 1, p. 43-65

VASS, D.; BAGDASARJAN, G.P.: A radiometric time-scale for Neogene in the Paratethys region. Amer. Assoc. Petr. Geol. Bull., Studies in Geology, Tulsa 6 (1978) p. 179-203

VASS, D.; BAGDASARJAN, G.P.; KONEČNÝ, V.: Determination of the absolute age of the West Carpathian Miocene. Földtani Közlöny, Budapest 101 (1971) 2-3, p. 321-327

VASS, D.; KONEČNÝ, V.; ŠEFARA, J.: Geologia Ipel'skej kotliny a Krupinskej vrchoviny. Bratislava: Geol. Inst. D.Št. 1979, p. 1-227

VASS, D.; TÖZSÉR, J.; BAGDASARJAN, G.P.; KALIČIAK, M.; ORLICKÝ, O.; ĎURICA, D.: Chronológia vulkanických udalostí na východnom Slovensku vo svetle izotopických a paleomagnetických výskumov. Geol. Práce, Spr., Bratislava 71 (1978), p. 77-88

VEIT, E.: Zur Stratigraphie des Miozäns des Wiener Beckens. Mitt. d. R.-A. f. Bodenf., Wien (1943)

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Explanatory Notes to Lithotectonic Molasse Profiles of the Carpathian Foredeep and in the Polish Part of the Western Carpathians (Comment to Annex 6 - 8)

by

NESTOR OSZCZYPKO[1]

1. Geographic and structural setting of molasse basins

The Carpathian Foredeep is the main area of occurrence of the Neogene molasses in the territory of Poland (Fig. 1). It represents a part of the extensive Carpathian foreland running from Vienna to Danube, in front of the Southern Carpathians. The Polish part of the foreland between Cieszyn and Przemyśl attains about 340 km in lenght. The generally accepted northern border of the Carpathian Foredeep runs along the outcrop area of the marine Miocene rocks in the Cracow Upland, the Miechów Upland, the Góry Świętokrzyskie Mts. and the Roztocze Range. The southern border has not been yet precisely delineated because it is deeply buried beneath the Carpathian Overthrust. Outside the Carpathians, the width of the Foredeep varies between 10 km and 15 km in the vicinity of Cracow, approaching 90 km at the meridian of Rzeszów (Fig. 1).

The Neogene molasses occur also in the Flysch Carpathians either in form of small erosion remnants or filling of intramontane depressions (the Orawa - Nowy Targ Basin, the Nowy Sacz Basin; Fig. 1). The molasse deposits are very poorly outcropped in the Carpathians as well as in the Foredeep, but their lithology, stratigraphy and lateral extent is relatively well recognized due to numerous deep drillings (over 2000 boreholes).

The Carpathian Foredeep originated at the junction between the platform consisting of pre-Baikalian, epi-Baikalian and epi-Variscan tectogenes and the Carpathian orogenes. On the basis of the general spatial relationships of the molasse deposits to these two

[1] Geological Institute, Carpathian Branch; Poland, 31-560 Kraków, ul. Skrzatów 1

DOI:https://doi.org/10.2312/zipe.1982.066

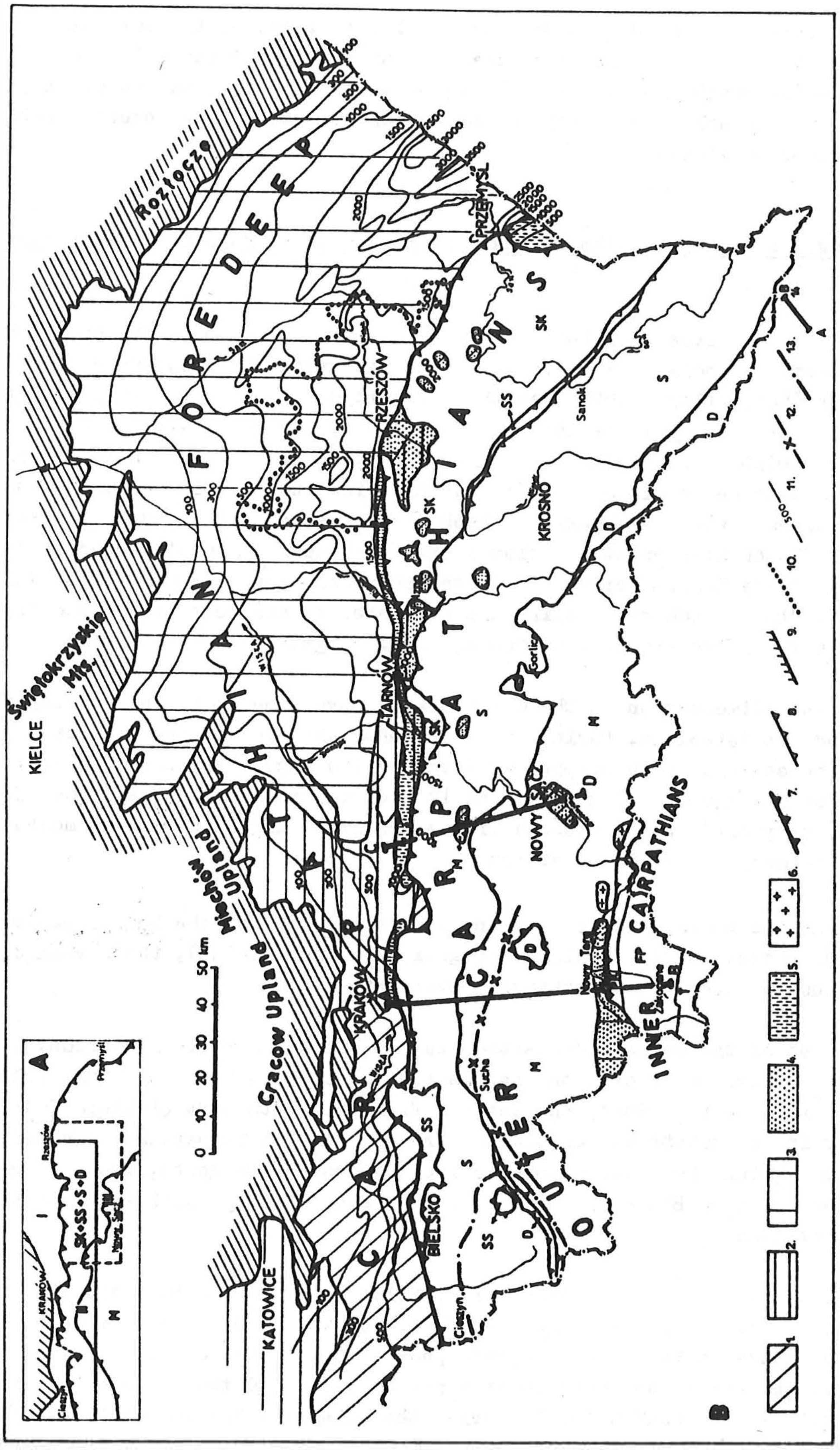
Fig. 1. A. Location map showing position of type profiles

I - outer part of the Carpathian Foredeep in the Cieszyn - Rzeszów area (Polish West Carpathians, Neogene), Annex 7; II - inner part of the Carpathian Foredeep in the Cieszyn - Rzeszów area (Polish West Carpathians, Neogene), Annex 6; III - Nowy Sącz and Rzeszów areas (Polish West Carpathians, Neogene), Annex 8. For explanation of additional symbols see Fig. 1 B

B. Distribution and thickness map for the Neogene molasses of the Carpathian Foredeep and Polish Western Carpathians, compiled on the basis of data from NEY et al. (1974), KSIĄŻKIEWICZ (1977) and from new deep-drillings

1 - Lower Badenian, 2 - Middle and Upper Badenian, 3 - Lower Sarmatian, 4 - Neogene in the Carpathians, 5 - folded Miocene in front of Carpathians, 6 - Neogene volcanics, 7 - Carpathian Overthrust, 8 - other important overthrusts, 9 - northern border of the Miocene marine deposits in the Carpathian Foredeep, 10 - areas lacking of Lower and Middle Badenian deposits ("Rzeszów Island"), 11 - thickness of Neogene deposits expressed in metres, 12 - supposed northern boundary of Lower Miocene deposits lying under the Carpathian Overthrust, 13 - areas devoid of Miocene deposits, below the Carpathian Overthrust, 14 - cross-section lines. Additional symbols: SK - Skole Unit, SS - Sub-Silesian Unit, S - Silesian Unit, D - Dukla Unit, Grybów Unit and Fore-Magura scales, M - Magura Unit, PK - Pieniny Klippen Belt, FP - Podhale Flysch, T - High Tatra Unit and Sub-Tatra units

DOI:https://doi.org/10.2312/zipe.1982.066



DOI:https://doi.org/10.2312/zipe.1982.066

geostructural units one can distinguish the following types of the molasses: (1) autochthonous molasses lying on the platform in front of the Carpathian Overthrust, (2) autochthonous and allochthonous molasses lying on the platform below the Overthrust and (3) parautochthonous molasses overlying the orogen and overthrust together with this onto the foreland molasses.

2. Geostructural evolution of the molasse basins and their relation to the adjoining areas

The origin of the Carpathian Foredeep bears a close relation to the evolution of the Outer Carpathian geosyncline. The geosyncline originated in the Jurassic time gradually becoming wider (KSIĄŻKIEWICZ 1977). At the Jurassic/Cretaceous transition the flysch sedimentation started to prevail there. The initially uniform basin was in the Albian and Cenomanian split by a cordillera into two troughs: southern and northern (KSIĄŻKIEWICZ 1956). The deposits of the future Skole, Sub-Silesian and Silesian Nappes accumulated in the northern trough, the axial part of which (Sub-Silesian unit) was characterized by generally non-flysch sedimentation (clayey and calcareous sediments). The deposits of the Magura and Dukla Nappes originated in the southern trough. According to KSIĄŻKIEWICZ (1977, p. 603) "the flysch geosyncline was alimented by sediments that came from the cordilleras in the interior and from the marginal ridges".

An intensive sedimentation in the Carpathian geosyncline took place during the Late Cretaceous and the Paleogene. During the Oligocene, the area of sedimentation gradually diminished. The sedimentation stopped at first in the Magura Basin whilst in the Skole Basin at the outer edge of the geosyncline it occurred for the longest time. The shortening of the geosyncline was connected with a northward migration of the movements, i.e. from the intersides towards the platform.

At first, at the Eocene/Oligocene transition the infill of the Magura Basin was folded. In the Late Oligocene and Early Miocene (Egerian - Eggenburgian), the flysch deposits were folded and reciprocally overthrust (Savian phase).

The main area of the molasse deposition was the platform which is divided into numerous structural units. The oldest one is the early Baikalian tectogene (the Małopolska Massif) adjoining the East-European Platform from the south-west (POŻARYSKI 1977). This massif occurs in the substratum of the eastern part of the Carpathian Foredeep. Towards the west this adjoins the Caledonian - Variscan units. These units, west of Cracow, pass into the Upper Silesian Basin filled up with molasse deposits which were derived from the Variscan orogene.

From the beginning of the Triassic till Tertiary, epicontinental deposits connected with numerous sea-level oscillations were formed on the Carpathian foreland (NEY 1968). In the Mesozoic, the early Alpine orogenic phases were marked on the foreland by vertical movements. The Lower San Anticlinorium was uplifted and the Miechów Synclinorium was formed at that time (JAWOR 1970). During the Paleogene the Carpathian foreland was being strongly denudated; this process, most intensely acting in the axial part of the Lower San Anticlinorium, gave rise to a complete removal of sedimentary cover down to

DOI:https://doi.org/10.2312/zipe.1982.066

the Precambrian rocks (KARNKOWSKI 1974). The clastic material derived from the eroded foreland was supplied to the Outer Carpathian geosyncline (KSIĄŻKIEWICZ 1962), chiefly to the sedimentary basin of the Skole unit.

Prior to the deposition of the Neogene molasses, the Carpathian foreland was levelled to a considerable degree and the existing elevations probably did not exceed 200 m in height (OSZCZYPKO and TOMAŠ 1976). The elevations were separated by flat lowlands gently inclined towards the margins of the flysch basin.

The Carpathian Foredeep began to form simultaneously with the folding and inversion of the Flysch Carpathians being filled up by products of erosion both derived from the uplifting mountains and from the platform. Initially, the Foredeep was created in the most marginal part of the geosyncline, at the junction with the platform. The deposits of the late-stage flysch sedimentation (the Polanica Beds of Oligocene age) were replaced there by sediments of the mixed flysch - molasse features (the Worotyszcze Beds of Egerian age), and the latter by a typical molasse (the Słoboda Conglomerate of Egerian to Eggenburgian age and the Stebnik Beds of Ottangian age). Such a transition between the flysch and molasse sedimentation are known only from the Borysław-Pokucie Folds in the Ukrainian Carpathians (BUROV et al. 1974). The transition between flysch and molasse rocks has not yet been recognized in the Polish sector of the Carpathian Foredeep, and is expected to be present probably far southward below the Carpathian Overthrust (ŻYTKO 1965; NEY 1968; WDOWIARZ 1976; OSZCZYPKO and ŚLĄCZKA (1980).

The data from hitherto known parts of the Foredeep show that the molasse deposits originated chiefly on the platform; marine incursions only rarely entered the folded Carpathians from the Foredeep. During the development of the Foredeep, the molasse depocentres migrated gradually northwards involving more and more extensive parts of the platform (NEY 1968; NEY et al. 1974; OSZCZYPKO and ŚLĄCZKA 1980). The northwards wandering of the molasse basin was associated with the overthrust movements of the Carpathians onto their foreland. These movements began at the Paleogene/Neogene transition and persisted in the Polish Carpathians till the early Sarmatian. Thus, a continous widening of the Foredeep towards the north was closely connected with a simultaneous diminishing of the southern sedimentary basins. Due to the thrust movements, the Flysch Carpathians covered most of their foredeep. The amplitude of the Carpathian Overthrust, defined on the basis of deep drillings, reaches 30 km at the meridian of Cracow (Fig. 2), although some facts indicate that it may attain 100 km (NEY 1976). According to estimations made by KSIĄŻKIEWICZ (1956) at the meridian of Cracow, the shortening of the Carpathians resulting from the fold and thrust movements is about 60 %.

Both in the territory of Poland and in the Ukrainian Carpathian foreland, the Carpathian Foredeep is commonly divided into two basins: the internal and the external ones (VIALOV 1965; NEY 1968; NEY et al. 1974). The Lower Miocene and Badenian molasses originated in the internal basin whereas those of the Lower Badenian and Sarmatian accumulated in the external basin. In the internal basin sedimentation began in the Eggenburgian. At that time, the deposits of the Worotyszcze Formation, developed partly in saline facies, were accumulated in this residual flysch basin which was situated along the border of the platform with the Ukrainian Carpathians. During the Ottnangian,

DOI:https://doi.org/10.2312/zipe.1982.066

the internal basin enlarged towards the west approaching the meridian of Limanowa and its axial part migrated northwards (NEY et al. 1974). At that time, the variegated deposits of the Stebnik Formation were accumulated and clastic material was supplied to the basin both from the platform and the Carpathian orogene. Allochthonous deposits of the Stebnik Formation, overthrust together with the flysch on younger Neogene sediments, are known from the vicinity of Przemyśl (NEY 1968). The autochthonous deposits of Ottnangian age, overlying the platform basement, have been recently encountered in the deep borehole Sucha IG-I (ŚLĄCZKA 1977). In the Karpatian the internal basin distinctly extended towards the north (NEY et al. 1974) and the marine embayment of the Ukrainian Carpathian foreland joined the sea of Moravia.

The sedimentation within the intramontane basins of the Carpathians started simultaneously with that of the foreland. The paleogeography of the Carpathian foreland underwent distinct changes in the early Badenian. At that time, the area of the molasse sedimentation enlarged over ten times which was caused by the extensive marine transgression that came both from the western Ukraine and Moravia (ALEXANDROWICZ 1963, 1965; NEY 1968; NEY et al. 1974). In the north, the transgression entered the Cracow and Miechów Uplands and the southern slopes of the Góry Świętokrzyskie Mts. (RADWAŃSKI 1968).

The external basin originated in the inundated part of the platform (NEY 1968). In the south (Fig. 3), the transgression encroached far upon the peneplainized Carpathians (ALEXANDROWICZ 1962, 1965; OSZCZYPKO 1973). In the middle Badenian the sedimentation was limited mainly to the outermost part of the Foredeep. Here, in the shallowing basin, the deposition of chemical sediments and the formation of the so-called Rzeszów island took place. At that time, the strongest subsidence of the basin floor occurred between Bochnia and Dębica somewhat north of the edge of the Carpathians. In the late Badenian the salinity of marine waters lowered and the transgression covered the Rzeszów island. During the early Sarmatian, the zone of maximum subsidence migrated northwards (POŁTOWICZ and STARCZEWSKA-POPOW 1974; NEY 1968) and the Foredeep broadened towards the north-east (Roztocze). The Sarmatian marine incursion entered the Carpathians only in the vicinity of Pilzno and Rzeszów. After the early Sarmatian, the sea retreated from the Carpathian foreland, shifting towards the south-east, and then, the denudation as well as the overthrusting of the Carpathians began.

The machanism of the overthrusting is still rather poorly understood. According to KSIĄŻKIEWICZ (1977), the flysch rocks were folded during the Early Miocene (Savian phase). In the Badenian and Sarmatian the folded flysch was "en bloc" displaced towards the north (Styrian phase). These movements ceased in the early Badenian in the area between Cieszyn and Cracow and still lasted after the early Sarmatian in the Rzeszów - Przemyśl area. An eastward migration of the orogenic movements was also suggested by ALEXANDROWICZ (1965) and WDOWIARZ (1976). OSZCZYPKO and ŚLĄCZKA (1980) consider that the overthrusting of the Carpathians was a continous process which caused the gradual diminishing of the molasse sedimentation area from the south. As is shown by reconstructions made by NEY (1968) for the eastern part of the foreland, the main phase of the overthrusting took place after the early Sarmatian.

DOI:https://doi.org/10.2312/zipe.1982.066

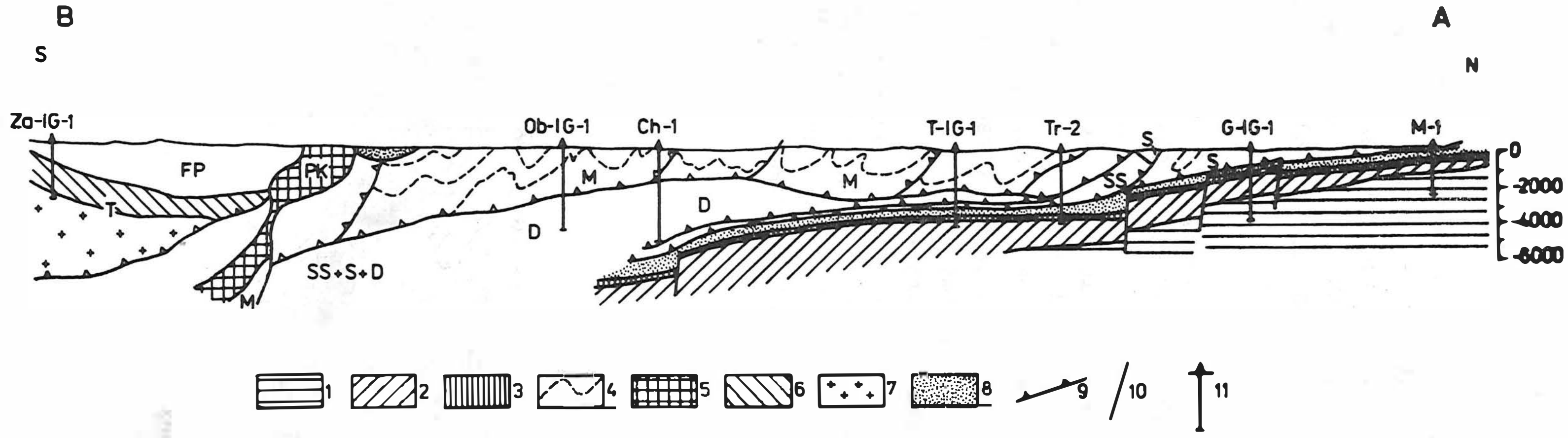


Fig. 2. Geological cross-section Kraków - Zakopane (after SIKORA, unpublished)

Platform: 1 - Cambrian, 2 - Middle Devonian - Lower Carboniferous; 3 - Upper Jurassic

Carpathian orogene: 4 - Cretaceous - Paleogene Flysch, 5 - Pieniny Klippen Belt, 6 - Sub-Tatra unit, 7 - High-Tatra unit, 8 - Neogene molasse of the Carpathian Foredeep and the Carpathians: 9 - overthrusts, 10 - faults, 11 - deep drilling. For additional explanations see Fig. 1B

DOI:https://doi.org/10.2312/zipe.1982.066

After the final shaping of the Carpathian Foredeep, the molasse sedimentation occurred in the Orawa-Nowy Targ Basin only, where continental, coarse clastics were accumulated.

The deposition of the molasse deposits in the Foredeep was not accompanied with large-scale, igneous processes. The only manifestations of volcanic activity is the presence of thin, rhyolite and dacite tuff layers found in the Badenian and Sarmatian deposits and small andesitic dykes that are present along the contact of the Outer Carpathians with the Pieniny Klippen Belt. According to BIRKENMAJER (1978), the origin of these dykes was connected with the Styrian orogenic phase.

The weak magmatic activity is related to the tectonics of the deeper parts of the Earth's crust. On the data from deep seismic soundings, SIKORA (1976) has distinguished in the lithosphere of the northern Carpathians three blocks differing in thickness of the crust. In the northern block (Metacarpathian block), where the Carpathian Foredeep was originated, the Moho discontinuity is situated at the depth ranging between 33 km and 52 km. In the middle block (Carpathian block) the Moho discountinuity has been detected at the depth of 35 - 65 km and in the southern one (Transcarpathian block) it is varying from 25 to 35 km. The Pericarpathian lineament separates the Metacarpathian and Carpathian blocks, while the border between the Carpathian block and the Transcarpathian blocks runs along the Peripieniny lineament. The lineaments began to form in the Oligocene and the main stage of their development is believed to have fallen in the Sarmatian and Pliocene. The volcanic activity in the Carpathians is considered to be connected with the Peripieniny lineament and the Transcarpathian block.

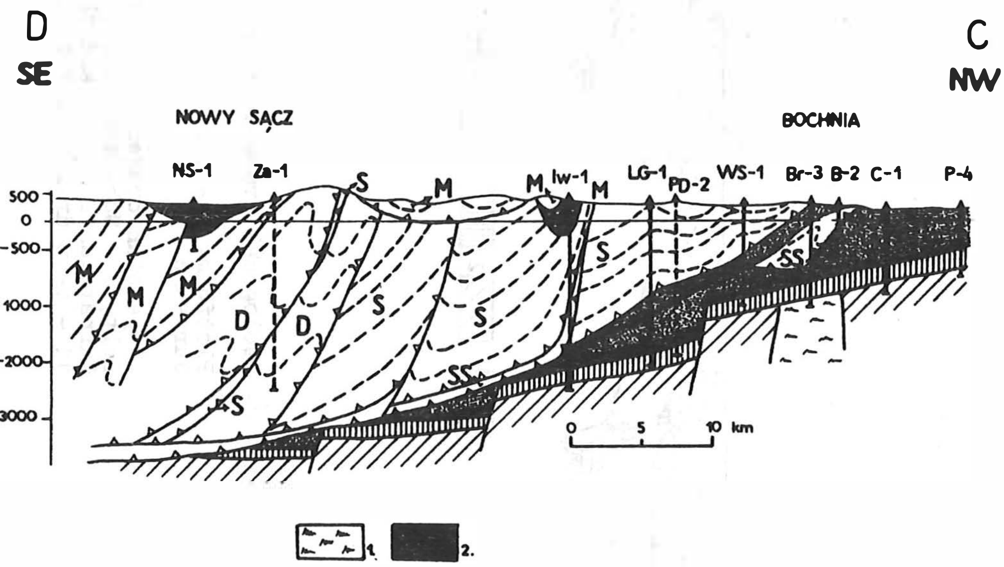


Fig. 3. Geological cross-section Nowy Sącz - Bochnia
1 - pre-Cambrian, 2 - Upper Cretaceous;
for additional explanations see Figs 1B and 2

DOI:https://doi.org/10.2312/zipe.1982.066

According to the plate tectonic view, the manifestations of the volcanic activity at the junction of the Outer and Inner Carpathians might have occured in response to the processes acting in the subduction zone which was running along the Pieniny Klippen Belt (NEY 1976; KSIĄŻKIEWICZ 1977).

3. General characteristics of the molasse basins

The Miocene deposits in the Polish part of the Carpathian Foredeep are of Eggenburgian to early Sarmatian age. The Lower Miocene deposits are hitherto known from the so-called Stebnik unit (NEY 1968), as well as from a few boreholes in the Carpathians (KUCIŃSKI et al. 1975; ŚLĄCZKA 1977). The only Badenian and Sarmatian deposits occur north of the Overthrust.

The lithostratigraphy of the Miocene deposits has been established in detail chiefly for the marginal part of the Foredeep. Distinguishing of lithostratigraphic units of its more internal parts, now buried beneath the flysch cover, is difficult because of rare core record and paucity of correlative lithologic horizons. For these reasons, the lithostratigraphic subdivision is ascertained there on the basis of electric-log correlations (JUCHA and WDOWIARZ 1974; POŁTOWICZ and STARCZEWSKA-POPOW 1974).

The lithostratigraphic scheme illustrated on Annex 6 - 8 is based on those by KUCIŃSKI (1971) and KRACH et al. (1971) and may be changed as a consequence of further works on the establishing of formal lithostratigraphic units.

The molasse of the Carpathian Foredeep consists of fine and coarse-grained clastic deposits with some admixture of pyroclastic rocks. Its overall thickness ranges up to more than 1000 m under the Carpathians, however, it was considerable reduced due to the overthrusting movements (WDOWIARZ 1976). As suggested NEY et al. (1974), the original thicknesses of the molasse deposits might have reached here 4000 - 4500 m.

In the external part of the Carpathian Foredeep, the thickness of the Miocene deposits ranges from a few tens of metres (in the more marginal part) up to 3500 m (in the southeastern part). Cyclic pattern of the sedimentation was hitherto encountered only in the chemical deposits (GARLICKI 1968). The molasse deposits of the Carpathian Foredeep originated mainly in a marine environment of variable salinity range. Deposition in continental condition took place chiefly during the Early Miocene, and later, continental deposits were incidentally laid down only in the marginal parts of the Foredeep.

For the Polish part of the Carpathian Foredeep three type profiles have been prepared: the first profile comprises the Miocene deposits lying under the Carpathian Overthrust (Annex 6), the second shows the Miocene deposits occurring in front of the Carpathians (Annex 7) and the third is representative of the Miocene overlying the folded Carpathians (Annex 8). These profiles are representative for the western and middle parts of the Carpathian Foredeep (up to Rzeszów in the east). The Lower Miocene deposits of the Stebnik Unit are intentionally not included on the drafts because they are best represented in the Ukrainian and Romanian Carpathians. A joint description of these profiles is given below.

DOI:https://doi.org/10.2312/zipe.1982.066

4. Description of the lithostratigraphic units

Sucha Formation

The formation was distinguished in the Sucha IG-I borehole (ŚLĄCZKA 1977), where it rests on the Upper Carboniferous rocks and is overlain by the Stryszawa Formation (Annex 6). The Sucha Formation consists of red and brown, non-calcareous shales, sandstones and rare conglomerate beds, that are separated by olisthostrome units. The sandstones are quartz-feldspathic arenites containing a small admixture of lithic fragments and muscovite. The olisthostromes are made up of flysch blocks up to several metres in size, which are dispersed in a clayey sand groundmass. The flysch blocks are chiefly represented by black and red shale (mainly of Paleocene age), with subordinate sandstones with anhydrite cement. The sandstone beds are commonly plane, parallel laminated or exhibit small-scale cross-lamination of wave origin. Mud cracks and bioturbation are also present. The thickness of the formation is up to 265 m, of which the olisthostrome units comprise 165 m.

The Sucha deposits were accumulated in a fluvial-lacustrine environment. The source area was situated in the south, close to the Carpathians. The distance over which the material was being transported probably did not exceed 10 km. The origin of the olisthostromes was related to the mass movements which at that time developed in the front the Carpathian orogene.

The formation described above is hitherto known only from the Sucha borehole (Fig. 1). Its probably lateral equivalent is the Stebnik Formation in the vicinity of Przemyśl (NEY 1968). The lower portion of the Stebnik Formation, up to 500 m thick, comprises thick-bedded sandstones consisting of quartz, limestone and green or red phyllite fragments. The upper portion, up to 700 m thick is represented by pink to brown, clayey-sandy deposits.

Stryszawa Formation

This formation was distinguished in the Sucha IG-I borehole (ŚLĄCZKA 1977), where it rests on the Sucha Formation and is overlain by the Skawina Formation (Annex 6). In the lower part of the Stryszawa Formation there occur polymictic conglomerates of the Stachorówka Member. The conglomerate clasts are poorly rounded and comprise limestones, dolomites, glauconite sandstones, cherts, siliceous marls and variegated shales. The sandstones consist of quartz, lithic fragments, feldspar and muscovite grains which are cemented by calcite or anhydrite. The conglomerates are overlain by olive to brown mudstones and calcareous shales containing locally thin, poorly consolidated sandstone and conglomerate interbeds. The thickness of the formation is 330 m, of which the conglomerates comprise 140 m.

The age of the above deposits is Karpatian and Ottnangian (zones: N 7 and N 8, CPN 4 and CPN 5) as indicated by the presence of Globoquadrina dehiscens and Globigerina bolli (STRZĘPKA 1977).

DOI:https://doi.org/10.2312/zipe.1982.066

The Stryszawa deposits were laid down at first in fluvial or deltaic environments and then in various subenvironments of the littoral zone. The clastic material was fed both from the platform (limestones and dolomites of Late Devonian age) and from the Carpathians. The deposition of the Stryszawa Formation was preceded by a period of intensive erosion.

The Stryszawa Formation may be correlated with the Balice Formation distinguished in the vicinity of Przemyśl (NEY 1968). This latter formation (up to 1000 m thick) consists of calcareous mudstones interlayered with sandstones, conglomerates and thin beds of epigenetic gypsum. The lateral equivalents of the Stryszawa rocks of the vicinity of Bielsko and from the Upper Silesia are dark-green, clayey-sandy deposits of the Bielsko Formation (KONIOR and KRACH 1965; KUCIŃSKI et al. 1975) and the Kłodnica Beds (ALEXANDROWICZ 1963, 1971), respectively.

Biegonice Formation

This formation has been distinguished by the present author in the Nowy Sącz Basin (Fig. 1 and 3). It rests with a distinct angular unconformity upon the flysch rocks and is overlain by the Skawina Formation (Annex 8). The Biegonice Formation exhibits a marked bipartition. Its lower part, up to 140 m thick, is dominated by mudstone/sandstone alternations. The sandstone interbeds range in thickness from a few centimetres up to 18.5 m. They are represented by poorly sorted, quartz-feldspathic arenites with some admixture of lithic fragments. In the bottommost part of the formation there occurs a flysch-rock bearing gravel bed 6 m thick. Within the muddy-sandy deposits OSZCZYPKO (1973) recognized an olisthostrome unit composed exclusively of flysch rocks.

The upper part of the formation (up to 400 m thick) is made up of clayey-sandy deposits containing numerous lignite beds. The claystones are dark-green, rarely brown or black in colour. Subordinately, there occur thin (from a few centimetres to a few metres) intercalations of fine-grained sandstones. Both mudstones and claystones contain numerous siderite and calcareous concretions. The thickness of the lignite beds commonly averages over a dozen centimetres exceptionally attaining 2 m. The sandstone interbeds commonly reveal plane, parallel lamination, and are rarely small-scale cross-laminated. In the upper portion of the formation, a few fining-upwards sequences (from a few to 2 m) have been recognized. The thickness of the Biegonice Formation varies between 540 and 600 m. Palynological evidence indicates its Karpatian age (OSZCZYPKO and STUCHLIK 1972).

The above deposits originated in fluvial and swamp environments in warm and wet climate. The Nowy Sącz Basin was fed from a local flysch basement, and sedimentation was accompanied with strong synsedimentary movements leading to the lowering of the axial part of the basin floor.

The equivalents of the Biegonice Formation occur in the vicinity of Grudna Dolna, south-east of Tarnów (Fig. 1) and in Upper Silesia (the Kłodnica Formation).

DOI:https://doi.org/10.2312/zipe.1982.066

Skawina Formation

The Skawina Formation was distinguished by ALEXANDROWICZ (1963). Under the Carpathian Overthrust, the formation rests on the Stryszawa Formation (Annex 6); in the Nowy Sącz Basin it overlies the Biegonice Formation (Annex 8) whereas in Upper Silesia it covers the Kłodnica Formation. For the most part of the Carpathian Foredeep and in the marginal parts of the Carpathians, the Skawina Formation lies transgressively directly upon the platform basement (Annex 7) or on the flysch. The formation ist overlain by the Bochnia Formation.

Under the Carpathian Overthrust, the Skawina Formation is represented by dark, clayey-sandy sediments which, in their bottommost part, contain locally coarse-grained deposits of the Dębowiec Conglomerate Member not exceeding 100 m in thickness. In the vicinity of Gdów, the clayey-sandy deposits enclose a huge complex of sands and gravels, which is more than 500 m thick (ALEXANDROWICZ 1965). Similar deposits, though of lesser thicknesses, are known from the vicinity of Spytkowice, west of Cracow.

Outside the Carpathians, the Skawina Formation consists of calcareous clays with thin interbeds of mudstones and sandstones. These lithologies are replaced, towards the north, by glauconitic marls and clays of the Baranów Beds which, in the northernmost part of the Foredeep, contain thin intercalation of the Lithotanmium limestone (ALEXANDROWICZ 1971; NEY 1968).

The fine-grained clastics of the Skawina Formation are commonly plane, parallel laminated; cross-stratification, graded bedding and convolutions are rare. On the sandstone soles, flute marks and load casts are sometimes found.

The thickness of the Skawina Formation is variable. Under the Carpathian Overthrust it reaches locally up to 1000 m, however, this figure is lowered due to the postdepositional tectonic reduction. Relatively large thickness (up to 1000 m) have been encountered in the western part (Fig. 1) of the Foredeep (NEY et al. 1974). In the remaining parts of the foreland, the thickness of the Skawina Formation rarely exceeds 30 – 40 m (Fig. 4), in the Carpathians it varies between 30 and 50 m in the Nowy Sącz Basin, reaching about 400 m in Iwkowa.

ALEXANDROWICZ (1963) distinguished in the Skawina Formation two microfaunistic zones IIA – IID corresponding to the Orbulina suturalis and Uvigerina costai zones (ŁUCZKOWSKA 1963). The Lower Badenian (Moravian) age of the formation is now accepted.

Sedimentation of the Skawina Formation was connected with the early Badenian transgression which was preceded by a period of erosion. The marine flood was gradually broadened towards the north and south where it encroached upon the Carpathians up to the meridian of Nowy Sącz. The Skawina deposits originated in shallow-neritic and littoral conditions. The depth of the basin might have exceeded 200 m in its axial part only. A marine bay in the Carpathians was joined with a series of brackish lagoons. The remaining part of the Carpathians constituted rather low land from where rivers entered the sea dropping their load in a form of subaqueous fans. The clastic material accumulated in a nearshore pile subjected from time to time to mass movements. In submarine channels coarse-grained sediments possessing an aspect of fluxoturbidites were

DOI:https://doi.org/10.2312/zipe.1982.066

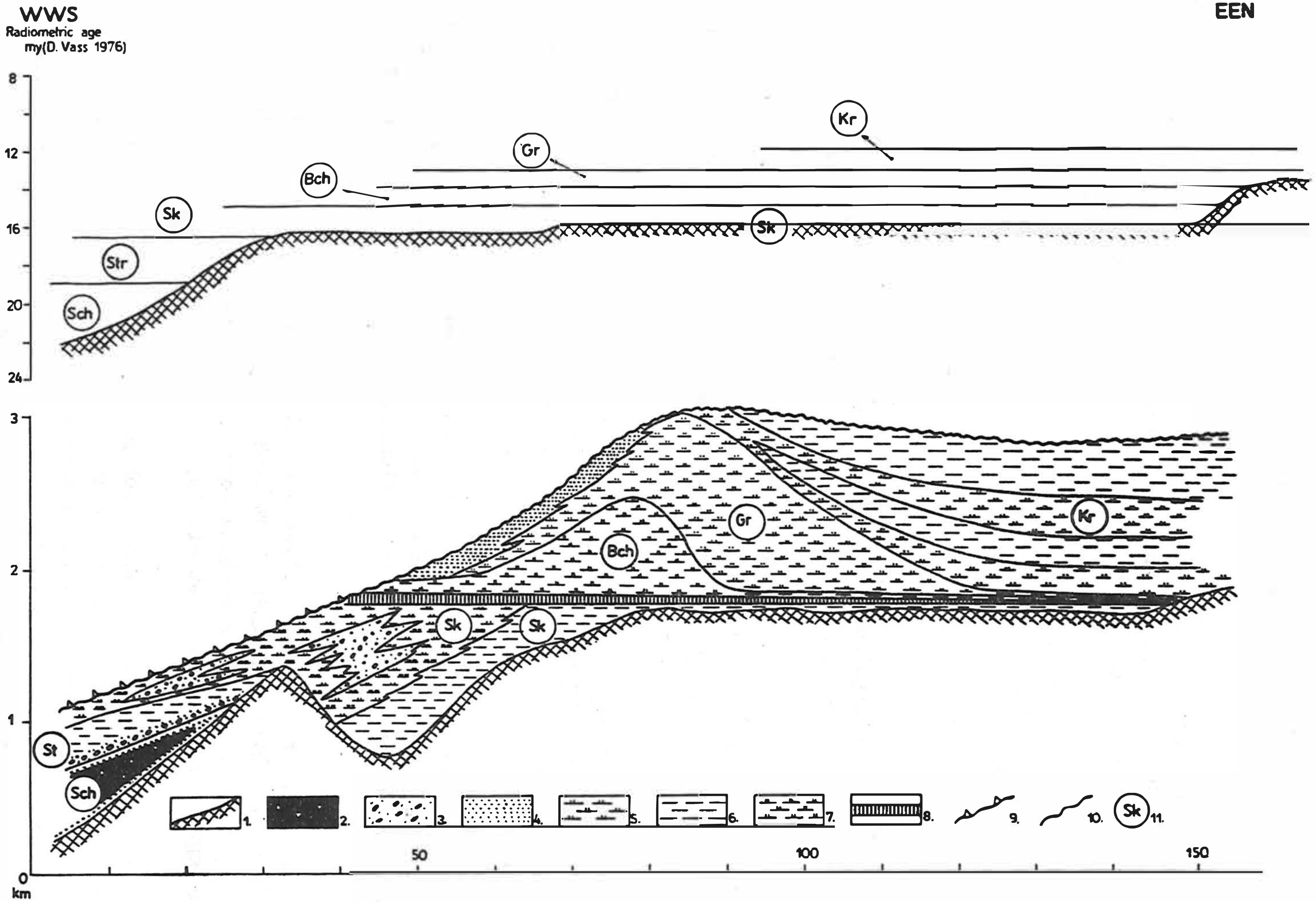


Fig. 4. Summary of the main trends showing migration of the depocentres in time and space within the Carpathian Foredeep (Sucha - Rzeszów area)

1 - platform basement, 2 - olistostromes, 3 - gravels and conglomerates, 4 - sand and sandstones, 5 - sandy-clayey deposits, 6 - clays, 7 - calcareous clays, 8 - chemical deposits, mainly anhydrites and gypsum, 9 - zones of tectonically reduced thickness, 10 - contemporary erosion surface, 11 - lithostratigraphic units: Sh - Sucha Formation, Str - Stryszawa Formation, Sk - Skawina Formation, Bh - Bochnia Formation, Gr - Grabowiec Formation, Kr - Krakowiec Formation

DOI:https://doi.org/10.2312/zipe.1982.066

deposited (Gdów, Bacharowice), whilst the basin plain was reached by more diluted turbidity flows from which fine-grained sandstone and siltstone beds of "distal turbidite" character originated. The early Badenian basin was also fed from the platform as is indicated by the clast composition of the Dębowiec Conglomerates which contain Devonian and Lower Carboniferous dolomite and limestone clasts as well as fragments of Upper Carboniferous coal (Annex 6). Sedimentation was associated with synsedimentary movements and volcanic activity in the Inner Carpathians.

The Skawina Formation is widely distributed in the Carpathian Foredeep and in the Carpathians. In the allochthonous Stebnik Unit the formation corresponds to the Przemyśl Beds composed of dark green mudstones interbedded with sandstones and conglomerates (NEY 1968). In the Nowy Sącz Basin, the lateral equivalent of the Skawina Formation is represented by Ceritia clays, muds and fine-grained sands whereas in the Rzeszów Bay it corresponds to the Lithotamnium limestones and clays.

Bochnia Formation

This formation has been distinguished by KUCIŃSKI (1971). It overlies the Skawina Formation or rests directly either upon the platform basement or on the flysch and is overlain by the Grabowiec Formation. Within the Bochnia Formation, the Wieliczka Member and the Chodenice Member are distinguished (Annex 6 and 7). The Wieliczka Member consists of rock salt, claystones, anhydritic mudstones, anhydrites, gypsum, limestones and marls. The Chodenice Member comprises clays with subordinate intercalations of sands. There occur also dolomitic marls and numerous tuffite beds.

The chemical deposits commonly display plane, parallel lamination, cross-lamination and convolute bedding. These structures are also widespread in the Chodenice Member. In the salt series GARLICKI (1968, 1979) has recognized five cyclothems, each of them up to 40 m in thickness.

The thickness of the salt deposits attains 110 m whilst that of gypsum and anhydrites varies commonly between 10 and 30 m (GARLICKI 1968). The Chodenice Member occurs only between Wieliczka and Dębica where its maximum thickness approaches 600 m (NEY et al. 1974).

The age of the formation has been established on microfauna found in the clayey-sandy deposits (III A assemblage, ALEXANDROWICZ 1958, 1963; assemblage with Neobulimina longa, ŁUCZKOWSKA 1963). Actually, the Bochnia Formation is considered to be of Middle Badenian age (ALEXANDROWICZ 1971; KRACH et al. 1971).

The sedimentation of the Bochnia Formation took place in hypersaline and euxinic conditions. GARLICKI (1979) believes that the basin formed a bay fed by marine waters from the south-west and south-east. The rock salt originated in its deepest part which was situated in the south, close to the border of the Carpathians. The area covered by rock salt accumulation comprised 1/18 part of the whole basin. At present, the rock salt occurs in a narrow zone along the border of the Carpathians and under the Carpathian Overthrust. Towards the north, the chloride facies is replaced by the sulphate

DOI:https://doi.org/10.2312/zipe.1982.066

one (anhydrites and gypsum) which now prevails in the Carpathian Foredeep. In the northern, marginal part of the Foredeep the gypsum is replaced by carbonate facies (GARLICKI 1971). In the zone of interfingering between gypsum and carbonates there occurs native sulphur within limestone, both being products of reduction of gypsum.

In the Carpathians, gypsum occurs in the vicinity of Rzeszów. Also, rock salt from the southern part of the Wieliczka-Bochnia mine area were formed on the flysch basement (POBORSKI and SKOCZYLAS-CISZEWSKA 1963). After the deposition of the Wieliczka Member the salinity in the basin diminished.

The Bochnia Formation originated in the basin of variable depth and in conditions of limited water circulation. The terrigenous input was low except in the southern part of the basin which was fed with detrital material from the Carpathians. The chemical sedimentation was controlled by synsedimentary movements.

Grabowice Formation

This formation rests either on the Bochnia Formation (Annex 7) or on the platform basement and is overlain by the Krakowiec Formation. In the south, the Grabowiec Formation consists of claystones interbedded with thin, fine to medium sandstone beds, which pass northerly into clays and muds of the Pecten Beds. In the vicinity of Cracow, sands and sandstones of the Bogucice Member are distinguished within the Grabowiec Formation. They are dark-yellowish, poorly sorted sands with thin lenses of fine gravels. Rarely, there occur mudstone and claystone interbeds up to a few metres in thickness. Towards the east (near Bochnia), the Bogucice Member is replaced by calcareous claystones and mudstones. Further east, clays with thin intercalations of fine sand and sandstone predominate. The Bogucice sands are cross-laminated and display also graded bedding (SKOCZYLAS-CISZEWSKA and KOLASA 1958).

For the most part of the Foredeep, the thickness of the Grabowiec Formation does not exceed 80 m, and only in the area between Tarnów and Rzeszów attains 1000 m (NEY et al. 1974).

On the basis of microfaunistic investigations of ALEXANDROWICZ (1958) and ŁUCZKOWSKA (1964), the Grabowiec Formation is believed to represent the upper Badenian.

The above deposits were accumulated in the neritic and littoral environments. At that time, the southern shore-line underwent periodic shifting (URBANIAK 1972). The salinity was much lower than that of the Bochnia time, and the basin had a partly brackish character which is indicated by the presence of Rotalia beccarii. The clastic material was derived both from the platform and from the Carpathians (SKOCZYLAS-CISZEWSKA and KOLASA 1958; POŁTOWICZ and STARCZEWSKA-POPOW 1974). According to OTFINOWSKI (1979) the Bogucice sands were deposited from proximal turbidity currents within a submarine fan whilst more clayey deposits of the north-east are interpreted as distal turbidites accumulated on the basin plain.

DOI:https://doi.org/10.2312/zipe.1982.066

The bulk of the Grabowiec Formation occours outside the Carpathian Overthrust. Its lateral equivalent of allochthonous Stebnik Unit is represented by the Radycz Conglomerates composed of flysch material (NEY 1968).

Krakowiec Formation

This formation overlies the Grabowiec Formation and its upper boundary makes the present-day topographic relief (Annex 8). The Krakowiec Formation is divided by KUCIŃSKI (1971) into the Jarosław Member and the Przeworsk Member. Other subdivision based on geophysical logs is employed by POŁTOWICZ and STARCZEWSKA-POPOW (1974). These authors have distinguished from the bottom: the I sandy complex "A", the clayey-silty complex "B", the II sandy complex "C", and the clayey-silty-sandy complex "D". In general, these are dark clay and claystones with beds of light grey sands and sandstones. On the data of POŁTOWICZ and STARCZEWSKA-POPOW (1974), the Krakowiec Formation can be divided into two, fining-upwards megacycles, each starting with a sandstone complex and capped by clayey complex.

The thickness of the particular complexes ranges from 100 to 1300 m. The entire thickness of the Krakowiec Formation increases rapidly towards the south-east attaining above 2400 m in the area between Rzeszów and Przemyśl (NEY et al. 1974).

ŁUCZKOWSKA has distinguished in the Krakowiec Formation several microfaunistic zones: the lower zone with Anomalinoides dividens and higher zones with Quinqueloculina karreri ovata, Quinqueloculina sarmatica and Elphidium hauerinum indicative of the Lower Sarmatian (Buhlovian and Volynian).

The Sarmatian deposits originated in the marine basin of low salinity within the littoral to neritic bathymetric range. According to KARNKOWSKI (1978), the basin was fed from the northwest by rivers that formed deltas at their mouths. On the basis of sand content data, POŁTOWICZ and STARCZEWSKA-POPOW (1974) believe that the lower part of the formation was fed from the Góry Świętokrzyskie Mts., whereas the upper one also from the Carpathians. The zone of maximum subsidence was situated at that time between Rzeszów and Przemyśl (Figs. 1 and 4).

In the northeastern, marginal part of the Foredeep (the Roztocze Range), the Krakowiec Formation is replaced by reef and detrital limestones (NEY 1968). Recently, continental Sarmatian deposits of fluvial origin have been recognized in the vicinity of Tarnów (DOKTOR 1977). They are exclusively composed of detritus derived from the Carpathians and reworked Badenian clastics.

5. State of deformation and tectonic position of the molasse deposits

As it was mentioned earlier, the molasses of the Carpathian Foredeep are grouped into large tectonic units. These are: (a) autochthonous Miocene, (b) folded Miocene and (c) Miocene overlying the flysch rocks. These units differ from each other either in the tectonic style or the state of deformation of the molasse deposits.

DOI:https://doi.org/10.2312/zipe.1982.066

The deposits of the autochthonous Miocene lying on different stratigraphic units of the platform basement occur both under the Carpathian Overthrust and in front of it, and span the stratigraphic interval between the Ottnangian and early Sarmatian. These deposits lie almost horizontally and are disturbed only by faults. The faulting occured during the northward migration of the molasse basins and, therefore, the faults are younger in the northern part of the Foredeep. Under the Carpathian Overthrust (Figs 2 and 3) the majority of the faults is older than the overthrust (WDOWIARZ 1976). North of the Carpathian Overthrust, some of the faults die out within the youngest deposits of the Krakowiec Formation (POŁTOWICZ and STARCZEWSKA-POPOW 1974). Most of the faults in the Foredeep developed along the older, partly Paleozoic dislocations.

The narrow zone of folded Miocene extending parallel to the Carpathians is overthrust onto the autochthonous Miocene. Within this zone, the Miocene deposits are often folded together with the flysch of the marginal part of the Carpathians. Within the folded Miocene KSIĄŻKIEWICZ (1977) has distinguished two units: the Stebnik Unit and the Badenian folds developed in the middle part of the Polish Carpathians (Fig. 1). In this interpretation, the Badenian folds represent a more external unit in relation to the Stebnik Unit. This latter unit consists of folded Lower Miocene and Badenian deposits that rest upon the flysch and are together with it overthrust onto the autochthonous Lower Sarmatian. Towards the east, the Stebnik Unit becomes considerably wider on the foreland of the Ukrainian Carpathians where it has been relatively well recognized (BUROV et al. 1974). Fragments of the Stebnik Unit have been encountered in a few boreholes located between Rzeszów and Dębica.

The Badenian folds are best developed between Wieliczka and Tarnów (Fig. 1). Between Wieliczka and Bochnia, the cores of the folds are made up of flysch rocks (Fig. 3), whilst in their limbs there occur deposits of the Skawina and Bochnia Formation (POBORSKI and SKOCZYLAS-CISZEWSKA 1963). A considerable distortion of these deposits was caused by plastic deformation of the rock salt (KSIĄŻKIEWICZ 1977). Both towards the west and east from the area mentioned above, the Badenian folds die out passing into a narrow zone of Miocene scales squeezed up between the autochthonous Miocene and the overthrust flysch rocks. Under the Carpathian Overthrust, the autochthonous Miocene deposits occur commonly in a residual form. The present-day distribution of the folded Miocene is probably a result of a mutual compensation of the flysch and Miocene deposits.

A different interpretation of the folded Miocene zone was proposed by NEY (1968), who included all the folded Miocene deposits present in front of the Carpathians into the Stebnik Unit. He believes that after the early Sarmatian the infill of the internal basin was thrust together with the flysch over the youngest deposits of the external basin.

The southermost tectonic element is represented by the Miocene deposits lying on the flysch and together with it overthrust either into the zone of folded Miocene or directly on the autochthonous Miocene. Here, the oldest deposits are represented by the Biegonice Formation (?Karpatian) and youngest is the Krakowiec Formation (lower Sarmatian). However, most often, the flysch is overlain by the Skawina Formation. In the Carpathians, the Miocene deposits rest upon the eroded flysch rocks. In the Nowy Sącz Basin, the Biegonice Formation commonly covers the tectonic contacts between the different tectono-facies zones of the Magura Nappe (OSZCZYPKO 1973).

DOI:https://doi.org/10.2312/zipe.1982.066

The Miocene deposits lying on the flysch show frequently a weak tectonic deformation. The strongest deformations affected those Miocene deposits which were accumulated in the more marginal parts of the Carpathians, and then, were involved in the overthrusting movements. These deposits constitute now the folded Miocene zone, discussed above.

6. Conclusions

1. The Miocene sedimentation began in the Carpathian Foredeep within the residual flysch basin which existed in the Early Miocene between the Carpathians and the East-European Platform. During the Neogene, the area covered by the molasse sedimentation gradually shifted northwards annexing more and more parts of the platform. The northwards wandering of the molasse basin was associated with the overthrusting of the Carpathians onto their foreland, which took place during the Early Miocene till the Sarmatian. In the Foredeep, the marine sedimentation prevailed and continental deposits originated only during the earliest Miocene.

2. In the Polish part of the Foredeep, a main phase of molasse accumulation occured in the Badenian and early Sarmatian. The sedimentation took place chiefly on the platform and appeared episodically in the Carpathians. Here, the molasse deposits filled rare intramontane basins and some parts of the foreland which were affected by marine ingressions coming from the Carpathian Foredeep. A typical example of intramontane basin is the Orawa - Nowy Targ Basin where subsidence was conditioned by the deep lineament separating the Outer and Inner Carpathians (BIRKENMAJER 1978). In this basin, lacustrine and fluvial sediments originated, and sedimentation began with the Styrian orogenic movements, survived here till the Early Pleistocene. In the Nowy Sącz Basin sedimentation started in the Karpatian, after the Savian phase, Initially, lacustrine and fluvial sediments were deposited and then shallow-marine ones.

3. The limited development of the Carpathian intramontane basins was probably caused by the predominance of uplifting movements during the Badenian and Sarmatian. Stronger subsidiary movements affected at that time only a zone of the Pieniny lineament and the Nowy Sącz Basin. The uplifted Carpathians were intensely eroded and delivered clastic material into the foredeep.

4. The molasse deposits of the intramontane basins were accumulated after the folding and the formation of more important overthrust. The molasse sedimentation was associated with residual movements and vertical movements, mainly the uplifting ones. The molasses have a parautochthonous character because they are overthrust together with the flysch into their lateral equivalents occuring in the Carpathian Foredeep.

5. In the Carpathian Foredeep, the molasse sedimentation was contemporaneous both with the folding of the marginal parts of the Carpathians and with the overthrusting movements towards the platform. As a result, fragments of the Neogene cover from the southern part of the Foredeep were detached from the basement, folded with the flysch and next displaced far northwards. The autochthonous molasse which occurs both under the Carpathian Overthrust and below the allochthonous Miocene as well as that lying outside the Carpathians, is weakly disturbed.

DOI:https://doi.org/10.2312/zipe.1982.066

6. Considering the spatial/temporal relationships of molasses to the fold and thrust movements, the molasses of the intramontane basins can be acknowledged as "late" (in sense of BUBNOFF 1956) whilst those of the Foredeep as "main", or eventually "late".

7. The sedimentary and tectonic processes described above were accompanied with a weak volcanic activity. In the Polish Carpathians the only known volcanic centre occured at the Peripieniny lineament (BIRKENMAJER 1978), where also a supposed subduction zone might have existed (NEY 1976; TOKARSKI 1978).

Acknowledgment

This paper was prepared in Geological Institute with cooperation to the Polish Academy of Sciences. I am extremely grateful to Prof. dr. hab. J. MALINOWSKI, Director of Geological Institute, for permission to publish this manuscript.

References

ALEXANDROWICZ, S.W.: Outline of Microfaunistic Stratigraphy of the Silesian-Cracowian Miocene (English summ.).
Kwart. geol., Warszawa 2 (1958) 1, p. 54-77

ALEXANDROWICZ, S.W.: Microfauna and stratigraphical position of Miocene clays from Iwkowa and Żegocina (Western Carpathians).
Bull. Acad. pol. Sci., Sér. Sci. geol. geogr., Warszawa 10 (1962), p. 161-166

ALEXANDROWICZ, S.W.: Stratigraphy of Miocene deposits in the Upper Silesian Basin (English summ.).
Prace Inst. geol., Warszawa 39 (1963), p. 130

ALEXANDROWICZ, S.W.: La molasse miocène aux environs de Gdów.
Bull. Acad. pol. Sci., Sér. Sci. geol. geogr., Warszawa 13 (1965), p. 49-57

ALEXANDROWICZ, S.W.: Regional stratigraphy of the Miocene in the Polish part of the Fore-Carpathian Trough.
Acta geol. Acad. Sci. hung., Budapest 15 (1971), p. 49-61

BIRKENMAJER, K.: Neogene to early Pleistocene subsidence close to Pieniny Klippen Belt, Polish Carpathians.
Studia geomorph. Carpatho-Balcanica, Kraków 12 (1978), p. 17-28

BUROV, V.S.; GLUŠKO, V.V.; DOLENKO, G.N.: Foredeep of the East Carpathians. In: MAHEL', M. (Edit.), Tectonics of the Carpathian-Balkan Regions, p. 217-220.
Bratislava: Geol. Inst. D. Št. 1974

DOKTOR, M.: Sandy gravels of Miocene age from Łeki Dolne (English summ.).
Rocz. pol. Tow. geol., Warszawa-Kraków 47 (1977) 3, p. 419-447

GARLICKI, A.: Autochtonous Salt Series in the Miocene of the Carpathian Foredeep between Skawina and Tarnów (English summ.).
Biul. Inst. geol., Warszawa 215 (1968), p. 7-77

GARLICKI, A.: Facial map of the Tortonian evaporite horizont in Poland.
Acta geol. Acad. Sci. hung., Budapest 13 (1971), p. 111-115

GARLICKI, A.: Sedimentation of Miocene Salts in Poland.
Prace geol. Kom. Nauk geol. pol. AN, Oddz. w Krakowie, Wrocław-Kraków 119 (1979), p. 67

DOI:https://doi.org/10.2312/zipe.1982.066

JAWOR, E.: The structure of the deep substratum in the region east of Cracov (English summ.).
Acta geol. pol., Warszawa 20 (1970) 4, p. 709-765

JUCHA, S.; WDOWIARZ, S.: Correlation lithostratigraphique des dépots miocénes dans la depression préoarpatique en Pologne.
Proceed. 10th Congr. Carp.-Balk. Geol. Ass., Stratigraphy and Paleontology.
Bratislava: Geol. Úst. D. Št. 1974

KARNKOWSKI, P.: Zapadlisko przedkarpaoki - Część wsohodnia (na wschód od Krakowa).
In: POŻARYSKI, W. (Edit.) Budowa Geologiczna Polski, t. IV, Tektonika, cz. 1, Niż Polski, p. 402-416
Warszawa: Inst. Geol. 1974

KARNKOWSKI, P.: Miocene paleodelta of the Carpathian Foreland (English summ.).
Przeglad geol., Warszawa 11 (1978), p. 625-629

KARNKOWSKI, P.; CIŁTUSZYK, S.: Geological atlas of the Polish Carpathian Foreland, 1 : 500 000.
Warszawa: Inst. Geol. 1968

KRACH, W.; KUCIŃSKI, T.; ŁUSZCZOWSKA, W.: Neue Grundlagen der Stratigraphie des Miozäns in Polen.
Földtani Közlöny, Budapest 101 (1971), p. 234-239

KONIOR, K.; KRACH, W.: On the Dębowiec conglomerates and the miocene fauna from bore-hole B 4 near Bielsko (English summ.).
Acta geol. pol., Warszawa 15 (1965) 1, p. 39-80

KSIĄŻKIEWICZ, M.: Geology of the Northern Carpathians.
Geol. Rdsch., Stuttgart 45 (1956) 2, p. 369-411

KSIĄŻKIEWICZ, M.: The tectonics of the Carpathians. In: POŻARYSKI, W. (Edit.), Geology of Poland, vol. IV-Tectonics, p. 476-620 Warszawa: Inst. Geol. 1977

KSIĄŻKIEWICZ, M.: (Edit.) Geological Atlas of Poland. Stratigraphio and facial problems. 13 Cretaceous and Older Tertiary of External Carpathians.
Warszawa: Geol. Inst. 1962

KUCIŃSKI, T.: Korelacja ramova utworów badenianu w Polsoe i na Ukrainie Zachodniej.
Spraw. z Pos. Kom. Nauk pol. AN, Oddz. w Krakowie, Kraków 14 (1971) 2, p. 641-644

KUCIŃSKI, T.; NOWAK, W.A.; SZOTOWA, W.: Problem stratygrafii utworów mioceńskich w otworze Bielsko 4 /B4/ i Kety 2 /K2/.
Kwart. geol., Warszawa 19 (1975) 4, p. 963-964

ŁUCZKOWSKA, E.: Foraminiferal zones in the Miocene, South of the Holly Cross Mts.
Bull. Acad. pol. Sci., Sér. geol. geogr., Warszawa 11 (1963) p. 29-34

ŁUCZKOWSKA, E.: The Micropaleontological Stratigraphy of the Miocene in the Region of Tarnobrzeg-Chmielnik (English summ.).
Prace geol. Kom. Nauk geol. pol. AN, Oddz. w Krakowie, Warszawa 20 (1964), p. 71

NEY, R.: The Role of the "Cracov Bolt" in the geological history of the Carpathian Foredeep and in distribution of oil and gas deposits (English summ.).
Prace geol. Kom. Nauk geol. pol. AN, Oddz. w Krakowie, Warszawa 45 (1968), p. 82

NEY, R.: The Carpathians and Plate Tectonics.
Przeglad geol., Warszawa 6 (1976), p. 309-316

NEY, R.; BURZEWSKI, W.; BACHLEDA, T.; GÓRECKI, W.; JAKÓBCZAK, K.; SŁUPCZYŃSKI, K.: Outline of paleogeography and evolution of lithology and facies of Miocene layers on the Carpathian Foredeep (English summ.).
Prace geol. Kom. Nauk geol. pol. AN, Oddz. w Krakowie, Warszawa 82 (1974), p. 65

OSZCZYPKO, N.: The geology of the Nowy Sącz Basin (The Middle Carpathians) (English summ.).
Biul. Inst. geol., Warszawa 271 (1973), p. 101-197

OSZCZYPKO, N.; STUCHLIK, L.: The fresh-water Miocene of the Nowy Sącz Basin, Results of geological and palynological investigations (English summ.).
Acta Paleobotanica, Kraków 13 (1972), p. 137-156

DOI:https://doi.org/10.2312/zipe.1982.066

OSZCZYPKO, N.; TOMÁS, A.: Pre-Tortonian relief of the Carpathian Foreland between Kraków and Dębica and its effect on Miocene sedimentation (English summ.).
Rocz. pol. Tow. geol., Kraków 46 (1976) 4, p. 525-548

OSZCZYPKO, N.; ŚLĄCZKA, A.: Relation between flysch and molasse in the Northern Carpathians.
Veröff. Zentral-Inst. Physik Erde, Potsdam (1980) 58, p. 209-220

OTFINOWSKI, M.: In: Guide to excursions. Working Group 3.3. Meeting in Poland.
Kraków 1979

POBORSKI, J.; SKOCZYLAS-CISZEWSKA, K.: Miocene in the Zone of the Carpathian Overthrust in the Area of Wieliczka i Bochnia (English summ.).
Rocz. pol. Tow. geol., Kraków 33 (1963) 3, p. 339-348

POŁTOWICZ, S.; STARCZEWSKA-POPOW, A.: The development of the Carpathian Foredeep between Tarnów and Przemyśl, Polish eastern Carpathian (English summ.).
Rocz. pol. Tow. geol., Kraków 48 (1974) 4, p. 495-516

POŻARYSKI, W.: The tectonic units of Poland. In: POŻARYSKI, W. (Edit.): Geology of Poland, Vol. IV - Tectonics, p. 50-57
Warszawa: Geol. Inst. 1977

RADWAŃSKI, A.: Lower Tortonian transgression onto the Miechów and Cracow Uplands (English summ.).
Acta geol. pol., Warszawa 18 (1968) 2, p. 387-446

SIKORA, W.: On lineaments found in the Carpathians.
Rocz. pol. Tow. geol., Kraków 46 (1976) 1-2, p. 3-30

SKOCZYLAS-CISZEWSKA, K.; KOLASA, M.: The Bogucice sands, Cracov area (English summ.).
Rocz. pol. Tow. geol., Kraków 28 (1958) 3, p. 285-314

ŚLĄCZKA, A.: Rozwój osadów miocenu z otworu wiertniczego Sucha IG-1.
Kwart. geol., Warszawa 21 (1977) 2, p. 404-405

STRZĘPKA, J.: Wyniki badań mikrofauny mioceńskiej z otworu wiertniczego Sucha IG-1.
Kwart. geol., Warszawa 21 (1977) 2, p. 405-406

TOKARSKI, A.K.: Orogenesis and morphogenesis of outer Carpathians and plate tectonics.
Stud. Geomorph. Carpatho-Balcan, Kraków 12 (1978), p. 29-43

URBANIAK, J.: Preliminary results of geological research of the Fore-Carpathian Miocene on Dunajec (English summ.).
Kwart. geol., Warszawa 16 (1972) 2, p. 347-359

VIALOV, O.S.: Stratigrafija neogenovych molass Priedkarpatskovo Progiba.
Kijev: Naukova Dumka 1965

WDOWIARZ, S.: On the relation of the Carpathians to the Carpathian Foredeep in Poland (English summ.).
Przeglad geol., Warszawa 6 (1976), p. 350-357

ŻYTKO, K.: Sur le rapport de la formation du petrole et l'orogenese des Karpates.
Reports of the VII Congr. Carp.-Balk. Geol. Ass., Part IV, p. 75-81
Sofia 1965

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Explanatory Notes to Lithotectonic Profiles of Miocene Molasses from Central Moldavia (Eastern Carpathians, Romania) (Comment to Annex 9 - 12)

by

MIHAI MICU[1]

The Miocene molasses of the Central Moldavia are developed in the outermost overthrusted units of the Eastern Carpathians (Fig. 1), the Marginal Folds Unit and the Subcarpathian Unit respectively. Representing pre-tectogenetic molasses in respect of the age of overthrusting, the Lower and Middle Miocene deposits situated west of the Pericarpathian Line - the front of the outermost and youngermost Carpathian overthrusting - overlie in both nappes Paleogene deposits developed in a flysch and bituminous facies.

The selection of the type-profiles of Miocene molasses in this area (Annex 9 - 12) takes into account both the intricacy of the structure and the lithological diversity of these deposits as well. On the other hand, the integrated analysis of the problems concerning the paleogeography of the Lower and Middle Miocene molasses of the Eastern Carpathians have imposed the comments on all type-profiles from Central Moldavia in a singular paper, in order to simplify the descriptions and eliminate unwelcome repetitions.

1. Miocene molasses of the Bistriţa Half-Window (Marginal Folds Unit)

In the Bistriţa Half-Window, the Miocene deposits in molassic facies overlie formations developed in a bituminous facies generally characterizing the Oligocene of the external zone of the Eastern Carpathians Flysch (Fig. 2). In the northern part of the Bistriţa Half-Window the molassic sedimentation begins practically since Oligocene as a green, sandy-conglomeratic facies, longitudinally and transversally interfingered with the bituminous facies with Kliwa sandstone.

[1] Institute of Geology and Geophysics; Romania, 78344 Bucharest, str. Caransebes 1

DOI:https://doi.org/10.2312/zipe.1982.066

G u r a Ş o i m u l u i B e d s were first separated by STOICA (1953) in the Tazlău Basin. A detailed study of these deposits is due to MIRĂUŢA (1969) who pointed out their lithological transition from a western flysch-like facies to an eastern, conglomeratic facies. In the internal (western) facies the Gura Şoimului Beds are constituted of an alternation of calcareous-muscovitic sandstones, quartzitic sandstones, grey marls and siltstones and, in places, bituminous marls and shales. In the external (eastern) facies, microconglomerates and conglomerates containing mostly greenschists elements also have intercalation of bituminous shales.

Calcareous nannoplankton of the Gura Şoimului Beds is represented by a Lower Miocene assemblage (Sphenolithus belemnos, Helicopontosphaera kamptneri etc.) associated with species continuing their evolution from the Oligocene (MICU and GHEŢA, unpublished data).

T e r m i n a l M e n i l i t e H o r i z o n was pointed out on certain profiles especially in the southern part of the Bistriţa Half-Window. Practically representing the last sequence of the bituminous facies this horizon (only several metres in thickness) is made-up of menilites (siliceous rocks of "chert"-type impregnated with bituminous matter) and thin bituminous shales.

The S a l t F o r m a t i o n overlies the Gura Şoimului Beds or the Terminal Menilite Horizon and consists generally of argillaceous breccia, gypsiferous clays, salt and potash salts. Breccias often contain pebbles of greenschists (Precambrian), Jurassic and Eocene fossiliferous limestones derived from the foreland, fragments of grey marls and sandstones, gypsum etc.

The Salt Formation has an almost continuous development in the frontal part of the Marginal Folds Unit, in places displaying a conspicuous diapir character. The accumulations of salt and potash salts have been identified at several levels by drillings and mine workings between Tazlău and Bălţăteşti. On certain profiles the upper part of the Salt Formation is well-bedded, micaceous grey sandstones with different mechanoglyphs at their lower surface occuring in association with grey clays.

Near Bălţăteşti, within the Salt Formation, COROBEA et al. (1975) pointed out a Lower Miocene foram assemblage belonging to the Globigerinoides primordius zone.

The C o n d o r S a n d s t o n e represents a well-individualized lithologically horizon overlying the Salt Formation, mainly constituted of arkosian sandstones stratified as thick layers interbedded with grey marls and clays, with a thickness usually not exceeding 30 - 40 m. This horizon shows an obvious tendency of thinning from the Tazlău Valley to the north; in this situation it is quite difficult to separate the horizon as such.

In the Bistriţa Half-Window the molassic deposits situated between the Salt Formation and the Grey Formation belongs to two synchronous heteropical lithofacies: Hîrja lithofacies, red coloured, and Almaşu lithofacies respectively, a gritty-conglomeratic, green-coloured lithofacies.

DOI:https://doi.org/10.2312/zipe.1982.066

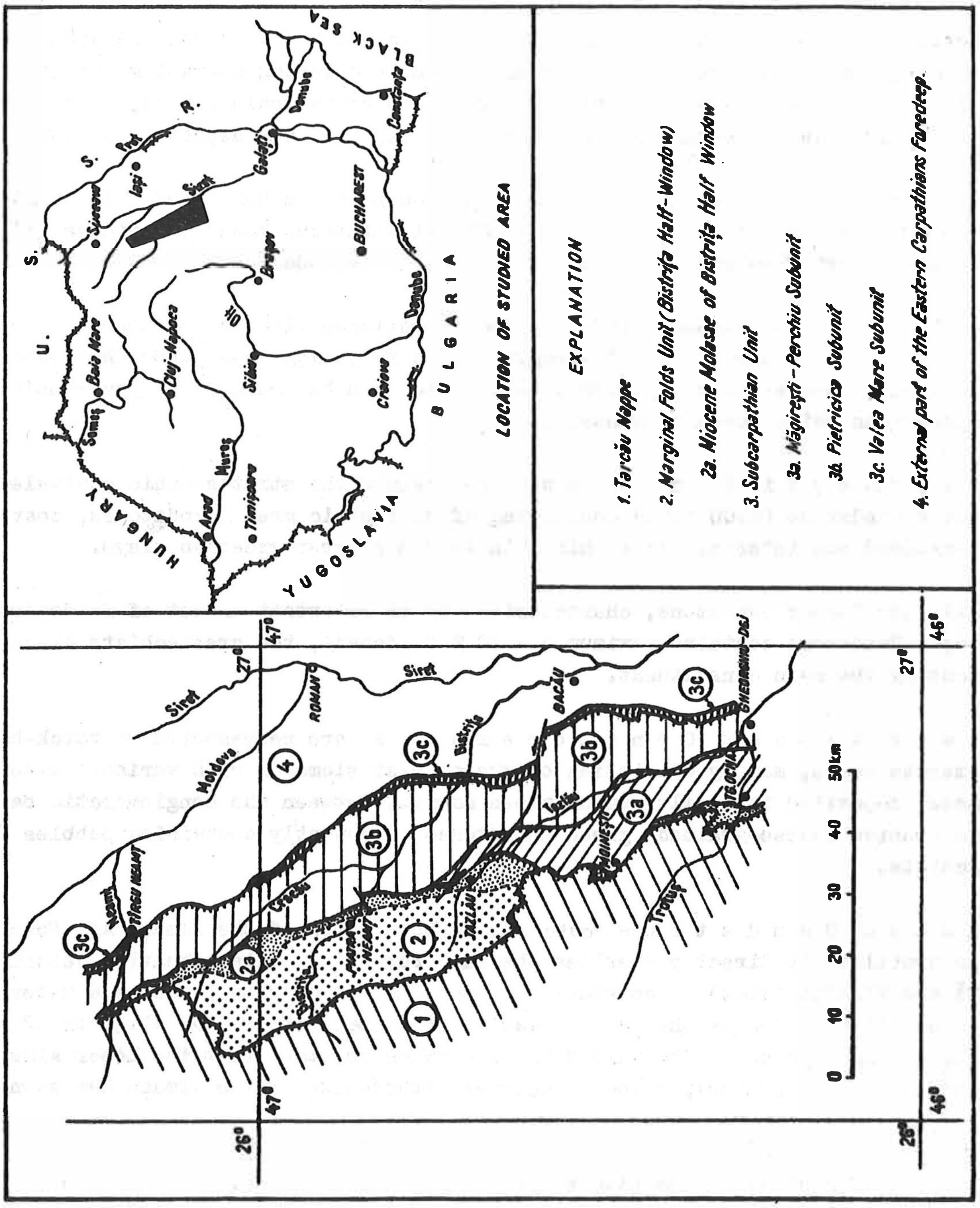


Fig.1. Tectonic Sketch-Map of Central Moldavia

DOI:https://doi.org/10.2312/zipe.1982.066

H î r j a B e d s follow in continuity of sedimentation the Condor Sandstone. Lithologically they are similar to the Măgirești Beds of the Subcarpathian Unit, being represented by an alternation of calcareous sandstones, red-violaceous and grey-greenish marls and siltstones.

Sandstones, fine- to medium-grained, are sometimes graded-bedded, microconglomeratic at the base, containing fragments of greenschists, and having current markings of various types in the lower part. The presence of ripple marks, rain prints, foot prints of birds and mammalians on sandstones indicates low depth of the depositional environment.

Almașu lithofacies is situated in the NE of the Bistrița Half-Window in the Almașu Antiform and its northern prolongation Bălțătești Antiform. These structures represent the eastern, overturned and reversed limb of the Horaița-Doamna Anticline.

The lithologic separations within the above-mentioned lithofacies seem to represent rather facial variations of a sandy-conglomeratic formation than proper horizons. In certain areas, however, a stratigraphic succession can be traced, the superposition of the separations being somehow constant.

B ă l ț ă t e ș t i S a n d s t o n e represents the stratigraphic equivalent of the Condor Sandstone (MICU 1976) consisting of decimetric green sandstones, coarse- to medium-grained and intercalated within thin layers of grey-greenish clays.

Unlike the Condor Sandstone, characterized by an important amount of feldspars, the Bălțătești Sandstone contains maximum 5 - 10 % feldspars, the greenschists elements representing the main constituent.

L o w e r A l m a ș u C o n g l o m e r a t e s are represented by thick-bedded conglomerate banks, mainly consisting of greenschist elements with variable sizes and roundness, deposited in a silty-sandy green matrix. Between the conglomeratic banks one can observe coarse-grained, green sandstones, frequently containing pebbles of greenschists.

A l m a ș u S a n d s t o n e outcrops on both limbs of the Almașu Antiform. On certain profiles, it directly overlies the Salt Formation. This situation determined MIRĂUȚĂ and MIRĂUȚĂ (1964) to consider the Lower Almașu Conglomerates as a heteropic, isochronous lithofacies of the Salt Formation or of part of it. The ubiquity of the Bălțătești Sandstone above the Salt Formation makes us state that the Lower Almașu Conglomerates are more probably a local, coarser lithofacies of the Almașu Sandstone (MICU 1976).

The Almașu Sandstone is constituted of massive or graded sandstones and green siltstones, frequently intercalated with microconglomerates. Within it PANIN (1964) described numerous ripple marks, rain prints, foot prints, coexisting together with current markings of different types. All this made him conclude that the sediments from which the Almașu Sandstone originate were deposited in a marginal marine environment intermittently affected by turbid sheet-flows of running water which could produce these current markings.

DOI:https://doi.org/10.2312/zipe.1982.066

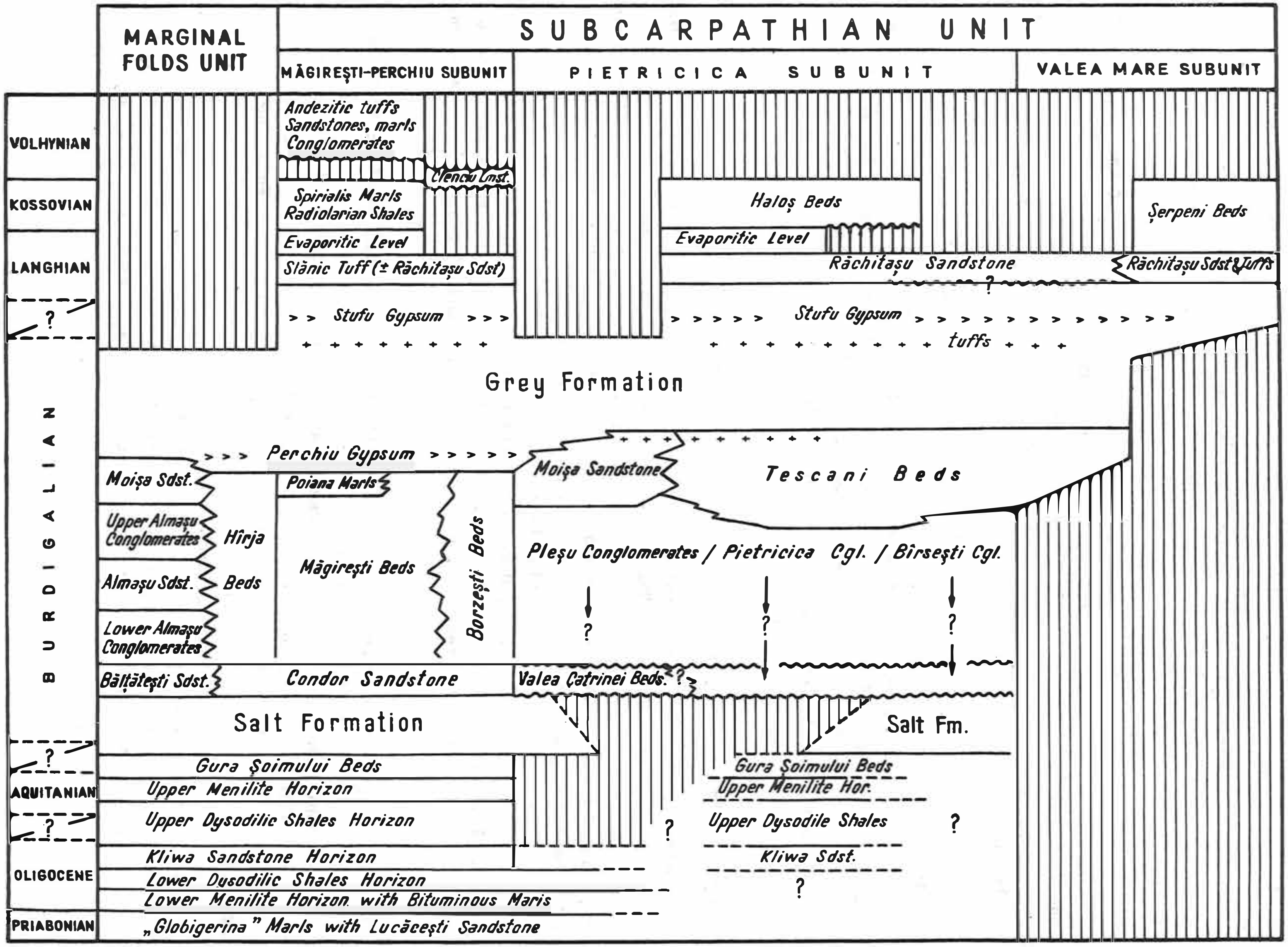


Fig. 2. Schema of stratigraphy of miocene molasse deposits and their substratum in Central Moldavia

DOI:https://doi.org/10.2312/zipe.1982.066

The U p p e r A l m a ş u C o n g l o m e r a t e s overlie the Almaşu Sandstone and have practically the same characteristics as the lower conglomeratic sequence of the Almaşu lithofacies. However, one can observe the presence of the Eocene limestones with Nummulites, Upper Jurassic organogeneous limestones, quartzites etc. more frequently than in the Lower Almaşu Conglomerates, out in all cases in smaller amounts beside the greenschist elements, the main constituent. The clayey-sandy matrix of the above-mentioned conglomerates is generally green-coloured, however red-coloured spots are frequently observed, too.

The M o i ş a S a n d s t o n e represents the last sequence of the Almaşu lithofacies, consisting of green sandstones, fine- to coarse-grained and green siltstones. In the Bistriţa Half-Window it was separated with this denomination by MIRĂUŢĂ and MIRĂUŢĂ (1964) as a lithologic and stratigraphic equivalent of the Moişa Sandstone of the Subcarpathian Unit.

The G r e y F o r m a t i o n has a fairly reduced outcropping area in the Marginal Folds Unit of the Central Moldavia, being known in the core of the Almaşu Antiform as well as in certain synclines south of the Bistriţa Valley where it is represented by grey clays and marls interbedded with poorly cemented sandstones in decimetric layers. In the base of this formation there occasionally occur gypsums considered as a possible equivalent of the Perchiu Gypsum of the Subcarpathian Unit.

2. Miocene molasses of the Subcarpathian Unit from Central Moldavia

The Subcarpathian Unit - the outermost folded zone of the Eastern Carpathians - outcrops between Suceava and Buzău Valleys on an area of several thousands square kilometres. The description of the type-profiles of the Miocene molasses of this unit in the area situated between the Bistriţa and Trotuş Valleys, in geomorphologic respect belonging to the Tazlău Subcarpathians, takes into account that:

(1) in this area the Subcarpathian Unit is the most widespread;
(2) here occur all the three subunits of this unit (Fig. 1);
(3) the lithostratigraphic sequences of the molasse deposits of the internal part of the Carpathian Foredeep in this area is by far one of the most complete and complex (Fig. 2).

The internal border of the Subcarpathian Unit is marked by the Marginal Fault of the flysch, by means of this major tectonic event the Marginal Folds Unit overthrusting the Subcarpathian Unit eastwards. A characteristic feature of the zone between Bistriţa and Tretuş Valleys is given by the fact that here the Marginal Fault of the Flysch Zone is situated between Miocene deposits belonging to both the Marginal Folds Unit and Subcarpathian Unit. This peculiar situation gave rise to many controversial interpretations of the tectonics of this area. In certain sectors of this region south of the Bistriţa Half-Window, due to the tendency of sinking of the Marginal Folds Unit, the marginal fault of the flysch is surpassed by the frontal line of the Tarcău Nappe whose flysch deposits tectonically overlie the Miocene of the Subcarpathian Unit (Uture, Berzunţi).

DOI:https://doi.org/10.2312/zipe.1982.066

The external border of the Subcarpathian Unit is represented by the Pericarpathian Fault which may be constantly traced between strongly folded and faulted Lower and Middle Miocene deposits belonging to the internal (epiorogenic) zone of the Carpathian Foredeep and the poorly deformed Sarmatian of the external (epiplatformic) part of the foredeep. The idea concerning the existence of tectonic relations between the Subcarpathian Miocene and the Sarmatian outside it belongs to MRAZEC and TEISSEYRE (1901). However, MRAZEC and POPESCU-VOITEŞTI (1914) are the first geologists who considered the Subcarpathian Miocene Zone an incipient nappe - Pericarpathian Nappe - as a result of the tectonic movements to the end of the Tertiary. The existence of the Pericarpathian Line and implicitly of a nappe of the Subcarpathian Miocene was subsequently contested; this idea was imposed definitely in the last decades as a result of detailed mapping of whole area, deep-drilling evidences and complex geophysical researches which brought decisive arguments in support of this point of view.

The Subcarpathian Unit was the subject of numerous attempts of division into several subunits, most of them being unilateral, structural or lithofacial, or referring to situations with a limited areal development which could not be generalized (PAUCĂ 1952; OLTEANU 1958; BĂNCILĂ 1958; SĂNDULESCU 1962; MIRĂUŢĂ 1965, 1969; HRISTESCU et al. 1969 etc.). After recent detailed studies SĂNDULESCU et al. (1975, unpublished data) concluded that the Subcarpathian Miocene may be divided into three subunits as follows (from the interior to the exterior): Măgireşti-Perchiu, Pietricica and Valea Mare subunits. The validity of the above subdivision, first established in the Tazlău Subcarpathians, has subsequently been confirmed by investigations in the whole outcropping area of the Subcarpathian Unit (SĂNDULESCU et al. 1976-1980, unpublished data).

2.1. Măgireşti-Perchiu Subunit

In this subunit the oldest deposits known are represented by Bisericani Beds (Priabonian) outcropping only in the core of Uture Anticline and overlain in continuity of sedimentation by Oligocene or Oligo - Miocene deposits developed in a bituminous facies: Lower Menilite Horizon with brown bituminous marls, Lower Dysodile Horizon, Kliwa Sandstone Horizon, Upper Dysodile Horizon and Upper Menilite Horizon (Fig. 2). The last three horizons are also found in the Ciertea-Scăriga Anticline where they have a diapir position.

Recent micropaleontological investigations in deposits belonging to the bituminous facies with Kliwa Sandstone or to its more internal equivalents (MARTINI and LEBENZON 1971; STEFĂNESCU et al. 1979) proved that the Oligocene Miocene boundary is situated in fact in deposits traditionally assigned to the Oligocene, consequently the Miocene starting here from the Upper Dysodile Horizon.

The deposits of the bituminous facies pass upwards into the G u r a Ş o i m u - l u i B e d s which represent a complex of transition to the Salt Formation. They outcrop in Tazlău Subcarpathians exclusively on the limbs of Uture Anticline, where they are represented by muscovitic-calcareous sandstones, quartzitic sandstones, grey marls and siltstones and even microconglomerates and conglomerates with greenschists elements of Dobrogean type. Gura Şoimului Beds contain also the last bituminous shales, announcing the end of the environmental conditions which generate bituminous facies.

DOI:https://doi.org/10.2312/zipe.1982.066

The succeeding lithostratigraphic unit - S a l t F o r m a t i o n - has quite reduced outcropping surface between Bistriţa and Trotuş valleys (Ludaşi, Ciortea, Tuta, Cernu and Berzunţi diapirs, Scăriga and Gura Văii scales, Uture and Măgireşti anticlines). Lithologically Salt Formation consists of clayey sedimentary breccia containing fragments of greenschists (Precambrian), Jurassic and Eocene limestones, conglomerates with greenschists pebbles derived from the foreland, gypsum, salt and sometimes potash salts. This brecciated part of Salt Formation, known also as the "salt breccia" represents a conglomerate mudstone (tilloid) that may be compared, up to a certain extent, with the wildflysch (SĂNDULESCU in IANOVICI et al. 1968). The bedded part of Salt Formation, occuring especially at the upper part of this, consists of grey and blackish marly and clayey shales, siltstones and sandstones. Small-sized conglomerates with green schists elements in a clayey matrix are locally present too.

C o n d o r S a n d s t o n e occurs only in places, where there is a normal, continuous passing from the Salt Formation to the Măgireşti Beds. Sandstones, usually coarse-grained, with calcareous cement, contain quartz, potash feldspars, plagioclases, muscovite, lithic fragments and in places garnets, iron oxides and glauconite (MIRĂUŢĂ 1969). The sandstones in decimetric or metric layers rhythmically alternate with grey marls, 5 - 10 cm thick.

The overlying deposits of Salt Formation and Condor Sandstone are represented in the Măgireşti-Perchiu Subunit by a "red formation" - M ă g i r e ş t i B e d s - whose denomination was introduced by MIRĂUŢĂ (1969) in order to differentiate it from the "red formation" (Tescani Beds) of Pietricica and Valea Mare Subunits, taking into account the heterochronism of this formation within the Subcarpathian Unit. Măgireşti Beds are composed of a rhythmic alternation of sandstones and marls resembling sometimes the flysch deposits. They were deposited under very shallow water conditions as indicated by the traces of rain prints and ripple marks at the upper part of the sandstones. At the lower part, the sandstones have numerous scour and tool marks. The load casts and flowage marks are also frequent. The sandstones are sometimes graded-bedded, with microconglomeratic sequences at the lower part. The micaceous, thin, well-cemented sandstone varieties often present an oblique lamination. The sandstones are reddish, greenish or grey, marls and siltstones being grey greenish with numerous violet-reddish laminas.

At the terminal part of the Măgireşti Beds a mainly marly, grey facies, known as P o i a n a M a r l s (OLTEANU 1953, 1954) develops in places; it is rapidly replaced by the red lithofacies typical of the Măgireşti Beds.

B o r z e ş t i B e d s , separated by OLTEANU (1954) in the Uture-Mihoc area, represent a local equivalent of the Măgireşti Beds, being constituted of green sandstones and conglomerates interlayered with grey-greenish siltstones and clays. Mention should be made of the fact that south and west of Uture Anticline one could observe intermediary aspects between the Borzeşti Beds and Măgireşti Beds, the facial changes taking places very quickly both transversally and directionally.

The sandstones of the Borzeşti Beds, medium-or coarse-grained, frequently contain greenschists pebbles, are graded-bedded and sometimes present load casts and groove

DOI:https://doi.org/10.2312/zipe.1982.066

casts. Erosional channels are quite frequently too. The well-bedded pelitic intercalations are greenish-grey or brown-reddish. Ripple marks and rain prints may often be observed.

G r e y F o r m a t i o n , situated between Măgireşti Beds and Slănic Tuff, has the most significant areal spreading in the Măgireşti-Perchiu Subunit. Having a complex lithologic constitution this formation at least in the Tăzlau Subcarpathians may be broadly subdivided into four main sequences.

The basal sequence is represented by the Perchiu Gypsum Complex wherein sandstones and grey marls rhythmically alternate and 1 - 4 packets of gypsum, known as the Perchiu Gypsum, are interlayered. The grey calcareous sandstones, usually well-cemented, occur in decimetric layers; the metric layers of sandstones, more rare in this sequence, are in general poorly-cemented. These sandstones correspond to the subgreywackes and contain approximately 50 % quartz and ca. 15 % feldspars. Lithic fragments, muscovite, biotite, rare glauconite occur as well. The sandstones have numerous internal structures of the oblique lamination type, parallel or, more rarely, convolute. The external structures are both syndepositional (different scour and tool marks) and post-depositional (load casts, flowage marks).

The Perchiu Gypsum is massive-bedded, nodular and bedded-mosaic (POPESCU in PATRULIUS et al. 1976). Bedded-massive gypsum is represented by thin to medium beds (frequently centimetric, not exceeding 1 m) of laminar gypsum with cryptocristalline partings composed of dolomitic clay. The bedded-massive gypsum occurs as distinct beds associated with nodular- or thick-bedded-mosaic gypsum.

Nodular gypsum is poorly developed, almost only in the lower part of the Perchiu Gypsum, where it is related to the bedded-massive gypsum. Nodules grade from nodular mosaic to completely separated by matrix. Sometimes nodules exceed in thickness, destroying the initial lamination and appearing as a discontinuous layer of nodular gypsum.

Bedded-mosaic gypsum is the principal component of the Perchiu Gypsum. The layers are usually decimetric, the bedsets reaching sometimes 8 m in thickness. Nodules are ellipsoidal, with long axes parallel, showing a tendency to be normal to the bedding. Occasionally within the bedded-mosaic, enterolitic structures of gypsum may be observed.

The second sequence of the Grey Formation is mostly constituted of marls and clays, rarely interlayered with grey sands and sandstones (Albele Sands).

The third sequence may be delimited between the first occurrence of Valea Calului Red Marls and a gypsum level, frequently associated with marly-dolomitic slates. The grey sands and/or sandstones are more poorly represented in this sequence.

The terminal sequence is also predominantly marly-clayey, practically starting with the first gypsum associated with marly-dolomitic slates. At this level gypsum is nodular or mosaic-nodular, strongly disturbing the pelites wherein it is interlayered, and represents the equivalent of the Stufu Gypsum of the Pietricica Subunit.

DOI:https://doi.org/10.2312/zipe.1982.066

This subdivision of the Grey Formation, generally valid within this subunit only in the Tazlău Subcarpathians, cannot always be recognized or applied either because of local particularities of the sedimentation or because of the variable degree of the outcropping of this formation from one region to another.

The microfaunal assemblages identified in the Grey Formation permit the assigning of the first two sequences to the upper part of the Lower Miocene. The most frequently recorded forams are as follows: Globigerinoides sicanus, G. triloba, Globigerina ciperoensis, G. tarhanensis, G. bollii, Globoquadrina praedehiscens, G. advena and Globorotalia (Turborotalia) siakensis (LUBENESCU et al. 1974; MĂRUNŢEANU 1974; SĂNDULESCU et al. 1975 - unpublished data). Besides the above mentioned species reworked Cretaceous and Paleogene foraminifera occur very frequently, too. Microfaunal evidences referring to the upper sequences of the Grey Formation comes only from the deposits belonging to the Pietricica Subunit; we shall present it further on.

S l ă n i c T u f f. In some synclines east of the Berzunţ Summit the Grey Formation is overlain, at least apparently in continuity of sedimentation by dacitic tuffs associated with Globigerina-bearing marls. They represent the equivalent of the Slănic Tuff of East Muntenia; however, they differ from the latter by some thin intercalations of glauconitic sandstones (Răchitaşu sandstones) which, at this level, are more developed in the Pietricica and Valea Mare subunits. The microfauna of the marls associated with tuffs permit the assigning of this horizon to the Middle Miocene.

"E v a p o r i t i c L e v e l" outcrops in the Măgireşti-Perchiu Subunit on a very reduced area, north of the Trotuş Valley occuring only on some profiles where it is represented by gypsums of variable thickness interbedded with layers of grey clays.

S p i r i a l i s M a r l s represent a marly sequence containing a microfauna with Ammonia beccarii, Porosononion granosum, Cribrononion flexuosum, Elphidium horridum, E. flexuosum, characteristic of the upper part of the Middle Miocene. Lithofacial features and the microfaunal assemblage of these deposits are similar to the Spirialis Marls typically developed in Muntenia. It is to be mentioned that here they substitute lithologically the horizon of Radiolarian Shales.

C l e n c i u L i m e s t o n e . This horizon, represented by organogenous limestones with tuff intercalations, occurs on very small surfaces near Gheorghe Gheorghiu-Dej City, unconformably overlying older formations (Grey Formation, Slănic Tuff). The faunal content (Chlamys malvinae, Mohrensternia sp., Ervilia sp., Ostrea sp., Lithothamnium sp.) permits the assigning of this horizon to the terminal part of the Middle Miocene (SĂNDULESCU 1962; LUBENESCU et al. 1974).

In the Măgireşti-Perchiu Subunit the youngest deposits known between Trotuş and Bistriţa valleys are represented by Volhynian conglomerates, which outcrop only east of the Berzunţ Summit, transgressively overlying older deposits. The fact that these deposits are in places overthrusted by the Marginal Folds Unit proves that the tectonic movements at the outer margin of the Flysch Zone continued during the Middle Sarmatian (Bessarabian), as well.

DOI:https://doi.org/10.2312/zipe.1982.066

2.2. Pietricica Subunit

As compared with other subunits of the Subcarpathian Unit the Pietricica Subunit has by far the widest outcropping surface in the Tazlău Subcarpathians.

The deposits older than Salt Formation outcrop in this subunit in Central Moldavia exclusively east of the Pietricica Summit where they are represented by the Upper Menilite Horizon. In the spring area of the Valea Mare Brook one may also notice occurences of the Gura Şoimului Beds, overlying the Upper Menilites and transgressively overlain by younger deposits (Fig. 2).

The outcrops of the Salt Formation are connected with the frontal fault (Dumache Fault) of the Pietricica Subunit, overthrusting the deposits of Valea Mare Subunit eastwards. Lithologically the deposits belonging to the Salt Formation in the Pietricica Subunit do not differ from those of the Măgireşti-Perchiu Subunit. The Salt Formation of the Pietricica Subunit has also been intercepted by drillings performed in the Tazlău Basin. Here it overlies Oligo-Miocene deposits of bituminous facies with Kliwa Sandstone and is transgressively overlain by a strong pile of conglomerates with green schists elements - Pietricica Conglomerates.

Between the Bistriţa and Trotuş valleys the Pietricica Conglomerates constitute the most coarse deposits of this subunit. Besides conglomerates, which form beds several metres thick, microconglomerates and coarse-grained green sandstones occur particularly towards the upper part of Pietricica Conglomerates. Graded bedding as well as small- to large-scale cross-bedding may be observed in places. The thickness of beds depends on the sizes of the elements forming the conglomerates, predominantly represented by green schists elements (Precambrian) of Dobrogean type. Apart from these one may also observe Middle Jurassic blackish limestones, Eojurassic white limestones, Eocene nummulite-bearing limestones, (Triassic?) red sandstones, quartzites etc. The conglomerate matrix is sandy or siltic, green-coloured.

The deposits belonging to the "red formation" of the Pietricica Subunit, lying between Pietricica Conglomerates and the Grey Formation are known as Tescani Beds. They consist of alternations of marly clays, reddish and greenish siltstones and centimetric or decimetric grey-greenish and reddish sandstones, sometimes microconglomeratic at the lower part. Intercalations of green conglomerates are also present, especially at the lower part of Tescani Beds.

In lithofacial respect, the Tescani Beds do not differ too much from the Măgireşti Beds. The differences consist chiefly in the coarser character of arenites of the Tescani Beds in comparison with Măgireşti Beds, the relative reduced percentage of the red marls and eventually the more irregular character of the rhythms. On the surface of the Tescani Beds sandstones one may frequently observe foot-prints of birds and mammalians, rain prints, ripple marks, proving that these beds were deposited sometimes under a very thin layer of water. Mud cracks which are rarely observed testify that intermittently parts of these deposits were sometimes subaerially exposed.

DOI:https://doi.org/10.2312/zipe.1982.066

The lithostratigraphy of the G r e y F o r m a t i o n within the Pietricica Subunit is somehow different from that of the Măgireşti Subunit. First of all one can notice that here, at the lower part of this formation a gypsiferous complex comparable with Perchiu Gypsum is not developed, evaporitic episodes occuring at this level in the Pietricica Subunit being accidentally and very poorly developed. On the other hand, in this subunit the Grey Formation may broadly be divided only into two sequences: a lower one, mostly marly-sandy sequence containing intercalations of Valea Calului Red Marls, and an upper sequence, more clayey, of schlier type. In the Tazlău Subcarpathians before-mentioned sequences are separated by a gypsum complex - Stufu Gypsum (SĂNDULESCU et al. 1975 - unpublished data) - commonly associated with marly-dolomitic slates.

Another characteristic of the Grey Formation in the Pietricica Subunit is given by the fact that the intercalations of Valea Calului Red Marls in places start very close to the base of this formation; partly this remark is also valid for the intercalations of marly-dolomitic slates. Towards the upper part of the lower sequence of the Grey Formation 1 - 2 yellowish sand levels, several metres in thickness (Lărguţa Sands) can be observed in the Tazlău Subcarpathians.

At the upper part of the Grey Formation in this subunit a microfaunal assemblage with Globorotalia scitula and Candorbulina suturalis is pointing to the Middle Miocene age. It is to be mentioned that in regions situated south and north of the Tazlău Subcarpathians Middle Miocene foraminiferal assemblages have been identified at the level of Stufu Gypsum, eventually even below it (SĂNDULESCU et al. 1977, 1979 - unpublished data).

The R ă c h i t a ş u S a n d s t o n e overlies the Grey Formation and is represented by Lithothamnium-bearing organogenous glauconitic sandstones with intercalations of tuffs and globigerina marls. In the Tazlău Subcarpathians this horizon represents the external equivalent of the Slănic Tuff outcropping in the Măgireşti-Perchiu Subunit. The number of the tuff intercalations is variable; however, it does not exceed 4 superposed levels. In certain zones in the east of the Pietricica Subunit, the Răchitaşu Sandstone seems to overlie unconformably the Grey Formation; on other profiles such intercalations of glauconitic sandstones occur since the terminal levels of the Grey Formation.

The microfaunal assemblages of this horizon characterizes the "Orbulina" suturalis/ Globorotalia bykovae Zone of the Middle Miocene: Praeorbulina transilvanica, Praeorbulina glomerosa, Candorbulina universa, Globorotalia mayeri, G. bykovae, Globigerinoides triloba, G. immatura, G. irregularis (SĂNDULESCU et al. 1975 - unpublished data).

The "E v a p o r i t i c L e v e l" is an important lithostratigraphic marker situated at the Langhian/Kossovian boundary which occurs only on some profiles nearby the confluence of the Tazlău with the Trotuş and is represented by massive gypsum with intercalations of marly-dolomitic slates. Gypsum is massive-bedded, with subcentimetric lamination, separated by thicker beds of grey clays. The intense crystallization leads sometimes to fibrous structures, which pseudomorphs the initial bedding of gypsum. Marly-dolomitic slates, numerous and often with metric thicknesses, present various deformational structures which change substantially the initial parallel lamination.

DOI:https://doi.org/10.2312/zipe.1982.066

H a l o ş B e d s are represented by a predominantly sandy-gritty, oligomictic series. At different levels, especially in their lower half, the Haloş Beds are interlayered with grey or brown, silty marls. Within the only outcrop with Haloş Beds, north of the town of Gheorghe Gheorghiu-Dej, they directly overlie the Răchitaşu Sandstone, this indicating the existence of a sedimentary gap locally preceding the deposition of Haloş Beds (SĂNDULESCU et al. 1980 - unpublished data).

Immediately north of the Trotuş Valley, the deposits of the Pietricica Subunit are transgressively overlain by Upper Bessarabian and Kersonian-Meotian deposits, proving the intra-Bessarabian thrusting of the Subcarpathian Unit over Sarmato-Pliocene deposits of the external part of the Carpathian Foredeep.

2.3. Valea Mare Subunit

In the Tazlău Subcarpathians, the Middle and Lower Miocene deposits of the Valea Mare Subunit are represented by Tescani Beds, Grey Formation, Răchitaşu Sandstone and Serpeni Beds. Deposits older than Răchitaşu Sandstone occur in this subunit only east of the Pietricica Summit where they present similar characteristics to the equivalent formations of the Pietricica Subunit (Fig. 2).

R ă c h i t a ş u S a n d s t o n e , with a maximum thickness of ca. 200 m, is constituted of organogenous glauconitic sandstones with rare tuff intercalation. However, north of Bistriţa Valley the Răchitaşu sandstones supply suddenly decreases, its occurrence in association with tuffs and globigerina marls which are predominant being occasional. Towards the upper part of this horizon compact grey marls are interlayered with sandstones.

Ş e r p e n i B e d s (SĂNDULESCU et al. 1976 - unpublished data) overlie in continuity of sedimentation the Răchitaşu sandstone. At the lower part of these deposits, generally marly with intercalations of calcareous sandstones, sands and grey siltstones, there are several gypsum levels which may represent the "Evaporitic Level" of the more internal subunits. Dacitic tuffs as centimetric intercalations also occur, especially in the base of these beds.

The upper sequence of the Şerpeni Beds consists of compact or poorly-cemented fine-grained white sands occuring as metric layers separated by grey, more rarely red marls. They represent the equivalent of the Haloş Beds of the Pietricica Subunit.

Mention should be made of the fact that the lithologic transition from the lower to the upper part of the Şerpeni Beds takes place gradually, their delimitation being conventional as in case of the separations made in the Grey Formation.

The gypsum intercalations of the Şerpeni Beds are usually bedded-massive gypsum, nodular gypsum being more rarely found. The terrigenous material within gypsum varieties sometimes exceeds 30 - 35 % (POPESCU in SĂNDULESCU et al. 1979 - unpublished data).

DOI:https://doi.org/10.2312/zipe.1982.066

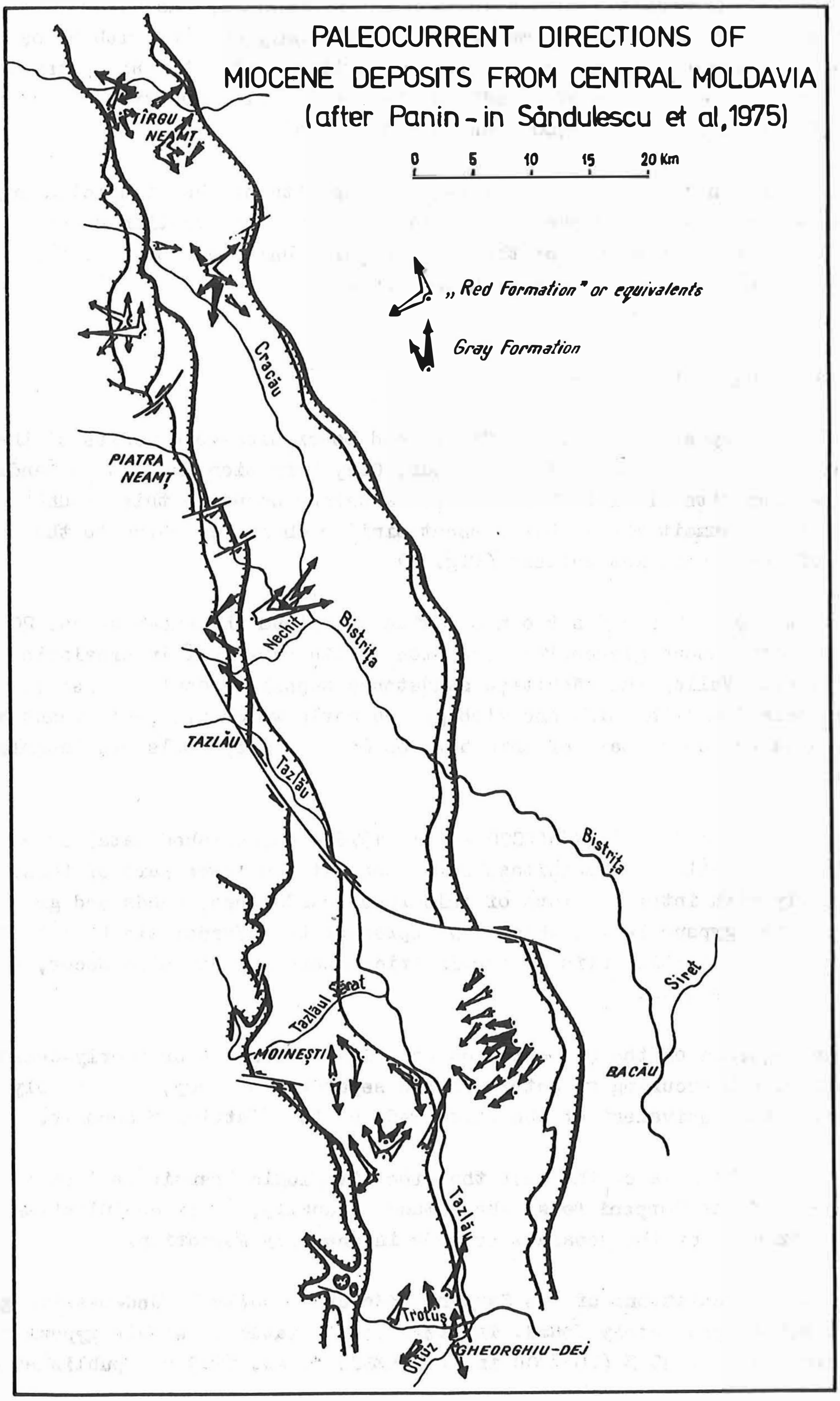


Fig.3

DOI:https://doi.org/10.2312/zipe.1982.066

3. Directional structures and directions of transport

The study of the directional structures carried out in the Tazlău Subcarpathians (PANIN in SĂNDULESCU et al. 1975 - unpublished data) pointed out interesting evidences related to transport directions and indirectly to the sedimentary environment during the deposition of the Lower and Middle Miocene molasse.

The arenitic deposits of the Red Formation (Măgireşti and Tescani Beds) present numerous current markings, among which tool markings predominate as compared with scour-markings. Load casts and flowage markings occur as well.

Internal structures (endoglyphs) are numerous and varied, those generated by the ripple transport being the most frequent. The asymmetrical or symmetrical ripple marks are in places weathered or superposed.

Ruditic deposits (Pietricica Conglomerates) show a clear imbrication of elements which permits a quite precise estimation of the supply direction of the material.

Within the Grey Formation the thin sandstones from the flyschoid sequences are generally graded-bedded. The abundance of the internal and external structures are characteristic, most of the current markings and tool markings known in the typical flysch deposits occuring here. Load casts, flowage markings and current lamination generated by the ripple transport appear as well. All this points out the existence of a rapid transport agent, with a high transport capacity. This agent might be represented by turbiditic currents which were propagated in a relative deeper zone of the sedimentary basin.

In the poorly-cemented thick sandstones and sands of the Grey Formation the external structures are missing. The internal structures are rarely found, the most frequent belonging to the structures generated during the ripple phase of transport. These deposits point to their deposition in a littoral accumulation zone under conditions of a constant supply of detrital material.

The study of the types of directional structures as well as the frequency of the ripple marks point out that the Tescani Beds seem to be deposited in a shallow-water zone. The oblique lamination is more often than not due to unstable hydrodynamic conditions proper to the shallow zones, which determined repeated rearrangements of the arenitic material. Both in the Tescani Beds and in the Pietricica Conglomerates the detrital material points to an ENE transport direction, from an upland having a high-energy relief. Referring to the Măgireşti Beds the transport direction from the east is maintained, the existence of a longitudinal transport being also observed.

The gritty deposits of the Grey Formation in the Pietricica Subunit - representing a littoral facies - have current directions from E and ENE, whereas in the equivalent deposits of the Măgireşti-Perchiu Subunit the current directions are longitudinal, the southern ones predominating. However, direct supplies from E and W may be observed, too.

DOI:https://doi.org/10.2312/zipe.1982.066

Concluding we can notice that the dispersion of currents in the Miocene deposits is much stronger than in the case of flysch deposits. The influence of the source areas is much more obvious in the molassic deposits and subsequently an intricated spreading of paleocurrents can be observed (Fig. 3).

4. Paleogeographic considerations

The discussion of problems regarding the whole sedimentary evolution and paleogeography of the Miocene in the Carpathian Foredeep starts from the premise that within this zone of the Carpathian orogene the proper molasse sedimentation becomes generalized after the deposition of the Lower Miocene Salt Formation (SĂNDULESCU et al. 1977). Mention should be made of the fact that the sedimentation of some molassic deposits however began before the deposition of the Salt Formation (Oligocene conglomeratic deposits in the northern part of the Bistriţa Half-Window, partly the Goru-Mişina and Gura Şoimului Beds in the Marginal Folds Unit).

Following a period of normal marine deposition (Gura Şoimului Beds / Goru-Mişina Beds), the Salt Formation has quite complex genesis conditions both as regards proper depositional mechanism and basinal paleogeography. The normal marine deposition preceding the Salt Formation is of short standing and settled after a long time when in the Oligocene basin, particularly in its eastern part, there were conditions of restrictive circulation of water (restricted basins) which generated the bituminous facies.

It is likely that the evaporites accumulated in more or less isolated basins, with a medium or shallow depth, but with a permanent subsidence. Halite deposited in the central (deeper) parts, while sabkha-type sulphate evaporites accumulated in the emerged adjacent areas.

Within this paleogeographic setting, certain difficulties are connected with the explanation of the mechanism of genesis of the clayey deposits having sometimes stratonomic features similar to the deposits generated by submarine slidings of olistostrome-type. As mentioned before, under these conditions the water was shallow enough and the basin floor relief without escarpments which could have facilitate the slidings.

In order to overcome these difficulties one may fancy a genetic process during which evaporites deposited alternatively with sedimentary clayey breccia, finally forming so called "salt breccia". These processes might have corresponded to rapid changes in the sedimentary environment: smaller depths during "evaporitic moments", followed by unitary and/or differentiate sinking during the "salt breccia" deposition. The above-mentioned scheme also permits the explanation of the presence of potash salts at several levels, whose genesis corresponds to the periods of severe aridity which mark the end of a sedimentary cycle. The coexistence of salt breccia with normal bedded deposits may be explained considering that the latter deposited in areas unaffected by slidings.

The deposition of the Lower Miocene Salt Formation ends concomitantly with the deposition of immature arkosian sandstones (Condor Sandstone) overlying a large area corresponding to the Marginal Folds Unit and the inner part of the Subcarpathian Unit.

DOI:https://doi.org/10.2312/zipe.1982.066

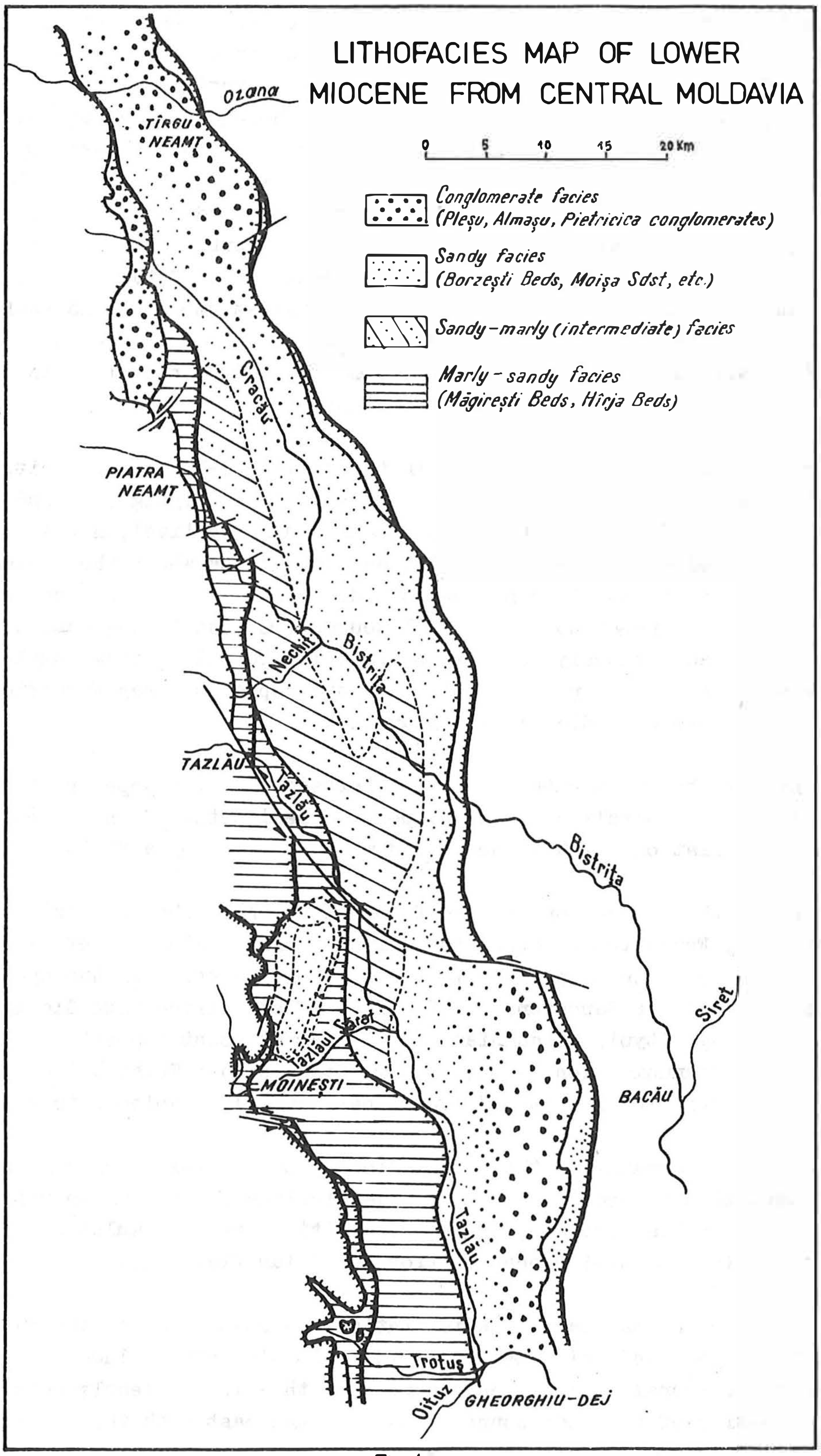


Fig. 4

DOI:https://doi.org/10.2312/zipe.1982.066

The gritty and/or conglomeratic molasse overlying the Salt Formation accumulated in a zone delimited outside (eastwards) by an active relief of the foreland from which the coarse, poorly sorted material accumulated as fan-shaped conglomerates (PANIA 1964; MIRĂUŢĂ 1965; POLONIC and POLONIC 1967). This coarse material was partly redistributed by longitudinal currents, which achieved a relative homogenization of the conglomeratic facies towards the interior (westwards); from north to south they are replaced by sandy molasses (Măgireşti Beds, Borzeşti Beds and, partly, Tescani Beds) in which arenites always present petrographic evidences indicating a foreland source (Fig. 4). Unlike it, pelites show that during their deposition there was a double supply: from the foreland, as indicated by clay minerals, and from the internal zones of the flysch, as shown by the resedimented Senonian and Paleogene foraminiferal assemblages. Intra-Lower Miocene gaps which, in certain areas, preceded the conglomeratic molasse deposition seem to be contemporaneous with the overthrusting of the Macla, Curvicortival Flysch and Audia Nappes (SĂNDULESCU et al. 1975 - unpublished data).

The Perchiu Gypsum Complex represents in the Măgireşti-Perchiu Subunit, as well as in the Marginal Folds Unit, the first evaporitic level overlying the sandy molasse mainly represented by red formations (Măgireşti Beds and respectively Hîrja Beds). It accumulated on flat sea delimited inwards by still subsiding area where the sediments of the terminal part of the Tescani Beds had deposited. Arenitic rocks interbedded in the Perchiu Gypsum Complex point to an internal source, whereas in the case of the Tescani Beds the foreland was obviously the main source. The Perchiu Gypsum Complex and the Tescani Beds are overlain by predominantly pelitic deposits (Grey Formation) wherein arenitic sequences are episodically interlayered.

Stufu Gypsum of the Subcarpathian Unit, interbedded in the upper part of the Grey Formation, marks the generalization of evaporitic sedimentation in the whole Subcarpathians. The tidal flat on which it deposited was delimited by a flattened relief.

Re-settling of the marine conditions of normal salinity characterizing the deposits overlying the Grey Formation announce themselves by intercalations of glauconitic sandstones and pelites containing planktonic foraminifera occuring in the upper part of the Grey Formation. Răchitaşu Sandstone and Slănic Tuff associated with Globigerina-bearing marls and containing a typical Langhian microfauna represent deposits accumulated during a period of broad communication between the Tethys and Para-Tethys. They are followed by the last evaporitic level of the Miocene, particularly developed in the Paratethys.

In the Tazlău Subcarpathians the Middle Miocene evaporites level consists of sulphate deposits (gypsum with intercalations of marly-dolomitic slates) which represent the extension in the Carpathian Foredeep of the evaporitic level accumulated also on large areas of the foreland (East-European Platform, Moesian Platform).

The conditions of normal marine sedimentation are resumed after the evaporite deposition (e.g. the Şerpeni and Haloş Beds). During this time strong Indo-Pacific influences are felt, the microfaunal assemblages occuring at this level clearly pointing out the temporary resumption of the wide connections from the east with the Tethys (POPESCU in SĂNDULESCU et al. 1979 - unpublished data).

DOI:https://doi.org/10.2312/zipe.1982.066

The maturity of arenites and relative abundance of pelites in the Middle Miocene point out the absence of an active relief at the margin of the depositional domain. The terminal part of the Middle Miocene indicates shallow marine sedimentary conditions (Clenciu Limestone), according to which a brackish molassic environment settled during the Sarmatian.

In the Volhynian the domain of sedimentation overlay to a large extent the area which would constitute subsequently the Subcarpathian Unit. The Volhynian gritty-conglomeratic molassic facies transgressively overlying older formations east of the Berzunţ Summit (Tazlău Subcarpathians) proves that in this area the shore-line must have been situated not very far to the west.

During the Bessarabian, the basin configuration underwent several modifications in the sense of a possible migration of it to the east and south. Such deposits occur north of Buhuşi transgressively lying on older Miocene deposits of the Pietricica and Valea Mare Subunits. The transgressive position of the above-mentioned deposits proves the Intra-Bessarabian age of the overthrust of the Subcarpathian Unit on the external zone of the Carpathian Foredeep.

A significant reduction of the domain of sedimentation on the present Subcarpathian Unit can be observed at the Meotian-Pontian boundary, deposits of this age being known only from the Trotuş Valley to the south.

References

BĂNCILĂ, I.: Geologia Carpaţiler Orientali.
Ed. Stiinţifică, Bucureşti, 1958, 368 p.

COROBEA, C.; GHEORGHIAN, M.; CORNEA, C.: Miocène inferieur de Bălţă teşţi (Avantfosse des Carpathes Orientales).
14th Int. Micropal. Colloquium, Guide of Ex., Ed. Inst. Geol. Geoph., Bucureşti 1975

HRISTESCU, E.; COMAN, V.; MARINESCU, I.; AGHEORGHIESEI, V.; SULER, V.: Asupra uner complicaţii structurale în Carpatii Orienţali la contactul eu verlandul.
Petrol şi Gaze, Bucureşti 20 (1969) 1

IANOVICI, V.; RĂDULESCU, D.; RĂDULESCU, I.; SĂNDULESCU, M.: Crystalline-Mesozoic Complexes and volcanism in the East Carpathians (Central Sector).
Int. Geol. Congress 23th Sess. Prague, Guide to Exc. 47 AC. Publ. Geol. Inst., Bucharest 1968

LUBENESCU, V.; COROBEA, C.; CORNEA, C.: Consideraţii asupra vîrstei uner complexe gipsifere din Miocenul din Moldova (V. Bistriţei-V.Caşinului).
Dări seamă şedinţ., Inst. Geol.(1972-1973), Bucureşti 60 (1974) 1, p. 131-138

MARTINI, E.; LEBENZEN, C.: Nannoplanktonuntersuchungen im oberen Tal des Tarcău (Ostkarpathen, Rumänien) und stratigraphische Ergebnisse.
Neues Jahrb. Geol.-Paläont., Stuttgart (1971) 9

MĂRUNŢEANU, M.: Notă preliminară asupra stratigrafiei molasei miocene din regiunea Helegiu-Poiana-Oraşul Gheorghe Gheorghiu-Dej.
Dări seamă şedinţ., Inst. Geol. (1972-1973), Bucureşti 60 (1974) 4, p. 139-154

MICU, M.: Flişul extern şi Miocenul subcarpatic dintre Valea Agapiei şi Valea Almaşului.
Dări seamă şedinţ., Inst. Geol. Geof. (1975), Bucureşti 62 (1976) 5, p. 53-73

DOI:https://doi.org/10.2312/zipe.1982.066

MIRĂUȚĂ, O.: Faciès et tectonique de la molasse miocène sub-carpathique, de la Moldavie Centrale.
7th Congress Carp.-Balk. Geol. Ass., Reports 2/2, Sofia 1965

MIRĂUȚĂ, O.: Stratigrafia şi structura Miocenului subcarpatic din regiunea Moineşti-Tazlău.
Dări seamă şedinţ., Inst. Geol. (1967), Bucureşti 54 (1969) 3, p. 203-211

MIRĂUȚĂ, O.; MIRĂUȚĂ, Elena: Faciesurile şi tectonica molasei miocene din anticlinalul fals Almaşu.
Dări seamă şedinţ., Inst. Geol. (1961-1962), Bucureşti 49 (1964) 2, p. 137-146

MRAZEC, L.; TEISSEYRE, W.: Ueber oligocäne Klippen am Rande der Karpathen bei Bacău (Moldau).
Jhrb. k.k. Geol. R.A., Wien 51 (1901)

MRAZEC, L.; POPESCU-VOITEŞTI, I.: Contributions à la connaissance des nappes du flysch carpathique en Roumanie.
An.Inst. Geol. Roum., Bucureşt 5 (1914)

OLTEANU, Fl.: Faciesurile şi tectonica Miocenului subcarpatic din regiunea Berzunţ.
Dări seamă şedinţ., Com. Geol. (1949-1950), Bucureşti 37 (1953)

OLTEANU, Fl.: Depresiunea subcarpatică în regiunea Solonţ-Drăgugeşti (Bacău).
Dări seamă şedinţ., Com. Geol. (1950-1951), Bucureşti 38 (1954)

OLTEANU, Fl.: Depresiunea subcarpatică între văile Ozanei şi Buzăului.
An. Com. Geol., Bucureşti 31 (1958)

PANIN, N.: Coexistenţa urmelor de paşi de vertebrate cu mecanoglife în molasa miocenă din Carpatii Orientali.
St. Cerc. Geol. Ac. R.P.R., Bucuresti 9 (1964) 2

PATRULUIS, D.; DRĂGĂNESCU, A.; BALTREŞ, A.; POPESCU, B.; RĂDAN, S.: Carbonate rocks and evaporites.
Publ. Inst. Geol. Geoph., Guidebook series, Bucharest 15 (1976) 82 p.

PAUCĂ, M.: Depozitele miocene presarmaţiene din regiunea de curbură a Carpaţilor.
An. Com. Geol.,Bucureşti 24 (1952)

POLONIC, P.; POLONIC, G.: Direcţii de transport în molasa helveţiană dintre Valea Sucevei şi Valea Trotuşului.
Dări seamă şedinţ., Com. Geol. (1966-1967), Bucureşti 54 (1968) 1, p. 205-215

SĂNDULESCU, M.: Stratigrafia şi tectonica molasei miocene din regiunea Valea Mare-Berzunţ-Oneşti.
Dări seamă şedinţ., Com. Geol. (1958-1959), Bucureşti 46 (1962)

SĂNDULESCU, M.; MICU, M.; POPESCU, B.: La structure et la paleogeographie des formations miocenes des Subcarpathes Moldaves.
11th Congress Carp.-Balk. Geol. Ass., Kiev 1977

STEFĂNESCU, M.; GHEȚA, N.; DICEA, M.: On the Oligocene-Miocene boundary in the external flysch zone of the Carpathian Bend.
Rev. Roum. Geol. Geoph. Geogr. - Geologie, Bucureşti 23 (1979) 1

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Explanatory Notes to the Lithotectonic Profile of the Getic Paleogene Deposits (Southern Carpathians, Romania) (Sedimentological Comment to Annex 13)

by

DAN C. JIPA[1]

1. Introduction

On the southern slope of the Southern Carpathian Mountains a thick sedimentary accumulation occurs within an area known in the geological literature as the Getic Basin. The outcropping zone of this accumulation unit extends from Otăsău River in the west to Doamnei River in the east (Fig. 1 and 2). In order to avoid a wrong paleogeographic image, we will rather use the name "Getic Accumulation Area" (or simply Getic Area) instead of the term "Getic Basin".

The Getic sedimentary sequence begins with Upper Cretaceous deposits laying directly on the crystalline rocks basement. Amounting more than 2000 m the Getic Paleogene sequence transgressively overlays the Cretaceous deposits as well as the basement rocks. The Paleogene deposits are similarly covered by transgressive Miocene deposits.

The Getic Paleogene sequence presents two important lithostratigraphic entities (Fig. 3): a Basal Conglomerates Horizon (Lower Eocene), followed by thick Marly Horizon (Upper Eocene and Oligocene). Westward of Olt River the Basal Conglomerates are also known as the Călimănesti Conglomerates. Locally an important coarse-grained sedimentary unit may occur within the Marly Horizon. This unit, developing in the lower part of Oligocene time, is known as Corbi Sandstone in the eastern part of the Getic Area, or as Cheia Conglomerates in the western part. Due to this occurrence the Marly Horizon is sometimes divided into two units: Lower Marls (also known as Olaneşti Marls in the Olt River zone) and Upper Marls (also named Pucioasa-type Marls in the western Getic Area).

1) Institute of Geology and Geophysics; Romania, 78344 Bucharest, str. Caransebes 1

DOI:https://doi.org/10.2312/zipe.1982.066

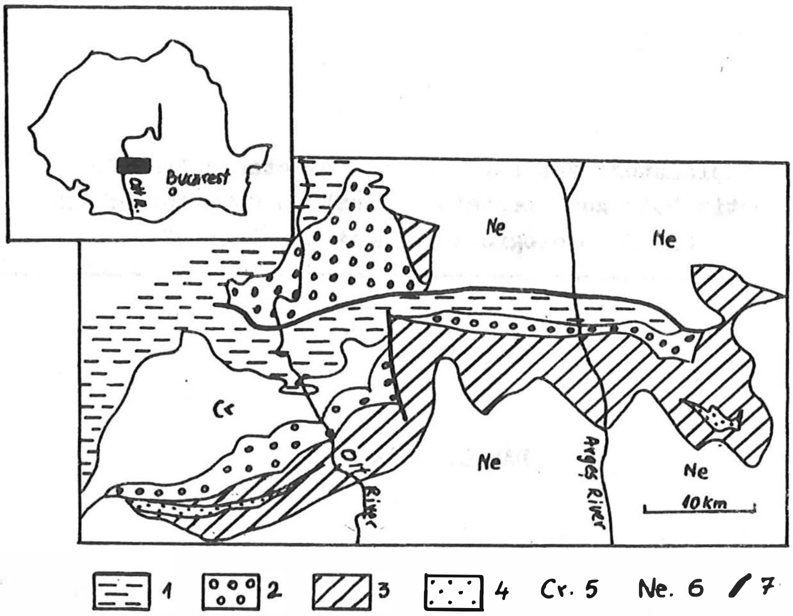


Fig. 1. Geological sketch showing the areal distribution of the main facies of the Getic Paleogene deposits. Simplified data from the geological map of Romania scale 1 : 50 000 and MURGEANU (1941)

1 - Crystalline rocks, 2 - Basal Conglomerates Horizon (Lower Eocene), 3 - Marly Horizon (Upper Eocene - Oligocene), 4 - Corbi Sandstone and Cheia Conglomerates (Lower Oligocene), 5 - Cretaceous deposits, 6 - Neogene deposits, 7 - fault

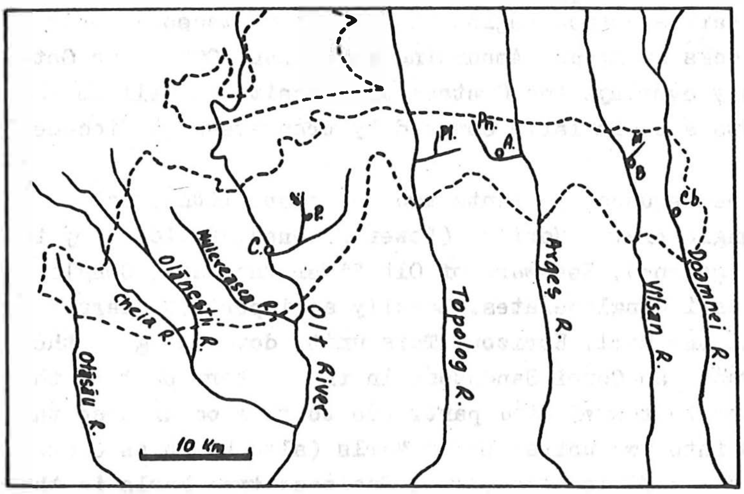


Fig. 2. Index map of the geographical names

C - Călimăneşti, P - Păteşti Village, S - Sălătruc Creek, Pl - Plopilor Creek, A - Arefu Village, Pn - Poieniţa Creek, B - Brădet Village, M - M - Mierlei Creek, Cb - Corbi Village

Dotted line marks the cropping out zone of the Getic Paleogene deposits

DOI:https://doi.org/10.2312/zipe.1982.066

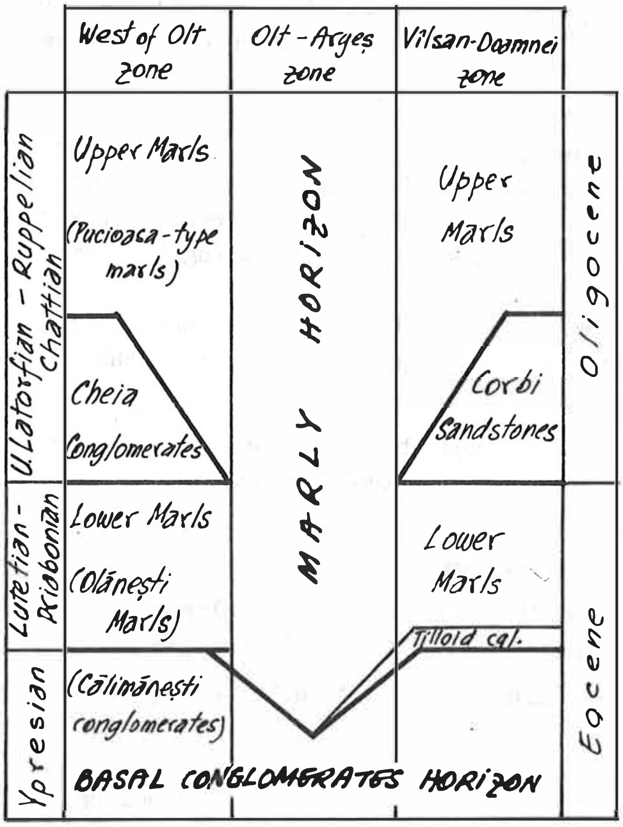


Fig. 3. Lithostratigraphic units of the Getic Paleogene formation. Simplified data from POPESCU et al. (1976) and MURGEANU (1941)

2. Sedimentary sequence

Basal Conglomerates Horizon

The Getic Paleogene sequence begins with very coarse rudites. The main petrographic types of elements are represented by crystalline schists (gneisses, mica schists, quartzites) and Jurassic limestones. The grain size sorting is poor and very poor. Small pebbles (2 - 3 cm) are frequently coexisting with large blocks (6 m or even longer). The big blocks are more frequent when the Basal Conglomerates Horizon is laying directly on the crystalline schists basement.

Usually the rudites at the lowest part of the Basal Conglomerates Horizon display no preferential orientation of the elements, no internal structures, very poor sorting and often include large blocks. Such sediments have been singled out with the field term "avalanche-type rudites". Occasionally, thinner bedded rudites with preferentially oriented and better sorted pebbles occur besides the disordered rudites. For field convenience also, this kind of rudites have been indicated as "normal current type rudites".

DOI:https://doi.org/10.2312/zipe.1982.066

Visual observations revealed that the rudites at the beginning of the Basal Conglomerates sequence show an almost equal participation of subangular (and angular) versus subrounded pebbles. These rudites appear to be at the limit between breccias and conglomerates.

Characteristically, the rudites at the very base of the Getic Paleogene sequence are practically devoid of finer grained (arenaceous or lutaceous) intercalations. That is why the bedding is sometimes difficult to be observed. However, in good exposures the whole sequence appears rather well bedded, including the "avalanche-type" rudites.

The above described rudites occur at the lowest part of the Basal Conglomerates Horizon. Advancing toward the upper part of this horizon the following variation trends develop:

- the rudites become finer grained, better sorted and thinner bedded, with better rounded and frequently preferentially oriented pebbles;
- more and more sandstones and lutites interbed in the sequence, reducing the rudites quota and making the bedding quite obvious;
- at the uppermost part of the Basal Horizon conglomeratic and sandy beds alternate with marls, the facies having a definite rhythmical appearance;
- frequent sedimentary structures (various sole casts, cross and parallel lamination, a.s.o.) can be observed.

As a result of these variations a gradual passage occurs from the coarse rudites existing at the very base of the Conglomeratic Horizon towards the overlying Marly Horizon. Such a very large scale graded bedding is rather seldom fully achieved. Usually the variation tendency is only partially realized or is showing aberrant evolutions. The vertical stratonomic changes manifested by the Basal Conglomerates Horizon (Fig. 4) are best shown from the Vîlsan Valley (JIPA 1980). In the western part of the Getic Area the upper part of the Basal Conglomerates Horizon becomes more sandy in composition; but the rhythmical facies does not develop.

On the left bank of the Olt River, at Călimănești resort town, the Basal Conglomerates Horizon is cross-bedded, the structure appearring at the scale of the whole horizon.

Tilloid Conglomerates Level

During the sedimentological researches carried out within the Getic Accumulation Area the existence of a tilloid conglomerates level has been recognized. These paraconglomerates develop on regional scale, marking the limit between the Basal Conglomerates Horizon and the Marly Horizon.

The tilloid conglomerates attain their fullest development in the easternmost part of the Getic Area, outcropping on Mierlei Creek, a tributary of Vîlsan River (north of Brădat village). In this outcrop the Tilloid Conglomerates Level is 40 - 50 m thick. The pebbles embedded in the lutaceous **matrix** consist mainly of rounded quartzites and

DOI:https://doi.org/10.2312/zipe.1982.066

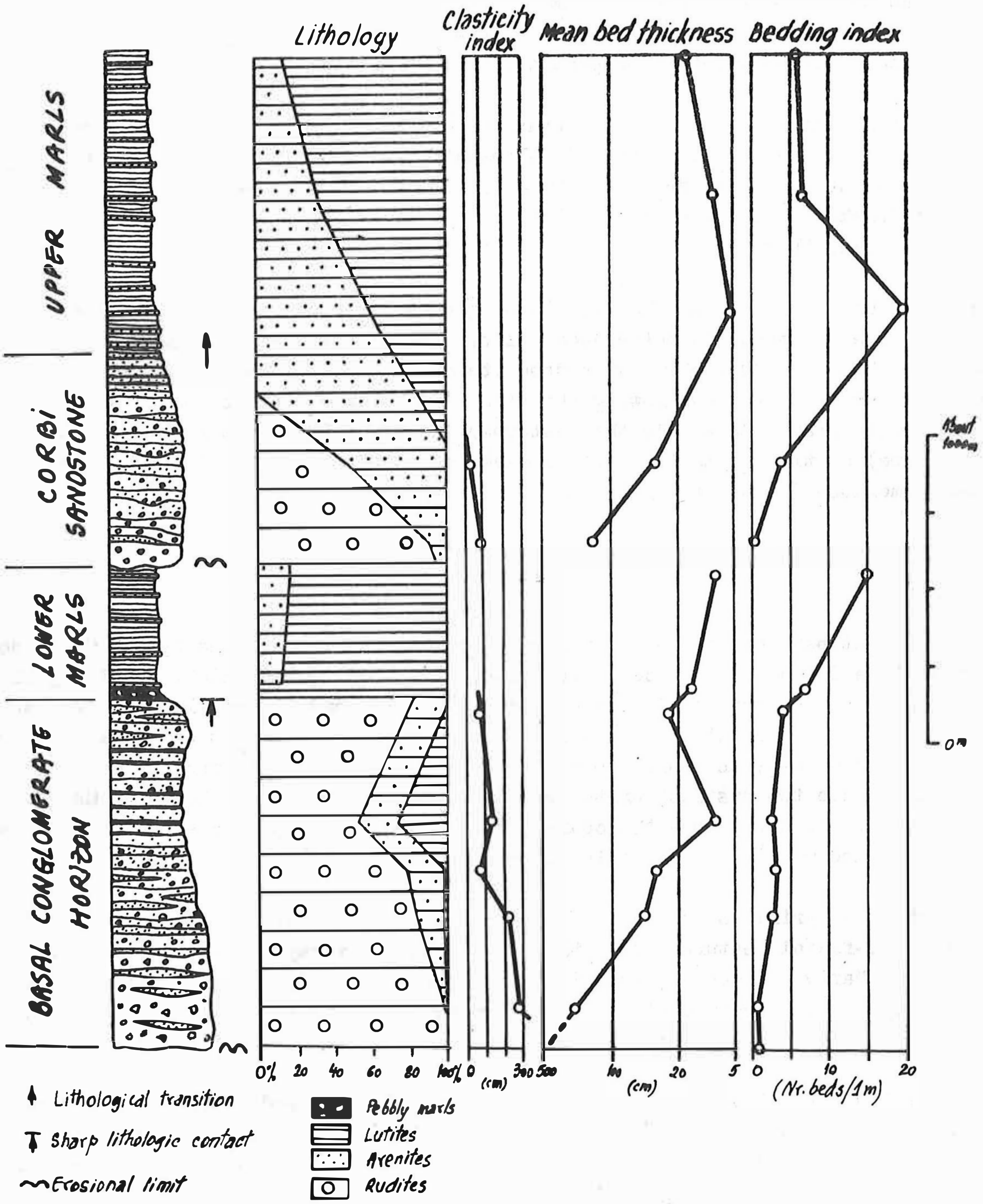


Fig. 4. Stratonomic profile of the Getic Paleogene deposits of Vîlsan Valley

DOI:https://doi.org/10.2312/zipe.1982.066

more angular gneiss fragments. All these pebbles are floating within a homogenous marly matrix. Blocks - up to 3 m large - are also set in the lutaceous matrix. In the lower part of the pebble-clay interval the matrix appears finer grained, with a smaller amount of scattered pebbles. In the upper half of the tilloid member the matrix seems more siltic, with a larger quantity of pebbles.

The Tilloid Conglomerates Level extends from Vîlsan River to Olt River, on about 40 km distance (Fig. 5). Along this development zone the thickness of the tilloid member shows a constant decrease: from 40 - 50 m in Vîlsan Valley to 10 - 30 m in Argeş Valley (Poieniţa Creek, Arefu village) and finally to 0.55 m in Olt Valley (Sălătruc Creek, Păţesti village) (Fig. 5).

Westward of the Olt River the Tilloid Conglomerates cannot be recognized as a stratigraphical level anymore. In Muiereasca Valley several thin pebble-marly beds are scattered throughout the 30 - 50 m thick deposits at the base of the Lower Marls. These tilloid occurrences are not showing the rounded quartzite pebbles characteristic of the Tilloid Conglomerates Level. In the westernmost part of the Getic Area (Olăneşti and Cheia Rivers) no tilloid manifestations have been observed at the limit between the Basal Conglomerates and the Lower Marls.

Marly Horizon

An important part of the Getic Paleogene deposits is represented by the Marly Horizon. This is a dominantly lutaceous sequence, more than 1000 m thick, overlying the Basal Conglomerates Horizon. Westward of the Olt River and in the Vîlsan Valley zone a thick sandy-conglomeratic sequence interposes in the middle part of the Marly Horizon (Fig. 3). Consequently in these two marginal zones of the Getic Area the Marly Horizon is separated into two distinct units, namely the Lower Marls and the Upper Marls. In the middle part of the Getic Area the coarse-grained sequence disappears and the two marly subdivisions are merging into a sole uniform horizon.

Even when appearing as two separate rock units the Paleogene marls display the same kind of litho-facial features. From the sedimentologic viewpoint the distinctive character of the Marly Horizon consists in the rhythmicity of its deposits. This feature results through the repeated alternance of sandy and marly beds, with the obvious dominance of the lutaceous rocks.

Usually the sandy interbeds are fine- and very fine-grained. Most sandstone beds are centimetres and even millimetres thick (0.3 - 10 cm). The decimetric sandstone beds (20 - 30 cm thick) are rather rare, while sandy beds thicker than one meter represent unusual occurrences.

Stratonomically the sandy interbeds can be classified as follows:

(a) rippled type (sandstone beds with clear-cut upper and lower limits, rippled upper surface ripple cross-laminated structure, devoid of vertical grain size grading);

DOI:https://doi.org/10.2312/zipe.1982.066

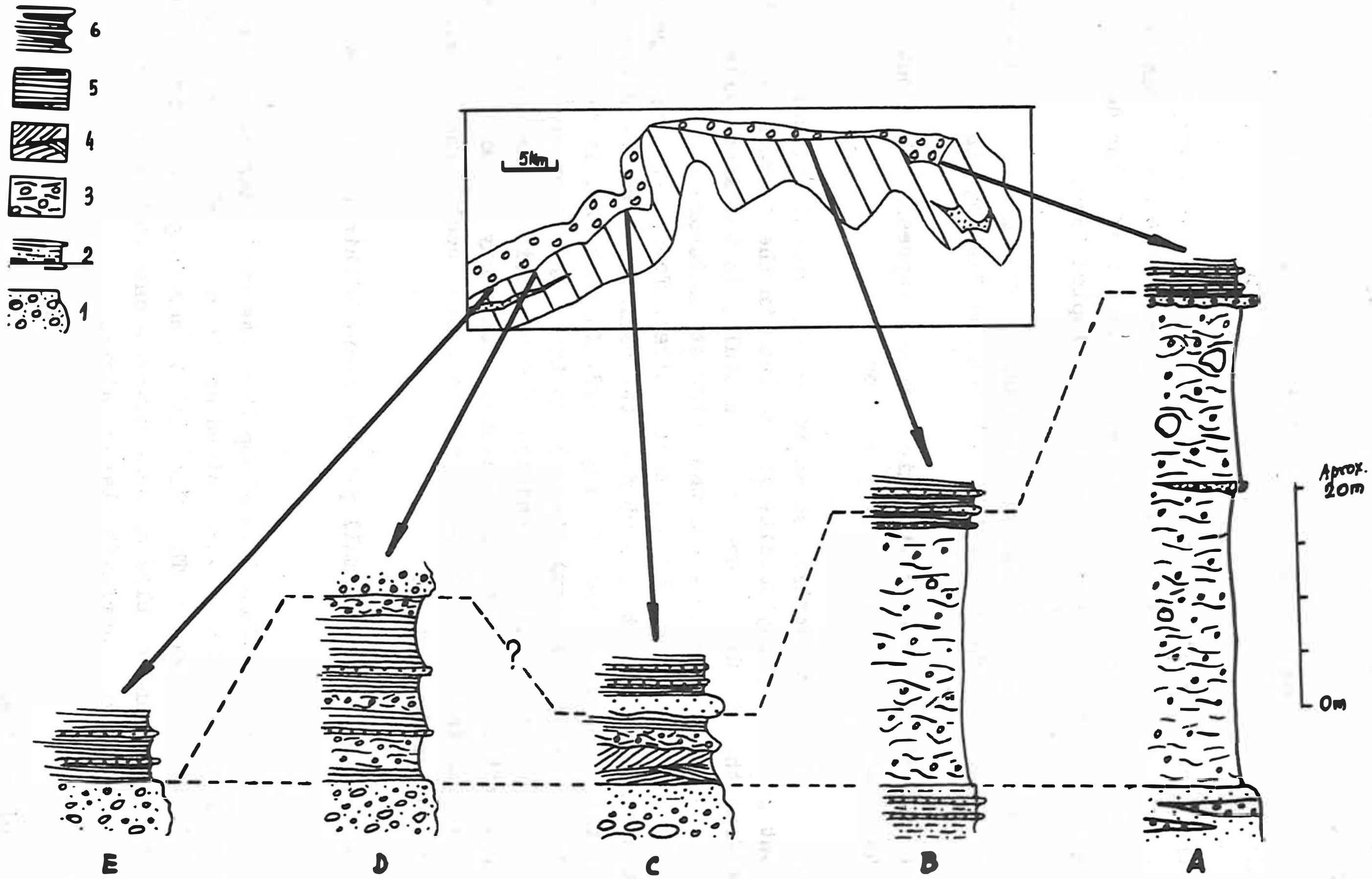


Fig. 5 Areal variation of the Tilloid Conglomerates Level

A - Mierlei Creek (Vîlsan Valley), B - Poienița Creek (Argeș Valley), C - Sălătruc Creek (Olt Valley), D - Muiereasca Valley, E - Olănești Valley

Top of the Basal Conglomerates Horizon: 1 - conglomerates with sandy matrix, 2 - siltic deposits with sandstone intercalations; Tilloid Conglomerate Level: 3 - pebble clay, 4 - marls with slump structure, 5 - normally bedded marls; base of the Marly Horizon: 6 - marls with sandstone intercalations.

Legend of the geological index sketch at Figure 1

DOI:https://doi.org/10.2312/zipe.1982.066

b) tabular type (sandstone beds with sharp and parallel limits, showing no graded bedding);

c) discontinuously graded type (normally graded sandstone bodies with both bedding surfaces sharply defined);

d) continuously graded type (normally graded sandstone units, with clearly cut lower limit and transitional upper limit).

A test to reveal the frequency of the four types of sandstone beds was carried out in the Upper Marls of Doamnei River. The results indicate that the non-graded beds (rippled and tabular) are almost as common as the graded sandstones. The dominant types are represented by the continuously graded beds and the rippled beds.

The sandstone interbeds - graded and nongraded - usually show more or less abundant sole marks, trace fossils, cross and parallel lamination and parting lineation.

The lutites clearly are the dominant lithologic element, representing about 70 % up to almost 100 % in the constitution of the Marly Horizon.

The rhythmic aspect of the Marly Horizon shows important variations, both vertically and laterally. The most pronounced rhythmicity is confined in the eastern part of the Getic Area, starting from the Olt River zone, but especially in the Argeș-Vîlsan zone. Even within these zones the most numerous and the thickest sandstone beds occur in the basal part of the Marly Horizon (or of the two marly units). Toward the upper part of the marly sequence the marls represent 90 - 95 % of the sediments, the sandstone intercalations being rare, thin-bedded and very fine-grained. In contrast, in the western part of the Getic Area (Cheia and Olănești Rivers) the Lower and Upper Marls characteristically show little or practically no sandstone intercalations. These marly members might be lithologically defined as lutaceous sequences with sandy and silty laminae. Most of these laminae are in fact very elongated ripples. Some beds thinner than 1 cm are parallel laminated and graded bedded.

Occasionally lenticular rudites with small pebbles occur within the Getic Paleogene marls.

The marly sequences sometimes include thin slump breccias with characteristic texture and structure. The most important diamictitic episod can be observed in Muiereasca Valley, locally topping the Pucioasa-type marls. The diamictitic lens-shaped body is up to 20 m thick. Blocks (up to 5 m long) and pebbles of quartzites, micaschists and older breccias and conglomerates are embedded in a dominant clayey matrix.

Intermediary rudites and arenites

Two lenticular bodies of arenites and rudites, several hundred meters thick, occur within the Getic Paleogene marls. These are "Corbi Sandstone" in the eastern part of the Getic Area (Vîlsan and Doamnei Rivers), and "Cheia Conglomerates" westward of Olt River.

DOI:https://doi.org/10.2312/zipe.1982.066

The Corbi Sandstone member is in fact about 90 % rudaceous (mostly fine-grained conglomerates), only a small part being represented by fine- to coarse-grained sandstones. The basal part of the sequence is constituted of thick bedded (up to 10 m) coarse-grained conglomerates. Some pebbles are made up of Nummulitic limestones reworked from the underlying Eocene deposits. Toward the upper part the conglomerates become finer grained, associating with more and more sandstones (Fig. 4). At the top of the Corbi Sandstone sequence 10 cm to 150 cm thick sandstone beds alternate with thin (5 - 10 cm) blackish marls.

Gradual lithological transition exists between Corbi Sandstone and the overlying Upper Marls. The passage is realized through the thinning of the sandstone beds, which become intercalations within a dominant marly mass.

The main sedimentary structures of the Corbi Sandstone are represented by sole casts, oblique and parallel laminations, erosional channels, trace fossils, a.s.o. In only one case, toward the upper part of the sequence, it has been observed a structure seeming to represent oscillation, symmetrical ripple marks.

Cheia Conglomerates are well exposed in the area between Cheia and Olăneşti Rivers. Toward the east the conglomeratic sequence is rapidly wedging out and disappearing.

The Cheia Conglomerates are overlying without lithological transition the Lower Marls. The rudaceous sediments are by far the dominant lithotype of the sequence. Due to frequently intercalated thin-bedded sandstones, the bedding and various internal structures are clearly showing up. Medium and large scale cross-bedding as well as erosional channels are common.

At their uppermost part the Cheia Conglomerates display a quite different facies. This facies consists of conglomerates and sandstones alternating with very thin-bedded siltic marls. This rhythmical facies seems to mark the transition to the overlying Upper Marls (Pucioasa-type Marls).

3. Tectonic control of sedimentation

The measurements carried out in the Getic Paleogene deposits point out that the main current directions are represented by (a) transversal paleocurrents flowing southward and (b) longitudinal currents directed toward the east (JIPA 1980).

The lithofacial units of the Getic Paleogene cannot be differentiated from the viewpoint of the main paleocurrent directions. Consequently it appears that the existence of the different Paleogene lithostratigraphic horizons was determined by the up and down movements of the same source area. This source was in a high position when it supplied the rudaceous material of the Basal Conglomerates Horizon. The lowering of the source area determined a drastic reduction in the supply of detrital material. Under such conditions the sediment accumulation was dominantly lutaceous, constituting the Marly Horizon. The sudden uplift of the same source area led to the accumulation of the intermediary coarse-grained units (Corbi Sandstone and Cheia Conglomerates).

DOI:https://doi.org/10.2312/zipe.1982.066

4. Sedimentation environment

Along its cropping out zone (about 100 km long) the Basal Conglomerate Horizon is characterized by important thickness variations, from over 1000 m to several tens of metres. This variation together with the very large scale cross stratification indicate that the Basal Conglomerate Horizon is constituted by a series of submarine fans. The marine character is indicated by the presence of large foraminifera (BOMBIŢĂ et al., in press) and the micropaleontological content of the lutaceous intercalations (POPESCU et al. 1976). According to their position at the contact with the source area the submarine rudaceous fans appear to have been accumulated in shallow water at the margin of a shelf zone.

Corbi Sandstone und Cheia Conglomerates also represent submarine fan deposits.

Marly Horizon includes sediments characteristic to the outer shelf environment. It seems logical to assume that during the inner shelf building up of the rudaceous submarine fans, an outer shelf, marly accumulation was taking place. Consequently the Marly Horizon is probably partly synchronous with the Basal Conglomerates Horizon. During low stand periods of the source area only sediments of the outer shelf type accumulated. This corresponds to the main developement of the Marly Horizon.

The Getic Area represents the south marginal shelf zone of the Paleogene geosyncline of the Eastern Carpathians. This correlation - already assumed in 1941 by MURGEANU - is clearly demonstrated by the paleocurrent pattern of the Getic Paleogene deposits and Sotrile Paleogene formation (JIPA 1980). Consequently the Getic Paleogene deposits cannot be considered a molasse facies. These deposits represent a marginal geosynclinal facies.

References

BOMBIŢĂ, G.; BRATU, E.; GHEŢA, N.; ION, J.; POPESCU, B.: Studiul foraminiferelor mari şi limitele lui în Depresiunea Getică.
Dări Seamă Sedinţ., Bucureşti (in Press)

JIPA, D.: Sedimentological features of the basal Paleogene in the Vîlsan Valley (Getic Area).
Guidebook for the field works of the group 3.3. Published by Institute of Geology and Geophysics, Bucarest (1980)

MURGEANU, G.: Recherches géologiques dans Valea Doamnei et Valea Vîlsanului (Mounténie Occidentale).
C.r. séances Inst. Géol. Roumanie, Bucarest 26 (1941)

POPESCU, B.; BRATU, E.; GHEŢA, N.; POPESCU, D.: Contribuţii la cunoaşterea stratigrafiei formaţiunilor paleogene dintre Olt şi Olăneşti.
Dări de seamă Sedinţ., Bucureşti 62 (1976) 4, p. 265-278

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Erläuterungen zu lithotektonischen Profilen der neogenen Molasse in Nordungarn und in der Großen Ungarischen Tiefebene (Annex 14 - 15)

von

K. HAJDÚ-MOLNÁR[1)] und G. HÁMOR[2)]

Das Pannonische Becken ist an der Westflanke der allmählich aussüßenden und sich in Teilbecken aufspaltenden Paratethys zwischen dem Wiener, dem Grazer, dem Kroatischen und dem Siebenbürgischen Becken entstanden. Eigentlich wird im allgemeinen der zentrale, als Folge miozän-pliozäner Einsenkung entstandene Teil des karpatischen postorogenen Beckenkomplexes als Pannonisches Becken bezeichnet (Abb. 1). Früher nahm man im Untergrund des Pannonischen Beckens - im Gegensatz zur karpatischen mobilen Umgebung - eine seit sehr langer Zeit starre Masse an. Die in letzter Zeit niedergebrachten Tiefbohrungen haben aber diese Vorstellung geändert. Der Bau des Untergrundes, auf dem die molasseähnlichen Sedimente Ungarns lagern, gleicht dem der angrenzenden mobilen Gebiete.

Oligozän

Die Ausbildung molasseartiger Sedimentfolgen beginnt auf dem Territorium Nord-Ungarns im Oligozän.

Das Oligozän liegt zwischen der pyrenäischen und der savischen orogenetischen Phase; die pyrenäischen Bewegungen haben das Sedimentationsbecken präformiert, die savische Phase führte zu einer regionalen Heraushebung am Ende des Oligozäns. Es muß erwähnt werden, daß sich in Verbindung mit der savischen Phase kein Vulkanismus nachweisen läßt, was eine sehr bemerkenswerte Tatsache ist.

[1)] Nehezipari Müszáki Egyetem, Földtan-Teleptani Tanszék; Ungarn, 3515 Miskolc, Egyetemváros
[2)] Ungarische Geologische Anstalt; Ungarn, Budapest XIV, Népstadion út 14

DOI:https://doi.org/10.2312/zipe.1982.066

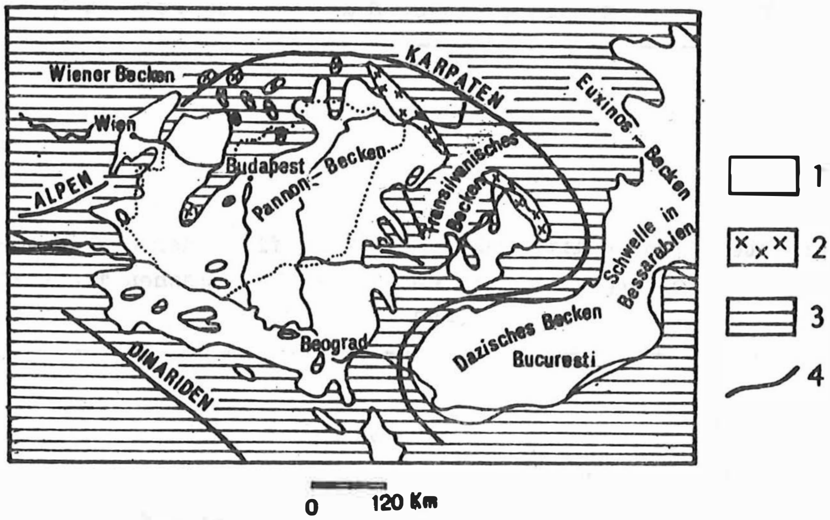


Abb. 1. Lage des Pannon-Beckens zwischen den Teilbecken der Parathetis
1 - pannonische Sedimente, 2 - pannonische Vulkanite, 3 - Festlandgebiete im Pannon, 4 - junges Faltengebirge

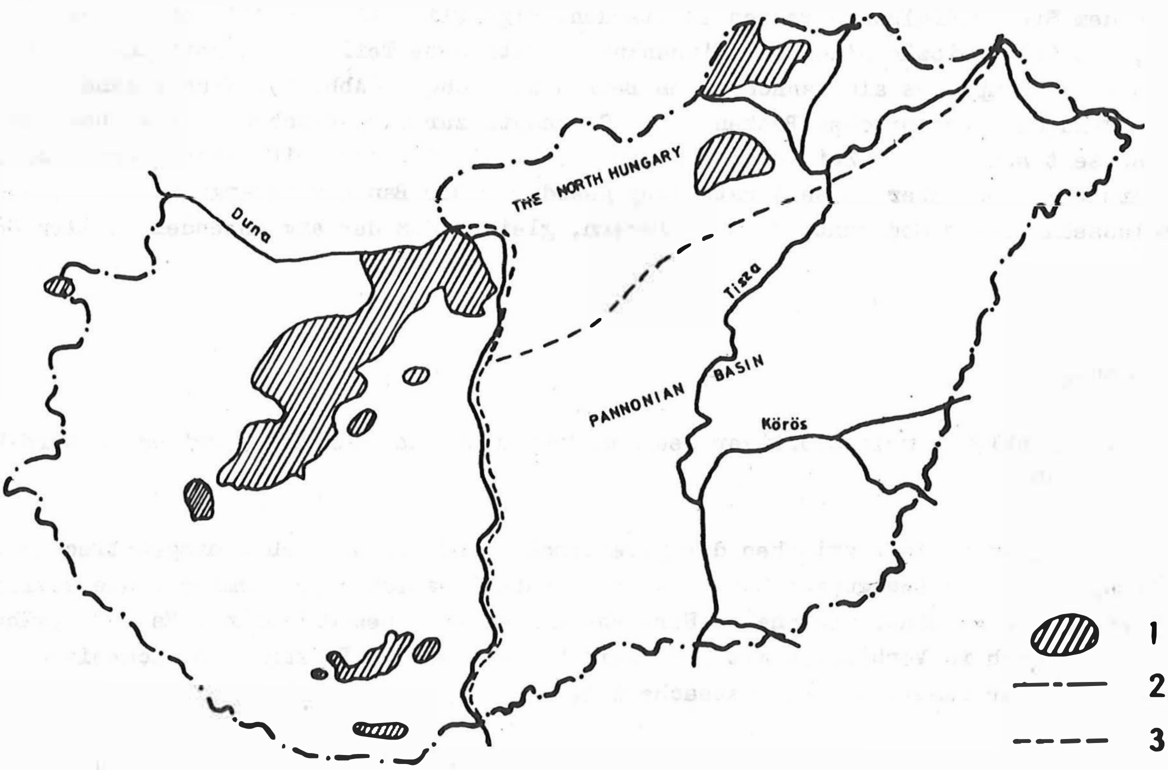


Abb. 2. Lage der lithotektonischen Profile 14 und 15
1 - vor-neogene Schichtfolgen, 2 - Staatsgrenze, 3 - Grenze des Geltungsbereiches der lithotektonischen Profile

DOI:https://doi.org/10.2312/zipe.1982.066

Die Gesamtmächtigkeit der dem oligozänen Zyklus angehörenden Sedimente beträgt nach unseren heutigen Kenntnissen maximal 3500 m.

Die Basisschichten des Zyklus werden von der Hårshegyer Sandsteinformation gebildet, die aus Schotter, Konglomerat und Sandstein besteht. Ein großer Teil des Zyklus wird von der Kisceller Tonformation vertreten, worauf die regressiven Endglieder des Zyklus folgen: die Egerer Formation, die Bérer Aleuritformation (früher chatter Schlier), die Pétervásáraer Formation mit glaukonitführendem Sandstein, die aus limnischen und Sumpfablagerungen bestehende Becskeer Formation und endlich der fluviatile Schotter der Csatkaer Formation.

Abgesehen von den limnischen und terrestrischen Bildungen am Zyklusende liegt der gesamte Zyklus in ununterbrochener mariner Ausbildung vor. Die maximale Wassertiefe entspricht einem bathyalen Milieu. Im oligozänen Sedimentationsbecken ist die vollständige laterale Faziesreihe vertreten; die Sedimente sind im allgemeinen dickbankig, häufig kommen Turbidite mit synsedimentären Gleitstrukturen, in der Mitte des Zyklus Laminite vor. Kalksteinbildungen sind nicht vorhanden.

Das gegenseitige Verhältnis bzw. der Übergang zwischen den im Tiefbecken östlich der Theiß wahrscheinlich vorhandenen Flysch- und den molasseähnlichen Ablagerungen ist z.Z. noch nicht bekannt.

Der oligozäne Zyklus füllt die von den Stufen Rupelien und Egerien vertretene Zeitspanne aus. Das Molassebecken hatte während des Oligozäns zur indopazifischen Region eine ständige, zur borealen Region eine zeitweilige Verbindung.

Miozän

Der kompressive, zur regionalen Heraushebung führende Abschnitt der savischen orogenetischen Phase erreichte seinen Höhepunkt in stellenweise in den Randzonen auftretenden, schuppenbildenden Aufschiebungen. Das führte zur Anlage einer Vortiefe, in die das Meer des Untermiozäns, welches mediterrane, atlantische Verbindungen hatte, mit einer regionalen Diskordanz transgredierte.

Das Untermiozän (Eggenburgien - Ottnangien) besteht aus zwei Sedimentationszyklen.

Der erste Sedimentationszyklus enthält folgende Einheiten: die Basissedimente aus Kalkstein mit Miogypsina (Bretkaer Schichtenglied) oder psammitische Ablagerungen (Schichten mit Großformen von Pecten, Budafoker Formation), in ihrem Hangenden dann die schlierartigen Sedimente mit Amussium, die der maximalen Wasserbedeckung entsprechen (Putnoker Schlierformation).

Der regressive Abschnitt des Zyklus wird durch Deltaablagerungen (Schotter), durch fluviatile Schotter und Konglomerate und durch terrestrische, buntgefärbte Tone gekennzeichnet (Zagyvapálfalvaer Formation, Szászvárer Formation). Bemerkenswert sind die weltbekannten Fährtenfunde (bei Ipolytarnóc) in den flußufernahen Schluffschichten, die den Zyklus abschließen.

DOI:https://doi.org/10.2312/zipe.1982.066

Die maximale Wassertiefe des untermiozänen Sedimentationsbeckens entspricht einem tiefneritischen Milieu, so ist die neritische und die gesamte laterale Faziesreihe nachweisbar.

Die Gesamtmächtigkeit dieses ersten Zyklus beträgt 800 - 1000 m.

Aus sedimentologischer Sicht steht der alpinen Süßwassermolasse die Szászvárer Formation am nächsten. Innerhalb dieser Formation kann man die zyklische und rhythmische Wechsellagerung von Wildbach-, Flußbett-, Hochwasser-, Sumpf- und Seeablagerungen beobachten. Der erste Zyklus wird von drei, aus 30 - 50 Kleinzyklen bestehenden mittleren Zyklen aufgebaut.

Dem zweiten Sedimentationszyklus ging die erste miozäne vulkanische Phase voran (im dilatativen Abschnitt der savischen orogenetischen Phase, entlang offener Klüfte). Ihre gluttuffartigen Förderprodukte lassen sich in den tektonischen Gräben überall nachweisen. Die stellenweise auftretenden schlammstromartigen Bildungen sind der gleichzeitigen fluviatilen Aktivität zuzuschreiben. Das mit der K-Ar-Methode ermittelte absolute Alter des Tuffs beträgt 20 - 21 Millionen Jahre. Den im Alpenvorland und im Siebenbürgischen Becken während des Ottnangien abgelagerten marinen Molasseformationen entsprechen in terrestrischer und epikontinentaler Ausbildung die braunkohleführenden Formationen Ungarns (Salgótarjáner Braunkohleformation und ihre Äquivalente: die Braunkohlen im Mecsek-Gebirge, bei Brennberg und in der Borsodes-Region).

Die Schichtenfolge des Ottnangien bildet einen mit Kohlenbildung beginnenden, nach oben hin mit marinen und Brackwasserablagerungen endenden, unvollständigen Zyklus.

Im Hangenden der Flöze sind die Schichten mit Congeria, Cardium und Fischschuppen charakteristisch. In den östlichen Gebieten, die zum Bildungsraum des Siebenbürgischen Beckens überleiten, enthalten diese Schichten dagegen Ostrea und Corbula.

Die Gesamtmächtigkeit des Ottnangien beträgt maximal 300 m.

Die paläogeographische Situation wird im Untermiozän durch NW--SO streichende tektonische Gräben bestimmt. Die altsteirische orogenetische Phase hat diese paläogeographische Orientation um 90° gedreht; die früheren paläogeographischen Verbindungen wurden unterbrochen und aus dem mediterranen Becken drang die Gransgression des K a r p a t i e n über den Adria-Graben in SW--NO streichende Grabenstrukturen vor.

Zu den untersten Formationen des neuen Zyklus gehören: ein Basalkonglomerat (Ligeterdöer Schotterformation), in küstennahme Milieu abgelagerte Sandsteine mit Chlamys (Egyházasgergeer Formation) und Lumachellenkalke, die im SW aus Congerien, im NO aus Rzehakien bestehen. Der transgressive Zyklus kulminiert in schlierartigen Formationen (Garáber Schlierformation, Tekereser Schlierformation), deren Mächtigkeit 800 - 900 m beträgt. Die Wassertiefe war 180 - 200 m, also neritisch bis subneritisch. Der Zyklus wird dann wieder durch küstennahe Ablagerungen abgeschlossen - Riffkalke mit Bryozoen und Balanus (Fóter Formation) und zuletzt Süßwasserablagerungen mit Limnaea.

DOI:https://doi.org/10.2312/zipe.1982.066

Das Karpatien wird aus fünf mittleren und 13 Kleinzyklen aufgebaut.

Während der Kulmination des Zyklus sind Laminite, Anzeichen von Schlammrutschungen, fluxoturbiditartige und von wühlenden Bodentieren verursachte, ungeschichtete, gestörte Sedimentstrukturen häufig. In der regressiven Phase des Zyklus sind Trockenrisse und im letzten Stadium der Heraushebung Wurzelstrukturen zu beobachten.

Am Zyklusende spielt sich (schon als Folge des kompressiven Auftaktes der einsetzenden neusteirischen orogenetischen Phase) ein Dazit-Rhyodazit-Vulkanismus mit explosiven Aschenwolkenprodukten ab. Die infolgedessen in großer räumlicher Verbreitung auftretenden Tuffschichten (der "mittlere Rhyolittuff", dessen mit der K-Ar-Methode bestimmtes absolutes Alter 16 - 17 Millionen Jahre beträgt) geben einen ausgezeichneten Anhaltspunkt zur paläogeographischen Korrelation. Die Mächtigkeit der Tuffdecke liegt zwischen 2 und 120 m.

Der dilatative Abschnitt der neusteirischen orogenetischen Phase hatte die Ausweitung der schon früher angelegten Grabenstrukturen und damit die sogenannte erste Transgression des B a d e n i e n zur Folge. Charakteristische Ablagerungen aus dieser Zeit sind der "untere Leithakalk" und der Badener Tegel (Nógrádszakáler Formation, Heterosteginenmergel). Dieser Zyklus des Unterbadenien hat sich nur bis zu seiner absinkenden Phase entwickelt, dann wurde er von dem Einsetzen der Leithaer orogenetischen Phase unterbrochen.

Die vulkanische Tätigkeit am Anfang dieser Phase hat zur Ausbildung der nordungarischen stratovulkanischen Glieder des innerkarpatischen vulkanischen Gürtels geführt. Die Gesamtmächtigkeit der vulkanischen Serie beträgt mehr als 2000 m. Sie besteht überwiegend aus rein kontinentalen stratovulkanischen Bildungen, doch kann man in den Randgebieten des Sedimentationsbeckens auch mit marinen Ablagerungen verzahnte Partien finden. Die K-Ar-Methode ergab für das Alter der vulkanischen Formation 14 - 15 Millionen Jahre.

Gleichzeitig setzte der Zyklus des Oberbadenien mit der Ablagerung von Braunkohleformationen ein (Hidaser, Herender, Várpalotaer Formation). Der Kulmination des Zyklus entsprechen der "obere Leithakalk" (Fertörákoser Formation) und pelagische heteropische Sedimente (Szilágyer Tonmergelformation). Die regressive Phase des Zyklus wird durch mesohaline Grobkalke bzw. Tonmergel mit Limnocardium vertreten (Kozárder, Tinnyeer Formation), die schon zum S a r m a t i e n gehören. Zuletzt folgen Süßwasserablagerungen der fluviatilen und lakustrischen Fazies (Sajóvölgyer Formation).

In Wechsellagerung mit den Sedimenten des sarmatischen, regressiven Teiles des Zyklus treten die Produkte des dilatativen Abschnitts der Leithaer orogenetischen Phase auf (Tokajer Formation und die Galgavölgyer Rhyolittuff-Formation), der "obere Rhyolittuff". Dieser besteht teils aus Gluttuff, teils aus einer an Grabenstrukturen gebundenen stratovulkanischen Serie. Das absolute Alter dieser Bildungen beträgt 12 - 13 Millionen Jahre.

Der zweite Sedimentationszyklus der Leithaer orogenetischen Phase wird von der "u n t e r p a n n o n i s c h e n" F o r m a t i o n gebildet, die bei einer mit der

DOI:https://doi.org/10.2312/zipe.1982.066

Sedimentation Schritt haltenden Absenkung des Untergrundes in brackigem und in kontinentalem Tiefseemilieu abgelagert worden ist. Ihr Alter kann noch als Miozän betrachtet werden.

Die vollständige Aussüßung wird durch die Makrofauna mit Congerien und Limnocardien, sowie durch das Fehlen einer Mikrofauna angezeigt.

Die Gesamtmächtigkeit der Ablagerungen der beiden Sedimentationszyklen der Leithaer orogenetischen Phase beträgt insgesamt etwa 1800 - 2000 m. Dazu kommt noch in ihren Ausbildungsräumen die 2000 m übersteigende Mächtigkeit der vulkanischen Formation.

Der erste Zyklus wird von litoralen-subneritischen Wassertiefen, von Saum- und Waldriffbildungen und von pelagischen Flachseeablagerungen (etwa 60 m) gekennzeichnet.

Das Unterpannon (zweiter Zyklus) gehört im allgemeinen der Flachseefazies an (Wassertiefe maximal 30) und weist Strömungsstrukturen, autigene Intraklasten und Anzeichen von Kompaktion auf.

Hinsichtlich der paläogeographischen Verhältnisse war die Unterbrechung des über die Dinariden führenden Transtethys-Korridors im Sarmat das entscheidendste Ereignis. Von diesem Zeitpunkt an bestanden paläogeographische Verbindungen nur noch über ein schwer nachweisbares Kanalsystem zum euxinischen Becken des Aral- und Kaspi-Sees.

Pliozän

Die Kompressionwirkung der rhodanischen orogenetischen Phase hat zu beträchtlichen seitlichen Einengungen geführt; diesem Umstand kann die lokal expansive Lagerung der "o b e r p a n n o n i s c h e n" F o r m a t i o n e n zugeschrieben werden, in denen sich infolge der rhodanischen Phase ein vollständiger Sedimentationszyklus ausgebildet hat, mit Basisschichten (Abrasionsschotter und -konglomerat), mit pelagischen und Süßwasserablagerungen, mit regressiven, im Süßwasser- und Sumpfmilieu entstandenen Lignitformationen, die die Heraushebung am Zyklusende andeuten, und zuletzt mit fluviatilen Schottern und Tonbildungen.

Ein charakteristisches Merkmal der den Zyklus aufbauenden Schichten ist die zyklische Wechsellagerung des durch Strömungen im Becken verteilten Sedimentmaterials verschiedener Korngröße: von Sand, Schluff und Ton.

Die Gesamtmächtigkeit der Schichtenfolge beträgt etwa 1500 - 3000 m.

Von der rhodanischen orogenetischen Phase wurde der finalen Charakter tragende Basaltvulkanismus des neogenen vulkanischen Zyklus ausgelöst; sein Alter beträgt 4,5 Millionen Jahre.

Die paläogeographischen Verbindungen entsprechen bis zur Kulmination des Zyklus den Verhältnissen, die im Unterpannon geherrscht haben; zur Zeit des regressiven Zyklusab-

DOI:https://doi.org/10.2312/zipe.1982.066

schnitts sind der heutigen orographischen Lage entsprechend abflußlose Sümpfe und aus den Karpaten herabziehende Schuttkegel charakteristisch.

Die geographische Lage der lithotektonischen Profile ist aus Abb. 2 ersichtlich.

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Объяснительная записка к литотектоническому разрезу неогеновой молассы Благоевградского грабена (Болгария) (комментарии к приложению I6)

Панайот Г. БАКАЛОВ[I)]

Благоевградский граоен расположен на территории Юго-Западной Болгарии между г.Станке Димитров и г.Благоевградом. С востока он ограничен Западнорильским разломом (БОЯДЖИЕВ I97I а), с запада - Струмским (БОЯДЖИЕВ I97I б), с юга - Димовским (ЗАГОРЧЕВ I970) а с севера - Станкедимитровским (рис. I).

Данные о геологическом строении грабена опубликованы в ряде работ (BOUÉ 1840; HOCHSTETTER 1870 ; ЗЛАТАРСКИ I885, I927; КОНЯРОВ I932; Е. БОНЧЕВ I960; БАКАЛОВ I977, I978, I979; и др.).

Отложения, выполняющие грабен, хорошо обнажены в многочисленных оврагах. Их обнажённость вполне достаточна для детального исследования и для корреляции разрезов. В морфологическом отношении грабен - это хорошо выраженная в рельефе межгорная ассиметричная впадина с высоким восточным бортом (гора Рила) и с низким западным, в котором выделяется гора Влахина.

I. Общие данные о тектоническом строении и палеогеографическо-палеотектоническом развитии области молассового бассейна и её смежных регионов

Благоевградский грабен, в согласии со взглядами Е. БОНЧЕВА, оформлен в Краиштидной линеаментно-геосинклинальной зоне, которая заложена на Фракийском срединном массиве, а массив расположен между северной и южной ветвями Альпо-Гималайского орогена на Балканском полуострове. Краиштидная зона является частью трансевропейского Краиштидно-Вардаридного линеамента, который, начиная с рифта Красного моря, прослеживается через всю Европу в северо-западном направлении до Среднегерманской главной линии включительно (Е. БОНЧЕВ I97I, I974).

Последнее складкообразование в Краиштидах установлено в отложениях палеогена (Е. БОНЧЕВ I97I; и др.). После него наступает период осушения и оформляется пенеплен.

I) Висший горно-геологический институт, Кафедра геологии и палеонтологии; Болгария, II56 София, Дырвеница

DOI:https://doi.org/10.2312/zipe.1982.066

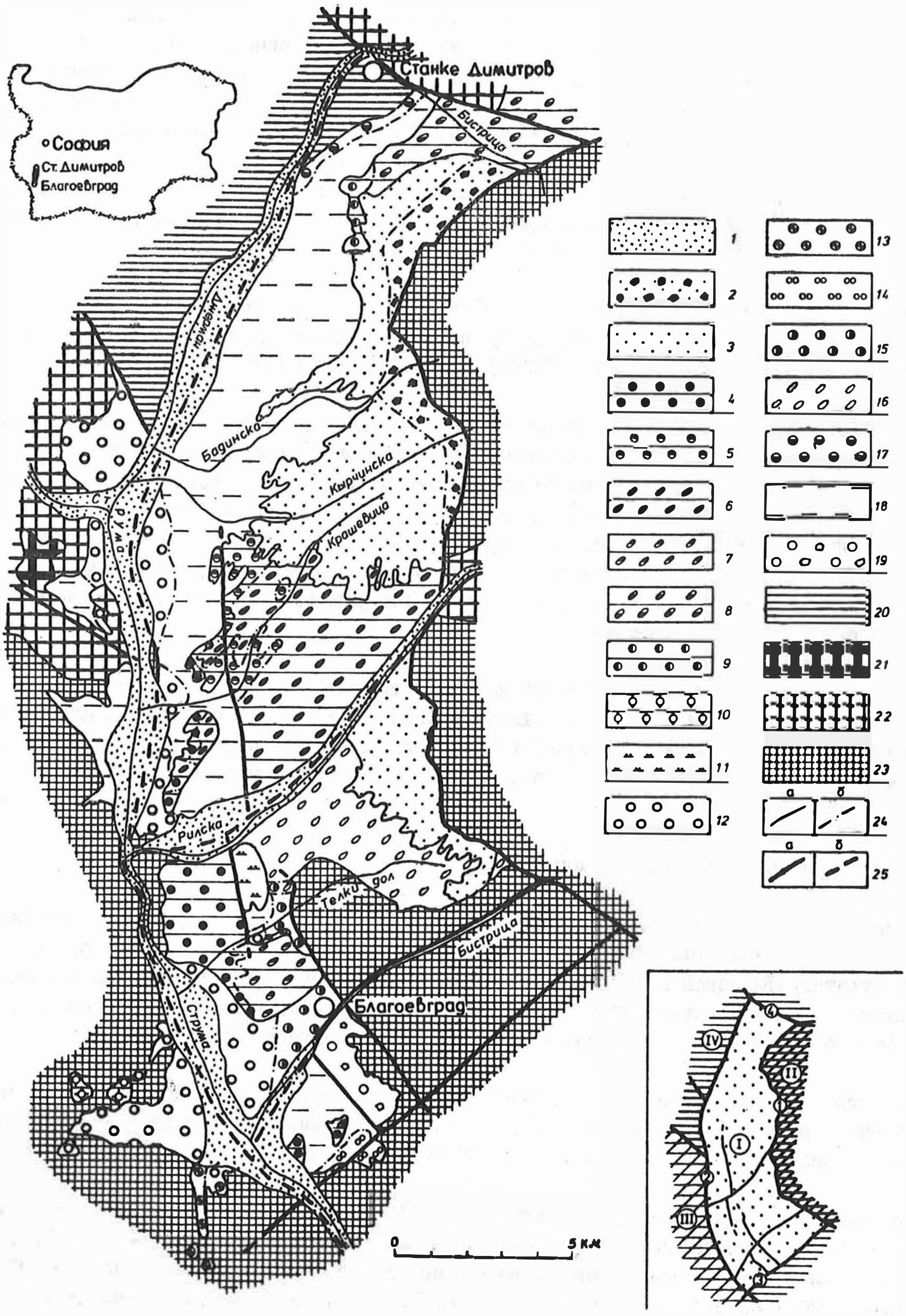
Рис. I. А. Геологическая карта Благоевградского грабена

I - голоцен, отложения русел и заливных террас,
2...3 - Бадинская свита, плейстоцен - вероятный вилафранк,
2 - Кырчинский член, 3 - Лешовский член,
4...I0 - Бараковская свита,
4 - Чапрашлыкский член, 5 - Мурсалевский член,
6 - Кочериновский член, 7 - Чифликчийский член,
8 - Бистрицский член, 9 - Беловодский член,
I0 - Селишкий член,
II - Топузишская свита,
I2...I7 - Покровникская свита, понт,
I2 - Драгоданский член, I3 - Поповский член,
I4 - Айдаревский член, I5 - Телкидолский член,
I6 - Пороминовский член, I7 - Злевскидолский член,
I8 - Джерманская свита, понт,
I9 - Эминовская свита, понт,
20 - моласса Бобовдолского грабена, палеоген,
2I - карбонатные породы и песчаники, триас,
22 - Струмская диоритовая формация и диабазово-филлитоидный комплекс, палеозой,
23 - метаморфические породы высокой ступени метаморфизма, докембрий,
24 - геологические границы
а - между породами разного возраста, б - между породами одного и того-же возраста,
25 - разломы
а - видимые на поверхности, б - захороненые

Б. Тектоническая схема
Номерами обозначены блоки и разломы ограничивающие Благоевградский грабен

I...IV - блоки
I - Благоевградский грабен, II - Рильский горст,
III - Лисийский горст, IV - Бобовдолский грабен,
1...4 - разломы, ограничивающие Благоевградский грабен,
1 - Западнорильский, 2 - Струмский, 3 - Димовский,
4 - Станкедимитровский

DOI:https://doi.org/10.2312/zipe.1982.066



А

Б

DOI:https://doi.org/10.2312/zipe.1982.066

Неогеновым блоковым расчленением этого пенеплена начинается неотектонический этап. В качестве новых структур, наложенных на более древние, начинают погружаться блоки Струмского грабенового комплекса (MOSKOVSKI 1969), в состав которого и входит Благоевградский грабен. Погружения компенсируются и даже перекомпенсируются континентальными молассовыми отложениями максимальной мощностью более 1600 м. Чётко выявляется тенденция более интенсивного воздымания восточных обрамляющих блоков по сравнению с западными. Наименее выразительное и, по всей вероятности, эпизодическое воздымание испытывали поперечные горсты, разделяющие грабены комплекса. Максимальная амплитуда вертикальных движений - 3500 м (MOSKOVSKI 1969).

Только в южных грабенах комплекса - в Санданском и Струмешницком, установлены проявления магматической деятельности, синхронной с осадконакоплением (туфы кислого состава и феноандезитовые порфириты - ПЕТРОВ 1960; МОСКОВСКИ 1971).

Отложения в грабеновом комплексе залегают горизонтально или моноклинально, погружаются на восток с максимальным наклоном в 40°. Буровыми скважинами установлено, что они залегают на блоково-денивелированном основании, и что их мощность увеличивается вкрест простирания грабенов - с запада на восток (её максимальные значения установлены около восточной границы грабеновой структуры) и вдоль грабенов - от обеих периферий к центральным частям. Выявляется сопряжённость вертикальных движений: максимальным воздыманиям горстов соответствуют максимальные погружения в грабенах, а минимальным воздыманиям - минимальные погружения.

Контрастность вертикальных движений на неотектоническом этапе, значительная мощность неогеновых отложений, большие относительные возвышения и возвышения над уровнем моря дают основание отнести Струмский грабеновый комплекс и прилежащие к нему территории к орогенным областям интенсивного горообразования в смысле ШУЛЬЦА (1979).

2. Общие данные о литотектоническом разрезе

Типовой разрез отложений, выполняющих Благоевградский грабен (прил. 16), составлен путём обобщения данных по естественным обнажениям. По своей сущности этот разрез является стратиграфической колонкой. В ней, кроме последовательности пластов и характера контактов между стратиграфическими единицами, приведены литологические данные, а также некоторые данные палеогеографического и тектонического характера.

Выделить биостратиграфические единицы невозможно, так как останки фоссилий встречаются очень редко. Тем не менее есть достаточные основания утверждать, что грабен заполнялся в диапазоне понт - вилафранк (ЗЛАТАРСКИ 1927; БАКАЛОВ и др. 1977).

Совокупность пород Благоевградского грабена ограничена несогласиями и представлена горизонтальными и моноклинально погружающимися на восток пластами (БАКАЛОВ 1977). Нижнее несогласие - угловое. В складчатом основании грабена самые молодые породы - палеогеновые. Верхнее несогласие совпадает с ещё незаконченным региональным послевилафранкским размывом. Кроме того, выявляются ещё три параллельных несогласия более высокого ранга. Они разделяют породы грабена на четыре подсовокупности разного возраста.

DOI:https://doi.org/10.2312/zipe.1982.066

В них выделены свиты (formation - по ISSC 1972). Самая древняя подсовокупность расчленена на три свиты (БАКАЛОВ 1978), а каждая из остальных подсовокупностей представлена одной единственной свитой (БАКАЛОВ 1979). В соответствии с литостратиграфическим расчленением самая верхняя свита - Бадинская - преимущественно брекчиевая и брекчиево-конгломератовая, мощностью до 500 м; возраст - плейстоценовый, по всей вероятности - - вилафранкский. Под ней располагается Бараковская, преимущественно конгломератовая свита, мощностью до 300 м. Вниз по разрезу последовательно выделяются: Топузишская свита - пёстроцветная, преимущественно песчанисто-алевритовая и песчанисто-глинистая, мощностью до 50 м, и располагающиеся в основании разреза три свиты одного и того же возраста: Покровникская (преимущественно конгломератовая), Джерманская (преимущественно песчанисто-глинистая) и Эминовская (преимущественно брекчиево-конгломератовая). Возраст этих трёх свит - понтийский, а суммарная мощность не превышает 400 м.

В перечисленных свитах, на основании наличия или отсутствия пластов, выделены два типа пачек:

1. неслоистый тип, представленный только одним видом. Он характерен только для брекчий;
2. слоистый тип, представленный четырьмя видами:
   а. брекчиево-конгломератово-глинисто-песчанистый вид. Это песчанистые глины с псефитами (> 1 мм), реже - без псефитов. Они чередуются с брекчиевыми конгломератами с валунами или без валунов (> 10 см), а местами - с конгломератами (1 - 10 см) - тоже с валунами или без валунов и в редких случаях - с песчаниками (1 - 0,1 мм), которые содержат или не содержат псефитовую составляющую;
   б. конгломератовый вид. Его пласты сложены только конгломератами, которые нередко содержат валуны;
   в. песчанисто-конгломератовый вид. Он представлен конгломератами с или без валунов, включающими песчаники с псефитами или без псефитов;
   г. конгломератово-песчанисто-глинистый вид. Представлен песчанистыми глинами с псефитами или без псефитов и конгломератами преимущественно без валунов, а также песчаниками с псефитами или без псефитов.

Мощность отдельных пластов непостоянна. Породы слагают плоские линзы с мощностью не более нескольких метров и длиной (на горизонтальной плоскости), редко превышающей 100 м. При исследовании вертикальной последовательности пластов выявляется весьма изменчивая по латерали цикличность (в понимании ДАФФА и др. 1971). Отдельные виды слоистых пачек различаются между собой по характеру цикличности (рис. 2). При выделении циклов приняты следующие условные обозначения для пластов:

A^{BC} - пласты брекчиевых конгломератов с валунами;
A - конгломератовые пласты с валунами;
B^{BC} - пласты брекчиевых конгломератов без валунов;
B - пласты конгломератов без валунов;
C - песчаниковые пласты с псефитами или без псефитов;
D - песчанисто-глинистые пласты с псефитами;
E - песчанисто-глинистые пласты без псефитов.

Вариации в составе A^{BC}, A, B^{BC}, B, C и D отражены при помощи индексов рис. 2. В качестве горизонтов-реперов, заканчивающих циклы, выбраны: D - для брекчиево-конгломератово-

DOI:https://doi.org/10.2312/zipe.1982.066

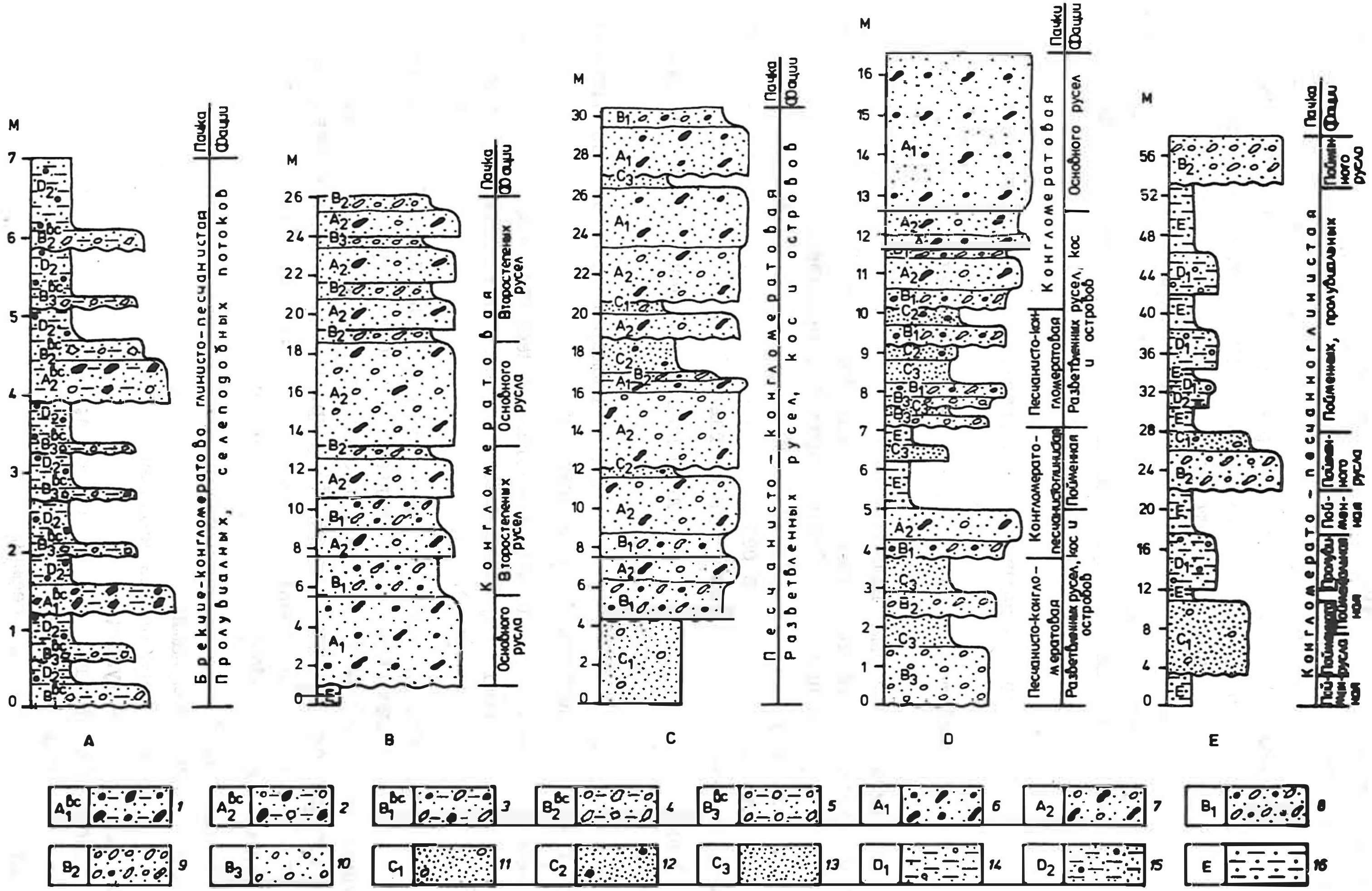


Рис. 2. Разрезы, иллюстрирующие характер циклов. Отдельные циклы выделены более толстой линией

I... 2 – брекчиевые конгломераты с валунами: I – с валунами более I0 %, 2 – с валунами менее I0 %,
3... 5 – брекчиевые конгломераты: 3 – крупнообломочные, 4 – среднеобломочные, 5 – мелкообломочные,
6... 7 – конгломераты с валунами: 6 – с валунами более I0 %, 7 – с валунами менее I0 %,
8...I0 – конгломераты: 8 – крупнообломочные, 9 – среднеобломочные, I0 – мелкообломочные,
II...I3 – песчаники: II – с обломками гальки, I2 – с гравийными обломками, I3 – без псефитовых обломков,
I4...I6 – песчанистые глины: I4 – с обломками гальки, I5 – с гравийными обломками, I6 – без псефитовых обломков

DOI:https://doi.org/10.2312/zipe.1982.066

-глинисто-песчанистых пачек; В - для конгломератовых пачек; С - для песчанисто-конгломератовых пачек и Е - для конгломератово-песчанисто-глинистых пачек. Установлены следующие циклы: $A^{BC}D$, $A^{BC}B^{BC}D$, $B^{BC}D$, AB, BAB, AC, BC, ABC, BABAC, CE, DE, BCE, BAE. Чаще всего встречаются: $B^{BC}D$ - в брекчиево-конгломератово-глинисто-песчанистых пачках; AB - в конгломератовых пачках; BC - в песчанисто-конгломератовых пачках и DE - в конгломератово-песчанисто-глинистых пачках.

Осадконакопление происходило в условиях аллювиальной равнины. Данные, доказывающие это предположение, приводятся при описании литостратиграфических единиц. Образование циклов в брекчиево-конгломератово-глинисто-песчанистых пачках (рис. 2, А) обусловлено кратковременными сезонными потоками селеподобного характера. Об этом свидетельствует не только плохая сортировка пород, но и плохая, по существу, окатанность содержащихся в них обломков. В породах этого вида седиментационные циклы имеют прогрессивный характер. Временные потоки были самыми бурными в начале своего развития, и на этом этапе своего существования оформлялся пласт A^{BC} (или B^{BC}). После быстрого спада их энергии отлагался пласт D. Местами в пластах A^{BC} (или B^{BC}) наблюдается обратная последовательность осадконакопления: обломочный материал делается всё более грубым снизу вверх. В таких случаях поверх пласта с обратной последовательностью залегает другой, тоже грубообломочный пласт, но с нормальной последовательностью. По данным ПОПОВА и др. (1956) обратная последовательность наблюдаемого типа связана с "выносом тонких осадков водяными струями, отжатыми из грязевой массы после остановки потока".

Образование конгломератовых пачек происходило в условиях значительной энергии потоков. В связи с этим и отлагались только грубообломочные породы. Наблюдаемые в них циклы (рис. 2, В) показывают, что на одном и том же участке энергия изменялась со временем. Эти изменения связываются (ДАФФ и др. 1971) главным образом с латеральной миграцией речных русел, что хорошо объясняет территориальную невыдержанность циклов. Всё же не следует полностью исключать влияние и такого фактора, как количество дождей, так как с ним непосредственно связан режим потоков.

В более спокойных русловых условиях происходило формирование песчанисто-конгломератовых пачек. В их циклах (рис. 2, С) появляются песчаники, которые, по всей вероятности, являются отложениями фации кос и островов.

Циклы конгломератово-песчанисто-глинистых пачек (рис. 2, Е) отражают сложные, непостоянные гидродинамические режимы больших заливных террас. В этих условиях, наряду с песчанистыми глинами без псефитов, отлагаются песчанистые глины с псефитами, и реже - песчаники и конгломераты. По всей вероятности, по обширным заливным террасам (пласты Е) проходили небольшие временные (пласты D) и небольшие постоянные (пласты В и С) потоки с непостоянной энергией.

3. Описание литостратиграфических единиц

Литостратиграфическое расчленение пород, выполняющих Благоевградский грабен, уже опубликовано (БАКАЛОВ 1978, 1979). Дешифровка палеогеографической обстановки выявляет существование древних рек. В связи с этим при обозначении древних рек используются

DOI:https://doi.org/10.2312/zipe.1982.066

наименования литостратиграфических единиц и приставки (в согласии с предотавлениями ГОРЕЦКОГО 1964) "палео" для плиоценового и"пра" - для вилафранкского возраста.

Цвет брекчий и брекчиевых конгломератов - коричневый до жёлтого; конгломераты, гравелиты и песчаники - жёлтые; песчанистые алевролиты и песчанистые глины - серо--зелёные, реже - жёлтые. Исключением являются пёстроцветы, которые часто окрашены в красный цвет. Степень литификации всех пород - слабая или средняя; сортировка - плохая. Пласты (толщиной от нескольких десятков сантиметров до нескольких метров) отличаются невыдержанностью, чёткими или нечёткими контактами, наличием или отсутствием эрозионных неровностей. Отложения неслоисты или имеют перерывистую непараллельно-волновидную слоистость. Разнонаправленная волновидно-косая слоистость характерна только для части конгломератов, гравилитов и песчаников. В таких случаях серии имеют толщину от нескольких десятков сантиметров до двух метров, а отдельные слойки - от нескольких до пятидесяти сантиметров. В обломках представлены свежие или выветрелые (в средней или сильной степени) породы. Их форма в брекчиях - угловатая или совсем угловатая, в брекчиевых конгломератах переходит к угловато-окатанной, а в конгломератах - преимущественно угловато-окатанная. В брекчиях и брекчиевых конгломератах представлены все фракции, но ни одна из них в количестве более 50%. При этом глинисто-песчанистая масса всегда превышает 30%. Часто отмечается отсутствие блоков, а местами и валунов. В конгломератах количество валунов - не более 20%, гальки - от 20 до 60%, гравия - от 10 до 30%, песчанистой фракции - от 15 до 30%, алевритовой - от 1 до 30% и глинистой - до 2%. В песчанистых алевролитах и песчанистых глинах псефитовые обломки встречаются в количестве не более 20%, песчанистая фракция - от 20% до 40%, алевритовая - - от 20 до 70% и глинистая - от 20 до 60%. В петрографическом отношении псефитовые обломки отдельных литостратиграфических единиц различаются. Их мы рассмотрим дополнительно. Псамитовые зёрна представлены кварцем, полевыми шпатами, мусковитом и биотитом. В красноцветных породах полевые шпаты отсутствуют.

Нормальная последовательность литостратиграфических единиц (снизу вверх) выглядит следующим образом: Эминовская, Джерманская и Покровникская свиты (одного и того же возраста); более молодая Топузишская свита; ещё более молодая - Бараковокая и самая верхняя - Бадинская свита.

Эминовская свита

Эминовская свита установлена к югу от г.Благоевграда (рис. 1). Если удаётся проследить её захороненные части, то выявляется, что она состоит из перерывистых по латерали тел, приуроченных к периферии грабена. Свита сложена полимиктовыми брекчиевыми конгломератами без валунов с прослоями глинистых песчаников. Их цикличность относится к типу А (рис. 2), но валуны отсутствуют. Обломки псефитовых размеров представлены пёстрыми и лейкократовыми гнейсами, пегматитами, кварцем и амфиболитами.

Свита залегает на метаморфических породах, её ничто не перекрывает, а контакт с Джерманской свитой проходит по разлому. Испытавший воздымание блок сложен метаморфическими породами высокой степени метаморфизма и отложениями Эминовской свиты, а в погруженном обнажается Джерманская свита, которая, по всей вероятности, перекрывает

DOI:https://doi.org/10.2312/zipe.1982.066

Эминовскую и связана с ней литологическим переходом.

Джерманская свита

Джерманская свита представлена прерывающимися по латерали телами с одними и теми же литологическими особенностями, стратиграфическим положением и возрастом. Они заполняют пространство между отдельными членами (member по ISSC 1972) Покровникской свиты и местами полностью их перекрывают. Свита сложена, главным образом, песчанистыми глинами. Их переслаивают песчаники, гравелиты и конгломераты без валунов. Состав всех пород - полимиктовый. Цикличность относится к типу Е (рис. 2). В псефитовых обломках отмечено присутствие лейкократовых гнейсов, амфиболитов и , совсем редко, красных песчаников нижнего триаса.

Джерманская свита залегает на складчатых доплиоценовых породах; по латерали и, до некоторой степени, по вертикали она замещает Покровникскую, и, по всей вероятности, Эминовскую свиту. Перекрывают её с параллельным несогласием остальные три свиты: Топузишская, Бараковская и Бадинская.

В отложениях Джерманской свиты установлены пыльцевые комплексы нижнеплиоценового возраста. Он уточнён как понт, благодаря останкам ископаемых млекопитающих (БАКАЛОВ и др. 1977).

Покровникская свита

Покровникская свита слагает геологическое тело сложной конфигурации. Оно состоит из сочленённых отдельных вытянутых и веерообразных тел, совокупность которых напоминает отложения реки и её притоков. Каждое из этих составляющих тел отличается от остальных по петрографическому набору пород, представленных в псефитовых обломках. На основании этого свита разделена на шесть членов. Один из них (с самым разнообразным петрографическим характером обломков) прослеживается вдоль всего грабена. Это Драгоданский член, который выделен в качестве главного. Остальные члены: Поповский, Айдаревский, Телкидолский, Пороминовский и Злевскидолский.

Покровникская свита сложена, главным образом, полимиктовыми конгломератами. Они встречаются самостоятельно или в комбинации с песчаниками, а местами - и с песчаниками и песчанистыми глинами. Количество валунов и крупной гальки уменьшается по направлению к главному члену, а в нём самом - с юга на север. Направление падения обломков в главном члене южное, а в остальных - к обрамлению грабена. Цикличность относится к типу В или С (рис. 2). На периферии конгломератовых тел она переходит в тип Е или D.

В псефитовых обломках Злевскидолского члена представлены только породы Струмской диоритовой формации и диабазово-филлитоидного комплекса. Набор пород в обломках всех остальных членов состоит из метаморфических пород высокой степени метаморфизма (гнейсы пёстрого и лейкократового облика, пегматиты, амфиболиты). Тем не менее, чле-

DOI:https://doi.org/10.2312/zipe.1982.066

ны различаются или по присутствию одного характерного компонента, или по специфическим количественным соотношениям остальных. Только в Драгоданском члене устанавливаются обломки розово-красных гранитов; в Поповском - амфиболитовых гранитов; в Пороминовском - биотитовых гранитов. Обломки Айдаревского и Телкидолского членов сложены только метаморфическими породами, но в первом из них количество амфиболитов превышает 20%, а во втором оно не более I - 3%.

Покровникская свита залегает с угловым несогласием на складчатых доплиоценовых породах. Она образована одновременно с Джерманской и Эминовской свитами. На них с параллельным несогласием располагаются Топузишская, Бараковская и Бадинская свиты.

Эминовская, Джерманская и Покровникская свиты - это три литофации, образованные в условиях аллювиальной равнины.

Брекчиево-конгломератовая Эминовская свита приурочена к обрамлению грабена. Для неё характерны: низкая степень окатанности обломков и присутствие глинисто-песчанистой массы всегда в количестве более 30%. Эти особенности, а также характер цикличности, показывают, что она является продуктом временных потоков селеподобного характера.

Сложное, вытянутое вдоль грабена тело конгломератовой Покровникской свиты латерально сочленяется с веерообразными поперечными к нему телами. Эта особенность, а также преимущественно угловато-окатанные обломки, небольшое количество глинистой фракции (не более 2%), тип цикличности, характер изменения зернометрического состава и имбрикации показывают, что Покровникская свита сложена русловыми отложениями. Главная палеорека текла в северном направлении. Её существование отмечено продольным к грабену конгломератовым телом. Остальные конгломератовые тела отложены палеопритоками, как правило, поперечными к простиранию грабена (рис. 3).

Песчанисто-глинистые тела Джерманской свиты занимают пространство между членами Покровникской свиты. Они образованы в результате заливно-террасовой аккумуляции. Невыдержанные песчанистые и конгломератовые пласты среди них показывают, что по поверхности заливных террас блуждали маленькие потоки.

Существование временных палеопотоков селеподобного характера и постоянных палеопотоков с отложениями, содержащими грубопсефитовые фракции, показывает, что в непосредственной близости с аллювиальной палеоравниной, развитой на грабене, располагался сильно расчленённый палеорельеф. Его следует связывать с интенсивными блоковыми движениями. Главная палеорека была приурочена к западной окраине грабена и текла в северном направлении. Из этого следует, что поверхность аллювиальной палеоравнины имела поперечный наклон - к западу и продольный - к северу. Поперечный наклон был связан с увеличивающейся в восточном направлении перекомпенсацией грабена, что, в свою очередь, было обусловлено быстрым воздыманием Рильского горста. Продольный наклон являлся следствием существования поперечного палеоводораздела в Струмском грабеновом комплексе. Он располагался на месте того небольшого горста, который отделяет сейчас Благоевградский грабен от находящегося к югу от него Ораново-Симитлийского грабена.

DOI:https://doi.org/10.2312/zipe.1982.066

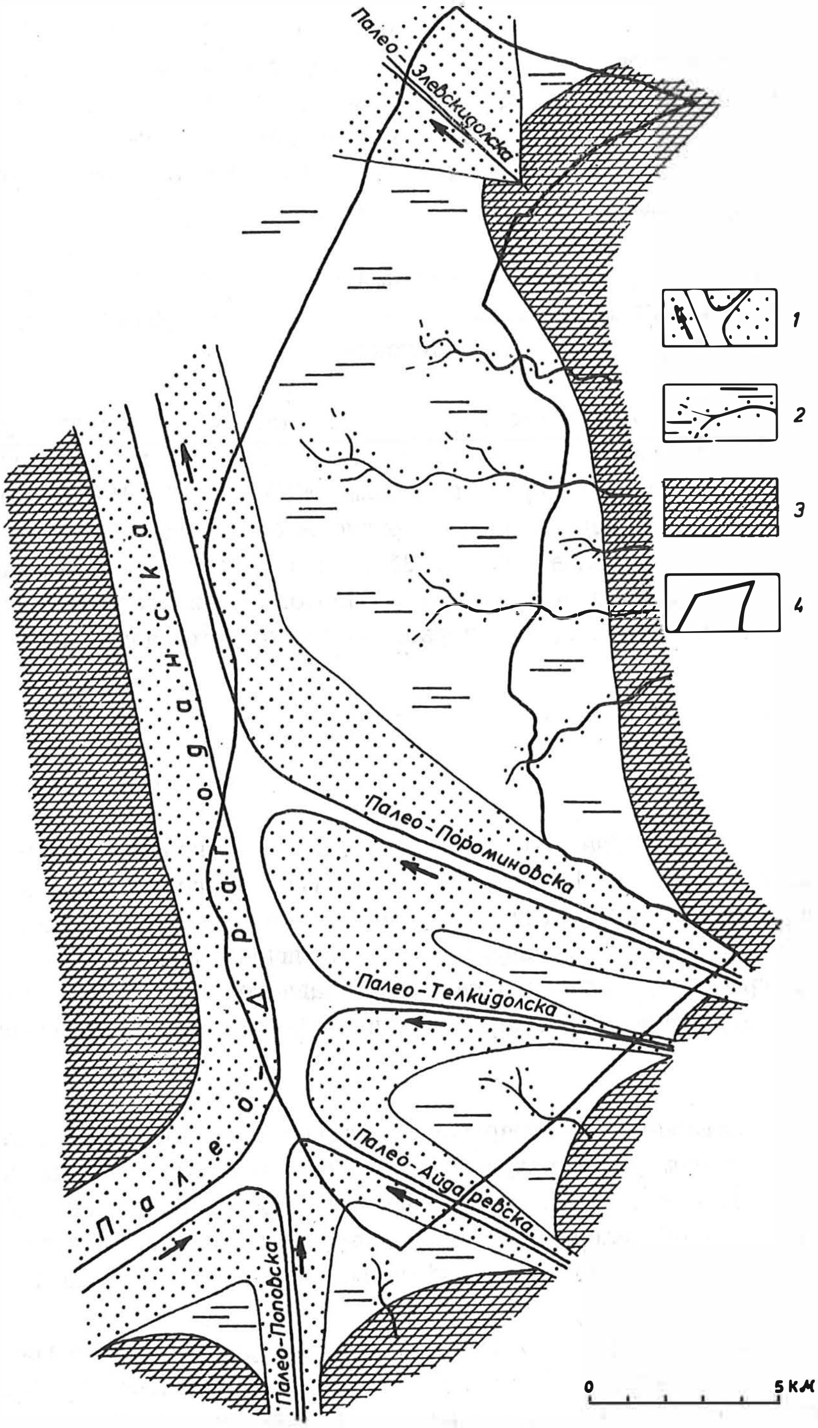


Рис. 3. Палеогеография для времени накопления Покровникской Джерманской и Эмиловской свит

I - область русловых отложений; 2 - область заливных террас и временных русел; 3 - контур окраины области сноса; 4 - разломы, ограничивающие Благоевградский грабен в современном структурном плане

DOI:https://doi.org/10.2312/zipe.1982.066

Топузишская свита

Эта свита представлена только в небольшом реликте площадью в 2,5 $км^2$ и мощностью до 50 м. Основная разновидность пород - это пёстроцветные песчанистые алевролиты и песчанистые глины без карбонатного содержания. Они включают гравилиты, песчаники, а местами и конгломераты без валунов и гальки. Цикличность относится к типу E (рис. 2), хотя конгломераты играют гораздо меньшую роль. В псефитовых обломках представлены только метаморфические породы высокой степени метаморфизма.

Снизу и сверху свита ограничена параллельными несогласиями. Она залегает на Покровникской и Джерманской свитах (понтийский возраст) и перекрывается Бараковской свитой, над которой залегает вилафранкская Бадинская свита.

Лишённые карбонатов пестроцветы без зёрен полевых шпатов свидетельствуют об образовании свиты в результате химического выветривания, об условиях гумидного климата и тектонического покоя (в согласии с представлениями АНАТОЛЬЕВОЙ 1978). Породы Топузишской свиты являются продуктом переотложения красноцветной коры выветривания. При этом денудация затронула и коренные породы. Об этом свидетельствует наличие свежих и слабо выветрелых обломков в некоторых пластах. Литологический состав и характер цикличности дают основание утверждать, что переотложение происходило в условиях заливной террасы.

Бараковская свита

Реставрированная первоначальная форма Бараковской свиты напоминает, также как и Покровникская, реку с притоками. На основании петрографического набора пород, представленных в псефитовых обломках, свита разделена на семь пространственно обособленных членов. Самым разнообразным составом обломков отличается Чапрашликский член. Он развит продольно ко грабену и выделен в качестве главного. Остальные члены развиты поперечно к нему. Это: Мурсалевский, Кочериновский, Чифликчийский, Бистрицский, Селишский и Беловодский.

Свита сложена полимиктовыми конгломератами, которые включают местами песчаники и песчанистые глины. В главном члене валуны отсутствуют, а в остальных их количество уменьшается по направлению к главному члену. Падение обломков в главном члене - северное, а в остальных - к обрамлению грабена. Цикличность относится к типу B или C (рис. 2), а в периферийных участках конгломератовых тел - к типу E или D.

Метаморфические породы высокой степени метаморфизма представлены в псефитовых обломках всех членов. Присутствие же обломков, сложенных биотитовыми гранитами, лидитами и нижнетриасовыми песчаниками характерно только для некоторых из них. По этому признаку члены разделены на четыре группы: I. Беловодский и Селишский члены - с псефитовыми обломками только из метаморфических пород; в Беловодском члене это главным образом лейкократовые гнейсы (всегда более 80%), а в Селишском - главным образом мезократовые, пестрые гнейсы и амфиболиты (около 60%); 2. Мурсалевский член - в нём устанавливаются не только обломки метаморфических пород, но также и лидитов и нижнетри-

DOI:https://doi.org/10.2312/zipe.1982.066

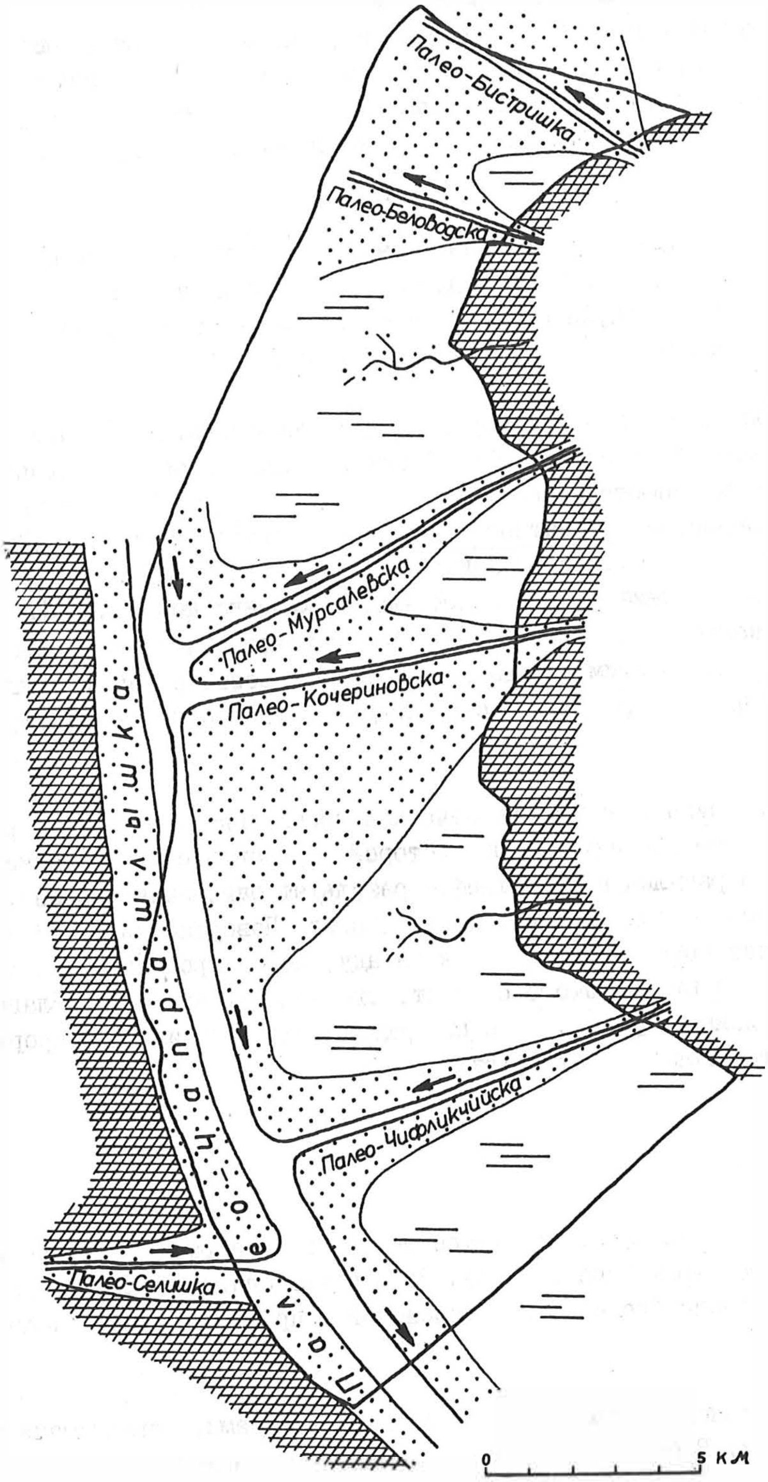


Рис. 4. Палеогеография для времени накопления Бараковской свиты
Условные обозначения – как на рис. 3

DOI:https://doi.org/10.2312/zipe.1982.066

асовых песчаников; 3. Кочериновский, Бистрицкий и Чифликчийский члены - в них присутствуют обломки и биотитовых гранитов. В первых двух количество амфиболитовых обломков составляет около 40 - 60%, а в третьем оно всегда меньше 20%; 4. Чапрашлыкский член - - с повсеместным присутствием кварцевых обломков в количестве более 40%. Кроме того, в нём представлены обломки всех остальных перечисленных петрографических разновидностей.

Бараковская свита несогласно перекрывает комплекс метаморфических пород высокой степени метаморфизма и залегает с параллельным несогласием на Покровникской свите (понт) и на более молодой - Топузишской. Её перекрывает тоже с параллельным несогласием Бадинская свита (плейстоцен - вероятный вилафранк).

По форме, цикличности, а также по структурным и текстурным особенностям Бараковская свита не отличается от Покровникской. Различия между ними устанавливаются по составу пород, слагающих псефитовые обломки (преимущественно в отношении их главных членов), а также при сравнении ориентировки главных плоскостей гальки. Из этого следует, что Бараковская свита аналогично Покровникской накоплялась в условиях аллювиального русла, но, в то время, как главный член Покровникской свиты был образован текущей к северу палеорекой, главный член Бараковской свиты отлагался рекой, текущей в южном направлении. С этим и связаны различия в составе пород, слагающих псефитовую кластику этих членов, различия, отражающие состав двух разных питающих областей.

Общая палеогеографическая и палеотектоническая обстановка отложения Бараковской свиты является повторением обстановки, при которой образовалась Покровникская свита. Снова выявляется сильно расчленённый рельеф - результат оживления блоковых движений. При этом интенсивнее всего воздымается Рильский горст. Поверхность новой аллювиальной палеоравнины снова имеет поперечный наклон к западу, но её продольный наклон направлен уже не на север, а на юг. Из этого следует, что водораздела между Благоевградским и Ораново-Симитлийским грабенами уже не существовало (он или был прорван ущельем, или оформляющий его блок испытал погружение).

Бадинская свита

Породы Бадинской свиты оформляют вытянутое тело, которое располагается непосредственно около восточного обрамления грабена. Весь объём свиты расчленён на два члена: Кырчинский - преимущественно брекчиевый и Лешовский - преимущественно брекчиево-конгломератовый.

Псефитовые обломки сложены лейко- и мезократовыми гнейсами, пегматитами и кварцем, а местами и амфиболитами. В брекчиевых конгломератах установлена цикличность типа А (рис. 2).

Бадинская свита залегает с параллельным несогласием на Джерманской, Покровникской и Бараковской свитах и перекрывается отложениями плейстоценовых незаливных террас. Находка ископаемого млекопитающего (Г. БОНЧЕВ 1912, 1917; ЗЛАТАРСКИ 1927) определяет её плейстоценовый, а по всей вероятности - вилафранкский возраст (БАКАЛОВ и др. 1977).

DOI:https://doi.org/10.2312/zipe.1982.066

По своим особенностям брекчиевые конгломераты Лешовского члена не отличаются от соответствующих отложений Эминовской свиты. Это показывает, что они тоже образованы временными потоками селеподобного характера. То же самое можно утверждать для брекчий Кырчинского члена, с той разницей, что аккумулировавшие его потоки имели более выраженный селевый характер. Обломочный материал этого члена переносился только грязевой суспензией и, в связи с этим, не испытал дополнительной обработки.

4. Выводы из описания типового разреза для понимания палеогеографических и палеотектонических условий образования моласс

Отложенная в Благоевградском грабене верхняя моласса даёт возможность выявить четыре этапа в его развитии. Первый этап отмечен отложениями Эминовской, Покровникской и Джерманской свит; второй – Топузишской свитой; третий – Бараковской и четвёртый – – Бадинской. Отложения каждого этапа испытывали денудацию непосредственно после своего формирования. В сявзи с этим возникли параллельные несогласия.

Первый этап (рис. 3): Этот этап совпадает с начальным импульсом погружения Благоевградского грабена в понтийское время. Создаётся межгорная котловина, в которой начинается накопление в обстановке аллювиальной равнины. Преимущественно брекчиево-конгломератовая Эминовская свита образуется временными потоками селеподобного характера в качестве шлейфа у подножья Рильского горста. Покровникская, преимущественно конгломератовая свита является продуктом русловой аккумуляции. Она связана с активной жизнью палеогидросети постоянных палеопотоков. Прерванные по латерали тела преимущественно песчанисто-глинистой Джерманской свиты образованы в обстановке заливной террасы.

Второй этап: Первоначально расчленённый горный рельеф обрамления грабена испытал денудационное понижение (по всей вероятности, в результате наступившего тектонического покоя). Это сопровождалось потеплением климата, но не изменением его гумидности. По породам обрамляющих блоков развилась бескарбонатная кора выветривания красного цвета. Главным образом за счёт её переотложения в заливных террасах образовалась пестроцветная Топузишская свита. Образованные параллельно с ней русловые и другие возможные генетические типы отложений полностью денудированы.

Третий этап (рис. 4): В связи с оживлением вертикальных движений грабен испытал новый импульс погружения, а его обрамление – новое воздымание. В результате русловой аккумуляции, связанной с действием новой палеогидросети, образовалась Бараковская свита.

Четвёртый этап: Брекчиевые конгломераты Бадинской свиты отложены вилафранкскими селевыми и селеподобными потоками. Они являются коррелятом нового импульса в интенсивном воздымании Рильского горста. Гидросеть того времени полностью унаследована современной гидросетью. На послевилафранкском денудационном этапе, в результате совпадения долин этих двух гидросетей, происходит ликвидация русловых и заливно-террасовых отложений, связанных с действием прарек.

DOI:https://doi.org/10.2312/zipe.1982.066

Грабен погружался импульсами. После каждого из них его негативные движения затухали до такой степени, что он вовлекался, хотя и на очень короткий срок, в общее воздымание района. В результате этого такие процессы как: погружение - осадконакопление, тектонический покой - затухание и прекращение осадконакопления, временное воздымание - денудация, повторились не менее четырёх раз.

Общая мощность отложений в грабене свидетельствует о том, что вкрест простирания грабена его суммарное погружение было самым слабым около западной и самым интенсивным около восточной окраины. В продольном разрезе самое слабое погружение приурочено к северной и южной периферии грабена, а самое интенсивное - к его центральной части. Поперечный наклон седиментационной поверхности при этом всегда был на запад, в то время как её продольный наклон изменялся: на первом этапе он имел северное направление, а на третьем и после этого - южное.

В исследованном районе, начиная с плиоцена, происходили только блоковые движения. На фоне хорошо выраженной тенденции погружения Благоевградского грабена и воздымания обрамления, вертикальные движения изменяли не только свою интенсивность, но временами и свой знак.

Литература

АНАТОЛЬЕВА, А.И.: Главные рубежи эволюции красноцветных формаций.
Новосибирск: "Наука" 1978, 202 о.

БАКАЛОВ, П.Г.: Стратиграфски единици в Благоевградския грабен, ограничени от несъгласия.
Палеонт., стратигр. литол., София 7 (1977), с. 60-74

БАКАЛОВ, П.Г.: Литостратиграфска подялба на Благоевградската синтема в обсега на едноименния й грабен. I. Подялба на Слатинската интертема.
Палеонт., стратигр., литол., София 9 (1978), с. 79-95

БАКАЛОВ, П.Г.: Литостратиграфска подялба на Благоевградската синтема в обсега на едноименния и грабен. II. Подялба на Елийската, Белополската и Стобската интертема.
Палеонт., стратигр., литол., София 10 (1979), с. 57-76

БАКАЛОВ, П.Г.; ИЛАТОВА, З.; НИКОЛОВ, ИВ.: Върху възрастта на оедиментите в Благоевградския грабен.
Спис. Бълг. геол. д-во, София 38 (1977) I, с. 98-99

БОНЧЕВ, Г.: Принос към петрографията и минералогията на Рила планина.
Спис. Бълг. Акад. Наук., София (1912), с. 1-176

БОНЧЕВ, Г.: Седиментните скали в България.
Сбор. Бълг. Акад. Наук., София (1917) 7, с. 1-162

БОНЧЕВ, Е.: Геология на България, ч. II.
София: "Наука и изкуство" (1960). 164 с.

БОНЧЕВ, Е.: Проблеми на българската геотектоника.
София: "Техника" (1971), 204 с.

БОНЧЕВ, Е.: Срединни масиви, централни масиви и платформи в Балканокия полуостров.
Изв. Геол. инст., сер. геотект., София (1974) 23, с. 5-35

БОЯДЖИЕВ, С.: Западнородопски блок. В: Тектонски строеж на България.
София: "Техника" (1971 а), с. 63-99

DOI:https://doi.org/10.2312/zipe.1982.066

БОЯДЖИЕВ, С.: Струмски дълбочинен разлом. - В: Тектонски строеж на България.
София: "Техника" (1971 б), с. 431-435

ГОРЕЦКИЙ, Г.И.: Аллювий великих антропогеновых прарек Русской равнины. Прареки Камского бассейна.
Москва: "Наука" (1964), 416 с.

ДАФФ, П.; ХАЛЛАМ, А.; УОЛТОН, З.: Цикличность осадконакопления.
Москва: "Мир" (1971), 248 с.

ЗАГОРЧЕВ, И.: Върху неотектонските движения в част от Югозападна България.
Изв. Геол. инст., сер. геотект., София 19 (1970), с. 141-152

ЗЛАТАРСКИ, Г.: Материали по геологията и минералогията на България.
Пер. сп. Бълг. книж. д-во, София (1885), с. 333-359

ЗЛАТАРСКИ, Г.: Геология на България.
София: "Художник" (1927), 266 с.

КОНЯРОВ, Г.: Кафявите въглища в България
Придвор. печатница, София (1932), 304 с.

МОСКОВСКИ, С.: Върху последователността на формиране на палеоген-неогенските ровови структури в Българските Краишиди.
Спис. Бълг. геол. д-во, София 32 (1971) 1, с. 21-31

ПЕТРОВ, П.: Геоложки и хидрогеоложки наблюдения около загасналия вулкан Кожух в Югозападна България
Труд. геол. Бълг., сер. стратигр. и тект., София 1 (1960), с. 295-318

ПОПОВ, В.И.; ГРИДНЕВ, Н.И.; НАБИЕВ, К.А.: Литология кайнозойских моласс Средней Азии, ч. 3.
Ташкент: АНУЗ ССР (1956), 290 с.

ШУЛЬЦ, С.С.: Тектоника земной коры.
Ленинград: "Недра" (1979), 272 с.

BOUÉ, A.: La Turque d'Europe.
Paris (1840) 1, p. 219-407

HOCHSTETTER, F.: Die geologischen Verhältnisse des östlichen Theiles der Europäischen Türkei.
Jahrb. Geol. Reichsanst. Wien, Wien 20 (1870) 3, S. 265-461

International Subcommission on Stratigraphic Classification: An international guide to stratigraphic classification, terminology, and usage, Rept. 7 (Introduction and Summary). In: H.D. Hedberg (editor).
Lethaia, Oslo 5 (1972) 3, p. 283-323

MOSKOVSKI, S.: Struma-Störungszone.
C.R. Ac. bulg. Sci., Sofia 22 (1969) 1, p. 65-68

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Объяснительная записка к литотектоническому разрезу кайнозойской молассы Афгано-Таджикской впадины (комментарии к приложению I7)

И.Г. ЩЕРБА[I)]

I. Введение

Афгано-Таджикская впадина является крупнейшей неотектонической структурой в эпиплатформенной орогенической области Средней и Восточной Азии. Она заключена между горными сооружениями Тянь-Шаня, Памира и Гиндукуша (рис. I), представляющими собой варисские складчатые сооружения. Судя по геофизическим данным, фундамент впадины также имеет варисский возраст.

В строении впадины и окружающих её поднятий участвуют три комплекса пород: палеозойский, представленный разнообразными отложениями геосинклинального и молассового облика; позднетриасово-эоценовый платформенный; олигоцен-четвертичный молассовый. Платформенные карбонатные и галогенные отложения, сменившие в разрезе пермо-триасовые варисские молассы, отличаются большой мощностью (I,5 - 4 км). Очевидно, в мезозое и палеогене территория Афгано-Таджикской впадины представляла крупную краевую впадину Туранской эпипалеозойской плиты, с которой она близка по типу отложений юры, мела и большей части палеогена. В целом неотектоническая впадина располагается на месте этой платформенной впадины, и при её заложении существенной перестройки структурного плана не произошло. В олигоцен-четвертичное время эта крупная отрицательная структура заполнялась мощными молассами.

2. Домолассовый комплекс

В течение мезозоя и палеогена впадина испытывала то замедлявшиеся, то усиливавшиеся опускания относительно окружающих поднятий, эпохи трансгрессии сменялись регрес-

[I)]Геологический институт АН СССР; СССР I090I7, Москва, Пыжевский пер. 7.

DOI:https://doi.org/10.2312/zipe.1982.066

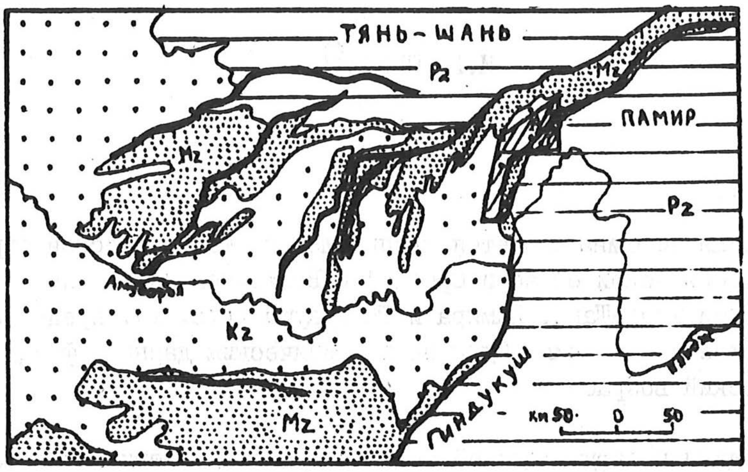


Рис. I. Положение Афгано-Таджикской впадины в структуре орогенической области Азии. Заштрихован район Придарвазья, в котором составлена приводимая колонка (прил. I7)

А - Хингоуская синклиналь

DOI:https://doi.org/10.2312/zipe.1982.066

сиями. Такое развитие продолжалось вплоть до эоцена, в течение которого отмечается два периода усиления прогибания.

В основании эоцена залегают (см. прил. I7) отложения сузакских слоёв (ипрский или бахчисарайский ярус), которые без несогласия сменяют известняки верхов палеоцена, а на поднятиях трансгрессивно налегают на нижележащие толщи. Это тонкие бескарбонатные глины, содержащие большое количество разнообразных донных организмов (кораллы, ежи, моллюски), которые, наряду с планктонными фораминиферами, свидетельствуют о нормальной солёности бассейна и о широком распространении трансгрессии этого времени. Исчезновение фораминифер в конце сузакского времени, появление карбонатного материала свидетельствует об обмелении бассейна и спаде темпа прогибания и начале накопления регрессивной серии. Её продолжают отложения начала алайских слоёв (лютет, симферопольский век), в которых среди карбонатных глин и мергелей появились пласты устречников, бентонные фораминиферы. Наиболее яркие регрессивные черты носят осадки середины алайского времени, когда накапливаются гипсоносные толщи, породы преобретают красную окраску.

В позднеалайское время вновь распространяются исключительно морские образования: карбонатные глины и глинистые илы, формирующие новую трансгрессивную серию, без несогласия сменяющую регрессивную нижнеалайскую. Углубление бассейна продолжалось в раннетуркестанское время (конец лютета, бодракский век), причём наиболее активно оно развивалось на западе Таджикской впадины, где отлагались тонкие глинистые илы. С Дарваза шло активное поступление обломочного материала. В конце туркестанского времени на всей территории начали накапливаться осадки, обогащённые песчаным материалом, связанные с морской регрессией. В это время отмечается активизация тектонических движений, проявляющаяся в частных размывах отложений на поднятиях: в хр.Арук--Тау, Кара-Тау и др. В низах риштанских слоёв (приабон, альминский ярус) встречаются окатанные раковины туркестанских моллюсков. Накопление регрессивной серии отложений продолжается в риштанское время, в начале которого отлагались преимущественно песчаные осадки (особенно в Кафирниганской зоне), в которых вблизи Дарваза появлялась примесь гравийного материала. Отмечается обеднение родового и видового состава фауны. В середине риштанского времени прекратилась связь бассейна с открытым морем - шло накопление глинисто-сульфатных отложений, а затем и красноцветных песчано-глинистых.

3. Молассовый комплекс

Переход от платформенной седиментации к молассовой совершился в олигоцене, когда на смену карбонатно-терригенным отложениям пришло накопление преимущественно красноцветных, лагунных, прибрежно-морских и терригенных пород, происходившее в условиях замкнутых и полузамкнутых бассейнов, окружённых вышедшими, в связи с началом горообразования, из-под уровня моря территориями.

Позднекайнозойская моласса Афгано-Таджикской впадины представлена мощной (до 5 - 6 км) толщей терригенных, преимущественно континентальных отложений олигоцена, неогена и антропогена. В разрезах центральной части депрессии преобладают тонко- и

DOI:https://doi.org/10.2312/zipe.1982.066

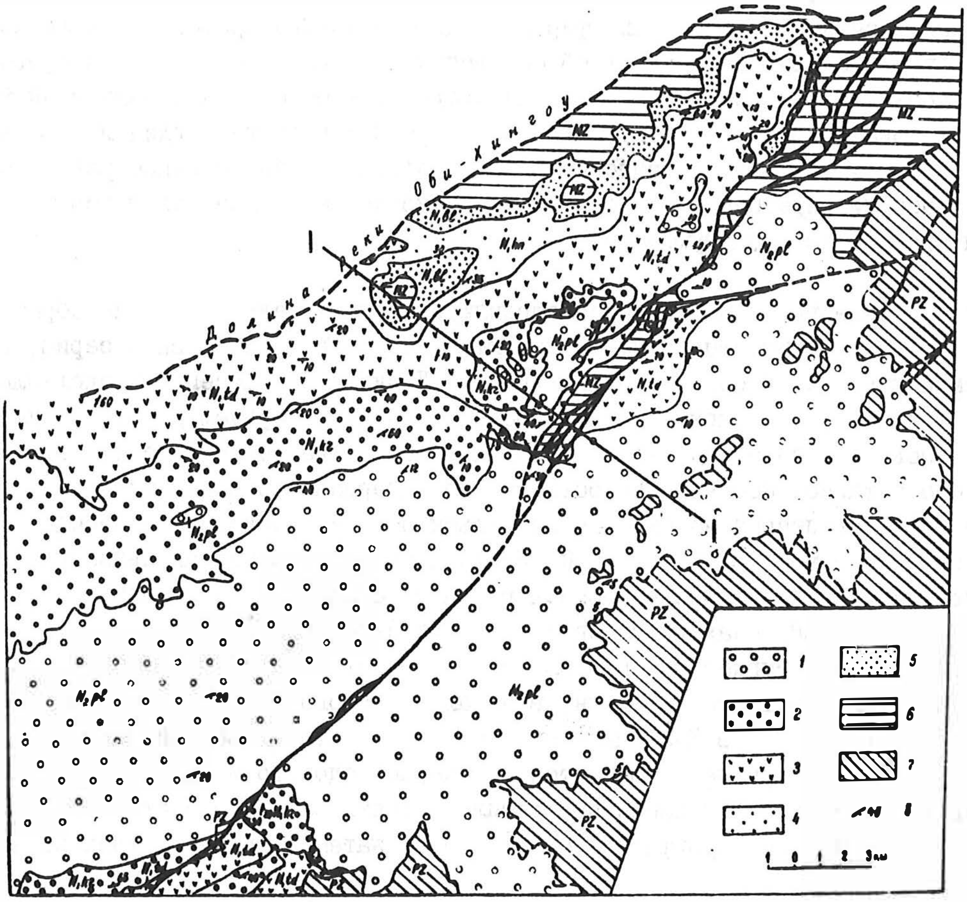


Рис. 2. Геологическая карта Хингоуской синклинали
I - полизакская свита, 2 - каранакская свита, 3 - тавильдарьинская свита, 4 - хингоуская свита, 5 - бальджуанская свита, 6 - отложения юры, мела, палеогена, 7 - отложения перми и карбона, 8 - элементы залегания

DOI:https://doi.org/10.2312/zipe.1982.066

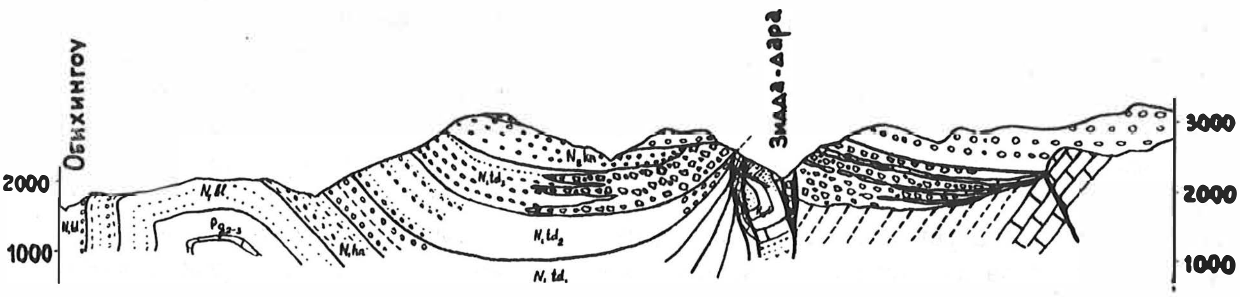


Рис. 2 А. Геологический разрез по линии I-I

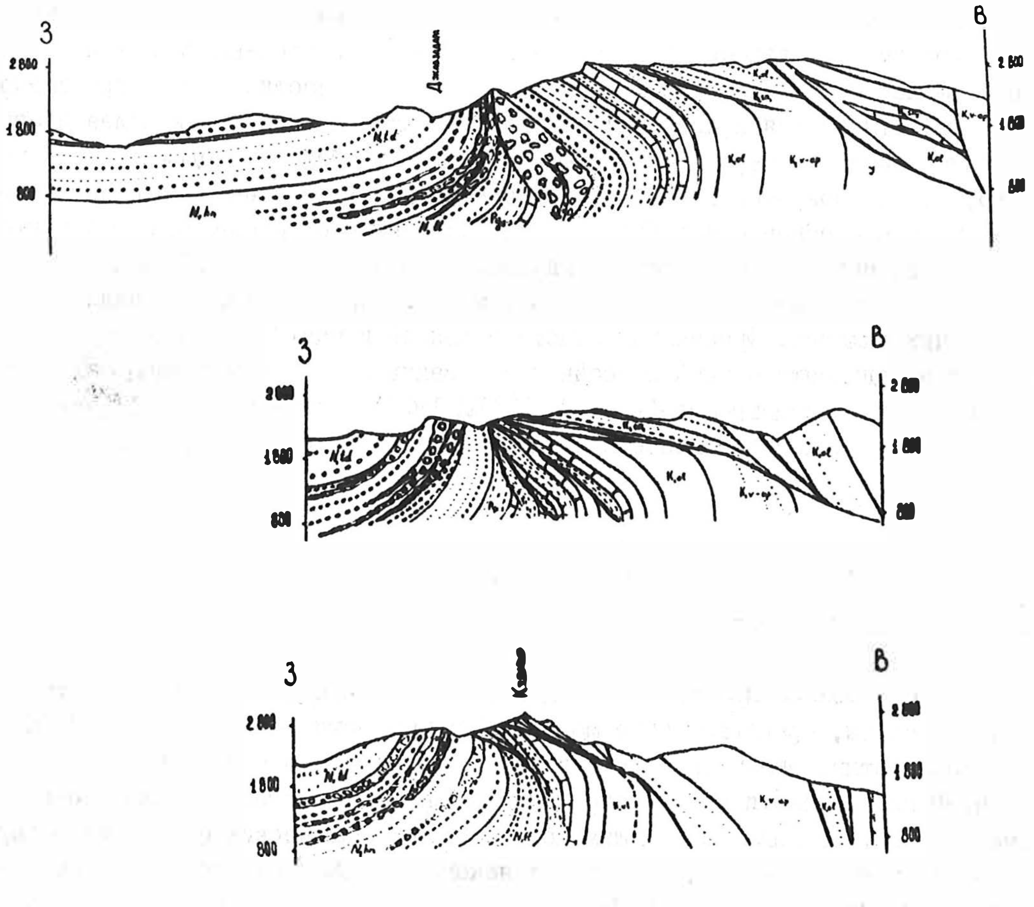


Рис. 3. Соотношение моласс и пород мела - палеогена в Придарвазьи, на границе впадины и горного поднятия

DOI:https://doi.org/10.2312/zipe.1982.066

среднеобломочные отложения речного, озёрного, реже прибрежно-морского происхождения, характеризующиеся относительным однообразием состава в разрезе и на площади. По окраинам депрессии на границе со складчатыми сооружениями Памира, Гиндукуша и Тянь-Шаня преобладают грубые отложения предгорных шлейфов, разделённые поверхностями размыва, угловыми несогласиями, позволяющими расчленить молассу на толщи, отличающиеся по литолого-фациальной характеристике и условиям залегания. Наиболее крупные из них выделяются в ранге свит. Возраст свит определяется очень условно по редким находкам прибрежной и континентальной фауны. Корреляция их в пределах депрессии также условна, но, за редким исключением, достаточно убедительна. В значительной мере она базируется на литостратиграфических исследованиях, изучении ритмических изменений в смене условий седиментации. Внутри молассового разреза намечаются и более общие циклы седиментации, обособление которых наиболее отчётливо проявлено в Придарвазье, где располагаются стратотипические разрезы моласс (рис. 2).

Все доакчагыльские отложения вместе с юрскими-палеогеновыми толщами участвуют в строении системы разломов и складок Таджикской виргации, в значительной степени наследующей седиментационные прогибы и поднятия. Более молодые отложения участвуют лишь в слабых приразломных изгибах слоёв. Граница между породами мезозоя-палеогена, с одной стороны, и неогена с другой, в зоне сочленения впадины с Памиром представлена крутой флексурой, осложнённой крутыми надвигами. В смыкающем крыле флексуры к границе комплексов подходят разные слои олигоцена-неогена и мезозоя--палеогена. Молассы частично прислоняются к основанию, частично трансгрессивно перекрывают его. Отмечается прислонение более молодых свит молассы к более древним, а также трансгрессивное перекрытие более древних свит более молодыми; имеет место, кроме того, резкое сокращение мощности отложений и погрубление обломочного материала вблизи границы с основанием. Все слои олигоцен-нижнеплиоценовых пород круто вздёрнуты, часто опрокинуты в сторону впадины. В мезозойских и палеозойских породах отмечается опрокидывание слоёв, надвигание, шарьирование в сторону впадины, образование лежачих складок. Фронтальные части шарьяжей и часть тектонических пластин обрушиваются в седиментационный бассейн и захораниваются среди молассовых толщ в виде олистоплак и олистостромов (рис. 3, ЩЕРБА 1975). Такие же соотношения наблюдаются и на границах частных конседиментационных прогибов и поднятий внутри впадины.

Исфаринско-ханабадская свита

В нижней части моласс Придарвазья выделяются исфаринско-ханабадские, сумсарские и шурысайские свиты, представленные морскими отложениями (нижняя моласса). На подстилающих сероцветных отложениях риштанских слоёв верхнего эоцена они лежат без несогласия. В нижней части исфаринско-ханабадских слоёв залегают малиново-красные и зелёные карбонатные глины с большим количеством пелагических фораминифер (преобладают булиминиды), свидетельствующие о некомпенсированном прогибании этой территории во время их накопления. В Придарвазье они частично замещаются песчаными осадками, в которых распространены моллюски, характерные для латерали (БУЗУРУКОВ 1974).

DOI:https://doi.org/10.2312/zipe.1982.066

В верхней части исфаринско-ханабадских слоёв наблюдается погрубение осадков и появление песчанистых красноцветных глин, а также изменения фауны: наряду с фораминиферами получают массовое развитие моллюски. Очевидно в конце ханабадского времени произошло обмеление бассейна и началось накопление регрессирующей серии осадков. Таджикские геологи по фауне моллюсков и фораминифер относят исфаринско-ханабадские слои к верхнему эоцену (сб. "Расчленение..." 1976). Однако В.В. ИЩЕНКО и Л.С. ГЛИКМАН, обнаружившие в них зубы акул олигоценового возраста (1967), вероятно более обоснованно считают эти отложения латторф-рюпельскими.

Сумсарская свита

Сумсарская свита в нижней части представлена преимущественно обогащёнными алевритом карбонатными глинистыми породами, которые в направлении Дарваза частично замещаются континентальными песчано-алевритовыми осадками. Для всех отложений сумсарских слоёв характерна красная окраска, связанная с субаэральными условиями седиментации. В верхней части песчаники и алевролиты уже преобладают, указывая на продолжавшееся обмеление и рост поднятий. В сумсарских отложениях обнаружены моллюски: Exogyra galiata ROM., Gryphaea sewerzowi ROM., Ostrea pigmaea VIAL., Cibicida susarensis N. BYCOVA, Maretrix bajsunica MANUJL., возраст которых предположительно определяется как нижне-среднеолигоценовый (сб. "Расчленение..." 1976). Вместе с тем, из сравнения всего разреза моласс (Таджикских) с копетдакскими (РАСЦВЕТАЕВ, ЩЕРБА 1980) вытекает, что образование сумсарских слоёв продолжалось до конца олигоцена. В конце сумсарского времени произошли тектонические подвижки, приведшие к воздыманию западной части депрессии. Здесь в Кафирниганской зоне и в Гиссаре отложения сумсарских слоёв полностью размыты в предшурысайское время.

Шурысайская свита

Шурысайская свита ложится на размытую поверхность различных слоёв эоцена и олигоцена вплоть до туркестанских (КРЕЙДЕНКОВ, БУЗУРУКОВ 1974). Она начинается с маломощной (от первых десятков метров до 150 - 200 м) трансгрессирующей серии осадков, представленной пестроцветной толщей коричневатых и красно-коричневых алевролитов, глин и песчаников с прослоями серых и зеленовато-серых глин, редко гипсов, доломитов и алевролитов, которые отлагались в замкнутых и полузамкнутых водоёмах или в континентальных условиях. Во второй половине шурысайского времени поднятия расширяются, реликтовые водоёмы сокращаются, накапливается регрессирующая серия осадков, в которых наряду с песчаниками и алевролитами в Придарвазье распространены гравелиты и конгломераты. К концу шурысайского времени во всей Таджикской депрессии наступает континентальный режим и начинается накопление мощных континентальных моласс. Таким образом, отложения свиты образуют определённый седиментационный ритм.

В отложениях свиты встречены моллюски, по которым её возраст не может быть определён точнее, чем олигоценовый (ГРАММ 1949; КРЕЙДЕНКОВ, БУЗУРУКОВ 1974). Но учитывая возраст нижележащих отложений, более вероятными кажутся мнения и о их принадлежности к миоцену (СОЛУН 1959; ГЛИКМАН, ИЩЕНКО 1967; РАСЦВЕТАЕВ, ЩЕРБА 1980).

DOI:https://doi.org/10.2312/zipe.1982.066

Бальджуанская свита

Отложения бальджуанской свиты начинают существенно новый этап молассообразования - этап накопления грубых континентальных моласс. На большей территории впадины бальджуанская свита представлена достаточно однообразными, относительно тонкими отложениями кирпично-красной окраски, которые ложатся на разные горизонты палеогена. Они образуются в условиях слабо дифференцированного рельефа за счёт размыва удалённых поднятий, по окраинам которых песчаные отложения замещаются конгломератами. В Придарвазье свита в основании (около 100 м) сложена красноцветными конгломератами с линзовидными прослоями красных суглинков. Конгломераты хорошо отсортированы, гальки окатаны и уплощены. Их снос шёл с внутренних частей Дарваза. В следующей пачке (100 - 250 м) количество суглинков в разрезе свиты резко возрастает, появляются прослои красных песчаников. Верхняя часть свиты (400 - 550 м), особенно в районах, непосредственно прилежащих к Дарвазу, вновь сложена конгломератами, ритмично чередующимися с гравелитами и песчаниками. Среди окатышей этих конгломератов, помимо аллохтонного материала (гранитов, кварца, метаморфических сланцев), присутствуют плохо окатанные глыбы и валуны близлежащих пород, состав которых значительно варьирует от места к месту. В отложениях верхов бальджуанской и низов хингоуской свиты распространены также линзовидные прослои олистостромов мощностью от 0,5 - 2 м до 20 - 50 м и протяжённостью в 5 - 6 км. Очевидно, в конце бальджуанского - начале хингоуского времени в краевой части депрессии произошли активные восходящие движения, приведшие к образованию грубых конгломератов и олистостромов.

В бальджуанской свите собрана пыльца широколиственных деревьев и ксерофитовых трав, принадлежащих к палинокомплексам B_I и B_2 (ПЕНЬКОВА, ПЕНЬКОВ 1973). Их таксоны Singuisorba minor SCHPH. u Ephedra clatats SCHKHM. позволят сопоставлять свиту с низами миоцена. По облику и положению в разрезе свита близка к тархан-чокракским отложениям Копетдага (РАСЦВЕТАЕВ, ЩЕРБА 1980).

Хингоуская свита

Хингоуская свита отделяется от нижележащей свиты благодаря резкой смене окраски на буровато-коричневую или фиолетово-коричневую и отчётливо проявленной ритмичности в чередовании конгломератов, песчаников и алевролитов. В составе обломочного материала резко сокращается количество кварцевых и гранитных окатышей, начинает преобладать местный материал. На склоне Дарваза в хр.Хозретиши отмечается несогласное налегание пород свиты на бальджуанскую и шурысайскую свиты, а также верхние слои палеогена и известняки верхнего мела, к эродированной поверхности которых хингоуские конгломераты прислоняются под крутым углом (рис. 4). Лежащие выше ритмично чередующиеся конгломераты, песчаники и алевролиты содержат горизонты олистостромов.

В отложениях хингоуской свиты обнаружены остракоды (ГРАММ 1949): Iliocypris brady SARS., Iliocypris cf. gibba RAMDOHR сходные с остракодами караганского горизонта Кавказа. Хингоуской свите принадлежит палинокомплекс "С" (ПЕНЬКОВА, ПЕНЬКОВ 1973), таксоны которого, ель Шренка и вельвигия, не противоречат отнесению свиты к среднему миоцену.

DOI:https://doi.org/10.2312/zipe.1982.066

Тавильдаринская свита

Отложения тавильдаринской свиты значительно продвинуты вглубь поднятий, обрамляющих депрессию (см. рис. 3 и 4). Они трансгрессивно залегают на поверхности пород палеозоя, мезозоя и нижележащих свит неогена. Отмечается значительное погрубение состава обломков и смена окраски пород на серо-фиолетовую. Наибольшего развития "трансгрессия" достигает в середине тавильдаринского времени, когда в спокойных застойных условиях идет отложение ритмично-слоистой флишеподобной конгломерато-песчано-алевритовой толщи среднетавильдаринской подсвиты (500 - 650 м).

В конце тавильдаринского времени происходит самое мощное образование олистостромов, резко грубеет состав обломочного материала. Вместе с тем и сокращается область распространения осадков, сосредоточенных лишь на границе с поднятиями. Это указывает на резкую активизацию тектонических движений в позднетавильдаринское время, сопровождающееся усилением воздымания горного сооружения, которое можно рассматривать как орогеническую фазу.

Отложения тавильдаринской свиты содержат пыльцу позднемиоценовых и плиоценовых растений: Phragmites oeningensis A:BR., Cypralites cf. deucalionis UNG., Pteris parschlugiana UNG., Dripteris meyeri (HEER) PALIB., Cheilantas laharpii HEER., Lastrea pulchella HR:, Aspidium lethacum.

По А.М. ПЕНЬКОВОЙ (ПЕНЬКОВА, ПЕНЬКОВ I973) пограничным слоям тавильдаринской свиты и хингоуской свиты соответствует палинокомплекс "Д" с коррелятивными таксонами Juniperus pistaciea.

В центральной части Таджикской депрессии в кровле кафирниганской свиты, соответствующей по объёму нерасчленённой хингоуской и тавильдаринской свитам, обнаружен (СОЛУН 1959) череп мастодонта, близкого к средне- позднемиоценовому Mastodon angustidens CUVIER, а также панцырь черепахи Testudo sp., близкой по В.В. КУЗНЕЦОВОЙ к плиоцену сивалика.Всё это позволяет вслед за Я.Р. МЕЛАМЕДОМ(I966) считать тавильдаринскую свиту позднемиоценовой.

Каранакская свита

Лежащие выше с видимым несогласием конгломераты каранакской свиты по условиям залегания и сложению существенно отличаются и от тавильдаринской свиты. Они характеризуются "раскрывающим" залеганием. Для них характерно сокращение площадей распространения по сравнению с отложениями бальджуанской, хингоуской, тавильдаринской свит, резкое выклинивание на границах с поднятиями, сопровождающееся прислонением к нижележащим свитам неогена (см. рис. 2). В отличие от нижележащих свит, каранакская не только на границе с поднятием, но и внутри депрессии в значительной мере сложена конгломератами. На реке Возгина в основание каранакской свиты проникают олистостромы, образование которых началось ещё в тавильдаринское время. Очевидно, тектоничес-

DOI:https://doi.org/10.2312/zipe.1982.066

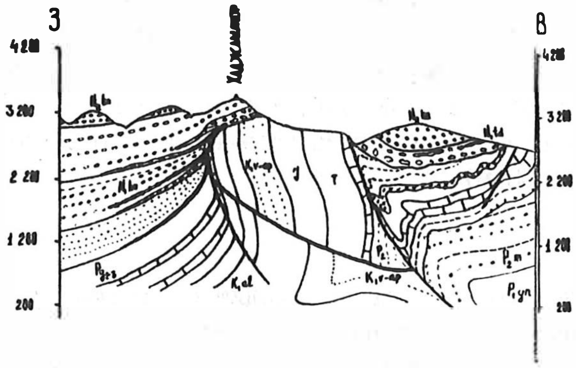


Рис. 4. Геологический разрез через хр. Хозретиши. Несогласное налегание пород хингоуской свиты на отложения мела и палеогена

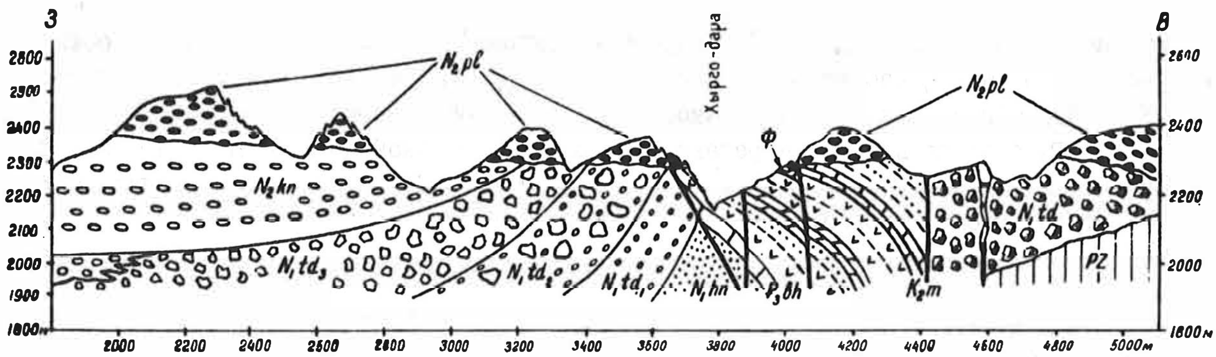


Рис. 5. Несогласное налегание полизакской свиты на нижележащие свиты, неогена, палеоген, мел и палеозой, в районе пер. Хабурабат

DOI:https://doi.org/10.2312/zipe.1982.066

кие движения конца тавильдаринского и предкаранакского времени частично захватили и начало каранакского времени и были весьма активными.

В каранакской свите во внутренней части депрессии обнаружены (ГРАММ 1949) остракоды **Candona albicans BR.**, которые характерны для верхнесарматских и понтических отложений. В неё распространяется палинокомплекс "Е". Отложения свиты имеют обратную намагниченность и выделяются в Кызылсуйский магнитный горизонт (ПЕНЬКОВА,ПЕНЬКОВ 1973), который, вероятно, можно сопоставить с эпохой Гильберта.

Кулябский комплекс

Характерной чертой отложений полизакской, куруксайской и каурубакской свит кулябского комплекса является их залегание выше поверхности регионального размыва и несогласия (ЩЕРБА1979). Взаимоотношения этих свит не установлены. Грубые конгломераты полизакской свиты распространены в Придарвазье, а в центральных частях депрессии развиты конгломераты, галечники и каменные лессы куруксайской и кайрубакской свит. Очевидна принадлежность этих свит новому этапу молассообразования.

В опорном разрезе в основании куруксайской свиты выделяется пачка (80 - 250 м до 400 м) линзовидно переслаивающихся конгломератов, рыхлых песчаников, плотных лессовидных суглинков. В кровле свиты лежит пачка (5 - 7 м) известковистых каменных лессов с многочисленными костными остатками илийского комплекса: **Equus stenonis COCCHI**, **Cervus bactrianus fossilis**, **Ovis ammon fossilis** (ЛОЗИЕВ, ЛИМ 1962), сопоставимого с акчагыльским ярусом Прикаспия. Там же обнаружены (НИКОНОВ и др. 1971) кости животных, которые сопоставляются с хапровским ярусом, чем обоснован их верхнеплиоценовый возраст.

Палеомагнитные свойства пород разреза характеризуются обратной полярностью с отдельными эпизодами прямой намагниченности (низы свиты и верхи каменных лессов). По мнению А.В. ПЕНЬКОВА (ПЕНЬКОВ и др. 1976), наиболее вероятно отнесение свиты к палеомагнитным эпохам Гаусса и Матуямы (1,5 - 2,5 млн. лет). Второй эпизод прямой намагниченности, сопоставляемый с эпизодом Гилза, отделяет верхнюю апшеронскую (эоплейстоценовую) часть разреза, которую А.В. ПЕНЬКОВ (ПЕНЬКОВ и др. 1976) выделяет в качестве самостоятельной кайрубакской свиты. В ней содержится таманский комплекс фауны с кабаллоидной лошадью. Свита представлена маломощными (60 м) каменными лессами, распространёнными на водораздельных поверхностях. В её основании местами проявляется несогласие.

Полизакская свита, распространённая в Придарвазье, также с несогласием, не считаясь со структурой нижележащих пород ложится как на более ранние отложения неогена, так и на породы мезозоя и палеозоя (рис. 5). Свита представлена в основании грубыми неотсортированными отложениями из автохтонных обломков, образованных в процессе быстрого размыва Памирского поднятия. В средней части полизакской свиты в районе пер. Хабурубат распространены крупные утёсы пермских известняков, предполо-

DOI:https://doi.org/10.2312/zipe.1982.066

жительно не имеющие корней. Возможно их проявление связано с активизацией тектонических движений, приходящихся на конец акчагыльского времени (время смены обратной намагниченности на прямую в центре депрессии).

В ущелье Хырго-Дара (бассейн р. Зидда-Дара) в базальном горизонте свиты[I] обнаружены (НИКОНОВ и др. 1973) раковины верхнеплиоценовых гастропод Planorbidae (gen. sp.), Limnea (gen. sp.), Succineidea (gen. sp.). По А. М. ПЕНЬКОВОЙ (ПЕНЬКОВА, ПЕНЬКОВ 1973) свиту характеризует палинокомплекс "$Г_I$", отвечающий этапу максимальной дифференциации растительности на горную и равнинную. На верхнеплиоценовый возраст свиты указывают палеомагнитные исследования, проведённые в хыргодаринских конгломератах А.В. ПЕНЬКОВЫМ в 1973 году. В целом, это - обратнонамагниченные породы, относящиеся к эпохе Матуямы. Нижний горизонт прямой намагниченности сопоставляется с эпохой Гаусса.

Кылысуйская серия

Выше лежит кылысуйская серия пород с прямой намагниченностью, относящаяся к палеомагнитной эпохе Брюнес (моложе 0,7 млн. лет). В её основании выделяется базальная пачка отрицательно намагниченных пород (60 - 100 м), лежащая на породах курруксайской и кайрубакской свит с угловым несогласием и отличающаяся от них меньшей дислоцированностью и более широким распространением. В лессовидных суглинках и красно-бурых погребённых почвах пачки собрана (ЛОСКУТОВ и др. 1965) фауна кошкурганского комплекса, аналогично тираспольскому, возраст которого не моложе нижней половины плейстоцена: **Dicerorhinus cf. etruscus FALL., Equus cabalus cf. mosbachensis (REICH.).**

О нижнечетвертичном возрасте вмещающих их отложений свидетельствует собранная одновременно флора: **Populus alba foss., Salix viminalis L., Phragmites communis TRIN.**, аналогичная комплексу флор бакинского и верхов апшеронского ярусов Прикаспия.

Над базальной пачкой лежат антропогеновые отложения, расчленённые на ряд свит или комплексов, соответствующих циклам террасообразования. Если все подстилающие комплексы заметно деформированы, то для антропогенового характерны лишь слабые приразломные изгибы и отдельные разрывы.

4. Выводы

Формирование позднекайнозойских моласс впадины начинается с увеличения интенсив-

---

[I] Предыдущие исследователи выделяли отложения с фауной в самостоятельную килимбинскую свиту. Однако, такой вывод противоречит геологическим данным, показывающим их принадлежность полизакской свите (ЩЕРБА 1979).

DOI:https://doi.org/10.2312/zipe.1982.066

ности движений. Время накопления тонкой молассы (конец эоцена - начало миоцена) - это начальная стадия воздымания горного сооружения. Начало накопления грубой молассы (начало миоцена) совпадает с началом интенсивных движений по всей области активизации и с существенным воздыманием обрамляющих горных сооружений. Затем следует непрерывно-прерывистое накопление молассы, область её распространения всё глубже проникает внутрь медленно растущего поднятия (стадия умеренного воздымания - до конца миоцена). В конце миоцена происходит активизация движений, приводящая к сокращению области аккумуляции в начале плиоцена. В середине плиоцена - повсеместный перерыв в осадконакоплении и деформация молассы. В конце плиоцена за более короткий срок, но с большей интенсивностью, повторился тот же цикл развития, что и в миоцене - раннем плиоцене, с активизацией движений на границе акчагыл-апшерон и апшерон-баку, началась стадия активного горообразования.

Литература

БУЗУРУКОВ, Д.Д.: Условия обитания моллюсков ханабадского моря на территории современной Таджикской депрессии. В кн.: Геологическое строение и нефтегазоносность Таджикистана.
Душанбе 1974

ГЛИКМАН, Л.С.; ИЩЕНКО, В.В.: Морские миоценовые отложения в Средней Азии.
Докл. АН СССР, Москва 177 (1967) 3

ГРАММ, М.Н.: Использование остракод для биостратиграфического расчленения кайнозойских молас в Ферганской и Южно-Таджикской депрессиях.
Тр. ин-та геол. АН Уз. ССР, 1949, вып. 4

КРАЙДЕНКОВ, Г.П.; БУЗУРУКОВ, Д.Д.: О предшурысайском размыве и олигоценовой трансгрессии в Таджикской депрессии и ее горном обрамлении В сб.: Геол. строение и нефтегазоносность Таджикистана.
Душанбе 1974

ЛОЗИЕВ, В.П.; ЛИМ, С.С.: О находке окаменелостей илийского фаунистического комплекса в северо-восточной части междуречья Кафирнигана и Иляха.
Докл. АН Тадж. ССР, т.У. 1962, № 5

ЛОСКУТОВ, В.В.; МЕЛАМЕД, Я.Р.; РАФИЕВ, А.; ТРОФИМОВ, А.Н.; ЧЕДИЯ, О.К.: О возрасте кулябской свиты Таджикской депрессии.
ДАН Тадж. ССР, т. 8, 1965, № 4

МЕЛАМЕД, Я.Р.: Типы разрезов и стратиграфия неогеновых отложений Южного Таджикистана.
Изв. высш. уч. завед., геол. и разведка, 1966, № 5

НИКОНОВ, А.А.; ПЕНЬКОВ, А.В.; ТРОФИМОВ, Б.А.; ВАНГЕНГЕЙМ, Э.А.; ДМИТРИЕВА, Е.А.; СОТНИКОВ, М.В.: Новые данные по геологии и фауне млекопитающих верхнего плиоцена и нижнего плейстоцена Таджикистана.
Бюлл. Московск. об-ва испыт. природы, отд. геол., Москва 76 (1971) 6, смр 146-147

НИКОНОВ, А.А.; ПЕНЬКОВА, А.М.; ПЕНЬКОВ, А.В.: Новые данные по верхнемиоценовым отложениям Дарваза (Таджикистан).
Докл. АН СССР, Москва 211 (1973) 3

ПЕНЬКОВ, А.В.; ГАМОВ, Л.Н.; ДОДОНОВ, А.Е.: Сводный палеомагнитный разрез верхнеплиоцен-плейстоценовых отложений бассейна р. Кызылсу (Южный Таджикистан).
Изв. АН СССР, сер. геол., Москва (1976) 9

ПЕНЬКОВА, А.М.; ПЕНЬКОВ, А.В.: Опыт комплексной характеристики палинологических и палеомагнитных реперов в неогеновых толщах Юго-Западного Таджикистана. Сб.: Проблемы нефтегазоносности Таджикистана.
Всесою. научно-исслед. геол. нефт. инст., Москва 142 (1973) 5

DOI:https://doi.org/10.2312/zipe.1982.066

Расчленение стратифицированных и интрузивных образований Таджикистана.
Душанбе, Дониш 1976

РАСЦВЕТАЕВ, Л.М.; ЩЕРБА, И.Г.: Структурно-стратиграфическая корреляция этапов накопления и деформации моласс на примере юга Средней Азии. В кн. Проблемы глобальной корреляции геологических явлений.
Москва: Наука 1980

СОЛУН, В.И.: Некоторые вопросы стратиграфии третичных отложений Таджикской депрессии.
Ученнезап. ЛГУ, сер. геол. наук, 1959, вып. 10

ЩЕРБА, И.Г.: Олистостромы в неогене Дарвазского хребта.
Геотектоника, 1975, № 5 Москва (1975) 5

ЩЕРБА, И.Г.: Полизакская свита и ее стратиграфические аналоги в молассах Афгано-Таджикской впадины.
Докл. АН СССР, Москва 246 (1979) 1

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Explanatory Notes to the Lithotectonic Molasse Profile of the Westphalian Depression (Ruhr District - Münsterland - Ibbenbüren, F.R.G.; Upper Carboniferous - Permian) (Comment to Annex 18)

by

GERHARD KATZUNG[1)]

1. General information about the area

The Westphalian Depression is situated in the northern part of the Federal Republic of Germany. It represents a section of the northern foredeep of the Variscan tectogene which extends from the British Isles across northern France, Belgium, the F.R.G. and the northern part of the G.D.R. to the southern part of Poland. In the SW it is limited by the Krefeld Uplift, which was active as epirogenetic structure during Upper Carboniferous time, whereas it continues in northeastern direction. The depression is filled up with marine barren measures of Namurian A and B age ("Flözleeres"), and the coal-bearing pretectogenetic molasses of Namurian B to Westphalian D age ("Produktives"). The Ruhr district is placed at the southern border of the Westphalian Depression and belongs to the Variscan tectogene. The Münsterland lies more or less in a transition region, and the Ibbenbüren area already lies in the northern foreland of the tectogene.

The R u h r d i s t r i c t extends immediately north of the Rheinisches Schiefergebirge over a length of 100 km in W--E direction, and a width of 50 km. Due to the abun-abundance of coal seams and the quite considerable lead-zinc mineralizations, it belongs to the best-developed and best-explored areas of Central Europe. Northwards the coal-bearing deposits undergo subsidence to a depth of much more than 1000 m, being overlaid in the M ü n s t e r l a n d by cover of a thick Upper Cretaceous as well as of older Mesozoic and Upper Permian (Zechstein) of more than 2000 m thickness. Only as far as 60 km north of the Ruhr district the coal-bearing Carboniferous again crops out in three upturned blocks (Schafberg, Hüggel, Piesberg) in the I b b e n b ü r e n a r e a . The Münsterland and the surroundings of Ibbenbüren have been investigated by means of a great number of boreholes, moreover the Carboniferous blocks have been developed by mining.

1) Zentrales Geologisches Institut; DDR, 1040 Berlin, Invalidenstr. 44

DOI:https://doi.org/10.2312/zipe.1982.066

2. Tectonic structure and paleogeographic-paleotectonic evolution

Tectogenesis and morphogenesis

In Central Europe, the closing of the Variscan geosynclinal stage was initiated at the end of the Visean. The inner parts of the geosyncline were folded in the Sudetic phase (turn from Visean to Namurian), the outer ones, including the internal limb of the foredeep, in the Asturian phase (turn from Westphalian to Stephanian). Subsequently the inner and outer parts were uplifted and continuously denuded. In the outer Variscan belt, the intensity of folding decreases outward and disappears towards the foreland. In the same direction, the enveloping contour descends and the orogenesis as a whole declined, so that in the central areas of the tectogene the crystalline basement was cut, whereas in the foreland only the fault-block and fault-fold structure was levelled. Apart from some slight movements at transverse faults and intensive faultings in the Ibbenbüren area the tectonic development of the Westphalian Depression has been closed in pre-Permian time.

Sedimentation and subsidence

Following the Sudetic phase, the residual geosynclinal sedimentation areas were confined to the foredeep during Namurian time. The foredeep developed without an interruption of sedimentation from that part of the Rhenish-Moravian flysch depression, which was not subjected to the Sudetic folding.

The Westphalian Depression developed from the Namurian as a WSW--ENE striking basin north of the deep Dinantian trough, which extended from the eastern part of the Rheinisches Schiefergebirge to the Oberharz (northwestern part of the Hartz Mts.); northwards this basin was bordered by the wide foreland or platform basin which can be followed over the North Sea up to North England and Scotland. During the Namurian the foredeep appeared most distinctly. A trough being approximately 100 km wide developed, in which thicknesses of more than 2000 m have been shown to occur (about 3000 m for the surface profile south of Bochum; boreholes Isselburg 3 - 2020 m, Münsterland 1 - 2238 m, Versmold 1 - 3314 m). Westwards, towards the Krefeld Uplift, the depression axis ascends over a short distance (Stenden 2 borehole - appr. 800 m of Namurian), while northeastwards the trough should continue striking with an apparently minor reduction in thickness. The main subsidence and the maximum thickness differentiation were reached during the Namurian A and B with the sedimentation of a series of alum slates, quartzites, graywackes and shaly clays, which is more than 2400 m thick and contains no seams.

The abrupt accretion of coarse sands and the change in sedimentation from marine "Flözleeres" to paralic coal-bearing molasses during youngest Namurian B reflect insetting morphogenesis after the Sudetic phase. With the molasse sedimentation more balanced conditions developed and the subsidence slowed down. The most important sandstone groups, beginning with the "Grenzsandstein" (boundary sandstone) at the base, show a fairly constant character and indicate markedly large sand accretions at the southern slope of the basin. The sediments were supplied above all from the south from the Variscan morphogene. In the foredeep itself follows the basin axis towards WSW, but also be-

DOI:https://doi.org/10.2312/zipe.1982.066

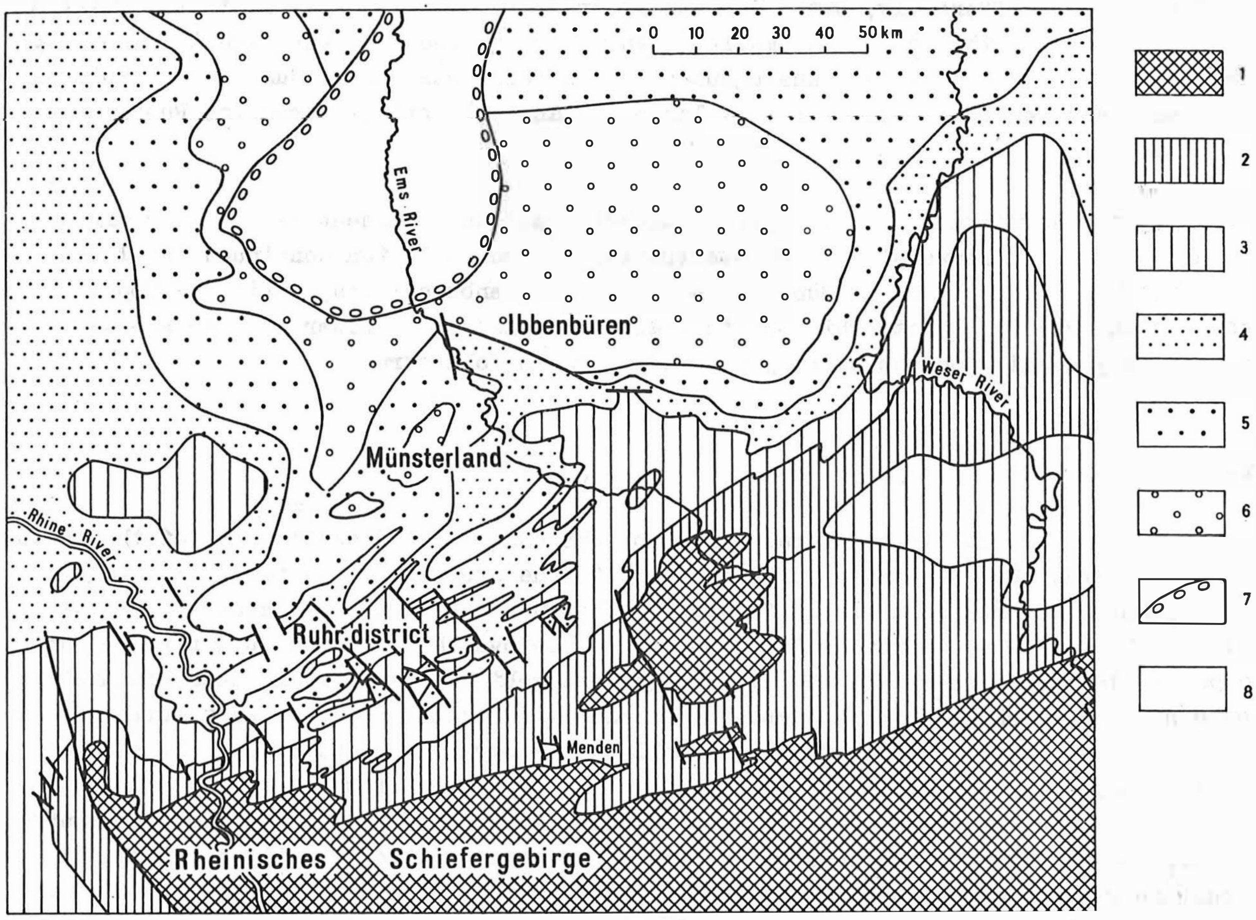


Fig. 1. The Variscan molasses north of the Rheinisches Schiefergebirge, outcropping as well as covered, according to TEICHMÜLLER, TEICHMÜLLER & BARTENSTEIN (1979), simplified

1 - pre-Namurian, 2 - Namurian, 3 - Westphalian A, 4 - Westphalian B, 5 - Westphalian C, 6 - Westphalian D, 7 - Stephanian, 8 - Lower Permian

DOI:https://doi.org/10.2312/zipe.1982.066

yond the axis supply towards N to NW has been encountered.

These tendencies continued during the Westphalian. The rates of sedimentation steadily decreased from 2.3 cm/100 a in the Namurian to 1.1 cm/100 a in the Westphalian D. In the foreland, the thicknesses of the Westphalian stages vary only within narrow limits, but show marked variations at short distance in the foredeep and slightly higher average values than in the foreland. During the Lower Westphalian A, the centres of subsidence still behaved indifferently, but since the Upper Westphalian A they distinctly shifted northwards, though the shift was smaller than in the period from Devonian to older Carboniferous. The facies behaves analogously to the thickness; individual seam complexes and sandstones can be traced over very large distances, partially from the Ruhr district up to the North Sea.

During the Asturian phase, the pretectogenetic molasse sedimentation was terminated in the Westphalian Depression. The interruption of sedimentation continued until the Upper Permian in the northern Münsterland and the Ibbenbüren area, until the Upper Cretaceous in the Ruhr district. Thin posttectogenetic molasses of Lower Permian age were deposited only locally on the already denuded Variscan fold structure.

Tectonic framework

The tectonic structure is characterized by the unrestricted development of the tectogenesis towards the foreland - quite contrary to the area bordering immediately westwards, where the extension of the folding is obstructed by the rigid abutment of the Wales-Brabant Massif, where the Variscan series are overthrusted upon the foreland up to 50 km. In that part of the Rheinisches Schiefergebirge, which is located immediately south of the Westphalian Depression, the intensity of tectogenesis shows a marked decrease towards the north; the folding finally disappears in the Ruhr district and the Münsterland. Highly special-folded anticlines and synclines of the Namurian and Westphalian A, which have approximately equal widths, still occur immediately at the southern border. Northwards the sinclines broaden more and more, so that finally a synclinal structure without anticlines is realized there (Figs 1, 2 and 3). The special folding decreases in the same direction. Initially the anticlines are still relatively narrow and special-folded, but then they are more and more replaced by flat-wavy archings and fault blocks of a simple structure. In the Ibbenbüren area, the beds are only just bent into flat waves and fractured.

Magmatism and mineralization

Apart from one exception, magmatic phenomena are not directly known from the time of molasse formation. However, primary-ascendant hydrothermal lead-zinc mineralizations on cross faults and diagonal transcurrent faults, which can be assigned to the time of the Asturian folding phase, are attributed to plutons which are said to have intruded at depths of 4000 to 5000 m and more. Due to the element and mineral association - sphalerite/galena/baryte in the upper floor, quartz/siderite+ankerite/chalcocite/pyrite in the lower floor - it suggests itself to assume palingenetic magmas as the bellies of ore.

DOI:https://doi.org/10.2312/zipe.1982.066

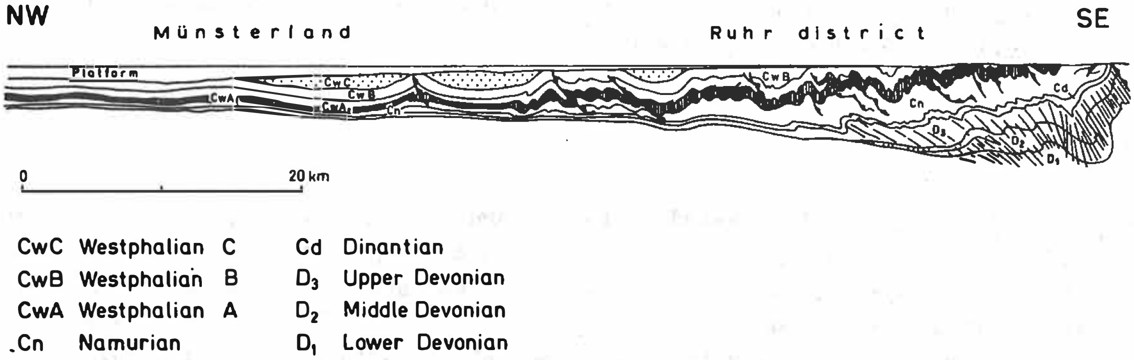


Fig. 2. Schematic cross-section from the Variscan tectogene (SE) to the northern foreland (NW) according to TEICHMÜLLER (1956)

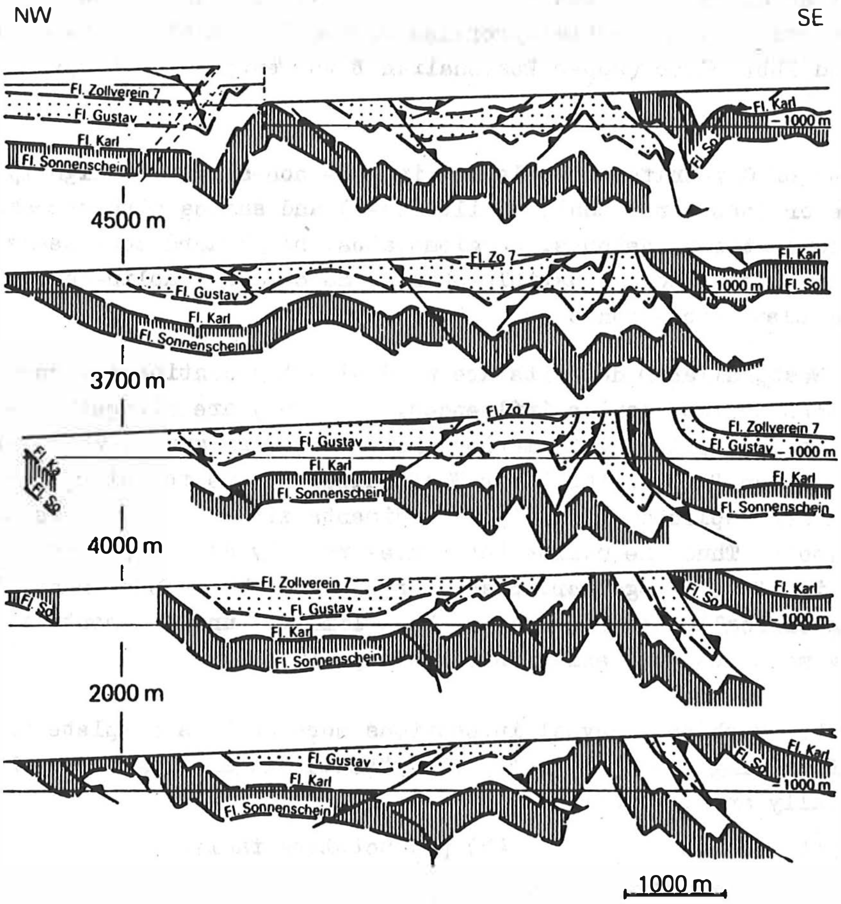


Fig. 3. Sections across the eastern part of the Essener Hauptmulde at distances from 2000 m up to 4500 m, showing deformations of Westphalian A and B deposits; no vertical exaggeration (taken from KUNZ 1979)

DOI:https://doi.org/10.2312/zipe.1982.066

An intrusive albite quartz porphyry observed in the upper Middle Devonian near Wuppertal is considered a descendant of this plutonism.

Substructure

There is relatively little knowledge of the structure of deeper parts of the crust. The geophysical investigations of the large magnetic and gravimetric anomalies of the Bramsche Massif which were carried out in the foreland north of Ibbenbüren show a laccolith-like basic intrusive body, which ascended to a depth of 5 km during the Lower Cretaceous, and is a discordantly intercalation into the flat-lying Paleozoic.

3. General information about the lithotectonio profile

The profile (Annex 18) shows molasse deposits from the Namurian B up to the Westphalian D as well as deposits of the Rotliegend (Lower Permian), with a thickness of 4000 m. It is composed of the partial profiles of the Ruhr district (Namurian B to upper Westphalian C) and Ibbenbüren (upper Westphalian B to Westphalian D) as well as Menden (Rotliegend).

The successions of Carboniferous molasses include non-sandy to slightly sandy shales (mudstones), more or less sandy shales (siltstones) and shales with streaks of sands, sandstones, conglomeratic sandstones, conglomerates, black hard coal seams (with underclays = stigmarian beds), and combustible shales. So-called "Kaolin-Kohlentonsteins" (= tonsteins) and olay iron-stones are interbedded.

Namurian B to Westphalian D deposits are predominantly continental ones which have been subject to more or less marine influences, i.e. they are altogether paralic deposits. The marine intercalations with marine micro- and megafaunae, which are frequently occurring from Namurian B up to the Lower Westphalian A, are receding from the upper Westphalian A and are replaced generally by sediments with fossil layers of non-marine (brackish) pelecypods. Thus the marine influences rapidly decreased and ended at the boundary Westphalian B/C. Altogether, plant fossils are then predominant. In what follows, these will not specifically be referred to. Pure limnal faunal elements are not known from coal-bearing measures, but exist in the Westphalian D.

All marine to brackish beds reveal in sections more or less complete and similar faunal cycles. The following types of facies (biophases) are distinguished which grade into one another laterally and vertically:

4a) goniatite facies 4b) productoidea facies

3) nuculacea facies

2) lingula facies

1) ophthalmoides facies

It is suggested that the types 1) to 4a) are reflecting a consequence of increasing marineness, in general linked to increasing depth of water. The epifauna is replaced by the infauna in the same direction. The goniatite facies is regarded as a slack water

DOI:https://doi.org/10.2312/zipe.1982.066

facies. In moved water it is replaced by the productoidea facies.

The marine horizons and the "Kaolin-Kohlentonsteine" gained importance as essential key horizons for the correlation of the individual profiles of the Westphalian Depression.

The succession is lithostratigraphically subdivided, where different features (marine horizons, significant sandstones, significant coal seams) are taken into account in defining the boundaries. The profile shows small-cyclic sequences with the following succession:

6) coal,
5) shale, non-sandy and slightly sandy (stigmarian beds),
4) sandy shale and shale with streaks of sand,
3) sandstone (climax of clastic sedimentation),
2) shale with streaks of sand and sandy shale,
1) shale, slightly sandy and non-sandy (frequently containing fossils of non-marine or marine fauna).

Thus the single cycle starts with a marine ingression and it ends with a regression. Swamps have been connected with regressions. They have taken a transitional position between fluvial fans, located in the immediate neighbourhood of the denudation area in the S to SE, and a marine to brackish lagoon (epeiric sea) in the N to NW (Fig. 4). The average thickness of these cycles is 7 to 8 m. Moreover, cycles of higher order can be observed.

Interruptions of sedimentation are not observed. Recent correlations with the Donez Carboniferous indeed allow the conclusion that there are extremely condensed parts of the profile in the range of the marine levels. Discordances do not occur within the type profile. The lower boundary at the base of the "Grenzsandstein" is sharp, but conformal. The Upper Carboniferous molasses, which are folded or faulted, are locally overlain by Lower Permian continental molasses of red beds character in the Menden area, while elsewhere they are overlain by the platform cover with a sharp discordance over large areas.

As a consequence of coal mining, the knowledge of the lithology can be judged to be good to very good. The coal seams themselves and certain key horizons such as the "Kaolin-Kohlentonsteins" as well as the marine horizons have been investigated most intensively, whereas the neighbouring rocks - mainly non-sandy shales to sandy shales and shales with streaks of sand - are less interesting; significant conglomerate and sandstone levels were subjected to a specific sedimentological research. The state of the paleontological and stratigraphic investigations is excellent.

DOI:https://doi.org/10.2312/zipe.1982.066

4. Description of the lithostratigraphic units

4.1. Upper Carboniferous (Silesian)

4.1.1. Namurian B - Westphalian C of the Ruhr district

In the Ruhr district, the Upper Carboniferous forms a succession of approximately 5500 m thickness from the Namurian A up to the Westphalian C. The lower boundary is defined at the base of the goniatite zone with Cravenoceras leion. It lies in the "Hangende Alaunschiefer", a succession of black to grey shaly clays being 50 - 200 m thick and having a varying content of FeS_2. This succession is overlain time-disconformally, but without a gap, by the thick "Flözleeres" which is divided into the "Quarzitzone", the "Grauwackenzone" and the "Ziegelschieferzone". The lower boundary of the "Flözleeres" is lithostratigraphically fixed at the base of the first thicker beds of graywacke. It ranges from the upper Eumorphoceras stage up to the lower Homoceras stage (middle Namurian A). The upper boundary lies at the base of the "Grenzsandstein" in the upper Reticuloceras stage (uppermost Namurian B).

The succession of the Upper Carboniferous molasses starts with the abrupt occurrence of this "Grenzsandstein" above the extremely fine-clastic, generally clayey, off-shore facies of the "Ziegelschieferzone", and ends within the Westphalian C. This so-called "Produktives" (productive measures) or "flözführendes Karbon" (coal-bearing Carboniferous) reaches a thickness of more than 3000 m. It consists of six lithostratigraphic units each being several hundred metres thick: Sprockhöveler Schichten, Wittener Schichten, Bochumer Schichten, Essener Schichten, Horster Schichten, Dorstener Schichten.

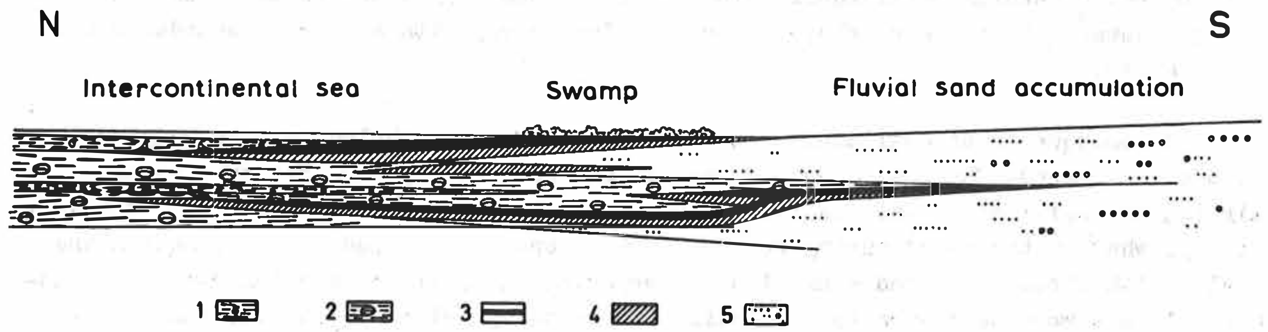


Fig. 4. Lithofacies changes during upper Namurian and lower Westphalian A time in a schematic N--S section according to TEICHMÜLLER (1955), somewhat modified

1 - marine clay, 2 - brackish mud, 3 - peat, 4 - fluvial mud, 5 - fluvial sand

DOI:https://doi.org/10.2312/zipe.1982.066

The S p r o c k h ö v e l e r S c h i c h t e n (uppermost Namurian B - Namurian C) are divided into two parts. The Untere Sprockhöveler Schichten begin, as was already mentioned, with the "Grenzsandstein", a group of beds being 10 - 15 thick, which can be traced also morphologically; the Obere Sprockhöveler Schichten begin with the marine horizon above the Hinnebeck seam. Maximum thickness is observed in the western part of the Ruhr district.

The cyclic sequences appearing distinctly in the "Flözleeres" continue in the Sprockhöveler Schichten, however with a general increase in the thickness of the cycles and an increase of the phases. The ideal cycle (see chapter 3) can be considerably modified both vertically and laterally by the varying thickness and the suppression of one or more phases respectively.

The Sprockhöveler Schichten are the mostly marine influenced beds of the lithotectonic profile. There occur six horizons with highly marine faunas as well as several slightly marine horizons. Moreover, marine influences can be proved in nearly all cycles. Reticuloceras superbilingue is typical of the Untere Sprockhöveler Schichten; Donezoceras sigma, Gastrioceras cancellatum, Gastrioceras crenulatum and Agastrioceras carinatum occur in the Obere Sprockhöveler Schichten. With the occurrence of Gastrioceras cancellatum in the marine Hauptflöz Horizon the boundary Namurian B/C is fixed.

The Untere Sprockhöveler Schichten do not contain any seams in their lower part being approximately 120 m thick (so-called Kaisberg-Schichten); in their upper part they bear non-workable seams. Only the seams of the Obere Sprockhöveler Schichten are exploited. The coals occur in the forge coal to anthracite stages.

The Kaisberg-Schichten deserve special consideration in as much as they start the molasse sedimentation. The accretion of thick fluvial sands and occasional conglomerates moving on delta planes into the water-covered depositional basin abruptly terminated the preceding offshore marine sedimentation. Changing marine-epeiric (i.e. sublitoral intercontinental sea) to litoral and palustrine conditions developed, shifting from SE to NW, which are characterized by the alternation of shales and compact sandstones as well as an extreme poverty of fossils in relation to the underlying "Ziegelschieferzone". The shales appear monotonous, while the sandstones are highly eventfull and not always persistent in their levels.

The Kaisberg sandstone, containing about 70 % of quartz, up to 15 % of feldspar and various rock fragments, can be referred to as greywacke, feldspar graywacke or subgraywacke. The cross bedding evidences accretions towards NNW and WSW. The main flow channel extends in a WSW--ENE direction. The material was supplied from the south into this channel. Analogous conditions in the Finefrau sandstone prove a persistence of these paleogeographic and deposition conditions up to the Lower Westphalian A.

The W i t t e n e r S c h i c h t e n (Lower Westphalian A) are divided into two parts. The Untere Wittener Schichten begin with the marine horizons above the Sarnsbank seam, the Obere Wittener Schichten with the marine horizon above the Finefrau-Nebenbank seam, which are the most important marine horizons of the Lower Westphalian A. Also for the Wittener Schichten, maximum thicknesses are reached in the western part of the Ruhr

DOI:https://doi.org/10.2312/zipe.1982.066

district. It is observed that the axes of subsidence are generally not W--E but NNE--SSW oriented.

The marine lower Sarnsbank Horizon is characterized by the occurrence of Gastrioceras subcrenatum; species of the genera Homoceratoides and Anthracoceras as well as the following marine fossil groups occur: lingulids, taxodonta, pectinoids, Myalina, and nautiloids. Additionally there are articulate brachiopods, heterodont pelecypods, bellerophontids and crinoids in the fossiliferous marine upper Sarnsbank Horizon. The marine horizon Finefrau-Nebenbank bears Gastrioceras circumnodosum, Gastrioceras listeri, Anthracoceras, pectinoids, lingulids and Planolites ophthalmoides. In addition, several thinner and less marine horizons are interstratified (cp. Annex 18).

With regard to the abundance of seams, the Wittener Schichten assume an intermediate position between the Sprockhöveler and the Bochumer Schichten. The seams are concentrated within three sections, i.e. the middle and the uppermost section of the Untere Wittener Schichten as well as the middle section of the Obere Wittener Schichten. The remaining intervalls, being several decametres thick, are barren. The seams in question consist mainly of forge coals and lean coals, to a less degree anthracites and fat coals. The optimum thicknesses of the individual seams are scattered over the entire Ruhr district. Splittings and thickness reductions of the seams towards epirogenic depressions or towards the centre of subsidence in the NW are as typical as in the Sprockhöveler Schichten.

The transport of the sands beneath the Mausegatt seam was also controlled from a centre of subsidence located in the NW. The main transport directions were SW, W and NW. Deviations resulted from flat ridges. Normal currents flew round the ridges which were overflown in the case of stronger currents. The sandstones at first filled the depressions and then also overlaid the ridges. When the power of transport decreased, the ridges at first were covered by silt. As a consequence of the northward shifting morphogenesis, beds of the deeper Carboniferous and the Devonian at the southern border of the Westphalian Depression were eroded at this time.

The deeper beds of the whole succession in the floor of the Mausegatt seam were deposited at the margin of an epeiric sea with a regressive tendency. The thin sandstones in the floor of the Fink seam are fillings of sand basins of the flat littoral zone. The thick sandstones in the floor of the Mausegatt seam are, with few exceptions, fluvial sediments being characterized by a rapid change in grain size, a poor roundness of the coarse material, and the occurrence of coarse drift wood. Meandering and braided rivers have deeply cut into the subjacent bed. These sediments were deposited on the highest part of a delta plain or in the lower river course of an estuary, i.e. at a shore line of emergence, and finally onshore on alluvial slope ascending very slightly towards the denudation area. The distance from the shore is uncertain. The transporting capacity varied; channel deepenings alternated with superficial transport.

Analogous conditions can be assumed for the Finefrau sandstone. Having a thickness of 15 - 45 m, it is a characteristic horizon widespread in the Ruhr district. Only in the eastern part it does not occur.

DOI:https://doi.org/10.2312/zipe.1982.066

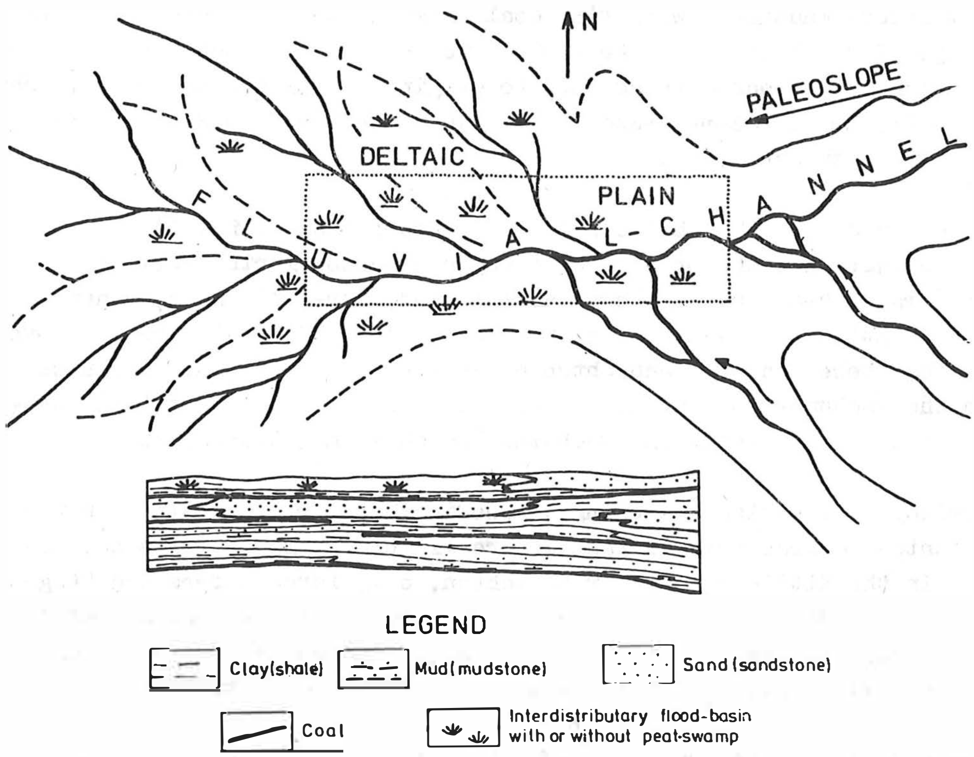


Fig. 5. A schematic reconstruction of depositional setting, showing dominant direction of paleoslope and possible occurrence of delta lobes in the Ruhr district (in rectangle) and around; shown below in an schematic cross-section of constituent lithofacies (taken from CASSHAP 1975)

Also for the succession in the floor of the Finefrau seam, a division of the sedimentation area into WSW--ENE striking, persistent rises and depressions, which plunge with a slight inclination of the axes towards the centre of the depression at the Rhine River, can be observed. They controlled the thickness and facies distribution as well as the transport of sediments. The Finefrau sandstone spreaded according to the slope of the axes in a WSW direction, at first by stream transport and then by coastal drift. During the channel phase, the Finefrau stream extended over approximately 100 km along the southern border of the foredeep. During the sheet phase the foredeep was covered by a uniform water surface.

The sandstones mainly consist of quartz and feldspar; muscovite and lydite recede. Only in the lower part the Finefrau sandstone is conglomeratic. The pebbles, which are usually well rounded, reach nut sizes. Quartz predominates also among the pebbles; additionally there are lydite, more or less metamorphic rocks (quartzite, metamorphic sand-

DOI:https://doi.org/10.2312/zipe.1982.066

stones, granite, quartz-feldspar aggregations, phyllite - totalling to less than 10 %), angular pyritiferous mudstones with fine coal pigment and, scarcely, also limestones with corals. The age of the lydites has been shown to be Silurian, that of the limestones Devonian. The metamorphic rocks are assumed to originate from the metamorphic margin of the Central German Crystalline Zone. Accordingly, an accretion from S to SE can also be supposed for the Finefrau sandstone.

The Bochumer Schichten (Upper Westphalian A) are divided into three parts. The Untere Bochumer Schichten begin with the marine horizon above the Plasshofsbank seam, which bears Gastrioceras amaliae and, here and there, other megafossils as well as frequently microfaunas. The Mittlere Bochumer Schichten begin above the Präsident seam, the Obere Bochumer Schichten above the Hugo seam. The thickness distribution changes with the Bochumer Schichten. The maximum lies in the SE, striking SW--NE. Thus the differences in the Wittener and Bochumer Schichten are compensated.

Marine horizons, or horizons showing marine influences, occur still in the Untere Bochumer Schichten. Characteristic fossils are lingulids; megafossils such as productids occur rarely. In the Mittlere Bochumer Schichten, only foraminifers and "Augenschiefertone" (eye shales) indicate very weak marine influences. A great number of layers with non-marine pelecypods in this section as well as in the Obere Bochumer Schichten evidence predominantly or exlusively non-marine conditions of sedimentation.

The Bochumer Schichten include the richest coal-bearing part of the entire Upper Carboniferous profile in the Ruhr district; the absolute maximum of the abundance of seams is reached between the Sonnenschein seam and the upper boundary of the Bochumer Schichten. Usually the coals concerned are fat coals, but there are also gas coals in the eastern part of the Ruhr district.

Characteristic lithostratigraphic horizons of the Untere Bochumer Schichten are the conglomeratic Schöttelchen sandstone, which is up to 30 m thick, and the Sonnenschein seam. In the Mittlere Bochumer Schichten, the partially conglomeratic sandstone above the Präsident seam can be traced over a large distance. Further significant horizons are the "Kaolin-Kohlentonsteins", which occur at this level for the first time. Such key horizons are lacking in the Obere Bochumer Schichten. Moreover, this stratigraphic sequence is distinguished by considerable facies and thickness variations as compared to the Mittlere and Untere Bochumer Schichten.

The sandstones in the section of the Dickebank, Röttgersbank and Matthias seams have been lithologically investigated in detail. In most cases they are fine- to medium-grained sandstones; coarse-grained ones locally contain intraformational pebbles. The detrital particles are embedded in a silty-clayey ground mass, the portion of which usually reaches more than 15 %, and locally, up to 40 %. Quartz predominates; additionally there are potash feldspar and lithic fragments of metasediments.

Most of the sand bodies exhibit a WSW--ENE orientation; they bifurcate and split off. From the Untere Bochumer Schichten to the upper ones, the belts of maximum sandstone thickness shifts from north to south. The sediments were transported towards WSW in an elongate marginal basin, but in part also towards NW, and deposited on a delta plain

DOI:https://doi.org/10.2312/zipe.1982.066

building up and prograding (Fig. 5).

The Essener Schichten (Lower Westphalian B) are likewise divided into three parts. The Untere Essener Schichten begin with the marine horizon above the Katharina seam. This horizon is very marked in its eastern part, in the range of maximum layer thicknesses, where it contains goniatites (Gastrioceras catharinae, Anthracoceras vanderbecki), towards the west the fauna impoverishes. The Mittlere Essener Schichten begin above the Grimberg 1 seam, the upper ones above the Zollverein 1 seam. The maximum thickness of the Essener Schichten is developed also in the SW. The inorease in thickness in this direction is accompanied by splittings of the seams.

Occasional, very weak marine influences above the Katharina Horizon are indicated by single foraminiferal layers and rare occurrences of small forms of marine pelecypods. Apart from this the Essener Schichten are developed exclusively non-marine.

The Untere Essener Schichten are poor, the Mittlere and Obere Essener Schichten are rich in coal seams. The coals in question are mainly gas coals, in part also fat coals and gas-flame coals. The neighbouring rocks are generally characterized by high facies changes; no one of the sandstone horizons can be traced with certainty over a larger distance.

Cyclically subdivided deposits with a great number of layers of non-marine pelecypods predominate in the Untere Essener Schichten. They can be correlated by means of the Laura 3 tonstein. For the Mittlere Essener Schichten, considerable seam splittings as well as an increase of the dirt beds were evidenced by means of "Kaolin-Kohlentonsteins". The same holds for the Obere Essener Schichten. The wall rocks are, however, characterized by even higher facies changes. Here the H1 tonstein is a significant key horizon.

The Horster Schichten (Upper Westphalian B) are divided into two parts. The Untere Horster Schichten begin with the Domina Horizon above the L seam, the upper ones, above the T seam. It appears that eastwards the Lingula-bearing Domina Horizon changes into a foraminiferal horizon. Above this only little foraminiferal horizons are known. Conchostracas and numerous non-marine pelecypods indicate the advanced, intensive freshening of the sedimentation area. For the Horster Schichten, an increase in thickness towards SE is likewise evidenced.

The coal seams occurring in the Horster Schichten mostly contain gasflame coals, in part also gas coals. Most of the workable seams occur in the Untere Horster Schichten. All the "Kaolin-Kohlentonsteins", except for the uppermost one, are extremely thin and do not persist over larger distances.

Altogether, the Horster Schichten are characterized by the occurrence of thick, partially conglomeratic sandstones, the thickness of which however varies considerably; occasionally they wedge out completely being represented by thick shaly series. Also the seams have a very irregular shape; frequently there are junctions and splittings in the individual seam groups. Numerous coal pebbles occurring in the sandstones evidence erosions of Upper Carboniferous seams.

DOI:https://doi.org/10.2312/zipe.1982.066

The D o r s t e n e r S c h i c h t e n (Westphalian C) are likewise subdivided into two sections. The Untere Dorstener Schichten begin with the marine Ägir Horizon above seam Z, the Obere Dorstener Schichten, above the Hagen 1 seam. The Upper Carboniferous profile of the Ruhr district ends with the Tristan group of seams. The Ägir Horizon, which is subdivided into 3 subhorizons, grows to a thickness of more than 30 m. Containing 36 genera of molluscs and brachiopods, it is that marine horizon of the Westphalian Depression which is richest in fossils. Individual foraminiferal layers as the last marine indications of this most intensive marine ingression extend up to 40 m into the roof. A subsequent intensive freshening of the area of deposition is indicated by the occurrence of non-marine pelecypods above many of the seams. A foraminiferal horizon above the Nibelung seam is considered to be a representative of the Top Marine Band of England in the more intensively freshened Westphalian Depression. Another foraminiferal horizon is known from the roof of the Parzival seam group, and finally a non-marine faunal layer exists above the Tristan seam group.

The numerous, frequently conglomeratic sandstones in the Dorstener Schichten, with considerable fluctuations in thickness and character, can partially be interpreted as fillings of erosional channels. They disturb considerably the small-cyclic sequences, complicating the correlation of the seams, above all in the highets sections. The coals of the Dorstener Schichten are flame and gas-flame coals.

The Ägir Horizon as well as three "Kaolin-Kohlentonsteins" and two conchostraca horizons in the lower and middle sections are characteristic key horizons. The tonstein in the Hagen 2 seam has yielded a significant bench mark on the absolute time scale with a physical age determination of 298 + 9 million years for sanidines. The Kobold-Loki and Midgard conchostraca horizons in the deepest Dorstener Schichten are the last key horizons in the Upper Carboniferous profile of the Ruhr district.

The Dorstener Schichten are discordantly overlain by the platform cover. The thickness distribution of the Untere Dorstener Schichten corresponds to that of the Horster Schichten.

4.1.2. Westphalien B - D of the Ibbenbüren area

In the Ibbenbüren area, the total thickness of the Upper Carboniferous by far exceeds 2000 m. Of these strata, a succession approximately 1800 m thick is known from hard coal mining and boreholes. The oldest encountered beds are of older Westphalian B age, the youngest ones are assigned to the Westphalian D.

The correlation with the profile of the Ruhr district is secured by floristic and faunistic investigations. Expecially the marine Ägir Horizon and "Kaolin-Kohlensteins" are of great importance in this respect. The seams are correlated with those of the Ruhr district up to the Tristan group, and recently they have also been correspondingly named.

Due to the high position in the Upper Carboniferous profile, sandstones as well as conglomerates are more numerous in the Ibbenbüren area than in the sequence of the Ruhr

DOI:https://doi.org/10.2312/zipe.1982.066

district. Their total portion increases towards the roof. In the same directions, the grey rock colours, typical of the Upper Carboniferous, are superseded by red shades, while the coal seams, which occur frequently in the grey part of the profile, disappear. The Ägir Horizon is the last purely marine intercalation. Foraminifers indeed also occur at yet higher levels. Intensive freshening of the depositional area is indicated also here by the appearance of non-marine pelecypods at many levels.

The coals occur in stages ranging between fat coal and anthracite. Indications from the platform cover as well as a regional decrease in the degree of coalification from N towards S suggest a young (Cretaceous) heating-up from northern direction in connection with a laccolithic abyssal intrusive activity (Bramsche Massif).

The sequence is divided into three lithostratigraphic units: the Alstedder Schichten, the Ibbenbürener Schichten, and the "Rote Folge".

The A l s t e d d e r S c h i c h t e n (Westphalian B) correspond to the Horster Schichten and, in their deepest section, to a part of the Essener Schichten. They are a sequence 550 m thick, containing 30 coal seams as well as several foraminiferal layers and horizons of non-marine pelecypods. Sandstones are already prevailing in the sandy-clayey alternating sequence. The Domina Horizon is indicated. For the Upper Westphalian B, a subtile comparison with the profile of the Ruhr district (Horster Schichten) has been carried out with success. Also the thickness of 330 m approximately corresponds to that in the northern Ruhr district.

The I b b e n b ü r e n e r S c h i c h t e n (Westphalian C - Lower Westphalian D) are divided into two parts. The Untere Ibbenbürener Schichten begin with the Ägir Horizon and end with the Dickenberg seam. Being 850 m thick and containing 46 coal seams, they represent the complete Westphalian C profile of the Westphalian Depression.

The Untere Ibbenbürener Schichten can likewise be correlated in detail with the Westphalian C of Ruhr district (Dorstener Schichten). Besides the floras and faunas, the Ägir Horizon and the "Kaolin-Kohlentonsteins" in the Erda and Hagen seams are important key horizons. The succession is very similar in both areas. In the Ibbenbüren area, the thickness of Westphalian C is only slightly reduced and the portion of more coarsely clastic accretions seems somewhat higher than in the Ruhr district. In the Ruhr district 220 m of Westphalian C above the Tristan seam group are removed, in which equivalents of the Bentingsbank (Undine), Glücksburg (Volker) and Zwilling (Walküre) seams developed in the Ibbenbüren area would to be expeced.

The Obere Ibbenbürener Schichten (Lower Westphalian D) begin with the occurrence of Neuropteris ovata immediately above the Dickenberg seam. Several coal seams are intercalated also in this sequence, which is 250 m thick. The portion of conglomeratic sandstones and conglomerates has further increased. A level containing foraminifers, which indicates a marine influence, occurs in the Itterbeck seam group.

The sandstones and conglomerates of the Upper Westphalian C (up from the Schmalebank seam) and the Lower Westphalian D have been sedimentologically investigated in detail. The conglomerates proved extremely unstable and unsuitable for establishing a type section. Since also seams are lacking in most cases, a clear succession of small cycles

DOI:https://doi.org/10.2312/zipe.1982.066

cannot be observed. Rapid lateral lithologic and grain size variations as well as scourings (channels and whirlpools) indicate turbulent sedimentation conditions. The cross bedding of the more coarse-clastic sandstones demonstrates accretions from NE to SE. The area of sedimentation is interpreted as a fluvial aggradation plain located near the supply region, which was temporarily covered by water.

The "R o t e F o l g e" (Upper Westphalian D) has a thickness up to 400 m and is directly overlain by the Zechstein. It consists of sandstones, conglomeratic sandstones and conglomerates with intercalated shaly clays. The flora occurring at the top of the Ibbenbüren profile already leads over to the Stephanian. The "Rote Folge" still contains stigmarian beds and perhaps even thin seams, which might suggest a partial seondary reddening.

4.2. Lower Permian (Rotliegend)

In the Menden area, at the southern border of the Ruhr district, the folded Upper Carboniferous is discordantly overlain by a series of red conglomerates and mixed silt/mudstones, being 200 m thick which is assigned to the Lower Permian (Rotliegend) and is called M e n d e n e r S c h i c h t e n . It shows a slightly synclinal structure; the WSW--ENE striking axis is dislocated at cross faults. It is an erosional outlier, which covers an area of nearly 10 km^2. The primary distribution province has been much larger and presumably elongated in WSW--ENE direction.

The Mendener Schichten show a tripartition into the "Hauptkonglomerat" (main conglomerate) up to 100 m, the "Letten-Folge" (lean clay sequence) up to 60 m, and the "Hangendes Konglomerat" (top conglomerate) above 50 m, the upper boundary being erosive. The "Hauptkonglomerat" mainly consists of fine to coarse and block-containing, largely unsorted, solid conglomerates as well as, to a minor extent, of mixed silt/mudstones and sandstones. Occasionally nodular limestones are intercalated. The "Letten-Folge" contains intensively red, sandy and carbonate mixed silt/mudstones. They are little consolidated and well bedded. Here and there calcareous sandstones are intercalated. In the overlying conglomerate, the maximum and average sizes of boulders are less than those of the "Hauptkonglomerat". It is also less consolidated. Moreover the two conglomerates differ from each other by their pebble content. While in the "Hauptkonglomerat" limestones are dominant with a percentage of 80 %, they are reduced to 50 % in the "Hangendes Konglomerat", where clastic sediments (35 %) and lydites (15 %) are more prominent.

The composition of the conglomerates suggests a supply region built up of Lower Namurian to Devonian deposits, which means that it is located in the south. The orientation of gravels secures sediment supplies from SW. The Menden occurrence is located right at the border of the primary distribution area. The accretions extended largely beyond the present range in a direction between north and east. A large extension of the distribution area must also be assumed for the "Letten-Folge".

Erosional disconformities within the two conglomerate sequences characterize an alluvial transport/sedimentation regime. Erosional channels are filled up with coarse conglom-

DOI:https://doi.org/10.2312/zipe.1982.066

erates, where the boulders of the largest sizes occur at the base. Episodic rivers with a high rate of stream-flow carried along boulders up to 50 m in size. The transport energy of the "Hangendes Konglomerat" is distinctly reduced as compared to the "Hauptkonglomerat". For the Menden occurrence, the conglomerate composition indicates a transport distance ranging from less than 10 km (Namurian to Upper Devonian gravels) to more than 30 km (Middle Devonian to Silurian gravels).

5. Conclusions

Since the Dinantian III beta the Westphalian Depression developed as a typical foredeep from the Rhenish trough of the Variscan geosyncline. In this period the greywacke accretions intensified from the south, while Culm clays were still deposited in the interior of the basin. From younger Dinantian to Namurian, the depression was considerably shifted to the north. With the last movements of the Sudetic phase the transport energy diminished and the greywacke sedimentation terminated rather abruptly. Quieter deposition conditions appeared in the older Namurian A ("Hangende Alaunschiefer"). Renewed accretions of coarser detrital material ("Quarzitzone" and "Grauwackenzone") at the turn from Namurian A to B coincide with the Erzgebirgian phase. The geosynclinal development in the narrower sense was terminated with fine-clastic off-shore sediments ("Ziegelschieferzone").

Sand accretions during the younger Namurian B initiated the molasse development in the Westphalian Depression. The sedimentation area of these sands extended itself over large distances already during the Namurian. During younger Westphalian the sands encroached up to 200 km and more in northern direction into the foreland basin. At the same time the marine environment was replaced by the continental one: the basin silted up. Completely marine conditions were restricted to relatively short, declining, and finally only sporadic marinings of an advancing fluvial aggradation plain. Another intensive marine ingression into the molasse basin occurred only at the turn from Westphalian B to C. The rivers swinging on the aggradation plain developed specific environments such as channels, flood banks, flood plains and boglands. But altogether, very uniform sedimentation conditions appeared in the foredeep and in the foreland.

Following the local paleo-slope, the sediments were transported towards WSW along the axis of the elongated foredeep, but also towards NNW to the foreland. The supply region was situated in the SE in the range of the Variscan morphogene. As in many elongated basins, in the Ruhr district the widespread WSW accretions should have been secondary material transports, i.e. transports which, after entering the sedimentation area, were diverted in the direction of the basin axis which plunged towards WSW. These accretion directions do not allow any direct conclusion as to the supply region. The occurrence of lydites, radiolarites, quartzites, metamorphites and granites together with typical rocks of the Rheno-Hercynian zone of the Variscan tectogene in the Finefrau sandstone can be brought into accordance with a sediment supply from the Variscan morphogene rather than with a supply from the Fennosarmatian Shield or its borderlands. Facies changes observed in the Westphalian C of the Westphalian Depression as well as the missing of coarse sediments of this age at the southern border of the "Fennosarmatian Highlands" exclude a supply from NE.

DOI:https://doi.org/10.2312/zipe.1982.066

Besides the shifting of the zone of strongest subsidence in the foredeep towards the foreland, above all the shifting of the sedimentation area in this direction indicates the northward extending morphogenesis and denudation during the molasse stage. Thus the proximal part of the fluvial accumulation area had already reached the foreland at the end of Westphalian C. The erosion of freshly deposited sediments at the southern border of the sedimentation area is indicated by clay boulders, angular coal fragments, and clay iron-stone boulders. Expecially during the younger Westphalian, the sedimentation area was restricted more and more.

Besides the small cycles, which are pronounced above all from Namurian C to Westphalian C and can be attributed to the interaction between sea level fluctuations and the supply of sediments, the profile shows larger cycles of different dimensions. These cycles are developed predominantly asymmetrical-progressive, i.e. they begin with coarse-clastic sediments (conglomeratic sandstones and sandstones) and end with fine-clastic, prevailing seam-bearing deposits. These cycles should reflect tectonic impulses. On this premises and together with the distribution of the sandstones and coals seams in the total profile, they allow conclusions about the sequence and the character of tectonic movements during the Upper Carboniferous.

Large-scale cycles, which become less distinctly towards the roof, are typical of the lower profile from the Namurian C up to the basal Upper Westphalian B. They result from a few tectonic impulses, which followed at greater distances and diminished. For the period from Namurian C to Lower Westphalian A, a connection to increased morphogenesis of the inner, Sudetically folded Variscan belt following to the Erzgebirgian phase is obvious. The Bochumer and Essener Schichten (Upper Westphalian A and Lower Westphalian B), where the coal-bearing reaches its maximum and compact sandstones largely diminish, represent a period of low tectonic activities and reduced transport energy.

Small scale cycles characterize the upper profile from Upper Westphalian B to Westphalian D. They show tectonic impulses, following each other in a rapid succession and an increasing intensity, of the Asturian tectogenesis which advanced into the Variscan foredeep from south to north. This tectogenesis reached its maximum at the turn from Westphalian to Stephanian. The Upper Carboniferous molasses were sheared off from the flat-lying substructure (Devonian to Namurian A/B), overthrusted and folded. This settled the tectonic evolution of the Westphalian Depression, as it must be concluded from the discordant overlapping of Stephanian on several units of Westphalian D in the Ems Depression located farther in the north. The foredeep was involved, though to a lower degree than the inner areas of the tectogene, in morphogenesis and denudation.

Only after a period of denudation, which included Stephanian and Autunian, conditions for an increased erosion and a new, short-term deposition of coarse-clastics of the Saxonian in comparatively limited areas were generated as a consequence of the Saalian movements.

DOI:https://doi.org/10.2312/zipe.1982.066

References

BACHMANN, M.; MICHELAU, D.; RABITZ, A.: Die Karbon-Ablagerungen in der Bundesrepublik Deutschland. III. A. 1. Das Rhein-Ruhr-Revier. a) Stratigraphie. Fortschr. Geol. Rheinld. Westf., Krefeld 19 (1971), p. 19-34

BÄSSLER, R.; HOYER, P.: Die Karbon-Ablagerungen in der Bundesrepublik Deutschland. III. A. 3. Das Karbon von Ibbenbüren, am Hüggel und Piesberg. b) Tektonik. Fortschr. Geol. Rheinld. Westf., Krefeld 19 (1971), p. 79-82

BÄSSLER, R.; HOYER, P.; JOSTEN, K.-H.: Die Karbon-Ablagerungen in der Bundesrepublik Deutschland. III. A. 3. Das Karbon von Ibbenbüren, am Hüggel und Piesberg. a) Stratigraphie. Fortschr. Geol. Rheinld. Westf., Krefeld 19 (1971), p. 75-78

BLESS, M.J.M.; BOUCKAERT, J.; CALVER, M.A.; GRAULICH, J.M.; PAPROTH, E.: Paleogeography of Upper Westphalian deposits in NW Europe with reference to the Westphalian C north of the mobile Variscian belt. Med. Rijks Geol. Dienst, N.S., 28 (1977) 5, p. 101-147

BOUROZ, A.; WAGNER, R.G.; GORDON, M.; MEYEN, S.V.; EINOR, O.L.: Predlozenija po sozdaniju mezdunarodnoj stratigraficeskoj skaly Karbona (Proposals for establishing an internationel stratigraphical scale of the Carboniferous). Izv. Akad. Nauk SSSR, Ser. geol., Moskva (1977) 2, p. 5-24

BRAUER, J.; BUNTFUSS, J.: Sedimentologische Untersuchungen im Oberen Westfal C und Unteren Westfal D des Ibbenbürener Karbons. Fortschr. Geol. Rheinld. Westf., Krefeld 13 (1966), p. 1095-1108

BURGER, K.; ECKHARDT, F.-J.; STADLER, G.: Zur Nomenklatur und Verbreitung der Kaolin-Kohlentonsteine im Ruhrkarbon. Fortschr. Geol. Rheinld. Westf., Krefeld 3 (1962) 2, p. 525-540

BURGER, I.; STADLER, G.; WOLF, M.: Die Karbon-Ablagerungen in der Bundesrepublik Deutschland. III. A. Der paralische Raum. 5. e) Kaolin-Kohlentonsteine. Fortschr. Geol. Rheinld. Westf., Krefeld 19 (1971), p. 125-128

CASSHAP, S.M.: Lithofacies analysis and paleogeography of Bochumer Formation (Westfal A2), Ruhrgebiet. Geol. Rdsch., Stuttgart 64 (1975), p. 610-640

DAMON, P.E.; TEICHMÜLLER, R.: Das absolute Alter des sanidinführenden kaolinischen Tonsteins im Flöz Hagen 2 Westfal C im Ruhrrevier. Fortschr. Geol. Rheinld. Westf., Krefeld 18 (1971), p. 53-56

DROZDZEWSKI, G.: Grundmuster der Falten- und Bruchstrukturen im Ruhrkarbon. Zeitschr. deutsch. geol. Ges., Hannover 130 (1979), p. 51-67

FIEBIG, H.E.R.: Die Karbon-Ablagerungen in der Bundesrepublik Deutschland. III. A. 1. Das Rhein-Ruhr-Revier. b) Entwicklung der Schichtmächtigkeiten. Fortschr. Geol. Rheinld. Westf., Krefeld 19 (1971), p. 35-40

FIEGE, H.: Das Namur C und Westfal im Niederrheinisch-Westfälischen Steinkohlengebiet. C.R.6. Congr. Strat. Géol. Carbonif. Sheffield 1967, Maestricht 1 (1969), p. 79-89

GREBE, H.: Die Karbon-Ablagerungen in der Bundesrepublik Deutschland. III. A. Der paralische Raum. 5. a) Mikroflora. Fortschr. Geol. Rheinld. Westf., Krefeld 19 (1971), p. 121-124

GRIBNITZ, K.-H.: Stratonomische Beobachtungen in den Magerkohlenschichten (Namur ob. C) Westfalens. Beih. Zeitschr. Geol., Berlin (1954) 9, 48 p.

HEDEMANN, H.-A.: Die Bedeutung des Oberkarbons für die Kohlenwasserstoffvorkommen im Nordseebecken. Erdöl u. Kohle, Hamburg 33 (1980) 6, p. 255-266

HEDEMANN, H.-A.; TEICHMÜLLER, R.: Die Karbon-Ablagerungen in der Bundesrepublik Deutschland. III. A. Der paralische Raum. 6. Die paläogeographische Entwicklung des Oberkarbons. Fortschr. Geol. Rheinld. Westf., Krefeld 19 (1971), p. 129-142

DOI:https://doi.org/10.2312/zipe.1982.066

HEITFELD, K.-H.: Die roten Schichten von Menden (Mendener Konglomerat).
Z. deutsch. geol. Ges., Hannover 106 (1956), p. 387-401

HOYER, P.; LEISSER, J.; TEICHMÜLLER, M.; TEICHMÜLLER, R.: Die Karbon-Ablagerungen in der Bundesrepublik Deutschland. III. A. 3. Das Karbon von Ibbenbüren, am Hüggel und Piesberg. c) Inkohlung.
Fortschr. Geol. Rheinld. Westf., Krefeld 19 (1971), p. 83-86

HOYER, P.; PILGER, A.: Die Karbon-Ablagerungen in der Bundesrepublik Deutschland. III. A. 1. Das Rhein-Ruhr-Revier. c) Tektonik.
Fortschr. Geol. Rheinld. Westf., Krefeld 19 (1971), p. 41-46

JOSTEN, K.-H.: Die mächtigsten Pflanzenfossilien des Ruhrkarbons und ihre Bedeutung für die Gliederung des Westfals.
Fortschr. Geol. Rheinld. Westf., Krefeld 3 (1962) 2, p. 753-772

JOSTEN, K.-H.: Zur Flora des jüngeren Karbons (Westfal C bis Stefan) in Nordwestdeutschland und ihr Vergleich mit anderen Gebieten.
Fortschr. Geol. Rheinld. Westf., Krefeld 13 (1966), p. 565-644

JOSTEN, K.-H.; TEICHMÜLLER, R.: Zusammenfassende Übersicht über das höhere Oberkarbon im Ruhrrevier, Münsterland und Ibbenbürener Raum.
Fortschr. Geol. Rheinld. Westf., Krefeld 18 (1971), p. 281-292

KNAUFF, W.; KÖWING, K.; RABITZ, A.: Der erste Nachweis von Horizonten mit Foraminiferen im Westfal D von Nordwestdeutschland.
Fortschr. Geol. Rheinld. Westf., Krefeld 18 (1971), p. 257-262

KUNZ, E.: Zum tektonischen Bau der östlichen Essener Hauptmulde und ihrer begleitenden Sättel.
Zeitschr. deutsch. geol. Ges., Hannover 130 (1979), p. 69-76

MALMSHEIMER, W.K.: Zur Sedimentation und Epirogenese im Ruhrkarbon. Die Sandsteine im Liegenden von Flöz Mausegatt (Oberkarbon, Westfal A, untere Wittener Schichten).
Forsch.-Ber. Land Nordrhein-Westfalen, Köln und Opladen (1968), 2000, 74 p.

PAPROTH, E.: Der Kulm und die flözleere Fazies des Namurs. Stand der Untersuchungen und offene Fragen.
Fortschr. Geol. Rheinld. Westf., Krefeld 3 (1960), p. 385-422

PAPROTH, E.: Die stratigraphische Verbreitung der nicht-marinen Muscheln im Westfal Nordwestdeutschlands.
Fortschr. Geol. Rheinld. Westf., Krefeld 3 (1962) 2, p. 787-794

PAPROTH, E.: Die Karbon-Ablagerungen in der Bundesrepublik Deutschland. III. A. Der paralische Raum. 6. a) Megafauna.
Fortschr. Geol. Rheinld. Westf., Krefeld 19 (1971), p. 109-112

PAPROTH, E.: Zur Folge und Entwicklung der Tröge und Vortiefen im Gebiet des Rheinischen Schiefergebirges und seiner Vorländer, vom Gedinne (Unter-Devon) bis zum Namur (Silesium).
Nova Acta Leopoldina, N.F., Halle (Saale) 45 (1976) 224, p. 45-58

PATTEISKY, K.: Die Goniatiten im Namur des Niederrheinisch-Westfälischen Karbongebietes.
Mitt. westf. Berggewerkschaftskasse, Bochum 14 (1959), 65 p.

PATTELSKY, K.: Die Goniatiten im Westfal des Niederrheinisch-Westfälischen Karbons.
Palaeontographica, Stuttgart, A 125 (1965), p. 1-45

PILGER, A.; STADLER, G.: Die Karbon-Ablagerungen in der Bundesrepublik Deutschland. III. A. 1. Das Rhein-Ruhr-Revier. c) Blei-Zink-Vererzung.
Fortschr. Geol. Rheinld. Westf., Krefeld 19 (1971), p. 57-60

RABITZ, A.: Die marinen Horizonte des flözführenden Ruhrkarbons. Rückschau und Ausblick.
Fortschr. Geol. Rheinld. Westf., Krefeld 13 (1966), p. 243-296

ROSENFELD, U.: Zur Stratigraphie der Kaisberg-Schichten (oberes Namur) im Ruhr-Karbon.
Geol. Rdsch., Stuttgart 56 (1967), p. 494-520

SCHAUB, H.: Über Sedimentationsrhythmen in den oberen Sprockhöveler Schichten (Namur C) an Rhein und Ruhr.
N. Jb. Geol. Paläont., Mh., Stuttgart (1955), p. 169-172

DOI:https://doi.org/10.2312/zipe.1982.066

SCHAUB, H.: Devonkalk-Gerölle im Finefrau-Konglomerat südwestlich von Duisburg.
Z. deutsch. geol. Ges., Hannover 107 (1956), p. 83-86

SCHERP, A.: Zur Petrographie des Finefrau-Konglomerates bei Essen und einiger anderer geröllführender Sandsteine des Ruhrkarbons.
N. Jb. Geol. Paläont., Mh., Stuttgart (1957), p. 240-244

SCHERP, A.: Die Petrographie der paläozoischen Sandsteine in der Bohrung Münsterland 1 und ihre Diagenese in Abhängigkeit von der Teufe.
Fortschr. Geol. Rheinld. Westf., Krefeld 11 (1963), p. 251-282

SCHERP, A.; SCHRÖDER, E.: Der Albit-Quarzporphyr von Langerfeld-Delle - eine spätorogene Intrusion in das Obere Mitteldevon des Bergischen Landes.
Fortschr. Geol. Rheinld. Westf., Krefeld 3 (1962) 3, p. 1205-1224

SCHRÖDER, L.: Einige charakteristische Züge der Oberkarbon-Sedimentation im nordwestdeutschen Raum.
C. R. 7. Congr. Int. Stratigr. Géol. Carbonif., Krefeld 4 (1975), p. 217-226

STADLER, G.: Die Kaolin-Kohlentonsteine aus dem Westfal C und B der Untertagebohrung 150 der Steinkohlenbergwerke Ibbenbüren und ihre Bedeutung für die Karbonstratigraphie Nordwestdeutschlands.
Fortschr. Geol. Rheinld. Westf., Krefeld 18 (1971), p. 79-100

STADLER, G.; TEICHMÜLLER, R.: Zusammenfassender Überblick über die Entwicklung des Bramscher Massivs und des Niedersächsischen Tektogens.
Fortschr. Geol. Rheinld. Westf., Krefeld 18 (1971), p. 547-564

TEICHMÜLLER. R.: Sedimentation und Setzung im Ruhrkarbon.
N. Jb. Geol. Paläont., Mh., Stuttgart (1955), p. 146-168

TEICHMÜLLER, R.: Die Entwicklung der subvariscischen Vortiefe und der Werdegang des Ruhrkarbons.
Z. deutsch. geol. Ges., Hannover 107 (1956), p. 55-65

TEICHMÜLLER, R.: Die paläogeographisch-fazielle und tektonische Entwicklung eines Kohlenbeckens am Beispiel des Ruhrkarbons.
Z. deutsch. geol. Ges., Hannover 124 (1973), p. 149-165

TEICHMÜLLER, M.; TEICHMÜLLER, R.: Die Karbon-Ablagerungen in der Bundesrepublik Deutschland. II. A. 1. Das Rhein-Ruhr-Revier. d) Inkohlung.
Fortschr. Geol. Rheinld. Westf., Krefeld 19 (1971), p. 47-56

TEICHMÜLLER, M.; TEICHMÜLLER, R.; BARTENSTEIN, H.: Inkohlung und Erdgas in Nordwestdeutschland. Eine Inkohlungskarte der Oberfläche des Karbons.
Fortschr. Geol. Rheinld. Westf., Krefeld 27 (1979), p. 137-170

WEHRLI, H.: Graptolithen führendes Kieselschiefergeröll aus dem Finefraukonglomerat des Ruhrgebiets.
Glückauf, Essen 74 (1938) 1, p. 249-250

WENDT, A.: Der Finefrausandstein - Sedimentation und Epirogenese im Ruhrkarbon.
Forsch.-Ber. Land Nordrhein-Westfalen, Köln und Opladen (1965), 1396, 47. p.

WOLF, M.: Vorkommen und Ausbildung des Kaolin-Kohlentonsteins in den Karl-Flözen (Westfal A).
C.R.6. Congr. Int. Stratigr. Géol. Carbonif., Sheffield 4 (1971), p. 1593-1604

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Explanatory Notes to the Lithotectonic Molasse Profile of the Central European Depression (North-East German Depression), G.D.R. (Comment to Annex 19)

by

G. KATZUNG[1)]

1. General information about the area

The Central European Depression extends from the southern North Sea across the northern parts of the Federal Republic of Germany and the German Democratic Republic to the eastern limb of Poland. In the G.D.R. this epicontinental basin is bounded to the north by the eastern prolongation of the Ringkøbing-Fyn High (Arkona Block of northern Rügen island), and on the south by the outcropping block-mosaic of the Variscan tectogene (Block of Flechtingen and Lusatian Block). This particular region, limited in the west and east by the frontier, is called North-East German Depression (Fig. 1). In this context it will be considered here.

This depression occupies an area of about 60000 km^2, and is filled up with deposits of Upper Paleozoic, Mesozoic, and Cenozoic age. Upper Carboniferous and Lower Permian molasses are concealed continuously by the epi-Variscan platform cover, which attains a thickness of more than 5000 m (Fig. 1). Molasses and associated volcanic rocks have been encountered to a certain extend in boreholes. On the elevated blocks at the southern border Lower Permian molasses are cropping out partially. In the North-East German Depression sediments of the younger Lower Permian (Saxonian) are relatively well known, whereas many wells have reached pre-Saxonian deposits indeed, but only in some cases sunk deeply into them.

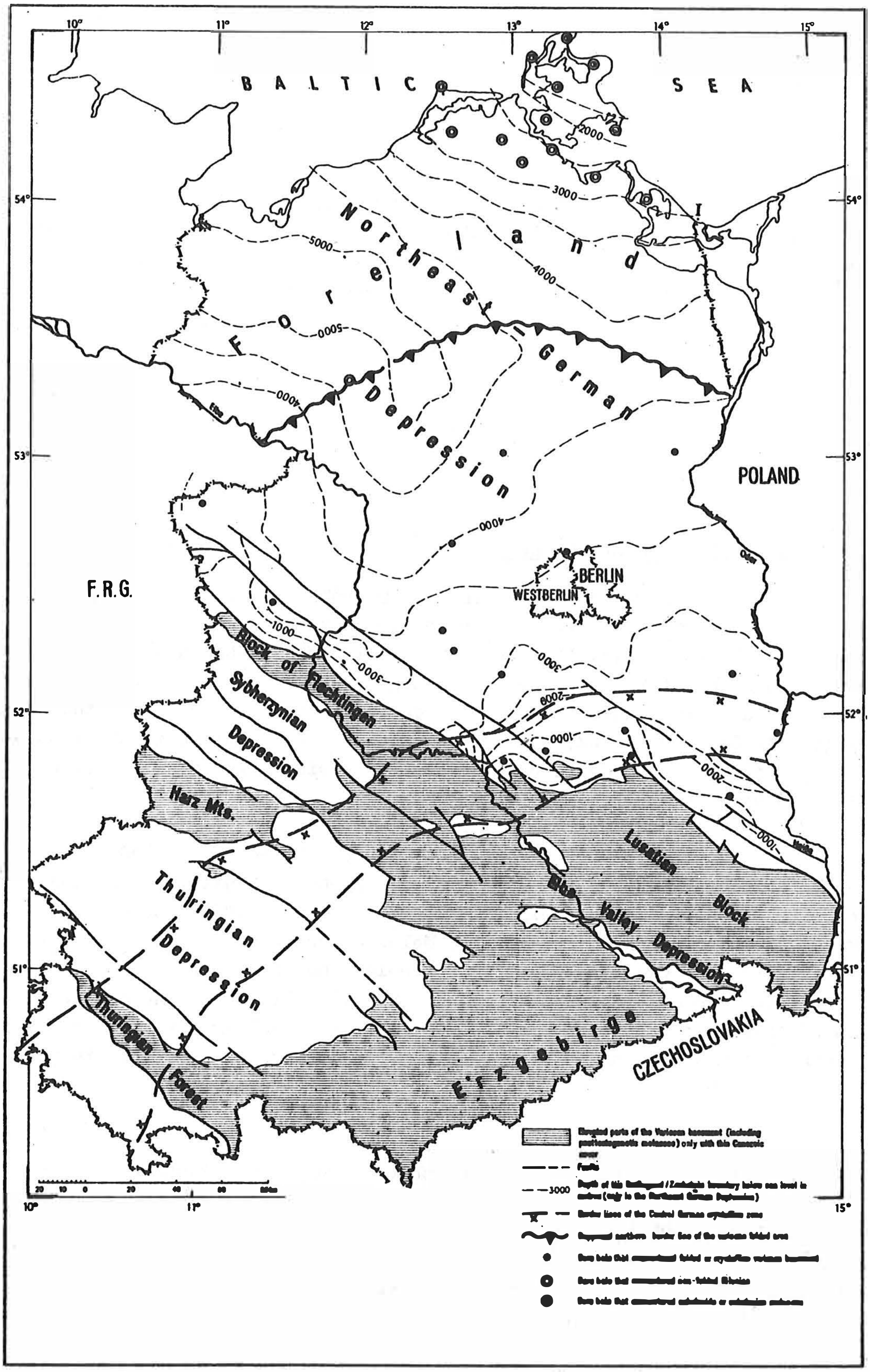
2. Tectonic structure and paleogeographic-paleotectonic evolution

Tectonic division of the basement

The basement of the North-East German Depression has been deformed and consolidated regionally at different times. Along the southern border and in the eastern central part

1) Zentrales Geologisches Institut; DDR, 1040 Berlin, Invalidenstraße 44

DOI:https://doi.org/10.2312/zipe.1982.066



DOI:https://doi.org/10.2312/zipe.1982.066

folded and metamorphosed rocks of the Variscan fold belt occur. They belong to the Rhenohercynian-Subvariscan Zone and to the Saxothuringian-Lugian Zone, as can be seen by the elevated blocks in the south and by boreholes. Adjoining to the north, in the eastern part of the depression a zone of Caledonian deformed rocks follows, encountered in boreholes on the Rügen island and in the borehole Loissin 1 near Greifswald in depth down to 7100 m. This zone borders the East-European Platform in the southern Baltic Sea. In the western part of the depression the supposed East-Elbe Massif of presumably Precambrian consolidation is situated between the Variscan and the Caledonian fold belts. These areas of different deformation ages are limited probably by large faults, partly having the character of deep fractures.

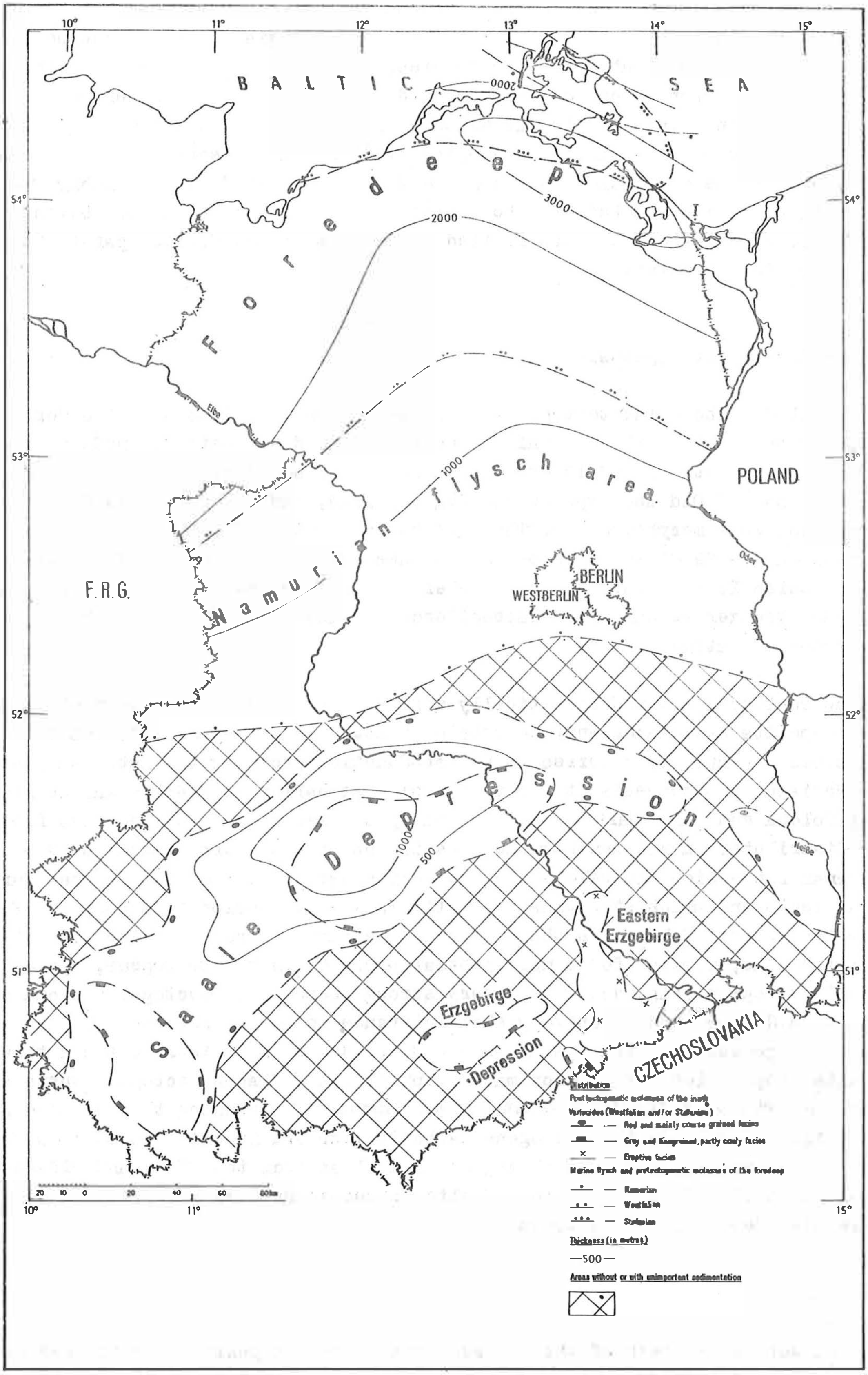
Tectogenesis and morphogenesis

The knowledge about the tectogenetic and morphogenetic history of the North-East German Depression starts with Caledonian events. Inclined and deformed mudstones, sandstones and greywackes of Middle Ordovician age are discordantly overlain by Middle Devonian molasses of Old Red type on the Rügen island, indicating likely Caledonian tectogenesis and weak morphogenesis. These rocks belong to the Caledonian Deformation Belt which runs in NW--SE direction along the south-western border of the East-European Platform from the Danish Islands through the southern Baltic Sea, northeastern G.D.R., and northern Poland. Younger Devonian and Carboniferous marine carbonate sediments represent the epi-Caledonian platform cover.

In the southern part tectogenetically deformed Devonian up to lowermost Upper Carboniferous deposits are discordantly overlain by Lower Permian sediments and volcanic rocks. This discordance must be referred to a post-Sudetic, probably the Asturian phase which closed Variscan tectogenesis at the turn from Westphalian to Stephanian. Weakly to moderately folded and only partially foliated Upper Visean to Lower Namurian flysch is widely distributed in the south-western region and the eastern central part of the North-East German Depression. It belongs to the very external zone of the Central European Variscan Tectogene which stretches generally in W--E direction from northern France and Belgium to southern Poland. On the other hand metamorphic rocks of the Central German Crystalline Zone, typical for a more central position in the tectogene, appear in the southeastern region (Fig. 1). Thus a very strong increase in tectogenesis and morphogenesis from N to S at a relatively short distance is to be accepted. In the opposite direction orogenesis declined as a whole but reached much farther to the N than in the Westphalian Depression. The approximate front of the Variscan tectogene turns arcuately W--E in the centre of the North-East German Depression, crossing the supposed East-Elbe Massif (Fig. 1). Outside the tectogene Carboniferous and Devonian deposits were block-faulted, as known from the coastal region as well as from the Rügen and Hiddensee islands. In pre-Permian time folded and block-faulted successions were levelled and covered by Lower Permian deposits in the whole area.

Fig. 1. Structural pattern of the Variscan tectogene and position of the Northeast-German Depression

DOI:https://doi.org/10.2312/zipe.1982.066



DOI:https://doi.org/10.2312/zipe.1982.066

Deposition and subsidence

In the North-East German Depression we have to distinguish three stages of molasse deposition with respect to the structural development:

1. pretectogenetic sedimentation of Upper Carboniferous (Silesian) molasses,
2. posttectogenetic accumulation of Lower Permian (Autunian) volcanic rocks and sediments,
3. posttectogenetic sedimentation of Upper Lower Permian (Saxonian) molasses.

The Silesian molasses are encountered at the external flank of the Variscan Foredeep and in the Foreland (Fig. 2). They have been included in deformation processes of the Variscan tectogenesis which resulted here in block-faultings only. In strict accordance with the tectonic evolution these molasses are belonging to the substructure, but also represent the epi-Caledonian platform cover.

The North-East German Depression began to subside in early Permian time, after the above-mentioned break in sedimentation, as a consequence of the late Carboniferous (Asturian) orogenesis and the following denudation. During Autunian time, Variscan subsequent volcanism resulted in accumulations of up to more than 2000 m of lavas, ignimbrites and tuffs in limited volcano-tectonic depressions, as reached in the borehole Friedland 1 near Anklam down to 6500 m depth. Such depressions with eruptive complexes are situated in the SW (Subherzyn-Altmark), E (East-Brandenburg), and N (Darß-Uckermark), whereas in other places volcanics are very thin or missing, like on the West-Brandenburg Uplift (Fig. 3). This differentiated subsidence is attributed to the effects of crossing of significant meridional fracture zones, together with fractures striking NW--SE in the bend range of the Variscan tectogenetical zones.

As a consequence of the Saalian tectonic processes at the turn from Autunian to Saxonian time, single depressions originated in most cases from late-Autunian sedimentary basins. They developed expansively and joined to the broad North-East German Depression during Saxonian time (Fig. 4). The intensity of tectonic movements slackened simultaneously, and the local fracture tectonics, dominating at the beginning, were replaced by a large-areal epirogenetic subsidence. They closed without attaining a direct connection to the starting of epi-Variscan platform stage. The centre of subsidence with up to more than 1000 m of clay and silt, associated with halite in the upper part of the progressive, large-scale cyclic sequence, was located in the north-western part of the North-East German Depression. The conglomerate-accompanied margins generally coincide with the present-day borders of the depression in the N and the S, respectively. In the S there were connections with the smaller molasse depressions of the inner Variscan zones, too (cp. ELLENBERG, this volume, p. 263).

True epicontinental development started in the late Permian (Zechstein) time with a marine transgression from the Scandic Ocean, extending far to the S beyond the Saxonian depression. Thick evaporite sequences were deposited in deep basins introducing platform development.

Fig. 2. Paleogeographic scheme of the Silesian

DOI:https://doi.org/10.2312/zipe.1982.066

Magmatism

The above-mentioned Autunian volcanic rocks indicate the most important magmatic event in the history of the North-East German Depression. Filling the whole depression, only small areas excepted, their volume is estimated to more than 50000 km^3. In no other region of the European Variscides such enormous quantities of volcanic rocks have been accumulated. They are associated with subvolcanic intrusions (dykes and sills) especially in the non-folded Carboniferous in the coastal region. There the physical age is dated to 260 ± 25 million years.

Substantially the following associations have been recognized:

1. basic rocks in small quantities from the isles of Rügen and Hiddensee,
2. intermediate to basic rocks in medium quantities from East Brandenburg,
3. acid to intermediate rocks in considerable quantities from Subherzyn-Altmark and Darß-Uckermark as well as from the centre of the North-East German Depression.

The volcanic rocks belong to two magmatic families. The basic rocks of association (1) are very similar to the type of olivine basalts, e.g. to the primary basaltic magma. They are ejectamenta of subcrustal depth and must be classified as products of the platform magmatism. The eruptive rocks of associations (2) and (3) show all features of the pacific (calc-alcalic) series. They have been generated by palingenesis of crustal parent rocks and represent the products of the far extended Variscan subsequent volcanism which was very intensive especially in this place.

3. General information on the type-profile

The type-profile shows sediments from Namurian B up to Saxonian age as well as volcanic rocks of Autunian age, with a thickness of about 4500 m. It is compiled of three partial profiles located in different areas of the North-East German Depression:

(a) north-eastern part: Namurian B and Westphalian A to Stephanian pretectogenetic molasses,

(b) central part: Autunian subsequent volcanic rocks and posttectogenetic molasses,

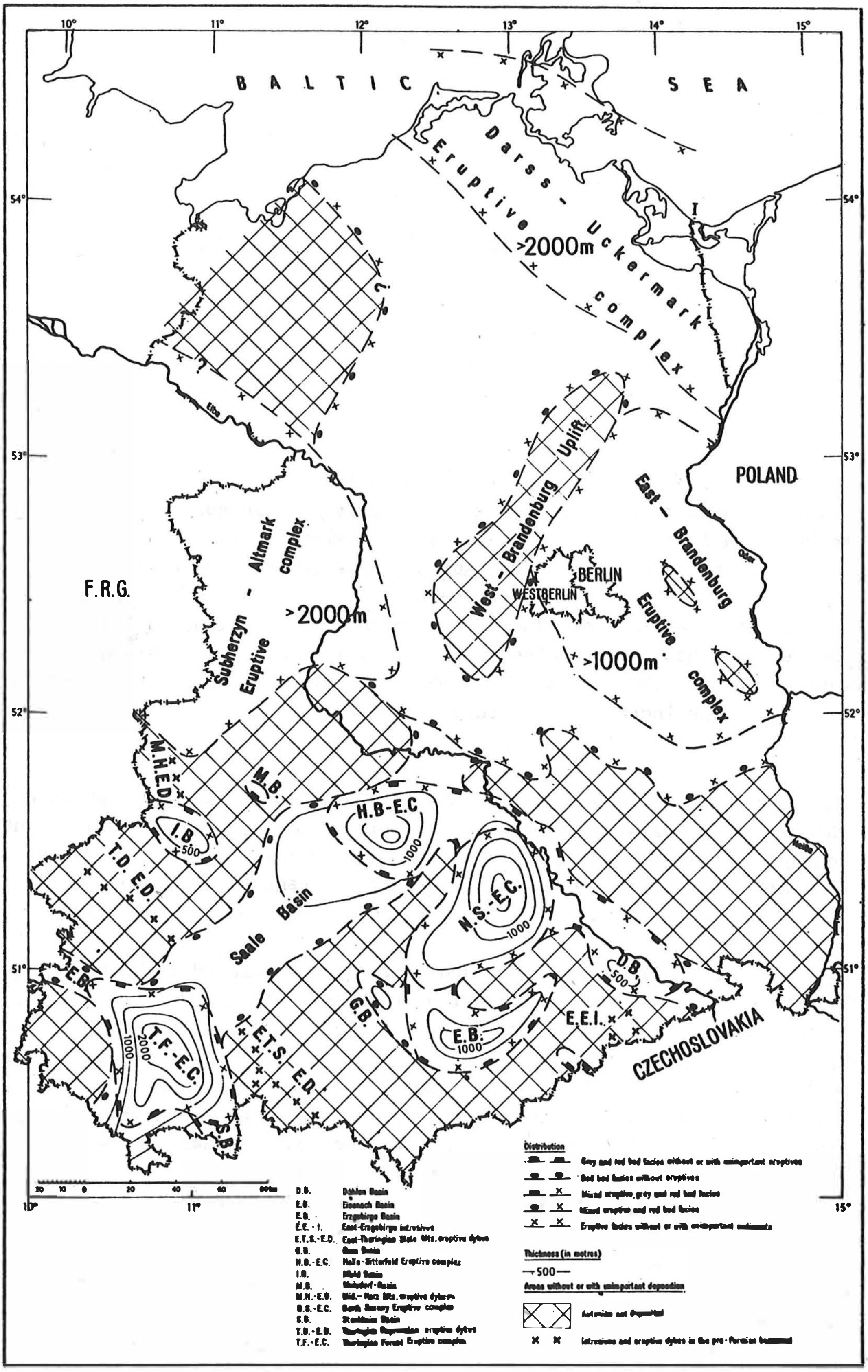
(c) south-western part: Saxonian posttectogenetic molasses.

3.1. Silesian pretectogenetic molasses

The Silesian molasses of the North-East German Depression are well known from the Rügen and Hiddensee islands. Here, sections from upper Westphalian A up to supposed Stephanian have been encountered in some boreholes. The Rügen-Hiddensee type-profile is supplemented to the bottom by two well-sections from the coastal region of the mainland where Westphalian A is proved more or less completely, and uppermost Namurian A

Fig. 3. Paleogeographic scheme of the Autunian

DOI:https://doi.org/10.2312/zipe.1982.066



DOI:https://doi.org/10.2312/zipe.1982.066

and Namurian B are developed as well. Though profiles on the mainland are thicker and more extensive, lower Namurian A and Namurian C deposits have not been found despite of continuous well-sections. Lacks of sedimentation are very probably. The succession of Silesian molasses includes alternations with variable portions of shales, siltstones and sandstones. More or less pure sandstones, pebbly beds and conglomerates occur especially in the upper part. Thin black coal seams and single carbonate rock layers, brackish and marine horizons, "Kaolin-Kohlentonsteins" and tuffite layers are lithologically characteristic intercalations. The succession is roughly subdivided into the so-called "Graue Folge" (Namurian A to lower Westphalian C) and "Rote Folge" (upper Westphalian C to Stephanian).

The profiles show small-scale cycles in the range of decimetres to decametres consisting of the above-mentioned main lithotypes. Progressive-asymmetrical cycles are dominating, whereas the percentage of recessive-asymmetrical and symmetrical cycles is very low.

Silesian molasses are predominantly continental ones which have been subjected sometimes to marine influences, i.e. they are partially paralic deposits. Intercalations with marine to brackish faunas occur above all in the Namurian A/B and Westphalian A deposits, seldom in the Westphalian B sediments, and a single layer at the base of Westphalian C. The latter has been identified as Ágir Horizon. It contains the following groups: Foraminifera, Productacea, Bryozoa, Nuculacea, Ostracoda, Crinoidea as well as conodonts, pelecypods, Planolithes ophthalmoides and others. The youngest reference to a brackish environment comes from the Westphalian D where cf. Planolithes ophthalmoides has been found. Thus, the main ingressions rapidly diminished and ended at the boundary Westphalian B/C, as in the Westphalian Depression.

Rich and stratigraphically important macrofloras, microfloras and faunas are restricted to the "Graue Folge". They disappear in the midst of the Westphalian C when the grey rock colours change to purple ones, i.e. in the transition zone between the "Graue Folge" and the "Rote Folge". From the "Rote Folge" single plant remains are known only. The most important is Pecopteris integra which shows together with other features Westphalian age.

The single well-profiles have been subdivided and correlated lithostratigraphically using the cyclic sequences, the association of these in larger sections, the appearence of marker sandstones, carbonate rock layers and "Kaolin-Kohlentonsteins" as well as the frequency of coal seams, and the combination of these features. The Ágir Horizon is the most important key bed. Examples of significant sections are (1) a 100 m thick shale-rich section, with tuffites and "Kaolin-Kohlentonsteins" near the base, immediately above the Ágir Horizon, (2) an about 50 m thick sandstone bed approximately 250 - 300 m above the Ágir Horizon, (3) a significant interbedding of sandstones, siltstones and shales with single limestone horizons in the higher part as well as (4) coarse sandstone and conglomerate beds in the uppermost part of the type-profile, furthermore (5) the main succession of seams immediately below the Ágir Horizon. On this basis the Rügen-Hiddensee type-profile is subdivided into eight lithostratigraphic units (from the bottom to the top): Hiddensee-Schichten, Wiek-Schichten, Lohme-Schichten, Jasmund-Schichten, Dornbusch-Schichten, Trent-Schichten, Rambin-Schichten, Mönchgut-Schichten. This lithological subdivision has been identified also in the coastal region of the mainland. There, equiva-

DOI:https://doi.org/10.2312/zipe.1982.066

lents of the Hiddensee-Schichten are lithologically quite different and to the bottom stratigraphically more comprehensive.

3.2. Autunian subsequent volcanic rocks and posttectogenetic molasses

The Autunian volcanic complexes are characterized by an extremely heterogenic structure, both laterally and vertically, as well as by strong variations in thickness. For this reason it becomes quite impossible to give one unified standard profile being valid for larger parts of the North-East German Depression. This refers especially to the above-mentioned volcano-tectonic depressions. Therefore a locality outside the areas of strong subsidence has been chosen for establishing the Autunian partial type-profile, taking in consideration the general development (subsidence, changing periods of sedimentation and volcanism, etc.) during Autunian time.

Besides volcanic rocks the Autunian successions comprise sections of continental sediments, especially at the bottom and at the top. The basal sediments are obviously widely spread in the North-East German Depression. They are lying with a sharp to moderate discordance on Carboniferous or older rocks. In most cases they start with conglomerates shading into red sandstones and siltstones. They contain no lithological key horizons, with the exception of some tuff horizons, but show in some cases floral remains which are indicating Autunian age. The roof sediments are restricted to some depressions which in every observed case have been the starting points for the following Saxonian subsidence, after a break in sedimentation. These late-Autunian successions above all consist of fine-grained, clayey and argillaceous to silty sediments with predominantly purple colours. They contain some tuff horizons as well as carbonaceous horizons and sometimes greenish to o grey coloured clastic intercalations. Fossils extremely rarely occur. Thin sedimentary strata are also intercalated into the volcanic sequences in limited regions, deposited in more or less shallow basins between the volcanic domes.

3.3. Saxonian posttectogenetic molasses

Saxonian deposits occupy the whole North-East German Depression in a quite uniform character. Continuous profiles have been encountered at many places. Thus Saxonian profiles can be correlated usually without considerable difficulties, with the exception of the successions at the coarse-clastic border zones in the NE and SE, respectively. Complete successions are restricted to the centre of the depression, whereas at the borders only youngest Saxonian has been deposited, as a consequence of a proceeding basin extension during Saxonian time. From there results that typical developed partial sections of the Saxonian hold different positions between the borders and the centre. For establishing the partial type-profile of the Saxonian, representative sections of some wells from the south-western part of the North-East German Depression have been chosen. The knowledge about this part is very well because of extensive exploratory works for natural gas.

The Saxonian is mainly developed in continental red bed facies. Clastics range from conglomerates to claystones. In the upper part, variegated (dark violet, greenish,

DOI:https://doi.org/10.2312/zipe.1982.066

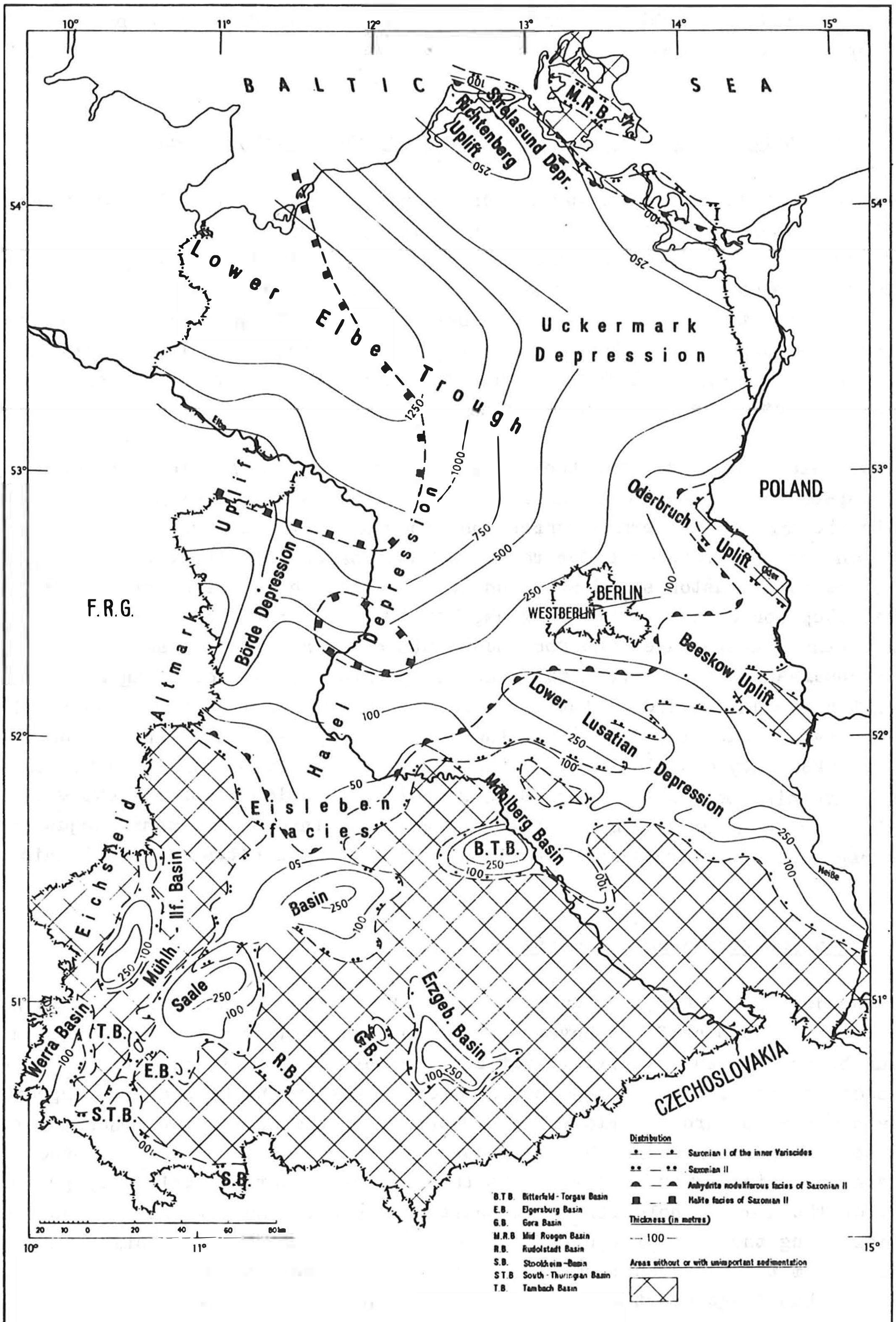


Fig. 4. Paleogeographic scheme of the Saxonian

DOI:https://doi.org/10.2312/zipe.1982.066

grey, black) thin laminated, calcareous to anhydritic beds as well as thick impure to clear halite layers are intercalated. Fossils (sporomorphs, ostracods) seldom appear only in these variegated intercalations. The associations of sporomorphs indicate vegetations growing on hot and dry sites in the highlands outside the sedimentation areas. Besides alluvial fan and fluvial deposits, inland sabkha or playa sediments and salt lake deposits, aeolian sandstones are locally represented. Single marine influences occur only immediately below the top boundary line, that means shortly before the following ingression of the Zechstein Sea into the Central European Depression. Thus the halites are continental ones, also proved by very low bromine contents.

Single Saxonian profiles are composed of cycles of different order, altogether arranged to an asymmetrical-progressive megacycle with a slightly recessive trend. Above all the upper part of the Saxonian succession shows well-developed microcycles of alternating sandstones and silt/claystones, whereas the lower and the middle parts consist mainly of sandstones which show slightly progressive cyclic successions, in the lower part also with recessive trends.

In most cases Saxonian deposits are lying with slight angles disconformably on Autunian, sometimes also on Carboniferous or older rocks. Occasionally the angles of discordance reach 40 degrees and more. Thus the basal boundary surface of the Saxonian is sharp, strengthened by the very sharp lithological change (basal Saxonian conglomerates on eruptive rocks or fine-grained clastic Autunian or quite another lithotypes, respectively). This significant boundary plane has been correlated with the lithologically corresponding boundary line between Autunian and Saxonian in the type-section of the Thuringian Forest in the southern part of the G.D.R. (cp. Annex 21). The top boundary surface is defined by the pronounced lithological change to the overlying marine, black "Kupferschiefer" (marl slate), the basal member of the Zechstein.

The subdivision and correlation of Saxonian profiles are based on the above-mentioned cyclic sequences, connected with lithologic key beds as conglomeratic horizons, basal sandstones of the cycles, the "laminites" as well as halite layers. The boundary lines drawn within the Saxonian in this way are synchronal ones, contrary to the asynchronal basal boundary surface of the Saxonian. On the strength of the overlapping of a younger succession on an older one, as can be seen very well at the south-west border, the Saxonian profile is divided into two formations: Havel-Folge and Elbe-Folge. Both have been subdivided into six "beds" (from the bottom to the top): Parchim-Schichten, Mirow-Schichten; and Rambow-Schichten, Eldena-Schichten, Peckensen-Schichten, Mellin-Schichten.

4. Conclusions

The development of the North-East German Depression was quite different from that of the Westphalian Depression. During and after the Sudetic tectogenesis in the south, i.g. before and during Namurian A and B, an extremely strong broadening of the foredeep occurred, directed to the north across the former foreland shelf. Thus in the coastal region of G.D.R., Upper Carboniferous deposition began with transgressing uppermost Namurian A. The grey to black sediments, claystones, siltstones and sandstones contain many marine and brackish horizons. In the marginal facies they bear some thin coal seams.

DOI:https://doi.org/10.2312/zipe.1982.066

These deposits are regarded as equivalents of the flysch at the southern slope of the foredeep.

At the beginning of Westphalian A, after a second stratigraphical gap comprising Namurian C, molasse sedimentation started with a new transgression much farther to the north beyond abraded flat anticlinal structures which originated in the northern foreland of the tectogene by only weak movements of the Sudetic phase. This transgression covered the middle part of Rügen during Westphalian A (Hiddensee-Schichten) and early Westphalian B (Wiek-Schichten) respectively, reached northeastern Rügen during late Westphalian B (Lohme-Schichten) and early Westphalian C (Lower Jasmund-Schichten). Then subsidence and sedimentation area diminished, indicated by red colours of deposits.

Despite of the affiliation to the large Upper Carboniferous sedimentation area north of the Variscan tectogene, which stretched from the British Isles to southwestern U.S.S.R., Silesian molasses of the North-East German Depression show some peculiarities especially in relation to the Westphalian Depression as the following: incomplete Namurian; discordantly overlaying on pre-Silesian; distinctly thinner Westphalian deposits; Stephanian develops unbroken from Westphalian; coal-bearing is remarkably poorer in Upper Westphalian B and finishing at basal Westphalian C; red colours are starting already in Lower Westphalian C; fracture tectonics and therefore flat layering.

Direct informations about sediment transport are not available. Probable regions of supply were the Variscan morphogene in the south and the Fennoscandian Shield in the north. The area of main subsidence has been situated in the nowadays coastal region of G.D.R. stretching SW—NE in the western part and NW--SE in the eastern part. Four asymmetric-progressive mega-cycles in the lower and the upper section as well as one symmetrical in the middle section can be recognized. It is suggested that these cycles are reflecting the tectonic development of the depression. That means, together with the distribution of coarse clastic sediments and coal seams, the deposits of Westphalian A to lower Westphalian C represent a period of low tectonic activities and reduced transport energy, interrupted in the upper Westphalian A by strong transgression and accretion of coarse and pebbly sands. On the other hand tectonic impulses intensified in middle Westphalian C and reached their culmination with influx of coarse clastic material at the base of Dornbusch- and Mönchgut-Schichten. This is underlined by small-scale cycles from middle Westphalian C to the top of the succession. The movements may be related to the Asturian tectogenesis which manifests itself in the outer foredeep only by the supply of coarse sediments.

After a period of uplifting and denudation, above all in the southern part of the North-East German Depression, renewed weak subsidence caused deposition of Autunian basal sediments. The following strong and quite diverse subsidence which was induced by block-faulting and accompanied by intense eruptions produced accumulations of thick volcanic sequences in different parts of the North-East German Depression. Intercalated sediments indicate periods of volcanic quiteness. In the late Autunian time volcanic activities and strong subsidence diminished. Volcanic deposits were replaced by fine-clastic sediments with only single tuff intercalations. At the end of the Autunian, Saalian movements produced tiltings to different extents.

DOI:https://doi.org/10.2312/zipe.1982.066

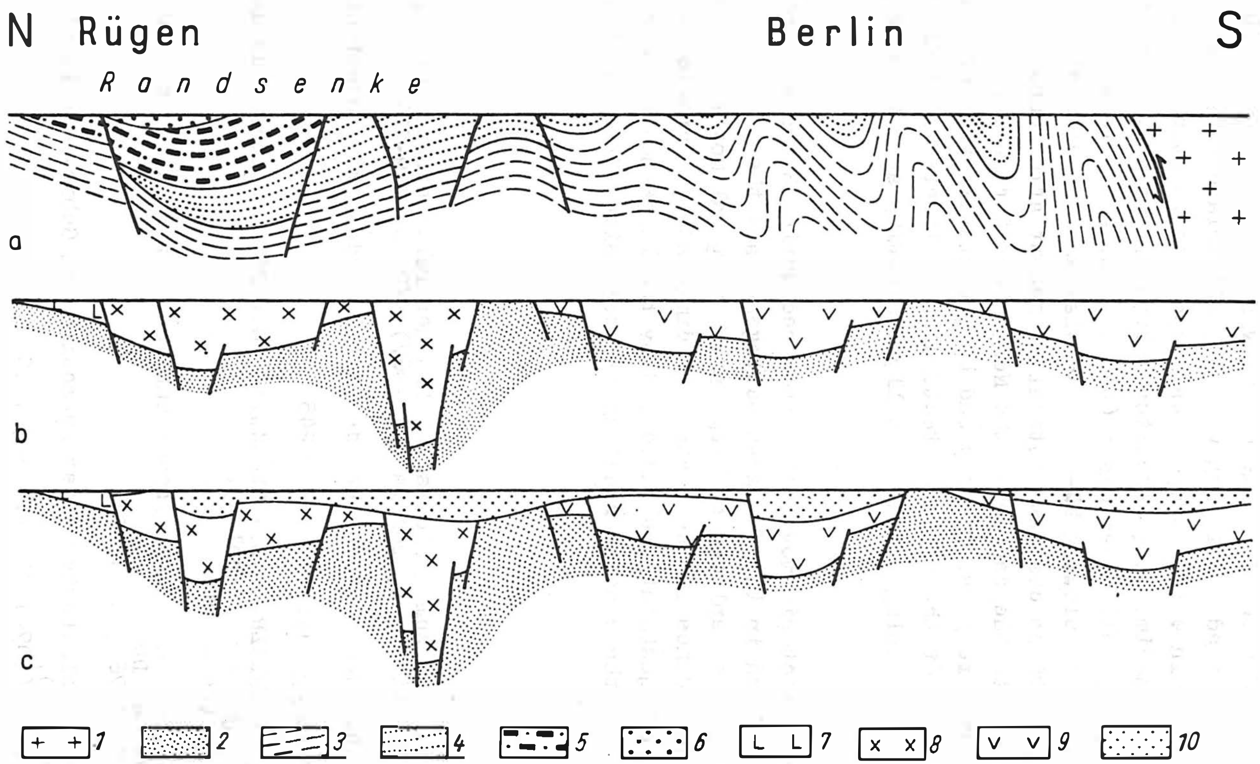


Fig. 5. Paleogeological sections through the North-East German Depression

a - end of Carboniferous, b - end of Autunian, c - end of Saxonian

1 - crystalline of the Central German Crystalline Zone, 2 - Pre-Permian generally, 3 - Dinantian, 4 - Namurian, 5 - Westfalian, 6 - Stefanian, 7...9 - Autunian, 7 - basic volcanic rocks, 8 - intermediate volcanic rocks, 9 - acid volcanic rocks, 10 - Saxonian

DOI:https://doi.org/10.2312/zipe.1982.066

After these tectonic events, single Saxonian depressions arose from late Autunian small sedimentary basins by stronger subsidence striking NW--SE and SSW--NNE. They developed transgressively and linked to the large North-East German Depression which expanded beyond the Autunian depositional area at the end of Saxonian.

The following environments are represented: (1) fluvial sediments in a wider sense (clastics transported and deposited by flowing waters), (2) inland sabkha or playa sediments (clastics and to a certain extent evaporites, deposited in standing and desiccating waters), (3) salt lake sediments (evaporites, above all halite, precipitated from salt brines in arid areas), (4) eolian sediments (sandstones, accumulated especially at the southern slope by trade winds blowing NE--SW). Fluvial and sabkha sediments show only partly the relations and formations characteristical of recent arid zones. Fluvial sand fans zonally advanced farther to the centre of the North-East German Depression than recently can be observed in arid regions. Thereby and by the distribution of aquatic and eolian sediments the influence of the Variscan tectogene on climate and sedimentation becomes visible. The range was rising morphologically and acting as a rain trap in most of Saxonian time yet.

However, the intensity of tectonic movements slackened during Saxonian, both in the North-East German Depression and in the Variscan tectogene, and the fracture tectonics dominating at the beginning were replaced by large-areal vertical movements, with uplifting in the south and subsidence in the north. The diminishing tectonic movements and the resulting morphological adjustment are indicated by the large-scale progressive cycle of the whole succession, i.e. the general reducing of grain sizes from the bottom to the top.

References

ALBRECHT, K.: Zur Ausbildung und zum geologischen Bau des Paläozoikums auf Rügen. Ber. deutsch. Ges. geol. Wiss., A, Berlin 12 (1967) 1/2, p. 149-164

ALBRECHT, K.; GOLDBECHER, R.: Neue Aufschlüsse des Rotliegenden im Norddeutschen Flachland. Z. angew. Geol., Berlin 10 (1964), p. 244-248

BARTHEL, M.; KATZUNG, G.; SIGENEGER, W.D.; UERCKWITZ, G.: Pflanzenfunde aus dem Autun bei Bebertal (Flechtingen-Roßlauer Scholle). Z. geol. Wiss., Berlin (in print)

BENEK, R.; KATZUNG, G.; RÖLLIG, G.: Variszischer subsequenter Vulkanismus und taktogene Entwicklung im Gebiet der DDR. Jb. Geol., Berlin 7/8 (1976), p. 17-31

BENEK, R.; PAECH, H.-J.: Zur Paläotektonik des Permosiles im Gebiet der Flechtinger Scholle (Bezirk Magdeburg). Z. geol. Wiss., Berlin 2 (1974) 10, p. 1143-1155

BENEK, R.; PAECH, H.-J.; SCHIRMER, B.: Zur Gliederung der permosilesischen Vulkanite der Flechtinger Scholle. Z. geol. Wiss., Berlin 1 (1973) 7, p. 867-878

BOCHMANN, M.; SCHMIDT, K.: Der Einfluß der sowjetischen Geologie auf die Entwicklung der Erdöl- und Erdgasgeologie in der DDR. Z. angew. Geol., Berlin 18 (1972) 12, p. VII-X

DOI:https://doi.org/10.2312/zipe.1982.066

BUSH, V.A.; KATZUNG, G.; KIRSANOV, V.V.; KIRYUKHIN, L.G.: Orogenetic Late-Palaeozoic structures of Central Europe.
Bjull. Mosk. obšč. ispyt. prir., Geol. section, Moskva 54 (1979) 1, p. 81-95 (in Russian)

BUSH, V.A.; KIRYUKHIN, L.G.: About development of Late-Palaeozoic subsequent effusive rocks in relation to the structure of Central Europe.
Sov. geol., Moskva 3 (1971), p. 66-76 (in Russian)

DABER, R.: Paläobotanische Hinweise auf eine paralisch beeinflußte Oberkarbon-Senke im tieferen Untergrund Nordostdeutschlands.
Geologie, Berlin 12 (1963), p. 683-699

DABER, R.: Paläobotanische Hinweise auf eine paralisch beeinflußte Oberkarbon-Senke im tieferen Untergrund Nordostdeutschlands. II. (Teil 1).
Geologie, Berlin 18 (1969), p. 253-297

DABER, R.; KATZUNG, G.; PFEIFFER, H.: Siles. In: Grundriß der Geologie der Deutschen Demokratischen Republik, Bd. 1.
Berlin: Akad.-Verl. 1968, p. 189-198

DÖRING, H.: Sporostratigraphische Untersuchungen im unteren Bereich des Siles ("Graue Folge") aus dem Raum Nordhiddensee.
Z. geol. Wiss., Berlin 3 (1975) 7, p. 997-1015

EIGENFELD, F.; SCHWAB, M.: Zur tektonischen Stellung des permosilesischen subsequenten Vulkanismus in Mitteleuropa.
Z. geol. Wiss., Berlin 2 (1974) 2, p. 115-137

ELLENBERG, J.; FALK, F.; GRUMBT, E.; LÜTZNER, H.; LUDWIG, A.O.: Sedimentation des höheren Unterperms der Flechtinger Scholle.
Z. geol. Wiss., Berlin 4 (1976) 5, p. 705-738

FRANKE, D. (with contribution by P. KRULL and H. PFEIFFER): Paleogeographic and tectonic development of the external Zones of the Central European Variscides and their northern Foreland.
Coll. intern. Centre Nat. Rech. Sci., Rennes 243 (1977), p. 515-529

FRANKE, D.; SCHROEDER, E.: Das variszische Orogen nördlich des Böhmischen Massivs.
Geologie, Berlin 17 (1968) 6/7, p. 647-660

GLUSHKO, V.V.; DIKENSHTEYN, G.CH.; SCHMIDT, K.: The Caledonides of the Rügen island.
Dokl. akad. nauk U.S.S.R., Moskva 214 (1974) 4, p. 885-888 (in Russian)

GLUŠKO, V.V.; DIKENSTEJN, G.CH.; SCHMIDT, K.; GOLDBECHER, K.: Zur tektonischen Rayonierung des Nordteils der DDR nach dem Alter des gefalteten Untergrunds.
Geol. Jb., Berlin 7/8 (1976), p. 9-16

HELLMUTH, H.-J.: Zur Fazies des Oberrotliegenden in NE-Mecklenburg.
Geologie, Berlin 17 (1968) 1, p. 52-59

HIRSCHMANN, G.; HOTH, K.; KLEBER, F.: Die lithostratigraphische Gliederung des Oberkarbons im Bereich der Inseln Rügen und Hiddensee.
Z. geol. Wiss., Berlin 3 (1975) 7, p. 935-996

HOFFMANN, N.; LINDERT, W.; WEYER, D.; ILLERS, K.H.: Zum Unterkarbon-Vorkommen auf den Inseln Rügen und Hiddensee.
Z. geol. Wiss., Berlin 3 (1975) 7, p. 851-873

HOTH, K.; PAECH, H.-J.; KAMPE, A.: Hinweise auf Intrusivkörper im nördlichen Teil der Flechtingen-Roßlauer Scholle.
Z. geol. Wiss., Berlin 1 (1973) 7, p. 861-866

KAHLERT, E.: Die biostratigraphische Einstufung der "Süplinger Schichten" (Flechtinger Höhenzug).
Z. geol. Wiss., Berlin 1 (1973) 7, p. 851-859

KATZUNG, G.: Stratigraphie und Paläogeographie des Unterperms in Mitteleuropa.
Geologie, Berlin 21 (1972) 4/5, p. 570-584

DOI:https://doi.org/10.2312/zipe.1982.066

KATZUNG, G.: Tektonik, Klima und Sedimentation in der Mitteleuropäischen Saxon-Senke und angrenzenden Gebieten.
Z. geol. Wiss., Berlin 3 (1975) 11, p. 1453-1472

KATZUNG, G.: Die Saxongliederung im Zentralabschnitt der Mitteleuropäischen Senke.
Z. angew. Geol., Berlin 23 (1977) 11, p. 559-561

KATZUNG, G.: Die posttektogenetischen Molassen und Subsequentite am Außenrand und im nördlichen Vorland des variszischen Tektogens.
Z. angew. Geol., Berlin 23 (1977) 12, p. 597-602

KOREJWO, K.: Stratigraphy and paleogeography of the Namurian in the Polish Lowland.
Acta geol. Pol., Warszawa 19 (1969) 4, p. 609-709

KORICH, D.: Eruptivgesteine im Rotliegenden des Nordteils der DDR.
Ber. deutsch. Ges. geol. Wiss., A, Berlin 12 (1967) 3/4, p. 231-242

KRAMER, W.; MUCKE, D.: Beziehungen zwischen Magmatiten und Sedimenten in sedimentären Komplexen.
Z. geol. Wiss., Berlin 1 (1973), p. 531-548

LAUTERBACH, R.: Rhenotype Strukturen im Bilde geologisch-geophysikalischer Untersuchungsergebnisse Mitteleuropas.
Ber. geol. Ges. DDR, Berlin 7 (1962), p. 325-336

LUDWIG, A.O.: Zur Bedeutung fossilführender Lagen in den Rotliegendsedimenten am Nordrand der Mitteleuropäischen Senke.
Z. geol. Wiss., Berlin 3 (1975) 11, p. 1491-1496

NÖLDEKE, W.; SCHWAB, G.: Zur tektonischen Entwicklung des Tafeldeckgebirges der Norddeutsch-Polnischen Senke unter besonderer Berücksichtigung des Nordteils der DDR.
Z. angew. Geol., Berlin 23 (1977) 8, p. 369-379

PENSOLD, G.: Zum Vorkommen von Intrusivgesteinen im Oberkarbon des Nordteils der DDR.
Ber. geol. Ges. DDR, A, Berlin 12 (1967), p. 223-229

PFEIFFER, H.: Der Magdeburg-Flechtinger Kulm und seine stratigraphische und regionale Stellung.
Geologie, Berlin 16 (1967) 7, p. 781-790

PLEIN, E.: Rotliegend-Ablagerungen im Norddeutschen Becken.
Z. deutsch. geol. Ges., Hannover 129 (1978) 1, p. 71-98

REMY, W.: Die Sphenopteris-germanica-Gruppe in den "Süplinger Schichten" (Flechtinger Höhenzug) -- ein Beleg für das Autun-Alter.
Arg. Palaeobot., Münster 5 (1978), p. 161-165

ROST, W.; SCHIMANSKI, W.: Übersicht über das Oberkarbon und das Rotliegende im Nordteil der DDR.
Ber. deutsch. Ges. geol. Wiss., A, Berlin 12 (1967) 3/4, p. 201-221

SCHMIDT, K.; FRANKE, D.: Stand und Probleme der Karbonforschung in der Deutschen Demokratischen Republik. Teil I: Unterkarbon.
Z. geol. Wiss., Berlin 3 (1975) 7, p. 819-849

SCHMIDT, K.; FRANKE, D.: Zur lithologisch-faziellen Entwicklung des Präperms im Nordteil der DDR.
Z. angew. Geol., Berlin 23 (1977) 11, p. 541-548

SCHMIDT, K.; KATZUNG, G.; FRANKE, D.: Zur Entwicklung des präpermischen Untergrunds und und des Magmatismus im südwestlichen Vorfeld der Osteuropäischen Tafel.
Z. angew. Geol., Berlin 23 (1977) 9, p. 426-436

SCHREIBER, A.: Das Rotliegende des Flechtinger Höhenzuges.
Freiberger Forsch.-H., Berlin C82 (1960), 131 p.

TESCHKE, H.-J.: Entwicklung und tektonischer Bau des südwestlichen Randbereichs der Osteuropäischen Tafel.
Schriftenr. geol. Wiss., Berlin 4 (1975), 151 p.

WEYER, D.: Biostratigraphie des Magdeburg-Flechtinger Kulms.
Z. geol. Wiss., Berlin 3 (1975) 5, p. 547-589

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982)

Explanatory Notes to the Lithotectonic Molasse Profile of the Upper Silesian Basin (Upper Carboniferous - Lower Permian) (Comment to Annex 20)

by

RYSZARD GRADZIŃSKI[1)]

1. Introduction

The type-profile (Annex 21) represents the Variscan molasse of the Upper Silesia and the neighbouring areas. The maximum stratigraphic thickness of the molassic rocks approaches 8000 m. Within the molasse two major parts separated by a regional unconformity are discernable. The lower one is a very thick coal-bearing succession associated with barren deposits (Kwaczała Arkose); the upper part consists of clastic sediments of the red-beds type and of subordinate volcanic and pyroclastic rocks.

In general, the molassic rocks occur now in a Variscan synclinorium deformed stronger in the western part (Fig. 1). This area called herein the Upper Silesian Basin must have been more extensive than that within the present-day boundaries of the molasse rocks occurrence. These boundaries are generally due to the Variscan and younger movements, and associated erosion.

To the west, the molasse rocks are limited by a folded zone of thick Culm deposits; this boundary is relatively well defined. To the south and south-east, the molasse continues below the Carpathian foredeep filled with Miocene deposits and below the Carpathian nappes. In the latter area, the coal-bearing deposits have been discovered in deep boreholes. The northern and eastern boundaries are erosional and, generally, they are covered by Mesozoic sediments. It should be stressed that not far to the east from the Upper Silesia thin coal-bearing deposits have been penetrated by some deep boreholes.

The Upper Silesian molasse is poorly outcropped. Therefore, the majority of important data on the region are provided by numerous deep boreholes and by mining works.

1) Polish Academy of Sciences, Institute of Geological Science, Sedimentological Laboratory; Poland, 31-002 Kraków, ul. Senacka 3

DOI:https://doi.org/10.2312/zipe.1982.066

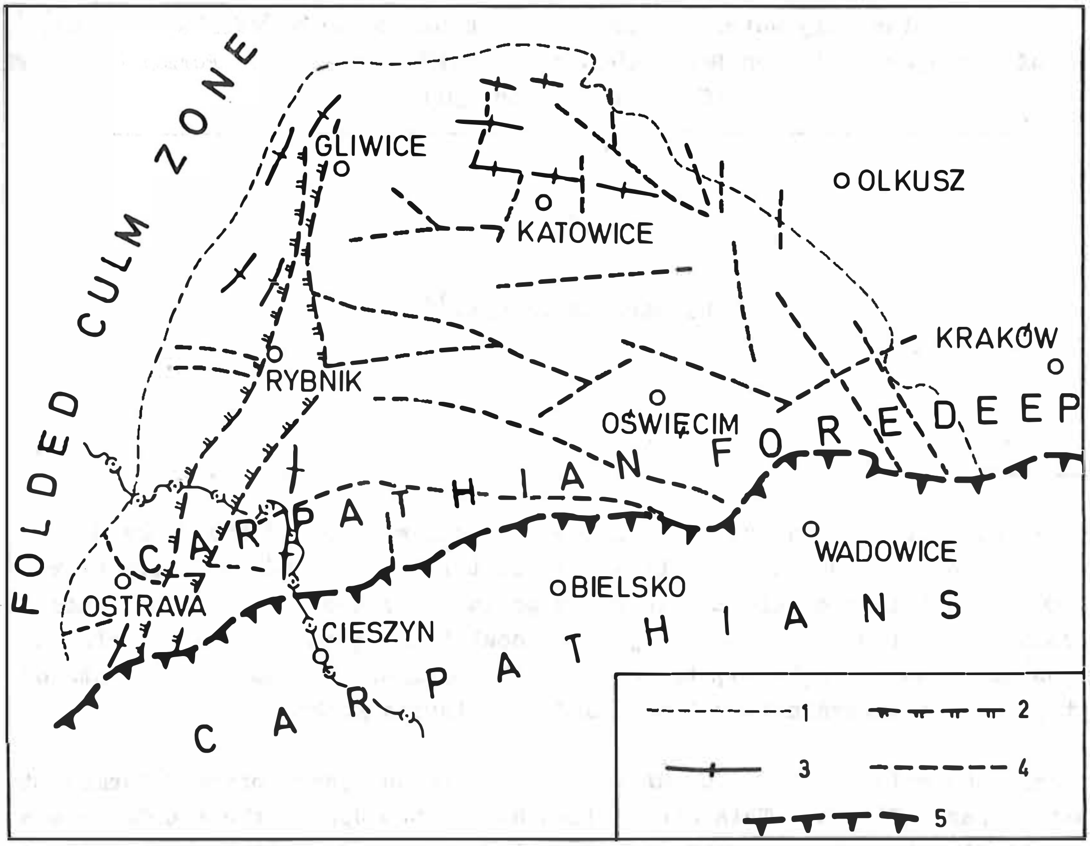


Fig. 1. Tectonic sketch map of the Upper Silesia
1 - present-day boundary of coal-bearing deposits, 2 - Variscan thrust fold, 3 - anticlinal axis, 4 - fault, 5 - northern boundary of the Carpathian overthrust

DOI:https://doi.org/10.2312/zipe.1982.066

The lithology, biostratigraphy and tectonics are relatively well understood (except the Lower Permian rocks) as a result of geological investigations connected with coal exploitation.

The lithostratigraphic division of the molasse rocks used at present is informal. It is based on lithology, but also on biostratigraphic data and on correlation of coal-seams, intercalations of deposits containing marine and brackish fauna and on rare tuffogenic horizons. The coal-bearing succession is divided into four main lithostratigraphic units, traditionally called "series" which may correspond to formal groups. The units of lower rank are named "beds".

2. Construction of the type-profile

The type-profile presents the general sequence of the molassic rocks in the Upper Silesian Basin. The lower part of the profile contains the uppermost unit of the molasse substratum and represents the sequence occuring in the western part of the basin. The middle and upper parts of the profile correspond to the sequences from the central and eastern part, respectively.

The column concerning lithology is most generalized. The lateral variability of deposits is not considered. Within the particular units, only the proportions between the main lithologies are presented, while their vertical sequence is shown schematically. Only some coal seams are marked. The transport directions (in the column and maps) are based on a few data and may be inaccurate. The composition of the deposits is presented comprehensively, separately for each complete unit; this is based on the data from various sources. The relative proportions of the particular components are approximate.

Because of the differences between the sequences of the eastern and western part of the basin, disconformities are not marked in the column, except the main one occurring at the base of the Permian succession. The hiatus characteristic of the eastern part of the basin is marked in the last column at the right and in Fig. 2.

3. Substratum of the molasse

The substratum of the coal-bearing molasse deposits is known only from the marginal zones of the Upper Silesian Basin (Fig.3A). These deposits are underlain by siliciclastic sediments resting upon carbonate facies. These sediments are represented by two major facies. In the western marginal zone and further to the west, there occur Culm flysch deposits (upper part of Lower Visean - lowermost Namurian A) passing toward the east into sediments of the claystone facies (Upper Visean - lowermost Namurian A). The differences between these two facies gradually disappear in the lowermost Namurian A (cf. KOTAS 1972); at the base of the coal-bearing succession the deposits are similar throughout the whole basin.

The Culm deposits build a wide folded belt which bordered the basin from the west. They approach c. 4000 m in thickness and display an assemblage of features typical of

DOI:https://doi.org/10.2312/zipe.1982.066

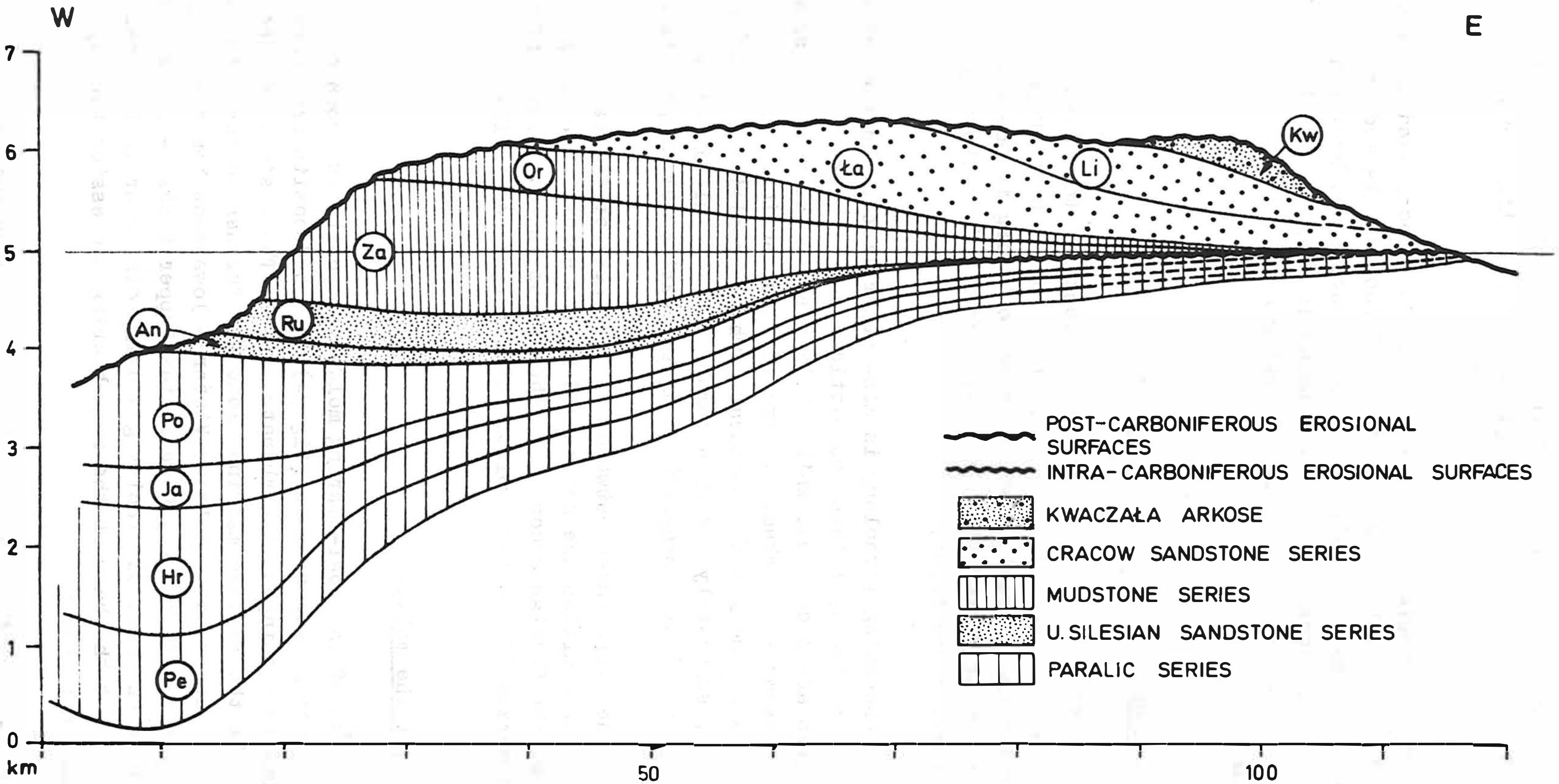


Fig. 2. Thickness distribution of the coal-bearing succession
(section along Rybnik-Oświecim line, tectonic deformations omitted)

DOI:https://doi.org/10.2312/zipe.1982.066

flysch sediments (cf. KUMPERA 1959, 1966; UNRUG 1964). The distribution of grain-size and the directional structures indicate that the detrital material of the flysch sandstones was transported by turbidity currents generally toward the north. Within the Kyjovice Beds (youngest unit of the flysch succession), a gradual transition to molassic deposits is observed (cf. KOTAS 1972). In the upper part of this unit fine-grained sediments prevail, plant fragments are relatively common, and there appear first rooty layers and minute coal-seams. The uppermost part is represented by the widespread fossiliferous Štur marine horizon.

The claystone facies is known from the north-eastern part of the basin (where it is named the Malinowice Beds) and from the south-eastern marginal zone, where it passes into the Zalas Beds. Most probably, the claystone facies is developed also in the central part of the Upper Silesian Basin (KOTAS 1972). This facies consists of claystones and mudstones with rare intercalations of fine-grained sandstones. In some places (in the south-eastern marginal zone) it contains rare intercalations of carbonate rocks, conglomerates and tuffites. The thickness of the claystone facies ranges from c. 1000 m (Malinowice Beds) to c. 100 m in the middle of the southern marginal zone.

The siliciclastic marine sediments which underlie the Upper Silesian molasse were correlated by KOTAS (1972). The lower boundary of the coal-bearing succession is arbitrarily placed at the top of the Štur marine horizon and its probable equivalents. This boundary is not entirely isochronous, but generally it occurs within a lower part of the Namurian A. No distinct breaks in sedimentation can be observed at the transition from the flysch and claystone facies into the coal-bearing deposits.

4. Coal-bearing succession

The coal-bearing deposits are divided into four main units (DEMBOWSKI 1972 a). Marine intercalations occur only in the lower unit (Paralic Series); the upper units contain deposits laid down exclusively in continental environments.

The P a r a l i c S e r i e s (KOTAS and MALCZYK 1972 a) extends throughout the basin. Its thickness amounts to c. 3500 m in the western part and decreases eastward to a few hundred metres (Figs 2, 3B). The series consists chiefly of alternating mudstones, fine-grained sandstones and subordinate claystones, while coarser sediments occur occasionally (first of all in the Zamek Conglomerate tongue within the Poruba Beds). The series contains about one hundred coal-seams usually less than 1 m in thickness; only some seams are about 2 m thick.

Deposits containing marine, brackish and fresh-water fauna are relatively common (cf. BOJKOWSKI 1972). Some of the marine bands may be traced over considerable distances. Most numerous marine intercalations occur in the north-western part of the basin (namely 22 intercalations in the vicinity of Gliwice). Generally, the numer of these intercalations decreases towards the south (7 in the Ostrava region) and the east (a few near Chrzanów), and some of them seem to be replaced by sediments containing brackish and fresh-water fauna.

DOI:https://doi.org/10.2312/zipe.1982.066

Fig. 3. Sketch maps showing the evolution of the Upper Silesian Basin

A - substratum of the coal-bearing deposits, 1 - culm flysch facies, 2 - claystone and associated facies, 3 - present-day boundary of the coal-bearing deposits, 4 - northern boundary of the Carpathian overthrust

B - Paralic Series; 1 - area of occurrence of the Paralic Series, 2 - zone of maximum thickness, 3 - isopachyte, 4 - general transport direction

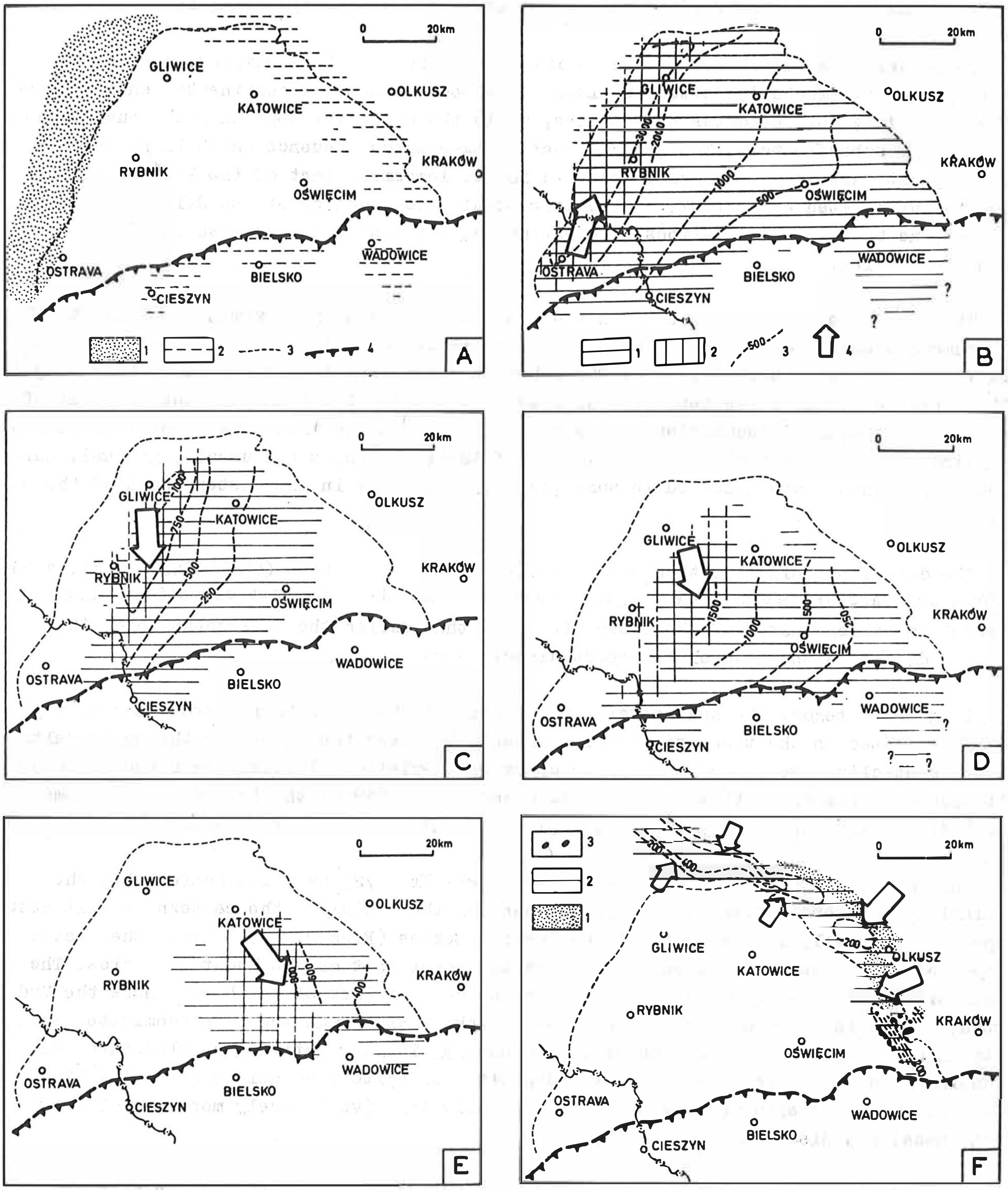
C - Silesian Sandstone Series

D - Mudstone Series

E - Łaziska Beds

F - Lower Permian rocks; 1 - Myślachowice Conglomerate, 2 - Sławków formation, 3 - volcanic rocks

DOI:https://doi.org/10.2312/zipe.1982.066



DOI:https://doi.org/10.2312/zipe.1982.066

The directions of cross-stratification, distribution of marine intercalations and the decrease of maximum pebble size in the Zamek Conglomerate tongue indicate that the detrital material of the Paralic Series was transported generally towards the north.

In general, the discussed series is interpreted as a deltaic complex, composed of alternating sediments deposited in mixed marine-continental or continental environments. The Lower delta-plain facies predominate, while the upper delta-plain and alluvial facies occur subordinately. The general coarsening-upwards sequence which is present in the topmost part of the Kyjovice Beds and in the lowermost part of the Petřkovice Beds may be interpreted as a result of the large-scale progradation of the deltaic body into the marine basin. Intercalations with marine and brackish fauna seem to be deltaic abandoned facies.

The Silesian Sandstone Series (see KOTAS and MALCZYK 1972 b) is composed mainly of fine- and medium-grained sandstones. In the western part of the basin it attains a thickness of c. 900 m but it wedges out toward the east (Figs 2, 3C). The series contains a few tens of coal seams. Generally, the seams are the thickest of all the coal-bearing succession (up to c. 24 m in the Anticlinal Beds). These seams are continuous over wide areas and the changes of their thickness are usually gradual. Large and deep washouts are observed in some places, especially in the western part of the basin.

The data concerning the transport directions are very scarce (GRADZIŃSKI et al. 1961; KOTAS and MALCZYK 1972). They suggest, however, that the transport directions were different in various parts of the basin. It seems that during the sedimentation of the series discussed the general transport direction changed.

In general terms, the sedimentary environment of the Silesian Sandstone Series may be interpreted as the transitional area situated between the lower and the upper delta-plain (Anticlinal Beds) and within the upper delta-plain - alluvial plain (Ruda Beds). It should be stressed, that according to HORNE et al. (1978) the thickest coal-seams occuring in the Appalachian Region are also connected within such transitional zone.

The Mudstone Series (see PORZYCKI 1972) overlies conformably the Silesian Sandstone Series in the western part of the basin; in the eastern part it rests upon the partially eroded units of the Paralic Series (Figs 2, 3D). There, the hiatus included the Silesian Sandstone Series and the lower part of the Mudstone Series. The axis of the maximum thickness zone lies in the central part of the basin where the Mudstone Series is c. 2000 thick. Fine-grained rocks (mainly mudstones) predominate, sandstones (chiefly fine-grained) occur subordinately, intraformational conglomerate beds consisting of mudstone clasts and of redeposited siderite concretions are thin. The coal-seams are numerous (about 150) but generally thin (very rarely more than 2 m in thickness) and discontinuous.

The sedimentary environment of the Mudstone Series is interpreted as an alluvial plain formed by the meandering river(s) characterized by a low bedload/suspended load ratio (RADOMSKI and GRADZIŃSKI, in press).

DOI:https://doi.org/10.2312/zipe.1982.066

The Cracow Sandstone Series (see DEMBOWSKI 1972 b) occurs in the central and eastern part of the basin (Figs 2, 3E). The predominating rocks are sandstones (usually coarse- and medium-grained, in places gravelly), while fine-grained rocks occur subordinately. The coal-seams are rare but usually thick (up to 5 m). The discussed series is considered as accumulated on an alluvial plain constructed mainly by sandy braided rivers (RADOMSKI & GRADZIŃSKI, in press).

The Kwaczała Arkose (see RUTKOWSKI 1972) occupies a small area situated in the eastern part of the basin (Fig. 2). This area was previously a depocentre of the Libiąż Beds. The arkose is lithologically similar to these beds but contains neither coal-seams nor fossils, except for the relatively abundant silicified stems of Dadoxylon. It seams that the arkose accumulated in continuation with the coal-bearing deposits but in conditions of more arid climate. The Kwaczała Arkose may represent the uppermost Westphalian D and/or Stephanian.

5. Red-beds succession

The Permian rocks forming this succession are separated from the older molassic deposits by an unconformity associated with faulting and gentle folding (Asturic phase ?) and with intensive erosion. The area of occurrence of the Permian rocks is relatively narrow and, as far as it is known, about 100 km long. This belt is situated more or less along the to-day north-eastern border of the Upper Silesian Basin (Fig. 3F).

The Karniowice Travertine is probably the oldest and the only paleontologically dated of the Permian rock-units. It covers several sq. kilometres, reaching c. 15 m in thickness. The travertine contains a rich and diversified flora (46 taxons) and fresh-water gastropods. LIPIARSKI (1971) ascribed the Lower (but not the lowermost) Autunian age to this unit. It is considered generally that this deposit has been formed by precipitation of calcium carbonate in surface water flowing and filling shallow ponds bordered by travertine dikes. Probably, the water flowed from near-by springs; its hardness might have been related to volcanic processes.

The Myślachowice Conglomerate occurs in the outer, eastern margin of the belt of the Permian sediments. Its area of occurrence is usually a few kilometres wide, the thickness is up to 80 m. The Myślachowice Conglomerate is an alluvial fan deposit representing a fanglomerate type. The source area of the detrital material was situated at the margin of the Upper Silesian Basin, in the zone of the Dębnik Ridge and its prolongation towards NNW. From this area, gravels of carbonate rocks (representing the Lower Carboniferous as well as the Middle and Upper Devonian) were transported. In places, mostly by the end of the conglomerate deposition, also gravels of Permian volcanic rocks were brought (SIEDLECKA 1964).

Towards the west, south-west and south, the Myślachowice Conglomerate passes laterally and interfingers with more fine-grained sediments of the red-beds type. These are sandstones, subordinate mudstones and marls, in places with gypsum and halite crystals. These rocks have several local names; for the sake of simplicity, they are called herein informally the Sławków formation. The thickness of this unit at

DOI:https://doi.org/10.2312/zipe.1982.066

tains 500 m. The Sławków formation fills, first of all, the depressions corresponding usually with the grabens which in the Lower Permian existed within the marginal north-eastern part of the Upper Silesian Basin. In the south-eastern part of the Permian belt, within the Sławków formation occur intercalations of melaphyre lava flows. The Sławków formation is considered as stream-dominated alluvial-fan deposit and subordinate playa sediments.

6. Volcanic and pyroclastic rocks

The oldest rocks associated with the volcanic activity belonging to the late Variscan cycle are known from Orlej (eastern part of the basin), where they are represented by the porphyry tuffs and porphyry blocks contained in the slump breccias of the uppermost Viséan deposits.

The pyroclastic material is common in the Paralic Series, occuring both in the sedimentary rocks and forming rare intercalations of tuffogenic beds. A few of such intercalations are also known in the Mudstone Series. The small quartz porphyry intrusions from the Dębnik Ridge and the laccolith from Zalas-Głuchówki are probably of the Lower Permian or uppermost Carboniferous age. Lower Permian age is ascribed to the extrusive quartz porphyry from Miękinia; this rests upon the Namurian rocks or upon the Myślachowice Conglomerate. The Lower Permian melaphyres are all extrusive rocks represented by several lava flows resting upon another or forming intercalations in the Sławków deposits. Probably the youngests are the porphyry- and melaphyre-tuffs and tuffites. Leaving the mineralogical differences, the chemical composition of all the Permian igneous rocks of the eastern part of the Upper Silesian Basin is uniform.

7. Concluding remarks

The present stage of knowledge of the sedimentary evolution of the Upper Silesian molasse allows to suggest that:

1. The Upper Silesian Basin represents a part of the foredeep.
2. The molasse overlies its substratum without any significant break in sedimentation.
3. During the molassic accumulation the zone of maximum subsidence shifted from the west (from the fold belt) to the east.
4. Within the basin the general transport directions of the detrital material of the coal bearing-succession were parallel to the fold belt but they changed during the accumulation of this succession.
5. The main change was probably due to an uplift of the foredeep area situated north from the Upper Silesian Basin, and resulted in molasse cannibalism.
6. Within the coal-bearing succession there are no angular discordances, except for the eastern part of the basin.
7. In the last stage of the molasse development the coarsest clastics of the red-beds type were accumulated. The strongest volcanism was connected with this stage.

DOI:https://doi.org/10.2312/zipe.1982.066

References

BOJKOWSKI, K.: A description of the Upper Carboniferous fauna of the Upper Silesian Coal Basin, (English summ.).
Prace Inst. geol., Warszawa 61 (1972), p. 81-134

DEMBOWSKI, Z.: General information on the Upper Silesian Coal Basin,(English summ.).
Prace Inst. geol., Warszawa 61 (1972 a), p. 9-22

DEMBOWSKI, Z.: The Cracow Sandstone Series of the Upper Silesian Coal Basin,(English summ.).
Prace Inst. geol., Warszawa 61 (1972 b), p. 509-538

GRADZIŃSKI, R.; RADOMSKI, A.; UNRUG, R.: Directions of transport of the clastic material in the Upper Carboniferous of the Silesian Coal Basin, (English summ.).
Kwart. geol., Warszawa 5 (1961) 1, p. 15-38

HORNE, J.C.; FERM, J.C.; CARUCCIO, F.T.; BAGANZ, B.P.: Depositional models in coal exploration and mine planning in Appalachain Region.
Am. Ass. Petrol. Geol. Bull., 62 (1978), p. 2379-2411

KOTAS, A.: The marine sediments of the Upper Carboniferous and their transition into productive deposits of the Upper Silesian Coal Basin, (English summ.).
Prace Inst. geol., Warszawa 61 (1972), p. 279-328

KOTAS, A.; MALCZYK, W.: The Paralic Series of the Lower Namurian stage of the Upper Silesian Coal Basin, (English summ.).
Prace Inst. geol., Warszawa 61 (1972 a), p. 329-426

KOTAS, A.; MALCZYK, W.: The Upper Silesian Sandstone Series of the Upper Namurian stage of the Upper Silesian Coal Basin, (English summ.).
Prace Inst. geol., Warszawa 61 (1972 b), p. 427-466

KUMPERA, O.: Přispevek k litologii biloveckych vrstev.
Přir. Čas. Slezsky, Wrocław 20 (1959), p. 139-160

KUMPERA, O.: Paleocurrents and the outline of the facies development of the Upper Visean strata in the Moravia and Silesia, (English summ.).
Sb. věd. Praci vysoké Školy báňské, Ostrava 12 (1966) 138, p. 31-50

LIPIARSKI, I.: La flore du Permian inférieur apparaissant dans le travertin de Karniowice aux environs de Cracovie, (French summ.).
Prace Inst. geol., Warszawa 57 (1971), p. 5-112

PORZYCKI, J.: The Siltstone Series of the Lower Westphalian stage of the Upper Silesian Coal Basin, (English summ.).
Prace Inst. geol., Warszawa 61 (1972), p. 467-508

RADOMSKI, A.; GRADZIŃSKI, R.: Facies sequences in the Upper Carboniferous alluvial coal-bearing deposits, Upper Silesia, Poland.
Studia geol. pol., Warszawa 68 (in press)

RUTKOWSKI, J.: The Stephanian sediments of the Upper Silesian Coal Basin, (English summ.).
Prace Inst. geol., Warszawa 61 (1972), p. 539-556

SIEDLECKA, A.: Permian in the north-eastern border of the Upper Silesia Coal Basin, (English summ.).
Roczn. pol. Tow. geol., Kraków 22 (1964), p. 300-348

UNRUG, R.: Turbidites and fluxoturbidites in the Moravia-Silesia Kulm Zone.
Bull. Acad. pol. Sci., Sér. Sci. geol. geogr., Warszawa 12 (1964), p. 187-194

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Explanatory Notes to the Lithotectonic Molasse Profile of the Saale Depression, Southwestern Part (Thuringian Forest; Upper Carboniferous - Permian) (Comment to Annex 21)

by

HARALD LÜTZNER[1)]

1. Introduction

The Variscan molasse deposits in the Thuringian Forest region represent a part of the Saale Depression which is one of the large inner molasse depressions elongated in accordance with the general trend of the Variscan tectogene. Molasse sedimentation starts in the uppermost Stephanian and comprises, above all, the Lower Permian or Rotliegendes which is overlain by marine Zechstein deposits (Upper Permian). The lithotectonic profile of the Thuringian Forest (Annex 21) characterizes the Variscan molasse of a permanent depressional zone in the region of overcrossing fault tectonics connected with strong volcanism of "subsequent" type.

The Thuringian Forest is a mountain range of medium relief with altitudes up to 950 m. In the deeply eroded valleys favourable outcrops prevail in parts, whereas the densily wooded crest of the range is very poor in outcrops. Tectonically, the Thuringian Forest represents an uplifted block bordered by NW--SE striking faults and flexures. The internal structure of the horst is complicated by numerous faults, too. The fault tectonics is predominantly Mesozoic-Cenozoic in age, however, some faults can be dated as Permian.

Rotliegendes mainly occurs in the middle and southeastern part of the Thuringian Forest. Here the mountain range provides a transversal section of the Saale Depression. Separated by the Ruhla Crystalline Complex, Rotliegendes occurs once more in the northwesternmost part of the range. These sediments paleogeographically belong to the Saar-Werra Depression, they are not represented in the lithotectonic profile.

1) Zentralinstitut für Physik der Erde AdW, Institutsteil Jena; DDR, 6900 Jena, Burgweg 11

DOI:https://doi.org/10.2312/zipe.1982.066

2. Paleotectonic and paleogeographic position

The position of the Thuringian Forest type section in its paleotectonic and paleogeographic framework is shown in Fig. 1. The elongated Saale Depression follows the tectonic zoning of the Variscan tectogene, especially it is superimposed on the Central-German Crystalline Ridge separating the Rheno-Hercynian and Saxothuringian zones which took a somewhat different development during the Lower Paleozoic geosynclinal history (FRANKE and SCHROEDER 1968; MÖBUS 1968).

The Central German Crystalline Ridge acted as a permanent rise during Upper Devonian and Lower Carboniferous. After the main folding the rise was intruded by large granitic and dioritic bodies the cooling of which was determined as Upper Carboniferous by isotopic ages (WERNER 1974). Contemporaneously, parts of the uplifted crystalline rise inverted to subsiding depressions which were filled up with molasse sediments. In the Saar Depression significant molasse accumulation began during Westphalian A. Local sedimentation during uppermost Dinantian and lower Westphalian is known, too, from the northeastern part of the Saale Depression (cf. ELLENBERG 1982, Annex 22) indicating initial subsidence.

In the course of Westphalian and Stephanian the basening expanded more and more to the southwest. Before accumulation of the molasse deposits, plutonic intrusions have been cut by erosion and in parts they were covered by a weathering crust. In the Thuringian Forest region, too, the molasse sedimentation began on a deeply weathered granitic surface. Near the margins the earliest sediments discordantly overlie the folded series of Precambrian to Lower Paleozoic age.

The configuration of the Saale Depression is rather well known between the rivers Saale and Werra. Between the surface outcrops in the regions of Halle and Thuringian Forest some boreholes permit to infer main features of the molasse sedimentation (STEINER and BROSIN 1974; LÜTZNER et al., in press). The prolongation of the Saale Depression to the southwest is not yet well known. During the Stephanian the Saar and Saale Depressions appear to be parts of only one subsiding zone (ЛЮТЦНЕР и др. 1977). During Autunian (?) and more clearly during Saxonian the Saar and Saale Depressions are separated by the Spessart - Ruhla Ridge, an uplifted rise of crystalline rocks belonging to the central part of the crystalline zone.

In Thuringia the Saale Depression only during the Stephanian was filled up with relatively uniform molasse deposits. In the Thuringian Forest, sedimentation starts rather late with the Basal Sediments of the Gehren Beds. Thereafter, in the Thuringian Forest as well as in the Halle region volcanic activity began to stamp the basin development. In the intermediate section (modern Thuringian Basin) volcanism is essentially missing. Thus, during the Lower Permian three types of sections coexist within the Saale Depression (Fig. 2). A characteristic feature is the combination of high thicknesses, occurrence of grey deposits and volcanic activity.

DOI:https://doi.org/10.2312/zipe.1982.066

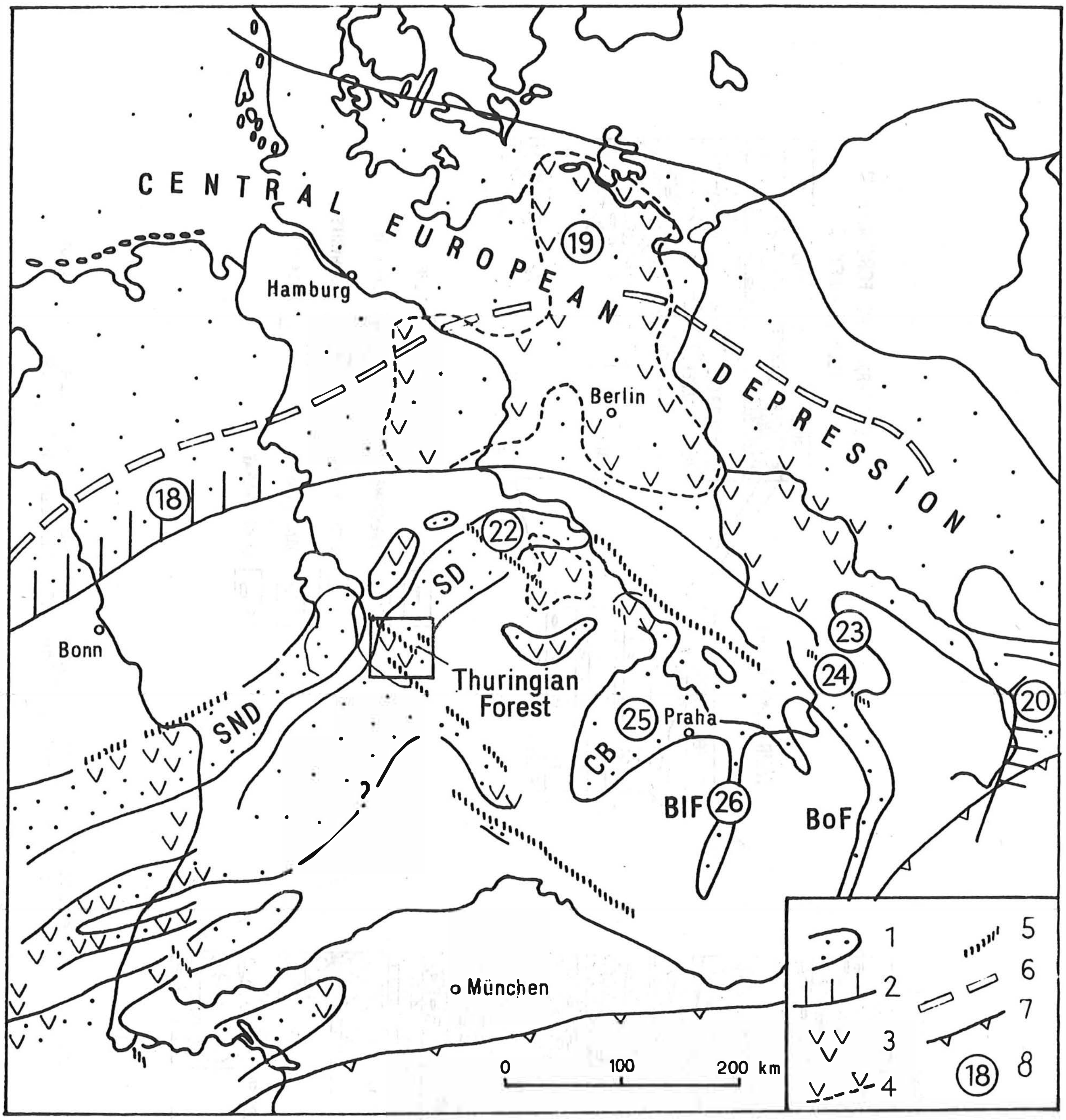


Fig. 1. General map of the Variscan molasses in Central Europe

1 - outline of molasse deposits, 2 - folded molasses of the Subvariscan foredeep, 3 - volcanic rocks, 4 - volcanic complexes with scarce sedimentary intercalations, 5 - paleotectonic fault zones, 6 - borderline of the Variscan belt, 7 - borderline of the Alpidic belt, 8 - sites of lithotectonic profiles (numbers refer to the Annex of this volume

Abbreviations: BlF - Blanice Furrow, BoF - Boskovice Furrow, CB - Central Bohemian Depression, SD - Saale Depression, SND - Saar-Nahe Depression

DOI:https://doi.org/10.2312/zipe.1982.066

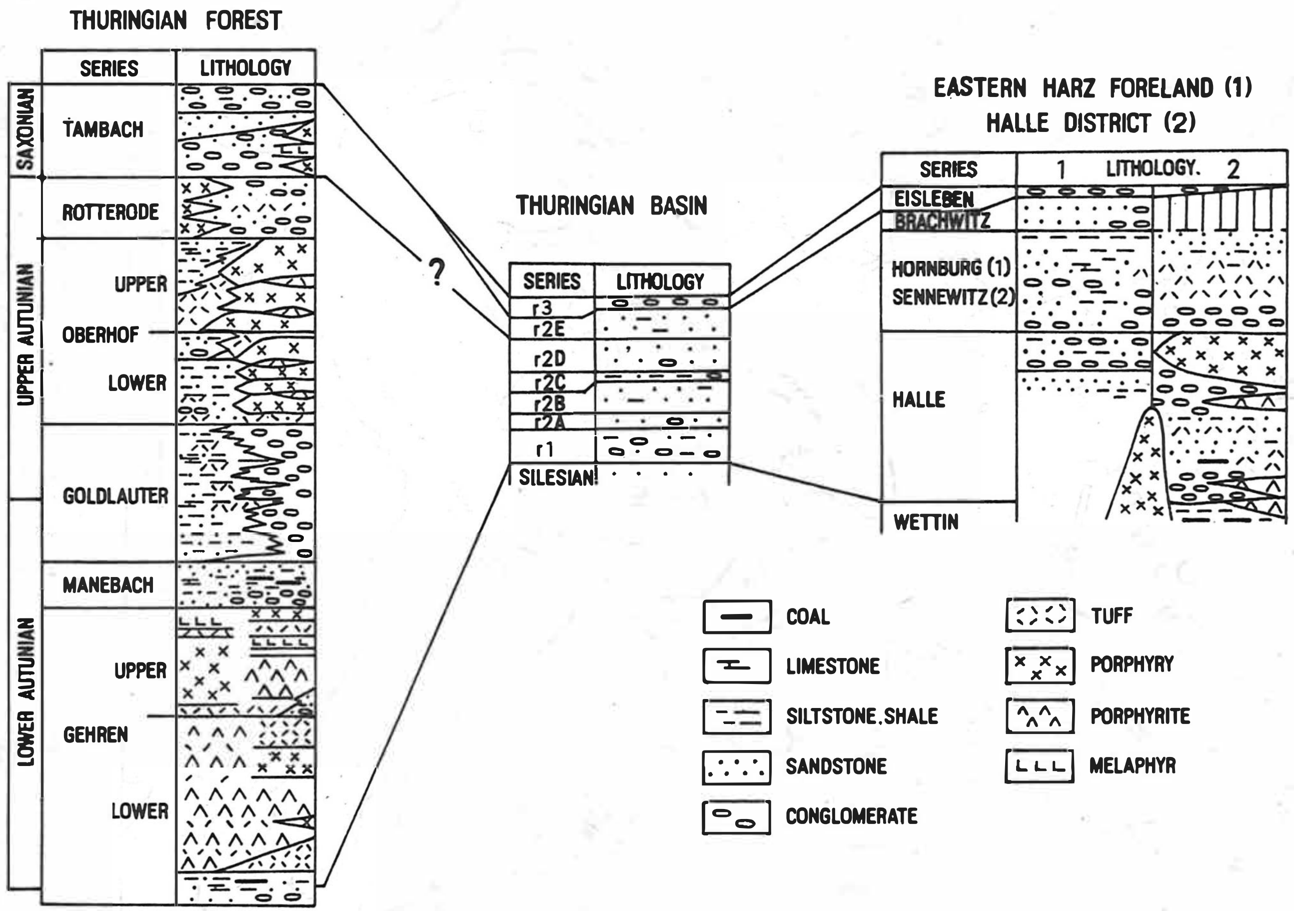


Fig. 2. Rotliegend lithostratigraphie profiles of the Saale Depression
Thuringian Basin profile after STEINER and BROSIN 1974

DOI:https://doi.org/10.2312/zipe.1982.066

3. General character of the molasse profile

3.1. Sedimentation

The Thuringian Forest molasse profile displays a repeatedly alternating succession of sedimentary, volcanic and mixed rock sequences. In the sedimentary members conglomerates, sandstones and shales are associated in a tight lateral and vertical facies relation proving a typical intramontane character of sedimentation. Frequently there are facies transitions from marginal conglomerates with cobbles and boulders up to 1 - 2 m in diameter passing into a fine grained basinal facies within a few kilometres, thus indicating sedimentary basins of limited extent which were sited very close to the source area.

The colour of sediments is grey and variegated in the lower part of the profile and becomes more and more red and reddish brown in the upper part. This reflects a general trend of climate from semihumid to dry but a strong arid climate is not attained. An essential part of the sediments are fluvial deposits. In the Stephanian and Autunian they are frequently connected with lake deposits. Coal-forming swamp environments are only locally known from lowermost Gehren and from Manebach Beds. In the upper Autunian and Saxonian the environments of permanent lakes are gradually substituted by playa environments. Alluvial fan deposits are known from all lithostratigraphic units.

The predominantly sedimentary sequences have a cyclic structure in the thickness order of 50 - 300 m which is interpreted to be due to tectonic impulses. Small-scale cycles locally occur, however, they are not a dominating feature. In sequences interbedded with lava flows and tuffs cyclicity is disturbed or obliterated.

The composition of clastic components indicate short distances of transport from a few up to some tens of kilometres. The main source areas are the folded series of Lower Paleozoic (up to Dinantian) geosynclinal deposits of the Saxothuringian Zone, bordering the Saale Depression in the southeast and, on the other hand, the metamophites and plutonites of the Ruhla Crystalline Complex which adjoined the sedimentary basin to the NW. To a high degree the Lower Permian volcanic rocks contribute to the clastics of the molasse deposits.

From the pebble composition it can be concluded that the level of Lower Permian erosion was not essential different from that exposed today. In detail, pebble composition in connection with paleocurrent pattern provides some clues to erosional processes during the molasse deposition and to the tectonic movements connected with them (Fig. 4).

3.2. Volcanic activity

Volcanic rock sequences are concentrated in two levels: in the Gehren Beds and in the Oberhof - Rotterode Beds. Last volcanic intercalations occur within the Tambach Beds. The Gehren Beds are characterized by predominating andesitoid rocks whereas rhyolitoids prevail in the Oberhof, Rotterode and Tambach Beds. The andesitic sequences of the Gehren Beds nearly exlusively consist of lava sheets and tuff intercalation. A broad zone of eruptions with dikes, necks and intrusions in known in the south-easternmost part of

DOI:https://doi.org/10.2312/zipe.1982.066

the basin between Gehren and Schleusingen. In this district volcanotectonic fault activities connected with ignimbritic ash flow eruptions have been proved (MICHAEL 1972). Further centres of eruption are supposed beneath the thick andesitic sequences in the middle part of the Thuringian Forest. The andesitic dikes predominantly trend NE—SW, e. g. parallel to the general contour of the Saale Depression, but NW--SE and N—S trends are occuring too.

An important centre of the Oberhof rhyolitic volcanism is situated in the surroundings of Oberhof. It is connected with NW—SE (and N—S) trending faults and intrusions. Oberhof or post-Oberhof volcanic dikes are found, too, beyond the recent extension of molasse deposits at the eastern flank of the Ruhla Crystalline Complex. These dikes predominantly strike E—W and N—S. In general, the rhyolitic sequences of the second volcanic period are much more interfingering with sedimentary deposits than the intermediate extrusions of the Gehren Beds.

Petrochemically the volcanic rocks belong to the calc-alkali province with a slight excess of alkalis (RÖLLIG and SCHIRMER 1979). In the STRECKEISEN diagram and following the calculation after RITTMANN (1973) the rocks fall predominantly into the fields of alkalirhyolite, rhyolite, trachyte, alkalitrachyte, latite and latitandesite. Alkalirhyolites occur in all volcanic series. Trachytes, latites and andesites are found in the Gehren Beds, whereas rhyolites are restricted to the Oberhof Beds. Some basaltic rocks of the last volcanic series (Tambach Beds) are considered to be of subcrustal origin. All other volcanic rocks are ensialic with a magma generation in different levels of the crust. However, many details of the formation of special rocks or rock associations are unsolved.

As lithostratigraphic names of volcanic rock bodies the old petrographic designations (porphyry, porphyrite, melaphyr) are still in use.

3.3. State of deformation

The molasse series of the Thuringian Forest has a posttectonic position in relation to the process of folding of the geosynclinal deposits (at the end of Dinantian) and plutonic intrusions (during Silesian). The Basal Sediments overlie to the most part a large weathered granite. The contacting series of crystalline schists in the northwest and of folded Precambrian and Lower Paleozoic in the southeast are discordantly covered.

In general, the molasse sequence is forming a broad syncline trending SW--NE and extending over the whole middle and southeastern Thuringian Forest (so-called Oberhof Syncline). A block structure with faults of NW--SE, E--W and N--S trend is superimposed on the Oberhof Syncline. Some of the faults are proved to have been active during the molasse stage, e. g. the Kehltal, Haidersbach, Inselsberg Faults and others (Fig. 3). During the Mesozoic-Cenozoic tectonic movements the faults were more or less reactivated, some of them with an opposite sense of displacement. Within the blocks bedding is horizontal or dipping gently. In some places there are irregular brachysynclinal undulations. As a whole, the tectonic deformation of the molasse is similar to that of the platform cover with some complications due to magmatic extrusions and intrusions.

DOI:https://doi.org/10.2312/zipe.1982.066

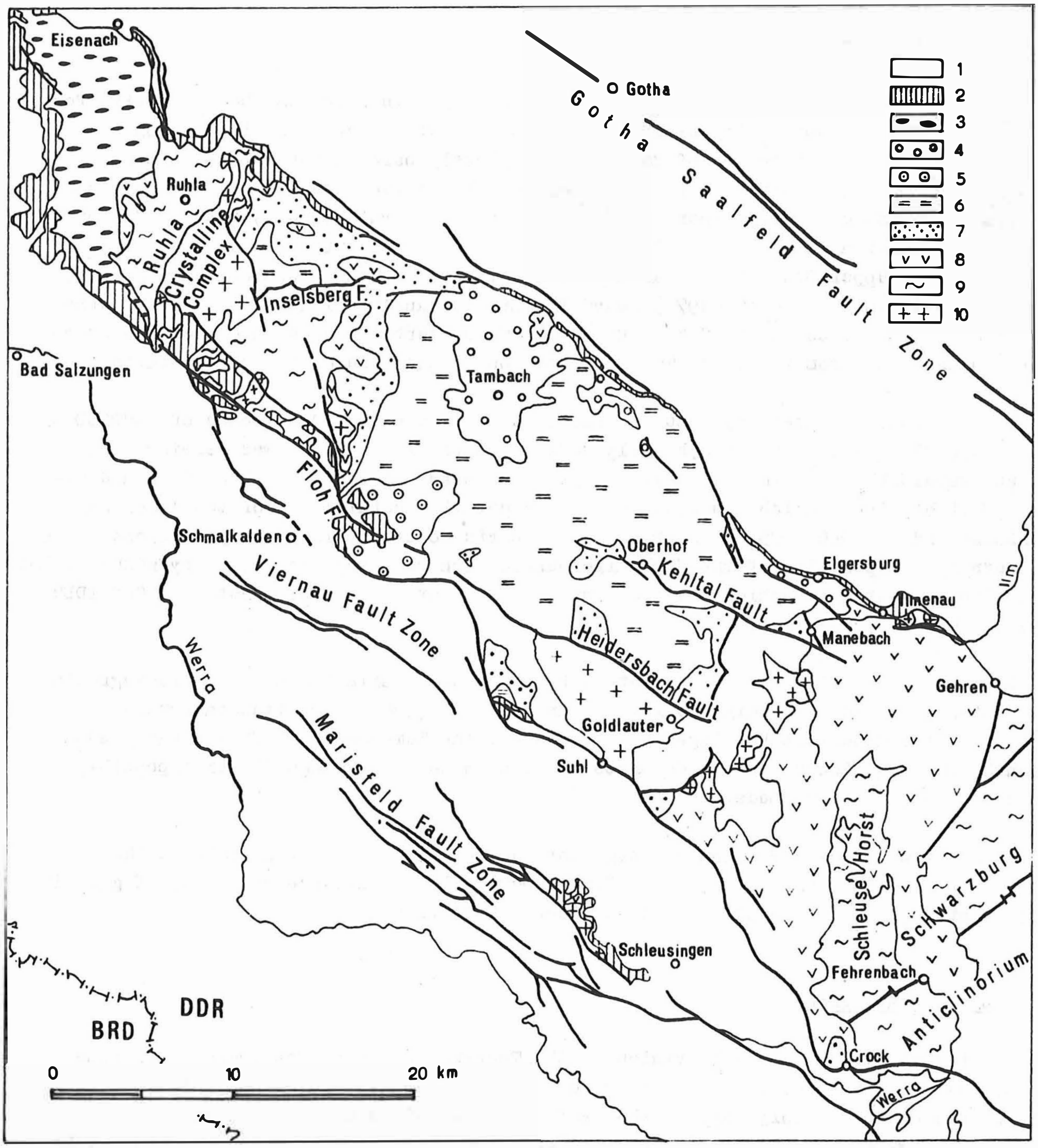


Fig. 3. Generalized geological map of the Thuringian Forest
1 - Mesozoic and Cenozoic deposits, 2 - Zechstein (Upper Permian), 3...8 - Lower Permian and uppermost Stephanian, 3 - Eisenach Beds, 4 - Tambach Beds, 5 - Rotterode Beds, 6 - Oberhof Beds, 7 - Goldlauter and Manebach Beds, 8 - Gehren Beds, 9 - late-Variscan granites (Upper Carboniferous), 10 - folded and metamorphic series (Precambrian - Dinantian)

DOI:https://doi.org/10.2312/zipe.1982.066

4. Succession of profile

4.1. Stratigraphic problems

The uppermost Stephanian and Lower Permian deposits include some horizons with fossils which are appropiate for biostratigraphic subdivision and correlation. On the other hand, some thick series of rocks are completely bare of fossils so that many problems of stratigraphic correlation remain still unsolved, especially as the fossils in limnic basins generally depend on facies conditions. The boundary between Carboniferous and Permian is drawn with the first appearance of Callipteris conferta or the occurrence of Upper Stephanian character plants, respectively. Considering spore associations, KATZUNG and DÖRING (1973) found the Stephanian/Autunian boundary within the Basal Sediments of the Lower Gehren Beds. The first certain Autunian macroflora association is known from the Lower Tonstein horizon at the base of the Upper Gehren Beds.

In the profile (Annex 21) Autunian and Saxonian are used in the sense of HAUBOLD and KATZUNG (1972) as biostratigraphically defined units within the Lower Permian. The stratigraphically most important groups of fossils are pteridopsids, conifers and tetrapode footprints, which are used for a more detailed subdivision of the Autunian (ANDREAS and HAUBOLD 1975; HAUBOLD 1980). In parts controversial interpretations, also concerning the position of the Carboniferous-Permian boundary, are given by KOZUR (1978). Additional biostratigraphic data from invertebrates are now in elaboration (SCHNEIDER 1979; MARTENS 1975).

Besides the stratigraphic correlation by means of fossils the use of paleomagnetic data was initiated. According to LÜTZNER and MENNING (1980) the Illawara reversal is placed in the uppermost Rotliegendes, c.e. above the Tambach Beds. Within the predominantly reversed Lower Permian deposits an event with normal magnetization possibly occurs in the Manebach Beds.

Under view of Lower Permian stratigraphy the Thuringian Forest profile is the most important reference profile in the G.D.R. However, the occurrence and range of gaps in the stratigraphic record is not yet sufficently understood.

4.2. Lithostratigraphy

The lithostratigraphic subdivision of the Thuringian Forest Rotliegendes is based on typical associations of sedimentary rocks and intercalations of volcanic rocks. In the course of the primary mapping the profile was subdivided into five units (BEYSCHLAG 1895). Following the general German usage of lithostratigraphic names, these "Schichten" have been and are understood till today as temporal sections materialized in sequences of rocks which are valid over the Thuringian Forest area. Tacitly it is accepted that the boundaries may be not exactly isochronic. Strong diachronism, however, is improbable. According to their thicknesses the "Schichten" correspond to "groups" or "formations", but it has to be mentioned that the majority of the "Schichten" include facies changes which should have given rise to separated designations of laterally adjacent "formations" or "members" after the nomenclature of the "International Stratigraphic

DOI:https://doi.org/10.2312/zipe.1982.066

Guide". HAUBOLD and KATZUNG (1980) have tried to treat the main lithostratigraphic units as "groups" which are subdivided into "formations". The abovesaid reservations apply to this effort, too. As the problem is yet under discussion among the geologists of the G.D.R. it is preferred here to use the general term "Beds" as translation of "Schichten". As far as necessary and already introduced by the regional geological literature the Beds are subdivided into "Lower" and "Upper".

Besides the main lithostratigraphic units there are a lot of local names of special horizons, usually in connection with a lithological term. Only those mentioned in the text are listed in the profile.

Gehren Beds

The Gehren Beds are characterized by the predominance of andesites alternating in parts with rhyolites and rarely with basaltic rocks. ANDREAS et al. (1966) introduced the subdivision into Lower and Upper Gehren Beds. In the southeastern Thuringian Forest the latter begin with the Lower Tonstein horizon which lies unconformably over the Lower Gehren volcanic succession.

The Lower Gehren Beds start with the lithologically rather uniform Basal Sediments. Their main features are shown in the lithotectonical profile. The configuration of the sedimentary basin is not known in detail. From the facies patterns (ANDREAS et al. 1966; cf. Fig. 4a) it is suggested that the basin margins and axis were in accordance with the trend of the Saale Depression. This type of a flat and wide basin which covers over the whole width of the Saale Depression does not recur in the further development.

The main part of the Lower Gehren Beds consists of very thick volcanic rock successions which display different columnar sections in NW and SE. In the northwestern part monotonous sequences of andesites with variable associations of phenocrysts prevail whereas in the SE andesitic lava sheets, in parts of other type than in NW, are alternating with rhyolites (MICHAEL 1972; VOIGT 1972). Thickness distribution also indicates a bipartite volcanic "basin" (Fig. 4b). In the southeastern part the Lower Gehren Beds are closed with an extremely ramified rhyolite intrusion connected with heavy volcanotectonic faulting and ignimbritic ash flow eruptions.

In the Upper Gehren Beds the division into two partial basins is continued and accentuated. In contrary to the northwestern part with reduced thickness and number of volcanic rock units the southeastern part has a profile of higher thickness with some sedimentary intercalations. This local basins which occur in different levels and places (Fig. 4c) are filled with detritus of the neary surroundings consisting predominantly of volcanic rocks. Near the southeastern margin the slate conglomerates of Crock and Fehrenbach are produced by the uplift of the Schleuse Horst lying between the two alluvial fans with opposite paleocurrent directions (Fig. 4c). The local basins have a diversity of narrow spaced environments from eluvial debris, alluvial fans and valley fills to small lacustric basins (LÜTZNER 1981).

DOI:https://doi.org/10.2312/zipe.1982.066

Fig. 4. Basin development of the Variscan molasse in the Thuringian Forest region

1 - outline of sedimentation areas, 2 - isopachs with thickness in metres, 3 - active faults, 4 - direction of transport according to paleocurrent measurements, 5 - direction of transport according to facies relations, 6 - conglomeratic marginal facies

a. Lower Gehren Beds, Basal Sediments

7 - outline of distribution of grey sediments, 8 - outline of the central facies (merely grey sediments, coal seams),

b. Lower Gehren Beds (volcanic series)

9 - boundary between andesitic (NW) and rhyolithic (SE) volcanic facies,

c. Upper Gehren Beds

10 - volcanotectonic collapse structure at the base of Upper Gehren Beds, indicated by the distribution of the Stützerbach Porphyry, 11 - areas with sedimentary members in the Upper Gehren Beds, 12 - area with vulcanoclastic sedimentation in northwestern Thuringian Forest,
abbreviations: CC - Crock Conglomerate, CF - Fehrenbach Conglomerate, HS - Höllkopf Sediments, ES - Erletal Sediments,

d. Manebach Beds

13 - occurrence of coal seams,

e. Goldlauter Beds

abbreviations: POR - Plaue-Ohrdruf Ridge, SCH R - Schleusingen Ridge,

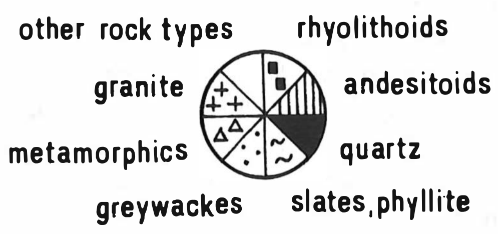
f. Oberhof Beds

14 - outline of Oberhof Volcanic Complex,
abbreviations: LO - sedimentation area of the Lower Oberhof Beds, OVC - Oberhof Volcanic Complex

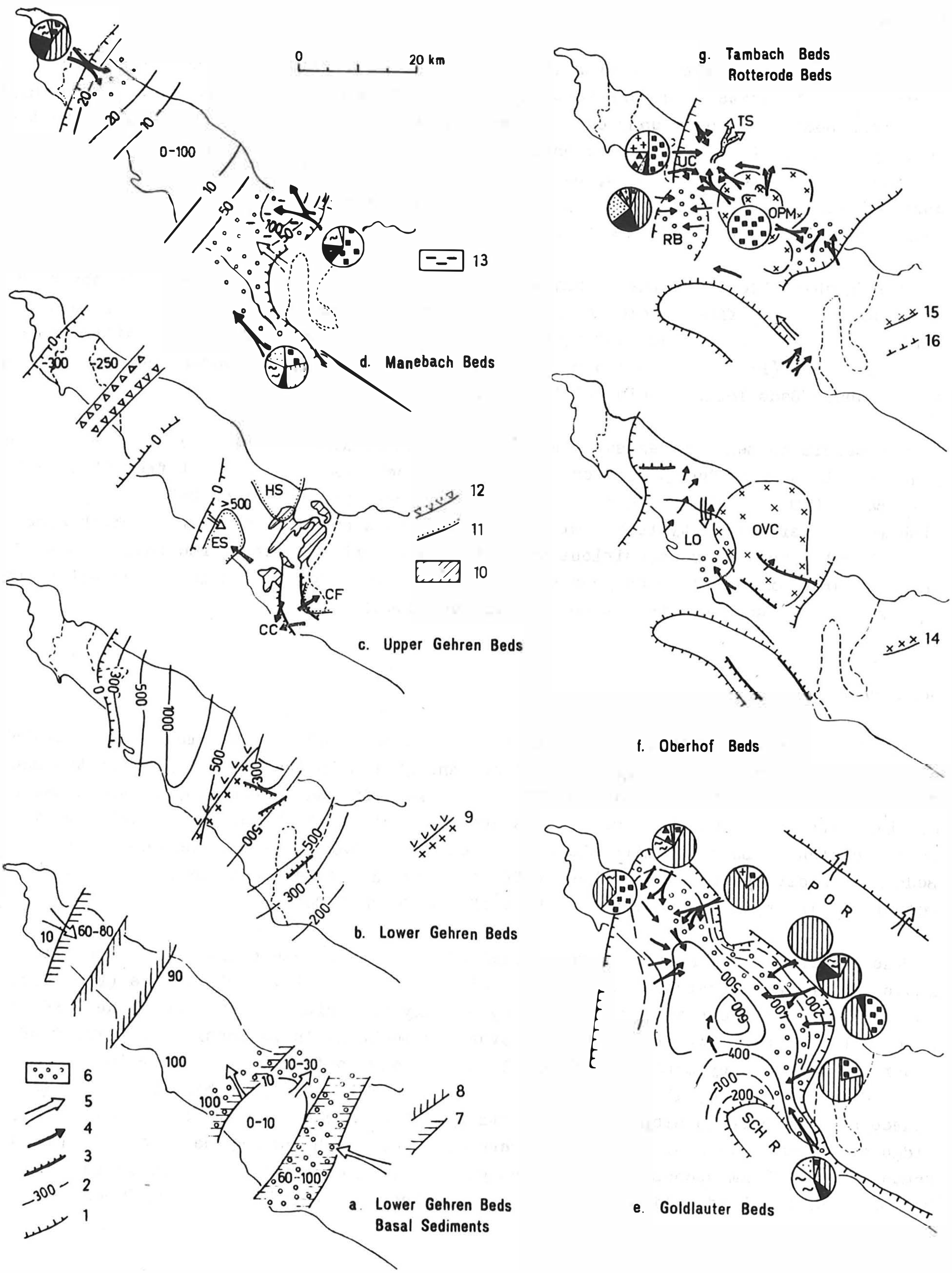
g. Rotterode and Tambach Beds

15 - Oberhof "volcanic mountains", 16 - sedimentation area of the Rotterode Beds,
abbreviations: OVM - Oberhof volcanic mountains, RB - Rotterode basin (facies, paleocurrents, pebble composition), TS - paleocurrent directions of the Tambach Sandstone, UC - Upper Tambach Conglomerate (Paleocurrents, pebble composition).

Circular diagrams indicate pebble composition (mean values):



DOI:https://doi.org/10.2312/zipe.1982.066



DOI:https://doi.org/10.2312/zipe.1982.066

Manebach Beds

The Manebach Beds almost exclusively consist of grey sediments. Sandstones and shales prevail, conglomerates are restricted to the NW and SE marginal zones. In areas of high thickness some thin coal seams occur, however, the deposits have in all places the typical appearance of a "coal formation", i.e. they contain a considerable amount of coaly particles. Characteristic rocks, but only found in thin layers, are black cherts and carbonate-siliceous rocks. A typical feature is the decoloration of the variegated volcanic rock pebbles to uniform grey.

The Manebach Beds have their maximum thickness at the type locality of Manebach. Here they form a well-defined sedimentary cycle which is uncomplete or bipartite in other parts of the basin. The sedimentary basin was widely expanded, the facies differentiation not very sharp (Fig. 4d). In the central part, where also Upper Gehren Beds are missing, the Manebach Beds locally thin out to zero.

The pebble content proves supplies from SE and NW. Along the Franconian Line (SE marginal faults of the Thuringian Forest) greywacke pebbles came at least from the Stockheim Basin (50 km). The sedimentary environments were fluvial, lacustrine and paludal, with low relief intensity in a humid and warm climate and with a generally high groundwater level. Under these conditions an allitic weathering crust of red soil developed in the near-basin source areas and elevations. The released silica was transported into the basin and caused the formation of siliceous rocks.

Goldlauter Beds

The Goldlauter Beds in their marginal facies consist of reddish brown conglomerates and sandstones passing into grey sandstones and shales in the central part of the basin. For lithostratigraphic subdivision ANDREAS (in ANDREAS and HAUBOLD 1975) used a series of thin tuff layers which in most cases are associated with black shale horizons. The Lower Goldlauter Beds end with the Acanthodes black shale horizon. The Upper Goldlauter Beds are subdivided by two or three tuff horizons. A further tuff layer of wide-spread occurrence is appointed to mark the base of the Oberhof Beds.

The Goldlauter basin represents a model of an intramontane basin with concentric facies zoning and a paleocurrent pattern directed towards the basin centre (Fig. 4e). To the northeast the basin is bordered by a newly appearing uplift, the Plaue-Ohrdruf Ridge, which trends NW--SE and crosses over the whole Saale Depression. The front of the ridge is edged by subaerial alluvial fan deposits extending 5 - 15 km into the basin and forming the marginal conglomeratic facies. This refers to high relief of the source area with steep slopes and suggests the Plaue-Ohrdruf uplift to represent a fault ridge or horst structure. The northeastern slope of the horst may be expected in a distance of 15 - 18 km because there is the prolongation of a fault line which is known as the southwestern border-line of the Rotliegend Rudolstadt Basin trending NW--SE.

DOI:https://doi.org/10.2312/zipe.1982.066

Furthermore, the Goldlauter sedimentary basin received supplies from west and southeast. Here, along the Franconian Line, southeast of Schleusingen, the Goldlauter Beds consist of valley-filling alluvial conglomerates and sandstones. This paleovalley, which runs into the Goldlauter basin proper, has been shaped by the contemporaneously uprising Schleusingen Ridge. This is confirmed by local stratigraphic gaps and discordances (LÜTZNER 1972).

The pebble composition of the Goldlauter conglomerates is variable and depicts the geological constitution of the source areas (Fig. 4d). The pebble content of the lowermost Goldlauter sediments reflects the reworking of the Manebach allitic weathering crust mentioned above. The detritus of volcanic rocks is altered to yellowish brown and orange-coloured products of weathering irrespective of the petrographical type. Upward in the profile the colours gradually change to pink, red, and finally to the primary colours of the rocks thus indicating reworking of successively deeper parts of the weathering crust.

In the interior of the basin after a short alluviation an eutrophic lake developed having varying size and reaching its maximal extent in the middle part of the Goldlauter Beds. At least for some time the lake was meromictic with a stagnant ground. Here finely laminated, varved black shales have been deposited.

The lacustrine deposits show a clear zonation of increased contents of nonferrous metals predominantly supplied from reworked volcanic rocks of the Gehren Beds (LÜTZNER and RENTZSCH 1975). A greyish-red dead facies at the outermost lacustrine margin is followed by a Cu-type strip 1.5 to 6 km wide, in front of which extends a Pb or Pb-Zn mixed zone. The Zn type is found near the basin centre.

In the central part of the basin the Goldlauter Beds altogether form a sedimentary cycle. In the belt of marginal to central facies transition several cycles of lower order appear to be developed. They are not yet sufficiently elaborated.

Oberhof Beds

The Oberhof Beds are marked by prevalent rhyolitoid volcanic rocks. Starting from faults which run transversal and oblique to the general trend of the Saale Depression the volcanic activity built up a volcanic complex with more than 1000 m of thickness. The centre, the so-called porphyric district of Oberhof, is situated nearly on the axis of the Saale Depression. The lower series of rhyolitoids has medium- to large-sized phenocrysts, whereas the younger series is characterized by small-size phenocrysts. ANDREAS et al. (1974) took this as basis to propose a subdivision in Lower and Upper Oberhof Beds.

In the volcanic centre the Oberhof Beds are built up almost entirely of rhyolitic lava sheets, intrusions and tuffs. Farther to the morthwest and southeast number and thickness of the rhyolitic bodies decrease and sedimentary sequences are intercalated.

DOI:https://doi.org/10.2312/zipe.1982.066

In the L o w e r O b e r h o f B e d s west of the Oberhof volcanic centre there continued to exist a narrowed lacustrine basin (Fig. 4f). The grey sandstones and siltstones accumulated here are very similar to the Goldlauter Beds in their central facies. The lake basin was gradually filled up with more and more sandy and gravelly deposits which are in part of delta type.

Within the sedimentary levels and areas of the U p p e r O b e r h o f B e d s red-coloured sandstones and siltstones prevail, often interbedded with tuffs and tuffites. The sediments originated from subaerial environments with ephemeral streams and playas in which the washout materials of ash falls and lava sheets were deposited after a short distance of transport tending to level the uneven relief. In a high lithostratigraphic level small eutrophic lakes have been distributed like oases in which grey sandstones, black shales and laminated carbonate layers accumulated from an environment rich in organic matter.

The paleocurrents were predominantly directed to the northeast, whereas in the Lower Oberhof Beds they tended toward the residual lake basin (Fig. 4f).

Rotterode Beds

The occurrence of Rotterode Beds (PATZELT 1966) is restricted to a rather small area around the village Rotterode east of Schmalkalden (Fig. 4g). They consist of conglomerates and sandstones with shaly intercalations. The sediments are reddish brown in general with intense red colour in siltstones and shales and violet to greyish colouring in some sandstone banks. Sedimentary structures and the high degree of pebble rounding suggest fluvial environments. As proved by fossil content of shales and siltstones the flood plains still offered favourable conditions for a xerophile flora and tetrapode fauna. Paleocurrent patterns and pebble content prove supplies from the west with granites and metamorphic rocks of the Ruhla crystalline basement as well as from the east with rhyolites of the Oberhof volcanic centre (LÜTZNER 1979).

Towards the southwest the Rotterode Beds are interfingering with a local rhyolite sequence the eruption of which may be attributed to an active fault (Floh Fault, PATZELT 1966). The Mesozoic-Cenozoic movements reactivated this fault with opposite sense of displacement. - The Rotterode Beds lie concordantly over the Upper Oberhof Beds as a part of which they are considered by some authors. The relationship to the Tambach Beds is not yet quite clear (cp. Tambach Beds).

Tambach Beds

Over a surface of general erosion which has been rather strong in places the Tambach Beds begin with very coarse-grained conglomerates. In the middle part sandstones occur. The profile ends again with conglomerates in which, however, pebble size is smaller and not equal to the cobbles and boulders found in the lower conglomerates. All deposits have red to reddish brown colour.

DOI:https://doi.org/10.2312/zipe.1982.066

The Tambach Beds were mainly deposited in two partial depressions represented by the Tambach and Elgersburg Basins (Fig. 4g). In the modern extension of outcrops the Tambach Beds lie on Gehren, Lower and Upper Oberhof Beds thus indicating nonconformity. Probable Tambach equivalents in front of the Schleusingen Ridge disconformably superpose also various members of the Goldlauter Beds (LÜTZNER 1972). The relation to the Rotterode Beds is obscure because a contact between the two units is not preserved (for discussion of the discordance described by HAUBOLD and KATZUNG 1972 see PATZELT 1977 and LÜTZNER 1981). It cannot be excluded without doubt that the Rotterode Beds in part are equivalent with the lower part of Tambach Beds. Doubtlessly, the very similar porphyry conglomerates of both units have the same source area.

The two partial basins of the Tambach Beds flanked the volcanic centre of Oberhof which now represented the principal source area with high relief (Fig. 4g). The volcanic activity was finished with exception of two rhyolite extrusions and a basaltic sheet within the Elgersburg Basin. In both partial basins the lower part of the filling originated by alluvial fans in a bolson-like environment, at the beginning with high portion of debris flow deposits coming from the Oberhof volcanic mountains. At the northwestern mountain slope several canyon-like paleovalleys are noticed which gradually have been drowned by the Tambach alluvial fans (CHROBOK 1967; LÜTZNER 1981). The basins have been supplied with clastic material from the opposite slopes, too.

In the Tambach Basin the lower conglomerate member is fining upward to the overlying Tambach Sandstone, a fluvial accumulation with a transport generally directed to the northeast (Fig. 4g). In the Elgersburg Basin two sandstone horizons are developed the upper of which is probably of eolian origin. A last reactivation of the source relief caused the deposition of the upper conglomerate members at the flank of the Ruhla Ridge as well as in the Elgersburg Basin.

Climate was rather dry during deposition of the Tambach Beds. However, a fauna of tetrapodes and invertebrates indicates that the environment was not extremely arid.

5. Conclusions

Under the aspect of lithotectonic development the Thuringian Forest molasse profile may be subdivided into three periods: pre-volcanic, volcano-sedimentary and post-volcanic. The first period is entirely represented by the Basal Sediments of the Gehren Beds. In other parts of the Saar and Saale Depressions (e.g. Saar Basin, Wettin Basin) the pre-volcanic period is represented by thick sedimentary sequences which are considered as the lower section of the main molasse (LÜTZNER 1981; LÜTZNER and VASS, in preparation).

The second period comprehends the succession from the Gehren volcanic sequences to the Rotterode Beds. The main mass of igneous rocks erupted in the time of Gehren Beds and of Oberhof-Rotterode Beds, respectively. Between these two culminations of volcanic activity at least from the Goldlauter Beds small tuff layers are known, thus demonstrating that activity was indeed reduced but did not completely die out.

DOI:https://doi.org/10.2312/zipe.1982.066

The whole second period is characterized by fault movements. Active faults have been proved already in the Gehren Beds (Fig. 3b, c). After a rather quiet development during the Manebach Beds a first culmination of faulting occurred at the beginning and during the Goldlauter Beds. These events result in the uplift of blocks transversal to the Saale Depression which strongly control the basin configuration. The main horst structure is the Plaue-Ohrdruf Ridge which is most conspiceous in the Goldlauter paleogeography (Fig. 3e). Later, the paleocurrent patterns of the Oberhof and Tambach Beds indicate the obliteration of the ridge. The Schleusingen Ridge, another uplifted block of smaller extent, first appeared in the Goldlauter Beds but persisted and was reactivated in the time of Oberhof or Tambach Beds in connection with rhyolite dike intrusions along the bordering faults (LÜTZNER 1972).

A second culmination of fault movements took place during the Oberhof and Rotterode Beds and was essentially finished before the Tambach Beds sedimentation. These movements which are the main reason of the unconformity below the Tambach Beds are summarized as Saalian movements. The Saalian movements decisively controlled the eruption of the Oberhof volcanic rocks. There are known a number of faults and fissures to which certain extrusive and intrusive bodies can be directly related (Fig. 4f; see also ANDREAS et al. 1974 and LÜTZNER 1974).

The post-volcanic period is represented by the Tambach Beds which contain only insignificant and local eruptions. Fault movements are dying out, too. The sedimentation of the Tambach Beds started on a relief of high intensity but the sedimentation tends to level the relief. Before peneplainization was attained the sedimentation ceased. - With these features the Tambach Beds are considered to represent the beginning of the late molasse.

Concerning the basin development the succession of sketch maps (Fig. 4) points out a slight shifting of depocentres from SE to NW. After a rather uniform thickness pattern in the Basal Sediments a division of the Saale Depression is first indicated in the Lower Gehren Beds. The Upper Gehren Beds have their maximum development in the southeastern Thuringian Forest. This situation is prolongated in the time of Manebach Beds. During Goldlauter Beds the depocentre moves to the central part of the Saale Depression. This position is maintained by the sedimentary members of the Lower Oberhof Beds. The sedimentary intercalations of the Upper Oberhof Beds as well as the Rotterode and Tambach Beds have the more important development in the northwestern Thuringian Forest.

Altogether, the Variscan molasse development in the Thuringian Forest region is determined by the permanent subsidence within the Saale Depression and the action of transversal fault tectonics which does not only control the sedimentary basins and cycles, but also the distribution of volcanic activity in space and time. Volcanism itself completely displaces sedimentation at times or divides it into local basins, directly influencing the conditions of transport and sedimentation by building-up volcanic reliefs and by providing large masses of loose volcanic ashes that can easily be transported.

DOI:https://doi.org/10.2312/zipe.1982.066

In relation to the total geological span of Variscan molasses the Thuringian Forest profile ranges in a relatively late position. Early molasse is missing. During the stage of lower main molasse this region was still elevated and was the place of plutonic intrusions. After cooling and inversion the sedimentation started at the end of the lower main molasse. The type region displays above all the basin development in an inner depression under control of overcrossing fault tectonics during the upper main molasse. The beginning of the late molasse stage can be traced but its essential sedimentary record is found outside of the Thuringian Forest section of the Saale Depression.

References

ANDREAS, D.; HAUBOLD, H.: Die biostratigraphische Untergliederung des Autun im mittleren Thüringer Wald.
Schriftenr. geol. Wiss., Berlin (1975) 3, p. 5-86

ANDREAS, D.; ENDERLEIN, F.; MICHAEL, J.: Zur Entwicklung des Rotliegenden im mittleren Thüringer Wald auf Grund neuer Kartierungsergebnisse.
Ber. dt. Ges. geol. Wiss., A, Berlin 11 (1966), p. 119-130

ANDREAS, D.; ENDERLEIN, F.; MICHAEL, J. et al.: Siles und Rotliegendes im Thüringer Wald und seinem südlichen Vorland. In: W. HOPPE; G. SEIDEL (Edit.): Geologie von Thüringen.
Gotha, Leipzig: VEB H. Haack 1974, p. 356-449

BEYSCHLAG, F.: Überblick über die geologische Zusammensetzung des Thüringer Waldes, in Sonderheit des Rotliegenden desselben, unter Vorlegung einer neuen geologischen Übersichtskarte i. M. 1 : 100 000.
Z. deutsch. geol. Ges., Berlin 47 (1895), p. 596-607

CHROBOK, S.M.: Zur Zeitproblematik stark reliefabhängiger Sedimentation am Beispiel der Tambacher Mulde (Thüringer Wald).
Geologie, Berlin 16 (1967), p. 901-908

ELLENBERG, J.: Explanatory notes to the lithotectonic molasse profile of the north-eastern Saale Depression (Dinantian to Lower Permian).
Veröff. Zentralinst. Phys. Erde, Potsdam 66 (1982), p. 255-265

FRANKE, D.; SCHROEDER, E.: Das variszische Orogen nördlich des Böhmischen Massivs. Ein Überblick.
Geologie, Berlin 17 (1968) 6/7, p. 647-660

HAUBOLD, H.: Die biostratigraphische Gliederung des Rotliegenden (Permosiles) im mittleren Thüringer Wald.
Schriftenr. geol. Wiss., Berlin (1980) 16, p. 331-356

HAUBOLD, H.; KATZUNG, G.: Das Typusgebiet der Autun/Saxon-Grenze im Thüringer Wald.
Ber. dt. Ges. geol. Wiss., A, Berlin 17 (1972), p. 849-863

HAUBOLD, H.; KATZUNG, G.: Lithostratigraphischer Standard für das Permosiles im mittleren und südöstlichen Thüringer Wald.
Z. angew. Geol., Berlin 26 (1980), p. 10-19

KATZUNG, G.; DÖRING, H.: Die Lage der Karbon/Perm-Grenze im Permosiles-Profil des Thüringer Waldes.
Z. geol. Wiss., Berlin 1 (1973) 5, p. 493-507

KOZUR, H.: Beiträge zur Stratigraphie des Perms, Teil III (1): Zur Korrelation der überwiegend kontinentalen Ablagerungen des obersten Karbons und Perms von Mittel- und Westeuropa.
Freiberger Forsch.-H., Leipzig C 342 (1978), p. 101-142

LÜTZNER, H.: Lithostratigraphie und Paläotektonik des Rotliegenden der Schleusinger Randzone (Thüringer Wald).
Ber. dt. Ges. geol. Wiss., A, Berlin 17 (1972), p. 811-834

DOI:https://doi.org/10.2312/zipe.1982.066

LÜTZNER, H.: Variscisch-spätorogene Bewegungen. In: W. HOPPE; G. SEIDEL (Edit.): Geologie von Thüringen.
Gotha, Leipzig: VEB H. Haack 1974, p. 354-367

LÜTZNER, H.: Transportanalyse der unterpermischen Sedimente im Thüringer Wald.
Veröff. Zentralinst. Phys. Erde, Potsdam 43 (1979), p. 1-132

LÜTZNER, H.: Sedimentation der variszischen Molasse im Thüringer Wald.
Schriftenr. geol. Wiss., Berlin (1981) 17, 217 p.

LÜTZNER, H.; MENNING, M.: Erste Ergebnisse zur Magnetostratigraphie des Rotliegenden der Saale-Senke.
Permian of the West Carpathians, Bratislava: Geologický ústav Dionýza Stúra 1980, p. 41-51

LÜTZNER, H.; RENTZSCH, J.: Sedimentation und Metallogenie in einem intramontanen Becken der variszischen Molasse.
Z. geol. Wiss., Berlin 3 (1975) 11, p. 1473-1490

MARTENS, T.: Zur Taxonomie, Ökologie und Biostratigraphie des Oberrotliegenden (Saxon) der Tambacher Mulde in Thüringen.
Freiberger Forsch.-H., Leipzig C 309 (1975), p. 115-133

MICHAEL, J.: Zur Paläogeographie der Gehrener Schichten im südöstlichen Thüringer Wald.
Ber. dt. Ges. geol. Wiss., A, Berlin 17 (1972), p. 835-847

MÖBUS, G.: Tektogenese und Magmatismus im Gebiet der Deutschen Demokratischen Republik.
Geologie, Berlin 17 (1968) 6/7, p. 631-646

PATZELT, G.: Bau und Schichtenfolge der Asbach-Rotteröder Mulde (Thüringer Wald) nach neuen Kartierungsergebnissen.
Hall. Jb. Mitteldeutsche Erdgesch., Leipzig 7 (1966), p. 39-60

PATZELT, G.: Nochmals zur Einstufung der Porphyrkonglomerate im Rennsteiggebiet des Meßtischblattes Tambach-Dietharz (Thüringer Wald).
Hall. Jb. Geowiss., Gotha/Leipzig 1 (1977), p. 115-119

RITTMANN, A.: Stable mineral assemblages of igneous rocks.
Berlin, Heidelberg, New York: Springer-Verlag 1973

RÖLLIG, G.; SCHIRMER, B.: On the petrological evolution and formational division of the Variscan subsequent volcanism in the southern part of the GDR.
Veröff. Zentralinst. Physik Erde, Potsdam (1979) 58, p. 229-239

SCHNEIDER, J.: Zur Taxonomie und Biostratigraphie der Blattodea (Insecta) des Karbon und Perm in der DDR.
Freiberger Forsch.-H., Leipzig C 340 (1979) 152 p.

STEINER, W.; BROSIN, P.: Siles und Rotliegendes nördlich des Thüringer Waldes.
In: W. HOPPE, G. SEIDEL (Edit.): Geologie von Thüringen, Gotha, Leipzig: VEB H. Haack 1974, p. 449-515

VOIGT, H.: Zur petrographischen Gliederung der intermediären Vulkanite des Thüringer Waldes.
Ber. deutsch. Ges. geol. Wiss., Berlin A 17 (1972), p. 865-879

WERNER, C.D.: Metamorphose und Migmatisation im Ruhlaer Kristallin (Thüringer Wald).
Freiberger Forsch.-H., Leipzig C 284 (1974), p. 1-134

ЛЮТЦНЕР, Г.; ГРУМБТ, Е.; ЭЛЛЕНБЕРГ, Ю.; ФАЛЬК, Ф.: Варисцискиe молассы Средней Европы.
Орогенные етап развития варисцид Средней Европы и СССР.
Москва Изд. Наук I977, 7-38

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Explanatory Notes to the Lithotectonic Molasse Profile of the Northeastern Saale Depression (Comment to Annex 22)

by

JÜRGEN ELLENBERG[1]

1. General remarks on the type area

In the area between Halle and Hartz Mountains there are cropping out Upper Carboniferous and Lower Permian rocks which belong to the filling of the northeastern Saale Depression. The lithotectonic profile (Annex 22) refers to these outcrops as well as to subsurface data which permit to outline approximately the extent of molasse deposits below the post-Permian cover. Depending on the variable size of the primary area of sedimentation and on intra- and post-Permian erosion the boundaries of the Saale Depression cannot be located exactly. The southwest boundary is approximately the line Kyffhäuser--Bottendorfer Höhe. The northwest boundary is given by the Hartz Mountains and the northeastern continuation of the Variscan trend up to Aken, and in the northeast the Saale Depression ends approximately at the Elbe River. In the southeast it is bounded by a line taking a SW--NE course through Leipzig (Fig. 1).

The Saale Depression was formed as an intramontane basin as the result of an inversion on the Central German Crystalline Ridge (cp. LÜTZNER 1982). The NE part described here gets in the course of its development an orifice to north and thus a connection to the external depression of the Variscan tectogene.

2. Paleogeographic-paleotectonic development of the type area and its framework

The area for the lithotectonic profile (Annex 22) belongs with its folded underground to the Saxothuringian zone of the Variscan tectogene. It is superimposed on the

[1] Zentralinstitut für Physik der Erde AdW, Institutsteil Jena; DDR-6900 Jena, Burgweg 11

DOI:https://doi.org/10.2312/zipe.1982.066

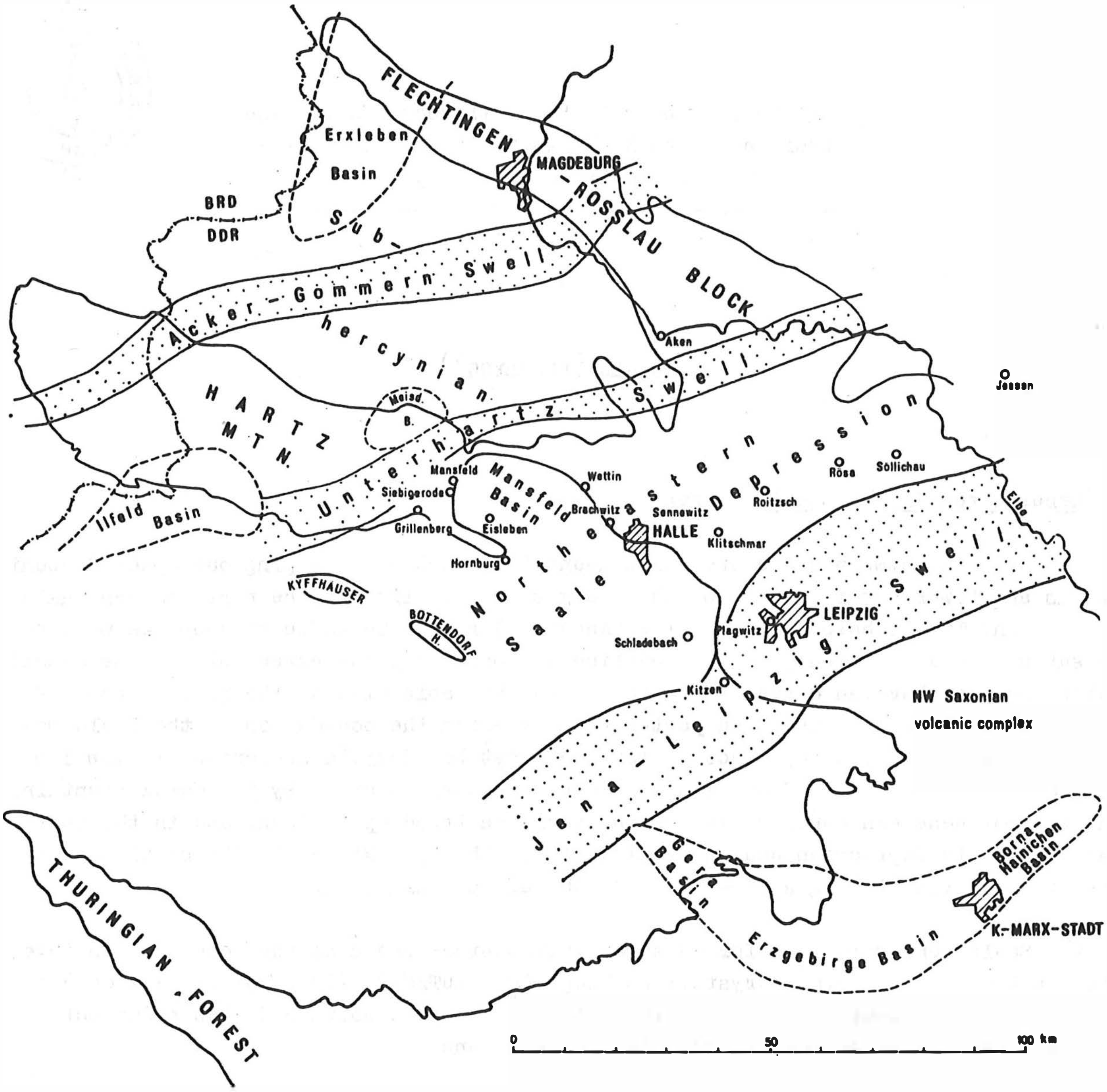


Fig. 1. Sketch-map with the position of the northeastern Saale Depression

DOI:https://doi.org/10.2312/zipe.1982.066

Central German Crystalline Ridge which, after BRAUSE (1970), represents the "orogenic main crest" of the Variscan tectogene. In the complex of Delitzsch the main folding took place before deposition of the Klitschmar Formation (Dinantian IIIα) which is regarded as early molasse (KNOTH and SCHWAB 1972, p. 1166). In the Westphalian single sedimentary basins (formations of Roitzsch, Kitzen, Söllichau, Jessen, Grillenberg) were formed by subsidence of limited extent. In the Stephanian was then formed - under wide subsidence - a coherent intramontane trough, reaching from the Halle-Wittenberg block (KNOTH and SCHWAB 1972) up to the Thuringian Forest (STEINER and BROSIN 1974).

A summarized description of the tectonic regime in the northeastern part of the Saale Depression before, during, and after molasse formation is given by SCHWAB (1977). The uniform development of the molasse basin up to the Silesian gets differentiated after the beginning of an intensive subsequent volcanism. Figs. 2a - d show the configuration during the lithostratigraphic units of the Rotliegendes (FALK et al. 1979). The change from intramontane sedimentation (Halle up to Brachwitz Formation) to the regime of external molasses (Eisleben Formation) forms the transition to the platform cover (GRUMBT et al. in press; LÜTZNER et al. in press).

3. General information on the lithotectonic profile

Because of its copper and coal mining the northeastern Saale Depression belongs to the classic areas of German geology (among other VELTHEIM in manuscript 1821-1829, 1940; LASPEYRES 1875). Since that time knowledge has continuously been improved by means of numerous publications, especially under consideration of drilling results.

The Variscan molasse of the northeastern Saale Depression contains sediments of Visean up to Saxonian age with cumulative thicknesses of 1360 to 3270 m. The mean total thickness of the sediments in the lithotectonic profile is 2600 m. The molasse sedimentation starts in the Visean IIIα. Between Visean IIIβ and Westphalian A the period of main folding is represented by an interruption of sedimentation. Furthermore, sediments of the upper Westphalian B up to the lowest Westphalian C have not yet been found.

As one can see at the profile (Annex 22), the sediments of the Stephanian, the Autunian 2 and the Saxonian 2 have a cyclic structure. The succession of beds consists mainly of sediments, where by sandstones and siltstones are predominating. Additionally there are occuring conglomerates, mudstones, locally coal seams and limestones, especially in cyclic successions. Rhyolitoid and andesitoid volcanic rocks occur mainly in the Halle Formation with precursors in the uppermost Stephanian and single tuffs in Autunian 1.

DOI:https://doi.org/10.2312/zipe.1982.066

4. Description of the lithostratigraphic units

4.1. Klitschmar Formation

The oldest known molasse deposit in the NE part of the Saale Depression is the Klitschmar Formation. It seems to have a local occurrence; it is known only from one borehole. The sediments being more than 400 m thick consist of grey sandstones, siltstones, mudstones and conglomerates with approximately 20 tuff layers of 2 mm up to 5 m thickness (KNOTH and SCHWAB 1972, p. 1155). The deposits have been formed under limnic conditions. The plants Sphenophyllum pachycaule, Cardiopteridium spetsbergense and Diplomena semiforum indicate a Visean IIIα age.

4.2. Roitzsch Formation

The deposits of the main molasse start with the Roitzsch Formation. They had been found in a borehole near Roitzsch (Fig. 1), their thickness is unknown. The sediments consist of light-grey mudstones, silty and fine-sandy with mica and fragmental plant remains. They were deposited in limnic environments. According to Saccopteris (Corynepteris) essinghi (ANDRAE) sp. KAHLERT (1967) suggested an age of Westphalian A/B.

After a stratigraphic gap, including nearly everywhere the Westphalian C, with the Westphalian D a complete succession of a molasse sedimentation is starting.

4.3. Grillenberg Formation and Jessen Formation

The Westphalian D is represented by the Grillenberg Formation and the Jessen Formation. The Grillenberg Formation extents in the central and western part of the northeastern Saale Depression. The Jessen Formation in the northern part has been proved only by one drilling (Fig. 1). As far as is known there is no connection between both areas of sedimentation.

The Jessen Formation (DABER 1963) is formed by partly conglomeratic and mostly sandy-clayish sediments where single, very thin coal seams are intercalated. Sedimentation had already started in the Westphalian C (Reticulopteris münsteri, Annularia aff. sphenophyloides, Sphenophyllum aff. majus, Linopteris obliqua, Cordaites principalis, Alethopteris lonchitica), seems to have lasted during the whole Westphalian D and continued into the oldest Stephanian (Odontopteris genuina, Cordaita principalis). The environments being predominantly paludal-lacustrine, an additional paralic influence is clearly to be seen.

The Grillenberg Formation (FRITSCH 1888) is known from the eastern Hartz Mountains margin and from different boreholes in the centre of the northeastern Saale Depression. According to a rich flora with Neuropteris ovata, Linopteris neuropteroides and Lepidodendron dichotomum, GOTHAN and SCHRIEL (1928) dated the Grillenberg Formation as Westphalian D.

DOI:https://doi.org/10.2312/zipe.1982.066

At the eastern margin of the Hartz Mountains the deposits consist of groy-violet fine and coarse conglomerates and fine to medium sandstones. Locally intercalations of dark mudstones and combustible shales occur. The Grillenberg Formation has a cyclic structure, and its total thickness is 30 - 50 m. In the association of pebbles quartz and quartzite are predominating. Variations in composition are dependent on local differences in the source area of the Wippra Metamorphic Belt (HÄNEL 1969). In the Schladebach borehole (Fig. 1) the Grillenberg Formation is 132 m thick. It is divided by BEYSCHLAG and FRITSCH (1899) into three horizons:

(3) grey sandstones and conglomerates,
(2) alternations of red mudstones and sandstones,
(1) basal grey, black, partly-spotted to red mudstones with grey sandstones and conglomerates; locally skins of coal.

With the Grillenberg Formation the solitary deposits of Kitzen, Rösa and Söllichau which were proved by boreholes, and the Plagwitz Formation (Fig. 1), outcropping at the Mulde River, are considered as contemperaneous accumulations.

4.4. Mansfeld Formation

The Mansfeld Formation was deposited in the Stephanian. It is subdivided in Lower and Upper Mansfeld Formation, the latter - regionally divided - being denoted Siebigerode Sandstone and Wettin Beds. Biostratigraphically there is a subdivision only between lower and upper Stephanian (KAMPE and REMY 1962).

The L o w e r M a n s f e l d F o r m a t i o n consists of a series of fining upward cycles in the order of 15 to 35 m. A complete cycle starts with conglomerate followed by sandstone, alternation of sandstone and siltstone, and finally siltstone and limestone. All clastic sediments have an intensive red colour. The pebbles of the conglomerates consist mostly of Acker and Gommern Quartzite. There was generally a fluvial environment, mostly of braided streams. Concerning plant remains, only a Sigillaria defrancei (SCHRÖDER 1935) has been found; limnic molluscs and gastropods occur in the limestones.

In the upper part of Mansfeld Formation red sandstones predominate at the western and northwestern flanks of the Mansfeld Syncline. This sequence is denoted as Siebigerode Sandstone. Near Wettin the (Lower) Mansfeld Formation is overlain by grey-coloured and coal-bearing deposits, the Wettin Beds. Between Siebigerode Sandstone and Wettin Beds a direct lithostratigraphic contact is not yet known. By reason of the fossil contend DABER (1961) regards both units as different facies of contemporoaneous accumulations.

The S i e b i g e r o d e S a n d s t o n e is characterized by violet colour, high feldspar and kaolinite content, many siliceous stems and a typical cyclic structure with predominantly fining upward cycles in the order of 10 to 15 m. Transport of the clastic material took place in a fluvial environment from southern direction, approximately from the area of the present-day Erzgebirge Mountains with more than 100 km distance of transport. Typical plant remains are Sphenophyllum longifolium and Odontopteris minor. They indicate deeper levels of the uppermost Stephanian.

DOI:https://doi.org/10.2312/zipe.1982.066

The W e t t i n B e d s are subdivided into two facies districts a red one without coal seams and a grey one with coal seams. After KAMPE and REMY (1962) all plants found indicate a higher Stephanian age. The facies without seams consists of red quartz sandstones and subordinately of siltstone; there are no conglomerates and tuffs, and the sandstones do not contain feldspar or kaolinite. The coal-bearing facies starts with a limestone horizon which contains Anthracosia, consists then of several sandstone-mudstone-coal-cycles and ends with the Muschelschiefer horizon (mudstone with shells). In the marginal regions of the basin there was a fluvial environment, and in the centre of it paludal environment prevailed. In the uppermost Stephanian subsequent volcanism starts with the andesites 1 and 2.

4.5. Halle Formation

In the area of the lithotectonic profile (Annex 22) the Permian sedimentation does not start everywhere at the same time. The oldest deposits - the Halle Formation - can be found in the Halle-Wittenberg Block, the northern part of the northeastern Saale Depression. After REMY and KAMPE (1961) the following flora is typical of this formation: Callipterides of the nicklesi-flabellifera group, Sphenopterides of the germanica-oblongifolia group, Odondopteris lingulata, O. osmundaeformis, Ernestiodendron filiciforme. Therewith the boundary between the Stephanian and Autunian 1 is fixed paleobotanically. Lithostratigraphically the Halle Formation is subdivided by volcanic intercalations:

Upper Halle porphyries	
Upper sediments and pyroclastic rocks	40 - 120 m
Alternation of sandstone, arkose, mudstone with lapilli and crystal tuffs and tuffites	
Andesite 4	
Medium sediments and pyroclastic rocks	10 - 150 m
Bituminous, dark mudstones and red mudstones with tuff layers	
Andesite 3	
Lower sediments and pyroclastic rocks	50 - 60 m
Green-grey sand- and mudstones with combustible shales, tuff and limestone layers	
Conglomerate zone	30 - 120 m
Fine- to medium-grained conglomerates with mainly quartzite and siliceous shale pebbles, single sand- and siltstones with feldspar	
Basal mud- and siltstones	0 - 120 m
Dark mud- and siltstones with single sandstone beds.	

The patterns of sedimentation have been altered as compared with the Silesian by volcano-tectonic processes. The Halle Formation is deposited in a closed basin (Fig. 2a). The environment in this heterogenous area of sedimentation is very variable (fans of local debris, fluvial accumulations, sedimentation in lakes and swamps) and it is influenced to a high degree by volcanic processes.

DOI:https://doi.org/10.2312/zipe.1982.066

4.6. Sennewitz Formation and Hornburg Formation

In the upper part of the Autunian two small basins came into existence separated by a swell which was probably connected with the ascending intrusion of the Lower Halle Porphyry. The relation of age between the two basins is not yet well understood. Some authors consides the Sennewitz Formation as the younger one. The representation in the profile follows the interpretation by SCHWAB (1977) who suggests contemporaneous basins.

The contemporaneity of both formations is supported by their fossil content. The flora of the Sennewitz Formation has a character of upper Autunian. In the Hornburg Formation, the biostratigraphic position is confirmed by the tetrapod footprints Amphisauropus cf. imminutus, Gilmoreichnus sp. and Dromopus lacertoides which, after HAUBOLD (1973), are typical of the uppermost Autunian.

The S e n n e w i t z F o r m a t i o n consists of red-brown and grey siltstones and fine sandstones with embedments of rhyolite tuffs, tuffites, arkoses, combustible shales and limestones seams. Fine conglomérates and coarse sandstones occur near the margin of the basin. The Sennewitz Formation is interpreted as the filling of a restricted volcanotectonic depression which was connected with the fade-out of the Autunian volcanism (SCHWAB 1977).

In the H o r n b u r g F o r m a t i o n conglomerates, sandstones, siltstones and mudstones is built up of two cycles of red beds. In the central part of the basin the lower cycle splits into two or three subcycles. The conglomerates predominantly contain porphyritic (andesitic) pebbles; the sandstones are in contrary to the Silesian poor in mica. In the cycles there is to be noticed a horizontal change of the environment, too: conglomerates as piedmont fans, in the direction to the basin grading into fluvial sands or sands deposited by sheet floods. The youngest beds of the Hornburg Formation, the Blätterton, consist of red, finely laminated claystones which are typical deposits of a desert lake or playa. Below the claystone there occurs a fine-grained sandstone of presumably eolian origin (FALK et al. 1979).

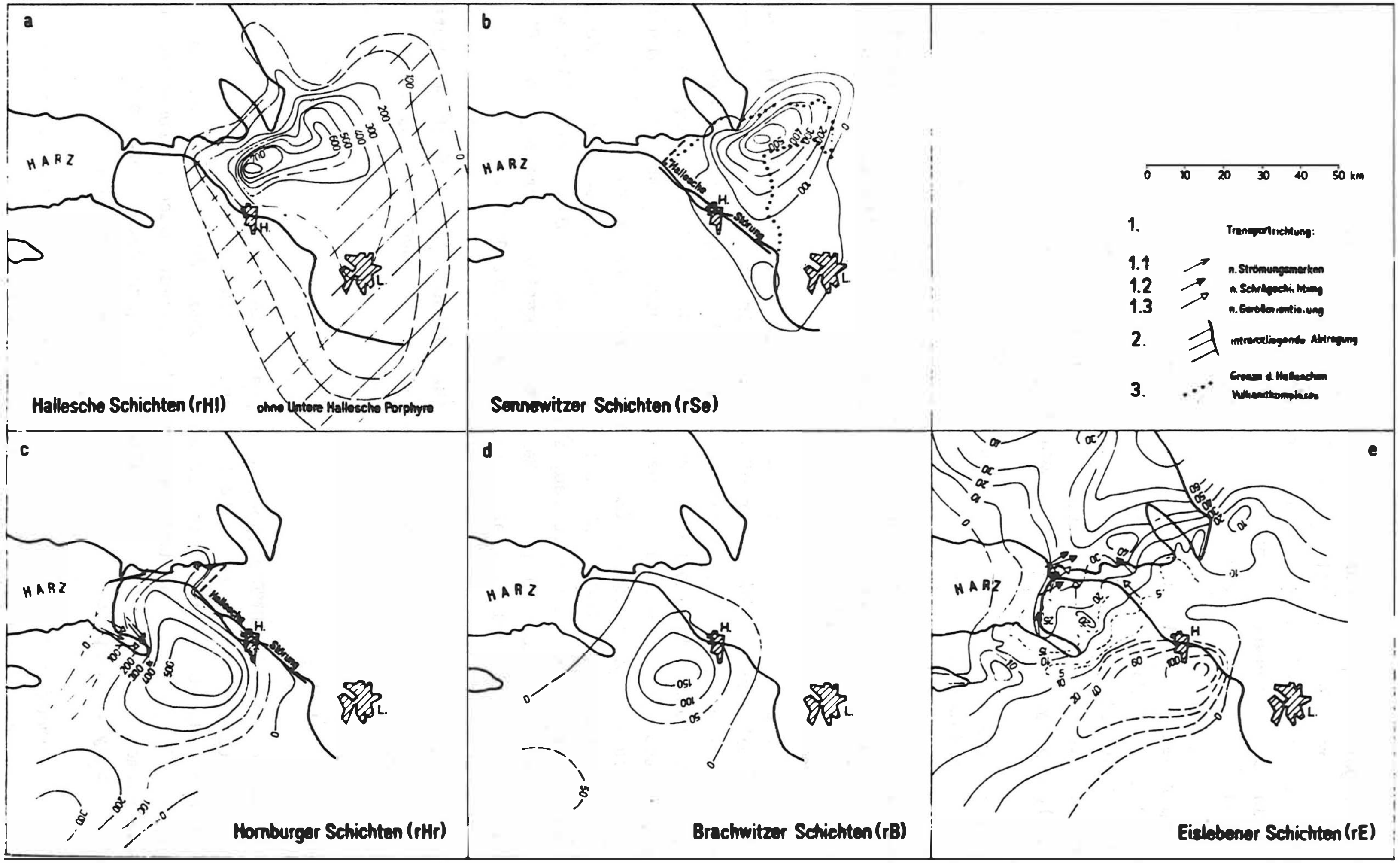
Volcanic processes do not play any role in the sedimentary basin of the Hornburg Formation, but the Halle Fault Line must have been active tectonically at that time.

4.7. Brachwitz Formation

The Brachwitz Formation (KUNERT 1966) accumulated in a restricted basin which had a connection with the southwestern Saale Depression. Tectonic and volcano-tectonic processes involved a sedimentation of clastic material from the margin areas into the basin (FALK et al. 1980). Regarding the occurrence in a restricted intramontane basin the Brachwitz Formation can be compared with the Hornburg Formation, according to their pebble spectrum they correspond to the younger Eisleben Formation.

The Brachwitz Formation consists of red sandstones and siltstones. Very typical are bimodal sandstones. At the eastern margin of the basin conglomerates and sedimentary breccias predominate which are connected with an escarpment of Halle porphyries along the Halle Fault Line.

DOI:https://doi.org/10.2312/zipe.1982.066



DOI:https://doi.org/10.2312/zipe.1982.066

4.8. Eisleben Formation

The Eisleben Formation (SCHIEMENZ 1953) was deposited under different tectonic conditions than those deposits described before. It forms the southern marginal facies of the Saxonian of the Central European Depression and reflects the transition to the platform cover (FALK et al. 1980). The sedimentation area of the Central European Depression in the Upper Saxonian extends beyond the area of the northeastern Saale Depression into SW direction. On the other hand, the erosional debris of the Variscan morphogene was transported northward (cf. also ELLENBERG et al. 1976). Thickness pattern of the Eisleben Formation is shown on Figure 2e.

Lithologically the Eisleben Formation forms a macrocycle with basal psephites and superincumbent fine clastic sediments (formerly "Porphyrkonglomerat" and "Sandsteinschiefer" horizons). In direction foward the margin of the basin the portion of conglomerates increase to an only-conglomeratic facies with 10 to 5 m thickness. In direction to the central parts of the basin the basal conglomerate disappears almost completely, only along the Eichsfeld-Altmark Ridge it extends further in northern direction. The basis of the Eisleben Formation runs diagonally through the time. The material was generally supplied from southern direction, in marginal parts there are occuring local deviations of the transport direction (Fig. 2e after LUDWIG 1977).

5. Conclusions

The sedimentation in the northeastern Saale Depression in the Carboniferous and Lower Permian developed in several stages from forming the Saale Depression as an independent structural unit to the platform cover.

After forming single sedimentary basins (Westphalian) the Stephanian stage was characterized by the development of a large intramontane trough. In the uppermost Stephanian the subsequent volcanism started. The Lower Permian shows a differentiation into individual basins which were partly influenced by volcanic processes (SCHWAB 1977). Only the uppermost Rotliegendes (Saxonian II) belongs to the posttectonic period like the platform cover.

Tectonic movements of the late-Variscan period were predominantly uplift and subsidence along faults. The classic area of Saalian movements therefore is not characterized by folding, but by discordances according to different vertical movements. So the Eisleben Formation covers discordantly the Brachwitz, Hornburg, Halle, and Mansfeld Formation. The angle between younger and older deposits is very small (0 to 5°).

Fig. 2. Isopach maps of Lower Permian formations in the northeastern Saale Depression (cf. FALK et al. 1979), a - Halle Formation (rHl), b - Sennewitz Formation (rSe), c - Hornburg Formation (rHr), d - Brachwitz Formation (rBr), e - Eisleben Formation (rE).
Explanations: 1 - direction of transport, 1.1 flute casts, 1.2 cross bedding, 1.3 pebble orientation; 2 - intra-Rotliegend erosion; 3 - boundary of the Halle volcanic rock complex

DOI:https://doi.org/10.2312/zipe.1982.066

References

BEYSCHLAG, F.; FRITSCH, K. VON: Das junge Steinkohlengebirge in der Provinz Sachsen und den angrenzenden Gebieten.
Abh. Preuß. Geol. Landesanst., Berlin N.F. 10 (1899)

BRAUSE, H.: Variszischer Bau und "Mitteldeutsche Kristallinzone".
Geologie, Berlin 19 (1970) 3, p. 281-292

DABER, R.: ru-Pflanzenfunde in der Harzumrandung.
Geologie, Berlin 10 (1961), p. 353-358

DABER, R.: Paläobotanische Hinweise auf eine paralisch beeinflußte Oberkarbon-Senke im tieferen Untergrund Nordostdeutschlands.
Geologie, Berlin 12 (1963) 6, p. 683-699

ELLENBERG, J.; FALK, F.; GRUMBT, E.; LÜTZNER, H.; LUDWIG, A.O.: Sedimentation des höheren Unterperms der Flechtinger Scholle.
Z. geol. Wiss., Berlin 4 (1976) 5, p. 705-737

FALK, F.; ELLENBERG, J.; GRUMBT, E.; LÜTZNER, H.; LUDWIG, A.O.: Zur Sedimentation des Rotliegenden im Nordteil der Saale-Senke.
Hall. Jb. Geowiss., Gotha/Leipzig 4 (1979), p. 3-22 (Teil 1), 5 (1980), p. 77-88 (Teil 2)

FRITSCH, K. VON: Das Saaletal zwischen Wettin und Könnern.
Z. f. Naturwiss., Halle 61 (1888), p. 114-142

GOTHAN, W.; SCHRIEL, W.: Die Grillenberger Schichten des Unterharzes, ein Äquivalent der oberen Saarbrücker Flamm-Kohlenschichten.
Jb. Preuß. Geol. Landesanst., Berlin 48 (1928), p. 366-375

GRUMBT, E.; LÜTZNER, H.; ELLENBERG, J.; FALK, F.; LUDWIG, A.O.; SCHWAB, M.: Zur Beziehung zwischen Innen- und Außenmolassen der Varisziden im Gebiet der DDR. (im Druck)

HÄNEL, M.: Fazies, Sedimentation und Paläogeographie der Grillenberger und Mansfelder Schichten am SE-Rand des Harzes.
Hall. Jb. Mitteldt. Erdgesch., Leipzig 9 (1969), p. 93-109

HAUBOLD, H.: Die Tetrapodenfährten aus dem Perm Europas.
Freiberger Forsch.-H., Berlin C 285 (1973), p. 5-55

KAHLERT, E.: Schieferton des Oberkarbons in einer Braunkohlenbohrung bei Roitzsch.
Z. angew. Geol., Berlin 13 (1967) 2, p. 105

KAMPE, A.; REMY, W.: Ausbildung und Abgrenzung des Stephanian in der Halleschen Mulde.
Mber. Deutsch. Akad. Wiss., Berlin 4 (1962), p. 54-68

KNOTH, W.; SCHWAB, M.: Abgrenzung und geologischer Bau der Halle--Wittenberger Scholle.
Geologie, Berlin 21 (1972) 10, p. 1153-1172

KUNERT, R.: Das Alter der Hornburger Schichten.
Geologie, Berlin 15 (1966), p. 1222-1224

LASPEYRES, H.: Geognostische Darstellung des Steinkohlengebirges und Rotliegenden in der Gegend nördlich Halle a.d. Saale.
Abh. geol. Spez. Karte Preußen, Berlin 1 (1875), p. 261-603

LUDWIG, A.: O granitze orogennovo (morfogennovo) i platformennovo etapov v variszidach Srednei Evropi.
Orogennii etap rasvitija variszid Srednei Evropi i SSSR, Moskva 1977, p. 39-51; russ.

LÜTZNER, H.: Explanatory notes to the lithotectonic molasse profile of the Saale Depression, southwestern part (Thuringian Forest, Upper Carboniferous - Permian).
Veröff. Zentralinst. Phys. Erde, Potsdam 66 (1982), p. 237-254

LÜTZNER, H.; ELLENBERG, J.; FALK, F.: Sedimentology and basin development of Rotliegend deposits in the Saale trough.
Proceed. Symp. Central Europ. Permian, Warszawa (in press)

DOI:https://doi.org/10.2312/zipe.1982.066

REMY, W.; KAMPE, A.: Ausbildung und Abgrenzung des Autunien in der Halleschen Mulde. Mber. Deutsch. Akad. Wiss., Berlin 3 (1961), p. 394-408

SCHILMENZ, S.: Schotteranalyse des Porphyrkonglomerates im obersten Rotliegenden des östlichen Harzvorlandes. Hall. Jb. mitteldt. Erdgesch., Halle 2 (1953), p. 3-27

SCHRÖDER, E.: Sedimentation und Tektonik im Jungpaläozoikum am östlichen Harzrande und in den Nachbargebieten. Jb. preuß. geol. Landes-Anst., Berlin 55 (1935), p. 168-197

SCHWAB, M.: Zur paläotektonischen Entwicklung des Halleschen Permosilesgebietes (Nordöstlicher Saaletrog). Hall. Jb. Geowiss., Gotha/Leipzig 1 (1977), p. 69-84

STEINER, W.; BROSIN, P.: Siles und Rotliegendes nördlich des Thüringer Waldes. In: HOPPE, W.; SEIDEL, G.: Geologie von Thüringen, p. 449-515. Gotha/Leipzig: Haack 1974

VELTHEIM, W.W. VON: Geognostische Betrachtung der alten Sandsteinformation am Harz und in den nördlich und östlich davon gelgenen Landstrichen. Bearb. von H. FREIDANK. Jb. Hall. Verbd., 18 (1940), p. 15-292

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Explanatory Notes to the Lithotectonic Molasse Profile of the Intra-Sudetic Basin, Polish Part (Sudety Mts., Carboniferous - Permian)
(Comment to Annex 23)

by

WOJCIECH NEMEC[1], SZCZEPAN J. PORĘBSKI[2], ANDRZEJ K. TEISSEYRE[1]

1. Introduction

During and after the Variscan orogenic movements, the northern periphery of the Bohemian Massif underwent strong tensional break-up which resulted in the origin of a belt of closely seated, small intramontane basins. The Intra-Sudetic Basin is the oldest and largest of the superimposed-type basins. It forms now a northwest--southeast trending synclinorial feature which is built-up of a thick sedimentary succession of Early Carboniferous to Late Cretaceous age. The succession exhibits few stratigraphic gaps of which the largest spans the Late Triassic and Early Cretaceous time period.

The Carboniferous - Permian segment of the Intra-Sudetic Variscan molasse has a maximum stratigraphic thickness of about 11 000 m and is dominated by coarse continental siliciclastics with subordinate volcanics. The basin infill is bounded against the uplifted surrounding tectonic units by prominent faults, some of which are believed to have been already active during the Early Carboniferous (A.K. TEISSEYRE 1968). The largest of tne surrounding units, which also partly underlie the basin itself, are: the Góry Sowie Gneissic Block, the Świebodzice Depression, the Góry Bardzkie (Mts.) Region, the Variscan range of the Góry Kaczawskie (Mts.), and the Rudawy Janowickie range which forms the eastern metamorphic shield of the Karkonosze granitic pluton (Fig. 1).

The basin-fill succession shows relatively weak tectonic deformation. The particular rock units occur as narrow belts running almost parallel to the basin margins and dipping gently towards its centre. Stronger deformations (overturning, folds) appear

[1] University of Wrocław, Institute of Geological Sci.; Poland, 50-205 Wrocław, ul. Cybulskiego 30

[2] Polish Academy of Sciences, Institute of Geological Sci.; Poland, 31-002 Kraków, ul. Senacka 3

DOI:https://doi.org/10.2312/zipe.1982.066

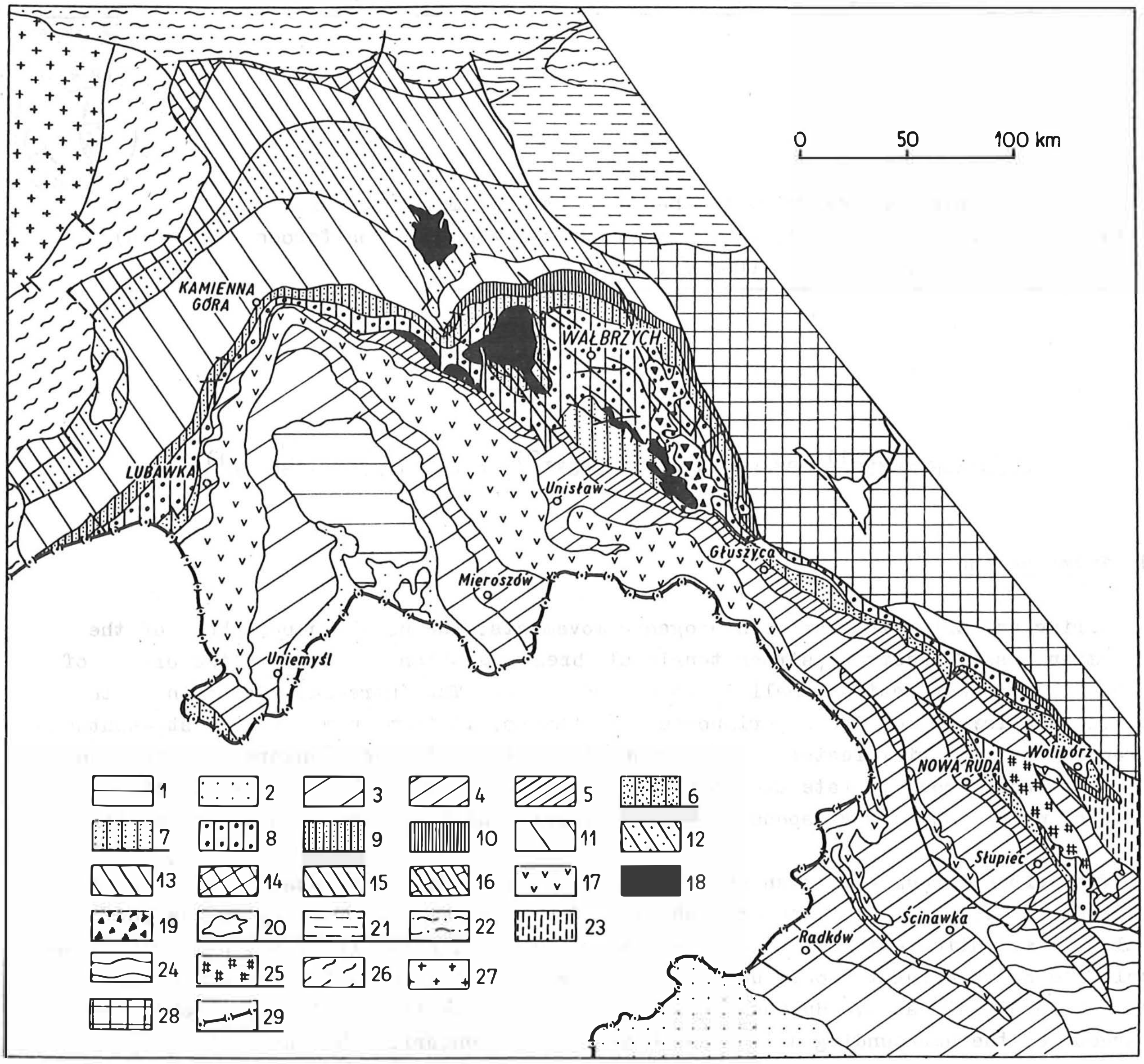


Fig. 1. Geological map of the Intra-Sudetic Basin (partly modified from AUGUSTYNIAK and GROCHOLSKI 1968)

1...20 - sedimentary and volcanic rocks

1 - Upper Cretaceous, 2 - Lower Triassic, 3...5 - Lower Permian, 3 - Radków Formation, 4 - Słupiec Formation, 5 - Krajanów Formation, 6...10 - Upper Carboniferous, 6 - Ludwikowice Formation, 7 - Glinik Formation, 8 - Žacléř Formation, 9 - Biały Kamień Formation, 10 - Wałbrzych Formation, 11...16 - Lower Carboniferous, 11 - Szczawno Formation, 12 - Lubomin Formation, 13 - Bogaczowice Formation, 14 - Figlów Formation, 15 - Sady Górne Formation, 16 - Ciechanowice Formation, 17 - Lower Permian volcanics (undifferentiated), 18 - Westphalian B/C and Stephanian rhyodacites, 19 - Westphalian-Stephanian rhyolitic volcaniclastics and intrusions

21...28 - surrounding units

21 - Świebodzice Depression, 22 - Góry Kaczawskie range, 23 - Góry Bardzkie range, 24 - Kłodzko metamorphicum, 25 - gabbros and diabases of Kłodzko arch, 26 - Rudawy Janowickie range, 27 - Karkonosze granitic pluton, 28 - Sowie Góry Block, 29 - state boundary

DOI:https://doi.org/10.2312/zipe.1982.066

mainly near large intrusive bodies and close to the basin marginal faults. The entire basin-fill is cut by numerous faults, what results in a graben-type tectonics of some parts of the basin. The generally brachysynclinal structure of the Intra-Sudetic Basin is considered to have been finally shaped by the Late Cretaceous and Tertiary tectonic movements.

The type profile (Annex 23), designed here to show the principal features of the Intra-Sudetic molasse, is based on the data derived from the Polish part of the basin, and the description of the profile is concerned primarily with this part of the unit. Though most of the lithostratigraphic units of the formation rank exhibit a basin-wide extent, it was impossible to include within a single vertical profile all of the lateral changes observed in particular rock units. The type profile has therefore been generalized and restricted mainly to the data derived from three major areas which, either for industrial reasons or better exposure, have been studied most extensively. These are the northeastern part of the Intra-Sudetic Basin in the case of the Lower Carboniferous rocks, the Wałbrzych Basin in the case of the Upper Carboniferous strata and the Nowa Ruda Basin in the case of the Permian strata.

2. Stratigraphy

In contrast to the Upper Carboniferous strata, the bulk of the Lower Carboniferous and Permian deposits under consideration contains only rare and scattered fossil remnants which, as a rule, are of rather low stratigraphic value. Therefore, the overall chronostratigraphy is based here mainly on the general spatial relationships of the non-fossiliferous rocks to those which are paleontologically dated as well as on some other lithological criteria commonly employed in such circumstances (cf. H. TEISSEYRE 1957).

The oldest Lower Carboniferous deposits contain clasts of lithified sedimentary rocks derived from the east, i.e., from the Świebodzice Depression. Thus, the oldest Intra-Sudetic Carboniferous is evidently younger than the Upper Devonian - ? lower Tournaisian Świebodzice succession (H. TEISSEYRE 1960). The oldest paleontologically dated Lower Carboniferous deposits (i.e. the Szczawno Formation) are related to the late Visean marine ingression which entered the Intra-Sudetic Basin from the east and left the fauna (goniatites, brachiopods, molluscs, etc.) indicative of the Go_{α} to Go_{β} subzones (ŻAKOWA 1963).

The biostratigraphic subdivision of the Upper Carboniferous deposits is primarily based on the rich macrofloral and paleontological evidence (for review see GÓRECKA 1969; GROCHOLSKI 1974). The lower Permian rocks, in turn, contain only few index fossils (mostly plants). Overlying the Rotliegend Radków and Mieroszów fanglomerates (i.e. the Radków Formation in the type-profile, Annex 24) are coarse siliciclastics interlayered with thin, impersistent horizons of limestones and dolomites. These deposits (the Chełmsko Śląskie Beds of AUGUSTYNIAK and GROCHOLSKI 1968) have been commonly thought to be of Zechstein age (e.g. DZIEDZIC 1961; AUGUSTYNIAK and GROCHOLSKI 1968; LORENC and MROCZKOWSKI 1978). However, ŚLIWIŃSKI (in press) has recently shown that these carbonates represent fossil caliche and related non-marine calcareous horizons which periodically developed at the top of the coarse Rotliegendes succession, and, therefore, he has included these deposits into the Rotliegend Radków Formation.

DOI:https://doi.org/10.2312/zipe.1982.066

The general lithostratigraphy of the Intra-Sudetic Carboniferous and Permian seems to be fairly well established though few lithostratigraphic units do meet the requirements of the formal classification. Since the end of the 19-th century, when geological investigations began in the Intra-Sudetic Basin, various names have been adopted to the same rock units at different sites. Most of the lithostratigraphic names used in the type profile have a long tradition of the common usage; some are new (subdivision of the Lower Permian is adopted from Nemec, in press). The correlation of the Upper Carboniferous and Permian deposits between the Polish and Bohemian parts of the unit (Annex 23, 24) is given in Table 1. The term "formation" instead of "beds" is commonly used throughout the profile. However, the formal description of the lithostratigraphic units are not included here because neither is possible nor necessary in this supplementary text to enter into such detailed account of sedimentological and other characteristics of the deposits in question.

STAGE		POLISH PART	BOHEMIAN PART
Thuringian		?	Bohuslavice Fm
Saxonian		Radków Fm	Trutnov Fm
Autunian		Słupiec Fm	Broumov Fm
		Krajanów Fm	Chvaleč Fm
Stephanian	C	Ludwikowice Fm	
	B		Odolov Fm
	A	Glinik Fm	
Westphalian	D		
	C		Žacléř Fm
	B	Žacléř Fm	
	A		
Namurian	C	Biały Kamień Fm	
	B	Wałbrzych Fm	
	A	Passage Beds	
Upper Visean		Szczawno Fm	Szczawno Fm

Table 1. Lithostratigraphic nomenclature of the Upper Carboniferous and Permian deposits in the Polish and Bohemian parts of the Intra-Sudetic Basin

3. Lithology and sedimentary environments

Lower Carboniferous

The Lower Carboniferous of the Intra-Sudetic Basin is typified by coarse breccias, conglomerates and sandstones with minor amounts of finer-grade sediments. Its stratigraphic thickness attains 4500 - 7000 m. In the northern part of the basin, the oldest Carboniferous deposits are represented in the east by the Sady Górne Formation which westwards is replaced by the Figlów and Ciechanowice Formations. These formations adjoin

DOI:https://doi.org/10.2312/zipe.1982.066

the metamorphic terrains of the Rudawy Janowickie and Góry Kaczawskie Ranges mostly along the tectonic contacts (A.K. THEISSEYRE 1968, 1975). The above-mentioned part of the molasse succession is conformably overlain by polymict coarse conglomerates, sandstones and mudstones of the Stare Bogaczowice and Lubomin Formations.

According to A.K. TEISSEYRE (1968, 1971, 1975), the above deposits were laid down in a strongly subsiding, approximately west--east trending intramontane basin. A dozen or so alluvial fans have been recognized as developed along the basin margins flanked by syndepositionally active faults. The alluvial fans periodically prograded onto and interfingered with the basin-floor alluvium constructed by braided and low sinuosity rivers. This central, contributive river system drained the basin generally towards the east.

The Lubomin Formation grades upwards and also partly laterally into the Szczawno Formation,which contains marine fossils of late Visean age. The thickness of this latter formation ranges from about 400 m north of Wałbrzych to 3000 m in the vicinity of Kamienna Góra. To the east, the Szczawno Formation consists mainly of flysch-like, sandstone/mudstone interbeds interlayered with conglomerates, pebbly mudstones and clayey sediments containing goniatite remains among the others. Towards the west, coarser clastics with local rooty layers prevail. These deposits are thought to have originated due to the progradation of coarse-grained continental facies over some deltaic units and relatively deep-water basinal facies (H. TEISSEYRE 1958, 1960).

In the Wałbrzych Basin, the Szczawno Formation grades upwards directly into the continental Namurian deposits of the Wałbrzych Formation (H. TEISSEYRE 1961; DZIEDZIC 1965; GROCHOLSKI 1960, 1974). In the western part of the Intra-Sudetic Basin, the Szczawno Formation is disconformably overlain by the Westphalian deposits.

Upper Carboniferous

The oldest and paleontologically dated Upper Carboniferous deposits are represented by the Wałbrzych Formation which occurs within two separate sub-basins close to the northeastern border of the Intra-Sudetic Basin. These are the Wałbrzych Basin and the Wolibórz Basin, in which the thickness of the formation attains 300 m and 250 m, respectively. The Wałbrzych Formation consits mainly of sandstones and mudstones with numerous plant remnants, interlayered with workable coal seams; subordinate conglomerates are concentrated mainly towards the base of the formation. Within the Wałbrzych Basin, a decrease in the amount of coarse clastics is observed towards the southeast and the extent of the successive coal seams increases in this direction.

Between the Wałbrzych Formation and the overlying Biały Kamień Formation[3)] a stratigraphic gap, comprising much of the Namurian B, was inferred by earlier authors (e.g. BERG 1925; KRAWCZYŃSKA-GROCHOLSKA 1966). However, this gap has not been confirmed by more recent palynological data (GÓRECKA 1969). The lower portion of the Biały Kamień Formation is composed mainly of coarse conglomerates and sandstones, whilst in its upper portion mudstone interbeds and thin coal-seams appear. In the Wolibórz Basin, a gabbroic waste is considered to represent a possible time equivalent of the Biały Kamień Formation (e.g. OBERC 1957; DON 1961; AUGUSTYNIAK and GROCHOLSKI 1968).

DOI:https://doi.org/10.2312/zipe.1982.066

The Biały Kamień Formation passes upwards into the Žacleř Formation which in part rests also upon the older basement. The Žacleř Formation extents throughout the Intra-Sudetic Basin and its thickness varies considerably, attaining the maximum values in three regions: in the vicinity of Lubawka (up to 750 m), in the Wałbrzych Basin (up to 900 m) and in the Nowa Ruda Basin (up to 400 m). The formation consists mainly of pebbly sandstones, sandstones and mudstones with numerous workable coal-seams.

The Žacleř Formation is overlain by the Glinik Formation which consists of pinkish-grey conglomerates and sandstones with frequent intercalations of red mudstone. These sediments, in turn, are partly covered and laterally replaced by the redbed deposits of the Ludwikowice Formation of late Stephanian age. The Ludwikowice Formation is composed mainly of pebbly sandstones and sandstones, which are organized into a fining-upward megasequence capped with a few metres thick mudrock unit known as the Lower Anthracosia Shale. This topmost horizon of the Ludwikowice Formation consists of medium-grained, feldspathic arenites interspersed with marly mudstone and dark claystone which contains locally thin intercalations of bituminous limestone. The claystones contain numerous fresh-water pelecypods (Anthracosia prolifera), fine plant detritus and also few thin coal seams. The Ludwikowice Formation is best developed in the Nowa Ruda district and wedges out northwesterly in the vincinity of Głuszyca, near Wałbrzych.

The coal-bearing formations of the Intra-Sudetic Upper Carboniferous originated mainly in a fluvial environment dominated by mixed-load streams of high to low sinuosity, which migrated over the extensive floodplain areas with repeating plant accumulation. The formations rich in coarse clastics are probably related to a broad braided alluvial-fan and floodbasin system with locally developed temporary lakes which trapped the finest material. The conglomerates are enriched in clasts of resistant rocks (quartzites, lydites, quartz), suggesting either the second-cycle detritus or relatively distant source areas. During the latest Carboniferous, a gradual change from warm humid to warm semiarid climatic conditions took place; this is indicated by the cessation of plant accumulation and by the deposition of redbeds.

Permian

In the southeastern and central parts of the Intra-Sudetic Basin the Rotliegend deposits rest upon the Ludwikowice Formation whilst to the northwest they show an overlapping relationship to the Glinik and Žacleř Formations[4]. NEMEC (1979a, and in press) has recently distinguished three formations within the Lower Permian of the Intra-Sudetic Basin. The lowest is the Krajanów Formation which comprises the following units distinguished by earlier authors: the Lydite Conglomerate (DATHE 1904), the Quartzite Conglomerate, the "sandstone equivalent" of the Quartzite Conglomerate, the Unisław Conglomerate, the Czarny Bór Conglomerate (DZIEDZIC 1961), the "red shales" (DON 1961) and the Upper Anthracosia Shale (PETRASCHECK 1936) as the topmost unit. The Słupiec Formation comprises the Building Sandstone and the Walchia Shale of DATHE (1904) and the "sandy shales" of DZIEDZIC (1961). Both the Krajanów Formation and the Słupiec Formation represent two successive fining-upward megasequences, comparable in scale and appearance to that represented by the above described Ludwikowice Formation. The Radków Formation contains the Radków and Mieroszów Fanglomerates of DZIEDZIC (1961), and also the Chełmsko Śląskie Beds of AUGUSTYNIAK and GROCHOLSKI (1968).

DOI:https://doi.org/10.2312/zipe.1982.066

The coarse facies of the Lower Permian deposits consists mainly of red conglomerates and quartzose/feldspathic arenites. The fine facies are represented by red siltstones and mudstones with subordinate dolomitic limestones and dark claystones containing the remains of fresh-water pelecypods, fish, plants (Walchia piniformis, Callipteris conferta), and coprolites; reptilian footprints are locally found. The Intra-Sudetic Lower Permian succession is thought to have been formed mostly through the action of ephemeral and braided-stream processes operating on the surfaces of large alluvial fans which, in their distal reaches, merged into an extensive floodbasin occupied by temporal lakes (DZIEDZIC 1961; NEMEC 1979a).

4. Igneous activity

The earliest manifestations of the volcanic activity in the Intra-Sudetic Basin are represented by the rhyolitic pisolite tuffs, which occur as thin interbeds within the coarse clastics of the Sady Górne Formation (A.K. TEISSEYRE 1966). These volcanic events are considered as having been connected with the earliest stages of the tectonic opening of the Intra-Sudetic Basin.

The next phase of an extensive volcanic activity began in the Westphalian A and was restricted mostly to the Wałbrzych Basin, where it lasted till the end of the Stephanian (GROCHOLSKI 1965; NEMEC 1979b). According to the most recent data and interpretations by NOWAKOWSKI (1978)[5] and NEMEC (1979b), the Late Carboniferous igneous activity was manifested in this region by the rhyolitic subaerial volcanism associated with shallow intrusions, and by the rhyodacitic subvolcanism accompanied with incidental effusions. The poly-orifice rhyolitic volcanism was primarily due to phreatic eruptions which produced a linear field of maar-volcanoes running along the Struga fault zone, i.e., the eastern border of the Wałbrzych Basin. The maars were formed diachronously, presumably in response to the gradual development of the Struga fault-zone in the southward direction and to the respective migration of the phreatic eruption centres. The rhyodacitic subvolcanism took place in two stages. In the first phase (Westphalian B/C transition), the spectacular Chełmiec laccolite and the lava sheet of Stary Lesieniec and Czarny Bór originated, whilst in the next phase (latest Stephanian) a dense network of complexely interrelated sills and dykes was formed throughout the Wałbrzych Basin.

These Late Carboniferous volcanic events are considered to have been related to the tensional disintegration and block-type splitting of the rigid crystalline basement of the basin (GROCHOLSKI 1965; NEMEC 1979b).

The third phase of strong volcanic activity took place during the Early Permian and its products are present throughout the entire Intra-Sudetic Basin. Three major effusive/eruptive cycles have been recognized in this phase of volcanic activity (KOZŁOWSKI 1958, 1963; NOWAKOWSKI 1968). Each cycle is interpreted by the latter authors as representing a sequence composed of trachybasalts ("melaphyres") overlain by rhyolites ("porphyries") and/or their tuffs and ignimbrites, with subordinate latites. These cycles have been, however, recently reinterpreted by DZIEDZIC (in prep.) as representing rock sequences with vertical trends just opposite to that mentioned above.

DOI:https://doi.org/10.2312/zipe.1982.066

5. Cyclic sedimentation

Repetitive patterns of sedimentation on a various scale exist in the Intra-Sudetic Molasse succession, and among them fining upwerd cycles are most common. A few tens of hierarchically organized fining-up cyclothems have been recognized within the Lower Carboniferous segment of the succession (A.K. TEISSEYRE 1968, 1975). The major cyclothems (a few tens of metres up to 500 m) form mapable bodies which can be traced along their strike almost throughout the basin and consist of a number of small-scale cycles showing greater lateral variability. These major cyclothems are juxtaposed as three fining upwards megacyclothems which correspond to three Lower Carboniferous formations destinguished above. Each of the major cyclothems typically begins with coarse conglomerates and sandstones (debris-flow and/or stream-channel deposits) and is capped with sandstone/mudstone alternations (floodplain and related deposits). A more pronounced cyclicity is seen within the basin-floor deposits and in the zone of their intertonguing with the marginal alluvial-fan facies, while it is less distinct within the most proximal alluvial-fan deposits.

In general, a fairly similar vertical organization of sedimentary facies is also present in the remaining part of the Intra-Sudetic molasse succession.

The origin of the small-scale, fining-up cycles may be explained in terms of fluvial autocyclic mechanism (e.g., lateral shifting of floodplain environment over channel-phase deposits due to the channel migration), although some of these cycles could be also distal representatives of some basin-wide retrogradational phases controlled by extrabasinal factors. This is because the latter factors exerted the dominant control on the formation of the major cyclothems, as it is indicated by their coarseness, stacked nature and the basin-wide extent (A.K. TEISSEYRE 1975). The major cyclothems originated probably due to periodic uplifts of the source areas, leading to the development of steep fault scarps along the basin margins. As the result of an initial downfaulting of the basin floor, an increase in the erosion rate occurred in the uplifted source terrains and the coarse proximal facies prograded rapidly onto the finer floodbasin facies. This was followed by a fairly slow sourceward migration of facies belt in effect of the declining sediment supply, presumably due to the scarp retreat and/or lowering of the source-area relief. Similar reasoning, assuming a repetitive faulting and downwarping of the basin margins due to crustal extension, has been recently proposed by NEMEC (1979a) for the explanation of four, stacked fining-upward megasequences representing the Stephanian/Lower Permian portion of the Intra-Sudetic molasse succession. DZIEDZIC (1961), however, has attributed their origin primarily to the periodic climatic changes (comp. also PETRASCHECK 1936).

Some of the Lower Carboniferous cyclic sequences show an upward increase in the grain size (A.K. TEISSEYRE 1975). They usually start with thin coal-seams overlain by turbidite-like, graded sandstone/siltstone couplets, and are capped with channel-phase conglomerates and sandstones. These coarsening-up sequences are explained in terms of the gradual filling of temporarily ponded parts of the floodbasin swamps by the crevasse-splay deposits and/or prograding distal-fan lobes. Some of the major cyclothems, either fining- or coarsening-up, might have originated due to periodic, transversal or longitudinal tilting of the basin floor; they may reflect as well a

DOI:https://doi.org/10.2312/zipe.1982.066

temporal damming of the basin by transversally growing alluvial fans. Some minor cycles might have been also controlled by climatic fluctuations, though such control remains difficult to prove.

The higher-order pensymmetric coarsening upward sequences (e.g., the Kocików Member, the Wałbrzych Formation) probably reflect large progradational phases of the entire depositional systems in a response to the regional base-level fall due to relative uplift of the highland source terrains.

6. Summary on the evolution of Intra-Sudetic molasse

The Carboniferous - Permian portion of the Intra-Sudetic sedimentary succession exhibits the whole set of the features which typify the internal molasse facies developed during the main and late orogenic phases in a basin which was superposed upon older, tectonically deformed and partly metamorphosed rocks.

In the northern fragment of the Intra-Sudetic Basin, the Upper Devonian - ? lower Tournaisian deposits may be expected to underlie the above described molasse succession. These deposits constitute the sedimentary infill of the Świebodzice Depression, the early history of which might have been connected with the earliest stages of the opening of the Intra-Sudetic Basin. During the (?)early Visean, the Świebodzice Depression acted as an important source of clastics for the oldest formations of the Intra-Sudetic Lower Carboniferous.

During the Early Carboniferous, the Intra-Sudetic Basin was the site of piedmont-type accumulation. The high-montainous terrains, surrounding the narrow basin, were fringed by a system of alluvial fans which merged basinwards with a valley-floor alluvium. The fans were characterized by a distributary braided-river system or were dominated by mass-flow processes, reflecting variable catchment settings. The valley floor was occupied by a system of sinuous, meandering or anastomosing streams which drained the basin generally eastwards. In the late Visean, a short-live marine ingression came from the Moravian-Silesian Basin, flooding large parts of the Intra-Sudetic Basin and the adjacent areas. As the lateral facies changes within the Szczawno Formation indicate, the basin plain was filled with turbidite sediments which passed landwards into deltaic bodies which, in turn, were replaced by proximal braided alluvium.

At the transition between the Early and Late Carboniferous, the tectonic movements affecting the basin margins caused the sea to retreat and resulted in differential subsidiary movements of the basin floor. This finally resulted in the formation of isolated basins in which the Upper Carboniferous deposits reached their maximum thicknesses. These deposits originated mainly in a fluvial environments dominated by mixed-load streams of high to low sinuosity, which migrated over floodplain areas covered by swamps and temporal lakes. Such depositional conditions were occasionaly interrupted by the rapid influxes of coarse clastics possibly due to progressive backfaulting of the basin margins and the enlarging of the drainage area.

In the Early Permian, the Intra-Sudetic Basin expanded laterally (primarily to the south and southwest) and associated vertical movements occurred along the basin margins;

DOI:https://doi.org/10.2312/zipe.1982.066

this is evidenced by the large production and rapid spread out of coarse material which "transgressively" overlapped the Upper Carboniferous formations and the older basement. The Early Permian sediments were laid down dominantly through the action of stream processes within an extensive system of sandy alluvial fans which, in their distal reaches, merged with a floodbasin periodically occupied by lakes.

The entire molasse sedimentation was accompanied by repetitive periods of volcanic activity which reached its climax during the latest Carboniferous and Early Permian. The sedimentation took place under conditions of strong differential tectonic movements. The tensional regime of the basin development resulted in the vertical movements along the basin margins and in the lateral expansion of the basin itself. The large-scale cyclic arrangement of the basin fill suggests that these movements occurred in the form of discrete pulses separated by periods of quiescence. The periodic uplift of the source terrains, accompanied by variable rates of basin-floor subsidence, resulted in the rapid paleogeographic changes and the formation of local depocentres and disconformities. This dominant tectonic control on the Intra-Sudetic molasse sedimentation is obvious, though the resultant stratigraphic complexity of the basin fill is probably an effect of a more complex interplay between the aforementioned extrabasinal factors and the autocyclic depositional mechanisms; finally, the climatic fluctuations might have been also an important factor. On the other hand, the fact that the climatic changes had largely acted in concert with major tectonic pulses seems to imply a complex relationship between these two controls of sedimentation too.

Through the most part of its history, the Intra-Sudetic Basin was fed centripetally from five principal source areas. Four of them occur along the present-day margins of the basin and these are: the Rudawy Janowickie, the Góry Kaczawskie (Mts.), the Świebodzice Depression, the Sowie Góry Block. The fifth important source area was the hypothetical "Southern Massif" which is considered to be actually buried under the thick cover of the Upper Paleozoic/Mesozoic rocks in the central part of the Intra-Sudetic Basin. The metamorphic terrains of the Góry Bystrzyckie/Orlickie (Mts.) and the Kłodzko Region are probably the remnants of the "Southern Massif". In addition, the Karkonosze granite and the Carboniferous series supplied the clastics for the Early Permian formations.

Footnotes 3 - 5

3) A. GROCHOLSKI (personal comm., 1980) has recently changed his view and tends to consider the so-called "Biały Kamień Beds" as a basal member of the Žacleř Formation, rather than a separate formation.

4) A. GROCHOLSKI (1974 and personal comm., 1980) tends to consider the "Unisław Conglomerate" of DZIEDZIC (1961) as a lateral equivalent of the Ludwikowice Formation in the northwestern direction.

5) Lecture no. 455 given at the meeting of the Wrocław Division of Polish Geological Society (30th November, 1978) in Wrocław

DOI:https://doi.org/10.2312/zipe.1982.066

References

AUGUSTYNIAK, K.; GROCHOLSKI, A.: Geological structure and outline of the development of the Intra-Sudetic Depression.
Biul. Inst. geol., Warszawa 227 (1968), p. 87-114

BERG, G.: Die Gliederung des Oberkarbons und des Rotliegenden im niederschlesisch-böhmischen Becken.
Jb. preuß. geol. Landesanst., Berlin 46 (1925), p. 68-84

DATHE, E.: Erläuterungen zur Geologischen Karte von Preußen. Lfg. 115, Blatt Rudolfswaldau, Neurode und Wünschelburg.
Berlin: Kgl. preuß. geol. Landesanst. 1904

DON, J.: The Permo-Carboniferous of the Nowa Ruda region, (English summ.).
Zesz. nauk. Uniw. Wrocł., Sér. B6, Wrocław 3 (1961), p. 3-54

DZIEDZIC, K.: Lower Permian of the Intra Sudetic Basin, (English summ.).
Studia geol. pol., Warszawa 6 (1961), 121 p.

DZIEDZIC, K.: Genesis of the Carboniferous troughs in the area of Nowa Ruda, (English summ.).
Kwart. geol., Warszawa 9 (1965), p. 551-564

GÓRECKA, T.: Stratigraphy of the Biały Kamien Beds in the north-western part of the Intra-Sudetic Trough on the ground of palynological researches, (English summ.).
Biul. Inst. geol., Warszawa 230 (1969), p. 167-291

GROCHOLSKI, A.: Notes on geological structure of western region of Wałbrzych, (English summ.).
Kwart. geol., Warszawa 4 (1960), p. 631-646

GROCHOLSKI, A.: The volcanic rocks in the Wałbrzych Basin in the light of structural studies, (English summ.).
Biul. Inst. geol., Warszawa 191 (1965), p. 5-67

GROCHOLSKI, A.: Stratigraphical problems of the Silesian in the Lower Silesian coal Basin, (English summ.).
Kwart. geol., Warszawa 18 (1974), p. 63-79

KOZŁOWSKI, S.: Permian volcanism in Głuszyca-Świerki region, (English summ.).
Rocz. pol. Tow. geol., Kraków 28 (1958), p.5-61

KOZŁOWSKI, S.: Geology of the Permian volcanic rocks in the central part of the Intra-Sudetic Trough, (English summ.).
Prace geol. Kom. Nauk pol. AN, Warszawa 14 (1963), p. 5-84

KRAWCZYŃSKA-GROCHOLSKA, H.: Le Namurian du bassin de Nowa Ruda a la lumiere des etudes palynologiques, (French summ.).
Geologia sudetica, Warszawa 2 (1966), p. 323-399

LORENC, S.; MROCZKOWSKI, J.: The sedimentation and petrography of Zechstein and lowermost Triassic deposits in the vicinity of Kochanów (Intra-Sudetic Trough).
Geologia sudetica, Warszawa 13 (1978), p. 23-35

NEMEC, W.: Słupiec Formation (Permian, Intra-Sudetic Basin); an example of alluvial sandstone-body in intramontane molasse basin. In: Guide to excursions, IX Problem Comitee, Working Group 3.3; Meeting in Pooland, p. 45-51
Kraków: Zakład Nauk geol. pol. AN 1979a

NEMEC, W.: Wulkanizm późnokarboński w niecce wałbrzyskiej (synklinorium śródsudeckiej).
Ph. D. thesis, University of Wrocław, 186 p.
Wrocław: 1979b

NOWAKOWSKI, A.: Permian volcanites of the Suche Mts in the Intrasudetic Basin, (English summ.).
Geologia sudetica, Warszawa 4 (1968), p. 299-408

DOI:https://doi.org/10.2312/zipe.1982.066

OBERC, J.: Stratigraphy and tectonics of the Upper Carboniferous and Lower Permian in the western part of the Bardo Region, (English summ.).
Biul. Inst. geol., Warszawa 123 (1957), 123 p.

PETRASCHECK, W.E.: Sedimentation, Vulkanismus und Kupfererzführung im mittelschlesischen Rotliegend. Festschrift zum 60. Geburtstag von Hans Stille, p. 65-85
Stuttgart: Enke 1936

TEISSEYRE, A.K.: On the Lower Carboniferous volcanism of the Intra-Sudetic Basin: new data about eruptive and pyroclastic rocks, (English summ.).
Acta geol. pol., Warszawa 16 (1966), p. 445-475

TEISSEYRE, A.K.: The Lower Carboniferous of the Intra-Sudetic Basin: a study in sedimentary petrography and basin analysis, (English summ.).
Geologia sudetica, Warszawa 4 (1968), p. 221-298

TEISSEYRE, A.K.: Sedimentology of the Kulm of Ciechanowice and palaeogeography of the lowest Kulm of the Intra-Sudetic Basin, (English summ.)
Geologia sudetica, Warszawa 5 (1971), p. 237-280

TEISSEYRE, A.K.: Sedimentology and palaeogeography of the Kulm alluvial fans in the western Intra-Sudetic Basin (Central Sudetes, SW Poland), (English summ.).
Geologia sudetica, Warszawa 9 (1975), p. 7-135

TEISSEYRE, H.: Niecka śródsudecka. In: Regionalna geologia Polski, p. 137-170
Kraków 1957

TEISSEYRE, H.: Zu dem Problem der Discordanz zwischen den Waldenburger Schichten und dem Kulm in der Innersudetischen Mulde.
Geologie, Berlin 8 (1959), p. 3-12

TEISSEYRE, H.: The Lower Carboniferous of the Middle Sudeten, (English summ.).
Ann. Silesiae 1 (1960), p. 411-452

TEISSEYRE, H.: On the problem of unconformity between the Lower and Upper Carboniferous in the Middle Sudetes.
Bull. Acad. pol. Sci., Warszawa 9 (1961), p. 53-61

ŻAKOWA, H.: Stratigraphy and facial extents of the Lower Carboniferous in the Sudetes, (English summ.).
Kwart. geol., Warszawa 7 (1963), p. 73-94

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Explanatory Notes to the Lithotectonic Molasse Profile of the Intra-Sudetic (Lower Silesian) Basin, Bohemian Part (ČSSR, Bohemian Massif and Sudety Mts.; Dinantian - Lower Triassic) (Comment to Annex 24)

by

V. HOLUB[1] and R. TÁSLER[1]

1. General characterization of the entire sedimentary basin

The Intra-Sudetic (Lower Silesian) Basin is situated on the territory of Czechoslovakia and Poland, in the frontier region of Bohemia, Lower Silesia and Kłodsko. It is encircled by the mountain ranges of the Krkonoše, Góry Sowie, Góry Bystrzyckie and the Orlické hory Mts. Orographically, the basin belongs to the Broumovské mezihoří Highland.

Geologically, the basin is a separate structural unit amidst the metamorphosed complexes of the West Sudetic geological unit. It was filled gradually since the Lower Carboniferous (Tournaisian), predominantly with continental sediments and volcanics, through the Upper Carboniferous and Permian. The basin is morphologically very dissected and its rocks are good exposured.

Geological investigation of the basin has a long tradition and reached a detailed level, especially those areas with coal deposits. The basin has been investigated in the second part of the 19th century, when the principles of stratigraphy and tectonic structure have been recognized. The latest results of the geological research and a summarization of the older investigations in the Bohemian part of the basin have been published in the year 1979 as a monographical elaboration called "Geology of the Bohemian part of the Intra-Sudetic Basin" ("Geologie české části vnitrosudetské pánve") by the Geological Survey, Prague.

Structurally, the basin is a complicated brachysyncline. Its present axis trends NW--SE and divides the basin into two limbs of different size. The south-western limb constricted by the Hronov-Poříčí fault, which bounds the basin in the SW, occurs only in

[1] Geological Survey; ČSSR, 11821 Praha 1, Malostranské náměstí 19

DOI:https://doi.org/10.2312/zipe.1982.066

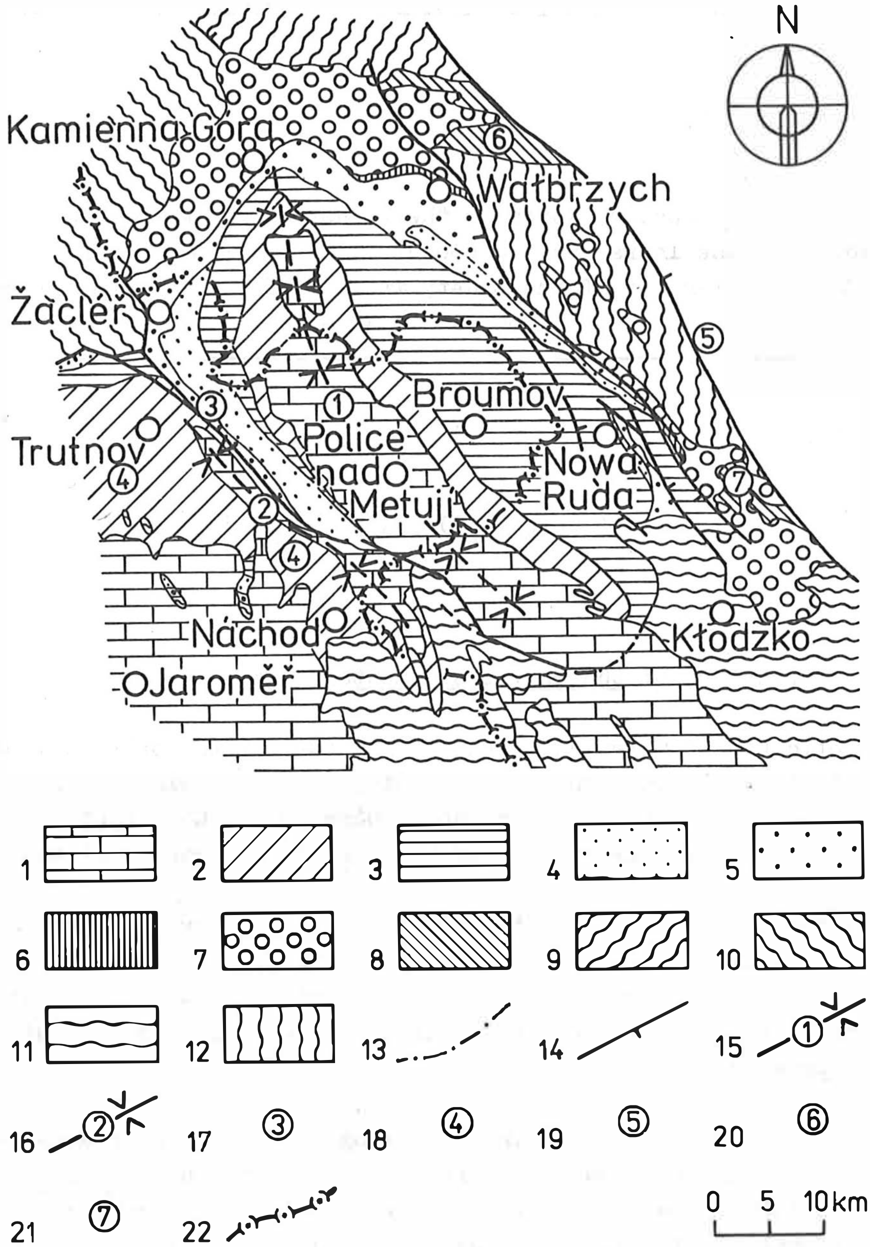


Fig. 1. Geological sketch map of the Intra-Sudetic Basin and the neighbouring area

1 - Upper Cretaceous, 2 - Saxonian, Thuringian and Lower Triassic (Trutnov, Bohuslavice and Bohdašín Formations), 3 - Stephanian C, Autunian (Broumov and Chvaleč Formations), 4 - Westphalian D, Stephanian A, B (Odolov Formation), 5 - Namurian C, Westphalian A-C (Žacléř Formation, incl. Biały Kamień Member in Poland), 6 - Namurian A (Wałbrzych Member), 7 - Lower Carboniferous, 8 - Upper Devonian and Lower Tournaisian in the Świebodzice Basin, Silurian to Middle Devonian in the Bardo Structure, 9 - sligthly metamorphosed Lower Paleozoic sequence of the Góry Kaczawskie Mts., 10 - Krkonoše-Jizerské hory crystalline massif, 11 - Orlické hory-Kłodzko Dome (including igneous masses), 12 - crystalline complex of the Góry Sowie Mts., 13 - inferred boundary of the Upper Paleozoic beneath the Cretaceous, 14 - master faults, 15 - main axis of the basin, 16 - axis of the Hronov-Poříčí graben, 17 - Hronov-Poříčí fault, 18 - eastern part of the Krkonoše-piedmont Basin with the Trutnov-Náchod depression, 19 - external Sudetic fault, 20 - Świebodzice Basin, 21 - Bardo structure, 22 - Czechoslovak/Polish frontier

DOI:https://doi.org/10.2312/zipe.1982.066

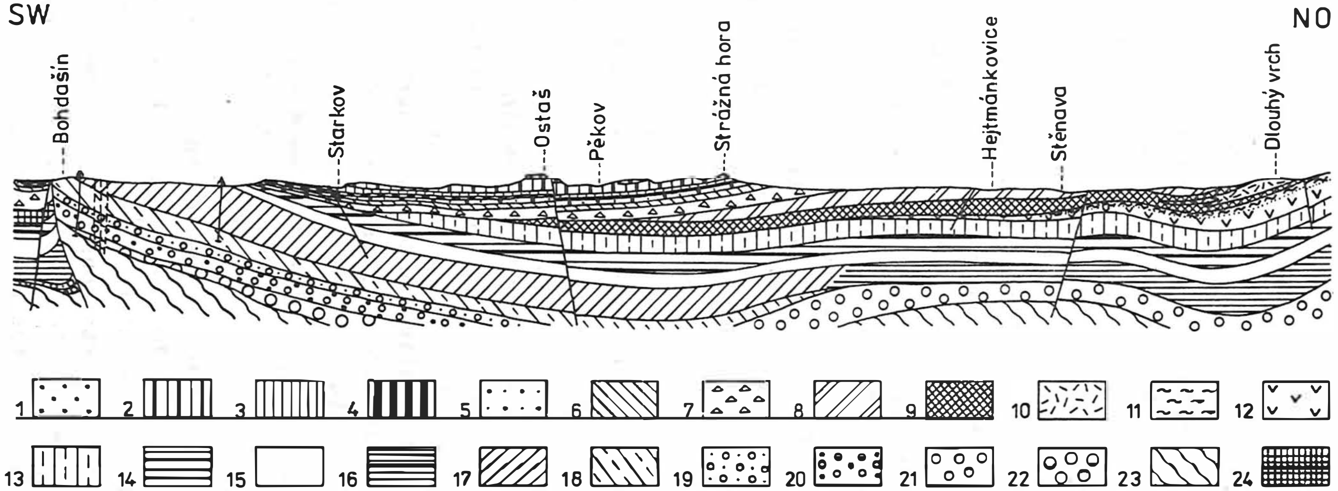


Fig. 2. Geological cross-section of the Intra-Sudetic Basin (Bohemian part) between Bohdašín near Červený Kostelec (SW) and Hermánkovice near Broumov (NE)

1 - Jizera Formation (?) - and younger - quartzose sandstones (Cretaceous), 2 - Jizera Formation, 3 - Bílá Hora Formation, 4 - Korycany Member, 5 - Bohdašín Formation (Triassic), 6 - Bohuslavice Formation (Permian), 7 - Trutnov Formation, 8 - Martínkovice Member, 9 - Olivětín Member, volcano-detrital facies, 10 - melaphyres of the Šonov Group, 11 - ignimbrites, 12 - tuffs, tuffites and transitional rocks, 13 - Nowa Ruda Member, 14 - Bečkov Member, 15 - Verněřovice Member, 16 - Odolov Member (generally) (Carboniferous), 17 - Jívka Member, 18 - Svatoňovice Member, 19 - Petrovice Member, 20 - Prkenný Důl - Žďárky Member, 21 - Žacléř Formation (generally), 22 - Lampertice Member, 23 - crystalline basement, 24 - Broumov Formation (generally) (Permian)

DOI:https://doi.org/10.2312/zipe.1982.066

Bohemia (the Bohemian limb). The largest part of the broad north-eastern limb occurs in Poland; its Bohemian portion is located in the Broumov depression.

2. General characterization of the tectonical structure, paleogeographical and tectonical history

The Intra-Sudetic basinal filling represents a complex of deposits originated in various sedimentary areas during individual intervals of the Late Paleozoic epoch, which have been saved where most subsiding areas had been taking place. The recent basinal axis of NW direction is a result of the last tectogenetical period (Saxonic movements) and does not correspond with the axis of sedimentary areas being active during the Late Paleozoic time. These axes migrated during the Variscan orogenesis and their ordering differs from recent orientation of the axes. Sedimentary areas during individual periods overlapped a recent extention of the basin and they united (joined) together the basin with Late Paleozoic basins in a neighbourhood, e.g. with the North Sudetic Basin in the North, and with the Krkonoše Piedmont Basin in the West. Those basins can be characterized as inner mountain (interior) depressions, filled by continental deposits, mostly of alluvial, alluvial-deltaic, lacustrine, proluvial and, locally, deluvial facies, and by products of volcanic activities. The sedimentary area of the basin became a part of a sea during two periods only: during the upper Viséan as a bay of Lower Carboniferous Variscan miogeosyncline and, during the Upper Cretaceous, as a part of an epicontinental sea.

Outstanding movements during the Variscan tectogenesis and during the Mesozoic, too, occurred before an Upper Cretaceous sedimentation caused disconformities between particular stratigraphical units, especially at the margins of the basin. Uneven movements in space and time caused recent asymmetric structure of the basin. Axes of the main stratigraphical units do not coincide one another. The present axis of NW--SE direction being conspicuous asymmetric in character with respect to the form of the basin originated during the Saxonic tectogenesis. It is identical with the recent axis of the Cretaceous sediments. The intensity of the tectonic deformations is dependent on the distance from the basinal margin; it is generally considered that an intensity of tectonical deformations of the filling decreases from the margins (with maximum dips of beds) towards the centre, where the dips are subhorizontal and the tectonic structure became a more simple character. In the NW the brachysynclinal closure of the basin occurs. This main closure changes towards the SE into the both limbs of the basin, into the one at the NE, which displays a monoclinal dipping of the strata to the SW, and into the SW limb (the Bohemian one), which dips to the SE. The south-eastern closure of the basin is hidden in respect to the transgression of the Upper Cretaceous deposits. The basinal margins are most involved in deformations which are of folds character. It occurs especially in the vicinity of Wałbrzych in the Polish part of the basin and in the neighbourhood of the Žacléř in the Bohemian part of the basin.

North-eastern monocline (the Polish limb of the basin) adjoints the crystalline block of the Soví hory Mts. mostly tectonically. Great faults of regional character stretch inside of the monocline parallel or moderate oblique to the margin of the basin; repetition of the Carboniferous and Permian strata or ascent of underlying rocks (crystalline fundament) occurs along these faults.

DOI:https://doi.org/10.2312/zipe.1982.066

The south-western monocline (the Bohemian part of the basin) is to be considered as a north-eastern limb of a great strike inverted fold with the axis of NW--SE direction, its apex succumbed to denudation and south-western limb was reduced by a great thrust being called as the Hronov-Poříčí reverse fault. The main overthrust is associated on the both sides with great or moderate strike oblique faults (sheer normal down faults and thrusts), which are known as the Hronov-Poříčí Fault Zone. These faults form a recent boundary between the Intra-Sudetic Basin and the eastern part of the Krkonoše Piedmont Basin. The intensity of dipping gradually decreases from the overthrust zone towards the centre of the basin. The central part of the basin is characterized by simple structure, which is formed by flat brachystructures with a very small amplitude.

The basinal filling has been disrupted by faults of radial and thrust character of all fundamental strikes. Genetically, these faults are to be considered as a younger element with regard to age of fold structures. The intensity of disruption of the filling changes with respect to an age of a geological unit. The older Late Paleozoic units, especially the Lower Carboniferous, Namurian and Westphalian, are more warped than the Saxonian and Thuringian formations.

Age of the basin and its tectogenetical history

The origin of the Intra-Sudetic Basin coincides with the early phases of the Variscan orogeny in the middle Devonian and lower Tournai (the Bretonian Phase), when orogenic movements took place in the neighbouring massifs. Since the sedimentation had started (probably during the upper Tournai) orogenesis has not occurred in the basin; all movements can be regarded as an effect of the taphrogenous energy. Taphrogenous movements, coinciding to the phases of the Variscan orogeny, are to be found as a fundamental cause of the cyclic structure.

From the stratigraphical and lithological study of the Permo-Carboniferous and the Lower Triassic of the Bohemian part of the Intra-Sudetic Basin it can be resulted that many of the important faults are connected to the lines which were active during the sedimentation as the elevations dividing the blocks of various mobility. Different intensity of downthrown blocks formed in that way morphological dissection (origin of the separate sedimentary areas) and influenced directly the origin of sediments; it brought about angle disconformities in some time intervals.

The first movements which demonstrable changed the shape of the sedimentary area of the Intra-Sudetic Basin coincide with the Sudetic phase. Above all these caused during the Viséan a communication of the interior sedimentary area with the sea. These movements terminated this sea transgression through gradual uplifting of the Soví hory Mts. block and the Orlice-Kładsko crystalline block at the end of the Viséan and at the beginning of the Namurian. In this way they definitively separated the basin, which developed since the beginning of the Mesozoic as an interior depression, that was separated from the Variscan miogeosyncline in the East. The taphrogenous movements, being held during the Namurian between the sedimentation of the Wałbrzych and Žacléř Formations, are the most important for the origin of the basin. In that basin the continental sedimentation took place only for the remaining period of the Paleozoic. The movements mentioned expressive-

DOI:https://doi.org/10.2312/zipe.1982.066

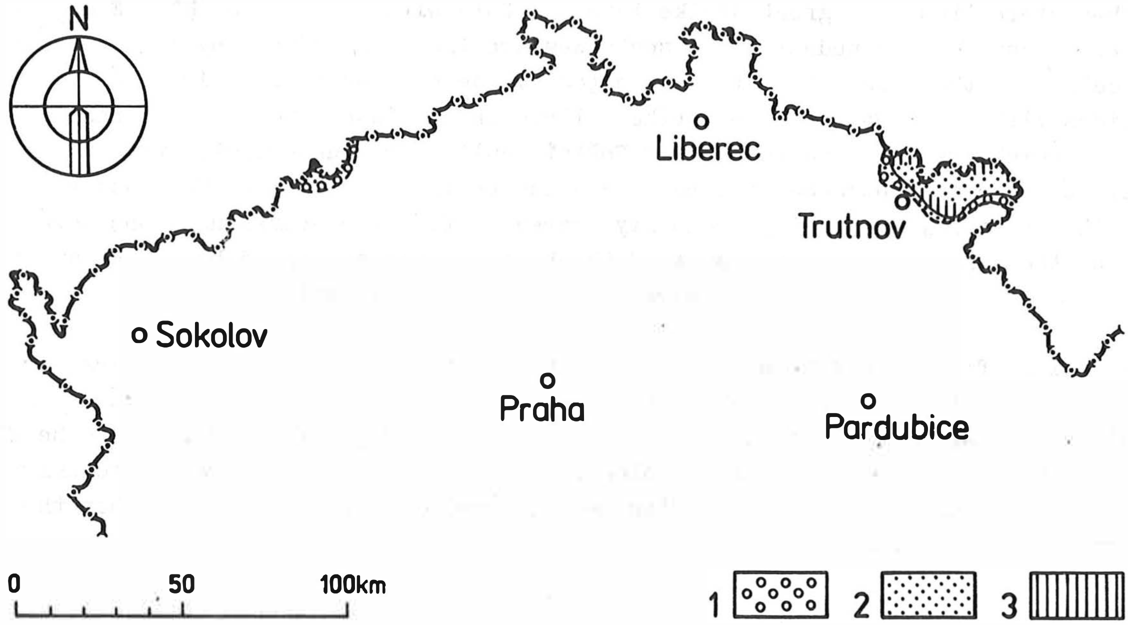


Fig. 3. Paleogeographical map of the Namurian

1 - proluvial sediments (alluvial fan and apron), 2 - proluvial sediments interchanging with alluvial plain sediments, 3 - alluvial plain, channel facies predominant, 4 - alluvial plain with small portion of ephemeral lake environment

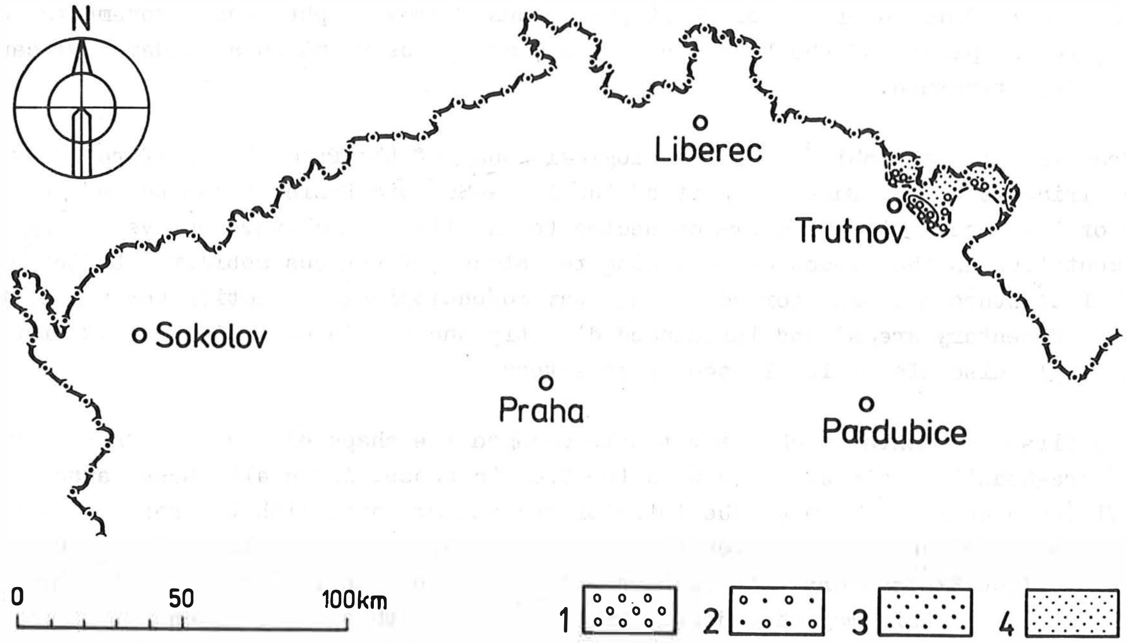


Fig. 4. Paleogeographical map of the Westphalian A

1 - alluvial fan, 2 - alluvial plain with a low proportion of lacustrine environment, 3 - fluviolacustrine environment with swamps, dashed line delimits the presumed area of sedimentation, full line indicates present occurrence (same as for all figures)

DOI:https://doi.org/10.2312/zipe.1982.066

ly transformed a hitherto sedimentary area and enlarged it in the opposite side, inwards the central part of Bohemia. This tectonical phase has an outstanding importance for the origin of the sedimentary area in the Bohemian part of the basin. These movements can be regarded temporaly to the late manifestations of the Sudetic phase, or to the Krušné hory Mts. phase.

The next period of the intensive taphrogenous movements in the Bohemian part of the basin coincides with the Westphalian C and D, the Stephanian C and the Autunian/Saxonian boundary intervals. The subsequent movements cannot be dated with precision. The most intensive movements occurred in the period between the Lower Triassic and Upper Cenomanian and that which followed the regression of the Cretaceous sea (Saxonic tectogenesis).

Paleogeographical development and paleoclimate

In the Bohemian part of the basin, sedimentation began in the Visέan, when several hundred metres of fluvial and proluvial deposits were piled up in the Žacléř and Králo-vec areas in the NW. After the interruption of sedimentation caused by tectogenesis in the middle Namurian, a new sedimentary megacycle started in Namurian C, which corresponds to the Žacléř Formation. In the depression near Žacléř and Královec, river deposits of cyclic structure (facies of stream beds and flood plains with marshes and peat moors) reached a great thickness. They lie unconformably on Visέan sediments. In the remaining parts of the basin, sedimentation was restricted to isolated depressions, where it began on the weathered crystalline basement (basal colluvial-proluvial or eluvial deposits). It persisted without interruption during the Westphalian B (the Prkenný Důl-Žďárky Member), under nearly the same facies conditions. The relief of the basin floor was levelled up and sedimentation expanded southwards beyond the present boundary of the basin.

The sedimentation regime changed as a result of movements in the marginal massifs and elevations inside the basin (movements partly reversed relative to downfaulting in the Westphalian A and B), which started at the end of the Westphalian B period. At that time the proluvial fans of coarse-grained psephites (Křenov and Hronov Conglomerates) were deposited, the formation of coal seams nearly terminated, and the Upper Carboniferous volcanism (melaphyres, rhyolite tuffs) culminated. The megacycle of the Odolov Formation was deposited in a greatly altered environment; at first in the Westphalian D (the Svatoňovice Member), sedimentation occurred on a wide alluvial plain of intermittent streams, on which temporary lakes appeared. The climate was changing gradually but not continuously from the warm humid in the Namurian and Westphalian A - B periods to semiarid. Towards the end of the Westphalian and in the initial phase of the Stephanian a regular stream pattern was developing. In the environment of flood plains and extensive plains with temporary lakes, coal seams were forming (coal seam horizons of the Svatoňovice Member). A major stream with its tributaries deposited in the Bohemian limb of the basin channel sediments (arkoses of the Jívka Member) in the Stephanian A, and in the stage of senility sediments of a wide flood plain alternating with peat moors and fluvial deposits (Radvanice Group of Coals).

Tectogenesis and change of climate in the Stephanian C remoulded the shape of the basin and practically brought the stream system to an end. The basin changed into a vast

DOI:https://doi.org/10.2312/zipe.1982.066

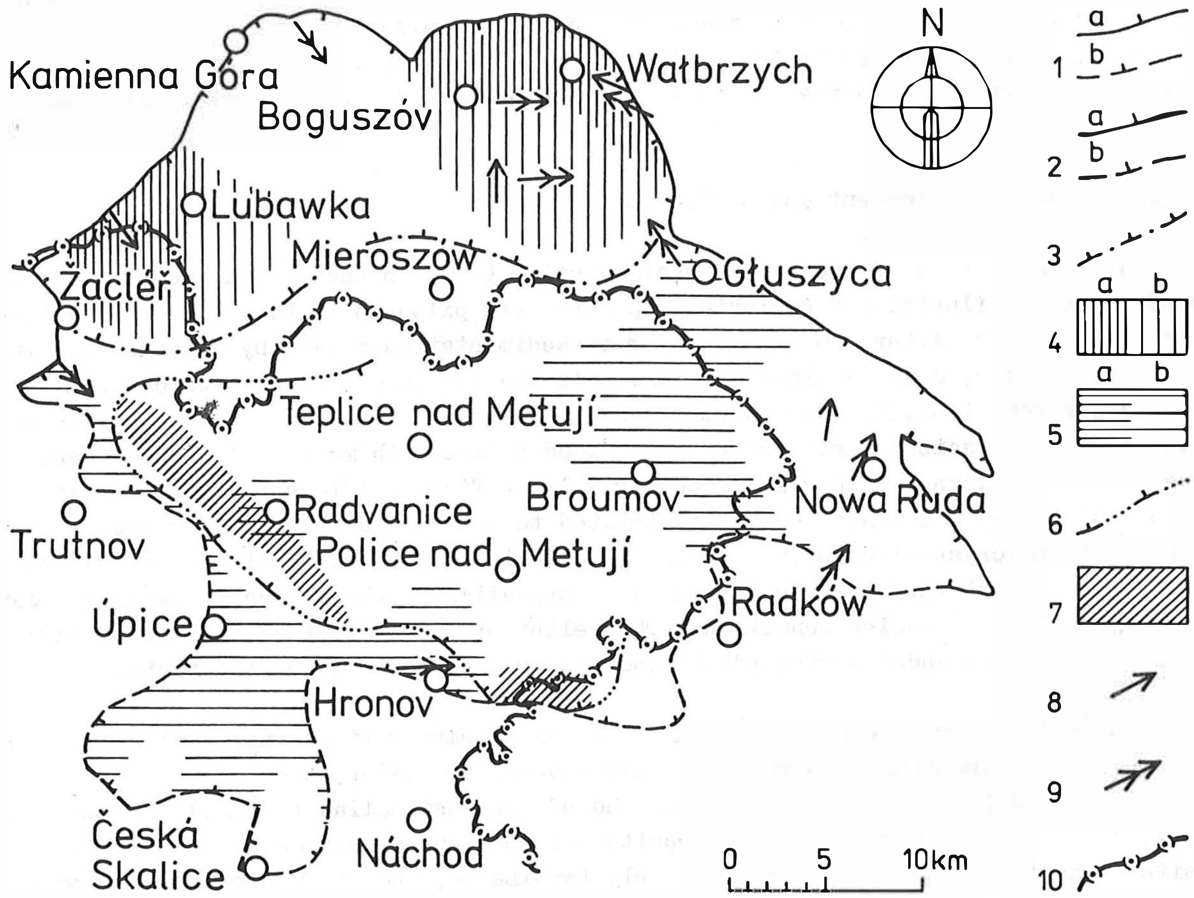


Fig. 5. Žacléř Formation, present-day distribution and main sedimentary areas
1 - boundary of the present-day distribution of the Žacléř Formation (a - proved, b - supposed), 2 - tectonic boundary (a - proved, b - supposed), 3 - main sedimentary depression of the Lampertice Member (supposed), 4 - optimum coal-bearing development of the Lampertice Member (a - proved, b - supposed), 5 - elevation with the activity during the sedimentation of the Prkenný Důl-Žďárky Member (a - proved, b - supposed), 6 - main sedimentary area of the Petrovice Member in the Bohemian part of the basin (supposed), 7 - maximum thickness of the Petrovice Member (proved), 8 - transport directions of the Petrovice Member (proved), 10 - state frontier

DOI:https://doi.org/10.2312/zipe.1982.066

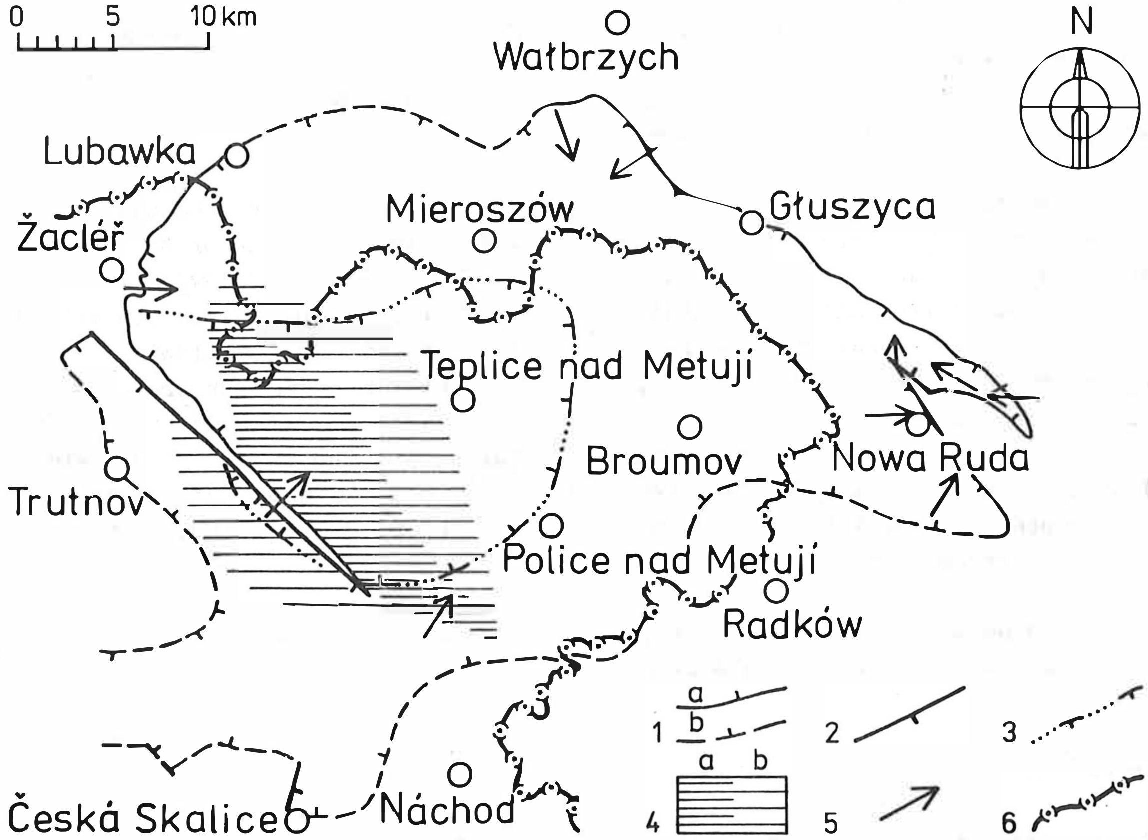


Fig. 6. Odolov Formation, present-day distribution and main sedimentary areas

1 - boundary of the Odolov Formation present-day distribution (a - proved, b - supposed), 2 - tectonic boundary, 3 - central depression of the Svatoňovice Member filled by lacustrine and proluvial facies (supposed), 4 - principal area of the channel facies development (arkose development) in the Bohemian part of the basin (a - proved, b - supposed), 5 - ascertained transport directions, 6 - state frontier

DOI:https://doi.org/10.2312/zipe.1982.066

depression, filled first with deposits of intermittent streams (proluvial fans - conglomerate horizons in the Chvaleč Formation). In certain periods, temporary and more or less permanent lakes originated in the depression area (limestone horizon of the Vernéřovice and Bečkov Members). The higher we proceed stratigraphically through the Autunian sequence, the more predominate the lacustrine sediments and the more recede the channel deposits of intermittent streams to the background (Broumov Formation). The climate was semiarid to arid in this period. A relatively short-term change in this regime and very likely also in the climate was due to intensive upper Autunian volcanism with repeated (in three cycles) melaphyre and rhyolite effusions and with the deposition of tuffs and ignimbrites. The several hundred metres thick complex of volcanics and tuffs was eroded to form a mountain range, at the foot of which proluvial sediments (volcano-detrital conglomerates, breccias and sandstones of the Olivětín Member) cumulated at a great extent; lacustrine deposits of a reducing environment (Walchia Shales of the Olivětín Member) were laid down in a more distant area.

The tectogenesis at the end of the Autunian and at the beginning of the Saxonian led to great changes in the configuration of the sedimentary area. A basin of the bolson type came into being, which was at first filled with proluvial and colluvial deposits. Subsequently, the environment assumed the character of alluvial plains of intermittent streams with temporary lakes (Trutnov Formation). In this and in the following periods (Thuringian) the climate became most arid. No eolian sediments have been preserved in the basin, but their existence is evidenced by the wind-worn clastic material, transported by streams and deposited inside the basin. During the Thuringian (Bohuslavice Formation) the basin was being filled with sediments of short intermittent streams, which were exposed to the influence of subaerial agencies for a long time, as is documented by the carbonate crusts.

Formation composed of deposits of the permanent streams and partly also of through-drainage lakes provides evidence of a new more humid period.

Volcanic activity

The Intra-Sudetic Basin is one of the Permo-Carboniferous areas of the Bohemian Massif that are characterized by volcanic activity of great extent and intensity. The volcanic products cover 15 % of the basin area.

The volcanism occurred in two phases, the first one in the Carboniferous, attaining maximum intensity in the Westphalian, and the second in the lower Permian, particularly in the Autunian. Petrographically, the volcanics fall into the group of acid rocks (rhyolitoids) and into the group of intermediate to basic rocks (melaphyres). Rhyolitoids corresponds in composition to rhyolites, rhyodacites to dacites; the melaphyric rocks range from quartz latites through quartz latite-andesites to quartz latite-basalts (which are most abundant), latite-andesite and latite-basalts to the field of basalts and andesites. In the $SiO_2 : K_2O + Na_2O$ diegram the rhyolitoids are definitely in the field of subalkalic rocks, whereas melaphyres fall more or less evenly in the subalkalic and alkalic fields. In the AFM diagram the majority of both these rock types fall in the alkalic-calcareous suite and only a part of melaphyres extends to the tholeiitic

DOI:https://doi.org/10.2312/zipe.1982.066

series. A great difference between the melaphyre and rhyolite volcanics exists in the index of explosivity. Whereas it is low in melaphyre volcanics, which make up prevalently small lava bodies, rhyolitic rocks build up extensive bodies of pyroclastic or ignimbrite character. Of the acid volcanic bodies only the complex of the Vraní hory Hills is exclusively of lava type. Magmas of the both rock groups existed perceptible separately. There were fundamental differences like in locating of their supply pathes, like in their number. Rhyolitoids, usually of explosive character, are to be derived from one or some more centres, while melaphyres originated from a great number of local throats.

3. General characterization of the type profile

The presented type profile demonstrates the filling of the Bohemian part of the Intra-Sudetic Basin from oldest Carboniferous sediments transgressing on the crystalline basement to youngest sediments which are considered as the Lower Triassic on the base of the lithological analogy and the correlation with the North-Sudetic Basin.

The sedimentary filling of the basin continued after a great sedimentary gap in the Mesozoic by the marine Upper Cretaceous sediments (at the base partly lacustrine and brackish) corresponding to the Cenomanian to Upper Turonian. These sediments have been preserved in the axial part of the basin.

The type profile has been constructed for a major part of stratigraphical units with regard to entire lithological profiles that had been obtained from the boreholes made in the basin. The profile of each lithostratigraphical unit (member, formation) represents an idealized profile of the most complete development of the basin. Thicknesses of the units represent median values; these have been chosen to express right conception concerning the total thickness of the basinal filling.

The age of the Carboniferous and Permian units has been paleontologically (esp. paleobotanically) proved. The Žacléř Formation holds the most fossiliferous layers and therefore can be devided in detail on the biostratigraphical base. The paleofloristical horizons decrease upwards. The age of the units classified to the Saxonian, Thuringian and Lower Triassic has not been biostratigraphically proved.

Individual lithostratigraphical units are defined by characteristic lithotypes and by percentual proportion of sediments and volcanics in profile. Individual units (formations and members) are determined in that way that correspond to sedimentary cycles of the high order. Sedimentary gaps and places of unconformable stratification are given in profile as well. They represent the periods with raised tectonic activity, so as they are given in the chapter 2.

Cyclic sedimentation has been ascertained in the sediments of the Upper Carboniferous and Autunian. While more phased cycles occur in the Carboniferous (especially during the periods with the origin of coal seams), two- or three-phases cycles (rhythms) originated in the Autunian.

DOI:https://doi.org/10.2312/zipe.1982.066

Altogether eight megacycles have been determined in the Upper Carboniferous and Permian. Two megacycles correspond to the Žacléř Formation, the same number to the Odolov one. The Chvaleč and Broumov Formations represent each by itself one megacycle.

The filling of the basin belongs mostly to the macrofacies as follows: proluvial, alluvial (especially during Upper Carboniferous), lacustrine (especially during Autunian) and volcanic (especially during Upper Carboniferous). A deluvial macrofacies occurs subordinately.

4. Lithological characterization of the stratigraphic units

The first sedimentary cycle, which very likely began in the Upper Tournaisian, is continental ("fluviatile Culm" - conglomerates, breccias, greywackes); the second cycle began with marine transgression in the Upper Viséan ("marine Culm") - greywackes, siltstones, occasionally carbonates. It ended with the sea retreat ("Transitional beds") and graded into the continental cycle of the Wałbrzych Formation of Namurian A age. The main sedimentary area filled with several hundred to thousand metres thick sediments of Lower Carboniferous and Namurian age was situated in the northern and eastern parts of the present Intra-Sudetic Basin; it did not extend far into Bohemia or the deposits have not been there preserved. In the Bohemian portion of the basin they have been so far found only near Zacléř and Královec in the NW; lithologically they correspond to the Błażków Formation in Poland.

Žacléř Formation

In the predominant part of the Bohemian limb of the basin, sedimentation begins with the megacycle of the Žacléř Formation, which rests directly on the crystalline basement (except to the N and NE of Žacléř).

The Žacléř Formation crops out along the margin of the Bohemian limb of the basin, except in the S, where it is truncated by the Hronov-Poříčí fault. This formation is composed for the most part by a cyclic sequence of conglomerate, sandstone, siltstone and claystone, in places with coal seams; the rocks show a characteristic grey coloration. At the base of the higher order cycles there are very coarse-grained, often distinctly polymictic conglomerates. Characteristic of the Žacléř Formation is the presence of oligomictic conglomerates, fine to medium-grained, with pebbles of stable rocks with sandstone to greywacke matrix and mostly siliceous cement.

The cyclic structure, differences in the composition of conglomerates and the presence of individual lithological types made it possible to divide the Žacléř Formation.

The L a m p e r t i c e M e m b e r is distinguished by cyclothems with large number of coal seams (the Šverma Mine Group of Coals near Žacléř includes as many as 52 seams). The Formation is developed on the one hand in depressions filled with Lower Carboniferous beds, attaining there its maximum thickness (up to 680 m near Zacléř and Královec) and on the other in depressions in the crystalline basement.

DOI:https://doi.org/10.2312/zipe.1982.066

The P r k e n n ý D ů l - Ž ď á r k y M e m b e r has a stable thickness of 150 - 300 m, and the proportion of coarse-grained conglomerates increases and the number of cyclothems decreases in it. The richest Group of Coals contains 8 - 11 coal seams with characteristic whitish tonstein intercalations.

The P e t r o v i c e M e m b e r (thickness 50 - 350 m), is distinguished by very coarse-grained conglomerates (e.g. Křenov and Hronov Conglomerates) and layers of variegated and reddish mudstones. The Křenov Conglomerates in the NW contain boulders of orthogneiss and the Hronov Conglomerates bear large pebbles of quarzite and volcanics decomposed into clayey material in the Hronov area.

The period of most intensive Upper Carboniferous volcanism was synchronous with the deposition of the Žacléř Formation (melaphyres and rhyolite tuffs in the Prkenný Důl-Žďárky Member and particularly in the Petrovice Member).

Odolov Formation

The Odolov Formation is formed predominantly of red and grey aleuropelites with subordinate coal seams and limestones, and of fine-grained psammites, which alternate with coarse-grained sandstones, arkoses and rare conglomerates. Metamorphic rocks and granitoids are more abundant in sandstones than in the Žacléř Formation.

In the central part the Odolov Formation can be divided into the Svatoňovice and Jívka Members. In the S v a t o ň o v i c e M e m b e r the aleuropelites cover more than 50 %. They are reddish in colour. Typical rocks of the lower Svatoňovice Member are lithic and polymictic sandstones composed of various quarzitic rocks and less of quartz grains.

The layers of variegated mudstones occasionally contain nodules and beds of limestone. In the Lower Svatoňovice Member the Carboniferous volcanism ends, being represented by thin, extensive bodies of effusive melaphyre. In the upper part of the Svatoňovice Member grey aleuropelites and fine-grained psammites predominate; feldspathic sandstones are subordinate. The sequence shows cyclic structure. Cyclothems with as many as six members and fairly extensive coal seams are concentrated into two seam horizons: the lower with one nearly continuous seam and the upper with three seams.

The J í v k a M e m b e r attains the maximum thickness of 1100 m in the centre of the south-western limb around Chvaleč and Radvanice and consists mainly of arkoses with conglomerate layers. Typical rocks of the Jívka Member are coarse-grained Žaltman Arkoses, frequently with layers of polymictic conglomerates. Silicified woods of Dadoxylon type are often found in the arkoses; coal seams occur in grey mudstones in the upper part of the unit. The Radvanice Group of Coals with six to nine seams of relatively large extent is 150 - 180 m thick. Separate coal-bearing layers constitute the lower lying Bystré Horizon (1 - 2 seams) and the deepest zones of Vítovy doly Horizon.

DOI:https://doi.org/10.2312/zipe.1982.066

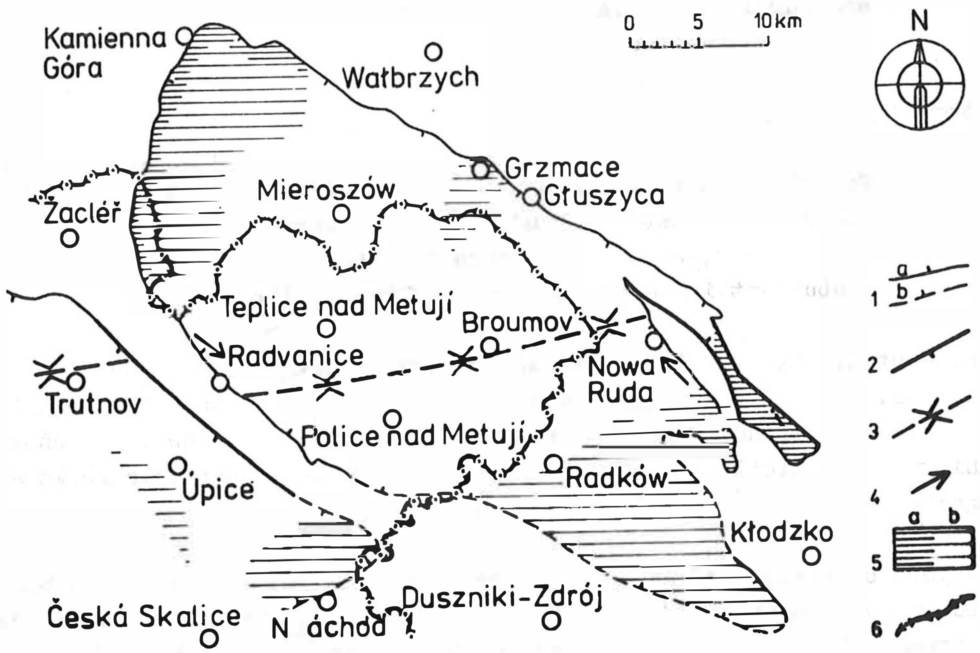


Fig. 7. Chvaleč Formation - sedimentary area and present-day distribution

1 - boundary of the Chvalec Formation present-day distribution (a - proved, b - supposed), 2 - tectonic boundary, 3 - axis of the main sedimentary area (supposed), 4 - proved transport direction, 5 - formation with reduced development (a - proved, b - supposed), 6 - state frontier

DOI:https://doi.org/10.2312/zipe.1982.066

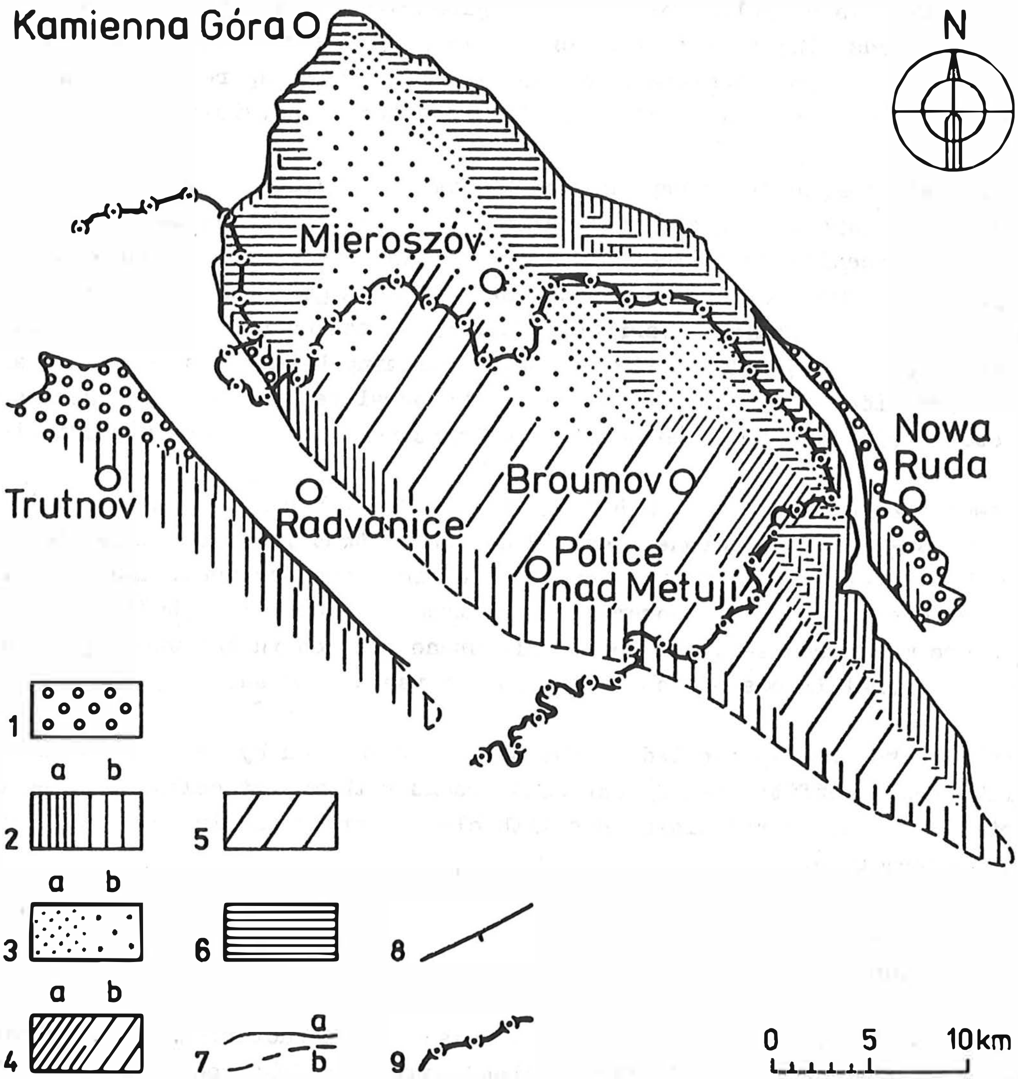


Fig. 8. Lithofacies map of the Broumov Formation

1 - channel facies of ephemeral streams and alluvial apron - sandstones and conglomerates, 2 - alluvial plain with ephemeral lakes - aleuropelites and carbonates (a - proved, b - supposed), 3 - predominantly proluvial sediments of volcano-detritic facies - breccias and sandstones (a - proved, b - supposed, 4 - "Walchia" shales facies: lacustrine and lacustrine deltaic deposits - grey siltstones, claystones and limestones (a - proved, b - supposed), 5 - lacustrine-deltaic sediments (supposed) - red and variegated aleuropelites, carbonates and fine-grained sandstones, 6 - volcanofacies (rhyolites, melaphyres, ignimbrites, tuffs), 7 - boundary of the Broumov Formation distribution (a - proved, b - supposed), 8 - tectonic boundary, 9 - state frontier

DOI:https://doi.org/10.2312/zipe.1982.066

Chvaleč Formation

The Chvaleč Formation was deposited after a hiatus evidenced by conspicuous erosion of the Odolov Formation and by a slightly transgressive character of the unit. The Chvaleč Formation is a cyclic complex of conglomerates, sandstones and mudstones with limestone interbeds. The aggregate thickness is about 350 m. The conglomerates are markedly polymictic and coarse-grained at the base. They make up relatively stable, well traceable layers in the field, which permit of further subdivision.

The carbonate component is represented by limestone concretions, and is concentrated in more granular layers in the rhythmically bedded types. Variegated, predominantly greyish-violet and greenish-grey mudstones form continuous horizons. Thinly bedded calcareous clayey siltstones contain shells of the molluscan genus Anthracosia and other organic remains (Anthracosian Shales). Variegated aleuropelites occasionally grade into grey silty-clayey rocks interbedded with pelites containing bituminous admixture and isolated coal seams (Rybníček near Bernartice). From the persistent carbonate layers organodetrital limestones with chert predominate and calcareous dolomites are subordinate.

The lower part of the V e r n ě ř o v i c e M e m b e r , about 140 m thick, is composed of coarse-grained conglomerates and one persistent layer of variegated and grey aleuropelites within the roof (the Vernéřovice Limestone Horizon). The about 200 m thick B e č k o v M e m b e r is poorer in conglomerates, but the rhythmically bedded aleuropelites are most frequent. The Bečkov Limestone Horizon in the upper part of the unit consists of several layers of carbonate-bearing variegated and grey aleuropelites.

Volcanic rocks are represented in the Chvaleč Formation by thin (of dm-order) tuff and tuffite beds; tuffites are either sandy rocks with magmatically corroded quartz and with biotite, or variegated claystones with clay minerals showing a mixed illite and montmorillonite structure.

Broumov Formation

The Broumov Formation (800 - 1000 m thickness) is characterized by an alternation of aleuropelites with predominantly fine-grained psammites. The rocks are dominantly of red colour. Variegated and grey siltstones and claystones are lithologically conspicuous but of subordinate amount. They contain interbeds of carbonates and bituminous claystones. The Broumov Formation displays a rhythmic structure.

The N o w a R u d a M e m b e r is the subunit of the greatest thickness of the Broumov Formation, attaining 300 m. Sandstones and arkosic sandstones, typical rock of the subunit, are usually fine- and medium-grained. The top part is formed by a rhyolite complex, up to several hundred metres thick, which is built up of effusive rhyolite bodies, ignimbrites and thick tuff deposits.

The O l i v ě t í n M e m b e r (200 m, and including volcanics, up to 380 m thick) is developed in two lithofacies. The volcano-detrital facies is characterized by variegated conglomerates, breccias and sandstones with solely volcanic clasts; it constitutes

DOI:https://doi.org/10.2312/zipe.1982.066

the internal rim of the outcropping Nowa Ruda Member. Towards the S and SE this facies passes finger-like into the facies of Walchia Shales, which is represented by grey, rhythmically bedded siltstones and claystones containing plant remains, by bituminous pelites and limestones with interbeds of fine-grained sandstones cemented by dolomite. The Ruprechtice Limestone Horizon (variegated mudstones and light-grey fossiliferous limestones) is developed continuously through both these facies complexes; its base divides the Olivětín Member into the upper and lower parts. The facies of Walchia Shales is confined to the upper part. The Autunian volcanism continued during the Olivětín Member with recurrent melaphyre effusions (Šonov group) and rhyolite tuffs.

The M a r t í n k o v i c e M e m b e r (300 m in thickness) is composed of the finest-grained sediments of Permian age. Variegated mudstones with limestone beds (in places dolomitic and of organogenic origin) and occasional cherts make up three persistent horizons: the Vižňov (at the base), Hejtmánkovice (in the middle) and Jetřichov (at the top) ones.

Trutnov Formation

The lower boundary of the formation is unconformable: the unconformity is erosional in the Broumov area and angular in the south-western limb. The thickness varies from 20 m in the SSW to about 300 m in the Broumov area. The sequence consists of generally reddish aleuropelites, psammites and psephites. Unstratified aleuropelites with dispersed sand grains and bimodal sandstones are characteristic rock types. Carbonates, predominantly calcite or calcite with dolomite, are usually dispersed as cement. The basal conglomerates and breccias vary greatly in thickness and grain-size. Characteristic feature of sandstones is the presence of perfectly rounded coarse grains in the basic fine-grained fraction.

Bohuslavice Formation

The Bohuslavice Formation is connected with the Trutnov Formation by a rapid rhythmical transition. Its thickness ranges from 80 to 120 m, dropping to 30 m. The Formation is a sequence of psammites and scarser psephites of various grain-size. Carbonates are non-uniformly distributed. Absence of stratification and poor sorting is characteristic of all rock types. Variegated mottled dolomitic sandstones and arkoses, often with pea-gravel admixture are typical rocks of the unit. The carbonate (dolomite and dolomite with calcite) gives a characteristic texture to the rock: freely scattered coarse sand grains in carbonate matrix. The carbonate component is also concentrated into nodules. Another widespread rock are reddish-brown poorly sorted sandstones with silty-clayey matrix and a very small amount of carbonate cement.

Bohdašín Formation

The Bohdašín Formation (total thickness up to 120 m) build up a sequence of fine- to coarse-grained sandstones and subordinate conglomerates, commonly with inclined bedding

DOI:https://doi.org/10.2312/zipe.1982.066

and an increased clay cement. Psammites are represented by polymictic varicoloured banded sandstones and by whitish and mottled arkosic sandstones containing abundant kaolinized feldspars. In the uppermost part, quartzose sandstones with clayey cement (minerals of the kaolinite group) and the underlying so-called "variegated horizon" (claystones, varicoloured banded clayey sandstones) have been preserved.

Paleontology

The oldest Carboniferous and Permian plant remains in the Intra-Sudetic Basin have been found in the Žacléř area (in the Błażków Formation). The younger, Westphalian A flora comes from a thick fossiliferous sequence of the Lampertice Member. The flora at the base of this unit may be even of Namurian C age. The plant assemblage found near Petrovice in the Svatoňovice area, is greatly impoverished due to a considerable reduction of the thickness of sediments. The Prkenný Důl-Žďárky Member yielded paleontological evidence from the Žacléř area as far as from Žďárky. The flora is of Westphalian B age and in the SE it is enriched with some Westphalian C species; in the Svatoňovice area it extends to the basal beds of the Petrovice Member. The Westphalian plant assemblage from the upper part of the Petrovice Member is known to occur from Lhota near Trutnov as far as the Svatoňovice area (red mudstones of the Lower Svatoňovice Member). In the Upper Svatoňovice Member the Lower Stephanian flora is distributed from Debrné to Hronov. Abundant Middle Stephanian floral finds derive from the upper part of the Jívka Member (between Hronov and the Vraní hory and near Radvanice). Stratigraphically younger material comes from the Autunian beds: the Vernéřovice Formation in the north-western part of the basin yielded a small amount of specimens, but the Broumov Formation around Broumov is very rich in plant remains.

Palynological study have shown that the coal seams of the Lampertice Member are very poor in megaspore species. On the contrary, the miospore assemblage, however, is unusually rich; it contains characteristic Westphalian A species, some of which disappear gradually in the following Prkenný Důl-Žďárky and Petrovice Members. The Svatoňovice Member bears some stratigraphically significant elements which would warrant its classification as Westphalian D. The Jívka Member is rich in common Stephanian species, but the Vernéřovice, Nowa Ruda and Olivětín Members of Permian age contain very poor spore assemblage both in amount and species.

The most important faunal specimens come from the Broumov Formation. Vertebrates have been found mainly in the limestones of the Olivětín Member (Ruprechtice and Otovice Limestones), molluscs and conchostraca in the Hejtmánkovice Limestone Horizon of the Martínkovice Member.

5. Conclusions

The origin of the Intra-Sudetic Basin, with regard to the Late Paleozoic sedimentary area, is referred to the early Variscan orogenesis (the Bretonian Phase). The onset of the filling coincided after fundamental orogenetic metamorphic processes with the Lower

DOI:https://doi.org/10.2312/zipe.1982.066

Carboniferous when principal massifs at the border of the Bohemian Massif were formed.

The Intra-Sudetic Basin came into being amidst the West-Sudetic Unit of the Variscan metamorphites, where the north-eastern spur of the Variscan median mass of the Bohemian Massif was projected to the Soví hory Mts. block. However, it is situated at the periphery of the intermediate mass in the neighbourhood of the Lower Carboniferous miogeosyncline, having some communication with it for a short time. The Intra-Sudetic Basin can be structurally regarded to inner molassic depression of the Variscan orogenetic belt; it changed its character during the Late Paleozoic in the continental (inland, limnic) basin. Through this anomalous change and through its position at the periphery of the Variscan median mass the Intra-Sudetic Basin wrenches itself out of a scheme of other continental basins in Bohemia and Moravia.

A special position of the basin in the peripheral zone of the median mass, which was during the Late Paleozoic period tectonically more labil as to the core part of it caused that the filling and forming process of the basin performed during the whole epoch of the Variscan tectogenesis. This fact is to be considered as an extraordinary phenomenon within the entire European Variscan orogenetic belt.

A long termed tectogenetical history of the basin terminated during the period of Saxonic tectogenesis, when came into being recent independent structure of the West-Sudetic regional geologic unit of the Bohemian Mass.

References

BERG, G.: Geologische Übersichtskarte des Braunauer Landes. 1:100 000.
Jb. Preuss. Geol. Landesanst., Berlin 6 (1908 a) 79, 1

BERG, G.: Zur Geologie des Braunauer Landes.
Jb. Preuss. Geol. Landesanst., Berlin 29 (1908 b), p. 23-37

BERG, G.: Die Gliederung des Oberkarbons und Rotliegenden im Niederschlesisch-Böhmischen Becken.
Jb. Preuss. Geol. Landesanst., Berlin 46 (1925), p. 68-84

BUBNOFF, S. VON: Die westphalische Sedimentation und die asturische Phase in der Innersudetischen Mulde.
Fortschr. Geol.-Paläont. Berlin 9 (1931) 29, p. 1-91

ČADKOVÁ, Z.: Distribuce kovových prvků v permských sedimentech vnitrosudetské pánve.
Sb. geol. věd, Ř. LG, Praha 14 (1971), p. 91-126

ČEPEK, L. et al.: Vysvětlivky k přehledné geologické mapě ČSSR 1:200 000 M-33-XVI-Hradec Králové.
Praha: Ústř. ústav. geol. 1963

DATHE, E.; PETRASCHECK, W.: Geologische Übersichtskarte des Niederschlesisch-Böhmischen Beckens.
Preuss. geol. Landesanst. Berlin (1913)

FEDIUK, F.; SCHOVÁNKOVÁ, D.: Permocarboniferous volcanism in the Czech part of the Intra-Sudetic Basin.
Acta Univ. Carol., Geol., Praha, in print

FRIČ, A.: Studien im Gebiet der Perm-Formation Böhmens.
Arch. naturwiss. Landesdurchforsch. Böhmen, Praha 15 (1912) 2

DOI:https://doi.org/10.2312/zipe.1982.066

GOTHAN, W.; GROPP, W.: Paläobotanisch-stratigraphische Untersuchungen im niederschlesischen Karbon.
Z. Berg-Hütten- u. Salinen. Preuss. St., Berlin 81 (1933), p. 388-398

HAVLENA, V.: Geologie uhelných ložisek 2.
Nakl. Čs. Akad. věd. Praha, 1964

HAVLENA, V.: Die späteren Entwicklungsetappen der Variszlden und die jungpaläozoischen Ablagerungsräume des Böhmischen Massivs.
Neu. Jb. Geol. Paläont., Stuttgart 2 (1971), p. 65-91

HAVLENA, V.: Einteilung der kohlenführenden variszischen Ablagerungsräume und deren Auffüllungen.
Sept. Congr. internat. Stratigr. Géol. Carbonif., C.R. Krefeld 3 (1974), p. 169-188

HOLUB, V.: Karbonský vulkanismus v české části vnitrosudetské deprese.
Acta. Mus. Reginaehradec., S.A., Sci. Natur., Hradec Králové 3 (1961), p. 1-2

HOLUB, V.: Permian of the Bohemian Massif.
In: FALKE, H. (Hrsg.): Rotliegend Essays on European Lower Permian, p. 137-188
Leiden: 1972

HOLUB, V.: The Permo-Carboniferous continental basins of Bohemia and Moravia.
In: HOLUB, V.; WAGNER, R.H. (Hrsg.): Symposium on Carboniferous Stratigraphy, p. 205-231, Praha: Vyd. ÚÚG. 1977

HOLUB, V.; PROUZA, V.; TÁSLER, R.: Nové litostratigrafické dělení svrchního karbonu v českém/jihozápadním/křídle vnitrosudetské pánve.
Čas. Mineral. Geol., Praha 10 (1965) 3, p. 331-336

HOLUB, V.; PROUZA, V.; TÁSLER, R.; VALÍN, F.: Geologie a litologie saxonu, thuringu a spodního triasu v severovýchodních Čechách.
Praha: MS Gefond 1969

HOLUB, V.; SKOČEK, V.; TÁSLER, R.: Palaeogeography of the Late Palaeozoic in the Bohemian Massif.
Palaeogeogr., Palaeoclimatol., Paleoecol., Amsterdam 18 (1975), p. 313-332

HOLUB, V.; TÁSLER, R.: Mladší paleozoikum a spodní trias v podloží české křídové pánve.
In: MALKOVSKÝ, M. et al. (Hrsg), Permokarbon a spodní trias v podloží křídového útvaru v sv. Čechách. Praha: MS Geofond 1971

HOLUB, V.; TÁSLER, R.: Filling of the Late Palaeozoic continental basins in the Bohemian Massif as a record of their palaeogeographical development.
Geol. Rdsch., Stuttgart 67 (1978) 1, p. 91-109

HRDLIČKOVÁ, D.: Ignimbrite volcanism in the Broumov area in north-eastern Bohemia.
In: FEDIUK, F.; FIŠERA, M.(Hrsg.), Palaeovolcanites of the Bohemian Massif. Praha: Univers. Karl. 1966

JAROŠ, J.: Geologické a litologické poměry v českém křídle vnitrosudetské deprese severně od Hronova. 1. Oblast Jívka-Bystré.
Sb. Ústř. Úst. geol., Odd. geol., Praha 23 (1957) 2, p. 272-321

JAROŠ, J.: Geologické a litologické poměry v českém křídle vnitrosudetské deprese severně od Hronova. 2. Oblast Rokytník-Žabokrky - Zlíčko.
Sb. Ústř. Úst. geol., Odd. geol., Praha 24 (1959) 2, p. 209-214

KOZŁOWSKI, S.: Subsequent Permian Volcanism in the Sudeten.
In: Paläovolcanites of the Bohemian Massif.
Praha: Univers. Karl. 1966

MÜLLER, G.: Der kontinentale Zechstein im Süden des Riesengebirges.
Abh. preuss. geol. Landesanst., N.F., Berlin 130 (1930), p. 1-90

NĚMEJC, F.: Floristicko-stratigrafická studie o poměrech v uhelných revírech u Žacléře, Svatoňovic a u Žďárků (blíže Hronova).
Věst. Čes. Společ. Nauk, Tř. math.- přírodověd., Praha 5 (1933), p. 1-34

DOI:https://doi.org/10.2312/zipe.1982.066

NĚMEJC, F.: Úvod do floristické stratigrafie kamenouhelných oblastí ČSR.
Praha: Nakl. Čs. Akad. věd. 1953

NĚMEJC, F.: Biostratigrafická studie v karbonu českého křídla vnitrosudetské pánve.
Rozpr. Čs. Akad. Věd, Praha 68 (1958) 6

PETRASCHECK, W.: Geologische Karte der österr. ungarischen Monarchie. Nv. Gruppe, Nr. 17,
Josefstadt-Náchod (s vysvětlivkami).
K. - kön. geol. Reichst., Wien 1913

PETRASCHECK, W.: Kohlengeologie der österreichischen Teilstaaten IV (das Schatzlar-Schwadowitzer Steinkohlenrevier).
Berg- u. Hüttenmänn. Jb. Montan. Hochsch. Leoben., Wien 71 (1923) 2, p. 1-28

PETRASCHECK, W.: Der böhmische Anteil der Mittelsudeten und sein Vorland.
Mitt. geol. Gesell., Wien 26 (1934), p. 1-136

PETRASCHECK, W.; WALDMANN, L.; LIEBUS, A.: Die Sudetenländer. (Handbuch der regionalen Geologie)
Heidelberg:

PROUZA, V.: Geologie svatoňovických vrstev v jz. křídle vnitrosudetské pánve. (Kandid. disert. práce).
Praha: MS Geofond 1964

SANDTNER, B.: Mapa žacléřsko-svatoňovického revíru.
Praha: Prometheus 1929

SANDTNER, B.: Pánev žacléřsko-svatoňovicko-zďárecká.
Hornicko-hutnický kalendář 1933, Praha

SCUPIN, H.: Die erdgeschichtliche Entstehung des Zechsteins im Vorlande des Riesengebirges.
Sitz. Ber. Dtsch. Akad. Wiss., Berlin 1916

STŘEDA, J.: Ložisková studie vnitrosudetské pánve (Surovinová studie).
Praha: MS Geofond 1972

STUR, D.: Die Karbonflora der Schatzlarer Schichten.
Abh. K.-Kön. geol. Reichsanst., Wien 11 (1885-1887)

SVOBODA, J. et al.: Vysvětlivky k přehledné geologické mapě ČSSR 1:2oo 000 M-33-X Liberec.
Praha: MS Geofond 1962

SVOBODA, J.: Regionální geologie ČSSR, 1/2.
Praha: Ústř. Ústav geol. 1964

SVOBODA, J.; CHALOUPSKÝ, J. et al.: Vysvětlivky k přehledné geologické mapě ČSSR 1:200000 M-33-XVII Náchod.
Praha: Ústř. Ústav geol. 1961

ŠETLÍK, J.: Etapes de l'évolution de la flore carbonifère dans la Bohême occidentale, centrale et nord-orientale.
Sept. Congr. internat. Stratigr. Geól. Carbonif., C.R. Krefeld 4 (1975), p. 227-238

TÁSLER, R. et al.: Závěrečná zpráva o základním geologickém výzkumu jihozápadního křídla vnitrosudetské pánve.
Praha: MS Geofond 1963

TÁSLER, R. et al.: Základní geologický výzkum broumovského permu.
Praha: MS Geofond 1966

TÁSLER, R.; STŘEDA, J. et al.: Ložisková studie vnitrosudetské pánve (černé uhlí).
Praha: MS Geofond 1965

TÁSLER, R. et al.: Geologie české části vnitrosudetské pánve.
Vyd. ÚÚG v Academii, nakl. ČSAV. Praha (1979) p. 1-292

VALÍN, F.: Litologie souvrství žaltmanských arkóz.
Sb. Ústř. Úst. geol., Praha 27 (1962), p. 409-444

DOI:https://doi.org/10.2312/zipe.1982.066

VALÍN, F.: Petrografie některých proplástků (tzv. "tonsteinů") kamenouhelných slojí ve stefanu vnitrosudetské deprese (Mronov - Radvanice).
Věst. Ústř. Úst. geol., Praha 38 (1963) 1, p. 11-21

VALÍN, F.: Petrografie permu v jihozápdním křídle vnitrosudetské pánve.
Sb. Geol. Věd., Ř.G., Praha 4 (1964), p. 7-44

VALÍN, F.: Litologie permokarbonu v české části vnitrosudetské pánve (Kandid. disert. práce).
Praha: MS Geofond 1967

VALÍN, F.: Nový doklad pro eolickou pouštní sedimentaci permu (saxonu) severovýchodních Čech.
Věst. Ústř. Úst. geol., Praha 47 (1972) 3, p. 141-146

WAGNER, R.H.: Proposal for the recognition of new Cantabrian stage at the base of the Stephanian series.
6e Congr. internat. Stratigr. Geol. Carbonif., C.R., Sheffield, Maastricht 1 (1969), p. 139-150

WEITHOFER, K.A.: Der Schatzlar-Schwadowitzer Muldenflügel des Niederschlesisch-Böhmischen Steinkohlenbeckens.
Jb. K.-Kön. geol. Reichsanst., Wien 47 (1897), p. 455-478

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde .AdW DDR, Potsdam (1982) 66

Explanatory Notes to the Lithotectonic Profile of the Permo-Carboniferous Basins of the Central Bohemian Region (CSSR) (Comment to Annex 25)

by

V. HOLUB[1]

1. General characterization of the entire sedimentary area

The presented profile represents the most extensive area of the continental Late Paleozic basins of the Bohemian Massif. Basins in the western and central Bohemia, from the Carboniferous occurrence at Stříbro in the south-western neighbourhood of Plzeň in the West, to the Mšeno Basin in central Bohemia in the East, belong into the group of the Permo-Carboniferous Basins of the Central Bohemian Region. The Maršovice-Bezděz elevation (being directed from Doksy NNE of Praha to Mladá Boleslav) is considered as a boundary of mentioned region with the Sudetic area. In the idealized profile is presented optimal development of the separate basins and depressions.

A number of basins and minor erosional outliers also belong to this group. Some of these basins represent classical areas for the fundamental research of the entire Carboniferous of the Bohemian Massif. In the western part of the area Permo-Carboniferous sediments crop out, in the eastern part they are concealed by younger formations. The main basins, from west to east, belonging to the group of the Permo-Carboniferous of the Central Bohemian Region are as follows: the Carboniferous at Stříbro, the basins of Plzeň, Manětín, Radnice, Žihle, Rakovník and Kladno. The Permo-Carboniferous sediments of the Roudnice, Česká Kamenice and Mšeno basins are overlain by younger formations.

The determination of the stratigraphic position and age of the most important coal basins of this area is based on a long tradition (the first written data about coal mining concerning the Malé Přílepy Carboniferous occurrence originate from fifteenth century), and the respective problems have already been geologically solved in rough outline in the second half of the 19th century, except for the areas where the Permo-Carboniferous has been encountered only recently by boreholes in concealed coalfields. For

[1] Geological Survey, Prague; ČSSR, 11821 Praha 1, Malostranské náměstí 19

DOI:https://doi.org/10.2312/zipe.1982.066

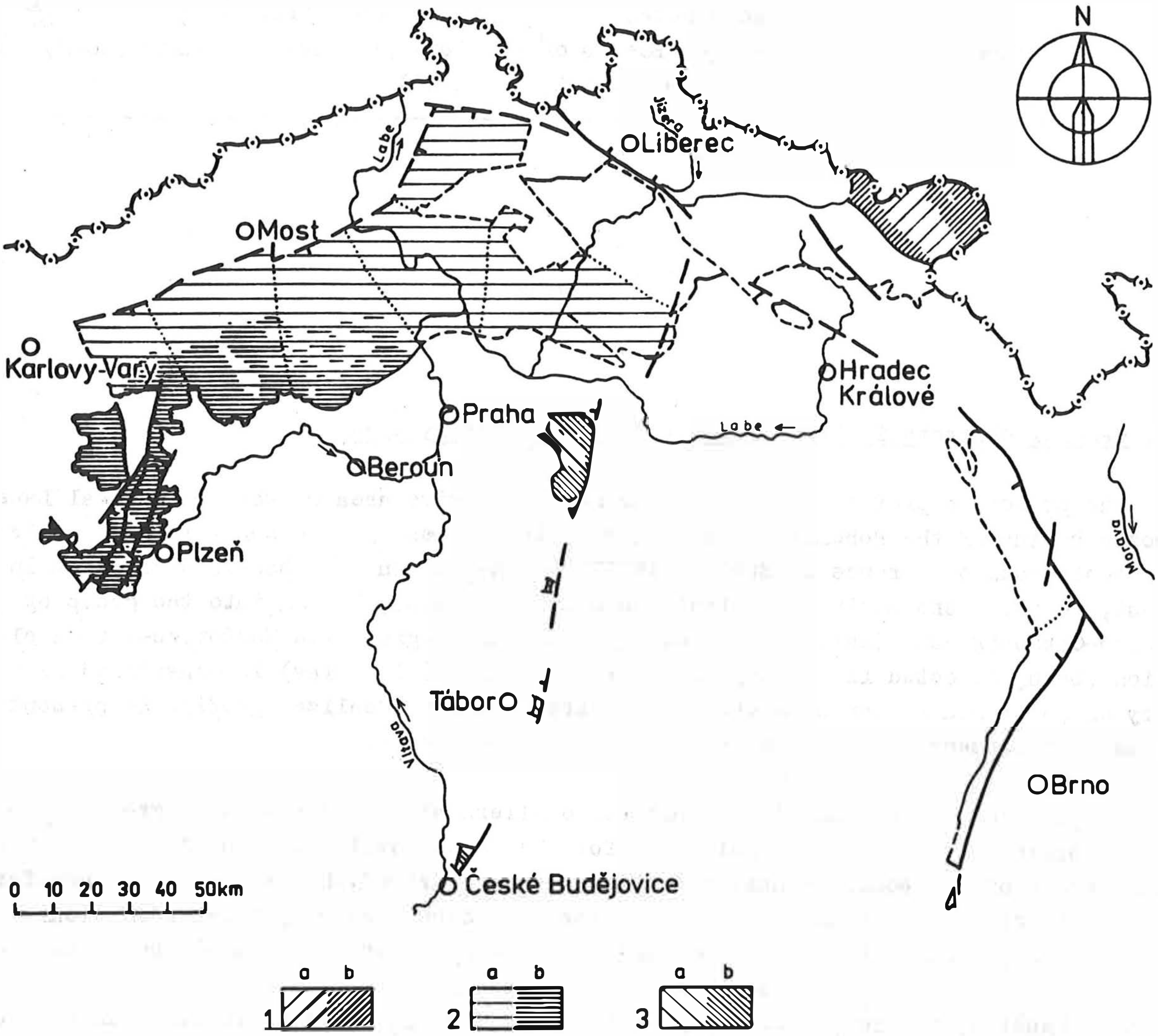


Fig. 1. Permo-Carboniferous continental basins of the Bohemian Massif

1 - Permo-Carboniferous of the Intra-Sudetic Basin, 2 - Permo-Carboniferous of the Central and Western Bohemian Region, 3 - Permo-Carboniferous of the Blanice Furrow (a - exposed, b - concealed beneath overlying formations)

DOI:https://doi.org/10.2312/zipe.1982.066

the elaboration of this profile a lot of borehole material has been used, which have been encountered through the coal-deposit prospecting made by Geological Survey of Prague and exploration organisations in the last three decades.

2. General characterization of the tectonic structure and basin development

Sedimentation started either in isolated depressions that were controlled by the course of the structures of a crystalline basement, or in the tectonically predisposed sedimentary trenches. The tectonic deformation is reflected by a system of faults; no fold structures were formed. Most of the basins in the Central Bohemian Region form a joint asymmetric megasynclinal structure the axis of which turns gradually from the NE--SW direction in the Rakovník and Kladno Basins and to the NW--SE direction in the Mšeno Basin. Elevations of the basement divided the whole synclinal structure into partial basins during the Westphalian, in place also later. The northern limb of the megasyncline, which is hidden below the Cretaceous deposits, probably ends on the large dislocations, which are partly copied by the present-day Ohře fault system. In the north-trending spur of the Roudnice Basin (Česká Kamenice Depression) the Permo-Carboniferous was probably preserved in a complicated system of variously sunken blocks confined by normal faults, which formed at the crossing of NW--SE and NE--SW striking faults.

Age of the sedimentary area and its tectonic structure and history

Sedimentation process began in various intervals of the Westphalian B and C gradually. It passes through Westphalian D and all substages of the Stephanian until Lower Permian. The Upper Radnice Member originated after weak tectonic movements. Westphalian time is in the area of Central and Western Bohemia a period of tectonic discomposure, that was manifested in different parts of the sedimentary area by various intensity. These movements are generally called as Asturian tectogenesis. First manifestations of this tectogenesis caused the onset of sedimentation in the basinal area of the Central and Western Bohemia (the Radnice Member). The movements between Westphalian C and D resulted in interruption of sedimentation and caused an extention of the sedimentary area and an inception of a new megacycle (Nýřany Member). Tectonic movements at the boundary between Westphalian and Stephanian came into being mostly at the marginal parts of the sedimentary areas only, sedimentation process inside the basins continued without interruptions (Týnec Formation). Sedimentation areas of the Permo-Carboniferous in the Central Bohemia and Sudeten jointed together during the Stephanian. A quick exposure of Variscan Massifs and lava effusions resulted in speedy deposition of wheathered detritus from these massifs in the sedimentation basin. The following tectogenesis originated during upper Stephanian (an Intra-Stephanian Phase) being located at the boundary between Stephanian B and C (between the Slaný and Líně Formations). This phase modificated an extension of the basin, caused overlapping the older stratigraphic units and brought about changes in source areas. In the Central and Western Bohemia this phase resulted in origin of a new sedimentary megacycle (the Líně Formation) and in transference of the sedimentation centre to the North. After Stephanian tectogenesis all continental Permo-Carboniferous basins in the Bohemian Massif joined together. In the area of the main axis of the sedimentary basins, running out from the Western Bohemia through Central

DOI:https://doi.org/10.2312/zipe.1982.066

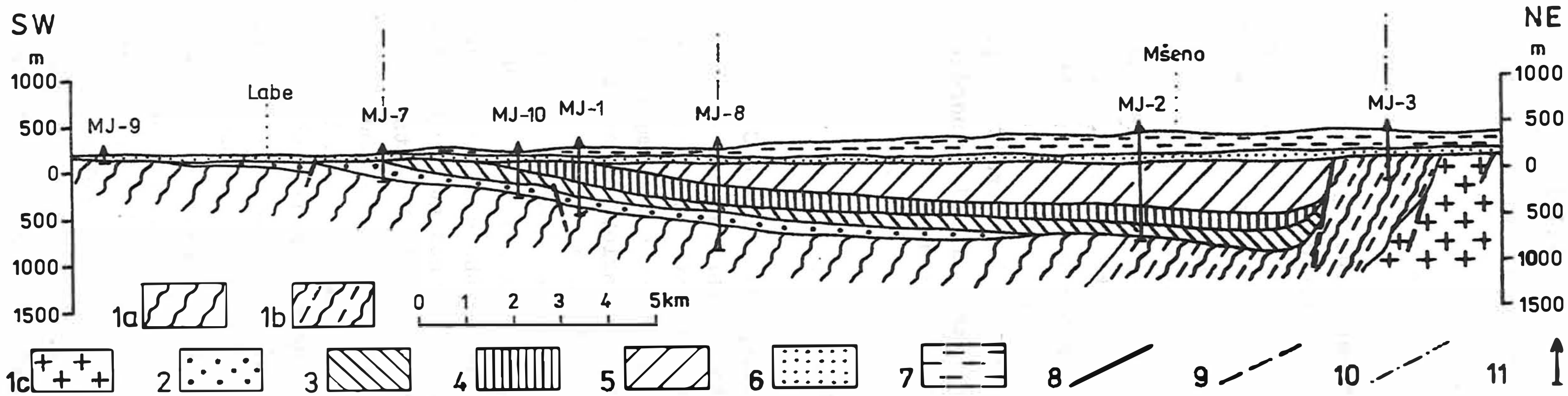


Fig. 2. Geological cross-section of the Mšeno Basin (western part) between Chlumín (near Mělník) and Doubravice (near Mšeno).

1a - crystalline of the Upper Proterozoic (quartz-albite-muscovite-chlorite) metamorphic subfacies, 1b - crystalline of the Upper Proterozoic (quartz-albite-epidote-biotite) metamorphic subfacies, 1c - granitic rocks, 2 - Kladno-Plzeň (Lower Grey) Formation, Carboniferous (Westphalian C-D), 3 - Týnec (Lower Red) Formation, Carboniferous (Stephanian A - Cantabrian), 4 - Slaný (Upper Grey) Formation, Carboniferous (Stephanian B), 5 - Líně (Upper Red) Formation, Permo-Carboniferous (Stephanian C - lower Autunian), 6 - Cenomanian (Upper Cretaceous), 7 - Turonian (Upper Cretaceous), 8 - fault (ascertained), 9 - fault (supposed), 10 - bend of profile, 11 - borehole

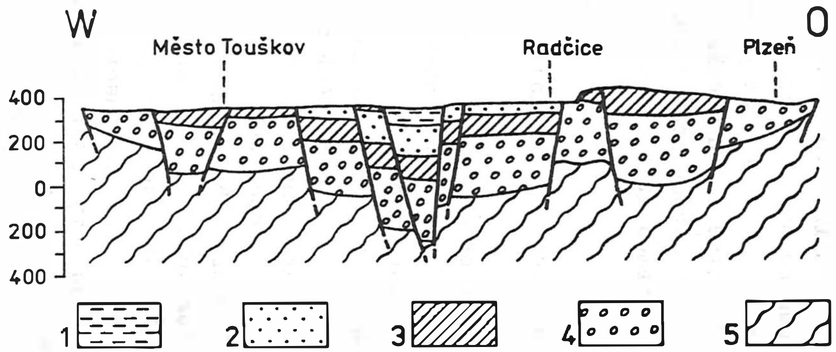


Fig. 3. Geological cross-section through the Plzeň Basin between Plzeň (East) to Město Touškov (West)

1 - Líně (Upper Red) Formation, Carboniferous (Stephanian C), 2 - Slaný (Upper Grey) Formation, Carboniferous (Stephanian B), 3 - Týnec (Lower Red) Formation, Carboniferous (Stephanian A - Cantabrian), 4 - Kladno-Plzeň (Lower Grey) Formation, Carboniferous (Westphalian D-C), 5 - crystalline basement (Upper Proterozoic)

DOI:https://doi.org/10.2312/zipe.1982.066

Bohemia into Sudeten area, the maximal thickness of the Upper Stephanian to Lower Autunian deposits existed. The youngest sediments of the Central Bohemian Permo-Carboniferous Region belong to Lower Autunian. Deposits of Upper Autunian and Saxonian have not been evidenced.

We suppose that Saalic tectogenesis has not given up entirely the sedimentation activity but sediments originated in small thickness had been denudated during sedimentary gap in the Mesozoic with respect to certain stagnation and later to uplifting of the basinal areas.

Genuine fold structures do not occurr in the basins of this region, as i.g. in the Upper Silesian Basin, or in the Sudeten area. According to general tectonic structure basins of the Central Bohemian Permo-Carboniferous Region can be devided into two groups:

1. In the first one belong the Rakovník, Kladno, Roudnice n. Labem and Mšeno Basins which form a wide continuous stripe of the Permo-Carboniferous in the Central Bohemia. From the tectonical point of view they form one great sedimentary area being general ordered into a megasyncline of asymmetric structure with an axis excentrical shifted to the North.
2. Into the second group belong the basins in the western Bohemia (Plzeň, Manětín, Žihle, and Radnice) and small isolated occurrences in the South of the region. These basins are tectonically strong broken by radial faults into separate blocks forming trenches and horsts. These blocks can be considered as denudation relics of an originally continuous cover that remained best saved in the downthrown blocks.

Paleogeography and tectogenetical evolution

Oldest sediments originated around the basinal slopes and are of coluvial and deluvial type. Their character was considerably influenced by the relief, and their thickness reached in places several hundred metres. In the flat areas (valleys and alluvial plains) fluviatile deposits came into existence. In places lacustrine and paludial sediments originated. In time of the Radnice Coals sedimentation there are records for stabilization of the sedimentation area, simultaneously with explosional volcanic activity. The overlying sediments of the Radnice Coal Horizon represent moderate rejuvenation of the relief with local erosions. The Lubná Coals Horizon stands for certain stabilization of the sedimentation region. A considerable sedimentation gap arose between the Radnice Member (Westphalian C) and Nýřany Member (Westphalian D). At that time outstanding change of the basinal form with remarkable enlargement of the sedimentation area came into being. Regional rejuvenation of a relief influenced expanding of sedimentary area (Mirošov conglomerates). These movements are due to the Asturian Phase. At the boundary between Westphalian and Stephanian local erosions in the marginal parts arose; in basinal centres the sedimentation continued without distinct gaps. During Cantabrian and Stephanian A first typical red beds originated. Before sedimentation of the Jelenice Member local erosions originated. The sedimentation of the Mšec Member passed under regional wide-spreading of the lake environment, when gigantic lakes arosed through the entire area of western and central Bohemia. These conditions were changed during the sedimentation of the Hředle Member (fluvial and deltaic deposits). Short time

DOI:https://doi.org/10.2312/zipe.1982.066

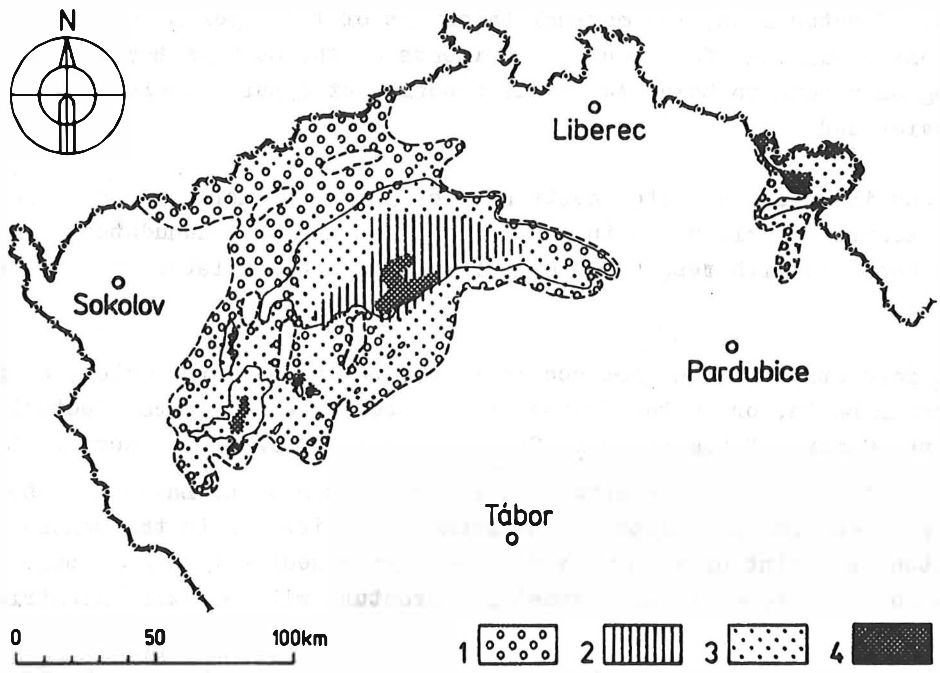


Fig. 4. Paleogeographical map of the Westphalian B-D
1 - alluvial apron and alluvial plain, 2 - prennial lakes and alluvial plain, 3 - alluvial plain, 4 - perennial lakes, swamps, alluvial and deltaic plain

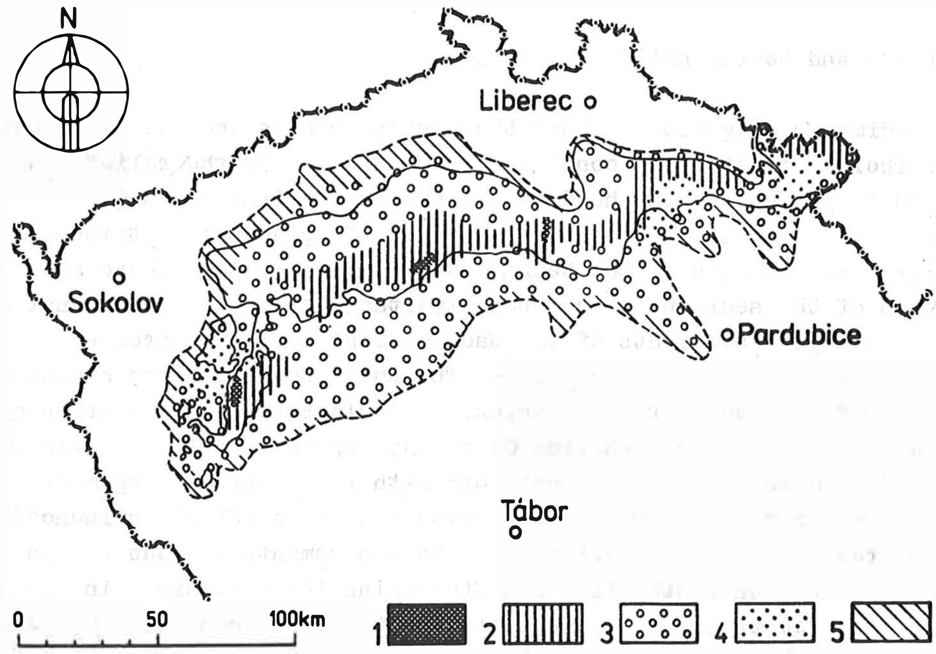


Fig. 5. Paleogeographical map of the Stephanian A (incl. Cantabrian)
1 - alluvial plain with local perennial swamps, 2 - alluvial plain with ephemeral lakes, 3 - alluvial apron and alluvial plain, 4 - alluvial plain, channel facies predominant, 5 - pediplain, alluvial fan, alluvial piedmont plain

DOI:https://doi.org/10.2312/zipe.1982.066

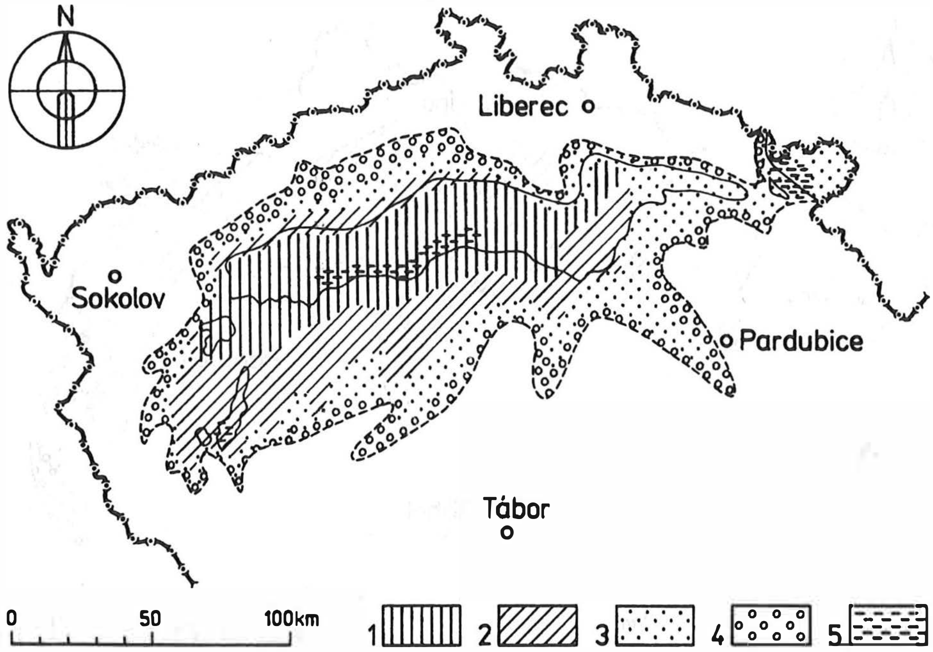


Fig. 6. Paleogeographical map of the Stephanian B

1 - perennial lake and alluvial or deltaic plain, 2 - alluvial plain and perennial lake, 3 - alluvial plain and alluvial fan, 4 - alluvial apron, 5 - swamp

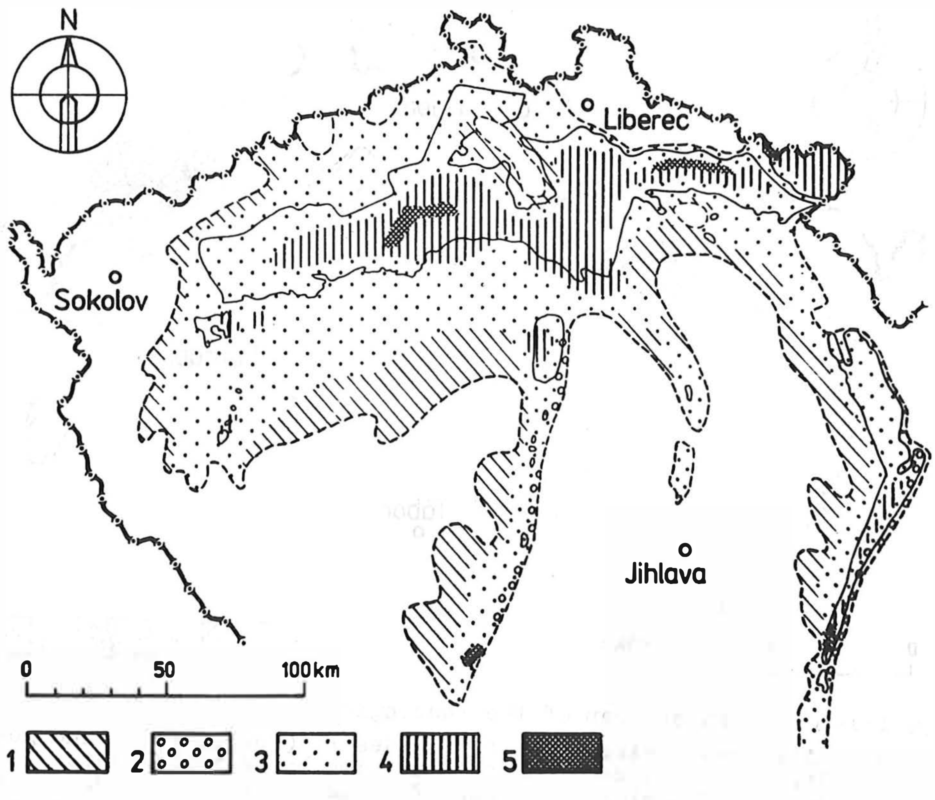


Fig. 7. Paleogeographical map of the Stephanian C - Autunian

1 - pediplain, 2 - alluvial fan, 3 - alluvial plain, 4 - alluvial plain with ephemeral lakes, 5 - alluvial plain with perrenial lakes and swamps

DOI:https://doi.org/10.2312/zipe.1982.066

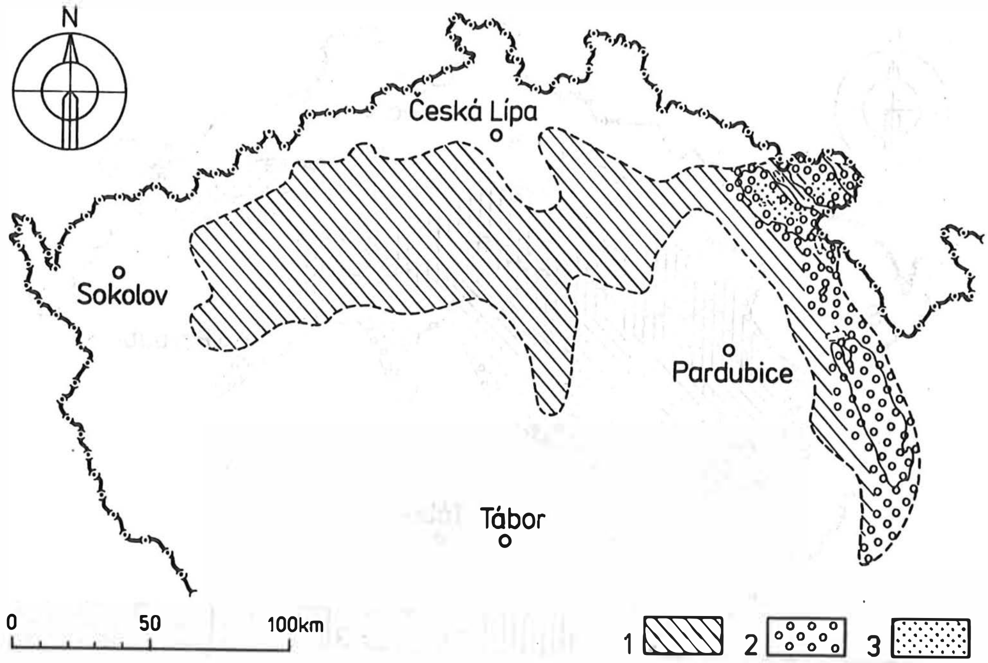


Fig. 8. Paleogeographical map of the Saxonian

1 - different environments of desert sedimentation (desert plains and gentle slopes covered from time to time by eolian or water-laid sediments, 2 - alluvial apron, 3 - alluvial plain with ephemeral lakes

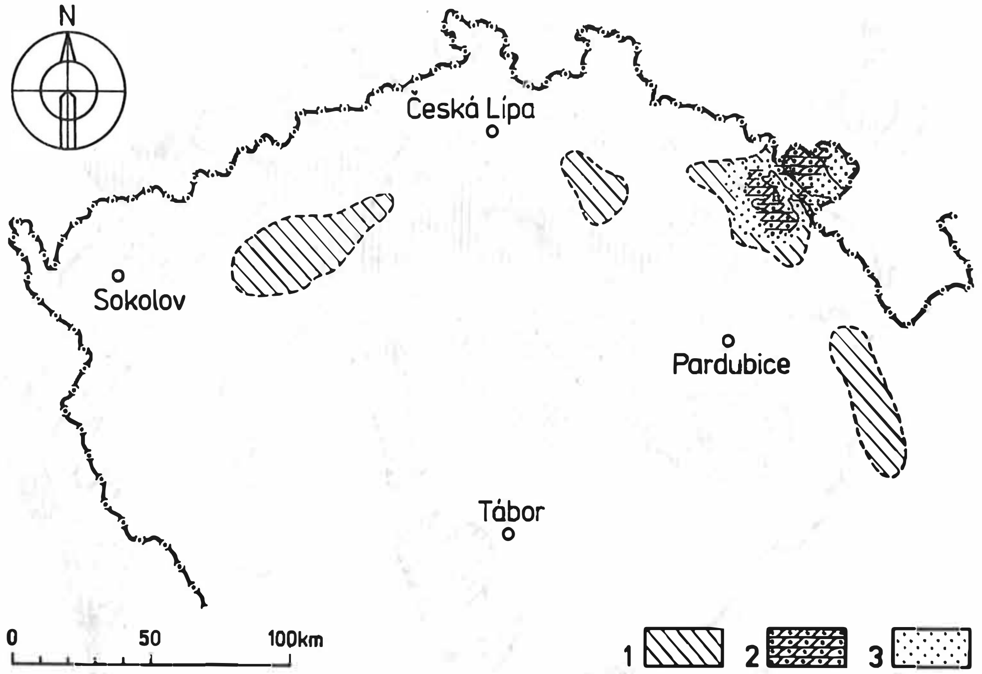


Fig. 9. Paleogeographical map of the Thuringian

1 - different environments of the desert (desert flats and gently sloping hills covered from time to time by eolian or water-laid sediments), 2 - alluvial plain of ephemeral water courses (carbonate cement common), 3 - alluvial plain of ephemeral streams (without carbonate cement)

DOI:https://doi.org/10.2312/zipe.1982.066

rejuvenation came into existence during sedimentation of the Ledce Member. The Kounov Member represents again certain stabilization of the sedimentation area (lake and paludial deposits). The sedimentation gap and change of paleogeographical conditions arose between sedimentation of the Slaný and Líně Formations. An enlargement of the sedimentation area and new paleogeographical and climatological regime came into being. In the Stephanian C and Lower Permian red beds sedimented. In the upper part the eolian deposits came into existence. In the Autunian (probable in its upper part) the sedimentation terminated with respect to the Saalian Phase which was connected with arching of the Massif core part and shifting of sedimentation to the periphery.

Volcanic activity

The Permo-Carboniferous basins of the Central Bohemian Region belong to the areas with rich volcanic activity which was predominantly of explosive character. The abundant tuffaceous layers occurring in a lot of horizons of the stratigraphic sequence are demonstrable evidences. Volcanic activity is mostly of rhyolitic character. In the time span of uppermost Stephanian and in the Lower Permian several lava sheets occurred (basic to intermediate types - basaltoids and andesitoids).

Volcanic activity passes in the following three time intervals: The oldest volcanic cycle took place during the Westphalian B and C, with after-effects during the lower part of the Westphalian D. In this period the oldest eruptions of so called Teplice rhyolitic complex came into being, which has a polyphases origin. "Radnice Whetstone Horizon" is one of the most conspicuous tuffaceous horizons. It originated in the interval between deposition of the Lower and Upper Radnice Coals. Radnice Whetstone Horizon can be petrographically devided into lower part (sandy tuffs) and the upper part (lapilli tuffs and tuffites). Its thickness reaches several metres (in average of 3 - 6 metres). It displays huge lateral extension and very persistent development. It came into existence all over the Permo-Carboniferous of the Central and Western Bohemia. The tuffaceous intercalations of the Main Radnice Coal Seam have the regular development. - The following stage of eruption development came into being in the period of Lubná Horizon deposition, its regional maximum displayed in the Rakovník area. During the predominant part of the Westphalian D (deposition of the Nýřany Member) and during the sedimentation of the Týnec Formation an interval without volcanic activity occurred. In that time span rare thin tuffaceous layers originated.

During the Stephanian B the next period with mass eruptions of tuffaceous rocks arose. It is manifested by many beds of rhyolitic tuffs and tuffites, especially during the sedimentation of the Jelenice, Mšec and Kounov Members.

The third period with a rich volcanic activity passed through the sedimentation of the Líně Formation. Besides of tuffaceous beds, which came into existence in connection with a rhyolitic volcanism and rarely with a basic one, the extrusions of lavas of basic to intermediate type (basaltoid and andesitic character) originated in the upper part of the strata.

DOI:https://doi.org/10.2312/zipe.1982.066

3. General charakterization of the type profile

The presented type profile demonstrates the filling of the Central Bohemian Permo-Carboniferous Basin. This basin includes Permo-Carboniferous continental basins in Western and Central Bohemia, and those underlying the Bohemian Cretaceous Basin till the Maršovice Bezděz Elevation, too. This elevation devides the mentioned region from the Sudeten. The stratigraphical range is defined from Westphalian B - C till Lower Permian. A rough stratigraphical division have been introduced by WEITHOFER (1896) and PETRASCHECK (1921-23) and is used till now. Several new modifications have been proposed later. In our profile there is applied that form, which is used in new geological maps.

The type profile has been constructed for the optimal development of the filling and is valid for all single and partial basins and denudation occurrences of the Permo-Carboniferous inside the respective area. The profile has been elaborated on the base of many boring-profiles, which have been made during last thirty years. Geological research has reached therefore detailed level. The profile of each lithostratigraphical unit represents an idealised profile of its most complete development. Various type of the relief, tectonic activity in the source areas and mobility of the basinal bottom are documented by various values of thickness, which are given in both limiting values. The thicknesses of oldest units are influenced by the period, when the sedimentation started.

Transport of detritus can be mostly characterized as short, at the basal sediments and at some younger deposits that originated on the base of sedimentary cycles as local; direction of transport has in mentioned area not been systematically measured. In the column of pebble composition there are shown the fundamental changes in a gravel fraction in various megacycles. The distinctive change of the source area (the Ore Mountains) is marked at the base of Líně Formation.

An age of the units has been proved by macrofossils and spores. The floral assemblages are decisive for the determination of the age of lithostratigraphical units. These assemblages occur in grey coloured sequences and coal-bearing horizons mostly and in grey and variegated horizons of red-beds sequences. These grey horizons represent more humid periods in the sequence. Faunal rests are not so abundant; the rests obtained are not modern biostratigraphically elaborated. The exact time when the sedimentation of the Late Paleozoic terminated has not been yet adduced.

Individual lithostratigraphical units are in profile defined by characteristic lithotypes and by percentual proportion of sediments and volcanics. Individual units (formations and members) are determined in that way as corresponding to sedimentary cycles of high order. Sedimentary gaps and places of unconformable stratification are given in the profile as well. They represent periods with raised tectonic activity, so as they are given in the chapter 2.

Cyclic sedimentation has been ascertained in all Permo-Carboniferous stratas and is schematically evidenced in the profile. The determined cycles are of various orders (two or three orders). In the whole sequence eight megacycles have been ascertained.

DOI:https://doi.org/10.2312/zipe.1982.066

Sedimentation conditions were dependent on the sedimentary environment and paleogeographical conditions. The basinal fillings belong mostly to the macrofacies as follows: fluvial, alluvial, lacustrine; volcanic facies has three maximums (Westphalian B - C), Stephanian B (lower part) and Stephanian C. Paludial, eluvial, colluvial and deluvial sediments are represented not too frequently. Rarely deltaic (during sedimentation of the Hředle Member) and eolian (partly during deposition of the youngest sediments of the Líně Formation) are present.

4. Charakterization of the stratigraphical units

With regard to the fact that certain migration of the sedimentary area took place during the deposition, the oldest units display the most complete development in the southern part of the basins, while the optimal development of the youngest units (Stephanian C and Lower Permian in age) can be found in the northern part. Some migration is documented in the direction from west to east as well. It demonstrates the fact that the Kladno-Plzeň Formation misses fast and the Týnec Formation is strongly reduced in eastern part of the sedimentary area (the Mšeno Basin). Some smaller occurrences contain limited successions only, these usually represent oldest sediments of the basinal fills (usually only a part of the Kladno-Plzeň Formation.

4.1. Stratigraphy and lithology

Kladno-Plzeň Formation

The Kladno-Plzeň Formation (PETRASCHECK 1921-23) or Lower Grey Formation (WEITHOFER 1896) or Formation No. 1 is formed by grey conglomerates and breccias, sandstones with arkosic proportion and arkoses, dark-grey siltstones, claystones, bituminous coal, intercalations of tuffogenous rocks and clay-carbonates, as well as tonsteins" grey and partly red and variegated basal breccias and conglomerates, aleuropelites with coarser clastic admixture form the fossil weathering mantle at the base of the Carboniferous. The sediments display distinct cyclic structure. Economically the Radnice Formation is the most important coal-bearing formation of the entire sequence. Its constituent members are those of Radnice and Nýřany.

The R a d n i c e M e m b e r usually commences with a suite of basal clastics, several tens of metres thick. The filling of basal depressions began with these clastics. The basal part of the Radnice Member contains the Plzeň seams which are described from the Plzeň District and rather insignificant from the point of exploitation view. It is followed by the Radnice Seam Group containing two mineable coals. The Lower Radnice Seam (also the Basal Kladno Seam) was formed in local depressions, its thickness in the Kladno Basin being on the average 1 - 1.5 m. The subsequent and regionally very important and chronostratigraphically significant "Whetstone Horizon" separates the Upper Radnice Seam from the Lower one. It is composed of various types of acid tuffaceous rocks (at the base a typical development of sandy material and higher up fined tuff layers and tuffites). The Whetstone Horizon is overlain by the Upper Radnice Seam (or Main Kladno Seam), pre-

DOI:https://doi.org/10.2312/zipe.1982.066

sently worked mainly in the Kladno area where the thickness in average is 6 - 8 m.

The Radnice seam group is overlain by the beds containing the Lubná Seam Horizon. It comprises several coal seams, beds of refractory claystones and tuffaceous strata. The Lubná Coal of Seams has been originally described from Rakovník area and will be exploited in the new coal district at Slaný.

The younger unit of the Kladno-Plzeň Formation is the N ý ř a n y M e m b e r of Westphalian D age. At its base a complex of conglomerates, sandstones and arkoses occurs. It is fairly conspicuous in places and is known as the Mirošov Arkoses. The Nýřany Group of coal seams are workable especially in the Plzeň Basin.

Týnec Formation

The Týnec (Lower Red) Formation (Formation No. II) consists mostly of red and variegated clastic sediments. Unfortunatelly, it does not contain any conspicuous and laterally stable lithological markers which allow a more detailed regional subdivision. Impersistent thin coals are sometimes present.

Slaný Formation

The Slaný (Upper Grey) Formation (Formation No. III) can be subdivided into subordinate lithostratigraphic units. The basal unit is represented by the J e l e n i c e M e m b e r . In the Mšeno and Plzeň basins, this member contains coal seams. Tuffaceous rocks (crystalline tonsteins) form partings in the coal bearing beds.

From the point of correlation view, the M š e c M e m b e r is the most important unit being most persistent lithological horizon of all basins of the Central Bohemian Region. It originated in an extensive and relatively deep lake which accumulated grey-black mudstones with a low content of bituminous material and with abundant organic remains among which fish scales and coprolites predominate. The Mšec Member contains a number of layers of argillitized acid tuffs, which are usually fine laminated. After the nature of the laminae they can be regarded as having been formed at the rate of one lamina per year so that they represent varvites (according to SKOČEK 1968).

The H ř e d l e M e m b e r is composed of rapidly alternating siltstones, sandstones and mudstones, showing a marked lamination. They were formed in a fluviatile to lacustrine-fluviatile (deltaic) environment. Some authors (e.g. NĚMEJC 1934; PEŠEK 1968) join the Mšec and Hředle Members into one unit (Malesice Member).

The L e d c e M e m b e r consinsts of psammitic deposits of alluvial origin.

The K o u n o v M e m b e r includes the Kounov Seam Group which is composed of lower and upper seam horizon. The coals are discontinuous and occur over certain parts of the area of sedimenation only (esp. in the Kladno and Rakovník Basins). Nevertheless, all over the area there it is possible to recognize at least the barren representatives of this coals.

DOI:https://doi.org/10.2312/zipe.1982.066

The youngest unit of the Slaný Formation, the Kamenný Most Member, originated in the Kladno and Rakovník Basins only; in other basins a sedimentation gap came into existence during the deposition of this unit.

Líně Formation

Líně (Upper Red) Formation (Formation No. IV) contains a sequence of red and variegated rocks with grey horizons, which are significant for correlation. The rocks of lacustrine origin contain freshwater limestones, cherts and especially, tuffaceous rocks (kaolinized and montmorillonitized sandy to lapilli-grade rhyolitic tuffs and tuffites attesting to a synchronous volcanism). In grey horizons thin coal seams appear. The lacustrine limestones and mudstones carry small remains of freshwater fauna (lamellibranchs, conchostraca etc.).

The Carboniferous-Permian boundary is placed within the Líně Formation, the lower part being considered as Stephanian C and the upper part as lower Autunian. These age attributions are based on the geological data interpretation and on the correlation with the Permian strata in the Sudetic region.

4.2. Paleontology

Biostratigraphy of this area is based on the fossil flora assemblages, which are very rich in grey coloured sequences, especially in coal-bearing stratas. Palynological studies are also of great importance. Lacustrine deposits display fauna remains, which have not been studied systematically (especially in carbonates and calcitic aleuropelites). Paleontological investigations dates from the early 19th century onwards.

The flora of the Radnice Member is very rich and is generally considered as characteristic of Westphalian C; HAVLENA (1964) regarded the flora of the horizon of the Upper Radnice Seam as representing the Westphalian B/C boundary, and therefore the lower part of the Radnice Member is assigned to the upper Westphalian B.

The fossil floral rests from the Nýřany Member, best known from the north-western limb of the Kladno Basin and from the Plzeň Basin, contain an assemblage giving evidence for the Westphalian D age.

The Týnec Formation contains well marked Stephanian flora which was assigned to the Stephanian A age, but which, according to R. WAGNER (1977), may be later in age, probably upper Stephanian B. Plant fossils occur mainly in grey intercalations and rarely in the red-coloured beds.

The Slaný Formation contains several horizons rich in fossil flora (especially in coal-bearing intervals). The assemblages are all similar and are clearly Stephanianmin character. It is assigned to the Stephanian B. In the seam horizon of the Jelenice Member a rich Stephanian flora occurs, which does not differ from those found in the top part of the Slaný Formation. The coal seams of the Jelenice Member have also yielded abundant

DOI:https://doi.org/10.2312/zipe.1982.066

spores. Lacustrine shales contain faunal remains of the groups Conchostraca, Lamellibranchiata and Pisces. The Mšec Member contain abundant organic remains among which fish scales and coprolites predominate. The plant remains are small and they are found dispersed in various localities within the extensive lake, having been transported by slow moving currents.

The plant remains of the Hředle Member are analogous to those found in the preceding units, except for small difference which can be attributed to different habitats from which part of the plant material was derived. - The Ledce Member is almost devoid of fossil rests.

During the sedimentation of the Kounov Member good conditions existed in many areas for the deposition of plant remains. Faunal remains have been recovered from lacustrine shales, and the formation has also yielded spore assemblages of Stephanian character.

The Stephanian part of the Líně Formation contains, as in the Týnec Formation, a much smaller percentage of plant fossils in the red sediments than in grey or differently variegated layers. In the red deposits small Walchia fragments are almost the only plant fossil preserved. From the other sediments, and especially from the grey layers, the common species of the Slaný Formation are recorded. Relatively much more remains of fossil fauna are present (Pisces, Insects, Lamellibranchs, Ostracods, Conchostraca et cet.).

5. Conclusions

The Permo-Carboniferous basins of the Central and Western Bohemia lie unconformably on the folded Early Paleozoic and Proterozoic rocks of the Teplá-Barrandian region as well as on granitoid intrusives of Variscan and pre-Variscan age.

Sedimentation occurred in the Central Bohemian Permo-Carboniferous Region in megafolded structures of the basement, partly came into being in tectonical predisposed trenches, but not simultaneously. The gradual beginning of sedimentation can be followed in various places of the basins, where it occurred partly by overlapping of the younger units over underlying elevations inside of basins, which morphologically devided the entire sedimentary area at the beginning of sedimentation, partly by shifting of the sedimentary area generally northwards and north-eastwards. The origin of the Central Bohemian Permo-Carboniferous was provoked by early sub-Asturian Phase. Their sedimentary area extended northwestward, northward and northeastward of the "Core area of the massif", which is the assyntian consolidated central block of the massif.

Originally separated sedimentary areas joined together in the later evolution (during the Stephanian, largest was during Stephanian C to Lower Autunian).

Deposition originated in the post-geosynclinal phase of the Variscan orogenic cycle. The basinal fillings are to be considered as molassoid fills in intramontane depressions formed after the Variscan fold movements.

DOI:https://doi.org/10.2312/zipe.1982.066

The basinal fills consists mainly of clastic sediments representing a periodic influx from the denuded part of the crystalline massives in the neighbourhood source areas. They are characterized by a cyclic sedimentation. Coal-bearing nature of these fills reflect the gradual decrease in humidity of the climate which shows gradually sparser intervals of precipitation, particularly during the upper Stephanian and Permian times. During the more humid intervals mainly grey formations with coal seams were deposited, whilst during the arid intervals of the Carboniferous reddish brown formations arose (a variegated facies including proper beds). Four times regular changes of coloration of the fill based the division into the two grey and two red formations. This division arosed at the end of the 19th century and has been valid till recent time, when the division based on regional names of the lithostratigraphical units was introduced.

The sedimentation of the Late Paleozoic of the Central Bohemian region was associated with outpouring of acidic and basic lavas. Volcanic activity of this region has been predominantly characterized by explosive volcanoes of acidic type, in the upper part of the fill (in Stephanian and Permian) the basic and intermediate types occurred too.

The history of the basinal filling terminated during the Lower Permian. Basinal fills have been substantially influenced by synsedimentary tectonical movements, that enabled the origin of relatively very thick sediment accumulations on the small sedimentary areas with relatively thick coal seams. The tectogenetical history of the basin terminated during the Saxonic tectogenesis, which appeared by radial faults, especially at the marginal parts of the sedimentary basins. Many of recent occurrences have been saved till now through intensive radial faults.

References

ČEPEK, L.: Kamenouhelná pánev u Břas.
Čas. nár. Muz., odd. přírodověd., Praha 105 (1931), p. 23-24

ČEPEK, L.: Vysvětlivky ke geologické mapě Československé republiky, list Kladno 3952, A.VI. Permokarbon, B.III. Pohercynská tektonika, C.II. Kamenné uhlí.
Knih. Stát. geol. Úst. Čs. Republ., Praha 17 (1936), p. 46-63, p. 84-87, p. 94-109

ČEPEK, L.: Vysvětlivky ke geologické mapě protekterátu Čechy a Morava, list Kralovice 4051, A.V. Permokarbon, B.III. Pohercynská tektonika, C.III. Kamenné uhlí.
Knih. geol. Úst. pro Čechy i Moravu, Praha 19 (1940), p. 41-65, p. 75-80, p. 87-122

FEISTMANTEL, K.: Die Steinkohlenbecken bei Přilep, Lisek, Stilec, Holoubkau, Mireschau, und Letkov.
Arch. naturwiss. Landesdurchforsch. Böhmens, Praha 2 (1877), Abt. 2, Teil 1, p. 19-98

FEISTMANTEL, K.: Der Hangendflözzug im Schlan-Rakonitzer Steinkohlenbecken.
Arch. naturwiss. Landesdurchforsch. Böhmen, Praha 4/6, p. 1-113

FEISTMANTEL, K.: Die mittelböhmische Steinkohlenablagerung.
Arch. naturwiss. Landesdurchforsch. Böhmen, Praha 5 (1883), geol. Abt. 3, p. 1-100

FEISTMANTEL, O.: Über das Verhältnis der böhmischen Steinkohlen- zur Permformation.
Jb. K.-Kön. geol. Reichsanst., Wien 23 (1883), p. 249-282

FEISTMANTEL, O.: Steinkohlen- und Perm-Ablagerungen im Nord-Westen von Prag.
Abh. deutsch. Ges. Wiss. Künste Prag, Praha 6 (1873) 6, p. 1-111

DOI:https://doi.org/10.2312/zipe.1982.066

FEISTMANTEL, O.: Studien im Gebiete des Kohlengebirges von Böhmen.
Abh. deutsch. Ges. Wiss. Künste Prag, Praha 6 (1874), 7, p. 1-177

FEISTMANTEL, O.: Die Versteinerungen der böhmischen Ablagerungen.
Palaeontographica, Cassel 23 (1874-76), p. 1-156, 173-316

HAVLENA, V.: Geologie uhelných ložisek, 2.
Praha: Nakl. Čs. Akad. věd 1964, 437 p.

HAVLENA, V.: Die späteren Entwicklungsetappen der Varisziden und die jungpaläozoischen Ablagerungen des Böhmischen Massivs.
N. Jb. Geol. Paläont., Mh., Stuttgart (1971), p. 65-91

HAVLENA, V.: Einteilung der kohlenführenden variszischen Ablagerungsräume und deren Auffüllungen.
C. R. 7. Congr. Int. Stratigr., Géol. Carbonif., Krefeld 1 (1974), 169-188

HOLUB, V.: Permokarbon v podloží křídy na Mělnicku (Permokarbon im Untergrund der Kreideablagerungen im Gebiet von Mělník).
Sborn. geol. Věd, R. Geol., Praha 9 (1965), p. 89-98

HOLUB, V.: Late Palaeozoic Deposits Underlying the Bohemian Cretaceous Basin in the North-eastern Part of the Bohemian Massif.
C. R. 6. Congr. Int. Stratigr. Géol. Carbonif., Sheffield (1967), p. 937-948

HOLUB, V.: Permian of the Bohemian Massif. - In: FALKE, H.: Rotliegend Essays on European Lower Permian.
Leiden: Brill (Holland), 1972, p. 137-188

HOLUB, V.: The Permo-Carboniferous continental basins of Bohemia and Moravia. - In: HOLUB, V.; WAGNER, R.H. (Edit.): Symposium on Carboniferous Stratigraphy (SCCS), Field and General Meeting, Czechoslovakia, September 17-27, 1973.
Praha: Vyd. ÚÚG, p. 205-231

HOLUB, V.; OBRHEL, J.: Profil karbonskou pánví u Malých Přílep ssv. od Berouna (Profil durch das Karbonbecken bei Malé Přílepy NNW von Beroun, Böhmen).
Čas. Mineral. Geol., Praha 12 (1967), p. 271-276

HOLUB, V.; SKOČEK, V.; TÁSLER, R.: Palaeogeography of the Late Palaeozoic in the Bohemian Massif.
Palaeogeogr., Palaeoclimat., Palaeoecol., Amsterdam 18 (1975), p. 313-332

HOLUB, V.; TÁSLER, R.: Mladší paleozoikum a spodní trias v podloží česke křídové pánve.
In: MALKOVSKÝ, M. et. al.: Podloží české křídy.
MS Geofond Praha

HOLUB, V.; TÁSLER, R.: Filling of the Late Palaeozoic continental basins in the Bohemian Massif as a record of their palaeogeographical development.
Geol. Rsch., Stuttgart 67 (1978), p. 91-109

KUŠTA, J.: Další příspěvky k seznání středočeského karbonu a permu.
Rozpr. Čes. Akad. Věd Cís. Františka Josefa Vědy, Slovesn. Umění, Tř. 2, math.-přírodn. 9/39, Praha (1900), p. 1-39

NĚMEJC, F.: A revision of the Carboniferous and Permian flora of the coal-districts of Central Bohemia. I. The Noeggerathiae and Archeopterides in the coal basins of Central Bohemia.
Palaeontographica Bohem., Praha 12 (1928), p. 1-82

NĚMEJC, F.: A revision of the Carboniferous and Permian floras of the coal-districts of Central Bohemia. II. Sphenopterides, A. Coenopteridae.
Palaeontographica Bohem., Praha 16 (1938), p. 1-56

NĚMEJC, F.: The Pecopterides of the coal districts of Bohemia.
Sbor. Nár. Mus. v Praze, Ř.B. přírodn. vědy, Praha 2 (1940) 1, p. 1-28

NĚMEJC, F.: Contributions to the stratigraphy of the Carboniferous and Permian of Bohemia.
St. geol. Úst., Praha 13 (1946), p. 207-257

NĚMEJC, F.: The Lepidodendraceae of the coal-districts of Central Bohemia.
Sbor. Nár. Mus. v Praze, Ř. B. přírodn. vědy, Praha 3 (1947) 2, p. 45-87

DOI:https://doi.org/10.2312/zipe.1982.066

NĚMEJC, F.: Paleobotanical and stratigraphical studies in the eastern corner of the coalfield of Kladno and Rakovník.
Sbor. Stát. geol. Úst., Praha 14 (1947), 361-416

NĚMEJC, F.: Odontopterides and Mixoneurae of the Permo-Carboniferous of Bohemia.
Sbor. Nár. Mus. v Praze, Ř. B. přír. vědy, Praha 5 (1949) 1, p. 1-32

NĚMEJC, F.: Studies on the Sigillariae of the Lower Grey Beds of the Carboniferous in Central Bohemia.
Sbor. Nár. Mus. v Praze, Ř. B. přír. vědy, Praha 7 (1951), 1-59

NĚMEJC, F.: On some more detailed problems in the stratigraphy of limnic Permocarboniferous basins of Bohemia and Moravia.
C. R. 3. Congr. Carbonif. Heerlen 1951, Maastricht (1952), p. 475-481

NĚMEJC, F.: Úvod do floristické stratigrafie kamenouhelných oblastí ČSR.
Praha: Nakl. Čs. Akad. Věd 1953, 173 p.

NĚMEJC, F.: A contribution to the problem of the II. and IV. Permocarboniferous Zone in the northern part of the coal basin of Plzeň.
Sbor. Ústř. Úst. geol., odd. paleont., Praha 23 (1957), p. 7-51

NĚMEJC, F.: Studies in the biostratigraphy of the Plzeň coal basin.
Rozpr. Čs. Akad. Věd, Ř. mat.-přír. věd, Praha 68 (1958) 4, p. 1-58

NĚMEJC, F.: Remarks on the dividing line between the Stephanian and the Lower Permian in Bohemia and Moravia.
Čas. Mineral. Geol., Praha 5 (1960), p. 452-455

NĚMEJC, F.: Paleofloristical problems relating to the Stephanian of the Plzeň coal basin in the light of the newest geological records.
Čas. Mineral. Geol., Praha 7 (1962), p. 52-58

NĚMEJC, F.: Stephanian floras in the coal-districts of the Czechoslovakia in the light of new investigations.
The Palaeobotanist, Lucknow, India 14 (1966), p. 70-72

OBRHEL, J.: Entwurf der eingehenden stratigraphischen Einteilung des oberen grauen Schichtenkomplexes im Kladno-Rakovník-Becken.
Věst. Ústř. Úst. geol., Praha 33 (1958), p. 370-373

ORLOV, A.: Die Sedimente des Flözzuges im Kladnoer Steinkohlenbecken.
Zpr. geol. Úst. pro Čechy a Moravu, Praha 17 (1942), p. 221-253

ORLOV, A.: Über die Zwischenmittel des Radnitzer Kohlenflözzuges im Bschaser Steinkohlenbecken.
Zpr. geol. Úst. pro Čechy a Moravu, Praha 18 (1943), p. 1-21

ORLOV, A.: Kaolinické jílovce (lupky) středočeských kamenouhelných pánví.
Rozpr. Čs. Akad. Věd, Ř. mat.-přír. Vid, Praha 54 (14) (1944) 2, p. 1-30

PEŠEK, J.: Geologická stavba a vývoj sedimentů plzeňské černouhelné pánve (Geologischer Bau und Entwicklung der Ablagerungen des Plzeň-Steinkohlenbeckens).
Sbor. Západočes. Muz. Odd. Přír., Plzeň 2 (1968), p. 1-110

PETRASCHECK, W.: Kohlengeologie der österreichischen Teilstaaten. I. Die kohlenführenden Formationen, III. Die mittel- und westböhmischen Steinkohlenbecken.
Berg- u. hüttenmänn. Jb. Montan. Hochsch. Leoben, Wien (1921-23) 1, p. 69-70, 2, p. 1-20, 3, p. 69-70, 4, p. 1-54

STERNBERG, C.: Versuch einer geognostisch-botanischen Darstellung der Flora der Vorwelt.
Regensburg, Leipzig, Praha 1828-1830

SVOBODA, J. et al.: Regional Geology of Czechoslovakia. I. The Bohemian Massif.
Praha: Nakl. Čs. Akad. Věd 166

ŠETLÍK, J.: Recherches paléontologiques et stratigraphiques sur le Stéphanien de la Bohême Centrale et de la Moravie.
Sbor. Ústř. Úst. geol., Praha 18 (1951), p. 437-448

DOI:https://doi.org/10.2312/zipe.1982.066

ŠETLÍK, J.: Příspěvek k fytopaleontologickému výzkumu nýřanských vrstev. Zpr. geol. Výzk. (Ústr. Úst. geol.), v r. 1961, Praha (1962), p. 97-98

ŠETLÍK, J.: Etapes de l'évolution de la flore carbonifére dans la Bohême occidentale, centrale et nord-orientale. C.R. 7. Congr. Int. Stratigr., Géol. Carbonif., Krefeld (1971)

ŠETLÍK, J.: Results of recent investigations on the Carboniferous flora of Bohemia. In: HOLUB, V.; WAGNER, R.H. (Edit.): Symposium on Carboniferous Stratigraphy (SCCS), Field and General Meeting, Czechoslovakia, September 17-27, 1973. Praha: Vyd. ÚÚG 1977, p. 315-340

Explanatory Notes to the Lithotectonic Molasse Profile of the Blanice Furrow (Bohemian Massif, ČSSR; Carboniferous - Permian) (Comment to Annex 26)

by

V. HOLUB

Summary

The Blanice Furrow belongs to the group of the Late Paleozoic basins which originated as elongate depressions trending NNE--SSW through the Bohemian Massif. Designation of the term furrow is limited on the one hand tectonically (narrow basins of meridian direction on line of tectonic weakness in the crystalline basement with western longer and slow limb and with coal sedimentation and with basinal axis approaching the eastern margin that displays usually of tectonic character), on the other hand through the age of the origin of the basinal fill being bound to the Asturian movements. The Blanice Furrow in the central part of the Massif came into existence in the north between the igneous rocks of the Central Bohemian Pluton and the Kutná Hora crystalline area belonging to the Moldanubian. The occurrences of the Permo-Carboniferous of the Blanice Furrow are situated in the tract passing from Český Brod (in the north) to České Budějovice (in the south). - Sedimentation set in during Stephanian C times (the Peklov Member), mostly as grey sediments containing lower coal horizon. Sedimentation continued without interruption into lower Autunian (the Lhotice Member with upper coal horizon). The Chýnov Member is a sequence of rocks of the red-beds type; it originated after small sedimentation gap in the upper part of the lower Autunian. The Bulánka Member came into being during the upper Autunian mostly as a marginal facies after tectonic movements corresponding to the Saalian subphase. - From the paleogeographical point of view sediments of fluvial (especially in the lower part of basinal fills) and lacustrine environments are represented; alluvial fan sediments occur substantially more during the Autunian period. As far tectonic point of view synsedimentary movements were very intensive in spite of small extent of the sedimentary area the thickness exceeds one thousand metres. Radial faults and tangential deformations originated predominantly even shortly after termination of sedimentary process during Variscan movements before sedimentation of the Cretaceous.

The full explanatory text will be published in a forthcoming additional compilation of molasse profiles.

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Explanatory Notes to Lithotectonic Profiles of the Variscan Molasse in the Czechoslovakian West Carpathians (Comment to Annex 27 - 30)

by

ANNA VOZÁROVÁ[1]

1. Introduction

The West Carpathians are a complicated mountain system with Alpine nappe structure. Information on the Variscan cycle of development is provided by fragments of Early and Late Variscan formations which were incorporated in the Alpine structural plan. They are represented in the tectonic units Tatric, Veporic, Gemeric, Hronic, Zemplinic (in the sense of division of tectonic units according to ANDRUSOV et al. 1973).

The analysis of the Variscan molasse formations shows that in the time of the Late Variscan cycle of development two structurally different regions existed, which passed through a different history also in the stage of the Early Variscan development. They were the Tatraveporide zone of the type of mobile platform and the geosynclinal Gemeride zone. On the fundament of these two structural zones three sedimentation areas formed - the northern, central and southern sedimentation zone (VOZÁROVÁ and VOZÁR 1975), in which molasse formations accumulated (Figs 1,2).

The Variscan molasse sedimentation zones may be divided in space and time. The most complete and also oldest sedimentary sequences are preserved in the central sedimentation zone which was founded at the southern margin of the Tatraveporide block and at the northern margin of the Gemeride geosynclinal zone. It consisted of a system of trough-like basins which originated in three sections of time and were linked spatially with one another. The precise dimensions and morphology of these basins are not known because in the time of Alpine orogeny the central sedimentation zone underwent intense deformation. A complicated folded-sliced and nappe structure originated. The probable development of this whole sedimentation area is derived from the correlation analysis of preserved fragments.

[1] Geologický ústav Dionýza Štúra; Czechoslovakia, 80940 Bratislava, Mlynská dolina 1

DOI:https://doi.org/10.2312/zipe.1982.066

The central sedimentation zone was initially formed in a narrow trough-shaped basin which had been parallel with the principal Variscan geosyncline. Its origin may be put into connection with the Bretonian phase when probably the main trough started to get closed, in which manifestations of gabbro-diorite intrusive magmatism occured later and which process was probably terminated as late as the Sudetic phase. This syngeosynclinal marginal trough was filled up with clastic sediments, accompanied by volcanics of the andesite-basalt suite and by carbonates of bioherm type altered into magnesites in the terminal stage of development. This first stage of development of the basin was probably synchronous with the termination of Variscan geosynclinal development in the main trough. The following stage of development was in the time of the Westphalian A-B-C-D to Stephanian A. This period signifies definitive consolidation of the Gemeride block. The basal parts of Westphalian formations are resting discordantly on folded geosynclinal formations which were already metamorphosed and also included intrusive magmatic members (evidence in the material of pebbles of basal conglomerates - ROZLOZSNIK 1935; KRIST 1954; VOZÁROVÁ 1973). The sedimentary basin extended, however, it preserved the character of a linear stretched sedimentation zone bordered by faults, along which vertical movements took place. The filling of the marginal trough was predominantly marine, composed of clastics, basic volcanics, volcanoclastics and carbonates, too, in the Westphalian to Stephanian A. The Leonian phase was shown in the development of a paralic clastic formation. It terminated the sedimentation in the basin, which was active in the Visean - Namurian and Westphalian - Stephanian. After closing the sedimentation zone was thrust north, i.e. over the Tatraveporide block. Its southern margin was fractured along a system of linear faults. The South Veporide, Zemplin and Hronic (Choč-Šturec) sedimentary basins were founded, the latter of which is of allochthonous position in the Alpine structure. In these basins paralic, grey-coloured formations of Stephanian age are developed.

Maximum development of the molasse basins began in the time of the Asturian phase, with generation of further sedimentary basins N and S of the central sedimentation zone. The northern sedimentation zone originated at the opposite northern margin of the Tatraveporide block and the southern sedimentation zone on the southern side of the Gemeride block. In general, varicoloured continental volcanosedimentary formations originated. The zone of most intense sedimentation was again the central sedimentation zone. In the Lower and Upper Permian the centre of sedimentation was in the Choč-Šturec sedimentation area, with intense andesite-basalt volcanism of TH-magmatic trend. In the Lower Permian the northern part of the Gemeride block became a sedimentation area again. This area is characterized by intense rhyolite-dacite volcanism of CA-Trend, with which also Permian granite plutonism coincides (KOVÁCH et al. 1979; KANTOR and RYBÁR 1979). In the central part of the central sedimentation area, in the Choč-Šturec area, was the zone of extension and, on the contrary, at its margins (North Gemeride and/or South Veporide sedimentation area) the process of shortening, with intensive manifestations of sialic volcanism, was taking place in the Permian. The northern sedimentation zone, situated on the Tatraveporide block, is typical in the development of a system of fault-bordered intracontinental basins of longitudinal shape. It was dissected by tectonic horsts which supplied clastic material to their close neighbourhood. The Tatraveporide block is characterized by intense granite plutonism. This structural phenomenon acted as a mobile platform in the period of the molasse stage of the Variscides.

DOI:https://doi.org/10.2312/zipe.1982.066

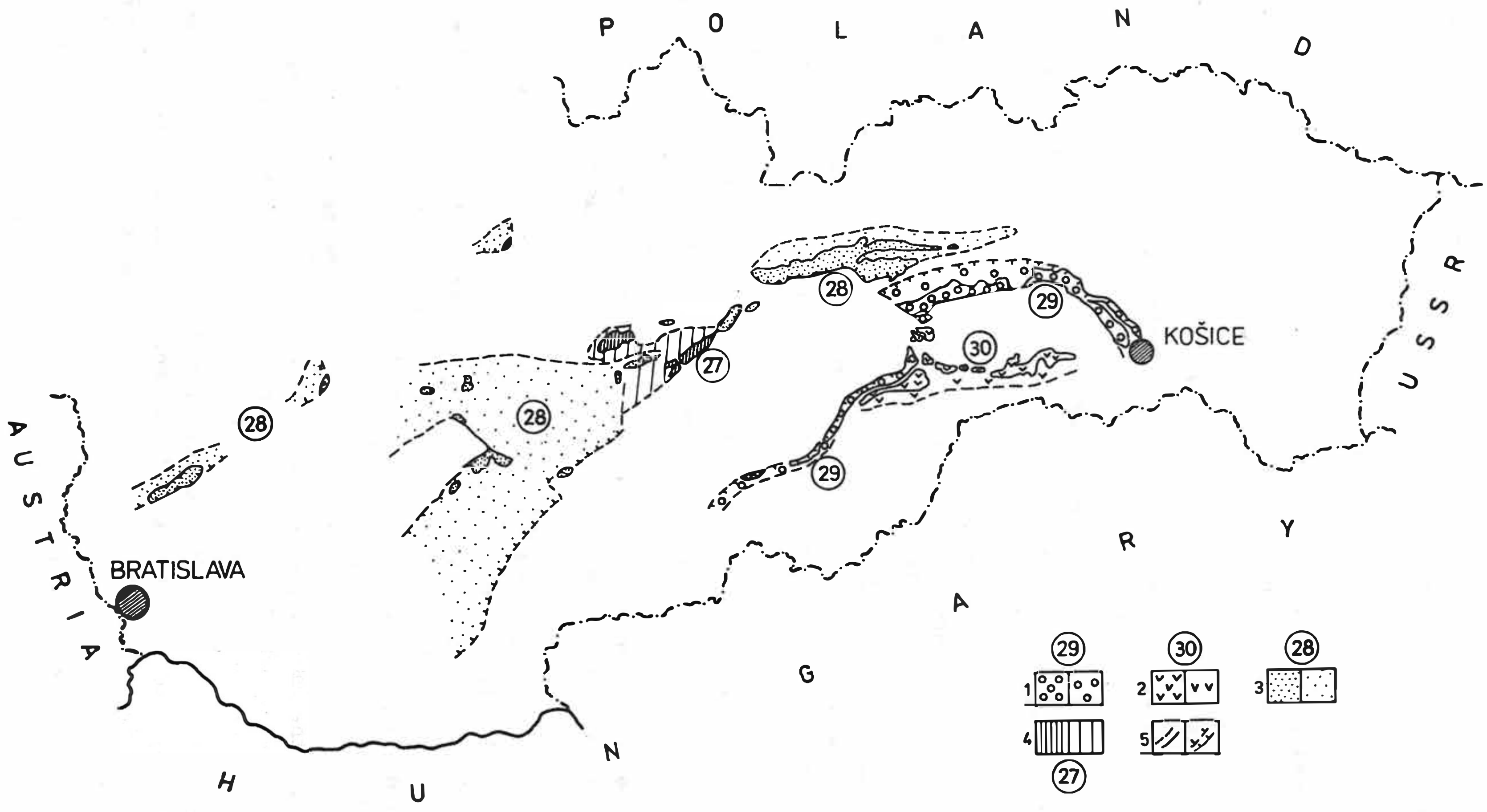


Fig. 1. Paleozoic molasses of the Czechoslovakian West Carpathians

1 - Paleozoic molasses of the North Gemeride basin (lithotectonic profile no. 29); 2 - Paleozoic molasses of the South Gemeride basin (lithotectonic profile no. 30); 3 - Paleozoic molasses of the Hronic (lithotectonic profile no. 28); 4 - Paleozoic molasses of the Lubietová (lithotectonic profile no. 27); 5 a - presumable confinement in basement and on surface; 5 b - overthrust lines

DOI:https://doi.org/10.2312/zipe.1982.066

The southern sedimentation zone was formed in the southern part of the Gemeride block in the time after the Asturian phase. It was founded at linear faults, parallel with the margin of the morphogene. At the base it contains continental volcano-sedimentary formations which are replaced by lagoonal - near-shore carbonate detrital formations.

The fundamental characteristic features of Variscan molasses of the West Carpathians may by summarized on the following points:

1. Absolute prevalence of detrital sediments, which are accompanied only by little amounts of evaporites, seldom by carbonates and thin coal seams.
2. Detrital material usually of low degree of maturity, derived from Variscan-folded mountains, often from nearest emerged areas.
3. Sediments of molasses are accompanied by volcanism, which also provided a considerable part of clastic detritus. Besides volcanics of ensialic character, as a consequence of formation of deep-seated faults reaching the mantle, also development of tholeitic trend (TH-trend) took place.
4. Variscan molasses of the West Carpathians often display cyclicity. Megacycles mainly play an important role in their lithostratigraphical subdivision.
5. The fundamental factors in formation of molasse sediments were river transportation and alluvial processes of sedimentation. Besides of that sedimentation took place in water basins of elongated shape of the type of large intracontinental lakes or shallow marine basins.
6. The prevailing mechanism were currents highly loaded with detrital material.
7. Geometric delimitation of molasse basins is of two types. In the northern sedimentation area basins of the type of intermontane depresions originated. The morphology of sedimentary basins of the central and southern sedimentation areas was of the character of throughs bordered by faults, oriented along the margin of the morphogene.
8. The Late Variscan development in the West Carpathians may be divided into three stages of development. The first stage (Postbretonian) of Visean`- Namurian age corresponds to a transitional stage between the geosynclinal and molasse development. The second stage (Postsudetic) of Westphalian - Stephanian age implies the commencing stage of development of molasses (perhaps it could correspond to early molasses in the sense of BUBNOFF 1949). - The third stage (Postasturian) is the period of development of the principal Variscan molasses in the West Carpathians. Already in that period the whole region of the Variscides was losing polarity which had been distinct in the period of the first and second stage and tectonic movements became more or less synchronous in the whole region.
9. Fading out vertical tectonic activity in the period of the Upper Permian to Lower Triassic was followed by gradual submersion of the whole Variscan-consolidated continent to the south and in the following time by transgression of the Triassic sea in direction from S to N.

DOI:https://doi.org/10.2312/zipe.1982.066

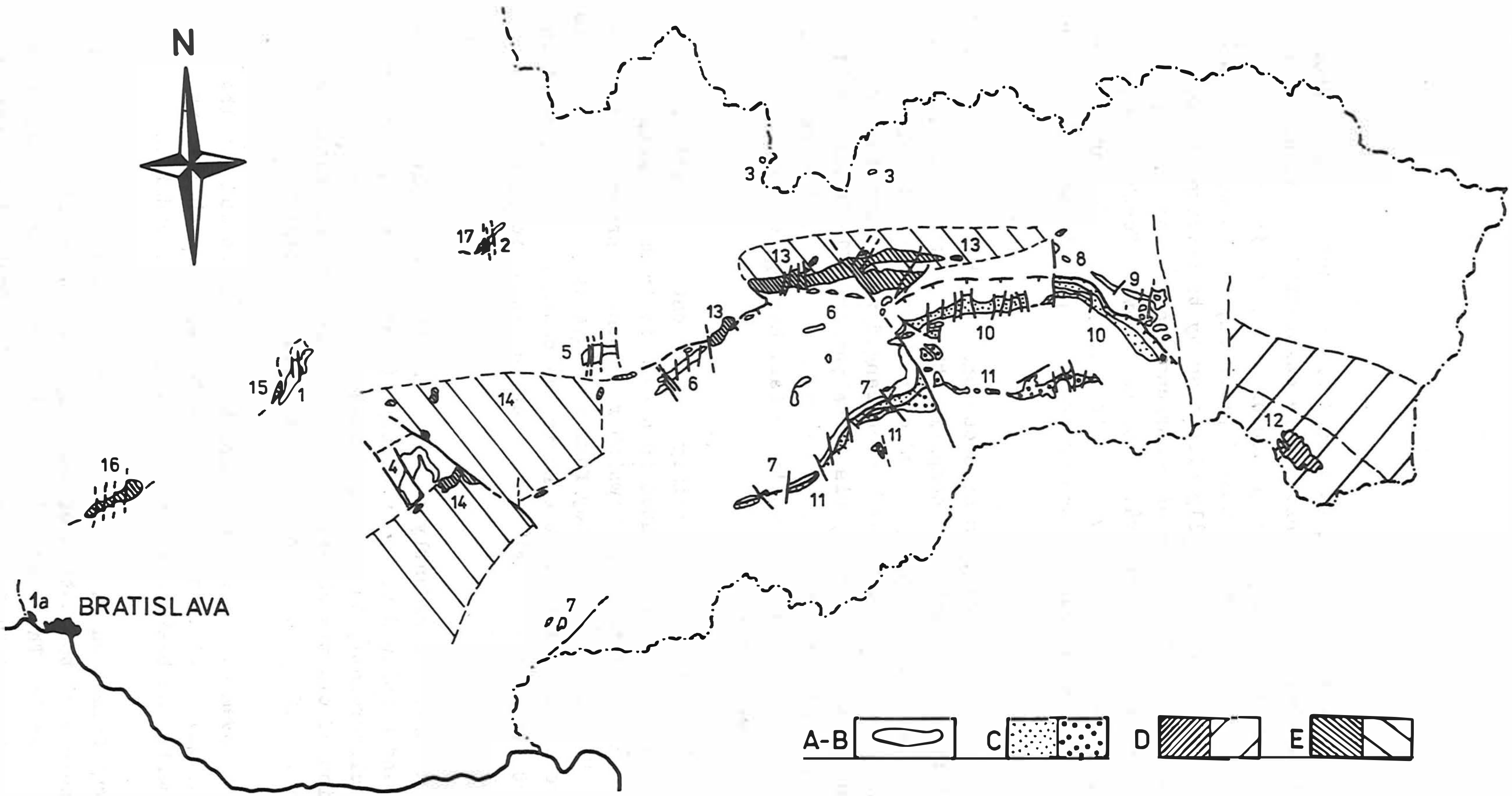


Fig. 2. Areas of Paleozoic molasses of the Czechoslovakian West Carpathians

A-B - Paleozoic molasses in the Tatric, Fatric and Veporic;
in the Tatric: 1 - Považský Inovec Mts., 1 a - Malé Karpaty Mts., 2 - Malá Fatra Mts., 3 - Vysoké Tatry Mts., 4 - Tríbeč Mts.,
in the Fatric: 5 - western part of the Nízke Tatry Mts.,
in the Veporic: 6 - northern part of the Veporské rudohorie Mts. and of the Nízke Tatry Mts., 7 - southern part of the Veporské rudohorie Mts., 8 - Branisko Mts., 9 - Čierna hora Mts.

C - Paleozoic molasses in the Gemeric: 10 - northern part of Spišsko-gemerské rudohorie Mts., 11 - southern part of Spišsko-gemerské rudohorie Mts.

D - Paleozoic molasses in the Zemplinic: 12 - Zemplínske vrchy Mts. and basement of Neogene in the East-Slovakia lowland.

E - Upper Carboniferous and Permian in allochthonous position in the Hronic (Choč nappe and/or Šturec nappe): 13 - Nízke Tatry Mts., 14 - Tríbeč Mts. and adjacent basement of the Neogene sediments and volcanic rocks, 15 - Považský Inovec Mts., 16 - Malé Karpaty Mts., 17 - Malá Fatra Mts.

DOI:https://doi.org/10.2312/zipe.1982.066

2. Ľubietová basin (Annex 27)

2.1. General features

The Ľubietová basin is situated at the northern border of the tectonic unit Veporic. The precise delimitation and morphology of the basin were destructed in the period of the Alpine orogeny. On the basis of preserved fragments of sediments it may be supposed that it was a sedimentary basin of the type of inner depression, of medium size, longitudinal shape, bordered by faults, morphologically dissected by transversal tectonic horsts. To the Ľubietová basin belong fragments of occurrences of the northern part of the Veporské rudohorie Mts. (Ľubietová-Podbrezová, SW of Ľubietová), further in the western part of the Nízke Tatry Mts. (Staré hory - Špania dolina - Baláže) and smaller occurrences of metamorphosed sediments found at the southern slopes of the Nízke Tatry Mts. (Jasenie, Jarabá).

The most completely preserved bed sequence is at occurrence in the area of Ľubietová - Podbrezová (Fig. 3), which serves as basis for compiling the lithotectonic profile. Stratigraphic assignment of sediments was mainly based on lithostratigraphical analyses and correlation studies. In general these complexes were ranged to the Permian (ZOUBEK 1936; KAMENICKÝ 1977). In the last time on the basis of palynology (PLANDEROVÁ in ILAVSKÝ et al. 1978) from the upper part of the complex Upper Permian was found. The basal parts of the complex have not been proved paleontologically so far. Most probably they correspond to the upper part of the Lower Permian.

The filling of the Ľubietová basin is formed mainly by sedimentary, clastic rocks. Volcanic and volcanoclastic members are represented in a relatively small amount. They occur in the area of Podbrozová - Ľubietová only, which represents a preserved fragment of the eastern margin of the Ľubietová basin. They form approximately 10 % of the whole volume of filling in this area. The filling of the Ľubietová basin in its northeastern part is dissected from the stratigraphic underlier to overlier into two lithostratigraphic units (VOZÁROVÁ 1979):

The basal Brusno formation rests discordantly on its substratum, a complex of crystalline schists, migmatites and granitoid rocks, probably of Early Paleozoic age. The Predajná formation overlaps discordantly the Brusno formation. This is proved by (1) changes in transport direction of clastic detritus and (2) change in composition of pebble material in conglomerates of the basal part of the Predajná formation.

Distinct vertical tectonic movements at the boundary between the periods of the sedimentation of both formations gave rise to new horst structures, which changed the water regime in the original sedimentation basin and also its borders and dimensions.

The thickness of the Brusno formation is estimated 100 to 750 m. It testifies to a considerable dissected morphology of the bottom of the original sedimentation basin, broken by faults into a horst mosaic. The Predajná formation reaches more stable thickness, about 300 - 450 m. The inner structure of sediments of the Brusno formation is characterized by weakly developed cyclicity. Cycles of the type of fining upward, typical of braided alluvium, with horizontal order of clastic particles with graded refinement of sandy particles in direction to upper parts of layers were established sporadically. In the cycles are missing almost totally finer aleuro-pelitic members. Mutual relations

DOI:https://doi.org/10.2312/zipe.1982.066

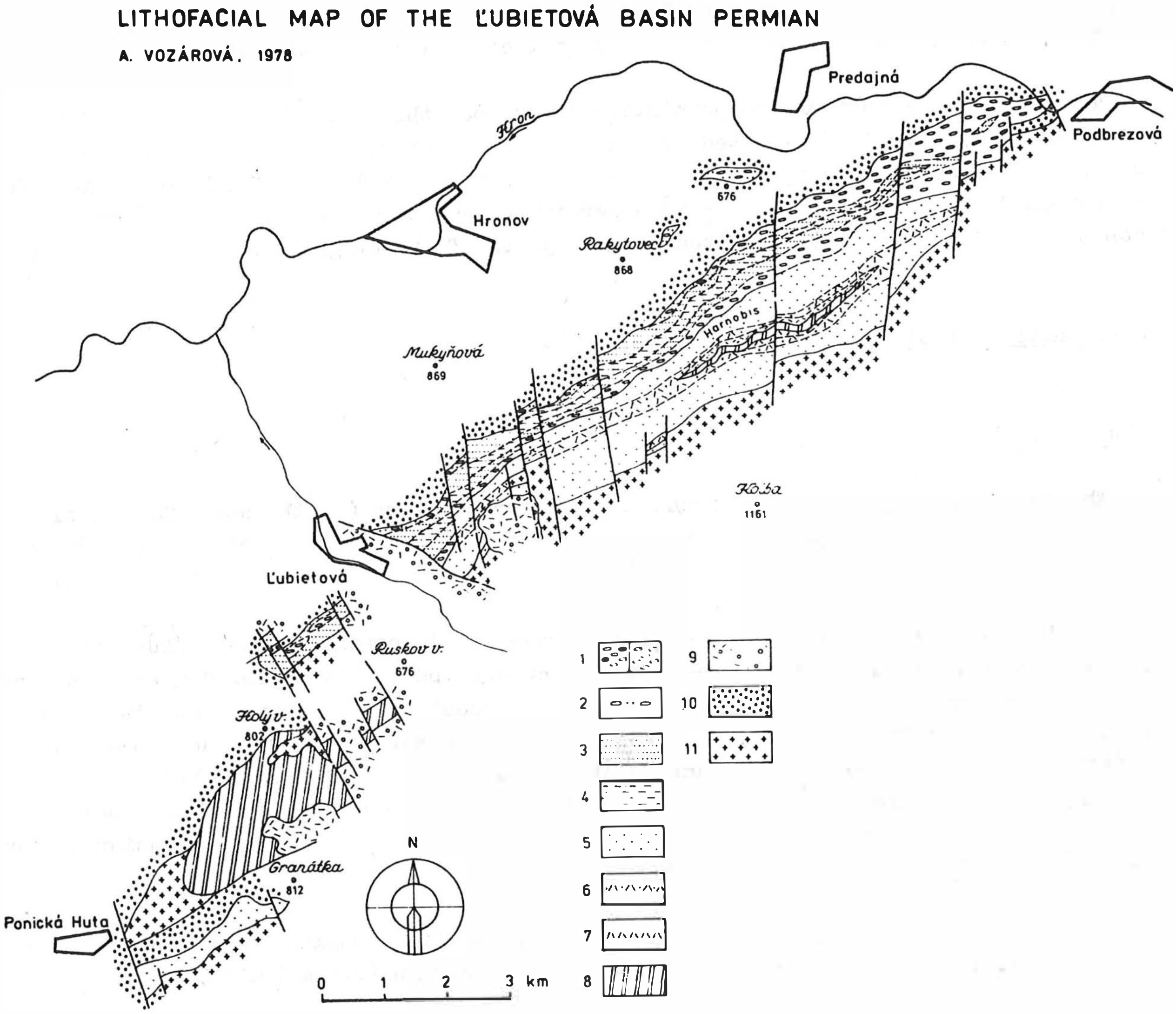


Fig. 3. Lithofacial map of the Permian in the NW part of the Ľubietová Basin

1...4 - sediments of the Predajná formation:
1 - polymict conglomerates, 2 - sandy conglomerates, 3 - lithic greywackes, 4 - sandy and aleuritic shales;
5...8 - sediments of the Brusno formation:
5 - feldspar greywackes, arcose wackes, greywackes with admixture of volcanogenic material, 6 - tuffitic sediments including the horizon with coarse fragments of dacites, 7 - tacite tuffs, 8 - dacites;
9 - Tertiary volcanics and sediments; 10 - Lower Triassic quartzites of the Mesozoic envelope group; 11 - Crystalline

DOI:https://doi.org/10.2312/zipe.1982.066

of particular sedimentary bodies are characterized by erosion wash-outs. The inner structure of the Predajná formation is typical with the development of megacycles. The megacycles reach orderly the size of 200 - 300 m. The Predajná formation is composed of two megacycles, the second megacycle is not completely preserved.

The sedimentary environment persisting throughout the sedimentation of both formations can be generally designated as continental of the type of braided alluvium but also with well-preserved facies of proluvial cones and proluvial inundation plain with occasionally originating lakes. A more permanent lacustrine sedimentary environment can be supposed in direction to the central parts of the original sedimentary basin.

2.2. Characteristic of the lithostratigraphic units

Brusno formation

The most important features of the Brusno formation are (1) the absolute prevalence of clastic sediments of psammite granularity and (2) the existence of a volcanogenic member approximately in its middle part.

Clastic sediments of this formation are prevailingly coarse-grained sandstones, characterized by light-grey to greenish-grey colour and with very low degree of structural and mineralogical maturity. The masses of sandstones are very often without structure or they form thick layers, reaching 2 - 2.5 m in thickness. The inner order of clastic particles is most often horizontal. In the frame of individual beds graded bedding is common. In the basal parts of beds there are scattered reworked pebbles which are prevailingly elongated. They are up to 10 - 15 cm in size and consist of leucocratic granites, aplites and quartz.

Relatively coarser detritus, reaching the size of fine conglomerates, forms lenticular bodies. It is composed of angular poorly sorted granitoid material.

Fine grained aleuropelitic members are almost absent in the sandstone complex. As far as they are preserved, they form thin (10 - 15 cm) layers of irregular thickness, in the uppermost parts of the bodies with graded bedding. Usually they are partly eroded by the overlying sandy body as also swarms of intraclasts in the basal parts of these bodies testify. Aleuropelites are of light-grey to greenish-grey colour, with strong admixture of angular sandy detritus.

The volcanogenic horizon of Harnobis is 150 - 200 m thick. It is composed of paleodacite effusions and accompanying volcanoclastic rocks. The volcanoclastics are represented by ash and lapilli tuffs. The desintegrated volcanoclastic material was transported to other parts of the sedimentary basin and formed various types of mixed sediments (tuffites, volcanoclastic sandstones).

The sandstones of the Brusno formation underlying the volcanogenic horizon correspond petrographically to arkose wackes and feldspathic greywackes. They contain in

DOI:https://doi.org/10.2312/zipe.1982.066

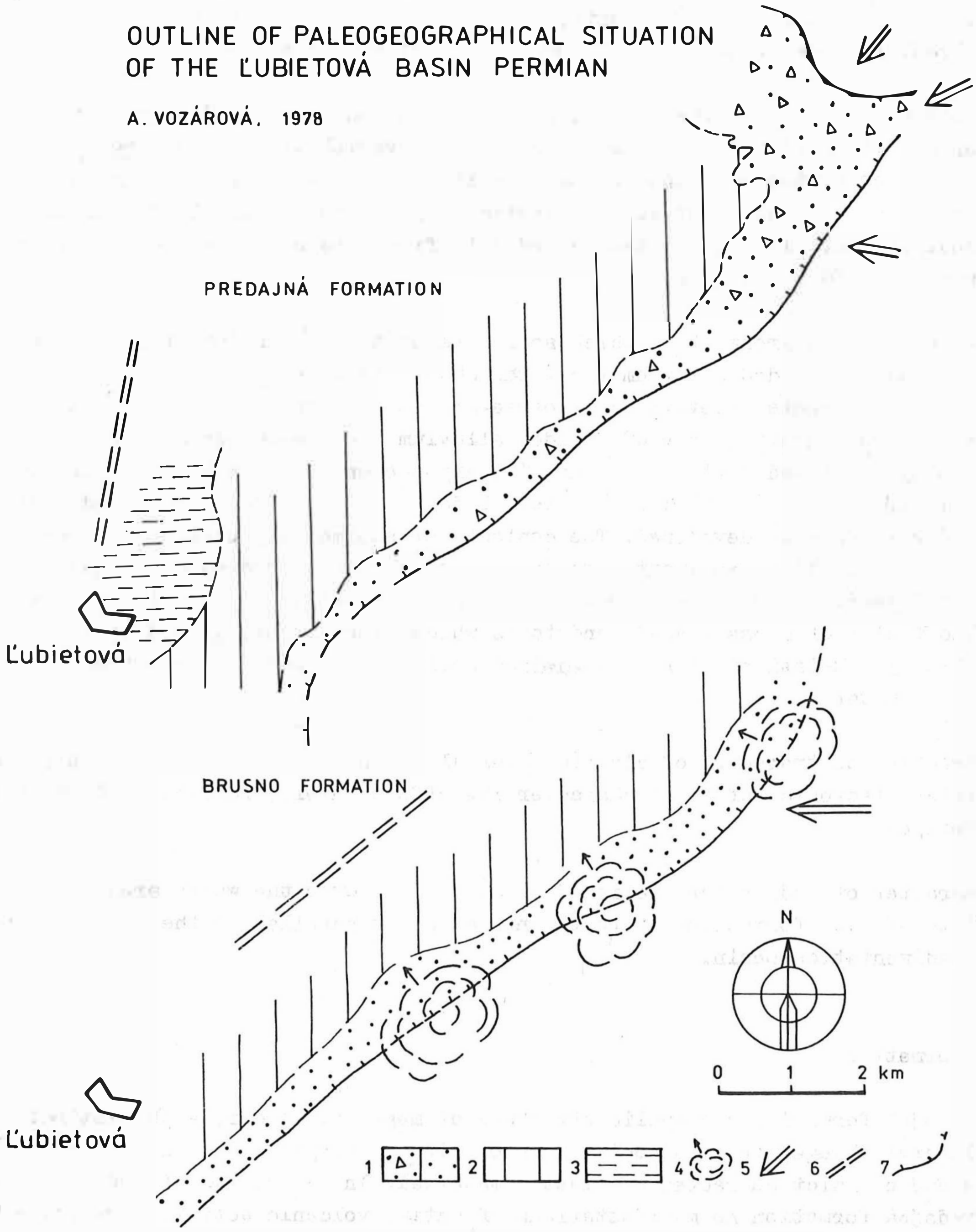


Fig. 4. Outline of paleogeographical situation of the Lubietová Basin Permian

1 - marginal facies, 2 - alluvial regime, 3 - lacustrine facies, 4 - volcanic centres, 5 - transport direction, 6 - axial part of basin, 7 - delimination of source area

DOI:https://doi.org/10.2312/zipe.1982.066

sandy fraction 24 % of alcalic feldspar on an average (orthoclase, microcline, microperthite), 6 % plagioclase, 57 % quartz, 5 % clastic mica, 8 % fragments of granitoids. The percentual representation of the groundmass varies within 30 - 43 %.

The sandstones overlying the volcanogenic horizon contain, besides granitoid detritus, reworked volcanoclastic material. Its quantity varies within the range 2 to 10 %. In close overlier of the effusions of paleodacites and their tuffs is a horizon of sediments with distinct content of volcanoclastic composition (tuffites, volcanoclastic sandstones). Irregularly distributed paleodacite fragments and their volcanoclastics attain up to 30 - 50 cm in size.

The sedimentary environment in which sediments of the Brusno formation originated was continental of braided alluvium type. The character of preserved structures and granularity of sediments (prevailingly coarse-grained sandstones with pebbles) testify to a proximal sedimentation zone of braided alluvium. The sediments are without texture or with weakly developed horizontal beds. The arrangement of clastic particles is horizontal, only in a few cases high-angle cross-bedding is developed. In bedded bodies normal graded bedding is developed. The contacts of sedimentary bodies are erosive. Partings of aleuropelitic sediments are rare. They form thin bodies of unequal thickness. The described facial complex represents a system of fossil longitudinal bars. It includes also facies of cross bedded sandstones which probably originated in adjacent smaller channels. Relatively more fine-grained sediments formed in locally originated reservoirs of water.

The direction of transport of clastic material was generally from east. An intensive synsedimentary tectonics of fault character was effective with formation of the volcanogenic horizon.

The character of sedimentary facies does not change over the whole area of occurrences of the Brusno formation. It represents a facies parallel to the margins of the original sedimentation basin.

Predajná formation

The Predajná formation has cyclic structure of megacycle order, with distinct vertical and lateral changes in lithological composition, variegation in the colouring of sediments and polymict character of clastic material. In the period of sedimentation of the Predajná formation no manifestations of active volcanic activity are evident.

The basal part of the Predajná formation is formed by polymict conglomerates. The thickness of this part reaches 50 - 100 m, with exception of the northeastern part of the Ľubietová basin where conglomerates are preserved throughout the section of the Predajná formation. The cyclic character of the formation is well developed in direction to the inner part of the original basin. The polymict conglomerates are gradually replaced by sandstones in vertical direction. The cycle is terminated with fine-grained sandstones and sandy shales, which are mutually alternating. In the overlier of the first megacycle a layer of polymict conglomerates appears again. It represents the

DOI:https://doi.org/10.2312/zipe.1982.066

basal parts of the further megacycle, which is not preserved completely.

The colour of sediments is violet to violetish-grey. In direction toward the supposed centre of the sedimentary basin the sediments with prevailing grey colour increase. In lateral extension of individual lithofacies distinct changes may be observed. Generally in direction from NE to SW a distinct reduction of the grain size of sediments, a higher mineralogical maturity and increasing amount of sandstone and shale facies are evident.

The conglomerates in the lower part of the first megacycle are medium- to coarse-grained, very poorly sorted granulometrically. The content of the pebble material in conglomerates varies within 40 to 70 %. Roundness of the pebble material is low, on average 0.37 units of rounding (according to KRUMBEIN 1941). The pebbles consist of quartz, granitoids, granite-aplites, microgranites, paleorhyolites, paleodacites, paleo-andesites, paleodacitic and paleorhyolitic volcanoclastics, mica schists, paragneisses, orthogneisses, tourmaline rocks. All these petrographic types can be correlated well with rocks derived from the crystalline of the adjacent part of the Veporic.

Laterally, i.e. in direction from NE to SW, in conglomerates of the first megacycle the content of pebbles of crystalline schists is sinking and, on the contrary, the content of pebbles of paleodacites and their volcanoclastics rises slightly. This dependence fully corresponds with relation of the size and petrographic composition of detritus. The conglomerates from the basal part of the second megacycle in direction NE-SW are laterally wedging out and replaced by sandy conglomerates with coarse-grained sandstones. In the same direction the percentual representation of fragments of crystalline schists decreases and the content of granitoids increases. Roundness of pebbles in conglomerates from the base of the second megacycle is relatively higher (0.41 units of rounding). In direct depedence on changes in composition and size of fragments also their roundness increases(0.48 units of rounding).

The sandstones of the Predajná formation show a low grade of mineralogic and structural maturity. On an average the sandy fraction contains 48 % quartz, 14 % alkalic feldspar, 6 % plagioclase, 8 % micas, 14 % fragments of volcanics and 10 % fragments of granitoids and crystalline schists.

The content of the groundmass in the sandstones of the Predajná formation varies with in the range 30 - 50 %. In petrography these sandstones correspond to lithic greywackes. Generally in lateral and vertical direction a higher maturity of sandstones is evident.

The sedimentary environment, in which the sediments of the Predajná formation originated, can be generally designated as continental of alluvial fan type. The proximal parts are represented by coarse-clastic sediments, most developed in the northeastern part of the Ľubietová basin. They are poorly sorted conglomerates with an inner structure corresponding to "debris-flow". The clastic material supplied from the morphogene was transported in relatively thinner suspensions in direction to the more distal part of the basin (generally toward south) and better sorted. The piedmont platform was rapidly covered with a bulk of clastic material. Relatively finer-grained sediments of sheet flood type, horizontal or flaser bedding originated here. In the central part

DOI:https://doi.org/10.2312/zipe.1982.066

of the basin in places water reservoirs with a higher concentration of organic material were formed (borehole LU-1, loc. Ľubietová, ILAVSKÝ et al. 1978).

The transport of the clastic material was generally from NE to SW. The synsedimentary tectonics was distinctly manifested with the origin of the megacyclic structure of the Predajná formation. It was of the character of vertical movements along faults which caused emergence of the basement in form of tectonic horsts.

2.3. General characteristic of the Ľubietová basin

The Ľubietová basin belongs to the inner depressions. It is a type of taphrogenic basin, characteristic in having a longitudinal shape, fault borders and inner horst dissection. Synsedimentary tectonics reflected distinctly in the megacyclic character of the sedimentary filling and in syngenetic volcanic activity. The filling of the Ľubietová basin is clastic, with accompanying volcanic material in basal parts.

The clastic detritus comes from close neighbourhood of the basin, from Veporic crystalline schists and granitoid rocks which also form the basement of the Ľubietová basin.

The Ľubietová basin originated on Variscan-consolidated basement. It was founded on a fault system, the activity of which diminished from the basal parts to the overlier. This is mainly shown in disappearing manifestations of volcanic activity and decreasing rate of sedimentation in younger levels.

The Lower Triassic sediments, of typical epiplatformic development in the Ľubietová basin, rest discordantly on sediments of the Predajná formation. They have a much higher degree of mineralogical maturity and attain essentially lesser thickness compared with the molasse filling of the Ľubietová basin. They signalize restriction of activity of the fault system, levelling of the morphogene relief and termination of the taphrogenic stage of the Ľubietová basin. The Lubietová basin originated on a continental type of crust, with well developed granite layer. The consolidation factor in the Veporic region was the Variscan orogeny, typical with intense granitization although it is not exluded that also fragments of older structural stages were incorporated in its structural plan.

3. Sedimentary basin of the Hronic (Annex 28)

3.1. General features

The Alpine orogeny, which mainly influenced the present structure of the West Carpathians, caused that a part of the Variscan molasse formations was torn off from their fundament and incorporated in the Alpine nappe structure. At present the fragments of these formations we are finding in allochthonous position in various mountain ranges of the West Carpathians (the Malé Karpaty Mts., the Považský Inovec Mts., the Malá Fatra Mts., the Nízke Tatry Mts., the Tribeč Mts. and basement of the Neogene of Central Slovakia). They form the basal parts of the Hronic tectonic unit. At all known

DOI:https://doi.org/10.2312/zipe.1982.066

occurrences general composition of these formations is equal. The most complete sequences of the Variscan molasses of the Hronic are preserved in the Nízke Tatry ts.

The stratigraphic range of these molasse sediments is Stephanian A - C, Lower and Upper Permian. The sedimentary sequences are continuous. From the underlier in direction to the stratigraphic overlier they are subdivided into two lithostratigraphic units (1) the Nižná Boca formation (200 - 500 m) and (2) Malužiná formation (about 2200 m) (VOZÁROVÁ and VOZÁR 1979 a). The essential part of the sedimentary sequences is composed of cyclically alternating sandstones, siltstones and pelites. They form cycles of first order, prevailingly asymetrical, typical in decreasing of grain size toward the upper parts. Only in minor part cycles of coarsening upward type are developed. The cycles are expressed either by gradation of bedding or by gradation of grain size.

Distinct coarsening upward is developed in the frame of cycles of second order (10 m) in the lower lithostratigraphic unit Nižná Boca.

The sedimentary cycles of first and second order are connected to distinctly developed megacycles, which are a characteristic structure element of the Malužiná formation. The basal parts of these megacycles are composed of coarse-grained clastic sediments (coarse-grained sandstones, sandy conglomerates, fine-grained conglomerates). The megacycles are typical in distinct fining upward of sediments, in their uppermost parts beds of aleuropelites with layers of carbonate concretions and gypsum lenticles are developed.

To fundamental diagnostic features of the Malužiná formation the presence of basalts to andesites of TH-magmatic series belongs, accompanied by volcanoclastics. The volcanic activity was of several phases and of the character of linear volcanism (VOZÁR 1971, 1974, 1977).

As far as sedimentary cycles of the first and second order are autocyclic, the megacycles and also the several-phases character of volcanism are reflection of synsedimentary tectonic activity in the sedimentation area. In the time of sedimentation of the Nižná Boca formation the sedimentary environment was deltaic to near-shore. The sediments of the Malužiná formation originated in a sedimentary environment which may be generally designated as deltaic-lacustrine.

3.2. Characterization of the lithostratigraphic units

Nižná Boca formation

The Nižná Boca formation represents the lowermost part of molasse sequences of the Hronic. Characteristic is a grey, greenish-grey (80 %), dark-grey, brownish-grey colouring (20 %). The original thickness of the formation is not precisely known due to tectonic reduction by Alpine nappes. Maximum thickness of preserved sediments is within the range 200 - 500 m. Stratigraphic assignment of the Nižná Boca formation was proved first as Westphalian C-D on the basis of palymorphs (ILAVSKÁ 1964). The found remnants

DOI:https://doi.org/10.2312/zipe.1982.066

of macroflora proved Stephanian only (SITÁR and VOZÁR 1973). In the last time PLANDEROVÁ 1979) determined the stratigraphic range Stephanian A to D on the basis of microflora. She designated the Westphalian microflora as redeposited. Remnants of macroflora (from the work by SITÁR and VOZÁR 1973): Asterotheca miltoni ARTIS, Asterotheca arborescens BRONGNIART, Cordaites palmaeformis GOEPPERT, Callipteridium gigas GUTBIER.

The sedimentary sequences of the Nižná Boca formation are composed of clayey and graphitic shales, siltstones, fine-, medium- and coarse-grained sandstones. In layers of aleuropelites fragments of allochthonous macroflora and indeterminable remnants of tree rind are abundant. The sandstones form approximately 50 - 55 % of sediments of the Nižná Boca formation. Traces of synsedimentary volcanic activity have preserved in a layer of lithocrystalloclastic tuffs (thickness maximum 2 m), inclining to dacites in petrographic composition. With manifestations of this volcanism also sporadical occurrences of centimeter to decimeter layers of silexites are connected. In negligible amount layers of pebble material occur in sandstones. The material of pebbles is mainly formed by quartz and granitoids, sporadically by acid volcanics, quartzites and lydites. The sandy detritus is composed of 40 - 50 % quartz and fragments of quartzites, 20 % potassium feldspars and plagioclases, 30 % fragments of granitoids, phyllites, acid and intermediate volcanics, sandstones, 5 - 10 % micas (biotite, muscovite).

The amount of groundmass varies from 15 to 30 %. The sandstones correspond in petrography mainly to lithic greywackes, less to lithic arenites, arcose and arcosic wackes. The association of clay minerals in the groundmass of sandstones comprehends kaolinite, illite, montmorillonite and chlorite (according to ĎUROVIČ 1971).

In composition of clayey shales take part clastic detritus (quartz, feldspar, micas, accessory minerals), authigenic minerals (carbonates, sericite, oxides and hydroxides of Fe) and clay minerals (illite, kaolinite, montmorillonite, chlorite) (ĎUROVIČ 1971). With the finest sediments centimeter to decimeter beds of grey crystalline carbonate are locally associated (the Malé Karpaty Mts.).

The sediments of the Nižná Boca formation form well developed bodies of equal thickness, composed of cycles of the first and second order. Most of them display normal structure, thus fining upward. To a limited extent also inverse cycles occur. In the whole section of the Nižná Boca formation is a tendency of slow coarsening upward of clastic material.

Mutual relation between cycles or individual beds are often erosive. The basal parts of bodies of relatively coarser-grained sediments contain numerous intraclasts of shales. The gradation in the frame of cycles is expressed either by the change of bed thicknesses of sediments of corresponding grain size or by the change of size of clastic grains of the sediment. The inner order of clastic particles within the individual sedimentary bodies is graded, laminar, less flaser-like. In aleuropelite layers bioturbation structures are common. Irregularly distributed fragmental plant remains are abundant.

The sedimentary environment in which these sediments originated may be designated as deltaic to near-shore. The clastic detritus supplied by a braided system of delta river

DOI:https://doi.org/10.2312/zipe.1982.066

channels was relatively coarse-grained, testifying to a dissected relief of the neighbourhood of the sedimentation basin, probably with steep slopes. The sediments which preserved in the section of the Nižná Boca formation represent foreset beds of distributary delta channels into a shallow sedimentation basin in the near-shore marine area. The delta stream beds also supplied plant detritus from the continent. Very probably in the area of the delta plain swamps and marshes formed, in which peat-bogs originated. The permanent change of the delta stream bed system resulted in disappearance of at least a part of these small sedimentation basins, as the abundant allochthonous detritus of carbonized macroflora remnants, various fragments of branches, plants and also carbonized remnants of tree barks testify. The well bedded bodies, their equal thickness with considerable areal extension, allochthonous macroflora, sedimentary structures, phenomena of bioturbation and also the relatively high content of clastic mica in sandstones point to deposition in a shallow water basin. The shallow-marine environment is also indicated by frequent findings of marine plankton (PLANDEROVÁ 1979).

In sediments of the Nižná Boca formation are sills and dykes of diorite porphyrite (VRÁNA and VOZÁR 1969) which belong to the subvolcanic apparatus of Permian volcanics associated with sediments of the Malužiná formation.

Malužiná formation

The Malužiná formation occurs in overlier of the Nižná Boca formation, from which it developed gradually, without break of sedimentation. The age of the Malužiná formation was proved as Upper Permian on the basis of palynology (PLANDEROVA 1973), from the upper part of the second megacycle. The first megacycle was ranged to the Lower Permian on the basis of lithological relation to the Nižná Boca formation (VOZÁR 1971, 1973), as was later also proved by finding of microflora (PLANDEROVÁ in VOZÁROVÁ and VOZÁR 1979 a). The principal features of the Malužiná formation are:

(1) megacyclic inner structure;
(2) manifestations of volcanism of basic to intermediate character;
(3) variety in colouring of sediments.

Thickness of the formation is about 2200 m. In contrast to the Nižná Boca formation the content of coarse-clastic detritus increases in sedimentary sequences of the Malužiná formation. The basal parts of all three distinguished megacycles are prevailingly composed of fine-grained conglomerates, sandy conglomerates and coarse-grained sandstones. The sediments form well bedded bodies, 2 - 4 m thick. The mutual contact of bodies is erosive. The most characteristic structural feature is distinct gradation according to granularity. The beds are of equal thickness and attain considerable areal extension. In the basal parts of bedded bodies are graded intervals and in upper parts of the bodies laminar or planar cross-bedded intervals.

The material of pebbles is composed of quartz, granitoids, metasediments, phyllites, lydites, acid and basic volcanics and rarely of crystalline schists from the group of mica schists. In the basal part of the first megacycle in some places cycles of fining upward type are developed, with well developed coarse-clastic and fine-grained member.

DOI:https://doi.org/10.2312/zipe.1982.066

The fine-grained member is represented by grey-coloured aleuropelites with the content of allochthonous plant chaff. These fine-grained members are usually partly eroded by the next sedimentation cycle.

The middle parts of the delimited megacycles are composed of cyclically sedimented clastic sequences of medium to fine granularity. The inner structure of this part of megacycles is composed of repeating cycles of first order. The cycles are asymmetric, consisting of medium to fine-grained sandstones, aleurolites and aleuropelites. The individual sandstone bodies show a turbidite inner structure consisting of a graded interval, above which is either a relatively fine-grained unbedded or laminated part, sometimes also a cross-bedded and ripple-mark part. The sedimentation of the bodies is terminated with aleuropelites, without texture or distinctly laminated. The sediments are of variegated colour, the red colour is bound to finest fractions of sediments. The basal parts of sandstone bodies contain many intraclasts of red shales and aleurolites. They reflect processes of sedimentary erosion. Preserved structures of erosional washouts are common, also traces of impression of relatively coarser-grained sediments into underlying finer-grained sediments.

The lamination in aleuropelite sediments is very often destructed by bioturbation processes of organisms. In these sediments many organic hieroglyphs were found. In the sense of SEILACHER (1953) were distinguished:

Domichnia - tubular forms very often in the shape of the letter "U",

Pascichnia - traces after clay-eaters which form a system of non-crossing furrows and tunnels,

Repichnia - chaotic system of crossing furrows and tunnels formed by animals crawling on the bottom.

Seldom an imprint of lamellybranch shell of the group Schizodus was found which could not be qualified because of bad preservation. In aleuropelite sediments concretions and septaria originated. The concretions are of pelosiderite and calcite-dolomite composition. The uppermost parts of megacycles are formed by fine-grained aleuritic and pelitic sediments. They have distinct horizontal bedding and variegated light greyish-red colouring. They contain carbonate concretions ordered into decimeter layers and individual lenticles of anhydrite-gypsum (maximum 30 m) in the uppermost parts of the first and second megacycle (DRNZÍK 1969; NOVOTNÝ and BADÁR 1971).

The clastic detritus has the following mineral composition: 60 - 70 % quartz, 15 - 20 % feldspar (plagioclase, orthoclase, microcline, microperthite), 10 - 20 % fragments of rocks (granitoids, metasandstones, phyllites, volcanics), 5 - 10 % micas (biotite, muscovite). Structural sorting of psammitic sediments is variable. The amount of groundmass varies from 10 to 40 %. In petrography the sandstones correspond to lithic arenites and to lithic greywackes. In the composition of aleuropelites and of the groundmass of sandstones occur illite, montmorillonite, kaolinite and chlorite (ĎUROVIČ 1971).

Synsedimentary volcanism of basalt-andesite formation is of multiphase character (VOZÁR 1971). The products of the first volcanic phase are linked with the first sedimentary megacycle. They represent multiple repeated lava flows. The volcanic activity

DOI:https://doi.org/10.2312/zipe.1982.066

terminated with deposition of fine volcanoclastic sediments the structures of which indicate a subaqueous sedimentary environment. In the time of sedimentation of the second megacycle manifestations of volcanic activity were weak. Maximum intensification occured during the sedimentation of the third megacycle. Multiple repeated effusions are accompanied by volcanoclastics. They display hyaloclastic textures in basal parts of the lava bodies which testify to fast lava cooling at the contact with water environment. The volcanism is of TH-magmatic trend (VOZÁR 1977).

In the eastern part of the Low Tatra the Kravany beds were defined as a special lithostratigraphic member (NOVOTNÝ and BADÁR 1971) which forms the upper part of the second megacycle. It is composed of cyclically alternating sandstones and aleurites, with diagenetic veinlets of gypsum. Upwards the character of the colouring of sediments changes. Grey and greyish-green colour prevails. The sediments contain many redeposited fragments of carbonized flora. The change in colouring of sediments is a reflection of diagenetic alternations and directly depending on the contents of organic matter. In the sedimentary sequences besides them, detritic dolomitic limestones and dolomitic sandstones are also associated.

In the Malužiná formation in direction from the stratigraphic underlier to overlier reduction of the grain size of sediments, decreasing sandstone/shale ratio and an increase of the mineralogical maturity of sandy sediments are evident.

	I. megacycle	II. megacycle	III. megacycle
sandstone	70 %	64 %	58 %
shale	30 %	36 %	42 %
quartz content	60 - 70 %	60 - 70 %	- 80 %

The sedimentary environment in which the sediments of the Malužiná formation originated can be generally designated as deltaic-lacustrine. A system of small river deltas may be supposed, which supplied detrital material from the morphogene into the sedimentary basin. The preserved types of sedimentary structures, prevalence of turbidite structures in sandstone bodies, the quantity of organic hieroglyphs in fine-grained sediments and the presence of chemical sediments in the upper parts of the first and second megacycle are an evidence of the existence of the system of water reservoirs of larger areal extent with higher salinity into which small river deltas disembouged. The basal parts of the megacycles represent overwater parts of deltas, fillings of distributive channels, composed of sandstones, often with pebbles and with abundant shreds of clayey shales. The essential part of the Malužiná formation sediments deposited below a stable water level. It comprises a complex of lacustrine bottom sediments, in which transported delta sediments, represented by repeating bodies of turbidite sandstones, wedged out. This sedimentary environment is also signalized by the presence of an amount of clastic mica, allochthonous plant detritus and marks due to an intensive bioturbation activity of organism.

DOI:https://doi.org/10.2312/zipe.1982.066

3.3. General characterization of original sedimentary basin of the Hronic

The original sedimentary basin of the Hronic can be characterized as narrow through of linear extension (VOZÁR 1971). It was founded on continental crust type, with gradual subsiding along a system of deep linear faults. The mineralogical composition of clastic detritus in sediments and also relics of the crystalline basement in the underlier of the Nižná Boca formation (VOZAROVÁ and VOZÁR 1979 b) prove that the fundament of the basin was mainly composed of granitoid or migmatitic complexes. Epi- to mesometamorphosed rocks were represented in minority.

The synsedimentary tectonic activity is bound to the vertical movements along the linear fault system at the margins of the basin and to movements of expansion in its inner part. The reflection of this is the megacyclic structure of the upper lithostratigraphical unit with coarse-clastic sediments in the basal parts of megacycles and repeated effusions of basic volcanites of TH-magmatic trend.

4. North Gemeride basin (Annex 29)

4.1. General features

The North Gemeride basin was situated along the northern margin of the Early Paleozoic Gemeric block. In the present-day structure of the West Carpathians it is not completely preserved. An intense deformation during the Alpine orogeny implied compression of the original sedimentary basin and also its partial amputation. For this reason there are difficulties with correlation of some occurences known nowadays. In spite of all these problems, however, the North Gemeride zone represents a region of the West Carpathians in which the individual steps of molasse development are preserved in most complete succession.

The North Gemeride sedimentation area was generally of longitudinal shape. It was parallel with the folded central part of the Gemeric. The Late Variscan filling of this basin is subdivided into lithostratigraphic groups and formations (Annex 29).

The Dobšiná group of formations (BAJANÍK and VOZÁROVÁ in BAJANÍK et al. 1979; MÁŠKA 195 represents marine sequences, distinctly reflecting tectonic unrest connected with Sudetic, Erzgebirge and Asturian movements. In its sedimentary and volcanogenic developments it reflects gradual transition from the geosynclinal (Ochtiná formation) to early molasse stage (Rudňany, Zlatník and Hámor formations).

The Krompachy group of formations (BAJANÍK in BAJANÍK et al. 1979), reflecting post-Asturian development of the region, implies the period of the main molasse-forming stage which is typical in the presence of terrigenous and volcano-terrigenous continental sequences (Veľká Knola and Petrová Hora formations). With intense development of rhyolite-dacite volcanism also granite intrusions are coincident. 250 mill. y. were evaluated on the basis of Rb-Sr (KOVACH et al. 1979) and K-Ar determination (KÁNTOR and RYBÁR 1980). The igneous rocks are probably reflection of the Saalian phase. The late molasse stage is characteristic in development of evaporite and accompanying terrigenous sediment (Novoveská Huta formation).

DOI:https://doi.org/10.2312/zipe.1982.066

4.2. Characteristics of lithostratigraphic units

Ochtiná formation

The Ochtiná formation is preserved in a zone of intense tectonic deformation and therefore its direct relation to the stratigraphic substratum cannot be defined precisely. In general the Ochtiná formation may be characterized as terrigenous-carbonate formation with occurrence of volcanic and volcanoclastic horizons. Thickness is estimated to 1000 - 1200 m. In the basal part terrigenous members (sandstones, fine-grained conglomerates) predominate which to the overlier are gradually replaced by fine sediments. They are accompanied by volcanoclastics and to a small amount also by effusions of basalt character. Carbonate bodies, altered into magnesites, are subordinately represented in this part of the formation. Approximately in the middle part a volcanogenic horizon which is composed of effusions of basalt character, accompanied by vein bodies of dyke type, is almost in constant stratigraphic position.

The upper part of the Ochtiná formation is terrigenous-carbonate, with prevalence of carbonate members. It is composed of graphitic and dolomitic shales as well as of banked and compact dolomites (originally bioherm bodies) a part of which is altered into magnesites.

The age of the upper part of the Ochtiná formation is proved as Namurian B-C on the basis of fauna coming from the magnesite horizon (BOUČEK and PŘIBYL 1960). From the close underlier of magnesites the Serpuchovian - Namurian A was proved on the basis of conodonts (KOZUR et al. 1976).

The sedimentary environment of the Ochtiná formation was marine, characterized by permanent oscillation of the bottom of sedimentary basin. The upper terrigenous-carbonate part of the formation testifies to distinct shallowing (shallow marine coast) with well developed coral and crinoid bioherms.

Rudňany formation

The Rudňany formation rests discordantly on the Early Paleozoic complex of the Gemeric (Rakovec group). It is exclusively composed of terrigenous sequences. In the area where it rests transgressively on the basement it is composed of polymict coarse-grained sediments (KRIST 1954; VOZÁROVÁ 1973). The clastic sequences display cyclic structure. The cycles of fining upward type are successively composed of conglomerates, sandy conglomerates and sandstones and finally sandstones with layers of shales. In these sequences remnants of silicified araucarite trunks were found.

The Ochtiná formation is overlain in some places by a preserved horizon of oligomict conglomerates (in lithotectonic profile, Annex 29, designated D) which is parallelized with polymict developments overlying the Rakovec group (ABONYI 1972). Thickness of the Rudňany formation is 50 - 170 m.

DOI:https://doi.org/10.2312/zipe.1982.066

The sedimentary environment of this formation was fluvial-littoral and littoral. Composition and structure of the individual sedimentary bodies reflect morphology of the original paleocoast. The direction of transportation of detrital material is generally from SSE to NNW.

The age of the Rudňany formation was proved on the basis of fauna and flora as Westphalian B (locality DOBŠINÁ; BOUČEK and PŘIBYL 1960) to lowermost Westphalian C (locality Rudňany; NĚMEJC 1947).

Zlatník formation

The Zlatník formation develops gradually as the overlier of the Rudňany formation. In general, it may be designated as terrigenous-volcanogenic formation, in the western part of the Gemeric also with occurrence of carbonate members.

Terrigenous sediments - shales, siltstones, fine-grained sandstones - predominate in the basal part of the Zlatník formation. Toward the overlier the intensity of volcanic activity increases. The volcanogenic members of the formation are formed mainly by fine volcanoclastics of basalt composition. A lesser part is formed by effusive basalt bodies with aphanitic, fine-grained, seldom porphyritic texture (ROZLOŽNÍK 1963; BAJANÍK in BAJANÍK et al. 1979).

The intensity of volcanic activity is laterally fading out to the west and on the contrary carbonate members are more abundant. Directly overlying the Ochtiná formation sequences of crystalline carbonates with content of basic volcanoclastic material are devoloped (ABONYI 1972).

The age of the Zlatník formation was proved as Upper Carboniferous on the basis of sporomorphs, without more detailed subdivision (SNOPKOVÁ in BAJANÍK 1976; SNOPKOVÁ 1978). Thickness of the Zlatník formation is 150 - 400 m. The sedimentary sequences of the Zlatník formation originated in shallow marine, neritic sedimentary environment.

Hámor formation

The Hámor formation is composed of terrigenous enriched in bituminous component sequences which are characterized by well developed cyclicity. The cycles of first and second order of fining upward type show multiple recurrence above one another. They begin at the base with fine-grained conglomerates, from which sandstones, sandy and graphitic shales develop gradually. In graphitic shales thin layers of anthracite are found in 3 cycles above one another. The sedimentary sequences are generally rich in clastic mica and graphitic substance.

Thickness of the Hámor formation is 250 - 300 m. Its stratigraphic assignment was proved on the basis of sporomorphs as Westphalian D - Stephanian (ILAVSKÁ in CHMELÍK 1962).

DOI:https://doi.org/10.2312/zipe.1982.066

The character of structures and also lithological composition of the Hámor formation indicate a deltaic sedimentary environment (MÁŠKA 1957).

Veľká Knola formation

The Veľká Knola formation is characterized by variegated terrigenous deposits predominantly composed of coarse-clastic angular material. The clastic material in the basal parts reflects in its petrographic composition the character of immediate underlier on which it is deposited. In petrographic composition of conglomerates and breccias 15 kinds of various rock types take part (BAJANÍK 1965). Thickness of the formation is 100 - 350 m. The sedimentation is cyclic, with development of cvcles typical of continental sedimentary environment of alluvial fan type.

The age of the Veľká Knola formation has not been proved biostratigraphically so far. On the basis of superposition, however, it should be supposed that it reaches as late as the Autunian.

Petrová Hora formation

The Petrová Hora formation is a typical volcano-sedimentary formation with development of plenty of volcanic and volcanoclastic rocks, predominantly of rhyolite-dacite composition and of CA-magmatic trend. Only a small part of volcanic rocks is tending petrochemically to intermediate volcanics (andesites).

Volcanism occurs in two horizons. The whole formation is of cyclic character. In basal parts of each cycle conglomerates and sandstones (arkoses, lithic and arkose wackes, volcanogenic greywackes) predominate and toward the overlier volcanoclastics and effusive rocks increase.

Nearly in the middle part of the formation there is a volcanic member of intermediate composition.

The clastic members of the formation contain in general a considerable amount of intraformational material, meinly redeposited material from syngenetic volcanics.

Thickness of the Petrová Hora formation is 350 - 600 m. The sedimentary environment was continental, with fluvial and fluvial-lacustrine facies.

The data of the age of the Petrová Hora formation were obtained on the basis of the analysis of isotopes from the first volcanic horizon - 264 mill. y. according to NOVOTNÝ and ROJKOVIČ (1980). The microflora found only sporadically points to the Lower/Upper Permian boundary (PLANDEROVÁ in VÁCLAV et al. 1980).

DOI:https://doi.org/10.2312/zipe.1982.066

Novoveská Huta formation:

The Novoveská Huta formation represents a terrigenous-evaporitic formation with cyclic development. It contains layers of intraformational conglomerates and breccias, mainly in places of the supposed marginal parts of the original sedimentary basin. A significant lithological member are evaporites, i.e. gypsum and rock salt with small amount of sylvine (MAHEĽ and VOZÁR 1973). The evaporites are accompanied by argillaceous and carbonate-argillaceous shales, dolomites, dolomitic and evaporite breccias. Thickness of the Novoveská Huta formation is 250 - 400 m. In this formation the cycles are composed of argillaceous shales and fine-grained sandstones at the base, higher up of dolomitic sandstones or detrital dolomites above which gypsum or salt is present, often in the form of salt breccias. Another type of cycles is alternation of argillaceous shale, gypsum and salt or shale and gypsum only.

The age of the formation was possible to find out so far at one locality only (Košická Belá). The association of sporomorphs points to the uppermost Permian (PLANDEROVÁ in VÁCLAV et al. 1980).

4.3. General Characterization of the sedimentary basin

The sedimentation area in the northern part of the Gemeric was in the initial stages of narrow trough shape which developed parallely with the main geosynclinal zone. This syngeosynclinal marginal basin, formed in the period after the Bretonian phase, was filled up with marine sequences (Ochtiná formation) which represent a transitional stage between the geosynclinal and molasse stage of development. In the time of the Erzgebirge phase configuration of the basin changed, a sedimentation area partly situated already also on the folded geosynclinal zone originated, from which it is separated by a fault system. It is filled up with marine and paralic formations of early molasse. The main development of continental molasse started in the time after the Asturian phase. The sedimentary basin preserved its longitudinal shape, however, was dissected by a system of faults, activity of which was directly reflected in the character of sedimentation and volcanism. Intense volcanism began in the Saxonian. It was accompanied by sinking of the sedimentary basin, reflected in thick volcanosedimentary filling. Tectonic activity of the region, which was of increasing character from the Westphalian, was culminating in that period. It is accompanied by granite plutonism. The Postsaalian period implies gradual fading out of volcanism and slowly slackening tectonic activity. A short period of stabilization was not before the Lower and Middle Triassic.

5. South Gemeride basin (Annex 30)

5.1. General features

The South Gemeride basin was situated along the southern margin of the Early Paleozoic Gemeric block. The basin was of longitudinal shape, bordered by a system of longitudinal faults. It represents a type of taphrogene basin, founded on the folded and metamorphosed Early Paleozoic of the Gemerides. In this region the Early Paleozoic is represented by

DOI:https://doi.org/10.2312/zipe.1982.066

the volcanosedimentary epimetamorphosed complex of the Gelnica group (Upper Cambrian to Lower Devonian, SNOPKOVÁ and SNOPKO 1979).

The filling of the sedimentary basin is mainly composed of clastic sedimentary sequences which are accompanied by volcanics and volcanoclastics of rhyolite-dacite chemical character in the lower part. The complex of these sequences was designated as the Gočaltovo group which includes two lithostratigraphical units - the Rožňava formation and Štítnik formation (VOZÁROVÁ and REICHWALDER in BAJANÍK et al. 1979). The Rožňava formation is coarse-clastic, accompanied by volcanic activity manifested at two levels. It attains thickness of 200 - 400 m. The Štítnik formation is composed of relatively fine-grained sequences and the manifestations of volcanic activity are sporadical only. Thickness of this formation is 400 - 600 m.

5.2. Characteristics of lithostratigraphic units

The Gočaltovo group of formations is composed of a complex of clastic sequences in which layers of acid volcanics and volcanoclastic sediments are included. The sedimentary sequences are formed by two megacycles which are typical in fining upward. The lower cycle contains relatively coarser-grained sedimentary members than the upper cycle which is terminated with sedimentation of detrital dolomitic limestones. Coarse-clastic sedimentation is the reflection of synsedimentary tectonic activity. Mineralogical maturity of the sandstone members of the Gočaltovo group decreases toward the upper parts, in dependence on higher tectonic activity.

The clastic sequences in the lower megacycle reflect in their petrographic composition the preceding stage of peneplanation in the source area, whereas the more upper sequences signalize tectonic activation of the relief with contemporaneous rapid accumulation in the sedimentary basin.

Rožňava formation

The most important features of the Rožňava formation are:

(1) absolute prevalence of sediments of psephite and psammite grain size;

(2) presence of two horizons of volcanics and volcanoclastics of rhyolite-dacite composition.

The oldest lithological member of the Rožňava formation are massive sandstones, developed only locally (maximum thickness 80 m). In petrography they belong to the group of quartz to arcose wackes with 85 - 100 % quartz, 2 - 6 %, rarely 10 - 12 % feldspars (plagioclase, potassium feldspar) and 1 - 6 % mica.

The sandstones are overlain by conglomerates which locally form the base of the Rožňava formation and are lying discordantly on Early Paleozoic rocks. Their petrographic composition is directly depending on composition of the underlying complexes. In the western part of extension of the Rožňava formation the conglomerates are oligo-

DOI:https://doi.org/10.2312/zipe.1982.066

mict, with pebbles of quartz and metaquartzites. In the eastern part they are polymict, with pebbles of quartz, sandstones, metaquartzites, various types of phyllites and rarely porphyroids. In general, in conglomerates the content of quartz increases toward the overlier, in contrast to other rock fragments (VOZÁROVÁ 1973).

An important horizon in the Rožňava formation are acid tuffs (thickness 5 - 20 m), which are of regional extension (REICHWALDER 1973) and are overlying, in places underlying the conglomerate horizon. Only seldom bodies of paleorhyolites and paleodacites are found in this position (KANTOR 1950; VOZÁROVÁ 1977; KULICH 1974).

From the conglomerates gradually a complex of sandstones develops in which bodies of sandy shales of lenticular, rarely of tabular shape are intercalated. The inner texture of this complex is distinctly cyclic, with cycles of fining upward type, mutually separated by erosion wash-outs. In the basal parts the cycles are coarse sandy to conglomeratic, toward the upper parts sandy, i.e. of braided alluvium type. The sandstones are composed of 80 - 95 % quartz; 1 - 3 % feldspars; 1 % mica and 12 - 13 % rock fragments.

The described sequences roughly correspond to the first megacycle. A further cycle begins to develop in the shape of a new conglomerate horizon. In time, manifestations of the following stage of volcanic activity are bound to this period. A complex of conglomerates and sandstones originated, which contains layers of volcanoclastic sediments and also small paleorhyolite bodies of felsitic texture (MIŠÍK 1953; IVANOV 1965). The volcanic material has a significant share in composition of accompanying clastic sediments. Volcanics of the Rožňava formation belong to subalkalic volcanics of alkalic-calcic series. Petrochemically they correspond to transitional members between high- and low-calcareous rhyolite-dacites (GREGOR et al. 1979).

The evidence of the age of the Rožňava formation is very rare. The sporomorphs found in the sandstone-shaly part of the first megacycle are of wide range from Stephanian D to Autunian (PLANDEROVÁ 1980).

The sediments of the Rožňava formation formed in a continental sedimentary environment of alluvial fan type. The proximal parts of the original sedimentary basin were bordered by a system of proluvial fans, in the present-day state of structurally unmature conglomerate bodies. The coarse-grained clastic material was transported by a system of braided stream beds and in the distal part a wide alluvial plain formed which was silted up by flood sediments. In the area of the alluvial plain temporary lakes originated in which well bedded, relatively fine-grained sediments deposited. They are well observed mainly in the upper parts of the megacycle.

Štítnik formation

The Štítnik formation represents the middle and upper part of the second megacycle. A characteristic lithological feature of the Štítnik formation is the alternation of sandstones and shales. The well-developed, bedded bodies display equable thickness. In general, in the basal parts of the sequence sandstones, locally coarse-grained,

DOI:https://doi.org/10.2312/zipe.1982.066

predominate. In petrography they correspond to quartz to arcose wackes, with 84 - 88 % quartz, 4 - 10 % feldspar, 5 - 7 % micas. Toward the overlier the amount of bodies of shales of greenish-grey and violet-green colour is higher, or shales completely predominate. In these parts of the profile of the Štítnik formation a discontinuously developed horizon of fine-grained light-grey sandstones occurs which is rich in feldspar detritus (25 - 30 %) and clastic mica (10 %). In texture the sandstones are relatively well sorted, with content of matrix around 15 - 20 %. In the uppermost parts of the Štítnik sequence carbonate shales, sandstones and detrital dolomitic limestones deposited. The latter form lenticular bodies 30 - 50 m thick. Manifestations of volcanic activity were sporadical in the time of sedimentation of the Štítnik formation. Effusive bodies of felsitic paleorhyolites and associated volcanoclastics were described in a volcanogenic horizon nearly 2 km long in strike and with a thickness of 80 - 120 m (STIMMEL 1968).

Biostratigraphic ranging of the Stítnik formation was considered mainly on the basis of the works by ŠUF (1960, 1963) which are based on finds of flora from the upper parts of the formation studied by NĚMEJC. NĚMEJC ranged fragments of branches and cones of the species Pseudovoltzia liebeana (GEIN) FLORIN and leaves of the genus Sphenozamites to the Upper Permian (in ŠUF 1963). ŠUF (1960) ranged bivalve shell remnants of the family Antracosiidae AMAL. 1892 or of the genus Carbonicola MC COY 1855 to the Lower Triassic. The last palynological studies of PLANDEROVÁ (1980) from the horizon of shales with carbonate bodies also confirmed the Lower Triassic.

The sediments of the Štítnik formation deposited in the area of an alluvial near-shore plain with a system of lakes. The amount of clastic material was supplied from the continent by river beds which disembogued into this zone. The uppermost parts of the sequence correspond to a lagoona-sabkha complex. The basin type of sedimentation is characterized by well-developed bedding, frequent lamination, allochthonous flora, the presence of clastic mica, abundant marks of bioturbation activity of organisms, imprints of bivalve shells.

5.3. General characterization of the South Gemeride basin

The South Gemeride basin belongs to the type of taphrogenic basins founded on continental type crust. It originated as a consequence of Asturian tectonic activity. The sedimentary filling was derived from immediate surroundings, generally from north to south. The fault systems on which the basin was founded were chimneys of volcanic centres. The material from them became part of the basin filling. Synsedimentary tectonics was reflected in megacyclic structure of the sequences and also in repeated activation of volcanic activity.

After the commencing stage of high tectonic activity of taphrogenic type, when the basin was morphologically highly dissected and filled up with continental facies, slow diminishing of activity of faults, also greater subsidence of the whole area was evident. The basin began gradually to communicate with the marine area situated to the south.

DOI:https://doi.org/10.2312/zipe.1982.066

References

ABONYI, A. et al.: Slovenské magnezitové ložiská. I., II.
Manuscript. Archív - Geofond, Bratislava 1972

ANDRUSOV, D.; BYSTRICKÝ, J.; FUSÁN, O.: Outline of the Structure of the West Carpathians.
10 th Congr. Carp.-Balk. Geol. Ass., Guide to Exc., Bratislava (1973), p. 5-43

BAJANÍK, Š.: Výsledky valúnovej analýzy permských psefitov v oblasti západne od Veľkej Knoly.
Geol. práce, Správy, Bratislava 34 (1965), p. 55-66

BAJANÍK, Š.: Vysvetlivky k listu Spišská N. Ves (1:50 000). Časť paleozoikum.
Manuscript, Archiv GÚDŠ, Bratislava 1967

BAJANÍK, Š. et al.: Vysvetlivky ku geologickej mape Spišsko-gemerského rudohoria (1:50 000).
Manuscript. Archiv GÚDS, Bratislava 1979

BOUČEK, B.; PŘIBYL, A.: Revise trilobitů slovenského svrchního karbonu.
Geologické práce, Zprávy, Bratislava 20 (1960), p. 5-51

BUBNOFF, S. v.: Einführung in die Erdgeschichte, 2. Aufl.
Halle: Mitteldeutsche Druckerei und Verlagsanstalt G.m.b.H. 1949

CHMELÍK, J. et. al.: Litofaciálny výskum Spišsko-gemerského rudohoria.
Manuscript. Archiv GÚDŠ, Bratislava 1962

DRNZÍK, E.: O zrudnení typu medhatých pieskovcov v perme melafýrovej série na severovýchodných svahoch Nízkych Tatier.
Mineralia Slovaca, Spišska N. Ves 1 (1969) 1, p. 7-39

ĎUROVIČ, V.: Sedimentárno-petrografický výskum vulkanosedimentárnej (melafýrovej) série centrálnych Záp. Karpát.
Acta geol. et geogr. Univ. Com., Geologica, Bratislava 23 (1971), p. 5-114

GREGOR, T.; REICHWALDER, P.; VOZÁROVÁ, A.: Kyslý vulkanizmus v perme rožňavsko-železnickej série.
Sborník referátov z Konferencie o paleovulkanitoch.
Z. Karpát, Bratislava, 1979 (in press)

ILAVSKÁ, Ž.: Sporen und Hystrichosphaeritiden aus dem Karbon der Niederen Tatra.
Geol. zborník, Geologica Carpathica, SAV, Bratislava 15 (1964) 2, p. 227-232

ILAVSKÝ, J. et. al.: Záverečná správa o vrtoch LU-1, LU-2, LU-3.
Manuscript. Archiv GÚDŠ, Bratislava 1978

IVANOV, M.: Litológia, petrografia a metamorfizmus paleozoika Spišsko-gemerského rudohoria.
Zborník geol. vied. Záp. Karpaty, Bratislava (1965) 3, p. 43-92

KAMENICKÝ, J.: Der geologische Bau des Nord-westlichen Teiles des Vepor-Erzgebirges.
Acta geologica et geographica Universitatis Comenianae, Bratislava 32(1977) p. 5-43

KANTOR, J.: Geologicko-montanistické pomery oblasti Štós-Hačava-Nižný Medzev.
Manuscript. Archiv GÚDŠ, Bratislava 1950

KANTOR, J.; RYBÁR, M.: Rádiometrické veky granitov zo Spišsko-gemerského rudohoria a priľahlej časti veporíd.
Geologické práce, Správy, Bratislava 73 (1979), p. 213-235

KOVÁCH, A.; SVINGOR, E. GRECULA, P.: Nové údaje o gemeridných granitoch.
Mineralia Slovaca, Spišská N. Ves 11 (1979) 1, p. 71-77

KOZUR, H.; MOCK, R.; MOSTLER, H.: Stratigraphische Neueinstufung der Karbonatgesteine der unteren Schichtenfolge von Ochtiná (Slovakei) in das oberste Visé und Serpukhovian (Namur A).
Geol. Paläont. Mitt., Innsbruck 6 (1976) 1, p. 1-29

DOI:https://doi.org/10.2312/zipe.1982.066

KRIST, E.: Karbonské zlepence bindt-rudňanského vývoja v severnej časti Spišsko-gemerského rudohoria.
Geol. práce, Zošit, Bratislava 36 (1954), p. 3-77

KRUMBEIN, W.C.: The effects of abrasion on the roundness of rock fragments.
J. Geology, Chicago 49 (1941), p. 64-72

KULICH, P.: Vysvetlivky ku geologickej mape M = 1:25 000, list Rožňava a Jablonov - paleozoická časť.
Manuscript, Archiv GÚDŠ, Bratislava 1970

MAHEĽ, M.; VOZÁR, J.: Geologická a litologická charakteristika štruktúrnych vrtov SM-1, SM-2 (Smižany).
Regionálna geológia Záp. Karpát, Bratislava 1 (1973), p. 5-78

MÁŠKA, M.: Správa o výskume paleozoika Spišsko-gemerského rudohoria (I.Perm).
Správy o geol. vyskumech ÚÚG v r. 1956, Praha (1957), p. 136-146

MIŠÍK, M.: Geologické pomery medzi Jelšavou a Štítnikom.
Geol. sborník IV., Bratislava (1953) 3-4, p. 557-585

NĚMEJC, Fr.: Příspěvek k poznání rostlinných nálezů a stratigrafických poměrů v permokarbonu na Slovensku.
Rozpravy II. tř. České akademie. věd., Praha 56 (1947) 15, p. 1-34

NOVOTNÝ, L.; BADÁR, J.: Stratigrafia, sedimentológia a zrudnenie mladšieho paleozoika chočskej jednotky severovýchodnej časti Nízkych Tatier.
Mineralia Slovaca, Spišská N.Ves 3 (1971) 9, p. 5-23

PLANDEROVÁ, E.: Biostratigrafické vyhodnotenie karbónu chočského príkrovu na základe palinológie.
Geol. práce, Správy, Bratislava 72 (1979), p. 32-61

PLANDEROVÁ, E.: Nové poznatky o veku rožňavsko-železníckej skupiny.
Spravy, GÚDŠ, Bratislava 74 (1980) (in press)

REICHWALDER, P.: Geologické pomery mladšieho paleozoika jv. časti Spišsko-gemerského rudohoria.
Západné Karpaty, GÚDŠ, Bratislava 18 (1973), p. 99-141

ROZLOŽSNIK, P.: Die geologischen Verhältnisse der Gegend von Dobšiná.
Geologica Hungarica, sér. geologica, Budapest 5 (1935), p. 4-117

ROZLOŽNÍK, L.: Bázické vulkanity v karbóne dobšinského vývoja.
Geol. práce, Správy, Bratislava 26 (1963), p. 35-49

SEILACHER, A.: Studien zur Palichnologie. I. Über die Methoden der Palichnologie.
N. Jb. Geol. Paläont., Abh., Stuttgart 96 (1953), p. 421-452

SITÁR, V.; VOZÁR, J.: Erster Fund einer Karbon-Flora in der Choč-Einheit der Niederen Tatra (West-Karpathen).
Geol. zborn. Geologica Carpathiaca, SAV, Bratislava 24 (1973), p. 441-448

SNOPKOVÁ, P.: Správa o vyhodnotení vzoriek za úlohu 122.
Manuscript. Archiv GÚDŠ. Bratislava 1978

SNOPKOVÁ, P.; SNOPKO, L.: Biostratigrafia gelnickej série v Spišsko-gemerskom rudohorí na základe palinologických výsledkov (Západné Karpaty - paleozoikum).
Záp. Karpaty, sér. geológia, GÚDŠ, Bratislava 5 (1979), p. 57-102

ŠTIMMEL, J.: Správa o výsledkoch prieskumu v okolí Gočaltova.
Archív GPÚP, 1968

ŠUF, J.: Nové poznámky ke geologii okolí Kobeliarova, Štítnika a Nádraže na jižním Slovensku.
Geol. práce, Zprávy, Bratislava 20 (1960), p. 111-126

ŠUF, J.: Správa o geologickém průzkumu okolí Štítnika.
Geologické práce. Správy, Bratislava 27 (1963), p. 63-67

VÁCLAV, J. et. al.: Výsledky II. etapy litogeochemického (metalometrického) výkumu z oblasti Košickej Belej.
Manuscript, Archiv GÚDŠ, Bratislava 1980

DOI:https://doi.org/10.2312/zipe.1982.066

VOZÁR, J.: Viacfázový charakter permského vulkanizmu chocskej jednotky v Nízkych Tatrách.
Geol. Práce, Správy, GÚDŠ, Bratislava 55 (1971), p. 131-137

VOZÁR, J.: Stavba permských vulkanitov chocskej jednotky na severných svahoch Nízkych Tatier.
Záp. Karpaty, sér. miner., petrogr., geochémia, loziská, GÚDŠ, Bratislava 1 (1974), p. 7-49

VOZÁR, J.: Magmatic rocks of the tholeiite series in the Permian of the Choc nappe in the West Carpathians.
Mineralia Slovaca, Spisská N. Ves 9 (1977) 4, p. 241-258

VOZÁROVÁ, A.: Valúnová analýza mladopaleozoických zlepencov Spissko-gemerského rudohoria.
Západné Karpaty, GÚDŠ, Bratislava 18 (1973), p. 7-99

VOZÁROVÁ, A.: Petrografia mladopaleozoických sedimentov v juhovýchodnej casti Spissko-gemerského rudohoria.
Západné Karpaty, sér. min., petr., geoch. a loziská, Bratislava 3 (1977), p. 147-175

VOZÁROVÁ, A.: Litofaciálna charakteristika permu v severozápadnej casti veporika.
Západné Karpaty, sér. min. petr. geoch. met., GÚDŠ, Bratislava 6 (1979), p. 61-117

VOZÁROVÁ, A.; VOZÁR, J.: Základné crty paleogeografie mladsieho paleozoika Západných Karpát.
Geol. práce, Správy, GÚDŠ, Bratislava 64 (1975), p. 81-96

VOZÁROVÁ, A.; VOZÁR, J.: Permian of the West Carpathians.
Guide book for geological excursion, Bratislava (1979), p. 3-80 (1979 a)

VOZÁROVÁ, A.; VOZÁR, J.: Crystalline complex in basal part of Choc nappe.
Geol. práce, Správy, Bratislava 72 (1979), p. 195-199 (1979 b)

VRÁNA, S.; VOZÁR, J.: Über die Mineralgemeinschaft der Pumpellyit-Prehnit-Quarzfacies in der Niederen Tatra.
Geol. práce, Správy, Bratislava 49 (1969), p. 91-101

ZOUBEK, Vl.: Poznámy o krystaliniku Západních Karpát.
Vestník S. Geol. úst., Praha 12 (1936), p. 207-239

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Explanatory Notes to Lithotectonic Profiles of Variscan Molasse in Bulgaria (Comment to Annex 31 - 34)

by

YANAKI G. TENCHOV[1)]

1. Introduction

1.1. General information

Variscan molasses are known on more than one third of the territory of Bulgaria, and namely, North Bulgaria (Danubian plain), in the Western and Central Balkan range, in the Sredna Gora Mts., Svety Illiya Hills, Strandja and Rhodope Mts. and the Kraishte region (Figs 1, 2).

These molasses are studied in different details. Thus, some of them - in the West Balkan range and a part of West Sredna Gora Mts. - are lithostratigraphically subdivided, mapped on the scale 1:25 000, and studied from lithologic and paleontological viewpoint. Others are mapped and subdivided (in the Central Balkan range), or separated from the basement and the cover only (mainly in Sredna Gora Mts. and the Kraishte region). For some areas (mainly in the south-east and south-west part of the country) the existence of Variscan molasses is supposed on the basis of scarce indications. Variscan molasses in North Bulgaria are covered by 800 to 3000 m younger formations. Therefore, they are studied more or less in details, in dependance on the core percentage. The core obtained in most cases is no more than 2 to 5 %. In all other regions the Variscan molasses are known from outcrops, or covered by Meso-Cenozoic rocks. There is no positive evidence about a possible existence of Variscan molasses in the main part of the Rhodope Massif, where such sediments are known only within the marginal parts.

1) Bulgarian Academy of Sciences, Geological Institute; Bulgaria, Sofia 1113, ul. Akademik Georgi Bonchev

DOI:https://doi.org/10.2312/zipe.1982.066

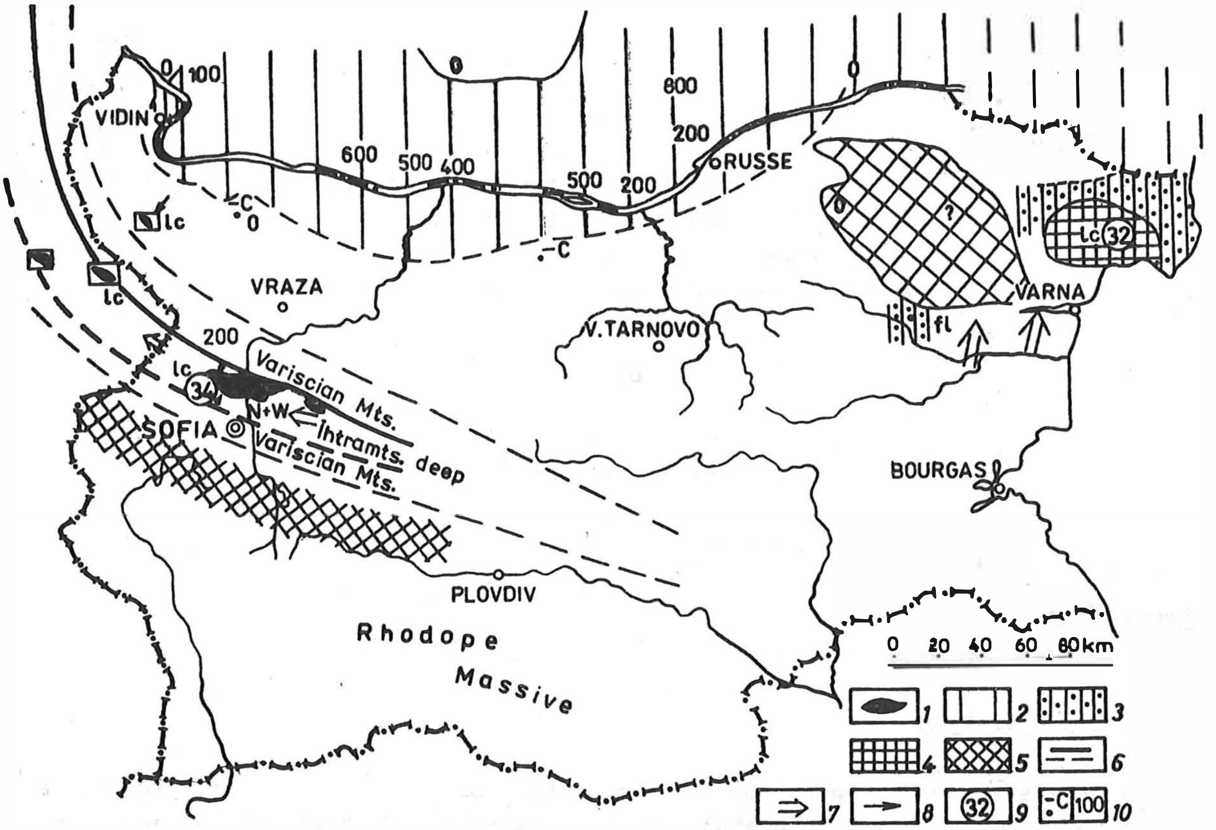


Fig. 1. Visean-Westphalian paleogeography of Bulgaria

1 - outcrops of molasse sediments, 2 - marine sediments in boreholes, 3 - paralic sediments in boreholes, 4 - Namurian C - Westphalian D limnic and fluvial sediments in boreholes, 5 - zone of erosion during the Carboniferous, 6 - Variscan folded belts, 7 - main transport directions, 8 - local transport directions, 9 - location of the lithotectonic profiles, 10 - lack of sediments or thickness of sediments in boreholes

1.2. Tectonic position

The Variscan molasses in Bulgaria are known from the foredeep - Dobrogea and the other part of the North Bulgaria plain; from the inner and intramountain depressions - Svoge Basin and the outcrops in the Balkan and the Sredna Gora ranges; from the backland - the Kraishte region; and from the border zone between Variscan ranges and the Rhodope Massif - South-West Bulgaria and possibly the Klokotnitsa outcrop.

2. Tectonic structure and development of Bulgaria in Variscan times

The uprise of the Variscan ranges, as a long-time positive part of the relief, is fixed by the flysch trough in the backland to the south of the range. The passage to a

DOI:https://doi.org/10.2312/zipe.1982.066

flysch sedimentation is dated as Frasnian (Chr. SPASSOV, recent investigation). Flysch sediments are not known with certainty to the North of the range. YANEV (in NACHEV & YANEV 1980) regarded some flysch-like sediments to the North of the Variscan ranges as Devonian in age, but there is no paleontological or isotopic evidence or lithological study in favour of this opinion. The full section of the Devonian in some deep boreholes in NW Bulgaria or neighbouring territories of Rumania does not contain terrigeneous sediments.

The formation of a relief, as a source area for the molasses sedimentation, is bounded with the Sudetian phase.

As a result of the Sudetian phase an anticlinorium was formed. Its central part was a depression formed over a synclinal or a graben. This intramountainous basin, the Svoge Basin, was filled with molasse sediments in Namurian A to Westphalian C. The basement of this basin, represented by Devonian flysch sediments and Ordovician an Silurian

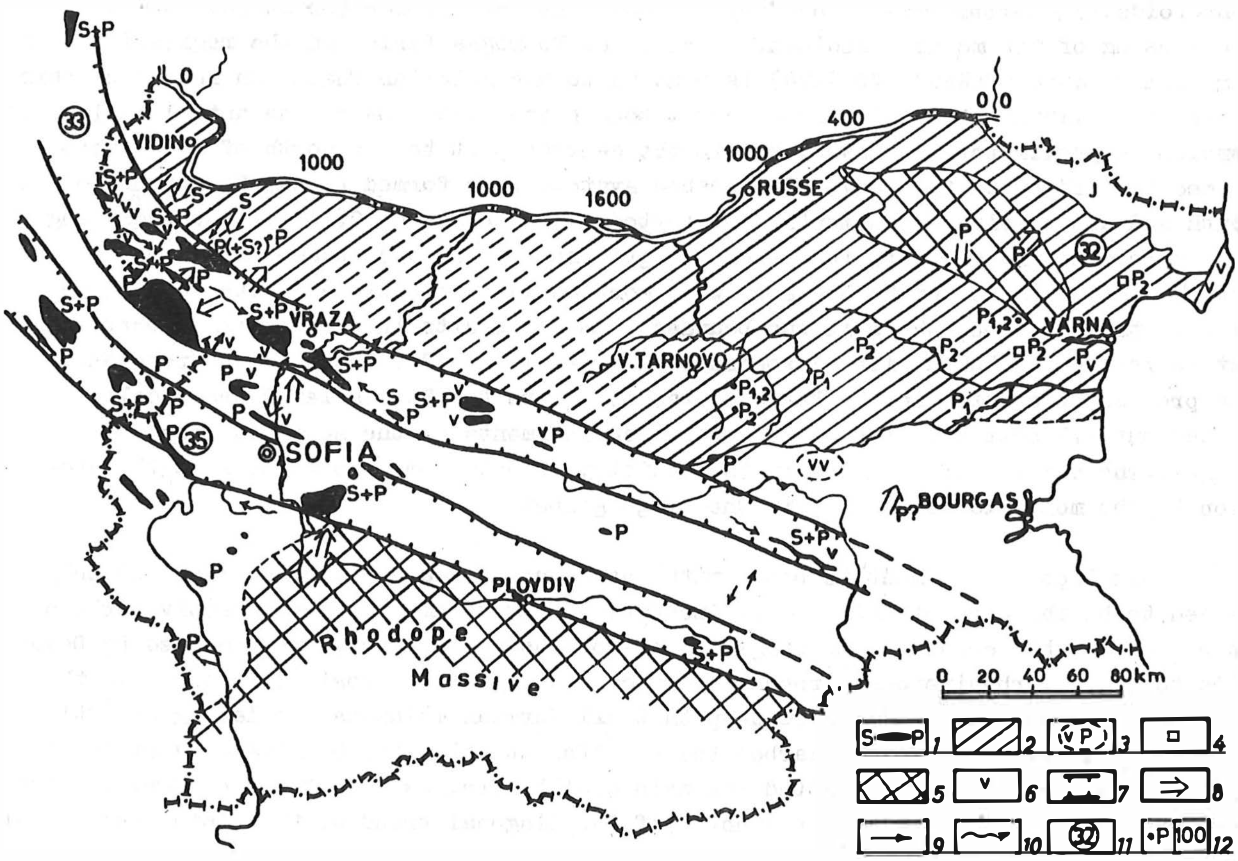


Fig. 2. Post-Asturian-phase (Stephanian C - Permian) paleogeography of Bulgaria

1 - outcrops of Stephanian C (S) and/or Permian (P) sediments, 2 - Permian foredeep sediments, 3 - allochthonous outcrop (Alpine tectonics), 4 - chemogenous sediments, 5 - erosive zone, 6 - volcanic rocks, 7 - foredeep and backdeep graben systems, 8 - main transport directions, 9 - local transport directions, 10 - river valley with transport direction and fluvial sediments, 11 - location of the lithotectonic profile, 12 - lack of sediments, or thickness of sediments in boreholes

DOI:https://doi.org/10.2312/zipe.1982.066

argillites, is covered by the molasses with angular disconformity (TENCHOV 1966). In the Kraishte region the Devonian flysch is covered by Permian molasse. There is no place in Bulgaria in which a gradual transition between Variscan molasses and flysch has been observed up to now. In the foreland the molasse of the Dobrogea Basin of uppermost Visean to Westphalian D age are laying over eroded surface of Upper Devonian to Tournaisian carbonates, while in the north-west part of the foredeep the carbonates are dated as Middle Visean (SPASSOV 1976). On the existence of these older levels of the main molasses in Dobrogea Basin is based a suggestion that the Variscan ranges are formed during the topmost Visean. Both Svoge and Dobrogea Basins show that during the Namurian and the Westphalian some movements supported the relief-building processes and are reflected in the conglomerates of the Svoge Basin and in conglomerates or thick sandstone levels in the Dobrogea Basin. In this manner movements of Erzgebirge, Silesian, Palentian (?) and Leonian Phases have been detected. As a result of the last the sedimentation in the Svoge Basin was interrupted. During the Leonian, or more probably with the Asturian Phase, the Svoge graben was intensely compressed with formation even of recumbent folds. The latter were covered by the sediments of Permian (or Stephanian C) age. The closing of the molasse sedimentation in the Dobrogea Basin and the regression of the sea from Romania (PARASCHIVE 1974) is bounded to the Asturian Phase. In result of this phase a rebuilding of the Variscan ranges took place. The area of the anticlinorium remained approximately the same, but in the central part to the North of Svoge were formed the ridges of the range. Two graben systems were formed to the North and to the South and upper molasse sedimentation started from Stephanian C. After the beginning of the Permian the marginal faults of the grabens revived and became magma conduits. The volcanoes of the northern graben were more active. Volcanic activity took place also in the foredeep, where it was bounded by major faults in the foreland, where no active folding is known, i.e. Saxonian-type tectonics is developed in the foreland. The process of erosion in the Variscan ranges before the Stephanian C practically washed out all post-Silurian and pre-Namurian sediments of the southern slope of the ranges. The remains of Devonian in the vicinity of Svoge are protected from the erosion by the molassic cover only in the Svoge graben.

Another important moment is bound with the Asturian Phase - the foreland not only ceased to be the area of molassic sedimentation, but became an area of active erosion. In result of this erosion some conglomerates of the north graben are composed by Devonian to Lower Carboniferous carbonate pebbles. The level of erosion, at least in the south part of the foreland, is so deep that all Permian molasses are laying directly over Upper to Middle Devonian carbonate. A differentiation in the movements diagonally to the Variscan range permitted the main coal-bearing molasse to be preserved (YANEV and TENCHOV 1979) and gave the beginning of the diagonal trend of the Alpine tectonical plan.

After the second main folding of the Variscan orogen the erosion was prevailing over the relief-building process. The relief only occasionally was revived at the boundary between the Lower and Upper Lower Permian and between the Lower and the Upper Permian. In result the territory of the molasse sedimentation expanded on account of the territory of erosion. In the sedimentation process feeding with reworked molasses became more active then the supply with fresh-eroded basement rocks. In the end of the formation of the Variscan molasses a chemogenous sedimentation took place and halite and anhy-

DOI:https://doi.org/10.2312/zipe.1982.066

drite were incorporated in the section. The last molassic sediments were not affected by any movements and so were covered with parallel unconformity by the platform cover, i.e. by the Lower Triassic sediments.

The magmatism, well dated and widely distributed, is mainly of the so-called subsequent effusive type. It starts about the beginning of the Permian. Some volcanic rocks are covered by Stephanian C near the village of Zverino, but the lower age-boundary is pre-Cambrium. Some pyroclastic sediments in the Westphalian of Svoge Basin are of unknown origin. In the Dobrogea Basin the Vranino Formation is built mainly on account of effusive rocks, but ashes are not known with certainty. Volcanic rocks are known some hundred kilometres to the West in the outcrop Runkula in Yugoslavia in the Westphalian B or C. This outcrop is in the same tectonic position as the Svoge Basin. The intrusive activity is not so well dated. One episode is related to the first main folding phase. It is represented by the Balkan Ca-alkaline and the K-alkaline plutons, that metamorphosed sediments incl. Silurian, and are known as pebbles in the conglomerates of the Namurian (Svoge Basin) as well as of the Stephanian. Plutonic activity related to the second phase of folding is not known up to now.

The molasses of the Variscan range in Bulgaria are tectonically deformed and at least some of the deformations are Variscan. So recumbent folds of the Svoge Carboniferous are covered by the Triassic, which builds a gentle normal anticline. The deformations belong to Leonian or Asturian folding, because the Stephanian-Permian is covered by the Triassic with an angular unconformity of not more than 15°. The same relation between the Permian and Triassic rocks is generally observed in the Variscan range flanks. Even less important is this unconformity in the foredeep of North Bulgaria. All Variscan molasses in the scope of the Alpine structures are additionally deformed.

3. General and stratigraphic information on the lithotectonic profiles

As far as the lithologic features of the sections are shown on the lithotectonic profiles, here they will not be discussed.

3.1. Variscan foredeep (Annex 32)

First information on the Carboniferous sediments in the Dobrogea (in deep borehole R-50 - Rakovski) was published by SPASSOV and YANEV (1966) and by TENCHOV (1967). Later TENCHOV and KOULAKSUZOV (1972) and KOULAKSUZOV and TENCHOV (1973) published lithostratigraphical and chronostratigraphical subdivision, the latter based on fossil flora. LATCHEVA and PETKOVA (1974) studied microflora assamblages. The Permian sediments were studied and subdivided by YANEV, but the lithostratigraphic units never have been officially introduced. The Permian salt deposits were dated palynological by SCHIRMER and KURZE (1960).

The accepted chronostratigraphic division is based on faunal and floral remains for the Visean, and on floral remains, for the Upper Carboniferous. For the Permian micro-

DOI:https://doi.org/10.2312/zipe.1982.066

floral data are used. Condensed information on them is as follows:

The B e l g u n F o r m a t i o n provides some conodonts: Gnathodus symmutatus, Hindeodella undata, H. subtilis etc., interpreted as lower part of the Upper Visean.

The T r i g o r t s i F o r m a t i o n with Archaediscus krestovnikovi, A. moelleri, Endothyranopsis crassus, Howhinia exilis, H. gibba Tetrataxis paraminima (MICHAILOVA-JOVTCHEVA 1971) and especially with Goniatites striatus (SPASSOV 1972) is dated as middle part of the Upper Visean. Some plant remains as Adiantites cf. tenuifolius, Lyginopteris cf. bermudensiformis, L. larischi are also found in this formation.

In K o n a r t s i F o r m a t i o n only plant remains occur in some intervals: Adiantites cf. tenuifolius, Rhodea aff. tenuis, Lyginopteris bermudensiformis, L. larischi, L. stangeri, Sphenophyllum tenerrimum, Mesocalamites cistiiformis, M. roemeri. Upper Visean age is suggested.

The I r e c h e k F o r m a t i o n is richer in plant fossils: Eleutherophyllum mirabile, Lepidodendron veltheimi, Cardiopteridium spetsbergense, Archaeocalamites radiatus, out of the plants known from the previous formation are found. The Upper Visean age suggested by TENCHOV is discussed by SPASSOV (1974).

The M o g i l i s h t e F o r m a t i o n covers with erosive surface different levels of the Irechek Formation. The time gap between both formations is from Namurian A to Namurian B, eventually a part of Namurian C. The fossil flora gradually changes from the base to the top and three different associations can be distinguished. The lower assamblage, in the lower 150 m, contains frequent Neuralethopteris schlehani, N. jongmansi, Paripteris gigantea, Mariopteris acuta, Sphenopteris hollandica, Mesocalamites sp. div. This flora is indicating Namurian C. In the next 160 m the second association is rich in frequent Calamites sp. div., Sphenophyllum cuneifolium, Paripteris gigantea, P. pseudogigantea, P. schützei, Neuropteris heterophylla, Lonchopteris baurii, L. conjugata, L. eschweileriana. It is regarded as Westphalian A. In the upper 220 m the third association is characterized by the appearance of Neuropteris obliqua, N. rarinervis, Lonchopteris silesiaca, Paripteris schützei and Sphenopteris striata. It is considered as the lower half of Westphalian B.

The V r a n i n o F o r m a t i o n , of sandy composition is poor in fossils. By its stratigraphic position it is regarded as Westphalian B.

In the M a c e d o n k a F o r m a t i o n are distinguished two associations of megaflora. The lower one has many elements in common with the upper association of Mogilishte Formation, and is marked by the appearance of Sphenophyllum emarginatum, Neuropteris obliqua, N. scheuchzeri and Sphenopteris obtusiloba. It is regarded as Upper Westphalian B. The next association is characterized by the disappearance of many taxa of the previous one and the appearance of Neuropteris semireticulata and Alethopteris densinervosa. It is regarded as Westphalian C - lower part.

In the V e l k o v o F o r m a t i o n no plant remains are found. By stratigraphic position it is regarded as Westphalian C. At the base is observed an eroded relief

DOI:https://doi.org/10.2312/zipe.1982.066

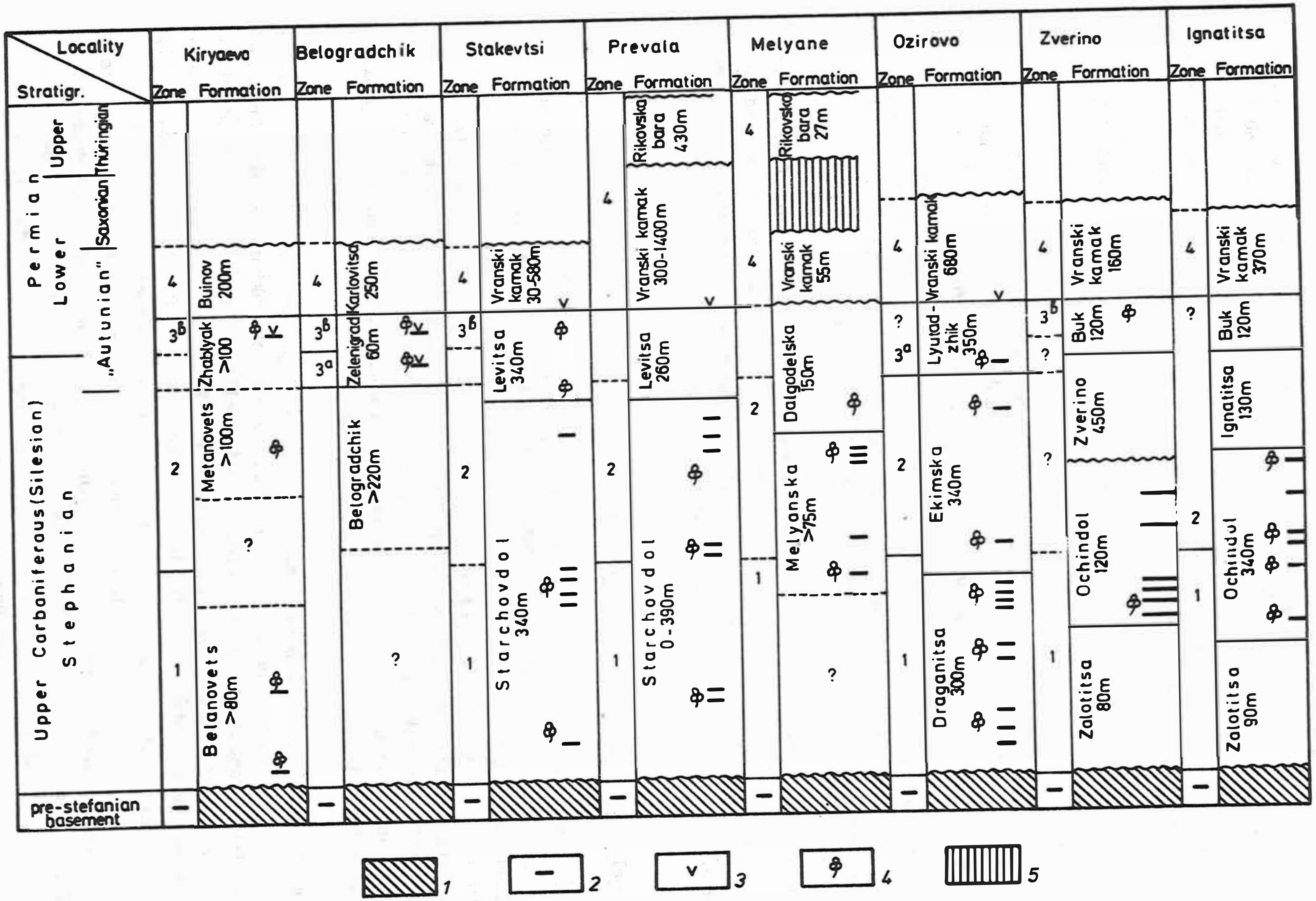


Fig. 3. Lithostratigraphic division and correlation scheme of Stephanian-Permian fossil-bearing sediments in NW Bulgaria (emended after TENCHOV 1973)

1 - pre-Stephanian rocks, 2 - coal seam, 3 - volcanogenous sediments or lava layers, 4 - fossil flora findings, 5 - break in sedimentation

DOI:https://doi.org/10.2312/zipe.1982.066

with height differences up to 100 metres.

In the next - K r u p e n F o r m a t i o n - the flora becomes poorer in species and from the third coal-seam new species are registered: Neuropteris ovata and Neuropteris scheuchzeri with big leaves. The interval below the third coal-seam is regarded as Westphalian C - upper part; the interval above the seam as Westphalian D. The upper part of the Formation is eroded in different places up to 30 m.

The P o l y a n t s i F o r m a t i o n is sandy, and no plant remains are registered. It is regarded as Westphalisn D.

The G u r k o v a F o r m a t i o n is the last one of the coal-bearing molasses. In the last year some boreholes penetrated higher levels of this Formation, and consequently they are not shown on the type profile (Annex 32). The Formation contains monotonous flora enriched in Pecopteris incl. P. unita, frequent Cordaites rest, Neuropteris ovata and N. scheuchzeri, as well as more Alethopteris species in the uppermost part, which are still in course of paleobotanical determination. It is difficult to say if the Stephanian is represented by its lower stage - the Cantabrian.

The third part of the molasses - the red molasses - are of unfavorable facies for megaflora conservation. In a part of North-East Bulgaria the salt-bearing part of them contains some microflora: Nuskoisporites klausi, Lueckisporites virkkiae, L. trisaccate etc. (SCHIRMER and KURZE 1960), that proves Upper Permian age.

3.2. Variscan belts, the north flanc (Annex 33)

The Paleozoic continental sediments in the north-west part of Bulgaria crop out in many places. They are mentioned first by TOULA (1877). At present all fossiliferous outcrops are studied lithologically and stratigraphically. The main part of the outcrops without fossils are also lithologically studied. The type-profile 33 is compiled on the base of detail data by different outcrops. On Fig. 3 is shown the lithostratigraphic division in fossiliferous outcrops and the florizone division after TENCHOV (1973). The subdivision on Vranski kamak I and Vranski kamak II Formations, as shown on the profile 33, never had been introduced, or discussed in an article.

The paleobotanical investigation of fossiliferous outcrops permits three zones to be distinguished and traced in the outcrops. The first zone is charakterized with Sphenophyllum oblongifolium, Pecopteris unita, Alethopteris zeilleri, Callipteridium pteridium and Taeniopteris jejunata, that prove Stephanian C age. The second zone contains Pecopteris bredovi, Sphenopteris leptophylla, S. decheni, S. fossorum, S. aff. matheti, Callipteridium zeilleri, C. pseudogigas, Neuropteris auriculata, N. neuropteroides, also typical for Stephanian C. The third zone is with two subzones. Subzone 3^a with the appearance of the first conifers (Lebachia parvifolia, L. piniformis, L. hypnoides and Ernestiodendron filiciformis) still indicated Stephanian C - the so-called "Walchia beds". The subzone 3^b has richer coniferous assamblage as well as Callipteris conferta, C. naumanni, C. lodevensis, and other Lower Permian species.

DOI:https://doi.org/10.2312/zipe.1982.066

The localities Kiryaevo and Belogradchik (1963), and Stakevtsi (1972) are studied by YANEV and TENCHOV. YANEV and TENCHOV published data for localities Melyane (1962), Zverino and Ignatitsa (1978), Prevala (1976). Draganitsa-Ljutadgic is studied by SPASSOV et al. (1961). The fossil flora is studied by HARTUNG (1935), NEMEJC (1943) and TENCHOV (1973 a, 1976 a, 1977 a, 1977 b), and the interpretation of the flora was given by TENCHOV (1973 b).

The outcrops without flora are studied as follows: Smolyanovtsi by TENCHOV, SHOPOV and YANEV (in: MOSKOVSKI et al. 1963); the peak Midjur locality (ČUMAČENKO and ŠOPOV 1965), Teteven (ČATALOV et al. 1962, 1963), Sveti Illiya Hills (ČATALOV 1965) - regarded as Namurian in age, but it seams to be Permian, as is the case with Klokotnitsa outcrop (KOZUCHAROV et al. 1968).

The paleogeography and generalization on lithology, for the mentioned localities, are discussed by YANEV in several articles (1969, 1970 a, 1970 b) and for the country by YANEV (in: NACHEV and YANEV 1980).

3.3. Variscan intramountain depression (Annex 34)

In the Variscan intramountain depression is deposited the coal-bearing molasse of Svoge Basin. First information on the basin is published by TOULA (1878). Then followed some stratigraphic studies, based on megaflora - KRESTEW (1928), HARTUNG (1935), NEMEJC (1943) - and a stratigraphic study with lithostratigraphic division, followed in the profile, by TENCHOV (1966). The fossil flora is studied in details by TENCHOV (1977). Special lithologic study still is not executed. The Permian part of the section is shown after unpublished data of YANEV and TENCHOV.

Here I will stress on the fact that Permian sediments are not laying directly on the Carboniferous, but crop out at some places at a distance of only 2 kilometers in the west part of the Svoge Basin. The Permian sediments are covered by Lower Triassic sediments with angular disconformity not exceeding 15° in all the area surrounding the Svoge Basin. The Lower Triassic sediments cover recumbent folds of the Svoge Carboniferous. This indicates an extremely active folding after the Westphalian C and prior to Stephanian C.

The dating of the Svoge Basin formations is as follows: The T s a r i c h i n a F o r m a t i o n contains two floral associations: the lower one with Sphenophyllum tenerrimum, Mesocalamites sp. div., Eleutherophyllum mirabile, Zeilleria moravica, Neuropteris antecedens etc., is regarded as upper part of Namurian A. The second association contains Sphenopteris konjaroffi, with the appearance of Sphenophyllum cuneifolium, and is refered to Namurian B. This Formation has no contacts with the Svidnya Formation.

The S v i d n y a F o r m a t i o n with Neuralethopteris schlehanoides, Paripteris gigantea, Mariopteris acuta is refered to Namurian C.

DOI:https://doi.org/10.2312/zipe.1982.066

The D r a m s h a F o r m a t i o n is practically without plant remains. According to superposition relations it is believed to belong to the base of Westphalian A.

The S v o g e F o r m a t i o n with Calamites sp. div., Sigillaria sp. div., Paripteris gigantea, Mariopteris muricata, Corynepteris angustissima is Westphalian A in age.

The B e r o v d o l F o r m a t i o n contains a flora poor in species, mainly Calamites and Lepidodendron, and according to its position is regarded as the lower part of Westphalian B.

In the C h i b a o v t s i F o r m a t i o n three associations are established. The lower one contains Neuropteris scheuchzeri and Sphenophyllum majus and is regarded as Westphalian B. The second association contains Sphenophyllum trichomatosum and S. myriophyllum and might be of Westphalian C age. The upper association with Corynepteris pecopteroides and Odontopteris sp. is refered also to Westphalian C.

TENCHOV (1976) on the basis of the composition peculiarities of Svoge flora supposed an uplift of the area of sedimentation of at least 2000 m for the period from Namurian A to Westphalian C.

The Svoge Carboniferous is important for the interpretation of the intramountain basins into Variscan belts as stable and long-living sedimentation zones. The sediments reflect a number of folding phases, which are not well expressed in the foredeep or the backdeep of the Variscan belts. In the same time such basins are important for understanding the assymmetrical development of the Variscan belts and the fact that the movements in the northern slope of the Variscids are not well reflected by molasse deposition in the backland and vice versae - the movements in the south slope are not well reflected in the molasse sedimentation in the foreland. The presence of such basins into Variscan belts is the only evidence that important changes in the structural plan of the belts took place after the Westphalian C or D and prior to Stephanian C, i.e. that a second main phase of folding in the Variscids should be accepted.

3.4. Variscan belts in the backland (Annex 35)

The study of Variscan backland molasses in Bulgaria is quite recent. Only a small part of the outcrops is divided from the Lower Triassic sediments. The most complete study is executed on Noevtsi outcrop by YANEV (1979) and ELLENBERG et al. (1979).

Profile 35 follows the subdivision proposed by YANEV (1979). Data on some more outcrops are published by SPASSOV (1956), THON (1961), ZAGORČEV (1966, 1980), ZAGORČEV and POPOV (1968), ZAGORČEV et al. (1976).

No fossil records are fixed in the sediments on Bulgarian territory of the Kraishte region. In Yugoslavia, some 100 km west of the Bulgarian border, in Suva Planina Mt. (PENTIČ 1961) a coal-bearing grey sedimentation with plant remains pre-dates the red beds. The list of the flora indicates a Stephanian age. In the outcrop Lozenska Planina

DOI:https://doi.org/10.2312/zipe.1982.066

Mt. some 50 km east of the profile 35 (unpublished data of YANEV and TENCHOV) the section is quite different and the sedimentation starts with Stephanian C grey and red beds. Microflora proves (LATCHEVA 1979) the age.

YANEV (1979, p. 245, and Annex 35) supposed that Noevtsi Formation is placed higher then the section along the Scrino gorge west of the village of BOBOSHEVO. Recent studies by ZAGORCEV (1980) of this strongly tectonized outcrops show after my opinion that this section is identical of that of Noevtsi. Therefore, the age accepted for Noevtsi section as Upper Permian is to be regarded as provisional.

References

ČATALOV, G.: Jungpaläozoikum in den Sveti-Ilija Höhen.
Bull. Inst. Geol., Sofia 14 (1965), p. 107-134

ČATALOV, G.; GANEV, M.; STEFANOV, S.: Notizen über das Perm im Vasiljovosattel (Gebiet Teteven).
Trav. Géol. Bulg., Sér. Stratigr. Tect., Sofia 4 (1962), p. 31-39

ČATALOV, G.; GANEV, M.; STEFANOV, S.: Altpaläozoicum und Perm in der Gložener Antiklinale (Gebiet Teteven).
Trav. Géol. Bulg., Sér. Stratigr. Tect., Sofia 5 (1963), p. 17-27

ČUMACENKO, P.; ŠOPOV, V.: Le Permien dans la Stara-Planina de Čiprovci.
Bull. Geol. Soc. Bulg., Sofia 26 (1965) 3, p. 360-365

ELLENBERG, J.; JANEV, S.; LÜTZNER, H.: Das Permprofil von Noevci und seine Stellung in der variszischen Molasse Westbulgariens.
Z. geol. Wiss., Berlin 7 (1979) 6, p. 705-718

HARTUNG, W.: Flora und Altersstellung des Karbons im Westbalkan (Bulgarien).
Palaeontographica, Stuttgart 80 B (1935)

KOULAKSUZOV, G.; TENCHOV, Y.: Stratigraphy of the Lower Carboniferous in the Dobroudja Coal Basin.
Bull. Geol. Inst., Ser. Stratigr. Lithol., Sofia 22 (1973), p. 39-53

KOZUCHAROV, D.; BOJANOV, I.; ŠAVOV, S.: Geologie des Gebietes zwischen Dorf Klokotnica und Stadt Marica, Haskovo Gebiet.
Jub. Geol. Vol., Sofia (1968), p. 37-50

KRESTEW, Kr.: Über das Karbon des Iskir-Défilés in Bulgarien und seine Altersstellung.
Jb. preuß. geol. Landesanst., Berlin 49 (1928) 1, p. 551-579

LATCHEVA, J.: Données palynologiques sur l'age Stéphanien d'une série terrigéne dans la partie orientale de la montagne de Lozen (SO de la Bulgarie).
C. R. Ac. bulg. Sc., Sofia 32 (1979) 12, p. 1687-1690

LATCHEVA, J.; PETKOVA, A.: Palynological zonation of the Westphalian section in the Dobroudja Coal Basin.
Bull. Inst. Botanique, 25 (1974), p. 123-143

MICHAILOVA-JOVTCHEVA, P.: Données microfaunistiques pour la division du Dévonien et la Carbonifére dans les trous de forages de la Bulgarie du Nord-Est.
Bull. Geol. Inst., Sér. Paleont., Sofia 20 (1971), p. 129-137

MOSKOVSKI, S.; NEDYALKOVA, S.; TENCHOV, Y.; HARKOVSKA, A.; SHOPOV, V.; YANEV, S.: Stratigraphical and lithological studies in the nucleus and part of the mantle of the Mihailovgrad Anticline between the Chouprenska and Rikovska Rivers (NW Bulgaria).
Trav. Géol. Bulg., Sér. Stratigr. Tect., Sofia 5 (1963), p. 29-67

NACHEV, I.; YANEV, S.: Sedimentary Geocomplexes in Bulgaria.
Sofia: "Nauka i Izkustvo" 1980, 203 p.

DOI:https://doi.org/10.2312/zipe.1982.066

NEMEJC, F.: Paläobotanische Studien im Gebiete des westbulgarischen Permocarbons. Mitt. geol. Anst. Böhmen u. Mähren 8 (1943), p. 129-156

PANTIĆ, N.: Phytostratigraphie der jungpaläozoischen Ablagerungen in Jugoslavien. C.R. IV Congr. Stratigr. Carbonifère 2 (1961), p. 463-469

PARASCHIVE, D.: Stratigraphical study of Devonian and Carboniferous from the Moesic Platform, West of the Arges River. Studii Techn. Econom. Ser. J. Bucuresti 12 (1974), 165 p.

SCHIRMER, H.; KURZE, M.: Die stratigraphische Stellung des Salzsedimentes der Bohrung No 5 von Provadia. Bull. Inst. Geol., Sofia 8 (1960), p. 29-45

SPASSOV, Chr.: Geologie des Gebietes zwischen den Flüssen Struma und Dzerman und der Landstraße Kjustendil - Stanke Dimitrov. Bull. Inst. Geol., Sofia 4 (1956), p. 37-58

SPASSOV, Chr.: Stratigraphie des Unterkarbons in einigen Bohrungen in Nordost-Bulgarien. Bull. Geol. Inst., Sér. Stratigr. Lithol., Sofia 21 (1972), p. 5-17

SPASSOV, Chr.: Über die Stratigraphie des Unteren Karbons in Nordostbulgarien. Bull. Geol. Inst., Sér. Stratigr. Lithol., Sofia 23 (1974), p. 5-24

SPASSOV, Chr.: Das Unterkarbon in Nord-Bulgarien und dem naheliegenden rumänischen Gebiet (Mösische Platform). Geol. Balc., Sofia 6 (1976) 3, p. 41-52

SPASSOV, Chr.; TENCHOV, Y.; JANEV, S.: Der geologische Bau des Paläozoikums zwischen den Dörfern Komarevo und Ljutadzik (Nordwestbulgarien). Trav. géol. Bulg., Sér. Stratigr. Tect., Sofia 3 (1961), p. 5-31

SPASSOV, Chr.; YANEV, S.: Stratigraphy of the Paleozoic sediments in drillings from N.E. Bulgaria. Bull. Géol. Inst., Sér. Stratigr. Lithol., Sofia 15 (1966), p. 25-77

TENCHOV, Y.: Lithostratigraphy and structure of the Svoge Carboniferous. Bull. Géol. Inst., Sér. Stratigr. Lithol., Sofia 21 (1966), p. 41-62

TENCHOV, Y.: Upper Carboniferous plants from Borehole R-50, near the village of Rakovski, in the North-East Bulgaria. Bull. Geol. Inst., Sér. Paleont., Sofia 16 (1967), p. 131-135

TENCHOV, Y.: Stratigraphy of the Stephanian-Permian fossil-bearing sediments in NW Bulgaria. Bull. Géol. Inst., Sér. Stratigr. Lithol., Sofia 22 (1973), p. 55-72

TENCHOV, Y.: The fossil flora from the Stephanian-Permian outcrops in NW Bulgaria. I. Sphenopsida and Lycopsida. Bull. Géol. Inst., Sér. Paleont., Sofia 22 (1973 a), p. 91-101

TENCHOV, Y.: Composition Peculiarities of the Carboniferous flora of the Svoge Basin, West Bulgaria. Geol. Balc., Sofia 6 (1976) 1, p. 3-11

TENCHOV, Y.: Fossil flora from the Stephanian-Permian outcrops of Northwestern Bulgaria. 2. Pteropsida-Pecopteridales. Paleont., Lithol., Stratigr., Sofia 4 (1976 a), p. 17-26

TENCHOV, Y.: Fossil flora from the Stephanian-Permian outcrops in Northwest Bulgaria. 3. Sphenopteris, Neuropteridaceae, Taeniopteris. Paleont., Lithol., Stratigr., Sofia 6 (1977), p. 15-26

TENCHOV, Y.: Fossil flora from the Stephanian-Permian outcrops in Northwestern Bulgaria. 4. Alethopteridaceae, Callipteris, Odontopteris, Gymnospermophyta, Seminae. Paleont., Lithol., Stratigr., Sofia 7 (1977 a), p. 3-14

TENČOV, Y.: Flora und Biostratigraphie des Oberkarbons im Svoge-Becken (VR Bulgarien). Schr.-R. geol. Wiss., Berlin (1977 b) 7, 163 p.

DOI:https://doi.org/10.2312/zipe.1982.066

TENCHOV, Y.; YANEV, S.: Stratigraphy and lithology of the Upper Stephanian and Permian near the town of Belogradchik and Kiryaevo village (North-West Bulgaria).
Trav. géol. Bulg., Sér. Stratigr., Tect., Sofia 5 (1963), p. 69-97

TENCHOV, Y.; KOULAKSUZOV, G.: Lithostratigraphy of the Carboniferous in the Dobrudja Coal Basin.
Bull. Géol. Inst., Sér. Stratigr., Lithol., Sofia 21 (1972), p. 41-62

THON, H.: Beiträge zur Frage der Perm/Trias-Grenze in West-Bulgarien.
Bull. Inst. Geol., Sofia 9 (1961), p. 285-304

TOULA, F.: Untersuchungen im westlichen Teil des Balkan.
Sber. Akad. Wiss., Wien 4 (1877)

TOULA, F.: Untersuchungen im westlichen Teil des Balkan.
Sber. Akad. Wiss., Wien 7 (1878)

YANEV, S.: Fazies und lythogenetische Typen in den jungpaläozoischen Sedimenten in Nordwest-Bulgarien.
Bull. Géol. Inst., Sér. Stratigr., Lithol., Sofia 18 (1969), p. 91-126

YANEV, S.: Paleogeography of NW Bulgaria during the Paleozoic.
Rev. Bulg. Géol. Soc., Sofia 31 (1970) 2, p. 197-208 (1970 a)

YANEV, S.: Gesteinstypen in dem Jungpaläozoikum im Nordwestbulgarien.
Bull. Géol. Inst., Sér. Stratigr., Lithol., Sofia 19 (1970), p. 111-136 (1970 b)

YANEV, S.: The Permian of Northeast Kraishte.
Rev. Bulg. Geol. Soc., Sofia 40 (1979) 3, p. 236-246

YANEV, S.; TENCHOV, Y.: Das Jungpaläozoikum und seine Grenze mit dem Buntsandstein südlich von Meljane, Bezirk Michajlovgrad (Nordwestbulgarien).
Trav. Géol. Bulg., Sér. Stratigr. Tect., Sofia 4 (1962), p. 5-29

YANEV, S.; TENCHOV, Y.: Stratigraphie und Lithologie der Stephan-Perm Gesteine bei dem Dorf Stakevci, Bezirk von Vidin.
Bull. Géol. Inst., Sér. Stratigr. Lithol., Sofia 21 (1972), p. 19-39

YANEV, S.; TENCHOV, Y.: Lithology and stratigraphy of the Young-Paleozoic Sediments between the Rivers of Lom and Chiprovska (North-West Bulgaria).
Paleont., Lithol., Stratigr., Sofia 5 (1976), p. 61-78

YANEV, S.; TENCHOV, Y.: The Stephanian-Permian rocks near the villages of Zgorigrad, Zverino and Ignatitsa, Northwest Bulgaria.
Paleont., Lithol., Stratigr., Sofia 9 (1978), p. 3-26

YANEV, S.; TENCHOV, Y.: Ancient origin of some diagonal fault systems.
Geol. Balc., Sofia 9 (1979) 2, p. 85-95

ZAGORČEV, I.: On the geology of the area West of the village of Bobosevo, district of Kjustendil.
Rev. Bulg. Géol. Soc., Sofia 27 (1966) 2, p. 117-126

ZAGORČEV, I.: Early Alpine deformations in the red beds within the Poletintsi-Skrino fault zone. I. Lithostratigraphic features in light of structural studies.
Geol. Balc., Sofia 10 (1980) 2, p. 37-60

ZAGORČEV, I.; POPOV, N.: Geology of the Padesh Paleogene Basin.
Jub. Geol. Vol., Sofia (1968), p. 23-35

ZAGORČEV, I.; TZANKOV, Tz.; SAPUNDZIEV, K.: Strain variation in a part of the Skrino Anticline, district of Kjustendil, determined from deformed reduction spots.
C. R. Ac. bulg. Sc., Sofia 29 (1976) 9, p. 1333-1336

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Объяснительная записка к литотектоническим разрезам палеозойского молассового комплекса Южного Тянь-Шаня (комментарии к приложениям 35 - 38)

К.Л. ВОЛОЧКОВИЧ[I)]

Южный Тянь-Шань - герцинская геосинклиналь, заложившаяся на докембрийском складчатом основании в начале кембрийского периода. Орогенный эпигеосинклинальный этап развития данной геосинклинали начался со среднего карбона и продолжался до пермского времени включительно.

Профиль, по которому отобраны разрезы молассового комплекса, проходит в центральной части Южно-Тяньшаньской складчатой системы от её северной границы до южной, составляет около 300 км и пересекает Ферганскую депрессию и Алайский хребет. В данном пересечении выделяется крупная орогенная Ферганская впадина, расположенная на месте бывшего Ферганского срединного массива; Сурметашская впадина, расположенная на месте бывшего остаточного миогеосинклинального прогиба и разделяющее их Алайское орогенное поднятие (рис. I).

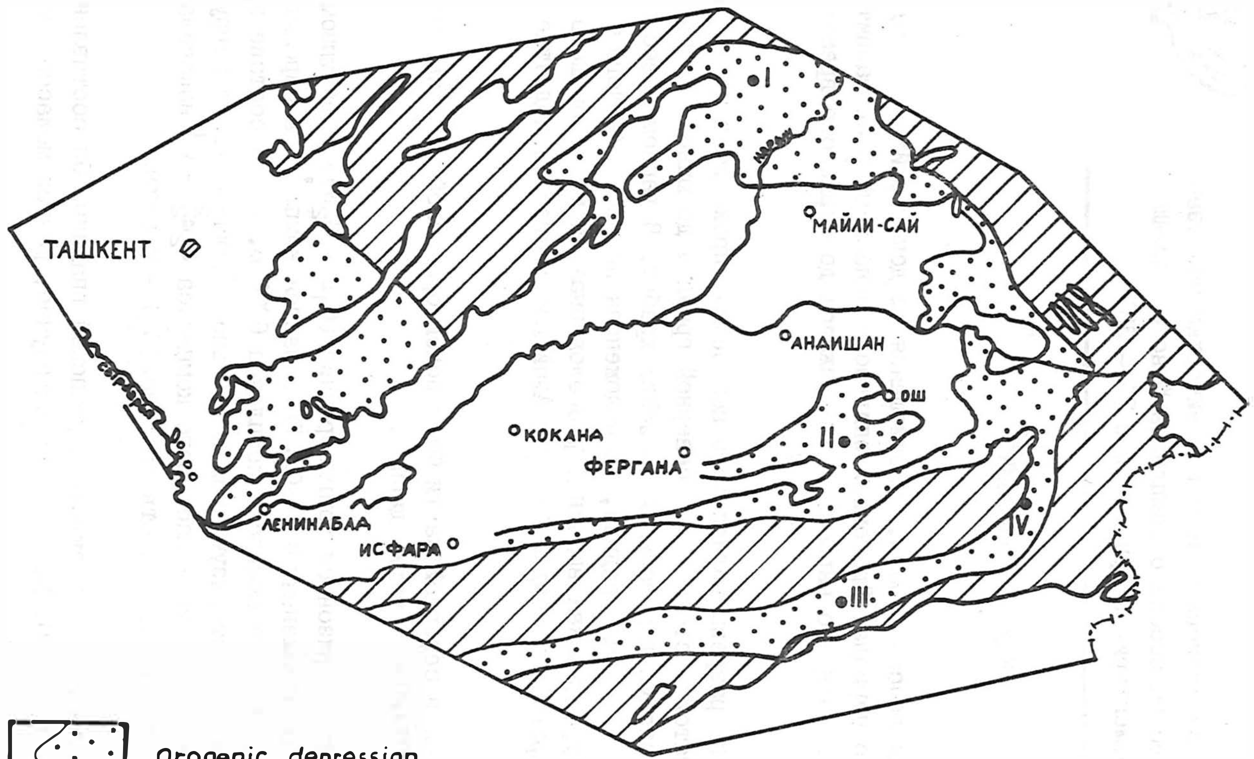
Разрез I (прил. 35) находится в северной части Ферганской орогенной впадины. Он составлен по материалам И.Ф. БОРОДАЕНКО и нашим данным.

Молассовый комплекс начинается горизонтом конглобрекчий ($C_1n - C_2b$), с размывом залегающим на терригенно-карбонатных отложениях $D_3 - C_1$. Завершается комплекс алевролитово-песчаниковыми отложениями P_1. Суммарная мощность комплекса 6200 м. В его составе преобладают осадки дельтового типа, характеризующиеся нормпльной цикличностью с погрубением зерна в нижней части ритма. Средняя часть молассового комплекса $C_2m_2^2 - C_3^1$ накопилась в прибрежно-морских условиях; незначительная часть разреза (C_3^2) - в лагунах.

Разрез II (прил. 36) находится на южном склоне Ферганской впадины. Он составлен по нашим данным и материалам И.Б. ТЕСЛЕНКО. Как и в первом случае, разрез молассового

I) Институт минералогии, геохимии и кристаллохимии редких элементов АН СССР; СССР, II3I27 Москва, Садовническая наб., 7.

DOI:https://doi.org/10.2312/zipe.1982.066



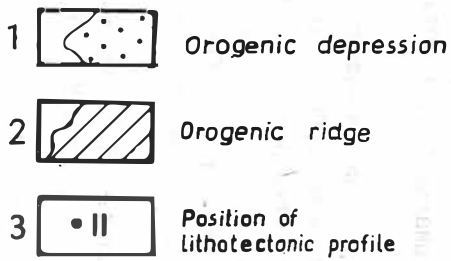


Рис. I. Схема расположения литотектонических разрезов палеозойских моласс на территории Алайского хребта и в обрамлении ферганской впадины

I – орогенные впадины, 2 – горные хребты. 3 – местоположение разрезов

I – разрез на северном склоне ферганской впадины,
II – разрез на южном склоне ферганской впадины,
III – разрез в Алайском хребте (р. Коксу),
IV – разрез в Алайском хребте (р. Гульча)

DOI:https://doi.org/10.2312/zipe.1982.066

комплекса начинается горизонтом конглобрекчий $C_1v_3 - C_2b_1$, залегающим с размывом на карбонатно-терригенных отложениях $S - D_2$. Завершается комплекс конгломератово-песчаниковыми образованиями P_2. Суммарная мощность комплекса 4400 м. В разрезе преобладают отложения дельтового типа, характеризующиеся нормальной цикличностью. В средней части разреза накапливались осадки прибрежно-морской зоны.

Разрез Ш (прил. 37) находится в осевой части Алайского хребта в орогенной Сурметашской впадине. Он составлен по нашим данным и материалам А.В. РАЗВАЛЯЕВА. В основании молассового комплекса располагается сланцево-конгломератовая формация $C_2m_2^2$, залегающая без видимого несогласия на домолассовых терригенно-карбонатных отложениях $C_2m_2^1$. Суммарная мощность комплекса 3500 м. Завершается он песчано-конгломератовыми отложениями(P_1). В разрезе преобладают осадки дельтового типа.

Разрез IV (прил. 38) находится в восточной части Алайского хребта в Сурметашском орогенном прогибе на продолжении простирания зоны, охарактеризованной разрезом III (прил. 37). Он составлен по нашим материалам и данным В.А. КЛИШЕВИЧА. Молассовый комплекс начинается с алевролито — сланцевых образований $C_2m_2^2$, согласно залегающих на карбонатно-терригенных домолассовых формациях $C_2m_2^1$. Завершается комплекс алевролитовыми отложениями C_3. Суммарная его мощность 2700 м. В разрезе преобладают отложения прибрежно-морской зоны и лишь в низах разреза - отложения дельтового типа.

Выводы по разрезам

I. Отмечается скольжение нижней возрастной границы молассового комплекса от $C_1v_3 - C_2b$ до $C_2m_2^2$. Раньше всего моласса начала накапливаться на бывшем Ферганском срединном массиве; позже всего - в пределах остаточного миогеосинклинального прогиба.

2. Молассовый комплекс представлен преимущественно морской молассой дельтового типа.

3. Отмечается изменение состава молассы по простиранию (Сурметашский прогиб).

4. Между молассовым и домолассовым комплексами отмечаются постепенные переходы без крупных угловых несогласий и небольшие перерывы в осадконакоплении. Постепенный переход в Сурметашском остаточном прогибе фиксируется по смене карбонатно-терригенных отложений более грубообломочными терригенными.

5. В развитии молассовых бассейнов видна цикличность с появлением более грубообломочных осадков в верхней и нижней частях всех разрезов. Средние части разрезов, по времени совпадающие с C_3, характеризуются более тонкообломочным карбонатно-терригенным составом.

6. Отмечается постепенное смещение горообразовательных движений с севера на юг. Первые интенсивные орогенические движения на севере прошли в начале среднего карбона, а на юге района - в верхнем карбоне.

DOI:https://doi.org/10.2312/zipe.1982.066

7. Интенсивные складкообразующие движения захватили молассовый комплекс вместе с подстилающим в конце орогенного этапа - в C_3 - P_I, что привело к созданию складчатости альпийского типа. Интенсивность складчатости неравномерная. В Сурметашском прогибе она весьма интенсивная, в Ферганской впадине более простая.

8. Интрузивный гранитоидный магматизм совпадает по времени со складкообразующими движениями C_3 - P_I.

Работа по составлению разрезов продолжается.

Литература

ВОЛОЧКОВИЧ, К.Л.: Типы палеозойских геосинклинальных и орогенных структур Центральной части Южного Тянь-Шаня.
Бюлл. моск. Общч. Испыт. Прир. Отдел. геол., Москва 24 (1970) 6

ВОЛОЧКОВИЧ, К.Л.; ГАВРИЛИН, Р.Д.; ИФАНТОПУЛО, Т.Н.: Типы палеозойских структур Южного Тянь-Шаня, их магматизм и металлогеническая характеристика.
Москва: "Наука" 1973

ВОЛОЧКОВИЧ, К.Л.; Структура и развитие Тянь-Шаня.
Из-е ИМГРЭ., 1975

ВОЛОЧКОВИЧ, К.Л.; РОГОЖИН, Е.А.; ЧЕРНЫШУК, В.Н.: Формации и структуры Алайского хребта (к проблеме шарьяжей).
Бюлл. моск. Общч. Испыт., Прир. Отдел. геол., Москва 54 (1979) 6

Геология СССР, т. 13
Москва: "Недра" 1972

Геология СССР, т. 25
Москва: "Недра" 1972

КЛИПЕНШТЕЙН, В.Я.: Пермский вулканизм Срединного Тянь-Шаня. Автореферат диссертации.
Алма-Ата 1979

МАСУМОВ, А.С.; БОРИСОВ, О.М.; БЕНШ, Ф.Р.: Верхний палеозой Срединного и Южного Тянь-Шаня.
Ташкент: "ФАН" 1978

МОССАКОВСКИЙ, А.А.: Орогенные структуры и вулканизм палезоид Евразии и их место в процессе формирования континентальной земной коры. Афтореферат диссертации.
Москва 1973

МОССАКОВСКИЙ, А.А.: Орогенные структуры и вулканизм палезоид Евразии.
Москва: "Недра" 1975

ПОРШНЯКОВ, Г.С.: Герциниды Алая и смежных районов Южного Тянь-Шаня.
Ленинград: Из-во Лен. Ун-та 1973

DOI:https://doi.org/10.2312/zipe.1982.066

Veröff. Zentralinst. Phys. Erde AdW DDR, Potsdam (1982) 66

Объяснительная записка к литотектоническому разрезу девонских моласс Минусинского бассейна (комментарии к приложению 39)

А.А. МОССАКОВСКИЙ[I)]

Минусинские межгорные впадины представляют собой крупные изометричные средне-верхнепалеозойские тектонические депрессии,расположенные на востоке Алтае-Саянской складчатой области. Это Южно-Минусинская, Чебаково-Балахтинская (Северо-Минусинская), Сыда-Ербинская и Назаровская впадины, разделённые горными перемычками (рис. I).

Горное обрамление и фундамент Минусинских впадин образуют верхнекембрийские геосинклинальные складчатые сооружения Кузнецкого Алатау, юго-западного склона Восточного Саяна и северного склона Западного Саяна, объединяемые в единую складчатую зону так называемых салаирид, развитие которых завершилось формированием верхнекембрийских и ордовикских нижних моласс, локализованных в узких приразломных прогибах.

Комплекс средне-верхнепалеозойских отложений Минусинских впадин залегает на нижнепалеозойском фундаменте с резким угловым несогласием и после большого перерыва в осадконакоплении, падающего на силур, большую часть ордовика, а местами и верхнего кембрия.

Нижняя часть стратиграфического разреза молассовых образований Минусинских впадин образована мощной (свыше 3000 м) вулканогенно-осадочной серией нижне-среднедевонского (доживетского) возраста, в которой разнородные продукты наземных вулканических излияний чередуются с красноцветными песчано-конгломератовыми и терригенными породами. В основании, как правило, залегает пачка (до 200 м мощности) базальных крупногалечных конгломератов.

В Назаровской, Чебаково-Балахтинской, Сыда-Ербинской и на северо-востоке и востоке Южно-Минусинской впадины, где в этой серии преобладают вулканические образования, она известна под названием быскарской серии (МОССАКОВСКИЙ 1963).

В юго-западной части Южно-Минусинской впадины в её составе преобладают осадочные, в основном терригенные,породы, характеризующиеся грубоцикличным строением. Здесь она разделена на следующие свиты снизу вверх (МЕЛЕЩЕНКО 1953):

I. Чиланская свита: диабазовые и лабрадоровые порфириты с прослоями и пачками красно-бурых грубозернистых песчаников, гравелитов и конгломератов, а также алевролитов.

I) Геологический институт АН СССР; СССР, 109017 Москва, Пыжевский пер., 7.

DOI:https://doi.org/10.2312/zipe.1982.066

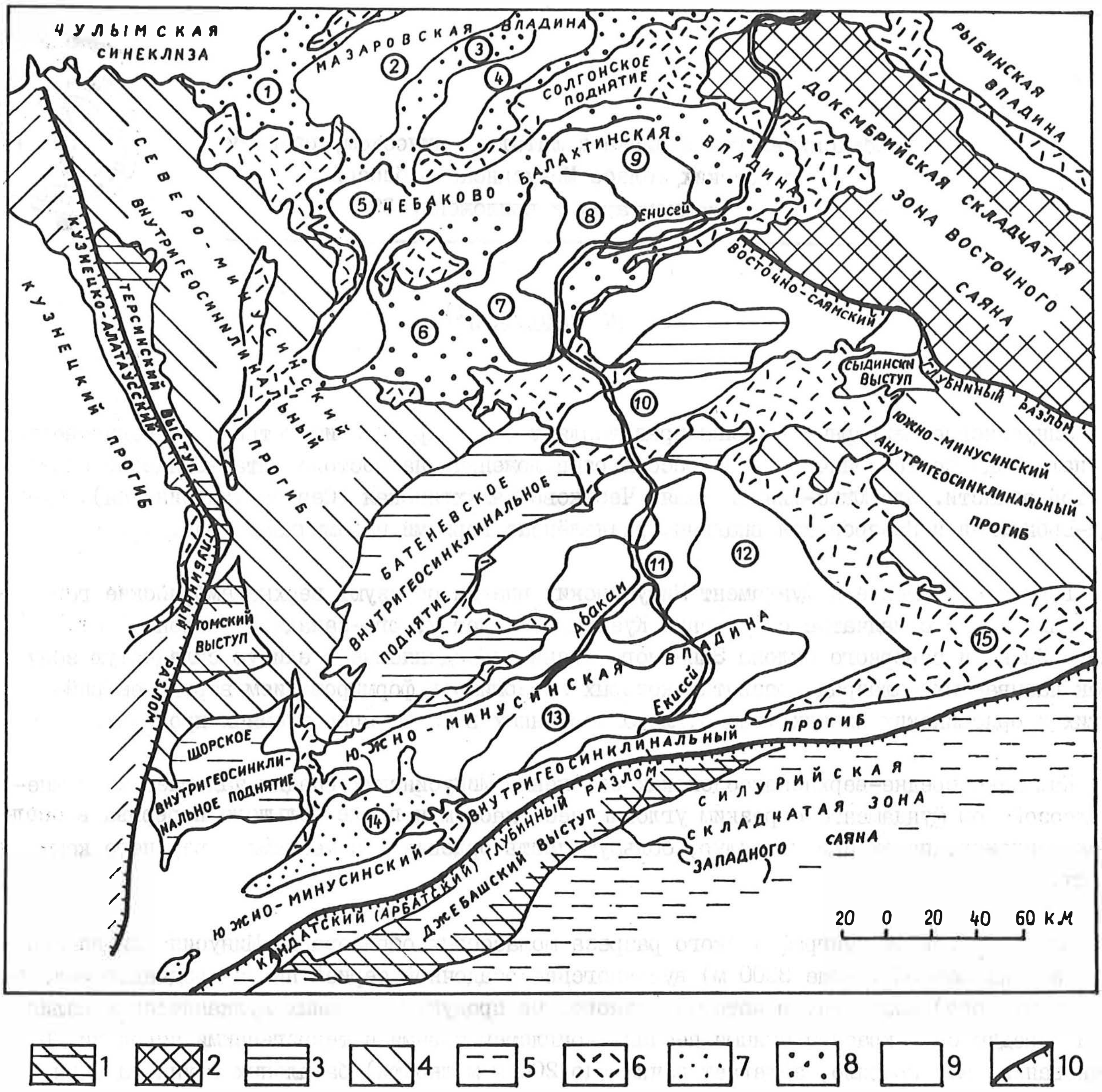


Рис. I. Схема тектонического районирования Минусинских впадин и прилежащих частей Западного и Восточного Саян

I – выступы досинийского фундамента, 2 – докембрийская (байкальская) складчатая зона Восточного Саяна, верхнекембрийская (салаирская) складчатая зона Кузнецкого Алатау, Горной Шории, северного склона Западного Саяна и юго-западного склона Восточного Саяна, 3 – внутригеосинклинальные поднятия, 4 – внутригеосинклинальные прогибы, 5 – силурийская складчатая зона Западного Саяна, 6 – Нижне-среднедевонский красноцветно-вулканогенный структурный комплекс, 7 – Абаканский прогиб, Средне-верхнепалеозойский осадочный чехол Минусинских впадин, 8 – внутренние и краевые поднятия, 9 – прогибы, I0 – глубинные разломы

Цифры в кружках обозначают: I – Аргинское поднятие, 2 – Березовский прогиб, 3 – Антроповское поднятие, 4 – Гляденьский прогиб, 5 – Чебаково-Салбатский прогиб, 6 – Копьево-Ширинское поднятие, 7 – Джиримо-Карасукский прогиб, 8 – Кокорево-Белоярское поднятие, 9 – Балахтинский прогиб, I0 – Сыда-Ербинская впадина, II – Черногорский прогиб, I2 – Алтае-Тагарское поднятие, I3 – Таштыпский прогиб, I4 – Абаканский прогиб, I5 – Амыл-Кандатский прогиб

DOI:https://doi.org/10.2312/zipe.1982.066

2. Имекская свита, образованная светло-серыми, тёмно-серыми и серыми песчаниками, чередующимися с прослоями алевролитов и мергелей. В алевролитах встречаются отпечатки нижнедевонских растений: Drepanophycus spinaeformis GÖPP., Psilophyton princeps DN. и остракод.

3. Толочковская свита: красно-бурые алевритовые мергели, тонкоплитчатые, переслаивающиеся с алевролитами и тонкими прослоями серых известняков.

4. Таштыпская свита, представленная тёмно-серыми и серыми пелитоморфными и органогенными известняками, мергелями с прослоями серых алевролитов и песчаников. Встречены остатки верхнеэйфельских брахиопод, пелеципод и кораллов: Acrospirifer subgregarius var. biplicata RŽON., A. kurbesekiona RŽON., Uncinulus taschtipiensis RŽON., U. cf. gaikes NOTT., Favosites alpina HÖRN., F. subbatus DUB. и др.

Таким образом, мощный нижне-среднедевонский молассовый комплекс наиболее глубоко прогнутой юго-западной части Южно-Минусинской впадины на двух стратиграфических уровнях - в верхах нижнего девона и в верхней части эйфельского яруса - прослоен относительно маломощными озёрными или ингрессивного типа морскими терригенно-карбонатными толщами.

В северном и восточном направлении, т.е. к соответствующим бортам Южно-Минусинской впадины, описанный тип разреза претерпевает значительные изменения: карбонатные и терригенно-карбонатные породы таштыпской и имекской свит полностью выклиниваются в толще красноцветных песчано-алевролитовых пород, а последние, в свою очередь, замещаются по периферии вулканогенными образованиями.

Как было установлено И.В. ЛУЧИЦКИМ (1960) для нижне-среднедевонских вулканических пород на площади Минусинских впадин характерны основной состав и повышенная щёлочность; они представлены здесь базальтами, трахибазальтами, диабазами, долеритами, диабазовыми порфиритами, трахиандезитами и андезитовыми порфиритами, лабрадоровыми и эссекситовыми нефелинсодержащими порфиритами при резко подчинённом количестве плагиопорфиров. В качестве интрузивных аналогов эффузивов отмечаются тела нефелиновых сиенитов, тералитов, тешенитов, габбро-сиенитов и габбро-диабазов. Учитывая существенно базальтовый состав вулканических пород и их субщелочной и щелочной характер, эту вулканическую серию можно выделить в качестве базальт-щелочно-базальтовой формации. Однако в пределах горных поднятий, ограничивающих Минусинские впадины, в составе нижне-среднедевонской вулканической серии, наряду с вулканитами основного состава, значительное место занимают альбитофиры, ортофиры, кварцевые и бескварцевые порфиры, фельзиты и фельзит-порфиры, находящиеся в тесной ассоциации с интрузиями граносиенитов, щелочных гранитов, кварцевых и нефелиновых сиенитов. Таким образом, здесь выделяются (МОССАКОВСКИЙ 1963) две одновозрастные наземно-вулканические формации: базальтовая и порфировая (рис. 2). Первая характерна для Минусинских впадин, вторая - для их горных поднятий, их обрамляющих.

В структурном отношении описанный нижне-среднедевонский комплекс Минусинских впадин резко обособляется от вышележащих средне-верхнедевонских красноцветных моласс,

DOI:https://doi.org/10.2312/zipe.1982.066

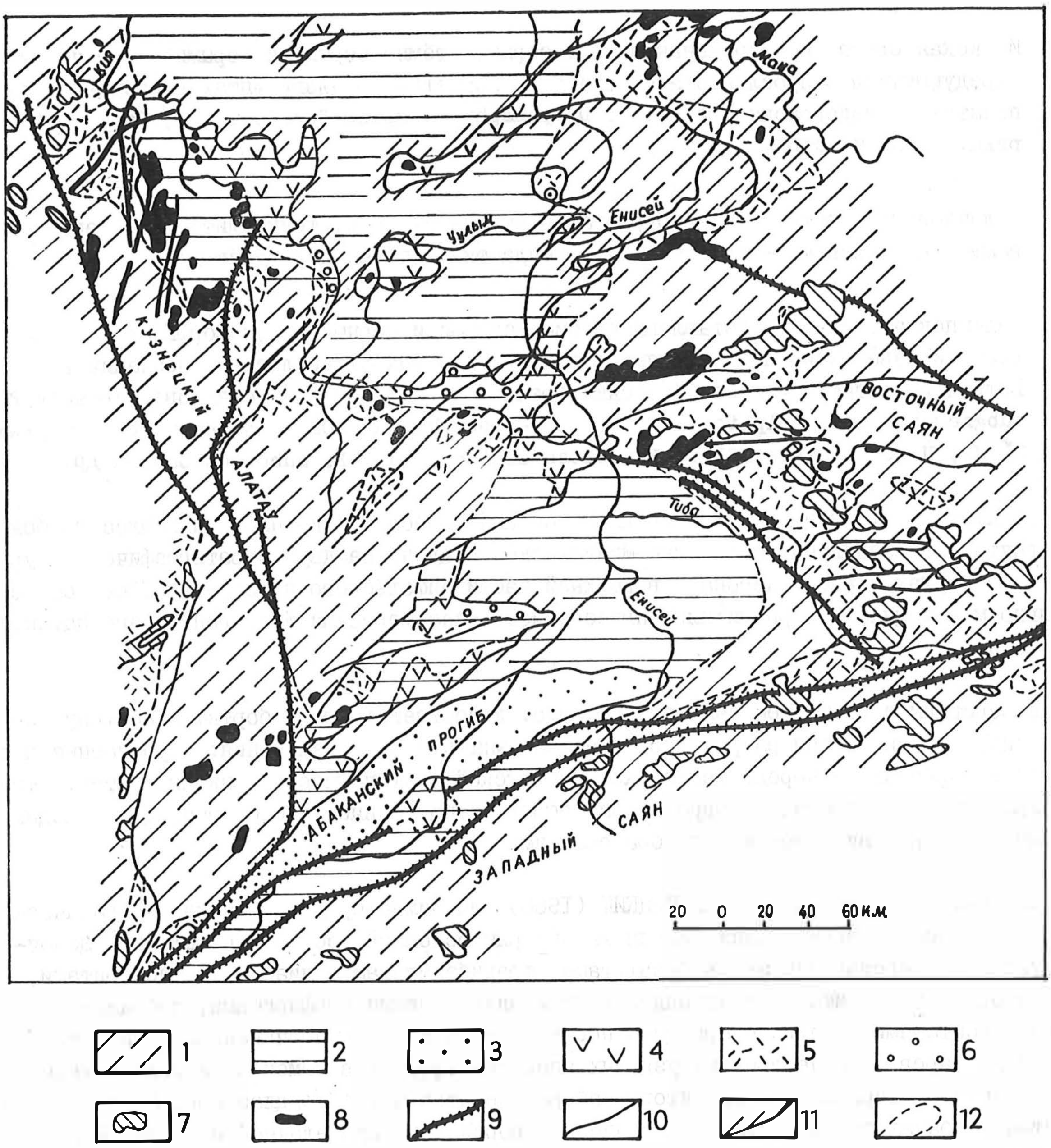


Рис. 2. Схема размещения девонских красноцветно-вулканогенных формаций и связанных с ними интрузий

I - структурные зоны, контролировавшие размещение формаций смешанного состава (порфировой), 2 - структурные зоны, контролировавшие размещение формаций основного состава (базальтовой), 3 - Абаканский прогиб с красноцветными песчано-глинистыми отложениями

Современное распространение фациально-литологических типов нижне-среднедевонских отложений: 4 - эффузивы и пирокластические образования основного состава, 5 - эффузивы и пирокластические образования кислого, среднего и основного состава, 6 - эффузивы и пирокластические образования основного состава, граувакковые песчаники и конгломераты, 7 - щелочные граниты, кварцевые сиениты и кварцевые диориты нижне-среднедевонского возраста, 8 - щелочные сиениты, нефелиновые сиениты и габбро-сиениты нижне-среднедевонского возраста, 9 - региональные разломы, I0 - второстепенные разломы, II - граница средне-верхнепалеозойского осадочного чехла Минусинских впадин, I2 - граница современного распространения фациально-литологических типов отложений

DOI:https://doi.org/10.2312/zipe.1982.066

от которых он отделён на большей части площади впадин поверхностью углового (в прибортовых зонах) или стратиграфического несогласия (МОССАКОВСКИЙ 1960). В качестве типичных доживетских структурных форм, которые образовались в его породах, можно выделить крупные и пологие куполовидные, валообразные, корытообразные структуры, мелкие брахиформные сопряжённые складки, а также грабены.

Верхняя часть разреза молассовых образований Минусинских впадин представлена исключительно осадочными образованиями живетского яруса среднего девона и всего верхнего девона, а также более молодыми карбонатно-терригенными и угленосными формациями карбона и перми. Обычно эта часть разреза в Минусинских впадинах выделяется под названием осадочного чехла.

В основании этого, верхнего молассового комплекса, который в целом лишён внутренних перерывов и несогласий, располагается первая красноцветная моласса, включающая породы абаканской свиты живетского яруса среднего девона Южно-Минусинской впадины и её стратиграфического эквивалента - толтаковской свиты в остальных более северных Минусинских впадинах. Она состоит из часто чередующихся конгломератов, красноцветных гравийных и пудинговых полимиктовых песчаников, косослоистых алевролитов, аргиллитов, образовавшихся в условиях горного расчленённого рельефа и континентального режима. Особенности распределения различных фациальных типов отложений для этого времени отражены на фациально-литолого-фациальных картах (рис. 3 и 4). Отчётливо намечается конгломератовая оторочка, фиксирующая борта межгорных впадин, а также закономерная смена грубообломочных отложений тонкообломочными в сторону центральных частей Южно-Минусинской и Чебаково-Балахтинской впадин. Одновременно выявлены ярко выраженные конседиментационные прогибы, характеризующиеся увеличенными мощностями осадков.

Выше следует морская терригенно-карбонатная формация, в состав которой включаются породы аскизской, илеморовской и бейской свит живетского яруса среднего девона. Для этой формации характерны тёмно-серые, часто битуминозные известняки, органогенные известняки, мергели, серые и зеленовато-серые аргиллиты, алевролиты и песчаники, повышенная кремнистость пород (окремнение известняков, желваки и пропластки кремня и халцедона), и обильные органические остатки - в илеморовской свите филлопод: Asmussia membranacea PACHT. и др., в бейской свите - брахиопод: Theodossia schmidti STUCK., Avicula (Leptodesma) asa B. NAL., Brachyspirifer cheehiel KON. и ругоз: Minussiella biensis BOLV.

На склонах некоторых внутренних поднятий во впадинах среди пород верхней части живетского яруса появляются относительно мощные (100 - 150 м) пачки, обогащённые гипсом и ангидритом.

Завершается разрез верхнего молассового комплекса Минусинских впадин второй красноцветной молассой, включающей породы ойдановской, кохайской и тубинской свит верхнего девона. По составу и структуре пород она почти аналогична первой молассе (живетской), отличаясь от неё лишь более тонким составом обломочного материала и повышенным содержанием кварца и минералов тяжёлой фракции. В породах ойдановской свиты обнаружены остатки панцырных рыб: Bothriolepis cf. cellulosa PAND., B. sibirica D. OBR., Holoptychius sp., а также растений: Pteridorhachis sp., указывающие на франский ярус. В кохайской свите широко распространены франские филлоподы: Asmussia rotundula LUTK.,

DOI:https://doi.org/10.2312/zipe.1982.066

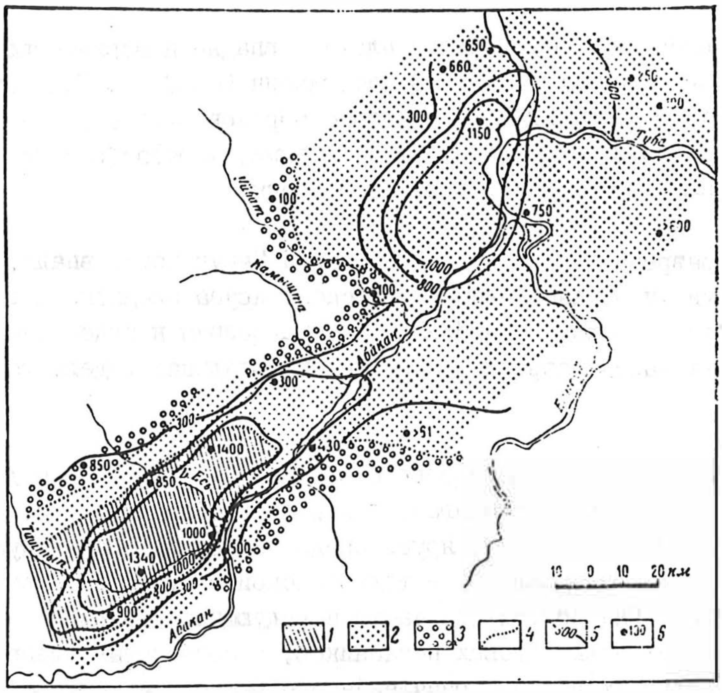


Рис. 3. Схематическая фациально-литологическая карта абаканской и толтаковской свит территории Южно-Минусинской впадины

I - мергелисто-алевролитовый тип осадков: красноцветные алевролиты с прослоями аргиллитов и пестрых мергелей, 2 - песчано-алевролитовый тип осадков: красноцветные песчаники и алевролиты с прослоями гравелитов и конгломератов, 3 - конгломерато-песчаный тип осадков: красноцветные конгломераты, гравелиты и песчаники, 4 - граница распространения фациально-литологических типов осадков, 5 - изопахиты, 6 - опорные разрезы, мощность в м

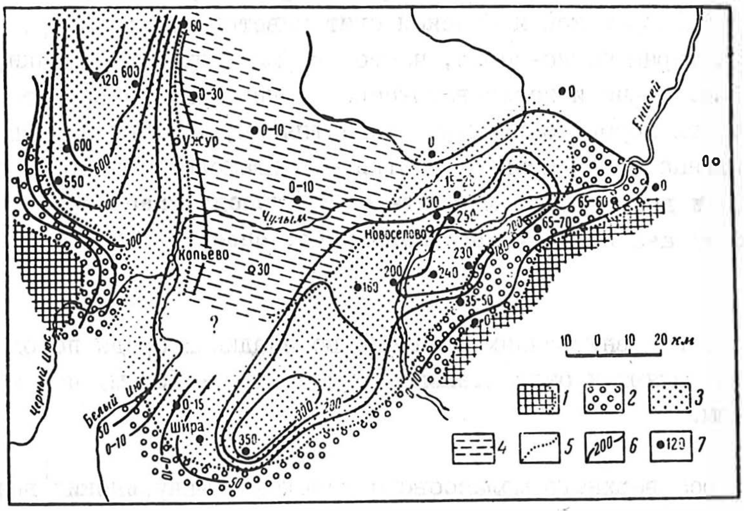


Рис. 4. Схематическая фациально-литологическая карта толтаковской свиты территории Чебаково-Балахтинской впадины

I - суша, 2 - конгломератовый тип осадков: крупногалечные конгломераты, 3 - конгломерато-песчаный тип осадков: красно-бурые конгломераты и гравелиты с прослоями песчаников и алевролитов, 4 - песчано-алевролитовый тип осадков: красноцветные мелкозернистые песчаники и алевролиты с прослоями красно-бурых известняков, 5 - граница распространения фациально-литологических типов осадков, 6 - изопахиты, 7 - опорные разрезы, мощность м

DOI:https://doi.org/10.2312/zipe.1982.066

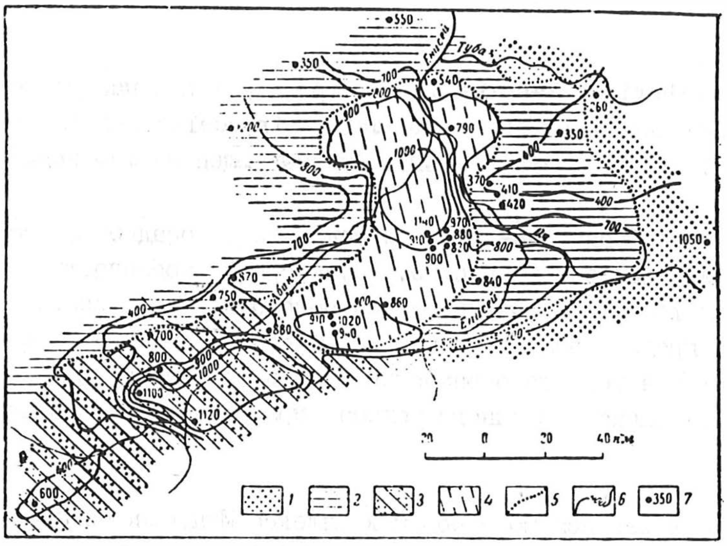


Рис. 5. Схематическая фациально-литологическая карта франского яруса (ойдановская и кохайская свиты) территории Южно-Минусинской впадины

I - песчаный красноцветный тип осадков: красноцветные мелкозернистые песчаники, реже алевролиты и аргиллиты, 2 - песчано-алевролитовый красноцветный тип осадков: красноцветные алевролиты и песчаники, пестроцветные аргиллиты и известняки, 3 - известняково-песчано-алевролитовый сероцветный тип осадков: серые, зеленовато-серые и коричневые песчаники, алевролиты и аргиллиты, известняки и мергели битуминозные, 4 - алевролито-мергелистый красноцветный тип осадков: красноцветные мергели, алевролиты и аргиллиты, 5 - граница распространения фациально-литологических типов осадков, 6 - изопахиты, 7 - опорные разрезы, мощность в м

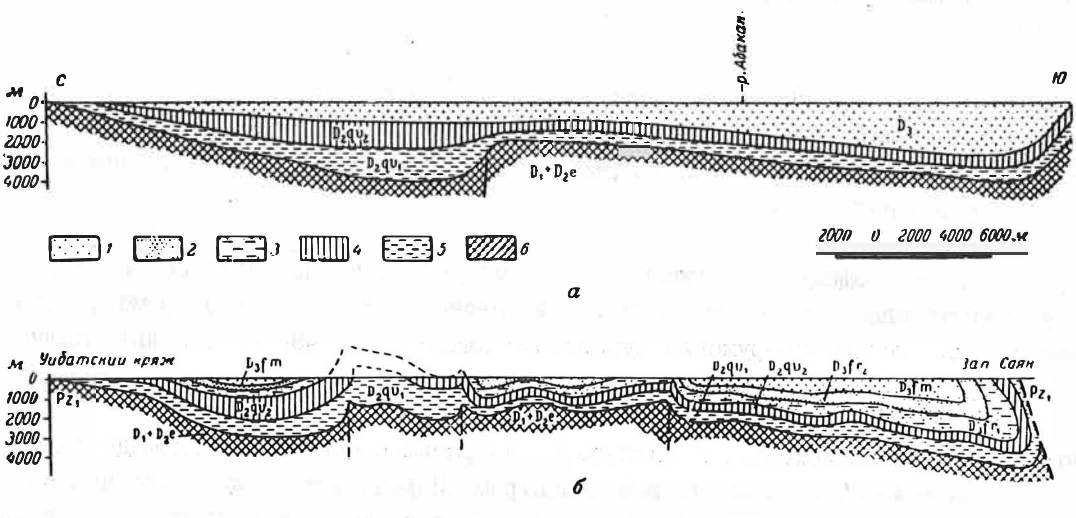


Рис. 6. Поперечный разрез через разновозрастные конседиментационные синклинали Таштыпского прогиба Южно-Минусинской впадины

а - к моменту завершения формирования верхнедевонской конседиментационной синклинали, б - после образования верхнепалеозойских штамповых складок

I - верхний девон, фаменский ярус, тубинская свита (D_3fm), 2 - верхний девон, франский ярус, кохайская свита (D_3fr_2), 3 - верхний девон, франский ярус, ойдановская свита (D_3fr_1), 4 - средний девон, живетский ярус, илеморовская, аскизская и бейская свиты (D_2gv_2), 5 - средний девон, живетский ярус, абаканская свита (D_2gv_1), 6 - нижне-среднедевонские красноцветные отложения нерасчлененные (D_1+D_2e)

DOI:https://doi.org/10.2312/zipe.1982.066

A. vulgaris LUTK., Euestheria hakassika NOV. и др., а также панцырные рыбы. В тубинской свите встречены остатки панцырных рыб - Thaumatolepis edelsteini D. OBR. и археоптерисовой флоры: Archaeopteris Roemeriana GOEPP., указывающей на фаменский ярус.

Характер распределения фациально-литологических типов осадков франского яруса Южно-Минусинской впадины показан на рис. 5. Характерной особенностью седиментации этого времени является то, что источники сноса обломочного материала в это время резко отодвинулись за пределы впадины и её ближайшего обрамления. Произошла определённая нивелировка рельефа горного обрамления и всей территории в целом, что указывает на постепенное отмирание орогенного режима, практически прекратившегося в раннем карбоне.

Структуры, развитые в верхнем молассовом комплексе Минусинских впадин, относятся к двум типам: конседиментационным и штамповым. К группе конседиментационных принадлежат антиклинальные поднятия и синклинальные прогибы (седиментационные ванны), которые, в свою очередь, состоят из более мелких конседиментационных структур второго порядка: мульд, куполов. Их развитие было обусловлено длительным прогибанием изометричных блоков фундамента (усиленным для синклинальных прогибов и мульд, более медленным на поднятиях и куполах). Эти структуры легко вычитываются на фациально-литологических картах (см. рис. 3, 4, 5). Штамповые структуры образованы в результате верхнепалеозойских тектонических движений блоков фундамента и имеют ярко выраженный постседиментационный характер. Они представлены коробчатыми складками, квадратной, треугольной и ромбовидной формы в плане и вертикальными и горизонтальными флексурами (рис. 6).

В целом этап формирования девонских моласс Минусинских впадин может быть разделён на две стадии: первую трансгрессивную, охватывающую живетский век среднего девона, и вторую регрессивную, очень длительную, начавшуюся с верхнего девона и закончившуюся в позднем палеозое.

В первую стадию площадь осадконакопления в Минусинских впадинах всё время расширялась, достигнув своего максимума в конце живетского века (бейское время), когда, по-видимому, даже горные сооружения Кузнецкого Алатау были частично залиты мелководным морем.

Во вторую стадию происходило медленное и необратимое сокращение площади седиментации по направлению от краевых частей к центрам Минусинских впадин, что приводило к постепенному замыканию седиментационных бассейнов и изменению характера седиментации в их пределах.

DOI:https://doi.org/10.2312/zipe.1982.066

Литература

АНАТОЛЬЕВА, А.И.: Стратиграфия и некоторые вопросы палеогеографии девона Минусинского межгорного прогиба.
Изд-во Сиб. отд. АН СССР, Новосибирск (1960)

ЛУЧИЦКИЙ, И.В.: Вулканизм и тектоника девонских впадин Минусинского межгорного прогиба.
Изд-во АН СССР, Москва (1960)

МЕЛЕЩЕНКО, В.С.: Некоторые вопросы геологии и стратиграфии девонских отложений Минусинских котловин. В сб.: Палеонтология и стратиграфия.
Труды ВСЕГЕИ, Москва 16 (1953)

МОССАКОВСКИЙ, А.А.: О преджи́ветском перерыве и угловом несогласии в девоне Минусинских впадин.
Докл. АН СССР, Москва 132 (1960) 6

МОССАКОВСКИЙ, А.А.: Тектоническое развитие Минусинских впадин и их горного обрамления в докембрии и палеозое.
Москва: Госгеолтехиздат 1963

МОССАКОВСКИЙ, А.А.: Девонские вулканогенные формации ранних каледонид (салаирид) Саяно-Алтайской области и проблема связи вулканизма с тектоникой.
Труды Лабор. Палеовулканологии КазНИИ и Минераль. сырья, Алма-Ата, 2 (1963)

МОССАКОВСКИЙ, А.А.: Орогенные структуры и вулканизм палеозоид Евразии и их место в процессе формирования континентальной коры.
Москва: "Наука" 1975

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

LEGEND TO THE LITHOTECTONIC PROFILES
OF CENOZOIC AND PALEOZOIC MOLASSES
(ANNEX 1 - 39)

LEGENDE ZU DEN LITHOTEKTONISCHEN PROFILEN
VON KÄNOZOISCHEN UND PALÄOZOISCHEN MOLASSEN
(ANNEX 1 - 39)

УСЛОВНЫЕ ОБОЗНАЧЕНИЯ К ЛИТОТЕКТОНИЧЕСКИМИ РАЗРЕЗАМИ
КАЙНОЗОЙСКИХ И ПАЛЕОЗОЙСКИХ МОЛАСС
(ПРИЛОЖЕНИЯ I - 39)

DOI:https://doi.org/10.2312/zipe.1982.066

Stratigraphy

Stratigraphie

Стратиграфия

Stratigraphical boundary of the regional scale
Stratigraphische Grenze der regionalen Skala
Стратиграфическая граница региональной шкалы

———	reliable biostratigraphical boundary sichere biostratigraphische Grenze надежная биостратиграфическая граница
– – –	unreliable or supposed biostratigraphical boundary unsichere bzw. vermutete biostratigraphische Grenze ненадежная или предполагаемая биостратиграфическая граница
....	conventional boundary without biostratigraphic evidence konventionelle Grenze ohne biostratigraphischen Beleg условная граница без биостратиграфического обоснования
‾7 ? ∠_	possible time interval for position of boundary möglicher Zeitraum für die Grenzziehung возможный интервал времени для проведения границ
··7 ? ∠_	possible time interval with conventional boundary möglicher Zeitraum mit konventioneller Grenze возможный интервал времени с условной границей

Lithology

Lithologie

Литологический состав

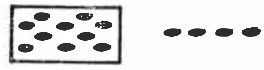
Lithology is represented seperately for sediments (left) and volcanic rocks (right) as a schematized standard section. Changes of sedimentary facies and interfingering of sediments with volcanic rocks are depicted as far as possible.

Der lithologische Aufbau wird getrennt nach Sedimenten (links) und Vulkaniten (rechts) als schematisches Normalprofil dargestellt. Dabei werden nach Möglichkeit die Verzahnung von Sedimenten und Vulkaniten sowie die Fazieswechsel in den Sedimenten mit abgebildet.

Литологический состав изображается раздельно для осадочных (налево) и вулканических пород (направо) в виде схематического профиля. При этом по возможности изображают взаимное проникновение осадочных и вулканических пород а также смену фаций осадочных пород.

DOI:https://doi.org/10.2312/zipe.1982.066

Sedimentary rocks, main rock types
Sedimente, Hauptgesteinstypen
Осадочные породы, основные типы пород



boulders, >20 cm
Block, Grobgeröll, >20 cm
крупные обломки, блоки, грубая галька, >20 см

gravel, pebbles, conglomerate
Kies, Gerölle, Konglomerat
гравий, галька, конгломерат

sedimentary breccia
sedimentäre Brekzie
осадочная брекчия

olisthostrome
Olisthostrom
олистостром

sand, sandstone
Sand, Sandstein
песок, песчаник

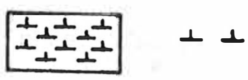
silt, siltstone, shale
Silt, Siltstein (Aleurit, Aleurolith)
алеврит, алевролит

clay, claystone, argillite
Ton, Tonstein (Argillit)
глина, глинистая порода (аргиллит)

limestone
Kalkstein
известняк

dolomite
Dolomit
доломит

magnesite
Magnesit
магнезит



marl
Mergel
мергель

dolomitic marl
Dolomitmergel
доломитовый мергель

anhydrite, gypsum
Anhydrit, Gips
ангидрит, гипс

DOI:https://doi.org/10.2312/zipe.1982.066

halite
Steinsalz
каменная соль

potash salt
Kalisalz
калийная соль

coal
Kohle
уголь

combustible shale
Brandschiefer
горючий сланец

siliceous rock
Kieselgestein
кремнистая порода

loess
Löß
лессы

Sediments, mixed rocks (examples)
Sedimente, Mischgesteine (Beispiele)
Осадочные породы, смешанные породы (примеры)

conglomerate, sandy
Konglomerat, sandig
конгломерат, песчанистый

sandstone, silty
Sandstein, siltig
песчаник, алевритовый

siltstone, sandy
Siltstein, sandig
алевролит, песчанистый

limestone, sandy
Kalkstein, sandig
известняк, песчанистый

limestone, silty
Kalkstein, siltig
известняк, алевритовый

limestone, argillaceous
Kalkstein, tonig
известняк, глинистый

limestone, siliceous
Kalkstein, kieselig
известняк, кремнистый

sandstone, calcareous
Sandstein, kalkig
песчаник, известковистый

sandstone, dolomitic
Sandstein, dolomitisch
песчаник, доломитовый

siltstone, calcareous
Siltstein, kalkig
алевролит, известковистый

alternation of claystone and sandstone
Tonstein-Sandstein-Wechsellagerung
переслаивание аргиллитов и песчаников

alternation of siltstone and sandstone
Siltstein-Sandstein-Wechsellagerung
переслаивание алевролитов и песчаников

DOI:https://doi.org/10.2312/zipe.1982.066

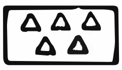
alternation of siltstone and claystone
Siltstein-Tonstein-Wechsellagerung
переолаивание алевролитов и аргиллитов

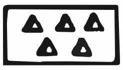
schlier; laminated marl with silt on the surfaces of lamination
Schlier; laminierter Mergel mit Silt auf den Flächen der Lamination
шлир; полосчатый (слоистый) мергель с алевритом на поверхности напластования

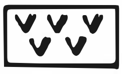
normal boundary between stratigraphical units (without break of sedimentation)
normale Grenze zwischen stratigraphischen Einheiten (ohne Sedimentationsunterbrechung)
нормальная граница между стратиграфических единиц (без перерыва седиментации)

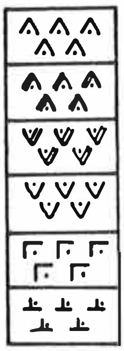
boundary between stratigraphical units with break of sedimentation or discordance
Grenze zwischen stratigraphischen Einheiten mit Sedimentationslücke oder Diskordanz
граница между стратиграфических единиц с перерывом седиментация или несогласием

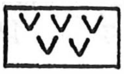
Eruptive rocks and volcanoclastites
Eruptivgesteine und Vulkanoklastite
Эруптивные и вулканокластические породы

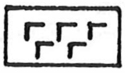

rhyolitoids
Rhyolithoide
риолитоиды

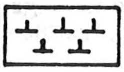

dacitoids
Dazitoide
дацитоиды

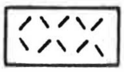

trachytoids
Trachitoide
трахитоиды


associated tuffs
zugehörige Tuffe
туфы соответствующего состова


andesitoids
Andesitoide
андезитоиды


basaltoid
Basaltoide
базальтоиды


tephritoids
Tephritoide
тефритоиды


tuffs, general
Tuffe, allgemein
туфы, вообще


tuffaceous-sedimentary mixed rocks
tuffig-sedimentäre Mischgesteine
туфогенно-осадочные смешанные породы


volcanic breccia
vulkanische Brekzie
вулканические брекчия

DOI:https://doi.org/10.2312/zipe.1982.066

Designation of the petrochemical province
Kennzeichnung der petrochemischen Provinz
Обозначение петрографической провинции

Ca — calc-alkali
kalkalkalisch
известково-щелочной

A — alkali
alkalisch
щелочной

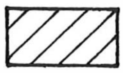
Th — tholeiitic
tholeiitisch
толеитовый

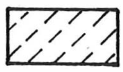
Rock colours

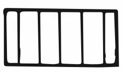
Gesteinsfarben

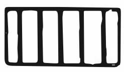
Цвет породы

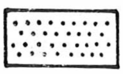

red, reddish brown
rot, rotbraun
красный, красно-бурый


violet, reddish violet, greyish violet
violett, rot-, grauviolett
фиолетовый, красно-фиолетовый, серо-фиолетовый

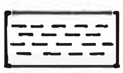

green, greyish green
grün, graugrün
зелёный, серо-зелёный


middle grey, dark grey
mittel- bis dunkelgrau
средне-серый, тёмно-серый


black
schwarz
чёрный


light brown, yellowish brown, yellow
hellbraun, gelbbraun, gelb
светло-бурый, жёлто-бурый, жёлтый


blue, blueish grey
blau, blaugrau
голубой, серо-голубой


white
weiß
белый

DOI:https://doi.org/10.2312/zipe.1982.066

Cycles

Zyklen

Циклы

grain size cycles
Korngrößenzyklen
циклы по фракциям зёрен

fining upward cycle
unten grob ⟶ oben fein
внизу грубый ⟶ вверху мелкий

coarsening upward cycle
unten fein ⟶ oben grob
внизу мелкий ⟶ вверху грубый

fining-coarsening upward cycle
unten grob ⟶ Mitte fein ⟶ oben grob
внизу грубый ⟶ в середине мелкий ⟶ вверху грубый

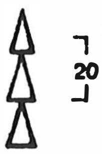
cycle according to other features
Zyklus nach anderen Merkmalen
циклы выделенные по другим признакам

cycle and partial cycles of second order
(representation of the sign over the whole thickness of the cycle)

Zyklus und Teilzyklen zweiter Größenordnung
(Darstellung des Zeichens über die gesamte Mächtigkeit des Zyklus)

цикл и частные циклы второго порядка
(изображение знака по всей мощности цикла)

cycle supposed
Zyklus vermutet
цикл предполагаемый



cycles of lower order in continuous sequence; the numeral indicates the number of cycles in a sediment thickness specified by the bracket (50 or 100 m)

Zyklen niederer Ordnung in lückenloser Folge; die Ziffer gibt die Anzahl der Zyklen in der von der Klammer abgesteckten Sedimentmächtigkeit an (50 oder 100 m)

циклы более высокого порядка в непрерывной толще пород; цифра указывает число циклов в толще, мощность которой показана скобкой (50 или 100 м)

DOI:https://doi.org/10.2312/zipe.1982.066

Δ cycles of lower order, occurring not continuously (vertically and laterally)

Zyklen niederer Ordnung, nicht kontinuierlich (vertikal und lateral)

Δ разобщенные циклы более высокого порядка (по вертикали, по горизонтали)

Composition of gravel, sand, and clay fraction

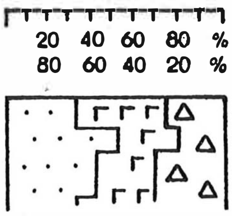
Komponenten der Kies-, Sand- und Tonfraktion

Компоненты валунной, песчанистой и глинистой фракций

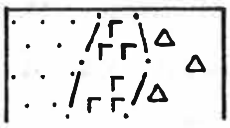
Variants of representing the composition

Varianten der Anteildarstellung

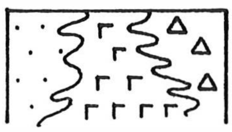
Варианты изображения содержания (доли)



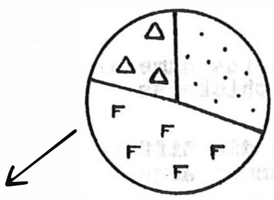
representative average values of profile sections
repräsentative Durchschnittswerte für Profilabschnitte
репрезентативные средние значения для отрезков профиля



sequence of samples
Folge von Proben
последовательные пробы



estimated variability of portions (with trend)
geschätzte Variabilität der Anteile (mit Trend)
оцененные изменения долей (с трендом)



circular diagram of single or average sample with information on position in the profile (arrow)

Kreisdiagramm von Einzel- oder Durchschnittsprobe mit Angabe der Lage im Profil (Pfeil)

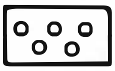
круговая диаграмма отдельной или усредненной пробы с указанием положения в профиле (стрела)

DOI:https://doi.org/10.2312/zipe.1982.066

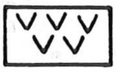
Gravel fraction

Geröllfraktion

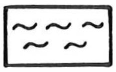
Валунная фракция



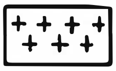
vein quartz, milky quartz
Gang-, Milchquarz
жильный кварц, молочный кварц



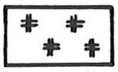
subsequent volcanic rocks
subsequente Vulkanite
субсеквентные вулканические породы



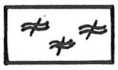
sedimentary rocks
Sedimentgesteine
осадочные породы



crystalline basement in general
kristallines Fundament allgemein
кристаллический фундамент без уточнения



plutonites
Plutonite
плутониты



gneisses, metamorphic rocks
Gneise, Metamorphite
гнейсы, метаморфические породы

The source of a petrographic class (foreland, orogene, tectonic units) may be marked by additional letters, for instance or - orogene, pl - platform

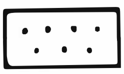
Die Herkunft einer petrographischen Klasse (Vorland, Orogen, tektonische Einheit) kann durch zusätzliche Buchstaben gekennzeichnet werden, z.B. or - Orogen, pl - Tafel

Просхождение петрографического класса (с платформы, орогена, тектонической единицы) можно отмечать дополнительными буквами как на пример or - с орогена, pl - с платформа

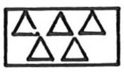
Sand fraction

Sandfraktion

Песчаная фракция

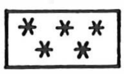


quartz
Quarz
кварц



rock fragments
Gesteinsbruchstücke
обломки пород

feldspar
Feldspat
полевой шпат



mica
Glimmer
слюда

DOI:https://doi.org/10.2312/zipe.1982.066

Clay fraction

Tonfraktion

Глинистая фракция

K	kaolinite Kaolinit каолинит	I	illite-sericite Illit-Serizit иллит-серицит
M	montmorillonite Montmorillonit монтмориллонит	ML	mixed layer minerals mixed layer Minerale смешанные глинистые минералы
Ch	chlorite Chlorit хлорит		

additional symbols: abbreviations of mineral names
weitere Symbole: Abkürzungen von Mineralnamen
другие символы: сокращения названий минералов

Length and direction of transport

Transportlänge und -richtung

Дальность и направление переноса

large transport distance (> 100 km)
große Transportlänge (> 100 km)
дальний перенос (> 100 км)

short transport distance (< 100 km)
geringe Transportweite (< 100 km)
близкий перенос (< 100 км)

local transport (< 10 km)
lokale Umlagerung (< 10 km)
местный перенос (< 10 км)

direction of transport (possibly with information on range of scattering, subordinate direction)

Transportrichtung (bei Bedarf mit Angabe des Streuwinkels, einer Nebenrichtung)

направление переноса (по мере надобности с углом рассеяния, с побочным направлением)

DOI:https://doi.org/10.2312/zipe.1982.066

Conspicuous sedimentary features
Auffallende sedimentologische Merkmale
Важные седиментологические признаки

Components
Bestandteile
Компоненты

clay and silt pebbles
Ton- und Siltgerölle
валуны глины и алеврита

siderite
Siderit
сидерит

coal pebbles
Kohlegerölle
валуны угля

g — glauconite
Glaukonit
глауконит

mica, b biotite, m muscovite
Glimmer, b Biotit, m Muskovit
слюда, b биотит, m мусковит

phosphorite
Phosphorit
фосфорит

pyrite
Pyrit
пирит

limonite
Limonit
лимонит

ore minerals
Erzminerale
рудные минералы

bituminous
bitumenführend
битуминозный

k, c, d, sd, an, qu —
concretions; carbonate, calcitic, dolomitic, sideritic, anhydritic, siliceous
Konkretionen; karbonatisch, kalzitisch, dolomitisch, sideritisch, anhydritisch, kieselig
конкреции; карбонатный, кальцитовый, доломитовый, сидеритовый, ангидритовый, кремнистый

clay iron-stone
Toneisenstein
глинистый железняк

carbonaceous ironstone
Kohleneisenstein
углистый железняк

conglomerate of clay iron-stone
Toneisensteinkonglomerat
конгломерат глинистого железняка

k, c, fe —
ooids; carbonate, calcitic, ferritic
Ooide; karbonatisch, kalzitisch, ferritisch
ооиды; карбонатый, кальцитовый, ферритовый

reduction spots
Reduktionshöfe
ореолы редукции

DOI:https://doi.org/10.2312/zipe.1982.066

Characteristic bedding features
Charakteristische Schichtungsformen
Характерные типы слоистости


stratified in thick beds
Bankung
расслаивание


platy beds
Plattung
плитняковая отдельность


lenticular and flaser bedding
Linsen- und Flaserschichtung
линзовидная и флазерная слоистость


transition between wavy and cross lamination
wellig-schräge Schichtung
косоволнистая слоистость


lamination
Feinschichtung, Lamination
слойчатость, ламинация

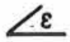

micro-cross bedding
Mikroschrägschichtung
микрокосослоистость


small- to medium-scale cross bedding (< 200 cm)
kleine bis mittlere Schrägschichtung (< 200 cm)
тонкая - средная косослоистость (< 200 см)


large-scale cross bedding (2-20 m)
große Schrägschichtung (2-20 m)
крупная косослоистость (2-20 м)


cross bedding with sets > 20 m
Megaschrägschichtung (> 20 m)
мегакосослоистость (> 20 м)


parallel bedding
Parallelschichtung
параллельная слоистость


type of cross bedding after ALLEN (1963)
Schrägschichtungstyp nach ALLEN (1963)
тип косой слоистости по ALLEN (1963)


graded bedding (fining-upward)
Korngradierung (unten grob)
градационная слоистость (внизу грубый)


inverse graded bedding (coarsening-upward)
inverse Korngradierung (oben grob)
обратная градационная слоистость (вверху грубый)

DOI:https://doi.org/10.2312/zipe.1982.066

Bedding plane markings and erosional features
Marken auf Schichtflächen und Erosionsformen
Знаки на плоскостях наслоения и формы эрозии


mud cracks
Trockenrisse
трещины усыхания


point marks ("rain prints")
Punktmarken ("Regentropfen")
точечные знаки ("отпечатки дождевых капель")


current marks
Strömungsmarken
знаки течения


small erosional channels (depth in the order of cm-dm)
kleine Erosionsrinnen (Tiefe im cm- bis dm-Bereich)
небольшие ложбины размыва (глубиной в см-дм)

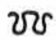

large erosional channels (depth in the order of m)
große Erosionsrinnen (Tiefe im m-Bereich)
большие ложбины размыва (глубиной в м)


erosion valley (depth tens of m)
Erosionstäler (Tiefe im 10 m-Bereich)
эрозионные долины (глубиной в десятки м)


symmetric ripples
symmetrische Rippeln
симметричные знаки ряби


asymmetric ripples
asymmetrische Rippeln
асимметричные знаки ряби

Deformational structures
Deformationsgefüge
Деформационные структуры


convolute bedding
konvolute Gefüge
конволютные структуры


slumping, pebbly mudstone
Rutschgefüge, Geröllton
структуры скольжения


clastic dikes
klastische Gänge
кластические жилы


load casts
Belastungsmarken
знаки давления

DOI:https://doi.org/10.2312/zipe.1982.066

Fauna and flora

Fauna und Flora

Фауна и флора

animal fossils in general
tierische Fossilien allgemein
остатки животных без уточнения

higher vertebrata
höhere Vertebraten
высшие позвоночные

fishes
Fische
рыбы

insects
Insekten
насекомые

trilobites
Trilobiten
трилобиты

pelecypdods
Muscheln
раковины

snails
Schnecken
гастроподы

cephalopods
Cephalopoden
цефалоподы

brachiopods
Brachiopoden
брахиоподы

bryozoans
Bryozoen
мшанки

conodonts
Conodonten
конодонты

ostracodes
Ostrakoden
остракоды

foraminifers
Foraminiferen
фораминиферы

radiolarians
Radiolarien
радиоларии

nannoplankton
Nannoplankton
наннопланктон

trace fossils
Fährten
следы

other lebensspuren
andere Lebensspuren
другие следы жизнедеятельности (биоглифы)

archaelogic finding
archäologische Funde
археологические находки

plant fossils in general
pflanzliche Fossilien allgemein
растительные остатки без уточнения

remains of leaves and fronds
Blatt- und Wedelreste
остатки листов и ваий

remains of stems, coal pipes
Stammreste
остатки стволов

layers of drifted wood
Lagen von Driftholz
пласт наносного дерева

fragmental plant remains
Pflanzenhäcksel
растительный детрит

rootled bed
Wurzelböden
ископаемая почва с отпечатками корней

DOI:https://doi.org/10.2312/zipe.1982.066


spores and pollen
Sporen und Pollen
споры и пыльцы


algae
Algen
водоросли


diatoms
Diatomeen
диатомовые водоросли


Characeae


Hystrichosphaeridae

Additional signs
Zusatzzeichen
Дополнительные знаки


fresh-water fossil
Süßwasserform
пресноводная форма


brackish water fossil
Brackwasserform
солоноватоводная форма


marine fossil
marine Form
морская форма

The additional sign is set below the fossil sign, for instance
Zusatzzeichen wird untergesetzt, z.B.
Дополнительный знак ставятся внизу, например


fresh-water snails
limnische Schnecken
озёрные гастроподы


brackish-water foraminifers
Brackwasserforaminiferen
солоноватоводные фораминиферы

DOI:https://doi.org/10.2312/zipe.1982.066

Sedimentary environments
Sedimentationsmilieu
Среда осадконакопления

one-letter symbols
einstellige Buchstabensymbole
однозначные буквы

c	continental kontinental континентальная	
m	marine marin морская	
b	brackish brackisch солоноватоводная	
h	hypersaline hypersalin повышенной солёности	

two-letter symbols
zweistellige Buchstabensymbole
двузначные буквы

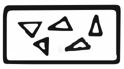
el	eluvial eluvial элювиальная
dc	deluvial, colluvial deluvial, colluvial делювиальная, коллювиальная
al	alluvial fans alluviale Fächer пролювиальная
fl	fluvial fluviatil речная
lk	laoustrine lakustrisch озёрная
pa	paludal (swamps) palustrisch болотная
ae	aeolian äolisch золовая
gl	glacial (tillites) glazial (Tillite) ледниковая (тиллит)
dt	delta (marine shore) Delta (Meeresküsten) дельта (морской берег)
ti	tidal flats Watten ватты
lg	lagoonal with barrier islands lagunär mit Strandwallinseln лагуна и ограждающий остров
li	near-shore litoral прибрежная
ne	off-shore neritisch неритовая
ab	continental slope and abyssal Kontinentalhang und abyssisch континентальный склон и абис-сальная
eu	euxinic euxinisch эвксинская

DOI:https://doi.org/10.2312/zipe.1982.066

The one-letter symbols may be combined with the two-letter symbols, for instance
Die einstelligen Buchstabensymbole können mit den zweistelligen kombiniert werden, z.B.
Однозначные буквы могут комбинироваться с двузначными, например

b / li	brackish near-shore brackisch-litoral солоноватая прибрежная	h / lg	hypersaline lagoonal hypersalinar-lagunär повышенной солёности лагунная

Structures of volcanic and volcanoclastic rocks
Vulkanit- und Tuffgefüge
Структуры и текстуры вулканических пород

fel	felsitic felsitisches Gefüge фельзитовая структура		volcanic breccia vulkanische Brekzien вулканические брекчии
po	porphyric porphyrisches Gefüge порфировая структура	agg	agglomeratic tuff Agglomerattuff агломератовый туф
o o	amygdaloidal Mandelsteingefüge мандельштейновая структура	lap	lapilli tuff Lapillituff лапиллиевый туф
vi	high content of volcanic glass hoher Glasanteil высокое содержание стекла	gr	grained tuff körniger Tuff зернистый туф
		ash	ash tuff Aschentuff пепловый туф

Magmatic and volcanoclastic bodies
Magmatische und vulkanoklastische Körper
Магматические и вулканокластические тела

sporadic, thin tuff layers
sporadische, geringmächtige Tufflagen
спорадические маломощные туфы

mass eruptions of tuffs
Masseneruption von Tuffen
массовые извержения туфов

DOI:https://doi.org/10.2312/zipe.1982.066


ignimbrites
Ignimbrite
игнимбриты


agglomerate conus
Agglomeratkegel
агломератовые конусы


stratovolcano
Stratovulkan
стратовулканы


lava sheets
Lavadecken
лавовые покровы


dome
Staukuppe, Quellkuppe
купола


subaquatic effusions
subaquatische Lavaströme
подводные лавовые потоки


subaquatic extrusions
subaquatische Extrusionen
подводные экструзии

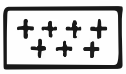

neck
Neck, Schlotgang
некки

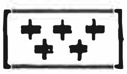

subvolcanic intrusive bodies
subvulkanische Intrusivkörper
субвулканические интрузии

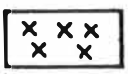

dikes of igneous rocks
Eruptivgesteinsgänge
жилы магматических пород

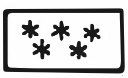

plutonic bodies
plutonische Körper
плутонические тела

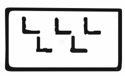
Petrography of intrusive bodies
Petrographie der Intrusivkörper
Петрография интрузивных тел

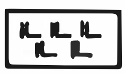

granitoids
Granitoide
гранитоиды

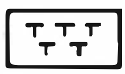

plagiogranitoids
Plagiogranitoide
плагиогранитоиды


syenitoids
Syenitoide
сиенитоиды


dioritoids
Dioritoide
диоритоиды


gabbroids
Gabbroide
габброиды


essexitoids
Essexitoide
ессекситоиды


ultrabasites
Ultrabasite, Mafitite
ультрабазиты

DOI:https://doi.org/10.2312/zipe.1982.066

Other features of igneous rocks

Weitere Merkmale der Eruptivgesteine

Другие признаки изверженных пород

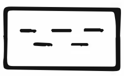
Postmagmatic alterations of igneous rocks
Postmagmatische Umwandlungen von Eruptivgesteinen
Постмагматические изменения магматических пород

arg	argillitization Argillitisierung аргиллитизация	ep	epidotization Epidotisierung эпидотизация
kaol	kaolonization Kaolinisierung каолинизация	sil	silicification Silizifizierung силицификация
hem	haematitization Hämatitisierung гематитизация	spil	spilitization Spilitisierung спилитизация
prop	propylitization Propylitisierung пропилитизация		

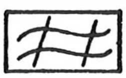
Tectonic deformations of the molasse rocks

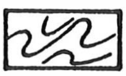
Tektonische Deformation der Molassegesteine

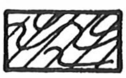
Степень деформации и метаморфизма молассовых пород


not or slightly deformed sediments
nicht und schwach deformierte Sedimente
недеформированные и слабо деформированные осадочные породы

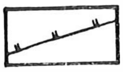

fault tectonics
Bruchtektonik
разрывная тектоника


germanotype folding and faulting
germanotype Falten- und Bruchtektonik
германотипная тектоника


Alpine-type folding
einfache alpinotype Faltung
простая альпинотипная складчатость


foliation
Schieferung
сланцеватость

DOI:https://doi.org/10.2312/zipe.1982.066



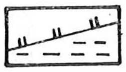
nappe tectonics
Deckentektonik
покровная тектоника

salt diapir
Salzdiapir
солевой диапир

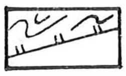
The sign is combined with one of the above signs which designates the position and state of the molasse formation, for instance:

Dieses Zeichen wird mit einem der oben angeführten Zeichen kombiniert, das Lage und Zustand der Molasseformation beschreibt, zum Beispiel:

Этот знак комбинируется с одным из вышеупомянутых знаков, который характеризует позицию и состояние молассовой формации, например:



molasse below the nappe, not deformed
Molasse unter der Decke, nicht deformiert
моласса под покровом, недеформирована



molasse within the nappe, folded
Molasse in der Decke, gefaltet
моласса в покрове, складчата

an

anchimetamorphism
Anchimetamorphose
анхиметаморфизм

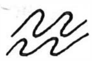
epi

epizonal metamorphism
epizonale Metamorphose
эпизональный метаморфизм

Tectonic events (processes)

Tektonische Ereignisse (Prozesse)

Тектонические события (процессы)



folding
Faltung
складчатость

synsedimentary folding
synsedimentäre Faltung
конседиментационная складчатость

faulting
bruchtektonische Bewegungen
образование разрывов

synsedimentary faulting
synsedimentäre Bruchbildung
конседиментационное образование разрывов

DOI:https://doi.org/10.2312/zipe.1982.066

disconformity on folded series
Diskordanz über gefalteten Serien
несогласие над толщами смятыми в складки

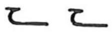
disconformity on nappe system
Diskordanz über Deckensystem
несогласие над покровным комплексом

disconformity with high angle
Diskordanz mit hohem Winkel
несогласие с резким угловым несогласием

unconformity with low angle, "non-evident" unconformities
Auflagerung mit geringem Diskordanzwinkel, "verborgene" Diskordanzen
несогласие с небольщим угловым несогласием

unconformity on faults
Diskordanz über Bruchstörungen
несогласие над разрывами

unconformities over dikes and intrusive bodies
Diskordanz über Gängen und Intrusivkörpern
несогласие над жилами и интрузивными телами



erosional horizons
Erosionshorizonte
горизонты размыва

diastem with concordance (hiatus)
Sedimentationsunterbrechungen ohne Diskordanz (Hiatus)
стратиграфические перерывы с согласным залеганием (пробел)

overlying series transgressive
auflagernde Serie transgressiv
налегающая серия трансгрессивна

underlying series regressive
liegende Serie regressiv
налегающая серия регрессивна

interruption of sedimentation with soil formation
Sedimentationslücken mit Bodenbildung
перерывы осадконакопления с почвообразованием

epochs of increased elevation and erosion in the environs of the basin
Zeiten verstärkter Heraushebung und Abtragung in der Umgebung des Beckens
этапы усиленного поднятия и размыва в обрамлении впадины

epochs of olisthostrome formation
Zeiten der Olisthostrombildung
этапы образования олистостромов

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066

DOI:https://doi.org/10.2312/zipe.1982.066