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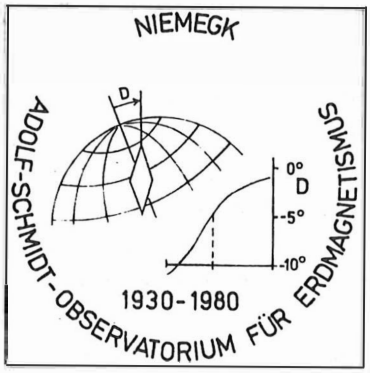
50 Jahre

Adolf-Schmidt-Observatorium für Erdmagnetismus in Niemegk



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Vorwort

Zum 70. Geburtstag von Geheimrat Prof. Dr. Adolf Schmidt, am 23. Juli 1930, wurden bei Niemegk, Kreis Belzig, die neu errichteten Anlagen des 1889 in Potsdam gegründeten Magnetischen Observatoriums im damaligen Preußischen Meteorologischen Institut offiziell ihrer Bestimmung übergeben und erhielt diese Einrichtung den Namen "Adolf-Schmidt-Observatorium für Erdmagnetismus in Niemegk". Das Symposium "Aktuelle Probleme der geomagnetischen Forschung", das vom Zentralinstitut für Physik der Erde der Akademie der Wissenschaften der DDR vom 2. bis 6. Juni 1980 in Belzig-Wenddoche und Niemegk veranstaltet wurde, war dem 50. Jahrestag dieses Ereignisses gewidmet.

Zum Symposium konnten die Veranstalter neben rund 30 Teilnehmern aus der DDR nahezu 70 Gäste aus weiteren 11 Ländern, dabei über 30 aus der UdSSR, begrüßen.

Zur Eröffnungsveranstaltung waren neben den Teilnehmern des wissenschaftlichen Symposiums der 1. Sekretär der Kreisleitung Belzig der Sozialistischen Einheitspartei Deutschlands und der Vorsitzende des Rates des Kreises Belzig sowie weitere Vertreter von Staatsorganen und gesellschaftlichen Organisationen des Bezirkes Potsdam, des Kreises Belzig und der Stadt Niemegk erschienen. In ihren Grußadressen würdigten der 1. Sekretär der SED-Kreisleitung, Genosse Schuster, und der Vorsitzende des Rates des Kreises, Genosse Dreese, die Tätigkeit der Mitarbeiter des Adolf-Schmidt-Observatoriums und ihre Wirksamkeit im geistig-kulturellen Leben der Stadt Niemegk und des Kreises Belzig. Im Namen ihrer Delegation und aller ausländischen Teilnehmer überbrachten Frau Prof. Dr. Benkova vom Institut für Erdmagnetismus, Ionosphäre und Wellenausbreitung der Akademie der Wissenschaften der UdSSR, Frau Prof. Dr. Petrova vom Institut für Physik der Erde der sowjetischen Akademie, Dr. Gelkin vom Sibirischen Institut für Erdmagnetismus, Ionosphäre und Wellenausbreitung Irkutsk, Prof. Dr. Voppel vom Deutschen Hydrographischen Institut aus der Bundesrepublik Deutschland und Dr. Kataja vom Geophysikalischen Observatorium Sodankylä aus Finnland den Mitarbeitern des Adolf-Schmidt-Observatoriums Niemegk zu ihrem Jubiläum die besten Grüße und Glückwünsche verbunden mit freundlichen Würdigungen der im vergangenen halben Jahrhundert in Niemegk erreichten wissenschaftlichen Leistungen.
Ihnen allen sei ebenso wie den Gästen, die den Mitarbeitern des Observatoriums zu anderer Zeit und Gelegenheit gratuliert haben, auch an dieser Stelle sehr herzlich gedenkt.

Mit besonderer Freude begrüßten alle Anwesenden die Teilnahme von Prof. em. Dr. phil. habil. Gerhard Fanselau, des hochverehrten Nestors der geomagnetischen Forschung in Potsdam und Niemegk. Prof. Dr. Fanselau nahm 1928 seine Tätigkeit im damaligen Magntetischen Observatorium Potsdam auf. Er war maßgeblich an der Einrichtung des Observatoriums in Niemegk beteiligt, Initiator des Wiederaufbaus des Observatoriums nach Kriegsende und sein Leiter seit 1945 sowie Direktor des Geomagnetischen Instituts Potsdam-Niemegk von 1950 an bis zu seiner Emeritierung wenige Monate nach Eingliederung dieses Instituts in das Zentralinstitut für Physik der Erde der Akademie der Wissenschaften der DDR im Jahre 1969. Prof. Fanselau hat als unmittelbarer Schüler von Geheimrat Adolf Schmidt das wissenschaftliche Profil der geomagnetischen Forschung in Potsdam und Niemegk entscheidend geprägt. Alle Wissenschaftler der DDR, die auf

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dem Gebiet des Geomagnetismus gearbeitet haben und noch arbeiten, bringen Prof. Dr. Fanselau ihren tiefempfundenen Dank entgegen.

Während des Symposiums wurden rund 50 wissenschaftliche Vorträge gehalten, von denen im vorliegenden Heft der Veröffentlichungen des Zentralinstituts für Physik der Erde 48 publiziert werden. Die Reihenfolge im Druck entspricht im wesentlichen dem zeitlichen Ablauf der Veranstaltung. Die weitaus überwiegende Zahl der Beiträge ist, wie aus dem Inhaltsverzeichnis ersichtlich, aktuellen Fragen der geomagnetischen Forschung gewidmet. Im Eröffnungsvortrag wird eine Übersicht über die in Potsdam und Niemegk im Verlauf von neun Jahrzehnten, d.h. seit Gründung des Magnetischen Observatoriums in Potsdam, durchgeführten wissenschaftlichen Arbeiten gegeben.
Die Veröffentlichung schließt mit dem interessanten Beitrag von Prof. Dr. Kertz von der Technischen Universität Braunschweig, Bundesrepublik Deutschland, zum Stand der Geophysik zum Zeitpunkt der Eröffnung des Adolf-Schmidt-Observatoriums in Niemegk.

Heinz Kautzleben

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H. Kautzleben, Potsdam

50 Jahre Adolf-Schmidt-Observatorium für Erdmagnetismus in Niemegk – 90 Jahre geomagnetische Forschung in Potsdam

Zusammenfassung: Es wird ein Überblick über die Entwicklung des Adolf-Schmidt-Observatoriums für Erdmagnetismus in Niemegk und seiner Vorgänger in Potsdam und Seddin gegeben. Zu den traditionellen Aufgaben dieser Einrichtungen gehören seit ihrer Gründung neben der Unterhaltung des Observatoriumsbetriebes die Entwicklung der erforderlichen Meßtechnik, regelmäßige Vergleichsmessungen mit anderen Observatorien, die Durchführung von magnetischen Landesvermessungen und von geomagnetischen Tiefensondierungen sowie Untersuchungen zur Auswertung des Beobachtungsmaterials. Das Observatorium gehört seit 1969 zum Zentralinstitut für Physik der Erde.

Summary: We give an outline of the development of the Adolf-Schmidt-Observatory for Geomagnetism in Niemegk and its predecessors in Potsdam and Seddin. Since their foundation the traditional functions of these institutions have not only been the carrying-out of the regular observatory tasks but also development of the necessary measurement technology, continuous comparison measurements with other observatories, carrying-out of geodetic magnetic surveyings and of geomagnetic deep soundings and investigations on evaluation of the observation material. Since 1969 the observatory has been a part of the Central Earth Physics Institute.

Резюме: Доклад содержит обзор развития Геомагнитной Обсерватории им. Адольфа Шмидта в Нимегке и ее предшественников в Потсдаме и Зеддине. С основания в состав традиционных задач этих учреждений входят не только проведение очередных задач обсерватории, но и развитие необходимой измерительной техники, постоянные сравнительные измерения с другими обсерваториями, проведение магнитных геодезических измерений, геомагнитных глубинных зондирований и исследования по обработке материала наблюдений. С 1969 г. обсерватория является частью Центрального Института Физики Земли.

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1. Die Eigenschaften des Erdmagnetismus und die Aufgaben eines geomagnetischen Observatoriums

Die Stellung der geomagnetischen Observatorien im Rahmen der Geowissenschaften wird durch die grundlegenden Eigenschaften des Erdmagnetismus und die daraus folgenden Besonderheiten der geomagnetischen Forschung bestimmt. Das Magnetfeld der Erde ist bekanntlich eine recht komplizierte physikalische Erscheinung. Im Vergleich zum Schwerefeld, das auch in geologischen Zeitmaßstäben gesehen zeitlich praktisch konstant ist und sich auch von Ort zu Ort nur sehr wenig ändert, weist das Erdmagnetfeld räumlich und zeitlich beachtliche Änderungen auf. Dementsprechend sind vielfältige meßtechnische Maßnahmen erforderlich, um die Struktur des Erdmagnetfeldes in Raum und Zeit erfassen zu können. Direkte Messungen des Erdmagnetfeldes gibt es erst seit einem halben Jahrtausend, mit ausreichender Präzision und Kontinuität jedoch erst seit etwa 100 Jahren.

Im Erdmagnetfeld wirken sich im wesentlichen drei unterschiedliche physikalische Vorgänge aus. Der weitaus überwiegende Teil wird durch physikalische Vorgänge im äußeren Kern der Erde verursacht. Dieser Teil, das Hauptfeld, ist über Jahre hinweg praktisch konstant. Im Maßstab von Tausenden bzw. Zehntausenden von Jahren ist das Hauptfeld starken Veränderungen bis zur völligen Umkehr der Feldrichtung unterworfen. Der Nachweis der räumlichen und zeitlichen Struktur dieser Langzeit-Änderungen kann nur mit Hilfe von paläomagnetischen Methoden erfolgen, bei denen das "magnetische Gedächtnis" der Gesteine ausgenutzt wird. Über kurze Zeiträume hinweg hat das Hauptfeld eine recht einfache räumliche Struktur; es kann sehr gut bereits durch einen Dipol im geometrischen Mittelpunkt der Erde beschrieben werden; wenn man dem noch einige wenige Multipole im Erdmittelpunkt hinzufügt, genügt die Beschreibung allen Anforderungen. Die Struktur des Hauptfeldes in der Nähe der Erdoberfläche zu einer bestimmten Zeitepoche wird durch eine weltweite Vermessung des Erdmagnetfeldes bestimmt, wobei heute künstliche Erdsatelliten al Träger der Meßinstrumente eine überragende Bedeutung gewonnen haben.

Dem Hauptfeld ist ein zeitlich konstanter Anteil überlagert, der durch den Magnetismus der Gesteine der Erdkruste verursacht wird. Änderungen dieses Anteils können nur durch geologische Prozesse verursacht werden, welche die Gesteine der Kruste selbst verändern.

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Dieser Anteil ist örtlich stark veränderlich; er stellt sich demnach als lokale bzw. regionale Anomalien dar und gibt wichtige Indikationen für die Lösung geologischer Fragen bis hin zur Suche von Lagerstätten.
Mit wachsender Entfernung von der Erdoberfläche schwindet der Einfluß der Anomalien in der Struktur des Erdmagnetfeldes sehr schnell. Im Abstand einiger Erdradien dominiert der Anteil des Dipols. Allerdings wird die Struktur des Dipolfeldes mit weiter wachsender Entfernung durch den Einfluß des ständig von der Sonne ausgehenden Stromes elektrisch geladener Teilchen vollständig verändert. Die Begrenzung des Bereiches, der vom Erdmagnetfeld noch beeinflußt wird, erhält dadurch die Form eines Tropfens mit einer Stoßfront auf der der Sonne zugewandten Seite und dem Schweif auf der abgewandten Seite. Diese Form ist zeitlich nicht konstant, sondern ändert sich im Rhythmus der Schwankungen des Sonnenwindes.
Der dritte, zeitlich stark veränderliche Anteil am Erdmagnetfeld resultiert aus den physikalischen Vorgängen in der Hochatmosphäre, der Magnetosphäre und an der Grenze zum Weltraum unter dem Einfluß der Sonne. Dieser Anteil ist die auffälligste Erscheinung in den Registrierungen an den magnetischen Observatorien. Er kann in qualitativer Form meßtechnisch recht einfach erfaßt werden. Die saubere Trennung von den beiden bereits genannten permanenten Anteilen erweist sich jedoch als eine äußerst anspruchsvolle wissenschaftlich-technische Aufgabe und erfordert vielfältige Maßnahmen und beharrliche Anstrengungen der Observatoren und ihrer Mitarbeiter.
Das kurzperiodische Ende im Spektrum der Variationen, die dem geomagnetischen Feld zugerechnet werden, wird konventionell bei 10 Hz bestimmt. Damit sind die Fluktuationen des natürlichen elektromagnetischen Feldes jenseits der Pulsationen nicht mehr Gegenstand der geomagnetischen Forschung.

Da der Erdkörper einschließlich der Gewässer elektrisch leitend ist, enthalten die zeitlichen Änderungen des Erdmagnetfeldes neben ihrem primären, durch die Vorgänge im Außenraum der Erde verursachten Anteil noch einen sekundären Teil, der durch die elektromagnetische Induktion der Variationen im Erdkörper bedingt wird. Dieser sekundäre Anteil wird außer durch die räumliche

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und zeitliche Struktur der Quellen im Außenraum auch durch die räumliche Verteilung der elektrischen Leitfähigkeit im Erdkörper bestimmt. Die Trennung des primären und sekundären Anteils ist deshalb theoretisch und praktisch sehr kompliziert; sie ermöglicht jedoch wichtige Aussagen über die Erdkruste und die Lithosphäre und hat großes wissenschaftliches Interesse. Die erforderlichen Meßdaten werden durch die geomagnetischen Tiefensondierungen beschafft.

Zusammenfassend läßt sich also sagen, daß die magnetischen Observatorien eine zentrale Stellung bei der Erforschung des Erdmagnetismus einnehmen. An den Observatorien erfolgt die ständige Überwachung der Schwankungen des Erdmagnetfeldes. Die Observatorien bilden die Basis und die Bezugspunkte für die flächenhafte Vermessung sowohl des permanenten Magnetfeldes wie auch des Variationsfeldes. An den Observatorien oder in enger Verbindung mit ihnen werden häufig auch gesteins- und paläomagnetische Untersuchungen zum Langzeitverhalten des Erdmagnetfeldes und von damit verknüpften geologischen, z.B. stratigraphischen bzw. tektonischen, Fragen durchgeführt.

Die magnetischen Observatorien befinden sich stets an sorgfältig ausgesuchten Standorten, die weitgehend frei von Störungen der natürlichen Verhältnisse durch Industrie, Verkehr, Siedlungen u.ä. sind. Sie verfügen über eine hochentwickelte Technik für höchstpräzise Messungen des natürlichen elektromagnetischen Feldes und betreiben häufig selbst den dazu erforderlichen Gerätebau.

Die Observatorien werden deshalb in allen Ländern auch für magnetische Präzisionsmessungen mit verschiedensten Zielstellungen genutzt.

Das unmittelbare Ergebnis der Arbeit eines jeden magnetischen Observatoriums ist die Bereitstellung zuverlässiger, mehr oder weniger vollständiger Meßdaten über die zeitliche und die räumliche Struktur des Erdmagnetfeldes. Die wissenschaftliche Analyse dieser Daten, ihre Verknüpfung mit weiteren Informationen und die Ausführung theoretischer Untersuchungen über die Ursachen des Erdmagnetfeldes erfolgt manchmal an den Observatorien selbst, zumeist jedoch an großen Forschungseinrichtungen, an welche die Observatorien gewöhnlich angeschlossen sind. In dieser Hinsicht entsprechen die Arbeitsweise und die organisatorische Stellung des Adolf-Schmidt-Observatoriums für Erdmagnetismus völlig der internationalen Norm. Sie haben sich über 90 Jahre hinweg als effektiv erwiesen und werden sich auch in Zukunft nicht ändern.

2. Geschichte und Vorgeschichte des Adolf-Schmidt-Observatoriums

Das Adolf-Schmidt-Observatorium für Erdmagnetismus in Niemegk ist die unmittelbare Nachfolgeeinrichtung der Magnetischen Abteilung des Meteorologisch-Magnetischen Observatoriums, das am 1. 1. 1890 als Bestandteil des Preußischen Meteorologischen Instituts Berlin mit regelmäßigen magnetischen Registrierungen auf dem Telegrafenberg in Potsdam begonnen hat. Als erster Leiter der Magnetischen Abteilung wurde Dr. Max Eschenhagen berufen; gleichzeitig wurde er zum Professor ernannt.

Nach dem frühen Tode Eschenhagens wurde 1902 zum Leiter der Magnetischen Abteilung und zugleich zum Direktor des Meteorologisch-Magnetischen Observatoriums in Potsdam der Gymnasialprofessor Dr. Adolf Schmidt berufen. Mit ihm übernahm ein äußerst befähigter und vielseitig begabter Wissenschaftler die Leitung, der in den folgenden 26 Jahren das Profil und den internationalen Ruf der geomagnetischen Forschung in Potsdam entscheidend bestimmt hat.

Auf die Arbeiten und Anregungen von Adolf Schmidt gehen vielfältige Traditionen zurück, die heute noch im Observatorium Niemegk, das mit vollem Recht seinen Namen trägt, gepflegt werden.

Adolf Schmidt wurde im Jahre 1929 zum korrespondierenden Mitglied der Berliner Akademie der Wissenschaften gewählt.

Adolf Schmidt hatte zweimal die äußerst schwierige Aufgabe zu erfüllen, das magnetische Observatorium durch Verlegung an einen neuen Standort vor industriellen Störungen zu sichern:

Im Jahre 1907 wurden die Registrierungen vom Telegrafenberg in den Forst von Seddin verlegt - zur Ausschaltung der Störungen durch den elektrischen Treidelbetrieb auf dem Teltow-Kanal.

1929/30 mußte wegen der Elektrifizierung der Berliner S-Bahn auch dieser Standort aufgegeben werden. Als neuer Standort wurde

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von Adolf Schmidt ein Waldstück am Rande von Niemegk/ Kreis Belzig ausgewählt, auf dem bis heute das Adolf-Schmidt-Observatorium für Erdmagnetismus nur mit der Unterbrechung infolge von Kriegseinwirkungen störungsfrei arbeiten konnte.
Die 1890 geschaffene Organisationsform hat die geomagnetische Forschungseinrichtung in Potsdam bis zum Jahre 1934 beibehalten. In diesem Jahr wurde das Preußische Meteorologische Institut in den neugebildeten Reichswetterdienst des faschistischen Deutschlands eingegliedert. Die Magnetische Abteilung wurde gemeinsam mit dem Adolf-Schmidt-Observatorium aus dem Meteorologischen Institut ausgegliedert und zu einer selbständigen Einrichtung, zum Magnetischen Observatorium der Universität Berlin, umgewandelt. Die Leitung des Magnetischen Observatoriums wurde Alfred Nippoldt übertragen, der 1928 als Nachfolger von A. Schmidt zum Leiter der Magnetischen Abteilung berufen worden war.
Die Organisationsform eines Instituts erhielt die geomagnetische Forschungsstätte im Jahre 1936 anläßlich der Berufung von Prof. Dr. Julius Bartels zum neuen Direktor nach dem Tod von Alfred Nippoldt. Die Forschungsstätte wurde in Geophysikalisches Institut Potsdam umbenannt und dem Preußischen Kultusministerium unterstellt. Julius Bartels wurde 1939 zum Ordentlichen Mitglied der Berliner Akademie der Wissenschaften gewählt. Er hatte die Leitung des Instituts bis zum Kriegsende 1945 inne.
Die Entwicklung in den ersten Jahren nach dem Zusammenbruch des faschistischen Reiches ist gleichbedeutend mit dem Neuaufbau der geomagnetischen Forschungsstätte. Der Institutsteil in Potsdam wurde unter Leitung von Prof. Dr. Richard Bock mit der Bezeichnung Geophysikalisches Institut der Geologischen Landesanstalt Berlin zugeordnet. Das Adolf-Schmidt-Observatorium in Niemegk, das noch in den letzten Kriegstagen erhebliche Zerstörungen erlitten hatte, wurde unter Leitung von Dr. Gerhard Fanselau Teil des Meteorologischen Dienstes. Beide Einrichtungen wurden nach dem Ausscheiden von Richard Bock im Jahre 1949 unter der Leitung von Prof. Dr. Fanselau zum Geomagnetischen Institut und Observatorium Potsdam-Niemegk im Meteorologischen Dienst der DDR vereinigt. Diese Einrichtung wurde ab 1. 1. 1957 von der Berliner Akademie der Wissenschaften als Geomagnetisches Institut übernommen. Der größte Teil

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des Geomagnetischen Instituts, darunter vollständig das Adolf-Schmidt-Observatorium in Niemegk, ist am 1. 2. 1969 im damals neugebildeten Zentralinstitut für Physik der Erde der Akademie aufgegangen und nimmt seitdem an der Entwicklung dieses Zentralinstituts teil. Gerhard Fanselau wurde nach 42 Jahren äußerst fruchtbarer Tätigkeit im April 1969 emeritiert.

Wenn wir heute die Einrichtung des Adolf-Schmidt-Observatoriums in Niemegk vor 50 Jahren würdigen, so würdigen wir zugleich die Eröffnung des Magnetischen Observatoriums und den Beginn der Registrierungen in Potsdam vor über 90 Jahren. Ungeachtet aller organisatorischen Veränderungen und trotz der beiden Verlegungen ist es den Leitern und Mitarbeitern im magnetischen Observatorium Potsdam-Seddin-Niemegk gelungen, eine weitgehend lückenlose homogene Beobachtungsreihe für einen Zeitraum von 90 Jahren zu gewinnen. Wir danken heute allen Mitarbeitern, die in diesem langen Zeitraum mit wissenschaftlicher Akribie und zäher Beharrlichkeit den Betrieb des Observatoriums gesichert haben. Die Entstehungsgeschichte des Magnetischen Observatoriums in Potsdam zeigt, daß für seine Gründung zwei Zielstellungen maßgebend waren, die in jenen Jahren in Preußen herangereift waren. Das Observatorium sollte zur Erfassung des Einflusses der Sonne auf die Erde beitragen und zugleich als Stützpunkt für die magnetische Landesaufnahme in Preußen dienen. Sehr bald nach der Entdeckung der Spektralanalyse durch Kirchhoff, bereits Anfang der sechziger Jahre des vorigen Jahrhunderts, war in den Wissenschaftler-Kreisen Berlins der Gedanke aufgetaucht, in oder bei Berlin ein Observatorium einzurichten, das speziell zur Erforschung der physikalischen Erscheinungen auf der Sonne bestimmt sein sollte. Die vom Direktor der Berliner Sternwarte, Prof. Dr. Wilhelm Förster, angefertigte Denkschrift vom 30. 9. 1871 sah vor, daß in der Nähe Berlins eine solche Sonnenwarte errichtet werden sollte; Hauptstation fungieren.

Die Gutachten der Berliner Akademie der Wissenschaften von 1872 und 1874 lehnten diesen Vorschlag jedoch ab und befür-

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worteten dagegen die Errichtung eines astrophysikalischen Observatoriums, an dem auch regelmäßige erdmagnetische Beobachtungen durchgeführt werden könnten. Realisiert wurde lediglich der Bau des astrophysikalischen Observatoriums Potsdam, das im Herbst 1878 eröffnet werden konnte. Die Einrichtung eines magnetischen Observatoriums blieb dem bereits 1847 gegründeten Preußischen Meteorologischen Institut überlassen. Maßgebend hierfür war, daß sich die magnetischen Beobachtungen in der Art und Weise ihrer Ausführung eng an die meteorologischen anschließen lassen und deshalb ein gemeinsamer Betrieb leicht zu ermöglichen ist und daß man andererseits einen Zusammenhang zwischen beiden Gruppen von Erscheinungen vermutete.

Die Pläne zur Reorganisation des Meteorologischen Instituts und zur Errichtung eines meteorologisch-magnetischen Observatoriums bei Berlin wurden von der preußischen Regierung jedoch erst 1885 gebilligt.

Auf dem Gebiet des Erdmagnetismus war in Preußen bisher praktisch nicht gearbeitet worden. Lediglich Alexander von Humboldt hatte in den 20er und 30er Jahren in Berlin zeitweilig ein privates magnetisches Observatorium betrieben. Eine magnetische Landesaufnahme unter Einbeziehung preußischer Gebiete hatte John Lamont um die Mitte des 19. Jahrhunderts von München aus durchgeführt. Diese Aufnahme mußte am Ende des Jahrhunderts wegen der säkularen Änderung unbedingt erneuert werden. Ausgelöst durch die Forderungen der Seefahrt befaßten sich die 1867 gegründete Deutsche Seewarte in Hamburg mit magnetischen Beobachtungen sowie mit magnetischen Vermessungen im Küstenbereich. Eine Ausdehnung auf das gesamte Staatsgebiet Preußens erforderte jedoch unbedingt ein ausreichend leistungsfähiges, zentral gelegenes magnetisches Observatorium. Unmittelbar nachdem der laufende Betrieb im neuen Observatorium in Potsdam gesichert worden war, begannen dann auch die Arbeiten zur Landesaufnahme.

Soviel zur Entstehungsgeschichte des Magnetischen Observatoriums in Potsdam. Sie ist über das historische Interesse hinaus insofern interessant, als daß die damals bereits verfolgten Zielstellungen die gesamte weitere Entwicklung unserer geomagnetischen Forschungseinrichtung maßgeblich bestimmt haben.

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3. Die wissenschaftlichen Arbeiten

Während der gesamten, nunmehr 90 Jahre umfassenden Entwicklung des Observatoriums Potsdam-Seddin-Niemegk haben alle verantwortlichen Observatoren und Institutsleiter diese Forschungsstätte stets als geomagnetisches Standardobservatorium verstanden. Von Beginn an war die Aufmerksamkeit darauf gerichtet, das geomagnetische Feld vor allem am Standort des Observatoriums meßtechnisch exakt zu erfassen. Nach dem Vorbild von Gauß und Weber wurden hierfür kontinuierliche Registrierungen der zeitlichen Änderungen in allen drei Elementen mit normalem Papiervorschub und in gewissen Abständen Absolutbestimmungen von D, I und H vorgenommen. Eschenhagen hat in späteren Jahren auch Registrierungen mit größerer Geschwindigkeit begonnen und dabei die von ihm "Elementarwellen" genannten Pulsationen entdeckt. Mit eingehenden Untersuchungen dieser kurzperiodischen Änderungen des geomagnetischen Feldes befaßte sich in Niemegk erstmals Horst Wiese unter Verwendung einer großen Induktionsspule. Diese Arbeiten sind in der Folgezeit auch in Niemegk stark ausgebaut worden.
Untersuchungen des geoelektrischen Feldes wurden in Potsdam im zweiten Jahrzehnt nach der Gründung des Observatoriums und dann erst wieder nach Einrichtung des Observatoriums in Niemegk aufgenommen. Sie mußten in Potsdam wegen industrieller Störungen, in Niemegk wegen instrumenteller Schwierigkeiten wieder eingestellt werden. Erst nach 1949 konnte in Niemegk die kontinuierliche Registrierung auch der geoelektrischen Variationen aufgenommen werden. Das Observatorium in Niemegk und Potsdam dient mehrfach als Basis für magnetische Landesaufnahmen in klassischem Sinne.
Ab 1947 wurde das Adolf-Schmidt-Observatorium auch zum Ausgangs- und Stützpunkt für die geomagnetischen Tiefensondierungen, die eigentlich eine Kartierung der räumlichen Unterschiede im geomagnetischen Variationsfeld im Periodenbereich der Normalregistrierungen sind.

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Es ist niemals versucht worden, das geomagnetische Observatorium durch Einbeziehung weiterer Parameter zu einem geophysikalischen Observatorium bzw. zu einem Observatorium für solar-terrestrische Physik auszubauen.
Wie ein roter Faden ziehen sich durch die gesamte Geschichte des Observatoriums die Arbeiten zur Entwicklung und Weiterentwicklung der erforderlichen magnetischen Meß- und Registriergeräte. Von Beginn an bis in die 60er Jahre waren die Arbeiten auf die instrumentell-technische Realisierung der klassischen magnetometrischen Meßprinzipien konzentriert, die bereits von C. F. Gauß und E. W. Weber ausgearbeitet wurden. Für die Erstausstattung des neuen Observatoriums in Potsdam erwies es sich als außerordentlich vorteilhaft, daß in Potsdam einige feinmechanische Werkstätten bestanden, die auf die Fertigung geodätischer Geräte eingestellt waren und sich ebenfalls der Fertigung magnetometrischer Geräte nach den Angaben der Wissenschaftler des Observatoriums annahmen. Die Qualität der auf diese Weise entstandenen Geräte war ausgezeichnet. Viele geomagnetische Observatorien in aller Welt sind auch heute noch mit magnetischen Instrumenten dieser Potsdamer Firmen ausgestattet.

Bereits 1888 wurden von der Firma Wanschaff nach den Entwürfen von Eschenhagen ein Registrierapparat mit vier Walzen und ein magnetischer Theodolit gefertigt. Diese Instrumente gehörten ab 1890 zur Grundausrüstung des Observatoriums. Die feinmechanische Werkstatt von G. Schulze in Potsdam baute nach den Angaben von Eschenhagen einen Erdinduktor, der hohe Meßgenauigkeit und Einstellsicherheit aufwies und größere Meßgeschwindigkeiten zuließ. Bereits im Jahre 1912 waren mehr als zwanzig dieser Geräte in ausländischen Observatorien im Einsatz. Von Eschenhagen wurden auch die ersten brauchbaren Unifilar-Magnetometer entwickelt und eingesetzt.
Für die magnetische Landesaufnahme baute die Firma Töpfer zwei Tesdorfsche Reisetheodoliten nach Plänen von Eschenhagen um. Nach den Plänen von Nippoldt fertigte die Firma Schulze einen neuen Reisetheodoliten. Diese Aufzählung könnte fortgeführt werden.

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Die von Eschenhagen begründete Tradition, daß sich die Leiter des Magnetischen Observatoriums intensiv mit der Entwicklung der magnetischen Meßtechnik zu befassen haben, ist von allen seinen Nachfolgern im Amte des Observators gepflegt worden. Zur größten Überraschung der Fachwelt erwies sich auch Adolf Schmidt, der als Theoretiker bekannt war, als glänzender Experimentator und Entwickler von magnetischen Geräten hoher Leistungsfähigkeit. Er entwickelte u.a. eine optische Anordnung zum Registrieren mit zwei verschiedenen Empfindlichkeiten und eine photographische Registriereinrichtung mit weiter Zeitskala bei sparsamem Papierverbrauch. Einen bedeutenden Fortschritt brachte sein magnetischer Normaltheodolit. Dieses Gerät wurde von den Askania-Werken in Berlin-Friedenau in größerer Zahl gebaut. Ein solcher Normaltheodolit ist auch heute noch im Observatorium in Niemegk im Meßeinsatz; er war das wichtigste Gerät bei der absoluten Neubestimmung der erdmagnetischen Feldgrößen in Niemegk in den Jahren 1950 bis 1952. Der Name Adolf Schmidts ist ebenfalls untrennbar mit der geomagnetischen Feldwaage verknüpft, die von ihm 1914/15 aus einem Variometer für den Prospektionseinsatz entwickelt wurde. Diese Feldwaage wurde industriell gefertigt und weltweit eingesetzt. Sie ist später mehrfach konstruktiv weiterentwickelt worden.
Die bedeutendsten Verbesserungen stammen von Fanselau, der in den Jahren nach 1945 u. a. die Schneidenlagerung des Magneten durch eine Fadenaufhängung ersetzte. Die Fadenwaage ist in weit über 1000 Exemplaren gefertigt und in alle Welt ausgeführt worden.

Gerhard Fanselau, der das Amt des Observators kurz nach der Errichtung des neuen Observatoriums in Niemegk übernahm, verdanken wir zahlreiche neue Entwicklungen. Er hat besondere Sorgfalt auf die zweckmäßige Gestaltung der Registrier- und Meßräume und deren Sicherung gegen äußere Störungen verwendet. Von Fanselau stammen weiter u. a. Spulensysteme für die Erzeugung weitgehend homogener Magnetfelder, eine Apparatur zur automatischen Schwingungsmessung und die von ihm entwickelte magnetische Feldregistrierstation.

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Darüberhinaus gab Fanselau zahlreiche Anregungen für weitere gerätetechnische Arbeiten an seine Mitarbeiter: z. B. für die Entwicklung eines elektrodynamischen Theodoliten, vor allem für die Aufnahme von Untersuchungen zur Verwendung neuartiger physikalischer Prinzipien zur Messung des Erdmagnetfeldes, von denen sich das Flux-gate-Prinzip und die freie Kernpräzession durchgesetzt haben. Von den heute verantwortlichen Observatoren sind besondere Anstrengungen u. a. zur Einführung der Prozeßrechentechnik in den Observatoriumsbetrieb unternommen worden.

Die Leitung und die Mitarbeiter des Observatoriums in Potsdam, Seddin und Niemegk waren stets an einer engen Kooperation mit den Fachkollegen in anderen magnetischen Observatorien, besonders mit denen in den europäischen Staaten, interessiert. Ein beredtes Zeugnis hiervon legen die zahlreichen Vergleichsmessungen ab, um das Bezugsniveau in allen Observatorien auf eine einheitliche experimentell gesicherte Basis zu bringen. In den Tagen, da unser Symposium stattfindet, werden wiederum mehrere Anschlußmessungen durch Teilnehmer des Symposiums in Niemegk ausgeführt. Eine weitere bemerkenswerte internationale Gemeinschaftsarbeit mit großem allseitigen Nutzen ist der regelmäßige Austausch von Momentanwerten zwischen den benachbarten europäischen Observatorien. Dieser Austausch wurde vor 25 Jahren von den Observatoren von Niemegk, Wingst, Fürstenfeldbruck und Wien-Auhof begonnen. Heute beteiligen sich daran über 20 geomagnetische Observatorien in Europa.
An unserem Observatorium sind mehrfach die Teilnehmer von Expeditionen ausgebildet und ausgerüstet worden, die in fernen Ländern, in der Arktis und in der Antarktis geomagnetische Beobachtungen durchführen sollten. Mitarbeiter des Observatoriums Niemegk waren 1958 und 1964 in Spitzbergen tätig. Seit 1973 werden in Niemegk die DDR-Teilnehmer an den Sowjetischen Antarktisexpeditionen vorbereitet, die den kontinuierlichen magnetischen Beobachtungsbetrieb in der DDR-Basis bei der sowjetischen Station Neulasarew unterhalten.

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Wenn man heute die 9 Jahrzehnte Forschungsarbeit in Potsdam, Seddin und Niemegk überblickt, so kann man mehrere Traditionslinien feststellen, die zu allen Zeiten von den Mitarbeitern des Observatoriums gepflegt worden sind. Neben der bereits behandelten Weiterentwicklung der Gerätetechnik gehört hierzu auch das ständige Bemühen um die zweckmäßigste Aufbereitung des Beobachtungsmaterials. Zum Observatorium Potsdam-Seddin-Niemegk gehört seit jeher das aussagekräftige Jahrbuch mit verschiedenartigen Tabellen, graphischen Darstellungen aber auch mit wissenschaftlichen Artikeln. Heute werden die Tabellen im Jahrbuch mit Hilfe unserer eigenen Rechneranlage automatisch berechnet.

Eine weitere traditionelle Aufgabe ist die Schätzung der geomagnetischen Aktivität und die Entwicklung dafür geeigneter Kennziffern. Hierbei sind besonders die Namen Eschenhagen, Schmidt, Bartels, Fanselau zu nennen. Die von Schmidt eingeführten Charakterzahlen werden ebenso wie die von Bartels entwickelten geomagnetischen Kennziffern K 1 noch heute von den Observatorien inaller Welt verwendet. Weit verbreitet sind ebenfalls die von Fanselau entwickelten Kennziffern K 2. Die mit der Schätzung der Aktivität verknüpften Probleme sind in Potsdam und Niemegk eingehend untersucht worden. Hierzu gehört z. B. die Unterscheidung von besonders ruhigen und besonders gestörten Tagen. Das umfangreiche Beobachtungsmaterial ist von verschiedenen Mitarbeitern für eingehende statistische Untersuchungen der Aktivität genutzt worden. Schmidt gelang dabei der Nachweis des sogenannten Ringstromes Dst mit Hilfe der sog. interdiurnen Veränderlichkeit. Fanselau hat sich eingehend mit der Feinstruktur der Variationen befaßt. Weitere Arbeiten betrafen z. B. die Bay-Störungen, die Solar-Flare-Effekte und die regulären Variationen.

Alle Potsdamer und Niemegker Observatoren haben, wie bereits erwähnt wurde, sehr eng mit ihren Kollegen an den benachbarten geomagnetischen Observatorien zusammengearbeitet. Die vielfältigen Instrumentenvergleiche haben zur Qualitätssteigerung aller beteiligten Observatorien beigetragen..Einige Male sind bei solchen Vergleichen neue Phänomene entdeckt worden. Die größte Bedeutung hat die Entdeckung der Auswirkungen von Leitfähigkeitsdifferenzen

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in der Lithosphäre in den geomagnetischen Variationen gewonnen. Nach Vorarbeiten, die bis in das Jahr 1907 zurückreichen, war der unmittelbare Anlaß der Austausch der Registrierkurven zwischen den Observatorien Niemegk und Wingst im Jahre 1948. Die damals sensationelle Entdeckung, daß die Baystörung in den Vertikalkomponenten an diesen Observatorien entgegengesetzt gerichtet ist, wurde in Wingst von Otto Meyer und in Niemegk von Horst Wiese im genannten Sinne gedeutet und löste intensive Arbeiten sowohl in der BRD als auch in der DDR aus. Für die erfolgreiche Weiterführung der Tiefensondierungen von Niemegk aus war das Vorhandensein der von Fanselau entwickelten Feldregistrierstationen günstig. In der DDR wurden erstmals planmäßig und umfangreich die Variationsanomalien untersucht in einer Form wie sie später in zahlreichen weiteren Ländern üblich wurde. Später wurden sie von den Niemegker Mitarbeitern in mehreren Ländern in Mittel- und Südosteuropa durchgeführt. Heute sind diese Untersuchungen ein wichtiger Bestandteil der Erforschung der Tiefenstruktur der Erdkruste. Dabei hat sich als sehr zweckmäßig eine äußerst anschauliche Darstellung erwiesen, die von Wiese eingeführt wurde und heute als Parkinson-Wiese-Induktionspfeil bezeichnet wird. Theoretische Untersuchungen zur Deutung der geomagnetischen Tiefensondierungen sind in Niemegk von Wiese, Fanselau u. a. ausgeführt worden. Die Leistungen auf dem Gebiet der geomagnetischen Tiefensondierungen reihen sich würdig in die besten Arbeiten ein, die im Observatorium Potsdam-Seddin-Niemegk durchgeführt worden sind.

Das Observatorium in Potsdam war der Bezugspunkt für die Landesaufnahme von Preußen durch Eschenhagen und Edler von 1898 bis 1903. Es wurde an 265 Punkten gemessen, was dem damals üblichen Punktabstand von 40 bis 50 km entsprach. Diese Aufnahme wurde in vorbildlicher Weise von Schmidt bearbeitet. Das Observatorium in Niemegk war die Basisstation für die sog. Magnetische Reichsaufnahme in den Jahren 1930 bis 1939 unter der Leitung von Bock, Burmeister und Errulat, die auch die Bearbeitung durchgeführt haben. Hierbei wurde angestrebt, möglichst an denselben Meßpunkten

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wie zur Landaufnahme von 1898 bis 1903 zu messen. Gegenüber dieser Aufnahme wurde vor allem die Meßgenauigkeit in Z verbessert.
Das Adolf-Schmidt-Observatorium war auch der Bezugspunkt für die Landesaufnahme der DDR von 1950 bis 1961. Durch den Einsatz der magnetischen Fadenwaagen sowie des Quarzfadenmagnetometers konnten die Meßgenauigkeit beträchtlich erhöht und die Meßgeschwindigkeit vergrößert werden. Der Punktabstand betrug im Mittel 9 km.
Die sehr eingehende Bearbeitung war Ausgangspunkt für wissenschaftliche Untersuchungen zur magnetischen Kartographie. Bei der einheitlichen Bearbeitung aller drei Landesaufnahmen ergaben sich Hinweise auf regionale Anomalien des Säkulargebietes der DDR, die bereits lange vermutet worden waren. Zur Prüfung dessen wurden weitere Säkularpunkte eingerichtet, an denen seit 1965 regelmäßig beobachtet wird.
Eine vierte Landesaufnahme im Gebiet der DDR mit dem Observatorium Niemegk als Hauptbezugspunkt ist z.Z. im Gange.. Hierbei kommen auch die neuen Meßgeräte zum Einsatz, und natürlich werden alle wissenschaftlich-methodischen Erkenntnisse genutzt.

In Verbindung mit den Arbeiten zur magnetischen Landesaufnahme stehen die Untersuchungen zum geomagnetischen Normalfeld, die im Observatorium und Institut ebenfalls Tradition besitzen.
An dieser Stelle sei auch auf die traditionellen Untersuchungen zur Berechnung des geomagnetischen Potentials verwiesen, die von den Potsdamer Wissenschaftlern durchgeführt worden sind. Zu nennen sind hier auch weitere theoretische Untersuchungen zum Hauptfeld und Arbeiten zur geologisch-geophysikalischen Interpretation geophysikalischer Anomalien. Sie stehen nicht unmittelbar mit den Aufgaben des Observatoriums in Verbindung und sollen deshalb hier nicht weiter erläutert werden. Aus dem gleichen Grund sei auch nur kurz auf die umfang- und ergebnisreichen Untersuchungen verwiesen, die im Geomagnetischen Institut in Potsdam auf dem Gebiet des Gesteins- und Paläomagnetismus hauptsächlich in den beiden Jahrzehnten von 1950 bis 1970 durchgeführt worden sind. Paläomagnetische Untersuchungen werden heutein Potsdam mit geologischer Zielstellung durchgeführt.

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4. Schlußbemerkung

Dieser kurze Überblick über die Entwicklung unseres magnetischen Observatoriums und die von den Mitarbeitern des Observatoriums ausgeführten Forschungsarbeiten ist natürlich unvollständig. Mir kam es darauf an, die hohe Kontinuität und die lebenskräftigen Traditionslinien in der wechselvollen Geschichte unserer Forschungsstätte seit ihrer Gründung in Potsdam zu verdeutlichen.

Wir würdigen mit unserem Symposium die Eröffnung des Adolf-Schmidt-Observatoriums in Niemegk vor einem halben Jahrhundert. Damit zollen wir zugleich hohe Anerkennung dem Lebenswerk unseres verehrten Nestors Prof. Dr. Fanselau, der das Observatorium in Niemegk zu dem gemacht hat, was es heute in der Fachwelt bedeutet. Wir müssen dabei stets daran denken, daß der vielversprechende Beginn in der Tätigkeit des Observatoriums in Niemegk durch den faschistischen Krieg bereits nach einigen Jahren beendet wurde und das Erbe des Krieges eine weitgehend zerstörte Forschungseinrichtung war. Dank dem aufopferungsvollen Einsatz einiger weniger Mitarbeiter des Observatoriums, an deren Spitze Gerhard Fanselau stand, gelang es mit Unterstützung der sowjetischen Militärverwaltung und der örtlichen Behörden innerhalb weniger Monate das Observatorium wieder in Gang zu setzen. Und nicht nur das! Nach dem schwierigen Wiederbeginn konnte der Aufbau und Ausbau kontinuierlich fortgesetzt werden. Es wurden neue Mitarbeiter eingesetzt, die Ausrüstungen wurden erweitert, neue Gebäude wurden errichtet. Die Bilanz der seit dem vergangenen 35 Jahre ist gut. Das Jahr 1969 markiert den Beginn einer neuen Etappe in der Entwicklung des Adolf-Schmidt-Observatoriums in Niemegk. In diesem Jahr erfolgten wesentliche organisatorische Maßnahmen im Rahmen der Umgestaltung der Berliner Akademie der Wissenschaften zur Forschungsakademie der sozialistischen Gesellschaft in der DDR. Am 1. Februar 1969 wurde das Zentralinstitut für Physik der Erde gebildet, in dem das Adolf-Schmidt-Observatorium in Niemegk und alle auf die Erforschung des Erdkörpers gerichteten Abteilungen

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des bisherigen Geomagnetischen Instituts aufgegangen sind. Die Abteilung zur Erforschung geomagnetischer Phänomene in den solar-terrestrischen Beziehungen wurde in das zur gleichen Zeit gebildete Zentralinstitut für solar-terrestrische Physik der Akademie eingegliedert. Diese Entscheidung entsprach dem erreichten Stand in der geomagnetischen Forschung selbst und den herangereiften Forderungen nach der komplexen Erforschung des Erdkörpers auf der einen Seite und der solar-terrestrischen Beziehungen andererseits.

Besondere Anstrengungen wurden seitdem unternommen, um das geomagnetische Observatorium auf einem hohen Niveau zu betreiben. Das betrifft vor allem die durchgehende Einführung der elektronischen Datenverarbeitung im Observatorium, wo wir seit einigen Jahren einen auch international beachtlichen Stand erreicht haben. Unser Ziel besteht jetzt vorrangig darin, diese technischen Möglichkeiten in jeder Hinsicht zu nutzen.
Die Entwicklung der geomagnetischen Forschung in den letzten Jahrzehnten zeigt, daß über das phänomenologische Bild des Erdmagnetfeldes hinausgehende Erkenntnisse vor allem bei einer interdisziplinären Erforschung der Ursachen des Erdmagnetfeldes zu erreichen sind.
In der Akademie der Wissenschaften der DDR besitzen wir in Form der beiden genannten Zentralinstitute für Physik der Erde bzw. solar-terrestrischen Physik hierfür gute Voraussetzungen. Damit setzen wir die Traditionen unserer vor etwa einem Jahrhundert gegründeten Vorgängerinstitutionen fort und ergänzen sie durch Arbeiten zur Lösung der aktuellen Fragen der Gegenwart in der DDR.

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ADOLF SCHMIDT

zum 120. Geburtstag

Von G. Fanselau [+)]

Das 50jährige Bestehen des Adolf-Schmidt-Observatoriums ist Anlaß dafür, derer zu gedenken, die mit ihrer Forschungsarbeit die Voraussetzungen für die nachfolgende Entwicklung geschaffen haben. Hier sei vor allem an ADOLF SCHMIDT erinnert, nach dessen Plänen und weitsichtigen Vorbereitungen das Observatorium errichtet wurde, in die die jahrzehntelange Erfahrung dieses großen Gelehrten einfließen konnte. Ihm zu Ehren wurde das Observatorium zu seinem 70. Geburtstag eröffnet, so daß das 50jährige Jubiläum mit seinem 120. Geburtstag zusammenfällt.

ADOLF SCHMIDT wurde am 23. Juli 1860 im damaligen Breslau, dem heutigen Wrocław (VR Polen) geboren. Sein Vater war Ingenieur in einer Fabrik in Breslau. Nach Ablegung der Reifeprüfung an einer Breslauer Oberrealschule bezog er die Universität seiner Vaterstadt, um Mathematik und Physik, aber auch die neueren Sprachen, Englisch und Französisch, zu studieren. Schon mit 22 Jahren promovierte er summa cum laude mit einer mathematischen Dissertation zum Doktor der Philosophie. Er erlangte außerdem die Lehrbefähigung für die Oberstufe an höheren Lehranstalten für Mathematik, Physik, Englisch und Französisch. Nach Abschluß der üblichen Vorbereitungszeit nahm er 1885 am Gymnasium Ernestinum in Gotha seine Tätigkeit als Oberlehrer auf.

[+)] Prof. Dr. phil.habil. GERHARD FANSELAU, Zentralinstitut für Physik der Erde der Akademie der Wissenschaften der DDR, 15 Potsdam, Telegrafenberg.

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War der junge Student schon während des 1. Internationalen Polarjahres 1882/83 mit der geophysikalischen Wissenschaft in Berührung gekommen, als er sich an der Auswertung geomagnetischen Beobachtungsmaterials beteiligte, so bot sich ihm in Gotha willkommene Gelegenheit, diese Studien fortzusetzen. Nicht zuletzt trug die Verlagsanstalt von Justus Perthes dazu bei, sein Interesse an den Geowissenschaften zu vertiefen und ihn zu selbständiger Forschungsarbeit, besonders auf dem Gebiet des Geomagnetismus, anzuregen. So entstanden in Gotha zwei seiner wichtigsten Arbeiten, die sich mit der Neuberechnung des geomagnetischen Potentials zur Epoche 1885 [1], [2] befaßten. Diese heute noch grundlegenden Veröffentlichungen trugen wesentlich zur Steigerung seines internationalen Ansehens bei und hatten zur Folge, daß er eine Einladung zur Teilnahme an der "International Conference on Terrestrial Magnetism and Atmospheric Electricity of the British Association for the Advancement of Science" im Jahre 1898 in Bristol erhielt. Diesen wichtigen Forschungsergebnissen verdankt er auch seine vorzeitige Ernennung zum Professor.

Sein internationaler Ruf hatte sich während seiner Gothaer Jahre so gefestigt, daß er 1902 zum Leiter des Geomagnetischen Observatoriums in Potsdam berufen wurde. Dort trat er die Nachfolge von Eschenhagen an, der das Magnetische Observatorium im Jahre 1889, also vor mehr als 90 Jahren, gegründet hatte. Es galt, manche Rückstände aufzuarbeiten und das gewonnene Beobachtungsmaterial statistisch und theoretisch auszuwerten.

Auch auf dem instrumentell-technischen Gebiet sah sich ADOLF SCHMIDT wichtigen Aufgaben gegenüber, die er in vollkommener Weise löste. In Potsdam entwickelte sich der bisher als hervorragender Theoretiker bekannte Forscher zum bedeutenden und recht geschickten Experimentator. Es seien hier nur zwei seiner wichtigsten experimentellen Forschungsarbeiten erwähnt, die Schmidtsche Methode zur Bestimmung der Parameter von Magneten [3] und die Konstruktion der geomagnetischen Feldwaage [4], die es dem Praktiker ermöglicht, die geomagnetischen Methoden in der Lagerstättenkunde erfolgreich einzusetzen. Im Jahre 1907 wurde er zum Honorarprofessor mit einem Lehrauftrag für Geophysik an der Berliner Universität ernannt. Leider zerschlug sich durch den 1. Weltkrieg die Berufung auf einen Lehrstuhl für Geophysik. Alle Pläne zur Errichtung eines Geophysikalischen Instituts an der Berliner Universität wurden zunichte gemacht und konnten auch in den Nachkriegsjahren nicht realisiert werden.

Auf Grund seiner hervorragenden Leistungen wurde ADOLF SCHMIDT eine große Zahl von Ehrungen zuteil: Er wurde Ehrenmitglied der Deutschen Geophysikalischen Gesellschaft sowie Mitglied der wissenschaftlichen Akademien in Berlin, Göttingen und Christiania, dem heutigen Oslo. Die Technische Hochschule in Berlin-Charlottenburg hatte ihm die Würde eines Dr.-Ing. e.h. verliehen. Außerdem erhielt er mehrere Orden und Ehrenzeichen.

Kurz vor seinem Übertritt in den Ruhestand am 1. Oktober 1928 hatte Geheimrat SCHMIDT noch eine wichtige Aufgabe zu erfüllen, nämlich die Verlegung des gesamten geomagnetischen Beobachtungsdienstes von Potsdam nach Niemegk. Die Elektrifizierung der Berliner Vorortbahn mit 800 V Gleichstrom hatte so starke vagabundierende Erdströme zur Folge, daß der magnetische Störpegel in Potsdam erheblich anstieg und Präzisionsmessungen völlig ausschloß. Auf seine Anregung hin wurde für das neue Observatorium ein Platz in der Nähe des Städtchens Niemegk am Fuße des Flämings gewählt, wo das nach ihm benannte und heute über 50 Jahre bestehende Adolf-Schmidt-Observatorium für Erdmagnetismus errichtet wurde.

Noch 16 Jahre seines Ruhestandes verbrachte ADOLF SCHMIDT zusammen mit Geschwistern im Kreise seiner alten Freunde in Gotha. Sein Lebensabend wurde durch die turbulenten Jahre vor und während des 2. Weltkrieges getrübt; er hatte sich von den politischen Zielen dieser Zeit distanziert und dafür manche Unannehmlichkeiten erfahren. Am 17. Oktober 1944 starb ADOLF SCHMIDT in Gotha und wurde dort beigesetzt.

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Drei Eigenschaften bestimmten Adolf Schmidts Leben: Klugheit, Bescheidenheit und Aufrichtigkeit. Seine Klugheit machte ihm das Leben leicht, während die beiden letztgenannten Eigenschaften ihm manche Nachteile brachten. Seine universelle Begabung und sein großes Interesse für das Geistesschaffen der Menschheit ließen ihn nicht nur auf dem Sektor der Mathematik und Naturwissenschaften, sondern auch auf dem Gebiet der Sprachen tätig sein. Lebhaft war er an den klassischen und slawischen Sprachen sowie an Esperanto interessiert. Auch auf dem Gebiet der Philosophie, ja sogar der Musikwissenschaft - "Zur zahlenmäßigen Darstellung der musikalischen Intervalle" - hat sein reger Geist wichtige Ergebnisse erarbeitet.

Mögen sein rastloser Fleiß und sein nie ermüdender Eifer, seine Klugheit und sein Wissen für die Geophysiker ein leuchtendes Beispiel für alle Zeiten bleiben. Sein ehrenwerter Charakter macht ihn zum Vorbild für die jüngere Generation. Es ist kaum möglich, über ADOLF SCHMIDTs Leben ein besseres Motiv zu setzen als den Spruch, den er bei der Einweihung des Adolf-Schmidt-Observatoriums in Niemegk am 23. Juli 1930 an seinem 70. Geburtstag in das Gästebuch eintrug:

"Stets vortrefflich zu sein und hervor sich zu tun vor
den anderen" .

Ἀιὲν ᾽αριστεύειν καὶ ῾υπείροχον ᾽έμμεναι αλλων.

DOI: https://doi.org/10.2312/zipe.1981.070.01

Literatur

[1] SCHMIDT, A.: Mathematische Entwicklungen zur allgemeinen Theorie des Erdmagnetismus.
Arch. Seewarte 12, 29 (1889).

[2] SCHMIDT, A.: Der magnetische Zustand der Erde zur Epoche 1895,0 analytisch dargestellt.
Arch. Seewarte 21, 72 (1898).

[3] SCHMIDT, A.: Über die gegenseitige Einwirkung zweier Magnete in beliebiger Lage.
Terr. Mag. 17, 181 (1912); 18, 65 (1913).

[4] SCHMIDT, A.: Ein Lokalvariometer für die Vertikalintensität.
Preuß. Met. Inst. Berlin, Tätigkeitsbericht 1914, Veröff. Nr. 283, 109, ebenda 1915, Veröff. 290, 87.

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AUSTER, V., LENGNING, K., MUNDT, W., SCHMIDT, H.

Die ständigen Beobachtungen des magnetischen Feldes der Erde, dargestellt an den Tätigkeiten des Adolf-Schmidt-Observatoriums (gekürzte Fassung)

In den letzten drei Jahrzehnten ist eine Veränderung in der Grundaufgabenstellung der geomagnetischen Observatorien zu verzeichnen gewesen. Wie bisher werden zwar Messungen und Registrierungen der zeitlichen Änderung des Vektors des geomagnetischen Feldes an einem Ort für das gesamte Periodenspektrum durchgeführt, jedoch ist die Bedeutung derartiger Meßergebnisse nicht mehr als regional aufzufassen. So genügt z. B. als Bezugspunkt für geomagnetische Messungen im Rahmen der angewandten Geophysik für das gesamte Gebiet der DDR nicht mehr ein zentral gelegenes Observatorium, da neben der regionalen auch die lokale Struktur des geomagnetischen Variationsfeldes zu berücksichtigen ist (magneto-tellurischer Effekt, lokale Anomalien der Säkularvariation). Damit verbunden führt heute die Notwendigkeit, auch in der allgemeinen geomagnetischen Forschung neben der regionalen verstärkt auch die lokale Struktur des Variationsfeldes zu untersuchen zu einer Annäherung der gerätetechnischen und methodischen Entwicklungen dieses Spezialgebietes und der Magnetik in der angewandten Geophysik.

Dieser Tendenz Rechnung tragend wurde und wird in der DDR versucht, Geräteentwicklungen mit Systemcharakter durchzuführen. Dabei werden stets die folgenden Gerätevarianten nach der jeweiligen Spezialanwendung unterschieden:

a) Stationsbetrieb
b) Außenstationseinsatz
c) Geländeanwendung
d) erschwerte Einsatzbedingungen (Antarktis, submarin).

Weitere Kennzeichen der Gerätesysteme sind ferner die Grenzempfindlichkeit, der Periodenbereich sowie die Form der Ausgangsdaten. Ausgehend hiervon versteht man gegenwärtig unter einem geomagnetischen Observatorium etwa eine Meßstation, die mehrere Meßsysteme für das gesamte Periodenspektrum der geomagnetischen Variationen umfaßt und über die Möglichkeit verfügt,

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die Primärauswertung off-line oder on-line mit entsprechenden Rechenautomaten vorzunehmen. Bei den feldeinsatzfähigen Einzelsystemen für einen speziellen eingeschränkten Periodenbereich mit besonderer Aufgabenstellung verzichtet man allgemein doch noch auf eine Primärauswertung und begnügt sich mit einer analogen oder digitalen Registrierung der Meßdaten.

Der gegenwärtige Stand der gerätetechnischen Observatoriumsausrüstung (Niemegk) besteht aus einer Mischung sogenannter klassischer geomagnetischer Geräte und moderneren Meßgeräten. In der Entwicklungs- und Erprobungsphase befinden sich neue Gerätesysteme: für den lang- und mittelperiodischen Bereich ein Protonenmagnetometer mit Zusatz zur Komponentenmessung und für den mittel- und kurzperiodischen Bereich eine spezielle Form des Ferrosonden - Magnetometers. Für den kurzperiodischen Bereich wird auch noch eine Entwicklung für ein Induktionsstab - Variometer weitergeführt. Dies wird besonders dann wichtig, wenn man den allgemeinen Trend zu einer Erweiterung des kurzperiodischen Gebietes unter 0,1 s berücksichtigen will.
Für die geomagnetischen Absolutmessungen (langperiodischer Bereich) wurde ein Universaltheodolit mit Protonenmagnetometermeßeinrichtung entwickelt. Als Zusatzfeldspule findet eine speziell berechnete und nach einer besonderen Technologie gefertigte Zylinderspule Verwendung. Diese ist mit einer entsprechend präzise gefertigten mechanischen Anordnung um ihre eigene Achse und um eine senkrecht dazu angeordnete drehbar gelagert. Ferner kann die Spulenachse durch entsprechend justierte Fernrohre parallel zu einer geodätisch bestimmten Richtung orientiert werden. Das Gerät gestattet Messungen der Komponenten F, Z, Y, aus denen sich alle anderen üblichen Komponentensätze berechnen lassen. Es wird eine Genauigkeit bei der Absolutmessung von 1 nT erreicht. Das Gerät hat wie ein normales Protonenmagnetometer digitale Datenanzeige und ist im Gelände einsetzbar. Aus Gründen der Meßmethodik ist ein Beobachter erforderlich. Um den Geländeeinsatz universeller gestalten zu können, kann das Gerät in Kombination mit einem Kreiselkompaß eingesetzt werden.

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Für den Bereich mittlerer Perioden wurde ein auf dem Protonenmagnetometer basierendes Variometersystem entwickelt, das eine mechanisch vereinfachte Variante des beschriebenen Universaltheodoliten darstellt. Die Meßwerte der zeitlichen Variation für F, Z, Y können automatisch direkt im Minutenrhythmus registriert und digital z. B. auf Lochstreifen gespeichert werden. Das Gerät ist im Gelände einsetzbar in Verbindung mit einer speziellen fotografischen Registriereinrichtung. Aus dem Gesamtsystem sind ferner Geräte zur Messung von F im Gelände mit 0,1 nT Empfindlichkeit und geringer Leistungsaufnahme hervorgegangen. In der Entwicklung befinden sich noch spezielle Versionen zur Messung in inhomogenen Feldern und für marine Anwendung. Für den kurz- und mittelperiodischen Bereich wurde ein Dreikomponenten - Ferrosondenmagnetometer entwickelt, das eine Empfindlichkeit von 0,5 nT aufweist. Diese kann durch magnetostatische Flußverstärkung (Munipermstäbe von 0,5 m Länge) noch um eine Größenordnung gesteigert werden. Die Registrierung der kurzperiodischen geomagnetischen Variationen erfolgt dann über elektronische Differenzierverstärker. Dieses Gerätesystem, das durch geringe Abmessungen und geringe elektrische Leistungsaufnahme gekennzeichnet ist , wurde besonders in Hinsicht auf Geländemessungen und Sonderanwendungen entwickelt.

Aus der Analyse des internationalen Trends kann abgeleitet werden, daß die Entwicklung der geomagnetischen Observatoriumsmeßtechnik in der DDR durchaus positiv zu beurteilen ist und daß teilweise neue Wege mit Erfolg beschritten wurden. Die Einführung der modernen Meßmethoden und Geräte in den Routinedienst der Observatorien geht im allgemeinen weitaus langsamer vor sich, als das bei der Magnetik der angewandten Geophysik der Fall ist. Hierbei spielen Befürchtungen, langjährige solide Meßreihen durch den unbedachten Einsatz neuer Geräte zu verschlechtern, und zweifellos auch subjektive Gründe die Hauptrolle. Als Übergangslösung wird allgemein ein längerer Parallelbetrieb alter und neuer Meßgeräte angestrebt. Der Schwerpunkt der bei uns betriebenen Geräteentwicklungen wird in der Perspektive zunächst wie oben beschrieben erhalten bleiben. Die Bemühungen werden weiter konzentriert auf eine fachspezifisch gegründete Konzeption

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der Gerätesysteme, die Erarbeitung der erforderlichen physikalischen Grundlagen sowie auf die Aneignung bestimmter Herstellungstechnologien. Überlegungen zur weiteren Erhöhung der Meßempfindlichkeit im Rahmen der geomagnetischen Messungen werden gegenwärtig zurückzustellen sein zugunsten der Interpretation und feineren Modellierung für die Prozesse, die Quellen für die bereits beobachtbaren Effekte sind. Der Bau von Geräten und Kleinserien wird auch zukünftig auf Institutsebene selbst durchzuführen sein, soweit es sich um die spezielle geomagnetische Meßtechnik handelt. Bei Fragen der Datenregistrierung, Speicherung, Primärverarbeitung und automatischer Überwachung, die zweifellos technische Probleme aller geophysikalischen Fachrichtungen sind, bestehen noch Reserven durch eine bessere Zusammenarbeit der einzelnen Institute untereinander oder auch im Idealfall mit der einschlägigen volkseigenen Industrie.

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Regionale und lokale Anomalien der geomagnetischen Säkularvariation in Mitteleuropa

Regional and local anomalies of the geomagnetic secular variation in Central Europe

von W. MUNDT [x]

Zusammenfassung

Auf der Grundlage von Säkularvariationsdaten europäischer Observatorien und Säkularpunkten der DDR wurden großregionale und lokale Anomalien der Säkularvariation abgeleitet. Als Methode dient die Approximation der Datenverteilung mittels Polynomen verschiedener Ordnung. Eine quellenmäßige Deutung der Anomalien steht noch aus. Korrelationen zu Wärmeflußanomalien und rezenten horizontalen Krustenbewegungen im lokalen Bereich sowie zu einer Mantelleitfähigkeitsanomalie im großregionalen Bereich deuten sich an.

Summary

On the basis of secular variation data of European observatories and at repeat stations on the territory of the GDR regional and local anomalies of the secular variation have been calculated. For this purpose the data were approximated by polynomials of different degree. An interpretation of the physical sources of these anomalies has not yet been done. There seam to be relationships to heat flow anomalies and recent horizontal crustal movements in the local area as well as to electrical conductivity anomalies situated in the upper mantle, in the continental area.

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Резюме

На основе данных вековых вариаций европейских обсерваторий и повторительных точек в ГДР были вычислены региональные и локальные аномалии вековой вариации. Приближение данных с помощью полиномов разных порядков служило методом для этого. Интерпретация физических источников этих аномалий еще не осуществлена. Существуют, по-видимому, отношения к аномалиям теплового потока и современным горизонтальным движениям земной коры в локальной области как и к аномалиям проводимости мантии в континентальной области.

1. Introduction

The geomagnetic field is characterized by its space-time structure. The space structure of the field of the inner sources is world-wide well known as a result of magnetic land surveys and aeromagnetic measurements over land and sea or by ship or satellite measurements. Compared to it the registration of the time structure of the magnetic field requires much more observations because of the 12 orders of magnitude (10^{-2}-10^{10}s) of the magnetic time spectrum. These observations are carried out mainly at the magnetic observations and to a smaller part at the repeat stations of the different countries.

For analyzing continental and large-regional structures a dense network of magnetic observatories with uniform data series for some decades of years are necessary. It is a supposition that these data are of high accuraca with only small variations in the accuracy. For analyzing regional and local anomalies one needs additionally a network of stabilized repeat stations or secular variation profiles with accurate data for longer time intervals. Measurements of different time epochs at identical stations of magnetic surveys can be used, too. These conditions are fulfilled for Europe in a large-regional scale while for the territory of the GDR in a local scale.

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2. Methods of analyses

In order to describe the large-regional structures of the secular variation in Europe as well as the regional and local anomalies on the territory of the GDR polynomials of different degrees in the following form were used:

$$E(\Delta\varphi, \Delta\lambda) = \sum_{i=0}^{\nu} \sum_{j=0}^{i} a_{i-j,j} (\Delta\varphi)^{i-j} (\Delta\lambda)^{j} \tag{1}$$

The corresponding coefficients $a_{i-j,j}$ are calculated by least squares fitting to the observed data Em.

$$Q = \sum_{m=1}^{N} \left[E_m - \sum_{i=0}^{\nu} \sum_{j=0}^{i} a_{i-j,j} (\Delta\varphi)_m^{i-j} (\Delta\lambda)_m^{j} \right]^2 \longrightarrow Min. \tag{2}$$

$\Delta\varphi, \Delta\lambda$ denote the coordinate differences as referred to a central point, E_m stands for the secular variation at the observatories or stations and δE_m denotes the errors of observation.

By calculating the differences

$$\Delta E_m = E_m - E \tag{3}$$

the following conclusions can be drawn:

$0 \leq \Delta E_m \leq \delta E_m$: Complete description of the local structure of the secular variation by polynomials of corresponding degree.

$\Delta E_m > \delta E_m$: Significant secular variation anomalies.

At first one has to look for the complete approximation of the observation data. After that the normal trend of the SV has to be defined by calculating polynomials of decreasing degree.

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3. Observation data

With the above-mentioned method, the observatory data in Europe as well as the SV-data in the territory of the GDR have been analyzed: From a statistical analysis of the shortperiodic variations of the annual means at the European observatories it follows that five-year averages of the secular variation are sufficient [1]. For that purpose the correlation coefficients for the annual means at the European observatories in respect to the Niemegk Observatory have been calculated.
The high correlation of these variations refered to a "westdrift-trend" in the Central European area indicates that they have low amplitude levels and do not show any irregular regional distribution.
As a result of this analysis the adjustments were based on five-year averages for the declination D, the horizontal intensity H, the vertical intensity Z and the total intensity T, respectively, at 44 European observatories for the 5 epochs 1952,5; 1957,5; 1962,5; 1967,5 and 1972,5.

For the territory of the GDR, three magnetic land surveys are available for the epochs 1901, 1935 and 1957. For supplementing these data, the declination D and the horizontal intensity H at 50 stations of the 1957 survey have been re-measured for the 1976 epoch [6].
These data had the highest weights at the analyses.
Altogether a network with an average point-to-point distance of about 40 - 50 km was available. However, the real basis for the investigation of the local structure of the secular variation in the territory of the GDR is formed by the network of 11 repeat stations with the Niemegk observatory as a central point.

4. Results

For the European data the analysis of the differences from a polynomial of degree 3 led to the results shown in Table 1. From this table it is observed that the mean differences are definitely within the error range for

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the annual mean values which must be assumed for most of the magnetic observatories in Europe. After that the magnetic secular variation can be completely described by a polynomial of degree 3.

Table 1

Differences E_m relative to a 3 rd degree polynomial

Element or component	Mean Differences E_m	Dispersion
D	$\pm$ 0,2' a^{-1}	$\pm$ 0,1 to $\pm$ 0,4' a^{-1}
H	$\pm$ 2 nTa^{-1}	$\pm$ 1 to $\pm$ 5 nTa^{-1}
Z	$\pm$ 2 nTa^{-1}	$\pm$ 1 to $\pm$ 4 nTa^{-1}
T	$\pm$ 1 nTa^{-1}	$\pm$ 0,1 to $\pm$ 4 nTa^{-1}

Nevertheless, the regional distribution of the differences is interesting. Because of the low significance of the individual differences, this analysis was carried out in a qualitative form [5]. Fig. 1 shows as an example the result for the declination. White circles indicate a prevalence of the positive sign at the respective station, while shaded circles indicate a prevalence of negative differences. Large circles indicate a uniform positive or negative sign for the 3 epochs, while small circles indicate a ratio of 2 : 1 of the positive to negative signs.
From the map it can be observed that the Central European region is characterized by a prevalence of positive "anomalies" of the secular variation. This is the case for T, H and Z, too.

This result will be found much more clearly in the differences in respect of a 1st degree polynomial. These differences are, in most cases, greater than the errors of the annual mean values [2]. Furthermore, the differences show a local constancy in each component for the 5 time epochs. The boundary zone of the large-regional secular variation anomaly is

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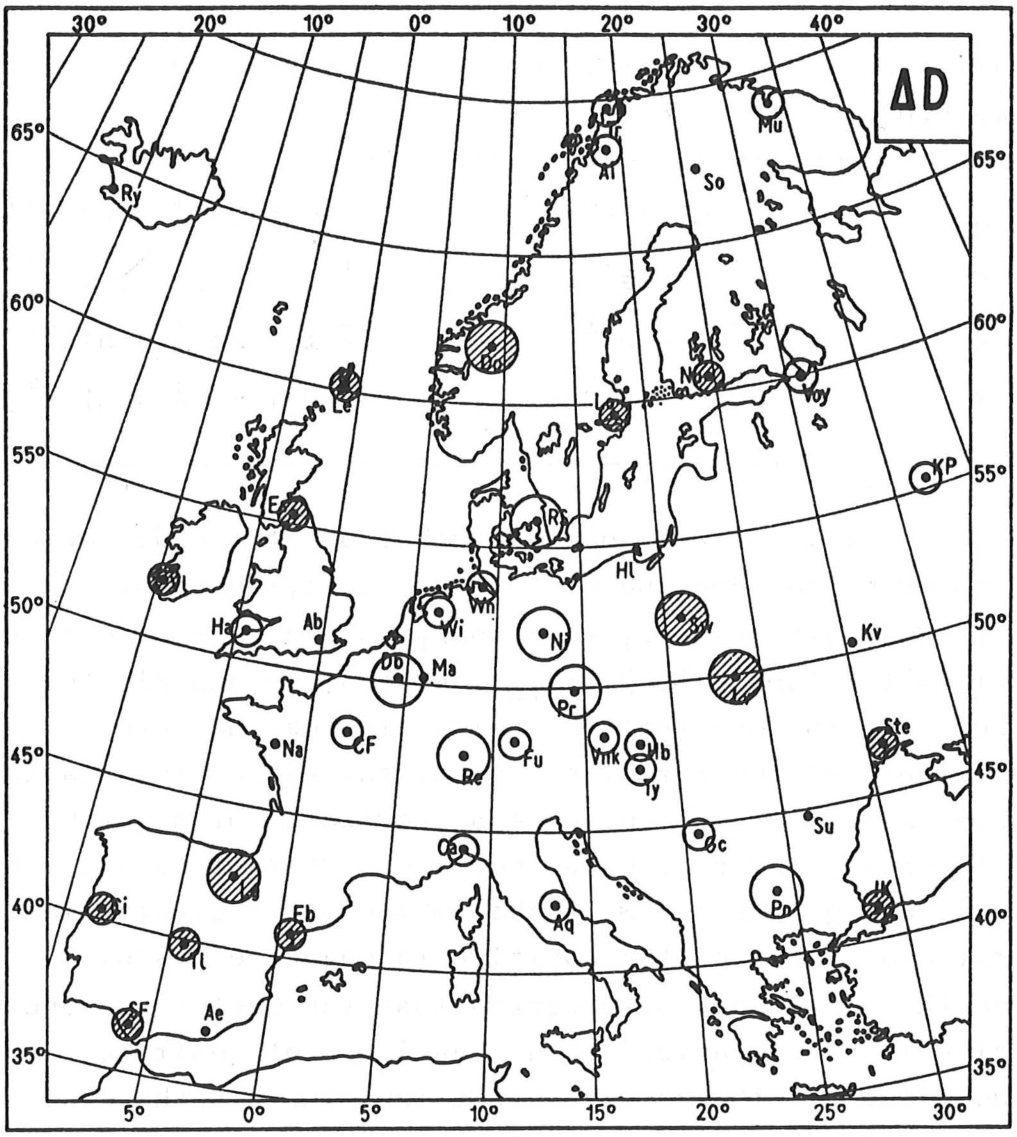

Fig. 1

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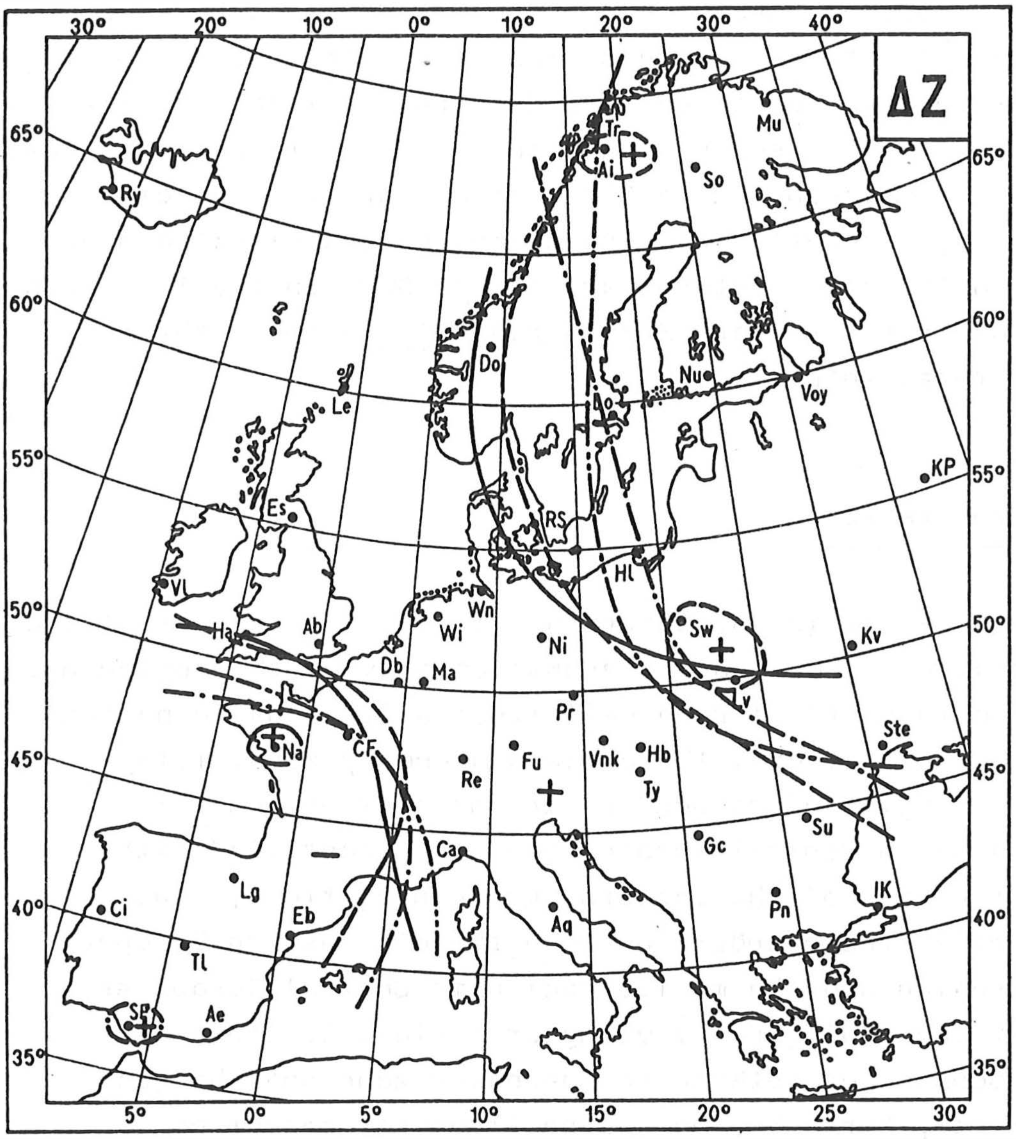

Fig. 2 δ(ΔZ) for epoch ———— 1952.5

– – – – – 1957.5

–··–··– 1962.5

–·–·–·– 1967.5

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observed, however, most clearly in the Z-component [2]. A corresponding analysis of IGRF-data for the 1965 epoch also shows negative anomalies of secular variation in the eastern and western part of Europe and positive data in Central Europe [3].
On the territory of the GDR three local anomalies of the secular variation have been found in D, H and T. Because of the great importance of the normal trends for the calculation of anomalies, two different trends were utilized. The first trend is a 1st degree approximation of the data at the repeat stations, the second one a 3rd degree approximation of the surrounding observatories. The anomalies are situated near Usedom in the northeastern part of the GDR, in the Thuringian basin and in the western Erzgebirge. Fig. 3 shows the anomalies for the total intensity.

5. Interpretation

Up to now we are in the interpretation of the sources of the large-regional and local SV-anomalies only at the beginning. There are in particular no definite results conserning the depths of the sources. The eastern boundary zone, lying between a region of reduced SV in the east and one of enhanced SV in Central Europe, could be identified with the west border of the Eastern European platform, thus representing the boundary between the old Eastern European stable region and the mobile region in Central Europe as a range of the geologically young orogenies. If there is a causal connection between the boundary zone and the geotectonically North Sea-Dobrudsha lineament cannot be decided exactly up to now.

For the interpretation, there are different possibilities:

a) The sources are situated in the uppermost parts of the Earth crust, where the tectonic processes are taking place.

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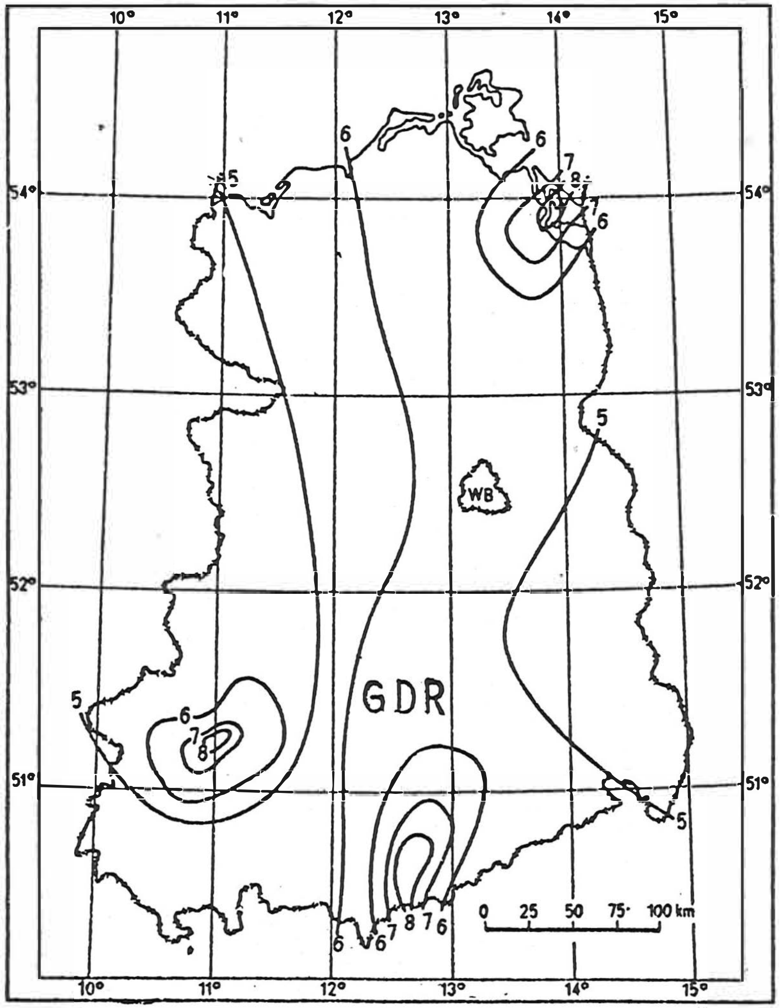

Fig. 3 Secular variation anomalies $\delta\Delta F$ [nT yr^{-1}]
Trend: 3. degree polynomial (European observatories)

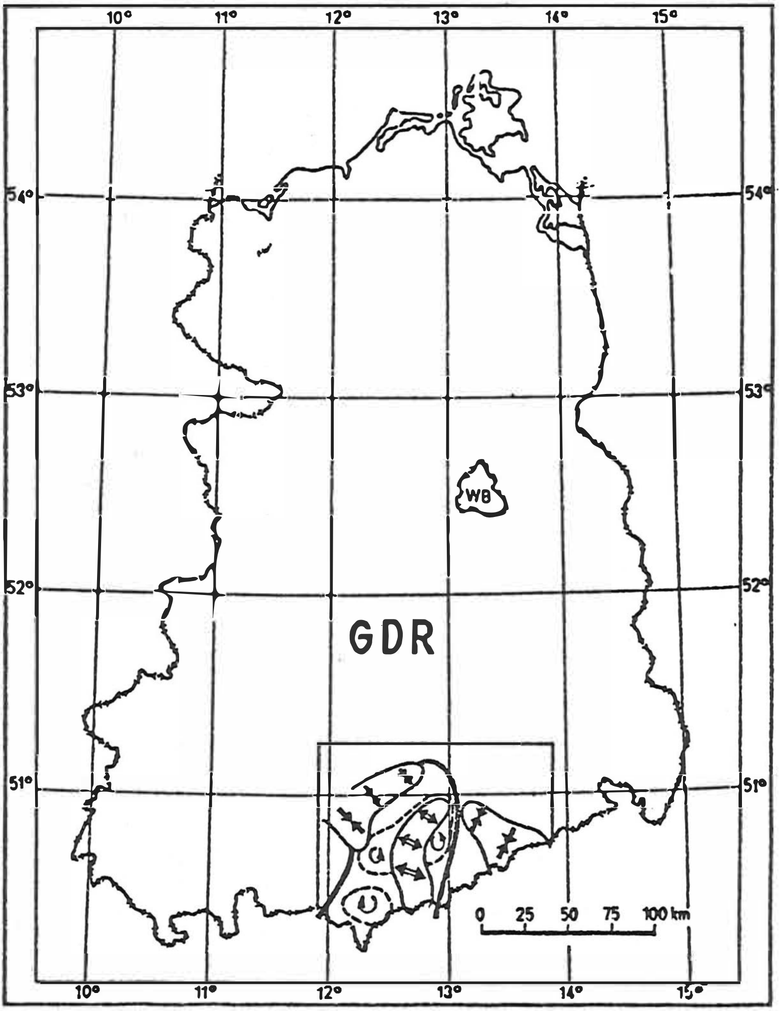

Fig. 4 Main strain and component of rotation in the area of secular-variation anomaly (after Thurm)
⟺ extension, →← compression, ↻ rotation

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b) If one takes into account the aspects of plate tectonics, the sources of the SV-anomalies could reach up to the lowest boundary of the lithosperic plates.

c) In a paper of Mundt and Porstendorfer [4] there was shown the possibility of interpreting these anomalies by a rising of high conducting material of the earth mantle from deeper than 2000 km up to about 500 km.

A complete interpretation of the local SV-anomalies in the territory of the GDR is impossible, too, but some interesting correlations with other geodetic and geophysical phenomena can be described. Especially a comparison of the SV-anomaly map with the maps of heat flow and recent movements of the earth crust shows interesting correspondences. It is observed that obviously positive anomalies of the SV for T are correlated with positive anomalies of the heat flow, even if all of the possible inaccuracies are taken into account. Concerning the recent horizontal crustal movements, we have a lot of information for the SV-anomaly in the western Erzgebirge. Fig. 4 shows the movements in a great detail. Extension is found to occur throughout the core of the anomaly, whereas compression zones are encountered at the north-west and east boundaries. Moreover, rotational movements occur in the region of the anomaly. That's why magnetomechanic phenomena could play a role.
If this assumption in true, this single SV-anomaly has been found only randomly because of the block structure of the recent crustal movements in the southern part of the GDR. (Fig. 5) In several cases the boundaries coincide with geological fault zones, where obviously a higher mobility has been preserved due to the reversals of movement directions occuring there (Elbe zone, Central Saxonian lineament, Flöha zone, Vogtland cross zone).

For analyzing this problem, secular variation profiles were established. The first profile along which measurements were carried out for the first time in 1978, extends in an NE-SW-direction in the southernmost part of the GDR. It is

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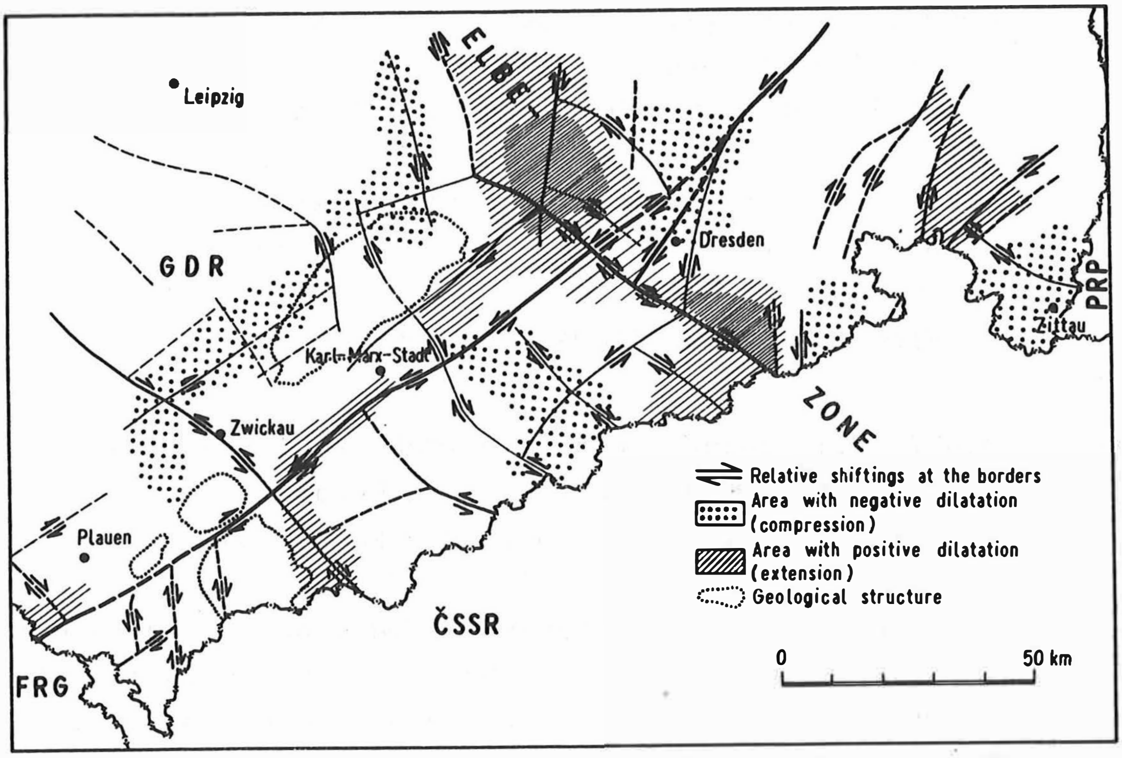

Fig. 5 Recent horizontal crustal movements, southern part of GDR (after P. and E. BANKWITZ)

about 170 km long, crossing the alreading discussed structures almost normally. The average point-to-point distance is 10 km. In both years the measurements were carried out in October. From the differences of the T-values for 1978 and 1979, $\Delta T = T_{79} - T_{78}$ [nTa^{-1}], one observes some interesting features in the secular variation at the profile. Negative peaks seem to be correlated with tectonic boundaries of areas with different amounts of recent horizontal crustal movements. However, the exact determination of the anomalies will be possible only after several years. Even using precise instruments as proton magnetometers, the geomagnetic secular variation remains a longterm phenomenon.

DOI: https://doi.org/10.2312/zipe.1981.070.01

References:

[1] MUNDT, W.: Analyse der magnetischen Säkularvariation in Europa
Gerl. Beitr. Geophysik 81 (1972) 240 - 250

[2] MUNDT, W.: Der Charakter der geomagnetischen Säkularvariation in Europa im Zeitraum von 1950 - 1970
Veröff. ZIPE 23 (1973) 1 - 22

[3] MUNDT, W.: Comparison of the IGRF Secular Variation with Observatory Data in Europe
Gerl. Beitr. Geoph. 86 (1977) 227 - 234

[4] MUNDT, W. u. G. PORSTENDORFER: Mögliche Zusammenhänge zwischen einer elektrischen Leitfähigkeitsanomalie im Erdmantel und anomalen magnetischen Säkularvariationen in Mitteleuropa
Geod. u. Geophys. Veröff. des NKGG, Reihe III (i. Druck)

[5] MUNDT, W.: On the analytical representation of the magnetic secular variation in Europe on the basis of observatory data
Gerl. Beitr. Geoph. 89 (1980), 129 - 134

[6] WOLTER, H.: Ergebnisse der Vermessung von D und H an 50 Säkularpunkten im Gebiet der DDR
Unveroffentlichter Bericht 1977

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THE INVESTIGATION OF REGIONAL MAGNETIC ANOMALIES IN THE SOUTH-WEST OF THE EAST-EUROPEAN PLATFORM

SUMMARY

The regional component of the anomalous magnetic field in the south-west of the East-European Platform was obtained by intagral smoothing with a radius of about 50 km. The regional magnetic anomalies are due mainly to the following causes: 1) the rocks magnetized all over the custal thickness, 2) variation of the crustal thickness and genetically connected lateral variation in the lower crust magnetization.

РЕЗЮМЕ

Региональная компонента аномального магнитного поля юго-западной части Восточно-Европейской платформы получена путем интегрального сглаживания с радиусом 50 км. Региональные магнитные аномалии обусловлены главным образом следующими причинами: I) породами, намагниченными во всем разрезе земной коры и 2) изменением мощности коры и генетически связанным с ним изменением намагниченности нижней части коры по латерали.

ZUSAMMENFASSUNG

Die regionale Komponente des anomalen Magnetfeldes des südwestlichen Teils der Osteuropäischen Tafel wurde durch Integralglättung mit dem Radius 50 km erhalten. Die regionalen magnetischen Anomalien werden hauptsächlich durch folgende Ursachen bedingt: 1. durch die Gesteine, die im ganzen Erdkrustenschnitt magnetisiert sind, 2. durch die Veränderung der Stärke der Erdkruste und der damit genetisch verbundenen Veränderung der Magnetisierung des unteren Teils der Erdkruste in lateraler Richtung.

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The spectral and correlation analyses of the anomalous magnetic field in the south-west of the East-European Platform have shown that the field is composed of, at least, two components - the local and regional one - with wavelengthes ranging from a few kilometers to a hundreds kilometers, respectively. It is the regional component that is studied here.

The area considered includes the following tectonic units (Fig.I): the western part of the Ukrainian Shield, Volyn-Podolsk Plate, Podlyask-Brest Depression, Pripyat Trough, Byelorussian Anteclise and Baltic Syneclise. The regions listed differ in the Precambrian basement depth which is dozens of meters under the shield, 0.3-0.9 km in the plate, 0.7-3.5 km in the depression, I.0-4.5 km in the trough, a few hundreds of meters in the anteclise and I.0-2.0 km in the syneclise. Since it is the Precambrian formations that are responsible for the supressed local anomalies, the variation of the depth to the Precambrian basement complicates significantly the separating of the regional component.

We believe that the best method of recognizing the regional anomalies is the field reduction technique involving a succesive substraction of the local source effects. However, the application of this technique in the region in consideration encounters many difficulties since, here, the basement geology and magnetic properties of the basement composing rocks are generally poorly studied. In this connection, in separating the regional anomalies we adopt the following approach.

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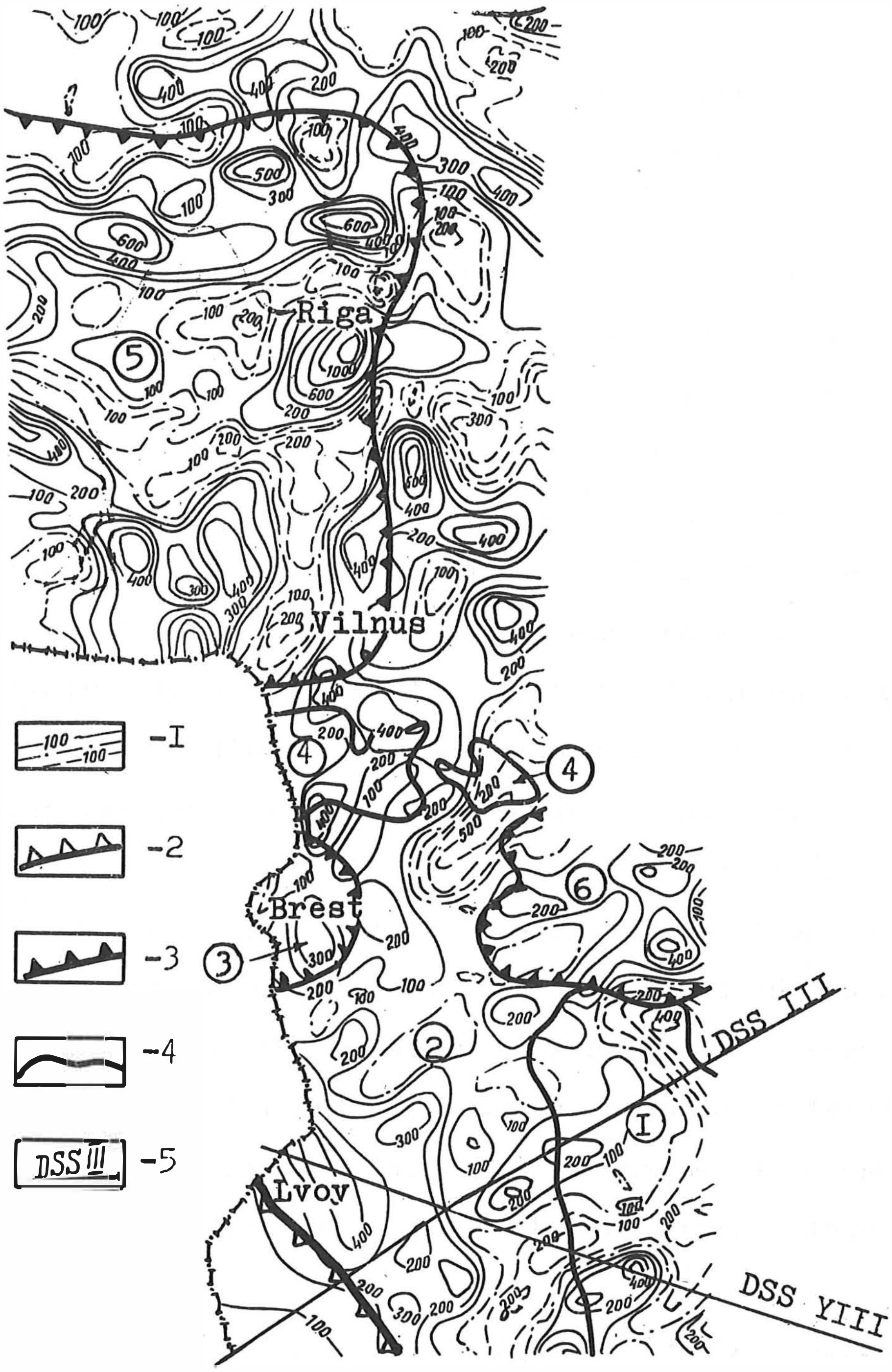

Fig. 1 Regional component of the magnetic anomaly field in the southwest of the East-European Platform obtained by integral smoothing

I - isolines $(\Delta T)_a$, nanoteslas
2 - border of the East-European Platform
3 - borders of depressions and troughs
4 - borders of Ukrainian Shield and Byelorussian Anteclise
5 - DSS lines

Circled numbers are tectonic elements:

I - Ukrainian Shield	4 - Byelorussian Anteclise
2 - Volyn-Podolsk Plate	5 - Baltic Syneclise
3 - Podlyassk-Brest Depression	6 - Prypyat Trough

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It is concluded from the joint analyses of the observed magnetic field, geologic and deep structure data and the previous results the regional anomaly interpretation in the Ukrainian Shield (Krutikhovskaya, Pashkevich, I979) that the sources of regional anomalies can be distributed over the etire crust, practically, from the basement surface to the Moho discontinuity. Magnetic inhomogeneities in the lower crust of a high magnetization (4 - 6 Axm^{-I}) can produce regional anomalies of wavelengths more than I00 km.

Proceeding from this conclusion and taking into account possible dimensions of regional anomalies, a filter is built with a weight function corresponding to this kind of the source distribution. The filter provides integral parabolic smoothing with a radius of about 50 km. With the aid of such filter we have obtained regional magnetic component over the territory studied (Fig.I).

Furthermore, a smoothing of various modifications and upward continuation of the field have been tested. Comparison of these results with the separated regional anomalies shows that the latter are close to the anomalies obtained by means of the integral parabolic smoothing. In the course of comparing, it is established that, strictly speeking, each regional anomaly should be separated with different smoothing radius.

Therefore, at the present stage of study, the ascertaining of the nature of regional anomalies using the same filter parameters yields only qualitative results. The quantitative interpretation of regional anomalies will make the next stage of our studies.

The method of an elimination of the effect of the upper crust horizons (to a depth of I0 km) is applied to DSS lines III (Fig.2) and YIII with the aime of obtaining the evidence on the existence of the regional magnetic component and estimating its intensity. For

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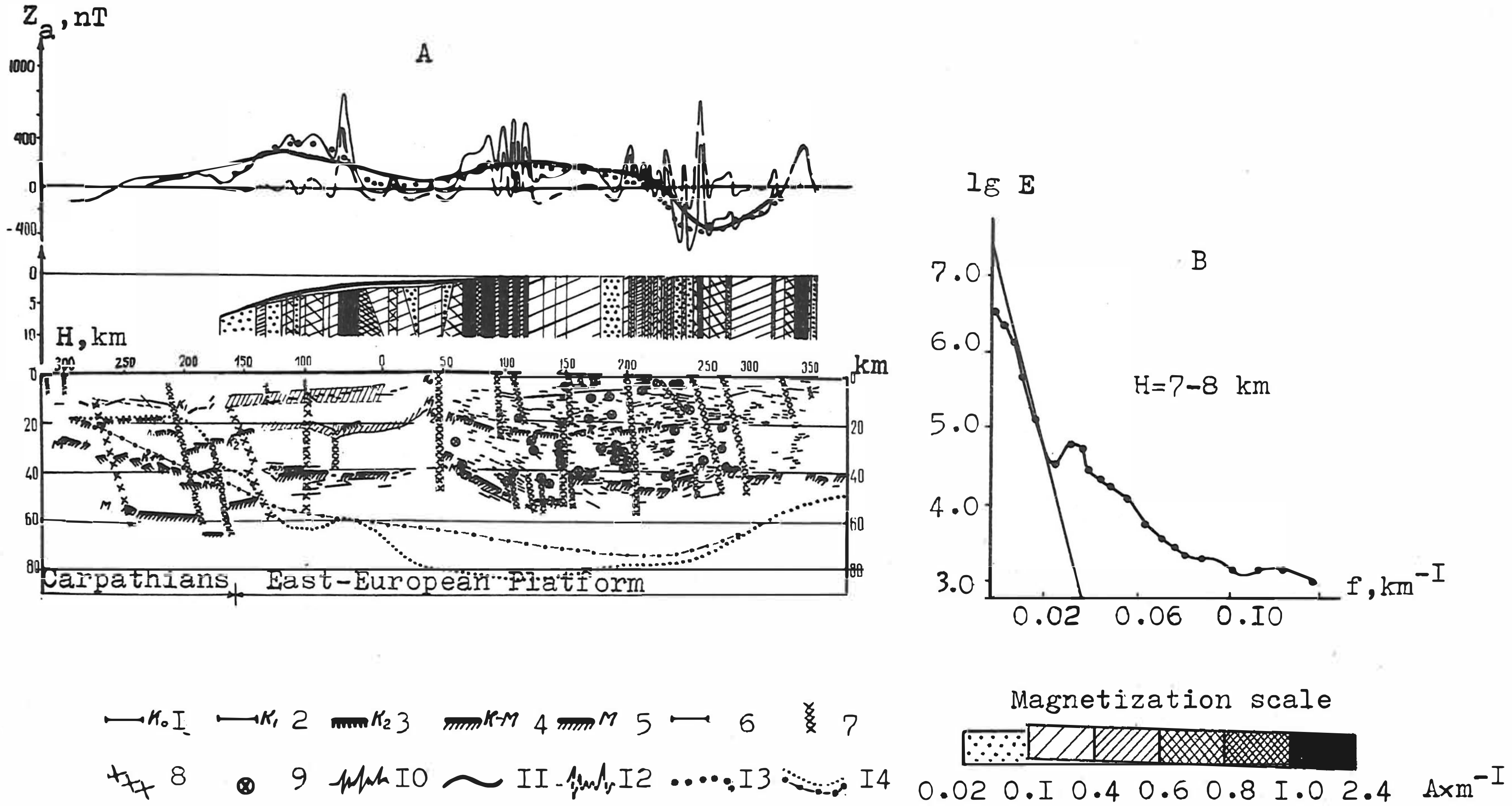

Fig. 2 Deep crustal section along DSS line III (geotravers II) by V.B. Sollogub et.al.,1980; and magnetic anomaly field caused by upper and lower crust (a); energy spectrum for magnetic anomaly field along profile (b).
I - surface of ancient basement; 2, 3 - reflectors in consolidated crust
4 - the "young" M-discontinuity in Carpathian Highlands 5 - M-discontinuity;
6 - reflectors; 7 - faults; 8 - deep faults; 9 - diffraction points;
10 - measured $(\Delta T)_a$-curve; 11 - regional component obtained by integral smoothing;
12 - upper crust magnetic effect; 13 - regional component obtained by elimination of the upper crust effect; 14 - isotherms: a - 580°C isotherm by V.V. Gordienko (Buryanov et al., 1980); b - 600°C isotherm by R.I. Kutas (1976)

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these profiles the effect of the upper crust sources is calculated with the account of the available data on the magnetization of the Precambrian rocks in the Ukrainian Shield (Krutikhovskaya, Silina, Bondareva, Podolyanko, I979) and the Riphean effusive covers. The sources of local magnetic anomalies are approximated by vertical layers (Fig.2). As seen in these pictures, part of the anomalous magnetic field to 250 - 350 nT on DSS line III and to 500 nT on DSS line YIII cannot accounted for by superposition of local anomalies and should be interpreted as due to magnetized bodies which are not exposed at the Precambrian surface. The depth estimates for the upper edges of regional anomaly sources derived from the energy spectrum of the magnetic field along the DSS profiles point to the existance of a deep magnetic stage (Fig.2).

The correlations of the regional magnetic field with tectonic features, crystalline basement structure, Moho surface topography and thermal conditions of the crust and upper mantle have been analysed. The analysis is based on the published Tectonic maps (Suveidzis,I979, Tectonics of the Byelorussia, I976), DSS data on the International DSS lines I,III and YIII (Guterch et al., I980; Posgay et al., I980; Militzer et al., I980), as well as on the depth calculations of the Curie magnetite isothermal surface (Kutas, I976; Buryanov et al.,I980).

Let us have another look at the map of the regional component (Fig.I). The large morphological tectonic units of the East-European Platform (Ukrainian Shield, Byelorussian Anteclise, Baltic Syneclise etc.) are not marked by specific feature of the regional magnetic field. The regional anomalies extend from the exposed part of the Shield into its slopes, or from Baltic Syneclise into Byelorussian Anteclise without essential variance of their intensity or morphology.

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As previously shown for the Ukrainian Shield, the anomalies of wavelengths from 60 to 300 km are mostly restricted to the second order Precambrian bloks but, sometimes, they continue into adjacent regions. Anomalies of a "through" extention have also been reported.

Comparison of the regional magnetic anomalies with the gravity field and large-block structure studied on the basis of petrography-density analysis leads to the conclusion that there are several types of correlation between these fields.

A direct correlation between the two types of the field is observed over large basement structures but is not always fully due to their effect.

The inverse correlation is generally found when regional magnetic anomalies mark large Precambrian granitic blocks.

So far unexplained is a correlation between a gravity high and the magnetic high and low occuring simultaneously.

There is also a certain "mixed" type of gravity-to-regional magnetic anomalies correlation. This type of correlation is often found over the "through" structures mentioned above.

Consideration of the field correlations leads to the following conclusions:

I) some regional magnetic and gravity anomalies can be due, completely or partially, to the composition and structure of the upper crust;

2) among the regional magnetic lows over granitoid massives there are some accompanied by gravity highs characteristic of a "heavy" crust. In such cases, the Precambrian basement, probably, has a two-stage structure. The lower crust can be built by nonmagnetic formations of high density;

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3) the "through" features of the fields can mark the zones where the earth's crust has been reworked to a great depth in different periods of tectonic evolution;

4) using the correlation between the Precambrian subsurface structure and the features of the regional magnetic and gravity fields one can distinguish between crustal areas of essentially different petrophysical characteristics and accordingly different composition (femic, sialic or intermediate) through the entire crustal section. The blocks of a femic composition can be divided in their lower part into "magnetic" and "nonmagnetic" ones.

Since heat flow data have been studied irregularly and interpreted ambiguously, the data on the lithospheric temperatures cannot be reliably used in explaining the regional magnetic field. In Fig.2 two results of the heat flow data interpretation are shown. However, the depth estimates available for the Curie magnetite surface prove, in spite of possible errors, that the thermal conditions within the earth's crust under platforms admit the existance of magnetized formations in the lower crust.

The analysis of the regional magnetic component-to-deep structure correlation (Fig.2,3) shows that this component has a clear inverse correlation with the Moho topography. The correlation coefficient of the regional magnetic field to the Earth crust thickness is 0.87 for the DSS line YIII and is 0.92 for the eastern part of DSS line III (Ukrainian Shield). This confirms the similar correlation obtained in the Ukrainian Shield and other Precambrian Shields (Krutikhovskaya, 1976). This correlation suggests high magnetization of the lower part of a thick crust and, inversely, a lower magnetization in a thin crust.

In the folded areas (Fig.2, the Carpathian region) the correlation

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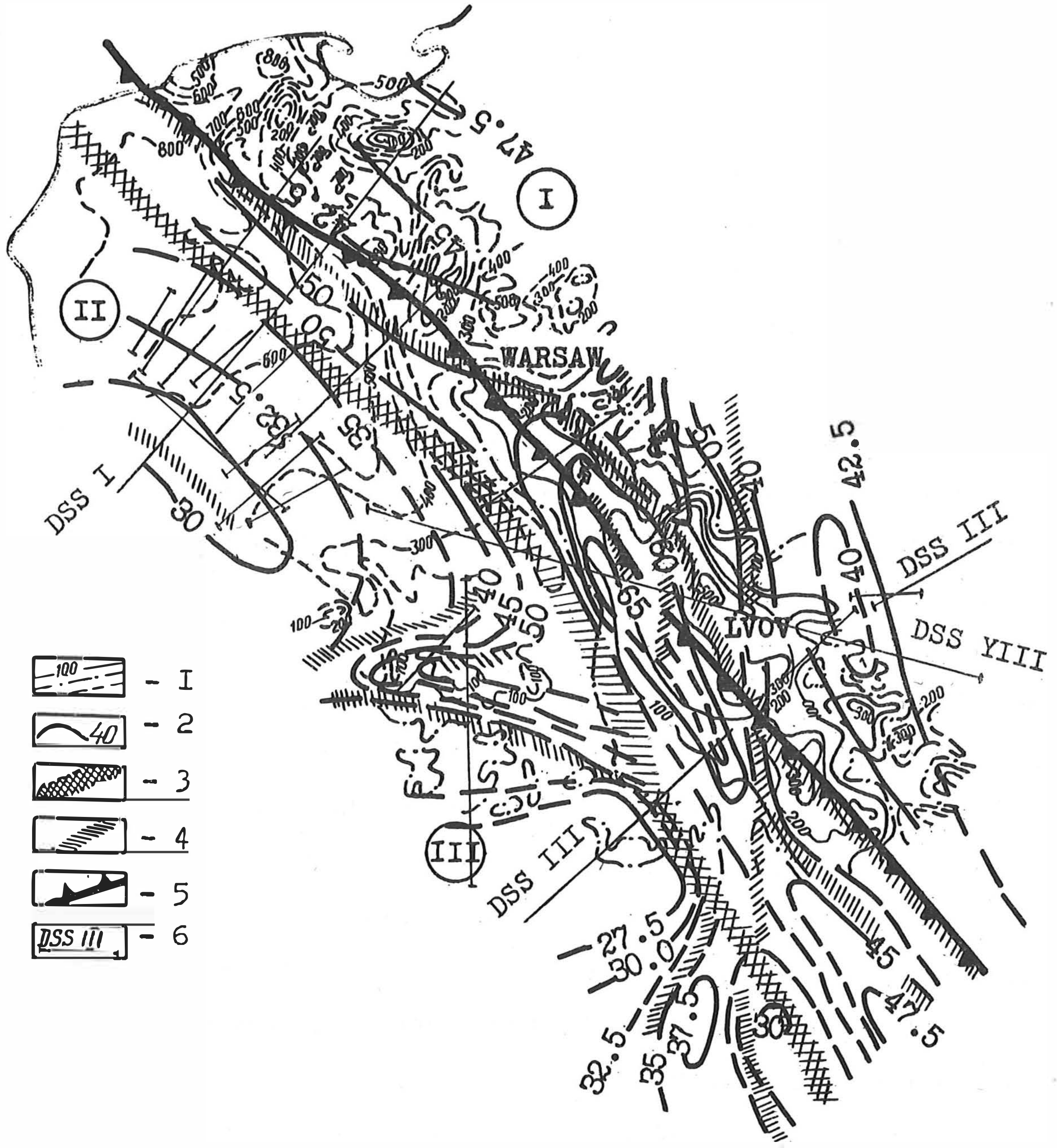

Fig. 3 Magnetic anomaly field in the zone of conjunction of the East-European Platform with the Epipaleozoic Platform and Carpathian region. M-surface contours by V.B.Sollogub, Hr. Dachev, Iv. Petcov et al., 1980

1 - (T)$_a$ isolines, nanoteslas;
2 - M-contour lines
3 - deep lineaments
4 - deep faults
5 - East-European Platform border
6 - DSS lines

Numbers in the circles:
I - East-European Platform
II - Epipaleozoic Platform
III - Carpathian region

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between regional magnetic component and crust thickness breaks.

In the zone of conjunction between the Precambrian East-European Platform and Epipaleozoic Platform (Fig.3) the correlation holds. So, as the crustal thickness on the Epipaleozoic Platform decreases by IO-I5 km, as compared with the Precambrian Platform, the intensity of the regional magnetic field decreases considerably. Thus, we believe that the regional magnetic anomalies are due mainly to the following three causes:

I) The rocks magnetized all over the crustal section and composing the tectonic blocks comparable in the lateral dimentions with the crustal thickness. Such anomalies are well studied in the Ukrainian Shield.

2) The crustal thickness variation and genetically connected variation in the lower crust magnetization. The sizes of the anomalies are, evidently, several times as great as crustal thickness, the intensity being lower than that in the anomalies due to cause (I).

3) Large lateral variations in the crust magnetization and thickness variations over hundreds of kilometers. The geolovical analog of these sources of regional anomalies is the conjunction zone of large tectonic structures, such as the Precambrian East-European Platform and Epipaleozoic Platform.

The last two tipes of anomalies may correlate and the first anomaly type may superimpose the second and the third.

Because there are several sources of regional magnetic anomalies the specific method of their separation is chosen depending on the anomaly wavelength.

A tipical feature the regional magnetic anomalies due to cause (I) is that these anomalies produce a "monolitic" effect on the observed field to create a thouroughly positive field almost whithout local

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lows. These anomalies can be derived by conventional upward continuation of the field or by field smoothing, etc.

The regional magnetic anomalies due to cause (2) can be obtained, to our notion, by constructing an envelope curve over the observed magnetic lows with account of the previously separated regional anomalies due to cause (I).

As to the regional anomalies due to cause (3), they can be isolated at the next stage of the construction of the lows envelope and require a special analysis of the reference field used.

Quantitative interpretation of the anomalies due to the any of these three causes would require a field separation with accuracy given in advance depending on the model chosen for distribution of the field sources within the crust and on the reliability of the model construction.

The analysis and interpretation of the regional magnetic anomalies, thus, involves the following procedure:

- The magnetic field anomalies are classified according the source depth on the basis the spectral and correlation analysis using the field reduction by means of a succesive substraction of the local source effects and by the use of the relevant geologic and geophysical data.
- The individual filter and its parameters are chosen for each regional anomaly or for the class of anomalies and the error of the field separation into components is estimated.
- The most probable models for the source distribution in the earth's crust are substantiated and equivalent solutions of the inverse problems are obtained in terms of the model selected.
- At last, a magnetic model for the earth's crust is constructed.

It is only the first stage of this work that has so far been com-

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pleted. The sdudy of regional magnetic anomalies in the south-west East-European Platform leads to the optimistic conclusion that magnetic anomalies provide powerful tools for the deep crustal structure study in platform areas.

LITERATURE

- Buryanov V.B., Gordienko V.V., Kulik S.N. et al.: Complex geophysical model of the East Carpathian lithosphere. In book: Earth crust structure in the Central and Eastern Europe by geophysical data. Kiev: Naukova Dumka, 1980, p.p.89-97 (in russian).
- Guterch A., Litvinenko I.V., Platonenkov L.N. et al.: Geotravers I. The Alps-Baltic Sea- Barents Sea. In book: Earth crust structure in the Central and Eastern Europe. Kiev: Naukova Dumka, 1980, p.p.7-10 (in russian).
- The map of the $(\Delta T)_a$ anomaly magnetic field of the USSR (continental part and some adjacent aquatories). Moscow, 1977.
- Krutikhovskaya Z.A.: Problems of the creating the earth's crust magnetic model for Ancient Shields. Geophys. Communications, 73,Kiev 1976, p.p.3-29(in russian).
- Krutikhovskaya Z.A., Silina I.M., Bondareva N.M. and Podolyanko S.M.: Relation of magnetic properties of the rocks of the Ukrainian Shield to their composition and metamorphysm. Can. J. Earth Sci., 16, p.p.984-991, 1979.
- Krutikhovskaya Z.A., Pashkevich I.K.: Long-wavelength magnetic anomalies as a source of information about deep crustal structure. J. Geophys., 46, p.p. 301-317, 1979.

DOI: https://doi.org/10.2312/zipe.1981.070.01

- Kutas R.I.: Temperature distribution within the Earth's crust in the territory of the Ukrainian SSR. Geophys. Communications, 70, 1976, Kiev, p.p.86-94(in russian).

- Militzer H.,Pomerantseva I.V., Polshkov M.K. et al.: Geotravers IY. North-Germany Depression -Swietokrzyskie Mautains-Ukrainian Shield. In book: Earth crust structure in the Central and Eastern Europe by geophysical data. Kiev: Naukova Dumka, 1980, p.p.18-22 (in russian).

-Posgay K., Litvinenko I.V., Platonenkov L.N. et al.:Geotraveps II.Adriatic Sea-Carpathians-Baltic Shield.In book: Earth crust structure in the Central and Eastern Europe by geophysical data. Kiev: Naukova Dumka, 1980, p.p.11-15(in russian).

- Sollogub V.B., Dachev Hr., Petkov Iv. et al.: Mohorovichich discontinuity. In book: Earth crust structure in the Central and Eastern Europe by geophysical data. Kiev: Naukova Dumka, 1980, p.p.123-126.

- Suveidzis P.I.: Tectonic setting of the region, principal structural elements and complexes of the Earth's crust. In book: Baltic Tectonics. Vilnus: Mckslas, 1979, p.p.19-21 (in russian).

- Tectonics of Byelorussia. Editor R.G.Garetsky. Minsk: Nauka i tehnika, 1976, 200p. (in russian).

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SPECTRAL AND TEMPORAL ANALYSIS OF THE GEOMAGNETIC FIELD AND ITS APPLICATION FOR THE SOLUTION OF SOME GEOPHYSICAL PROBLEMS

Summary

A spectral and a spectral-temporal analysis of stationary time series of average annual values of the field in the world observatory net has been carried out. A 60-year variation for which amplitudes and phases are determined and polarization vectors are constructed has been selected. On the base of the covariant structure a prognosis for 5 years of the field and its secular variations has been worked out.

Zusammenfassung

Es wurden eine Spektral- und eine Spektral-Zeit-Analyse von Zeitreihen der Jahresmittelwerte des Feldes im Welt-Observatoriumsnetz durchgeführt. Die 60-jährige Variation wurde ausgesondert, Amplituden und Phasen für sie bestimmt und Polarisationsvektoren erstellt. Auf der Basis der kovarianten Struktur wurde eine Prognose für 5 Jahre des Feldes und seiner Säkularvariationen erarbeitet.

Резюме

Выполнен спектральный и спектрально-временной анализ временных рядов среднегодовых значений поля по мировой сети обсерваторий.

Проведено выделение ,60-летней вариации, для которой определены амплитуды, фазы, построены вектора поляризации.

На основе ковариационной структуры сделан прогноз на 5 лет поля и его вековых вариаций.

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Introduction. The magnetic field variations observed at the Earth's surface may be due both to external and internal sources. The latter contain information about the source itself and the electric properties of the medium. There are about 150 magnetic observatories all over the world, some of which have been carrying out continuous registrations for 90-120 years. Two approaches have outlined to the analysis of this information. The first may be called a time-amplitude or a time-space analysis [1]. The second approach is a spectral one [2-3] . The advantages of the spectral and temporal analysis allowing us to determine the main spectral characteristics of the process and estimate their variations over a given time interval.

Determination of the trend. As seen from the literature, the time rows of the annual means contain variations a) with a period more than 100 years that over short time intervals look as a trend; b) with characteristic periods of about 60 years and less that will be treated here, and probably c) random noise-like variations. Once determined as a variation with characteristic period of more than 100 years, is trend that it may be approximated by the polynomial

$$y(t) = \beta_0 + \beta_1 t + \beta_2 t^2 + \cdots + \beta_K \cdot t^K, \qquad (1)$$

with coefficients estimated by the method of least squares. Now the main problem is to determine the power of the polynomial. The problem has been solved by two methods: by the method of finite differences and by field expansion is orthogonal polynomials with subsequent analysis of unbiased dispersion estimates. The results

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have shown that at a time row of the order of 90-120 years long, even the second-power polynomial leads to distortions in the 60-year variation. The trend elimination with the help of a first-power polynomial is enough for correct determination of correlation functions and the spectral density.

Spectral analysis. The simplest way to discover the periodicity in the residual field (the time row after the trend being eliminated) is determinating the correlation functions. For most European observatories, the autocorrelation function of each component may be approximated by:

$$R(\tau) = e^{-\alpha|\tau|} \cos \beta\tau \qquad (2)$$

Rather essential in this case is a small damping ($\alpha \approx 0$) and a large (with respect to the given time interval) oscillation period ($T = \frac{2\pi}{\beta}$).

However the results are much better even compared to the usual spectral analysis, if a more complicated of maximum entropy method (MEM) is applied. The advantages of the method have been shown by a number of authors using both the models [4] and the real time rows [5]. Nevertheless, its application to geomagnetic field variations having a specific spectral composition needs additional approbation.

The parameter M characterizing the length of the filter seems to be most important both to the MEM and to other methods used for spectral density calculations [4-5]. If M is too small, it leads to an oversmoothed spectrum, if it is too large, the spectrum becomes unstable. We have considered a model example:

$$y = 200 \cdot \sin \frac{2\pi t_k}{60} + 20 \sin \frac{2\pi t_k}{20} + 10 \frac{2\pi t_k}{11} + \sigma , \qquad (3)$$

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(where σ is the white noise) for the case of N=130, i.e. an example close to geomagnetic field variations as given by observatory data. Taking different values of M (from 2 to N/2), we have found N/3 to be closest to the optimum.

The application of MEM to real time rows of observatory data has allowed us to return to the question of power of the trend-approximating polynomial. When determining the spectrum of residual fields obtained after elimination of the trend approximated by different-power polynomials, we have found out that as the polynomial power grows, the spectral maximum characterizing the 60-year variation decreases in power and shifts towards the high-frequency edge.

The results of application of the method can be illustrated by different examples of field variation from observatories Niemegk, Witteveen, Rude Skov, Shambon,Foret, Durb (fig 1). In all cases one can see pronounced pickes around the years 60-70, i.e. the so called 60-year variation. The analysis of field variation data over the world magnetic network has shown the variations in the vertical component to have larger period than in horizontal ones. If the 60-year variation is reliably determined, a detailed study of the higher frequencies having smaller amplitudes is possible only after its elimination [6] .

The amplitude and phase of the 60-year variation have been estimated by the method of least squares. Since at short sets the method of maximum entropy may give a bias in estimates, the calculations were made for several periods around that determined by MEM. The quality of determination and elimination of the 60-year variations has been checked by calculating the rms of the resi-

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duals. The repeat application of MEM after elimination of the main 60-year period usually showed its absence.

To begin the study of spatial structure, we have determined the distribution of polarization in the horizontal component by estimating the polarization ellips parameters. For the European area, where the majority of observatories with long time rows are situated, such representation allows us to reveal the particular features of polarization distribution, to find the stations with practically linear polarization (Rude-Skov, Niemegk, Sodankyla) and those with obviously distorted polarization (Dusheti, Valencia, Coimbre) [7].

Spectral-time analysis. Different sources may give variations with close characteristic times. In this case, the spectral analysis alone may be inefficient. The determination can be realized using the spectral-time analysis that makes it possible not only to plot the spectrum, but also to follow its time variation [8]. Since it is the first time that the method has been applied to the secular variation, let us give its brief description. The first stage consists in estimating the spectral density:

$$F(\omega_\kappa) = \frac{1}{N} \sum_{j=0}^{N-1} y_j \exp\left[-i\,\frac{2\pi \kappa j}{N}\right], \quad \kappa = 0.1 \ldots N-1, \qquad (4)$$

where y_j is the initial information determined by N discrete values

$$y_j = y\,(T + jh), \quad j = 0.1 \ldots N-1 .$$

The values of $F(\omega_\kappa)$ are calculated for discrete frequencies $\omega_\kappa = \frac{2\pi\kappa}{Nh}$. Then the $F(\omega_\kappa)$ set of data is multiplied by the frequency characteristic of the filter. For a frequency "window" one may use the Guassian filter with the frequency characteristic of

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the type

$$H_i(\omega) = \exp\left[\alpha_i\left(\frac{\omega-\omega_i}{\omega_i}\right)^2\right], \qquad (5)$$

where i is the filter number, ω_i is the central frequency of the filter, α_i is the quality factor of the filter. For the filtered out set $\Phi = \{H(\omega)\cdot F(\omega)\}$, we calculate the phase and modulus of the envelope by means of a single reverse Fourier transformation for which the simultaneously obtained real and imaginary parts are used.

As a result of this procedure, we obtain the matrix of the modulus and argument values of $S(\omega_K, t)$ function, where

$$S(\omega_K, t) = \sum_{K=0}^{N-1} \Phi_K \cdot \exp\left[i\frac{2\pi j K}{N}\right],$$

the totality of which for all ω_K gives a plane representation of t, ω.

The most interesting result of STA application is the possibility to establish the variation law for the dispersion of initial realization frequencies, $\omega(t)$. This possibility is based on the fact that the response of the Gaussian filter depends on the input signal, being maximum at the time of the stationary phase which corresponds to the maxima of the envelopes. Thus, the time sequence of the maxima of envelopes at corresponding frequencies can be expressed as the time dependence of instantaneous frequency [8]

The magnetic field variations at a given point are composed of field variations from at least two sources: internal, situated at the core-mantle boundary, and external, located at the magnetosphere-ionosphere interface. We shall consider here the possibilities based on the above spectral and temporal analysis. This analysis has discovered a number of facts useful for such discrimination, namely:

1. A deep minimum observed in the spectrum between 20- and

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11-year maxima and the ratio of their amplitudes suggest that the boundary should pass between these maxima.

2. The azimuth variations of the major axis of polarization ellips plotted as a function of the period show a sharp change of the former in the vicinity of the 20-year period.

3. The structure of the envelope is the same within $\sim 5 \div 20$ years. But maximum delay falls on different moments for $60 \div 20$ years.

As a result, it may be suggested that the variations with a period less than ~ 20 years are due to external sources, whereas the internal ones are responsible for longer variations.

Co-variation structure and prediction of geomagnetic fields' elements. Co-variation structure of time series was investigated at magnetic observatories. Using this structure could be compiled an integrated model of antoregression-running mean.

Joint solution of equations, which connect auto-correlation function with autoregression parameters, allows to define these parameters and to apply the model to time series prediction with the minimal mean square error. The investigation of time series at some magnetic observatories (San Juan, Hartland, Tucson, Niemegk)[9] has led to a conclusion on sufficiency to consider the order of autoregression and running mean within 3. In this case the residual dispersion will be within 5-13nT,^{2}, 2-8nT^2, 9-100nT^2 for X,Y andZ components respectively. Thus the prognosis for 5 years can be carried out with the mean square error not exceeding 7nT in field and 4nT in its SV.

In fig.2 a graph is given of predicted values for 2 elements up to 1985 (dots) at Niemegk observatory.

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The dots in fig.2 show two versions of the autoregression-running mean integrated model: (a) that for X and Z components of the initial curves of the secular variation from the Niemegk observatory and- (b) the other one for the secular variation curves averaged using a 5-year smoothing. The points beyond the limits of solid (initial) curves display the epignoses up to 1886 and the forecasts up to 1985.

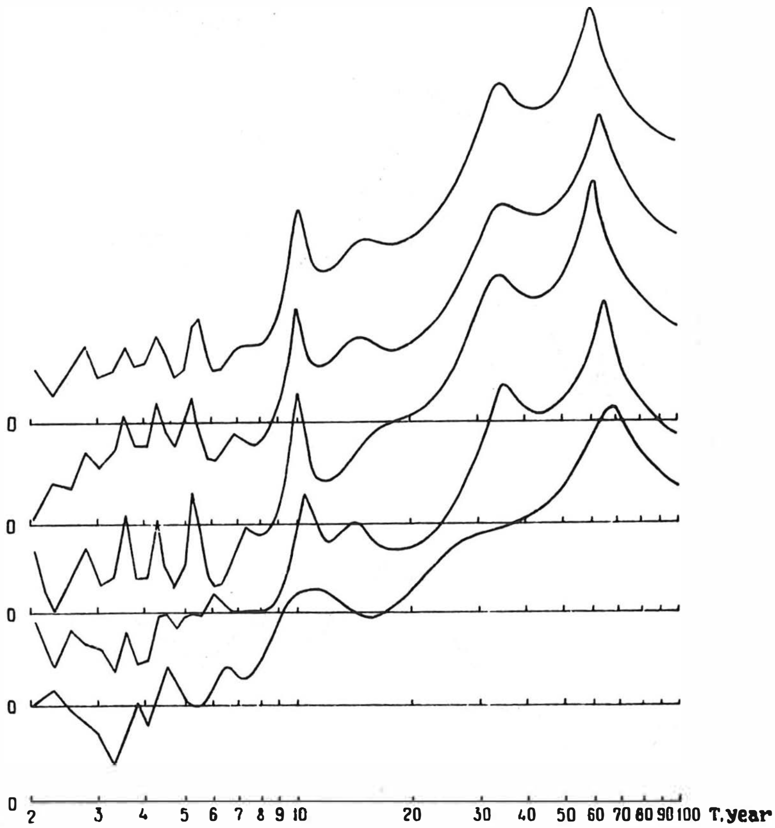

Fig. 1

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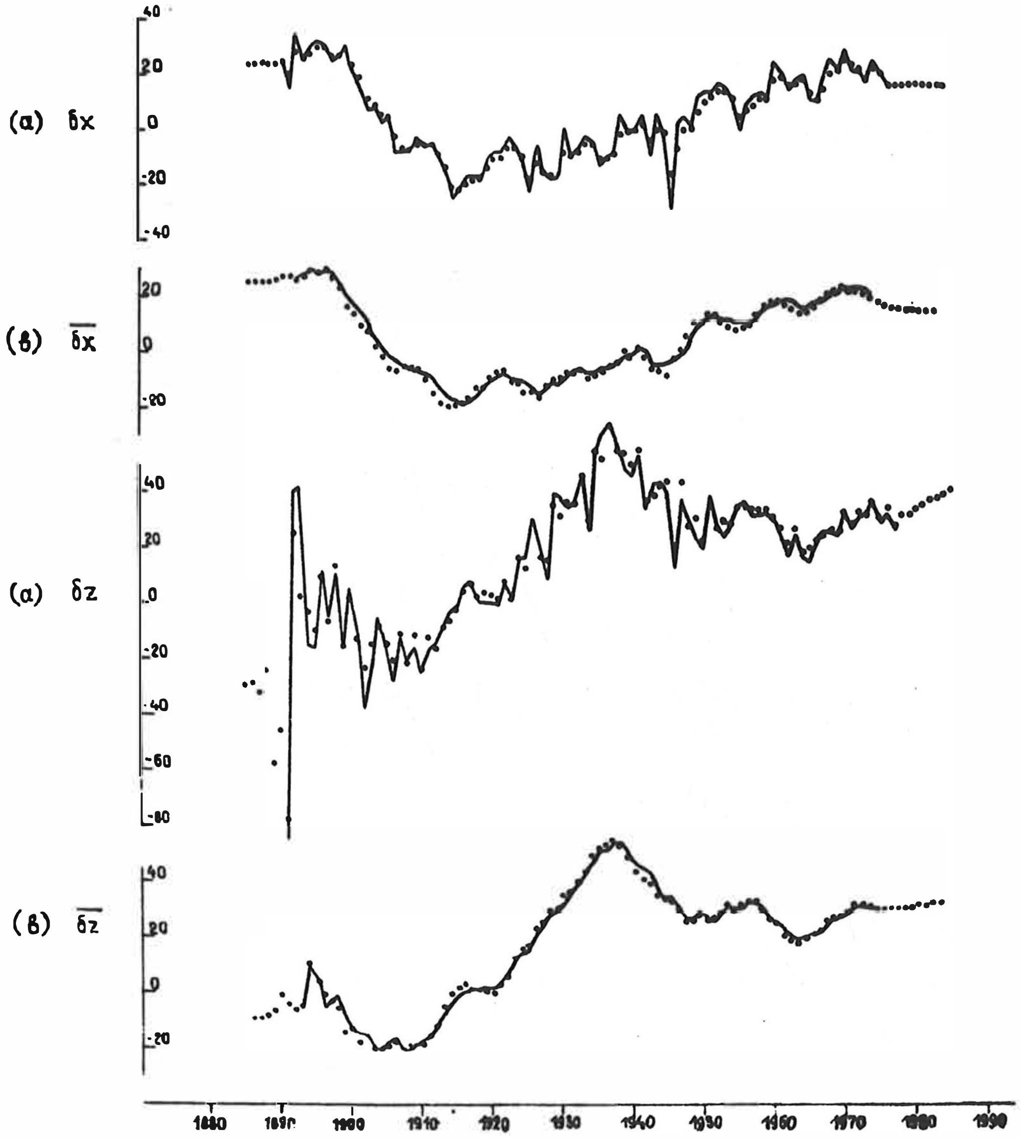

Fig. 2

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References

1. В.П.Головков, Г.И.Коломийцева Геомагнетизм и аэрономия, 1971, 11, 674.
2. R.G.Currie Astrophys. Space Sci., 1973, 21, 425.
3. Н.М.Ротанова, Н.Е.Папиташвили, А.Н.Пушков Геомагнетизм и аэрономия, 1979, 19, 1091.
4. В.Ф.Писаренко Сб. "Вычислительная сейсмология", вып.10. "Наука", 1977, 118.
5. V.E.Courtillot, J.L.Le Mouel, P.N.Mauand Journ. Geophys. Res., 1977, 82, 2641.
6. Н.М.Ротанова, Н.Е.Папиташвили, А.Н.Пушков Препринт №/,, ИЗМИРАН, 1979г.
7. Н.Е.Папиташвили, Н.М.Ротанова, А.Н.Пушков Геомагнетизм и аэрономия, 1980, 20, 711.
8. Н.М.Ротанова, Л.В.Кошелева, А.Н.Пушков Препринт №38, ИЗМИРАН, 1979г.
9. Т.Н.Бондарь, Г.Н.Коломийцева, А.Н.Пушков Геомагнетизм и аэрономия, 1980, 20 .

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Spectral analysis of the annual mean values of the geomagnetic observatories

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Summary

The cycles of the secular variation can be obtained from the spectral analysis of the annual mean values of the geomagnetic observatories. The application of the fast Fourier transform (FFT) and the maximum entropy method (MEM) has yielded effective estimations of the power spectra of the geomagnetic element data. The application of these procedures is illustrated by the calculations of the power spectra of the Niemegk and Tihany geomagnetic observatories.

Zusammenfassung

Die Zyklen der sekulären Variation können durch die Spektralanalyse der jährlichen Mittelwerte der erdmagnetischen Observatorien erhalten werden. Die Anwendung der "schnellen Fourier-Transformation" (FFT - fast Fourier transform) und der Methode der maximalen Entropie (MEM) lieferte effektive Abschätzungen der Leistungspektren der Werte der erdmagnetischen Elemente. Die Anwendung dieser Methoden wird durch Berechnung der Leistungspektren der erdmagnetischen Observatorien von Niemegk und Tihany demonstriert.

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Резюме

Периоды векового изменения магнитного поля могут быть определены из данных магнитных обсерваторий. В докладе показана возможность использования быстрой трансформации Фурье (FFT) и метода максимума энтропии (MEM) для анализа данных магнитных обсерваторий. Эффективность методов проиллюстрирована на примере спектрального анализа данных нимекской и тиханьской магнитных обсерваторий.

Introduction

The geomagnetic secular variation can be obtained from the records of the geomagnetic observatories. A number of authors have published interesting investigations based on different methods. The methods for deriving the geomagnetic secular variation can be devided into two large categories: first, we can analyse the time variation of the spherical harmonic coefficients, second, we may also use directly the time series formed by the annual mean values of the geomagnetic observatories.

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The spherical harmonic analysis of the geomagnetic field was proposed by C.F. Gauss in 1835. Several versions of the determination of harmonic coefficients have been published. They refer to different epochs and they are based on different data and methods (Malin, S.R.C., 1969; Yukutake, T., 1979; Yukutake, T., Cain, J.C., 1979). B.R. Barrachlough summarised in a review paper a total of 91 models which refer to epochs extending from 1650 to 1975 (Barrachlough, B.R., 1974; 1976). Now we do not go into more details of the determination of the spherical harmonic coefficients we remember only Adolf Schmidt, whose the name bears the Niemegk Geomagnetic Observatory, who proposed a method for determining the Gauss coefficients normalized by the g_1^0 value.

This kind of analysis can reveal the character of the global geomagnetic secular variation such as the time variation of the central dipole, its moment and the position of its direction. The secular variation of the non-dipol field can be derived from the higher harmonics.

The spectral estimation often forms the basis of the time series' analysis. For a long time the Fourier spectrum analysis was the single tool of the spectral estimation. During the past decade a totally different non-Fourier spectral estimation technique has emerged the maximum entropy spectrum analysis. In the followings this method will be summarized or rather before it the Fourier analysis will be

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depicted by the help of the FFT algorithm.

Discrete Fourier transform

The discrete Fourier transform of time-series data x_i, $i = 0,\ldots,m$ is

$$X(kf_o) = \sum_{i=0}^{m} x_i \exp(-j2\pi kf_o i),$$

where $f_o = 1/(m+1)$ is the frequency spacing and k is an integer. The estimation of the discrete power density spectrum is

$$S(kf_k) = \frac{1}{m+1} \left| X(kf_o) \right|^2$$

In the spectrum only those harmonics can be distinguished whose frequency spacing is approximately equal or greater than the reciprocal of the observation window width. The former estimation of the power density spectra assumes that implicit condition that the data are cyclic with the period $(m+1)$ outside the observation window. This effect may occour when only a fraction of a cycle is recorded. The additional disturbing effect is the "leakage" phenomenon. This occours when the integer multiple of the frequency spacing is not equal to the frequency of the actual data series.

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The power density spectra of the annual mean values of D, H and Z components measured in Niemegk and Tihany gemagnetic observatories were determined by the application of the fast Fourier transform algorithm. As it is well known this technique, suggested first by Cooley and Tukey in 1965, reduces the number of the arithmetic operations necessary to perform the discrete Fourier transform and the computations can be done substantially more economically (Cooley, J.W., Tukey, J.W., 1965; Singleton, R.C., 1967).

Maximum Entropy Method

The spectrum estimation can also be based on the principle of maximum entropy as it has been shown by J.P. Burg in 1967. This procedure has also met with considerable success (Lacoss, R.T., 1971; McDonough, R.N., 1974; Ulrich, T.J., Bishop, T.N., 1975; Ulrich, T.J., Clayton, R.W., 1976).

Since it is perhaps less familiar than the application of the discrete Fourier transform let us summarise the main ideas of the maximum entropy processing.

Some linear random processes may be represented by finite order autoregressive processes which are described by the relationship

$$x_t = \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \dots + \alpha_M x_{t-M} + z_t,$$

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where $\alpha_1, \ldots, \alpha_M$ are the coefficients of the difference equation, z_t is a white-noise series with zero-mean and varience σ_z^2. The z_t is usually called the innovation of the autoregressive process (Box, G.E.P., Jenkins, G.M., 1970).

The power spectrum estimation of an autoregressive process of order M is given by

$$S(f) = \frac{2\sigma_z^2}{\left|1 - \sum_{k=1}^{M} \alpha_k \exp(-j2\pi fk)\right|^2}$$

A. van den Bos showed that the previous estimation of the power density spectrum of an autoregressive process is equivalent to the estimation of the power density spectrum of a stacionary Gaussian process given by

$$S(f) = \frac{P_{M+1}}{f_N \left|1 + \sum_{k=1}^{M} \gamma_k \exp(-j2\pi fk\Delta t)\right|^2}$$

where P_{M+1} is a constant, the γ_ks are the predition error coefficients, f_N is the Nyquist frequency (van den Bos, A., 1971). This estimation is a result of a variational procedure in which the entropy of a distribution is maximized. It follows from these equations that the autoregressive coefficients are this the coefficients of an M-point prediction error filter. The aim is the determination the

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coefficients of an autoregressive process which is to be fitted to the data.

The length of the M-point prediction error filter was proposed by J.G. Berryman (Berryman, J.G., 1978). The length of the filter: $M = 2N/\ln 2N$, where N is the number of the data samples.

Let us review now the results and their interpretation obtained by the maximum entropy analysis. R.G. Currie presented the spectral analysis of 49 geomagnetic observatories (Currie, R.G., 1973). The annual mean values of the H and Z components were used as input data for the calculations. The detected two periods at 21.4±2.4 year and at 10.5±0.47 year correspond to the double solar cycle and the solar cycle respectively. The local maximum of the cluster at 6.07 year can indicate the free modes of the electromagnetically compled core-mantle Earth system which has an oscillation period of about 6.7 year. This period was calculated by T. Yukutake. The cluster at 2.15 year may be correlated with some other oscillations e.g. the variation in cosmic ray data, the oscillation in stratospheric temperature or quasi-biennial variation in the geomagnetic field. R.G. Currie found the 60 year spectral line too. In his interpretation that line probably represents the spectral analogue of the variable motion of the eccentric dipole.

V.E. Courtillot and J.L. LeMouël analysed the annual mean values of 38 geomagnetic observatories in the interval between 1947 and 1972 (Courtillot, V.E., LeMouël, J.L., 1976). They also used the maximum entropy spectral analysis and found significant peaks at 11, 5.5 and 3.66 year in contrast with the results obtained by R.G. Currie.

In the paper of R.S. Jin and D.M. Thomas, published in 1977, the time series of the geomagnetic dipole moment were analysed also by the maximum entropy method and the length of day fluctuations was investigated in the time interval between 1901-1969 in the same manner (Jin, R.S., Thomas, D.M., 1977). The values of the geomagnetic dipole field were determined from the Gauss-Schmidt coefficients of the spherical harmonic analysis. The peaks corresponding to the periods of 66 and 33 years were observed in both power spectra. The higher harmonics with periods 22, 17, 13, 11 and 9 years were also detected in both spectra of the length of day fluctuations and the geomagnetic field. They thought that the 22 and 11 year spectral lines were not attributed to the solar cycles unambiguously they are the higher harmonics of the 66 year period. The similarity of the previous spectra related to the motion inside the fluid core of the Earth.

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Power spectra of the Niemegk and Tihany geomagnetic observatories

The calculated power density spectra of the annual mean values of D, H, Z components measured in Niemegk and Tihany will be depicted as illustrations of the above mentioned methods. First the results obtained by the fast Fourier transform will be discussed. The annual mean values of D, H and Z components recorded in Niemegk between 1890 and 1977 (N = 88) can be seen in the Figure 1. Figure 2 depicts the power density spectra of the D, H, Z components respectively calculated from the Niemegk data. The frequency spacing has been 1/128 years. This involves that the resolving in the low frequency range is rather poor. Some of the first periods which appear in the spectra are 128, 64, 42,7, 32, 25.6 years etc. The energy of harmonic components with periods between these values leaks through to other components in their neighbourhood. The second half of the power spectra which contains the periods less then 4 years is dominated by random noise. The limitations of the Fourier analysis do not allow us to obtain but rough estimates of the significant components.

Figure 3 shows the maximum entropy spectra of the same three components. The cycle about 10 years has emerged in every power density spectrum. This peak could express the effect of the solar cycle. The additional cycles in the

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component D are 6,13 years, 7, 10, 14, 30, 78 years in the component H, and 4, 11, 20, 44 years in the component Z. The significant peaks corresponding to longer periods about 70 years in the components D and H can be considered very interesting. The source of the long period component is not quite clear and it is the object of intensive research.

Similar results were obtained from the analysis of the magnetic components measured in Tihany. Figure 4 shows the variation of the annual mean values of the magnetic elements recorded in Tihany N = 106. The results of Fourier and maximum entropy spectral analysis, shown in the following two figures Figure 5 and Figure 6, depict the same character as we have seen in the case of the Niemegk Observatory.

Acknowledgements

The author should like to express his thanks to Dr. K. Lengning, who kindly sent him the year book of Niemegk Geomagnetic Observatory, and to Prof. Gy. Barta for encouragement. The computations were done by the computer CDC-3300 of Hungarian Academy of Sciences. The use of the computing facilities is highly acknowledged.

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References

Barraclough, D.R., 1974, Spherical Harmonic analysis of the geomagnetic field for eight epochs between 1600 and 1910, Geophys. J.R. astr. Soc. 36, 497-513.

Barraclough, D.R., 1976, Spherical harmonic analysis of the geomagnetic secular variation - A review of methods, Physics of the Earth and Planetary Interiors, 12, 365-382.

Berryman, J.G., 1978, Choice of operator length for maximum entropy spectral analysis, Geophysics, 43, 7, 1384-1391.

Box, G.E.P., Jenkins, G.M., 1970, Time series analysis forecasting and control. Modden-Day, Inc., San Francisco, Cambridge, London, Amsterdam.

Cooley, J.W., Tukey, J.W., 1965, An algorithm for the machine calculation of complex Fourier series, Math. of Comput., 19, 297-301.

Courtillot, V.E., LeMouël, J.L., 1976, Time variations of the earth's magnetic field with a period longer than two months, Physics of the Earth and Planetary Interiors, 12, 237-240.

Currie, R.G., 1973, Geomagnetic line spectra - 2 to 70 years, Astrophysics and Space Science, 21, 425-438.

Jin, R.S., Thomas, D.M., 1977, Spectral line similarity in the geomagnetic dipole field variations and length of day fluctuations. Journal of Geophysical Research 82, 5, 828-834.

DOI: https://doi.org/10.2312/zipe.1981.070.01

Lacoss, R.T., 1971, Data adaptive spectral analysis methods, Geophysics, 36, 661-675.

Malin, S.R.C., 1969, Geomagnetic secular variation and its changes, 1942.5 to 1965.5, Geophys. J.R. astr. Soc. 17, 415-441.

McDonough, R.N., 1974, Maximum-entropy spatial processing of array data, Geophysics, 39, 843-851.

Singleton, R.C., 1967, A method for computing the fast Fourier transform with auxiliary memory and limited high speed storage, IEEE Transactions on Audio and Electroacoustics, AU-15, 2, 91-97.

Ulrych, T.J., Bishop, T.N., 1975, Maximum entropy spectral analysis and autoregressive decomposition, Review of Geophysics and Space Physics, 13, 183-200.

Ulrych, T.J., Clayton, R.W., 1976, Time series modelling and maximum entropy, Physics of the Earth and Planetary Interiors, 12, 188-200.

Van den Bos, A., 1971, Alternative interpretation of maximum entropy spectral analysis. IEEE Trans. Inform. Theory, IT-17, 493-494.

Yukutake, T., 1979, Review of the geomagnetic secular variations on the historical time scale. Physics of the Earth and Planetary Interiors, 20, 83-95.

Yukutake, T., Cain, J.C., 1979, Solar cycle variation of the first-degree spherical harmonic components of the geomagnetic field , Journal of Geomagnetis and Geoelectricity, 31, 509-544.

DOI: https://doi.org/10.2312/zipe.1981.070.01

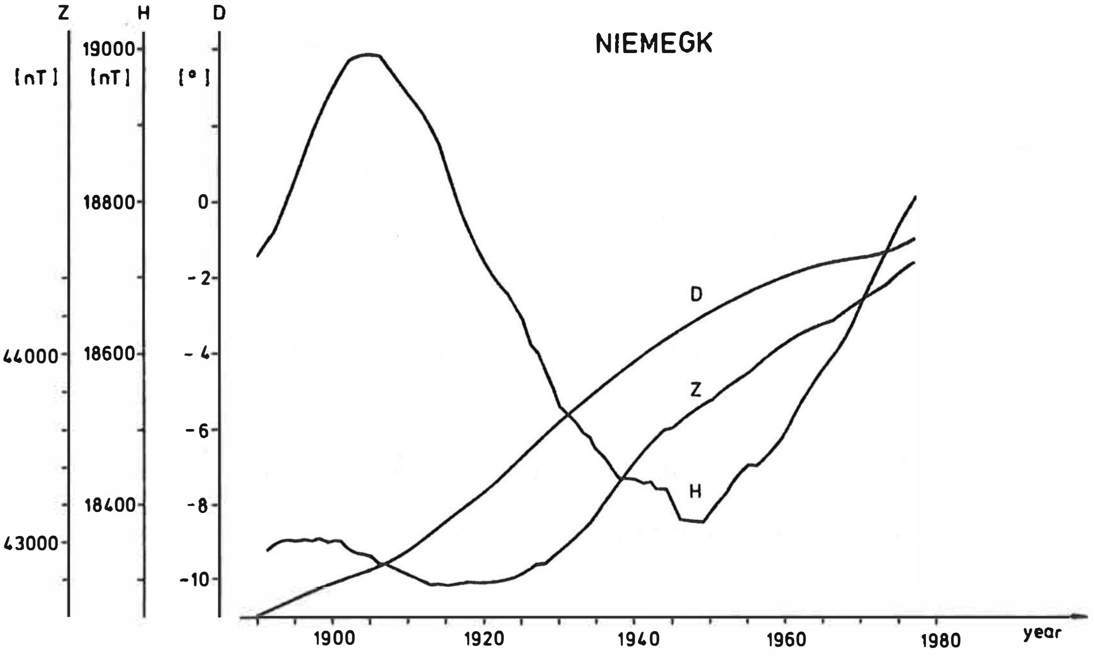

Fig. 1. The annual mean values of the D, H and Z components, recorded in Niemegk Geomagnetic Observatory

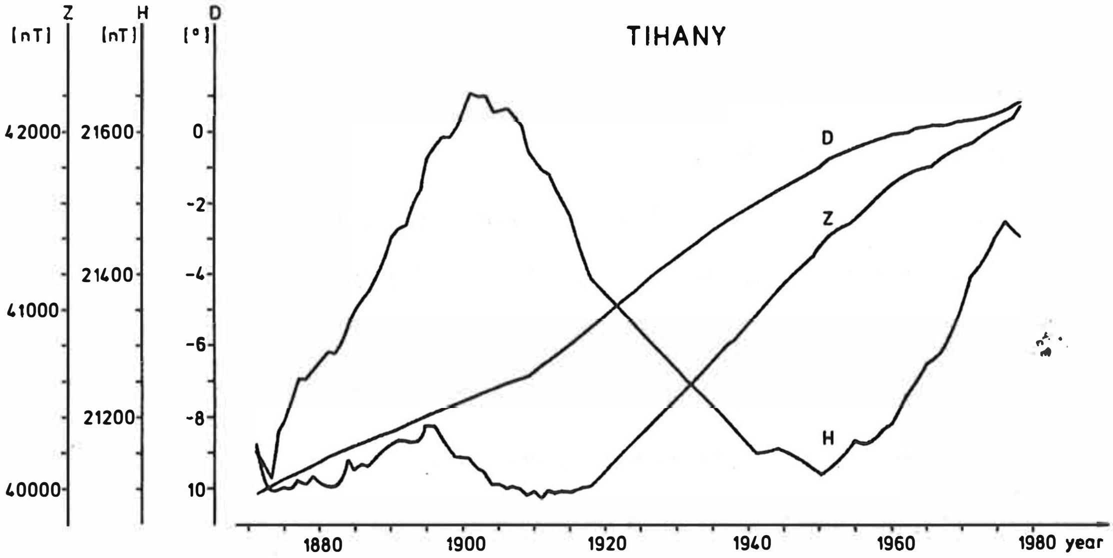

Fig. 4. The annual mean values of D, H and Z components, recorded in Tihany Geomagnetic Observatory between 1871-1978

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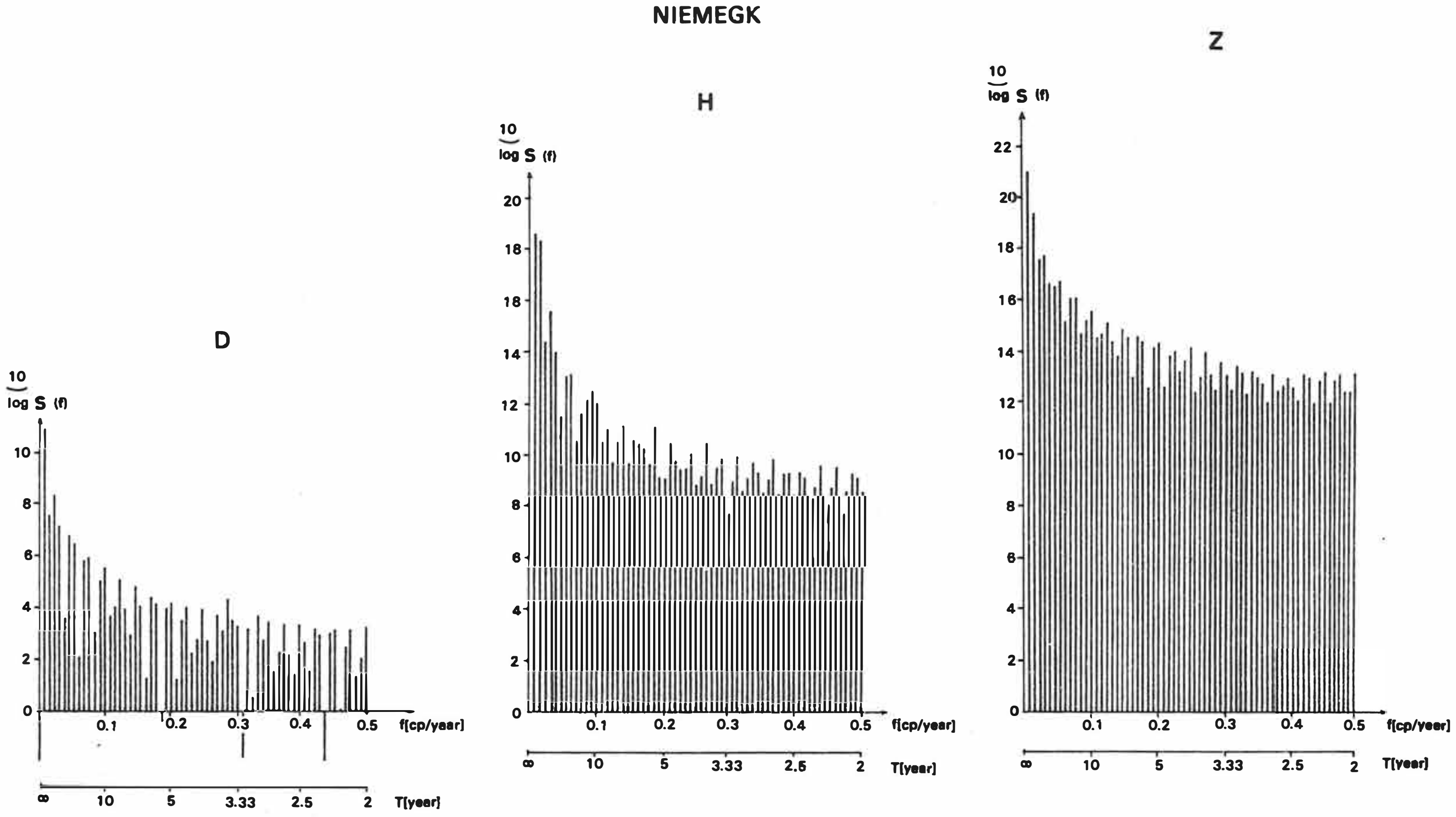

Fig. 2. The power density spectra of the D, H, Z components calculated from the Niemegk data. Spectra were obtained by the fast Fourier transform.

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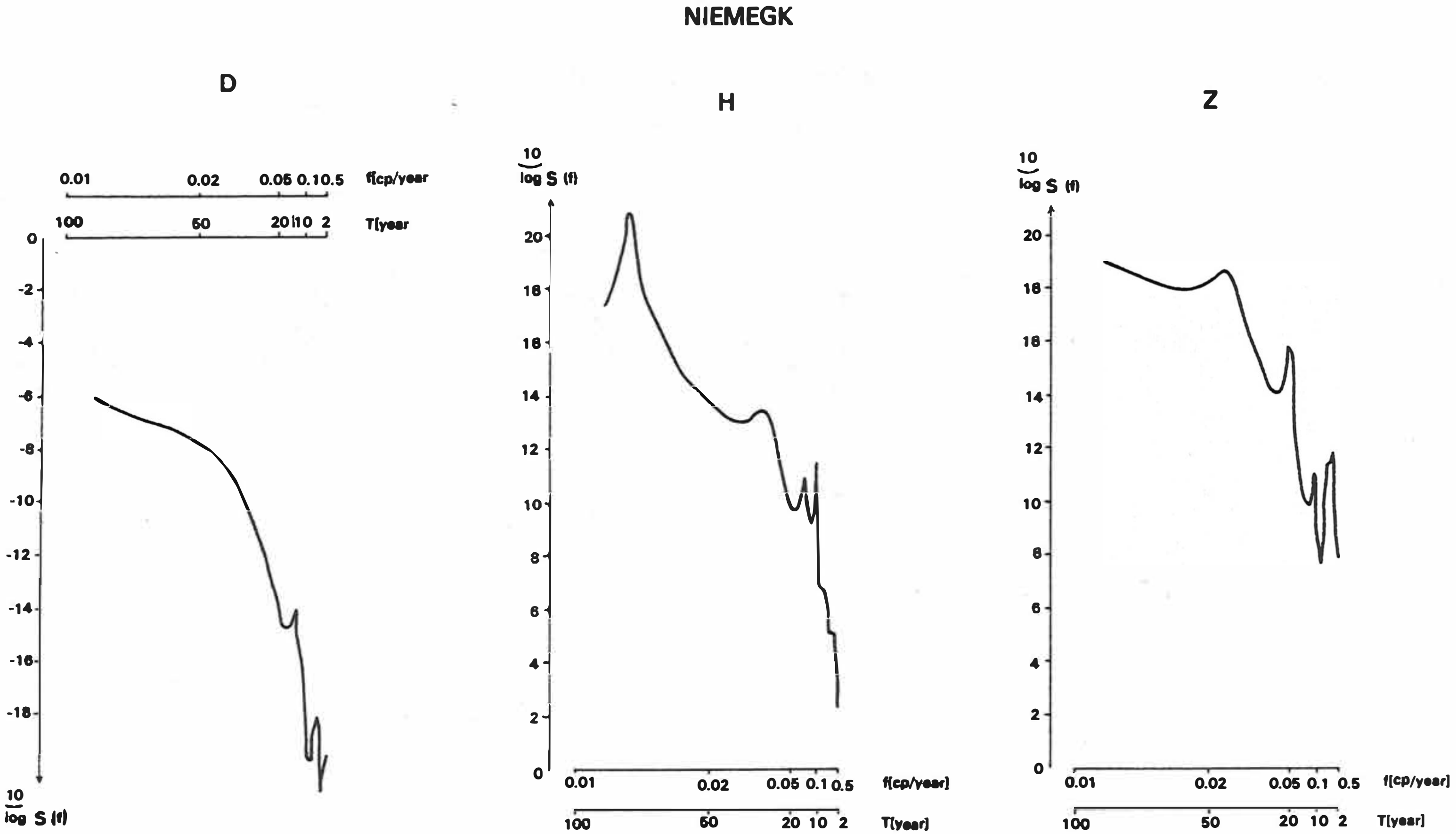

Fig. 3 The maximum entropy spectra of the D, H, Z components calculated from the Niemegk data.

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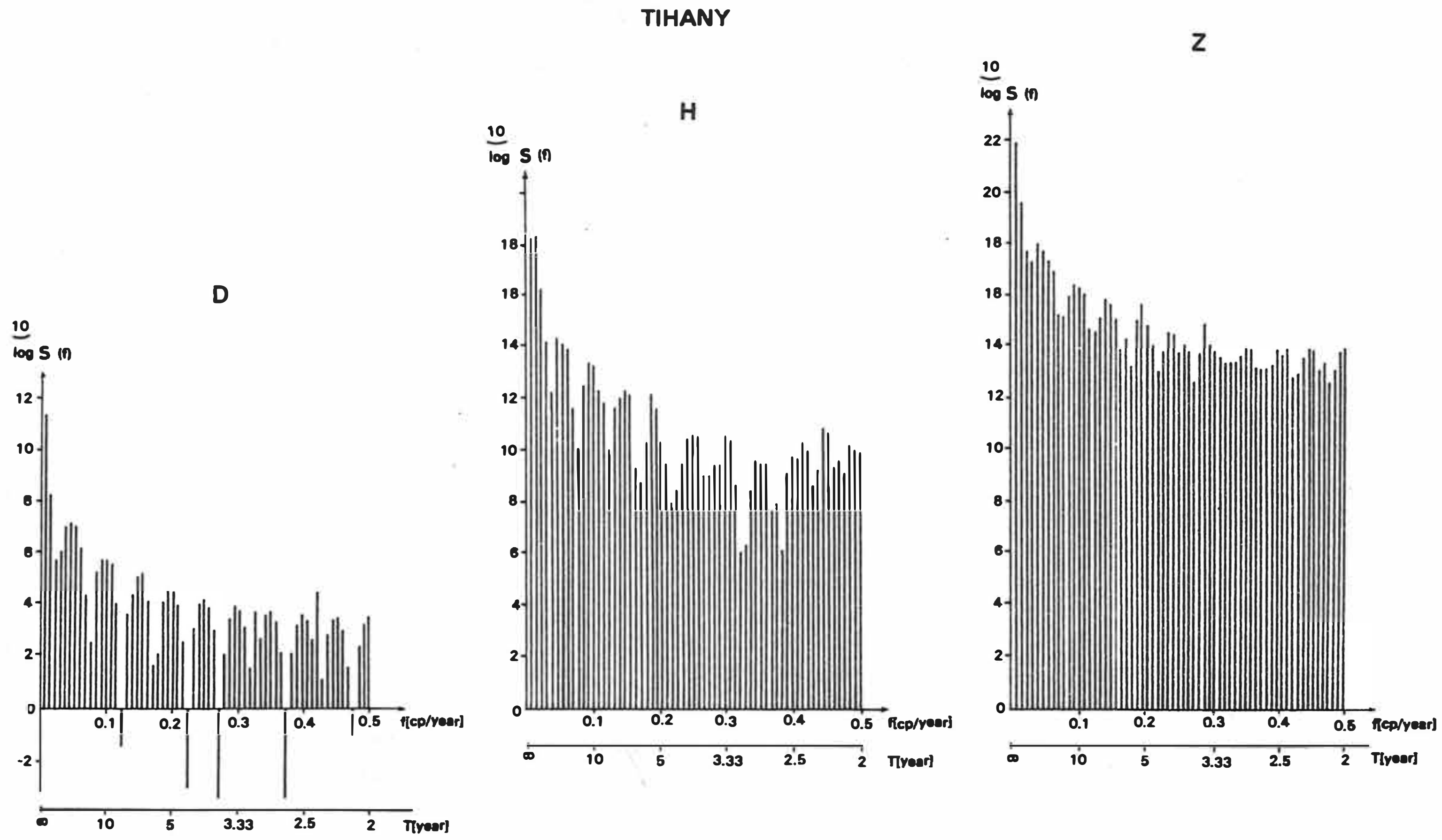

Fig. 5. The power density spectra of the D, H, Z components calculated from the Tihany data. Spectra were obtained by the fast Fourier transform

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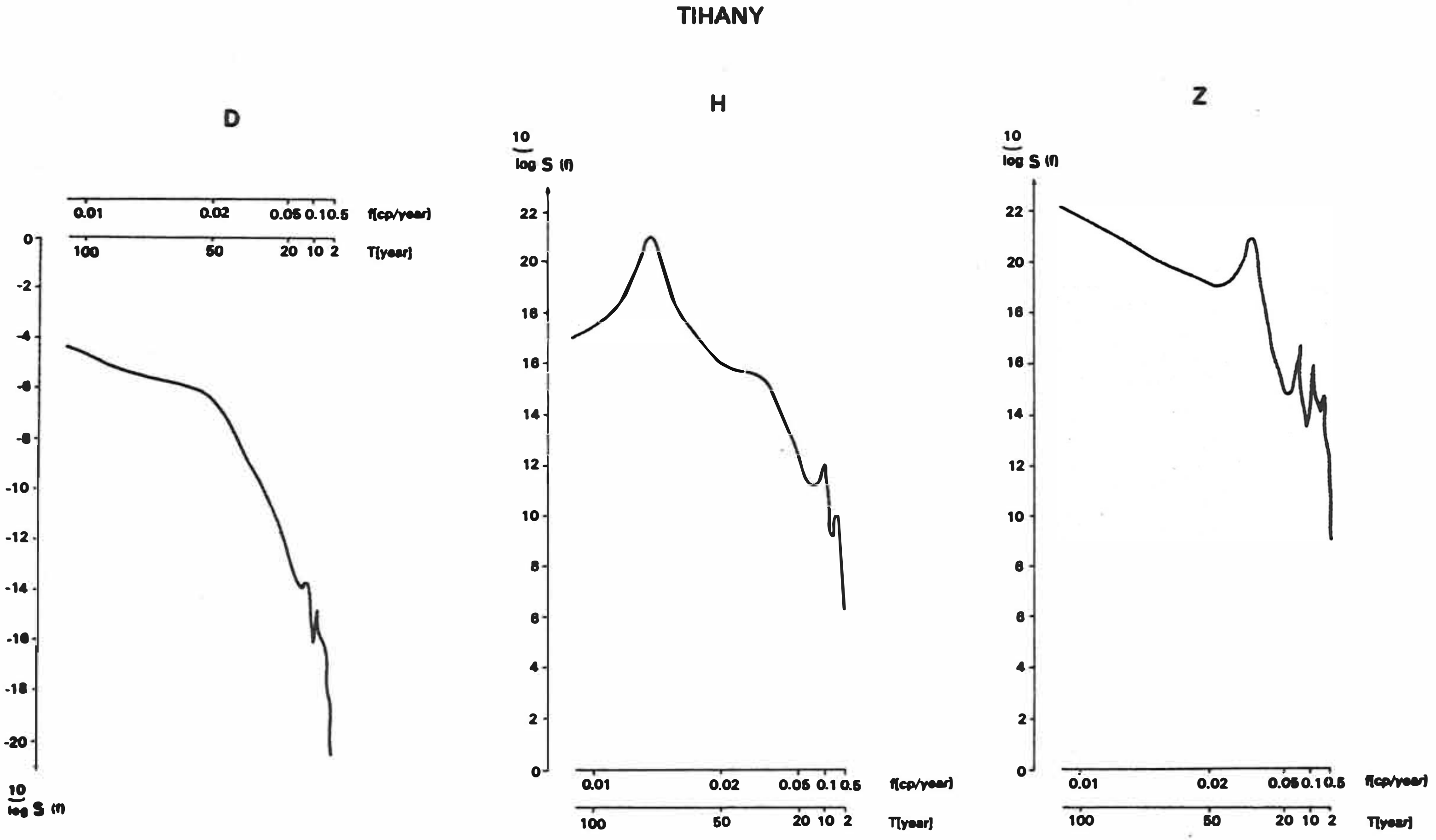

Fig. 6. The maximum entropy spectra of the D, H, Z components, from the Tihany data.

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A remark on the influence of a differential rotation of the Earth's core on the degree of axisymmetry of the magnetic field

Abstract

The processes generating the Earth's magnetic field considerably depend on whether or not a differential rotation takes place in the Earth's core, or in the core-mantle boundary layer. A differential rotation influences the axisymmetric and the non-axisymmetric part of the magnetic field in different ways. Compared with the axisymmetric part the non-axisymmetric part is subjected to an enhanced dissipation. Thus the deviation of a field from axisymmetry is reduced. By means of a simple model an estimate is given of this effect of differential rotation, and some consequences for the Earth's magnetic field are discussed.

Zusammenfassung

Die für das Magnetfeld der Erde verantwortlichen Vorgänge hängen stark davon ab, ob der Erdkern oder die Kern-Mantel-Grenzschicht eine differentielle Rotation aufweisen. Eine solche differentielle Rotation beeinflußt den zur Rotationsachse symmetrischen Anteil eines Feldes in anderer Weise als den nicht-symmetrischen. Verglichen mit dem symmetrischen, wird der nicht-symmetrische einer stärkeren Dissipation ausgesetzt. Damit wird die Abweichung des Feldes von der Symmetrie bezüglich der Rotationsachse verringert. Anhand eines einfachen Modells wird eine Abschätzung für diese Wirkung einer differentiellen Rotation gegeben, und es werden einige Folgerungen für das Magnetfeld der Erde diskutiert.

Резюме am Ende der Arbeit

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1.

When looking for processes in the Earth's interior, which could be responsible for the Earth's magnetic field, we encounter the question whether or not the core, or the core-mantle boundary layer, shows a differential rotation. No satisfactory answer to this question has been given up to now. In this paper we suppose a differential rotation to exist and discuss how it influences the degree of axisymmetry of the magnetic field. When speaking of axisymmetry we refer, of course, to the axis of rotation.

2.

As far as axisymmetric fields are concerned, the effect of differential rotation can easily be followed up. In the example depicted in fig. 1a we start from an axisymmetric dipole field which penetrates a sphere of electrically conducting fluid and continues in the free space outside. We suppose that the inner parts of the fluid rotate in the indicated way whereas the surface is at rest. This differential rotation leads to a winding-up of the field-lines. The resulting configuration may be understood as superposition of the original dipole field and two field belts with opposite orientation in the two hemispheres. The effect of differential rotation thus consists only in the generation of these field belts inside the sphere. In particular, the field outside remains unaffected.
With non-axisymmetric fields the influence of differential rotation is more complex. In the example depicted in fig. 1b we start from a dipole field the axis of which lies in the equatorial plane of the rotating sphere. The winding-up of the field lines provides a field pattern in which lines with opposite orientation lie closely together. In this way, of course, the dissipation of the field inside the sphere is enhanced, and then also the field in outer space is influenced. Supposed there is only a radial but no latitudinal shear of the fluid, this field retains its dipolar structure; of course, the field pattern will rotate in the sense of the fluid motion. Contrary to the axisymmetric case, however, the magnitude of this field is diminished by differential rotation.

Let us now assume that there is initially a dipole field with an axis showing some inclination against the axis of rotation. Decompos

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this field in two fields of the types considered before, we may easily study the influence of differential rotation.
The latter results in a reduction of the non-axisymmetric part of the field, i.e. there is a tendency towards axisymmetry. If again only a radial shear is considered, the field in outer space retains its dipolar structure. However, the inclination of the dipole axis becomes smaller. Furthermore, the magnitude of this field is diminished.
The statement that differential rotation reduces the deviation of a magnetic field from axisymmetry holds not only for dipole fields but can also be established for fields corresponding to higher multipoles.

2.
In order to give an estimate of the discussed effects of differential rotation on a magnetic field, some results for a simple model are presented. (For details see RÄDLER and ELSTNER [1])
We again consider a sphere of electrically conducting fluid which carries out a differential rotation, and suppose all surrounding of it to be free space. In a certain inner layer of this sphere a electromotive force is assumed such that, in absence of rotational shear, currents would be driven which produce a dipole field.
The inclination of the axis of this field against the axis of rotation is denoted by φ_0. As for the differential rotation a radial shear is assumed, i.e. the angular velocity, ω, increases or decreases with the radial coordinate, r. Then, of course, the field inside the sphere generally shows a complex pattern. Outside, however, it continues as a dipole field. We restrict our attention to the steady state. The inclination of the axis of this dipole field outside the sphere against the axis of rotation, denoted by φ, depends on the angle φ_0 and on the magnetic Reynolds number Rm.
The latter is defined by $Rm = \mu\sigma\Delta\omega R^2$, where μ and σ are magnetic permeability of free space and electrical conductivity of the fluid, $\Delta\omega$ is the difference of the angular velocities of the inner and the other parts of the sphere, and R is the radius of the sphere.
In fig. 2 some results are depicted for the case in which the electromotive force is concentrated in the layer $0.4 \leq r/R \leq 0.6$, and the rotational shear takes place in the layer $0.7 \leq r/R \leq 0.9$.

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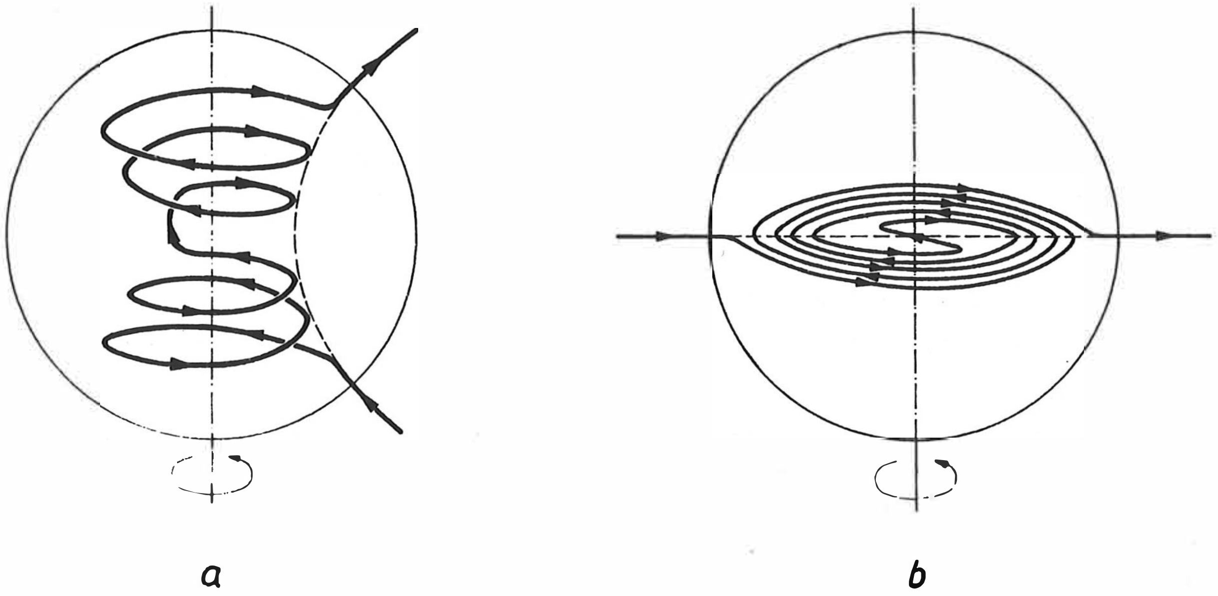

Fig. 1 The effect of differential rotation on axisymmetrical and non-axisymmetrical dipole fields. The initial field lines are depicted by dotted lines, the later field lines by solid lines.

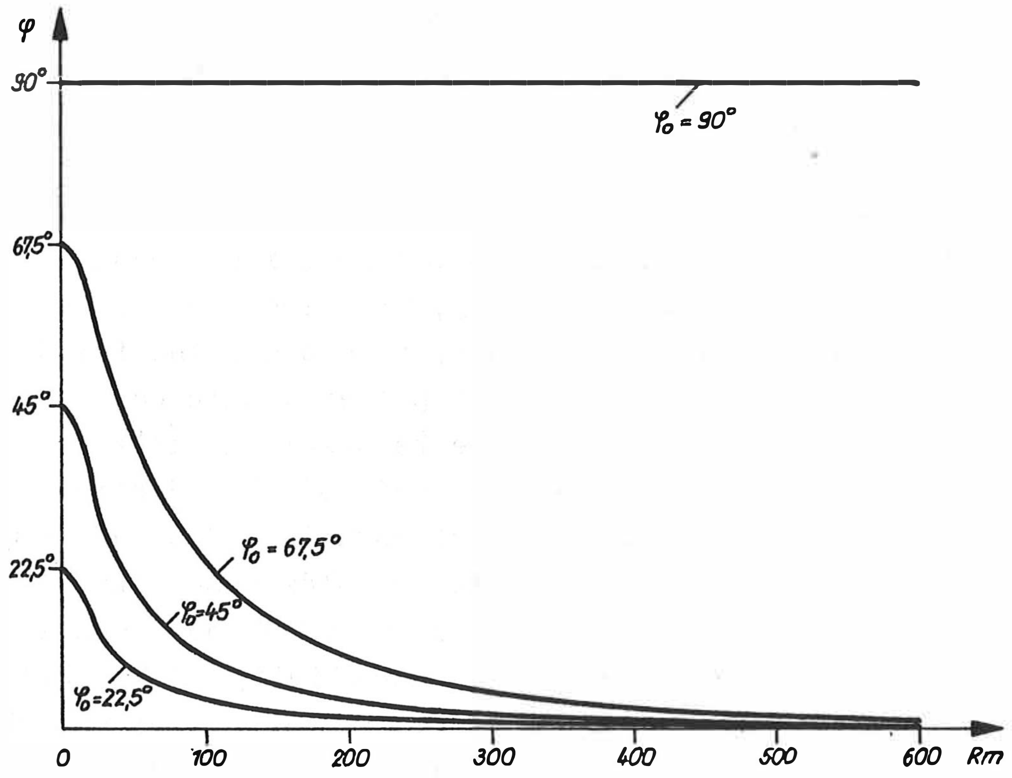

Fig. 2 The dependence of the inclination φ of the dipole axis on the angle φ_0 and the magnetic Reynolds number Rm.

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The magnitude of the dipole field outside the sphere may be described by the magnitude of the dipole moment. This quantity, scaled by its value in the case of vanishing rotational shear, is denoted by m. Then $m = 1$ for all φ_0, if $Rm = 0$. In general, m again depends on both φ_0 and Rm. For all φ_0, it decreases with increasing Rm, and it tends to $\cos\varphi_0$, as $Rm \to \infty$.

3.

Let us discuss the implications of these results for the Earth's magnetic field.

We imagine the sphere of conducting fluid considered so far to be the Earth's core. For an estimate of Rm, we put $\mu = \mu_{\text{vaçuum}} = 4\pi\cdot 10^{-7}\text{Hm}^{-1}$, $\sigma = 3\cdot 10^{5}\ ^{-1}\text{m}^{-1}$, $\Delta\omega = \varepsilon$ degrees/year, $R = 3\cdot 10^{6}\text{m}$, thus obtaining $Rm \approx 2\cdot 10^{3}\cdot\varepsilon$. It seems reasonable to assume that the difference of angular velocities of the inner and the outer parts of the core is comparable with the westward drift rate of the magnetic field. Putting $\varepsilon = 0.05 \ldots 0.2$, which corresponds to this drift rate, we obtain $Rm \approx 100 \ldots 400$.

As is well known a magnetic field due to a dynamo mechanism in the Earth's core can never be purely axisymmetric. It is at least worth discussing the possibility that the field strongly deviates from axisymmetry inside the core, and that its higher degree of symmetry outside the core is only due to a differential rotation in the outer layers of the core. Suppose, e.g., that the dynamo mechanism in absence of differential rotation generates a dipole field the axis of which shows an inclination of 45° against the axis of rotation. Even a differential rotation with $Rm = 100$ should be able to reduce the inclination outside the core to about 10°.

On the basis of mean-field theory several dynamo mechanisms for the Earth has been discussed. It may be of interest in this context that in the case of the α^2-mechanism not only axisymmetric but also non-axisymmetric mean fields are possible (see, e.g., KRAUSE and RÄDLER [2]). Even under conditions favouring the generation of non-axisymmetric mean fields inside the core, the differential rotation in an outer layer of the core may lead to a nearly axisymmetric field outside.

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The interpretation of paleomagnetic observations within the frame of plate tectonics is usually based on the assumption that the magnetic field of the Earth has always been of dipole type and that the dipole axis has always been nearly parallel to the axis of rotation. This assumption, however, is not imperative. It is noteworthy that each argument in favour of a differential rotation in the Earth's core supports this assumption.

The ideas presented are of interest not only for the Earth but also for other cosmical objects. There are a number of stars, the magnetic stars, with strong magnetic fields considerably deviating from symmetry with respect to the axis of rotation. This deviation must be interpreted as a hint that the outer layers of these stars possess no strong differential rotation.

References

[1] K.-H. RÄDLER and D. ELSTNER, Astronomische Nachrichten, in preparation

[2] F. KRAUSE and K.-H. RÄDLER, Mean-field Magnetohydrodynamics and Dynamo Theory, Akademie-Verlag Berlin 1980

Резюме

Процессы, порождающие геомагнитное поле, существенно зависят от наличия или отсутствия дифференциального вращения в ядре земли. Осесимметричная и несимметричная части магнитного поля изменяются дифференциальным вращением различным образом. Несимметричная часть подвергается большей диссипации, нежели симметричная. Таким образом, результирующее поле приближается к осесимметричному. простая модель используется для демонстрации симметризирующего действия дифференциального вращения. Обсуждаются последствия данного эффекта для геомагнитного поля.

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ON THE RECENT (1956-78) GEOMAGNETIC SECULAR VARIATION

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Abstract *)

Features of global geomagnetic secular variation for 12 epochs between 1956 and 1978 were studied using a four-dipole model corresponding in accuracy to a 5th degree spherical harmonic model. According to the model, the secular variation accelerated from 1956 to about 1970 and has subsequently slowed down. The variation was most rapid in Eurasia, where the positive $\dot{Z}$ focus near the Caspian Sea disappeared in about 1960 and a negative focus formed in southeast Asia and began drifting northeast. In about 1976 a positive $\dot{Z}$ focus was again forming near the Caspian Sea, indicating a cyclic variation in the isoporic patterns in Eurasia.

The areas of negative $\dot{Z}$ in the northern hemisphere and positive $\dot{Z}$ in the southern grew during 1956-70, and this was seen as an acceleration in the rate of decrease of the main axial dipole (g_1^0). This decrease is predicted to be slower in the near future.

1. *Introduction*

Yearly secular variations of the X, Y and Z components for 12 epochs between 1956 and 1978 from 43 to 76 geomagnetic observatories throughout the world were fitted into a model consisting of four radial and eccentric magnetic dipoles at a constant distance of $0.25R_e$ from the geocentre. The secular variation data used in the analysis were taken from catalogues published by FISHER (1976) and PUSHKOV and IVCHENKO (1979).

Six parameters were needed to characterize each dipole. Thus, the four-dipole model consisted of 24 coefficients (for details, see NEVANLINNA, 1980a, 1980b). The isoporic charts calculated from the model had a mean vector rms error (= $\sqrt{(\sigma_X^2 + \sigma_Y^2 + \sigma_Z^2)/3}$) of 9nT/y corresponding in accuracy to charts calculated from a 5th degree spherical harmonic analysis.

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*) "Zusammenfassung" and "Резюме" at the end of the paper

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The purpose of this paper is to demonstrate some typical features of the global and regional secular variation obtained from isoporic charts based on the four-dipole model.

2. *Isoporic field of* $\dot{Z}$

In order tostudy the features and trends in the recent geomagnetic secular variation, isoporic charts of $\dot{X}$, $\dot{Y}$ and $\dot{Z}$ were calculated for alternate years between 1956 and 1978. As an example, Fig. 1 shows isoporic charts of $\dot{Z}$ for the epochs 1856.0, 1968.0 and 1978.0. The typical features in these charts are the rapid intensification of the large Atlantic negative $\dot{Z}$ cell and the remarkable disappearance of the well-known Caspian positive $\dot{Z}$ cell. The shape of the isolines of the Atlantic cell has been rather stable, whereas in Asia and Australia there have been large changes in the isoporic lines.

Fig. 1 also shows that secular change in Eurasia has been cyclic with a period of about 20 years: in the mid-fifties and late seventies $\dot{Z}$ was positive over Asia, wheras in the mid-sixties it was negative, with a negative $\dot{Z}$ cell in central Asia.

In the northern hemisphere $\dot{Z}$ has developed towards negative values and in the southern towards positive ones. Using the terms of spherical harmonic analysis, this trend can thus be interpreted as an acceleration in the rate of decrease of the main axial dipole (g_1^0). Fig. 2 shows this in a more quantitative way. It depicts $\dot{g}_1^0$ for 1956-78 as derived from the coefficients of the four-dipole model. It can be seen that $\dot{g}_1^0$ increased from its long-term average value (NAGATA, 1965) of 15nT/y to 22nT/y in 12 years. By means of quadratic trend analysis of the calculated $\dot{g}_1^0$, the rate of g_1^0 is predicted to slow down and the predicted value of $\dot{g}_1^0$ for 1980 is 21nT/y.

3. *Isoporic field of* $\dot{X}$ *and* $\dot{Y}$

As shown in the previous chapter, the largest changes in the isoporic lines of $\dot{Z}$ were concentrated in central Asia. Thus the horizontal components, X and Y, can also be expected to change rapidly at some distance around the Asian $\dot{Z}$ focus. In general, there is a negative $\dot{Y}$ cell about 40° west of a negative $\dot{Z}$ focus and a positive $\dot{X}$ cell about 40° north (NEVANLINNA, 1980a). The decreasing trend of $\dot{Y}$ and increasing trend of $\dot{X}$ observed in Europe and

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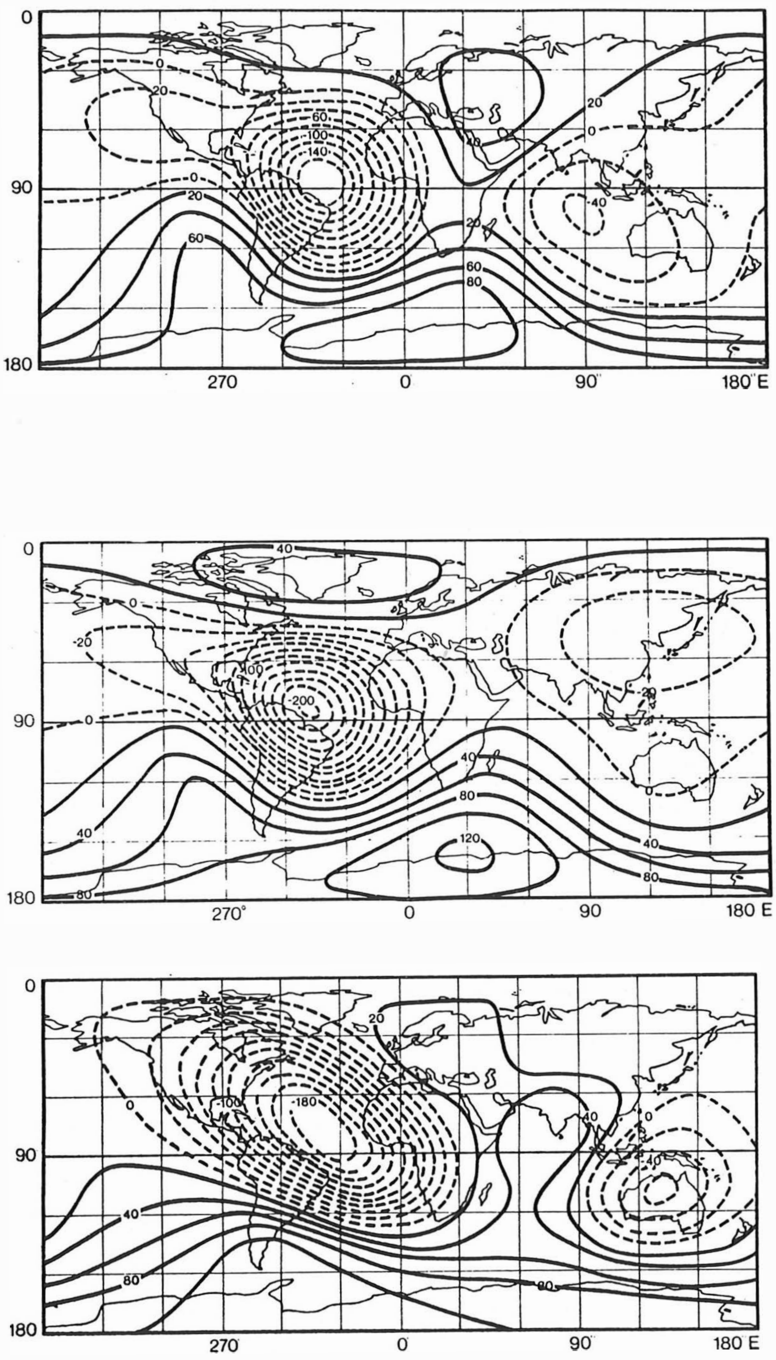

Fig. 1. The yearly secular variation of Z (with a contour interval of 20 nT/y) for the epochs 1956.0 (up), 1968.0 (mid) and 1978.0 (below) as calculated from the four-dipole model.

Solid lines: Z 0

Dotted lines: Z 0.

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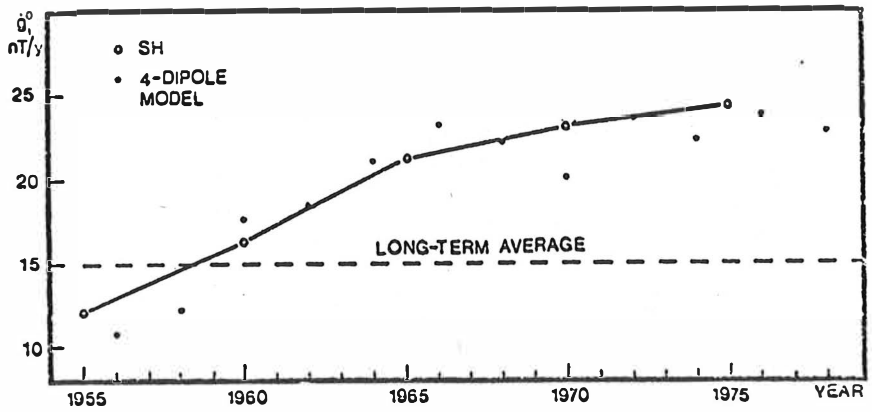

Fig. 2. $\dot{g}_1^0$ (solid circles) as calculated from the four-dipole model. The open circles denote $\dot{g}_1^0$ obtained from spherical harmonic (SH) models by MALIN (1969) for 1955.0 and 1960.0, MALIN and CLARK (1974) for 1965.0, HURWITZ et al. (1974) for 1970.0 and by PEDDIE and FABIANO (1976) for 1975.0.

western Asia during 1956-70 were thus connected with the negative $\dot{Z}$ cell in central Asia. The present increasing trend of $\dot{Y}$ and decreasing trend of $\dot{X}$ indicate a positive $\dot{Z}$ cell in central Asia. As can be seen in Fig. 1, a new positive $\dot{Z}$ cell is forming near India.

The changes in X and Y were also studied by plotting the zero isopores for alternate years between 1956-78 in the charts shown in Fig. 3. The figure shows that the zero line of $\dot{Y}$ drifted westwards from 1956 to about 1970. The total drift was about 60°. This period of westward drift corresponds to the change of $\dot{Z}$ from positive to negative in central Asia. After 1970 the drift was eastwards, corresponding to a change of $\dot{Z}$ from negative to positive in Asia. In $\dot{X}$ there was a northward drift up to 1970, after which the drift was southwards. The positions of the $\dot{X}$ and $\dot{Y}$ zero isolines are now roughly the same as they were in 1956, indicating a cyclic variation in the horizontal field, too, with a period of roughly 20 years.

The correlation between the changes in X and Y in Europe can be seen in Fig. 4, which depicts the yearly variation of X and Y recorded at the geomagnetic observatory Niemegk (GDR). It can be seen that $\ddot{Y} > 0$ indicates $\ddot{X} < 0$, and vice versa. It can also be seen that the variations in the horizontal components have a period of roughly 60 years. Thus the 20-year period found here may be only a subharmonic of the 60-year periodicity.

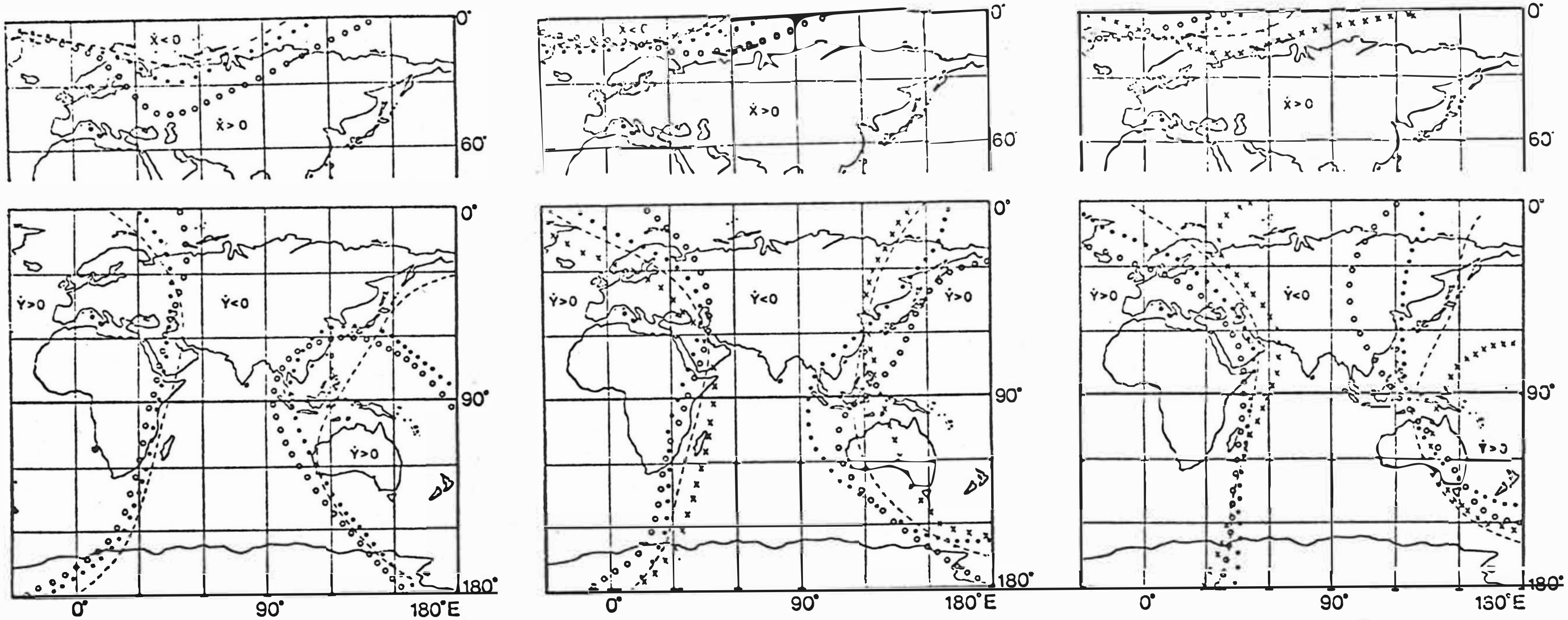

Fig. 3. Top: Zero lines of $\dot{X}$ obtained from isoporic charts based on the four-dipole model.

Below: Zero lines of $\dot{Y}$.

○ = 1956.0
• = 1958.0
— = 1960.0

○ = 1962.0
• = 1964.0
— = 1966.0
× = 1968.0

○ = 1970.0
• = 1972.0
— = 1974.0
× = 1976.0

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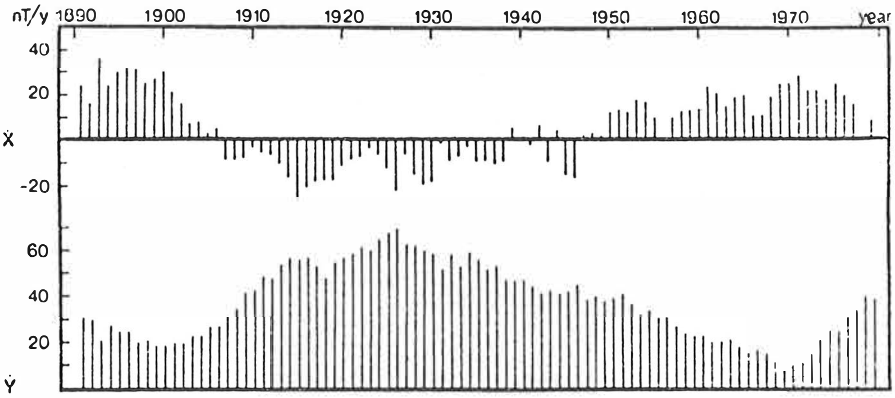

Fig. 4. Secular variation of X and Y at the Niemegk observatory (GDR) and its predecessors Seddin and Potsdam.

4. *Discussion*

The global secular variation during the last 25 years is typified by a rapid intensification, as measured by the spherical harmonic term $\dot{g}_1^0$. Another typical feature was the cyclic variation of $\dot{X}$, $\dot{Y}$ and $\dot{Z}$ isolines in Eurasia with a period of about 20 years.

Based on the isoporic charts, some qualitative predictions can be made about the trends of the geomagnetic field in the near future. Globally, the rate of decrease of the main axial dipole (g_1^0) is slowing down. The predicted value of $\dot{g}_1^0$ for 1980 is 21nT/y.

In Europe: $\dot{Y} > 0$ and $\ddot{Y} > 0$
$\dot{X} < 0$ and $\ddot{X} < 0$ in northern Europe
$\dot{X} \simeq 0$ and $\ddot{X} < 0$ in central and southern Europe
$\dot{Z} > 0$ and $\ddot{Z} \geq 0$

A new positive $\dot{Z}$ focus is forming near the Caspian Sea (40°N, 45°E) with a predicted focal intensity for 1980 of 60nT/y.

References

FISHER, M.P.: Annual means of geomagnetic elements since 1941. Natural Environment Research Council, Inst. of Geol. Sci., Geomagn. Bull., 6, 1976.

HURWITZ, L., FABIANO, E.B. and PEDDIE, N.W.: A model of the geomagnetic field for 1970.0. J. Geophys. Res., 79, 1716-1717, 1974.

MALIN, S.R.C.: Geomagnetic secular variation and its changes, 1942.5 to 1962.5. Geophys. J. R. astr. Soc., 17, 415-441, 1969.

MALIN, S.R.C. and CLARK, A.D.: Geomagnetic secular variation, 1962.5 to 1967.5. Geophys. J. R. astr. Soc., 36, 11-20, 1974.

NAGATA, T.: Main characteristics of recent geomagnetic secular variation. J. Geomagn. Geoelectr., 17, 263-276, 1965.

NEVANLINNA, H.: Interpreting regional geomagnetic anomalies and their secular change with the aid of radial dipoles and current loops. J. Geomagn. Geoelectr., 32, 13-36, 1980a.

NEVANLINNA, H.: Global geomagnetic secular variation from 1956 to 1976 as described by a four-dipole model. Geophysica, 14, 1980b (in press).

PEDDIE, N.W. and FABIANO, E.B.: A model of the geomagnetic field for 1975. J. Geophys. Res., 81, 2539-2542, 1976.

PUSHKOV, A.N. and IVCHENKO, M.P.: The summary of the annual mean values of magnetic elements at the world magnetic observatories. Vol. 14, IZMIRAN, Acad. of Sci. of the USSSR, 1979.

Zusammenfassung

Untersucht wurden Grundzüge der globalen geomagnetischen Säkularvariation (SV) von 12 Epochen von 1956 bis 1978, wobei ein 4-Dipol-Modell verwendet wurde, das in der Genauigkeit einem Kugelfunktionsmodell 5. Ordnung entspricht. Danach beschleunigte sich die SV von 1956 bis ca. 1970 und wurde dann langsamer. Die Variation war am schnellsten in Eurasien, wo der positive $\dot{Z}$-Quellpunkt am Kaspischen Meer etwa 1960 verschwand und ein negativer Quellpunkt in Südostasien entstand und nordöstlich zu driften begann. Ungefähr 1976 bildete sich am Kaspischen Meer erneut ein positiver $\dot{Z}$-Quellpunkt und bestätigte somit eine zyklische Variation in den Isoporen in Eurasien.

Die Gebiete von $\dot{Z}$-negativ in der Nord- und $\dot{Z}$-positiv in der Südhemisphäre nahmen von 1956 bis 1970 zu, und dies wurde als Beschleunigung der Abnahmerate des Hauptachsendipols (g_1^0) angesehen. Diese Abnahme soll in der nahen Zukunft langsamer werden.

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Аннотация

Изучены детали глобальной геомагнитной вековой вариации I2 эпох с I956 до I978 гг., применяя 4-дипольная модель, которая по точности соответствует сферической гармонической модели 5-ой степени. Согласно модели, вековая вариация ускорила с I956г. до приблизительно I970г. и после этого замедлялась. Вариация была скорее всех в Евразии, где положительный $\dot{z}$-фокус у Каспийского моря исчезал приблизительно в I960 году и негативный фокус, образованный в юго-восточной Азии, начал дрейфовать в северо-восточное направление. Приблизительно в I976 году у Каспийского моря снова образовался положительный $\dot{z}$ -фокус и подтвердил таким образом циклическую вариацию в изопорах в Евразии.

Области негативного $\dot{z}$ на северной и положительного $\dot{z}$ на южней гемисферах увеличивались с I956 до I970 гг., а это принималось за ускорение в отношении уменьшения главного осевого диполя / g_{I}^{0}/. Предсказывается, что уменьшение в ближайщее будущее замедляется.

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On spectral analyzing the time series of the geomagnetic field

Summary

The time variations of the geomagnetic field are to be attributed partly to external and partly to inner sources. The investigation of periodic constituents of the internal geomagnetic field has a great importance for studying and characterizing the physical process in the core-mantle region of the Earth.
Especially spectral-analytic methods as f.i. the maximum-entropy-method are qualified for determining harmonic constituents of more or less extended records beset by certain errors when in a first approximation the time series of the observed geomagnetic components can be supposed to be a realization of a stationary linear random process. There arises the problem of the significance of the determined periodicities and this has become a very essential one. Applying the different well-known spectral-analytic estimation methods to the geomagnetic time series result in variant behaviour of the corresponding spectra. The stability of the peaks in the different spectra and in relation to the used calculus as well as against the data interval could be used as an effective significance creterion. Methods for approximating and eliminating the about 60 year periodicity of high amplitude are essentially helpful for finding out the significant peaks.

Zusammenfassung

Die zeitlichen Variationen des geomagnetischen Feldes sind wie bekannt z.T. äußeren und z.T. inneren Quellen zuzuordnen. Dabei hat die Untersuchung der periodischen Anteile des geomagnetischen Innenfeldes große Bedeutung für die Erforschung und die Charakterisierung der physikalischen Prozesse im Kern-Mantel-Bereich der Erde.

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Insbesondere spektralanalytische Verfahren wie die Maximum-Entropie-Methode eignen sich zur Ermittlung harmonischer Konstituenten von mehr oder weniger langen, mit gewissen Fehlern behafteten Registrierungen, wenn die Zeitreihe der magnetischen Elemente in erster Näherung als Realisierung eines stationären linearen Zufallsprozesses aufgefaßt werden kann. Es zeigt sich, daß bei der Bestimmung der in der Zeitreihe enthaltenen Periodizitäten die Aussage über deren Signifikanz eine entscheidende Problematik darstellt. Die Anwendung der verschiedenen gebräuchlichen Spektralschätzverfahren auf die geomagnetische Zeitreihe ergibt ein unterschiedliches Verhalten der einzelnen Spektren. Die Stabilität der Peaks in den Spektren sowie gegenüber den Parametern des Kalküls und bei Veränderungen des Datenintervalls konnten als empirische Kriterien zur Beurteilung der Signifikanz der Peaks herangezogen werden. Methoden zur Erfassung und Eliminierung der mit prozentual großer Amplitude enthaltenen ca. 60-jährigen Periode tragen wesentlich zur Auffindung der signifikanten Peaks bei.

1. Introduction

Investigating the internal geomagnetic field as obtained from observatory data for time periodic constituents has a great importance for the investigation and characterization of the physical processes in the core mantle region of the Earth. Gaining knowledge of this field is an essential prerequisite for a further development of the theory of the hydromagnetic dynamo.

There are already several papers dealing with the investigation by spectral analysis of the geomagnetic field f. i. publications by CURRIE, 1973, 1974; COURTILLOT and LE MOUEL, 1976; COURTILLOT, LE MOUEL and MAYAUD, 1977; RADOSKI, FOUGERE and ZAWALICK, 1975, 1976; ALLDREDGE, 1977; PAPITASHVILI and ROTANOVA, 1979. The results show that in many cases the calculated spectra do not allow an unambiguous decision as to which of the peaks can be associated to significant periodicities. Furthermore the observatory data contain both the external and the internal field and the contributions of them cannot reliably be separated.

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Therefore the well-known solar cycle is represented in the spectrum as an essential time periodic constituent.
Certainly the data material as well as the methods and their algorithms applied by the individual authors are not always identical. Therefore, for making a contribution to the decision concerning the significance of the peaks in the spectrum, several methods were used simultaneously for a carefully selected data material, and different time series were compared for the observatories considered.

2. On the methods used

In a statistical sense, to a first approximation it is possible to consider the time series of the geomagnetic field to be a stationary linear random process, i. e. the mean value and the variance are assumed to be time-independent. According to World's decomposition theorem, a stationary linear random process is understood to be a superposition of a non-deterministic basic process and a deterministic process containing the harmonic components to be determined.
Accordingly the spectrum consists of the continuous spectrum of the basic process and the discrete line spectrum of the harmonic components, for the identification of which the methods of estimating power spectra are the suitable ones. The practical calculation of the power spectra of a stationary random process can be carried out by means of a Fourier transform of the autocovariance function. Since there is only a single realization of the process, according to the ergodicity principle the ensemble mean value taken over all of the possible realizations is replaced by the time average taken over a single realization of sufficient length. Since this realization has only a finite length, there arises the problem to estimate the spectral representation of the overall process as accurately as possible. By a finite number of discrete data points of the stationary time series one estimates the autocovariance function, which is unbiased but inconsistent. A smoothing operation in the time range which uses a window function yields a weakly consistent estimate.

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The Bartlett spectral istimation and the Maximum - Likelihood spectral estimation make use of a window function, the first of them of a triangular window function, where there are not objectively justifiable criteria for optimally determining the cut-off point, at which the window function becomes zero.
When calculating the maximum - likelihood spectral estimation, the time series is decomposed into individual sections and thereafter multiplied by a time-dependent window function. The quality of fitting the maximum - likelihood estimation to the data to be evaluated depends on the constancy of the model parameters contained. Especially time variations in the amplitude, phase and frequency may result in erroneous estimations.
For eliminating the influence of the error introduced by rigid window functions and using data-adaptive optimization criteria, the Maximum-Entropy-Method utilized the principle of maximum entropy in the sense of Shannon's information measure. An arbitrary but fixed number of data points of the autocovariance function is assumed to be exactly known, the remaining values being implicitly extrapolated in the sense of maximal entropy density. By way of example, the recursive solution of the Yule-Walker set of equations can be obtained by means of the correlation matrix. In this case the ME spectral estimate is obtained as the reciprocal amplitude spectrum of the first column of the correlation matrix.
With the use of the autoregressive modelling of the stationary random process, the autoregressive spectral estimation likewise leads to the Yule-Walker set of equations, being obtained in its generalized form as a reciprocal summary spectrum of all columns of the inverse correlation matrix. For each of the four spectral estimation methods applied, it is necessary to optimize the choice of the arbitrary but fixed number of data points, and hence of the length of the autocovariance function, being identical with the order of the autoregressive model.

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3. Data

The geomagnetic time series of the Niemegk observatory and of other European observatories were analyzed. For Niemegk semiannual, quaterly, and monthly means were used in addition to the annual means, so that it was possible to modify the frequency range from which conclusions are possible. Generally the available observatory data with high standard quality cover the interval from about the end of the last century to the present time, for Niemegk the time series started form 1890. All of the time series had to be trend-corrected before applying the procedure.

The magnetic elements are the components of a vector field for which a potential is supposed to exist. Therefore principially all the magnetic elements contain the same set of information about the sources of the internal field. Nevertheless the spectra were calculated for several components because there are influences being different to the field components e.g. measurement error, noise, constituents of the external field.

Since the signal contained in the time series is relatively weak the spectral-analytic methods and especially the ME-method are subject to considerable numerical instability in dependence of the condition of the corresponding system of equations. Furthermore the algorithm for solving this system of equations is susceptible to numerical influences. Consequently up to now there exist some algorithms and in the literature a lot of aspects are discussed by which the accuracy and the reliability of statements from ME method are influenced . (cf. SAITO, 1978; KANE, 1979; CHEN and STEGEN, 1974).

All the spectral analytic methods refered here demand stationarity of the process and of all its constituents as a necessity but this condition certainly is satisfied only to a first approximation or in a very limited way. Supposed long-periodic variations with a periodicity length of some hundreds of years had to be eliminated but because of the short time series this is impossible.

A very distinctly marked period of approximately 60 years with a relatively large amplitude in relation to all of the other periodicities is contained in the time series with about one period length. It was advantageous to eliminate it as much as possible.

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A piecewise linear trend correction as a first very rough approximation was useful, the break points were empirically determined from the curve of the time series. Forming empirically a time function with a period of about 60 years and subtracting it proved to be more convenient.

4. Results

The following figures illustrate some characteristical results by example for the X component taken from the set of calculated spectra. Period and frequency units are indicated on the abscissa. The frequency scale refers to the reciprocal value of the length of the scanning step of the time series. The ordinate shows a logarithmic amplitude scale. It should be noted that for the data adaptive spectra (ME and AR) there do not exist any amplitude relations being comparable with each-other. It is the distribution of the peaks from which conclusions are possible. However the area covered by the peaks represents some measure for the amplitude intensity.

Fig. 1 shows a comparison of the four calculated spectra for the time series of the yearly means for Niemegk, 1890-1978, X. You can suppose peaks for 9.5; 3.6 and 2.8 years besides the clear one for about 60 years.

Fig. 2 gives the same, being piecewise trend-corrected with wellobservable peaks at the same values 9.5; 3.6 and 2.8 years.

Fig. 3 shows the results for the time series of the semiannual means for Niemegk, 1890 - 1978, X, also piecewise trend-corrected and also containing these peaks.

Fig. 4 is referred to the time series of the quaterly means for Niemegk, 1890-1978, X, being piecewise, trend-corrected. The peaks occuring at a period of 1.0 year stands out markedly, especially in the ME-spectrum.

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Fig. 5 shows the results for the time series of the monthly means for Niemegk, X and compares the interval 1890-1978 with a uniform trend correction and 1947-1973 with a piecewice trend-correction. The peaks at 1.0 and 0.5 years stand out much more significantly in the last case.
Generally the information content of the ME and the AR spectra is much higher than that of the other two spectra used.

From the great number of analysis, or even from the examples presented here results that the appearance of the spectra, especially of the ME-spectrum, and hence the significance of the peaks critically depend on the choise of the length of the autocovariance function and on the order, respectively, of the autoregressive model in relation to the length of the time series.

Fig. 6 illustrates the role of this parameter very clearly.

Criteria proposed in the literature for the choise of the length of the autocovariance function, like those of, say, AKAIKE (1970) which do not work anyway, for short lengths of the time series ranging between 20 and 40 values, fail here. Therefore the stability of the peaks was tested by comparing the different spectra and when varying the length of the autocovariance function, by investigating the time series for different scanning steps which vary the information - containing frequency range, and by investigating different time intervals, and this stability was used as a criterion of significance. The obtained optimal length of the autocovariance function in relation to the length of the time series rather well agrees to the values resulting from a formula derived empirically by BERRYMAN (1978).
On the otherhand it turned out that the assumption of the stationarity of the process, being an essential one in all of the investigations, certainly is satisfied only to a first approximation or in a very limited way. As the case may be, this should not equally hold for all periodicities contained in the process.

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Tab. 1 compares the peaks occuring in the ME spectrum when the calculation is based on the data series for Niemegk, 1890-1978, or 1978-1890 and carried out by the Levinson-algorithm and by the Maxen-algorithm. The influences of the used algorithms and of the accurary of measurement data are evident. Since the ME method extrapolates the last part of the time series on the basis of the first M values and their information content changes in the accuracy of data have to be taken into consideration. Furthermore by table 1 the necessity is emphasized for evaluating the peaks in the calculated spectrum for their significance. The peaks occuring in the spectra had been assessed for significance by their stability behaviour with respect to the following aspects:

- different spectral-analytic estimation methods
- variation of the length of the used autocovariance function, i.e. the order of the autoregressive model
- displacement of the time series interval
- application of different trend corrections (uniform or piecewise linear trend function, parabolic trend)
- variation of the scanning step of the time series the calculations are based on (yearly, half yearly, quaterly and monthly means, respectively)
- orientation of the time series direction
- numerical algorithm
- rough elimination of the about 60-year periodicity.

Taking into account the mathematical assumptions used in the method and the method-specific problems described here, from our point of view the probable values for periodicities of the geomagnetic time series are given for 5 European observatories listed in table 2.

Since stationarity is only a first approximation for the real process the periodicity values can only be mean values. There is the necessity to estimate the deviation from stationarity. At present it is not possible to make any reliable statements about the range of errors for the presented periodicity values.

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Table 1: Niemegk, X, YM, peaks in the ME - spectrum

Levinson-alg.		Maxen-alg.
1890-1978	1978-1890	1890-1978
60.3	64.3	85.3 64.0
14.2		10.0
9.2		
6.1	7.9	
4.7	4.9	4.8
4.1	4.1	
3.6	3.5	3.8
3.2		
2.8	2.8	2.7
1.9		
1.0		

Table 2: Probable periods /y/ for 5 European observatories
(X component)

Observatory	periods /y/					
Sodankylae	11.1		4.4		3.6	2.8
Eskdalemuir	10.6			4.0	3.4	2.6
Witteveen	10.3		4.7	4.0		2.9
Niemegk	10.0		4.5		3.5	2.8
Chambon-la-Forêt	9.8	5.6	4.3		3.6	2.8

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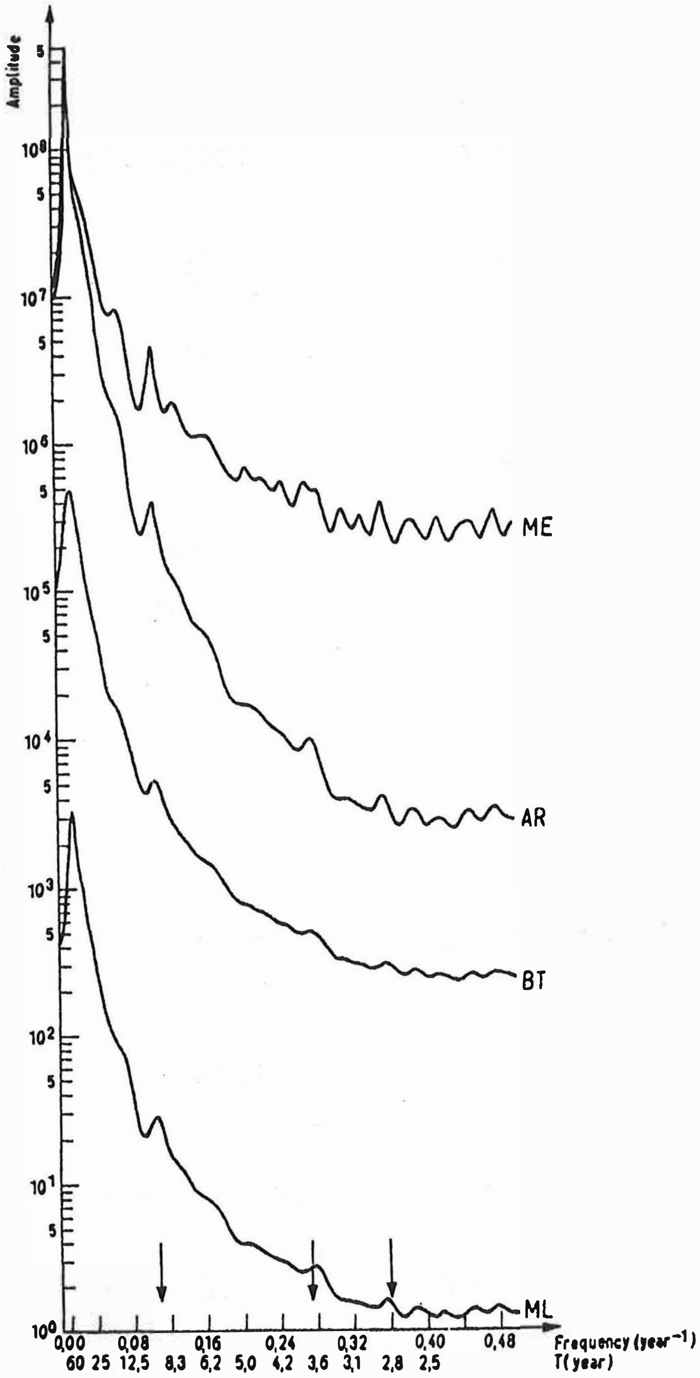

Fig. 1 Niemegk, 1890 – 1978, X, JM, LAKF = 50, comparison of spectra

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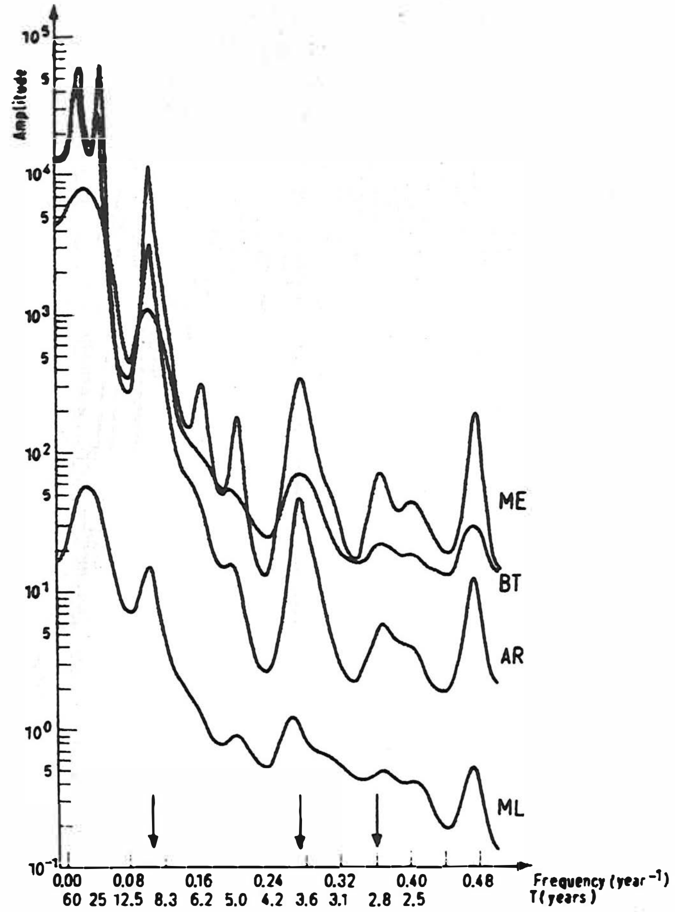

Fig. 2 Niemegk, 1890–1978, X, YM, LAKF = 30, piecewise trend correction, comparison of spectra

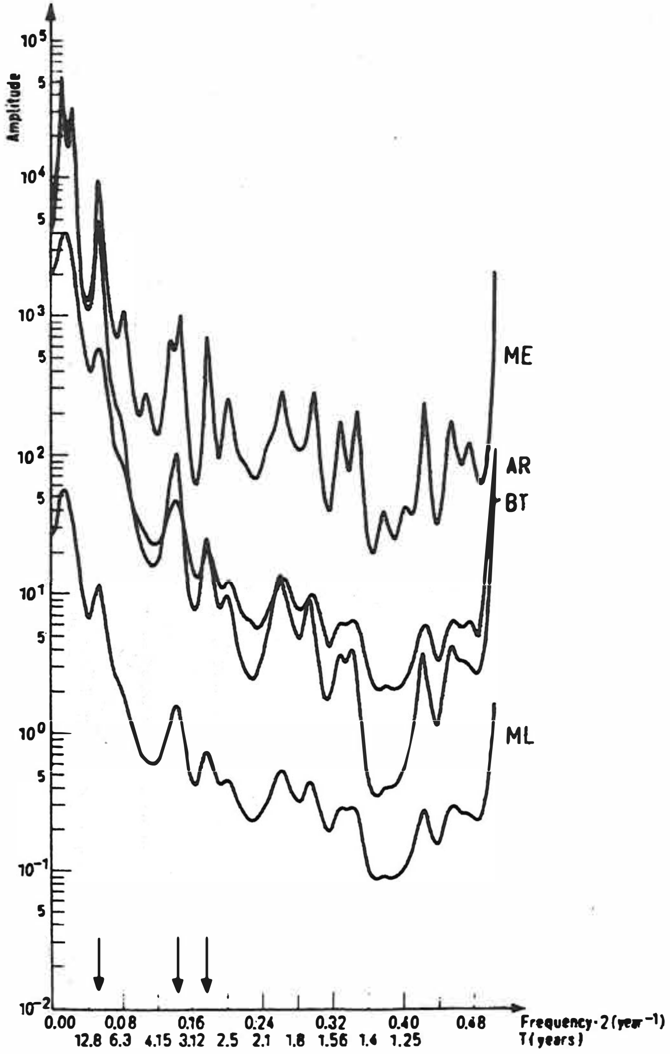

Fig. 3 Niemegk, 1890–1978, X, HYM, LAKF = 50 piecewise trend correction, comparison of spectra

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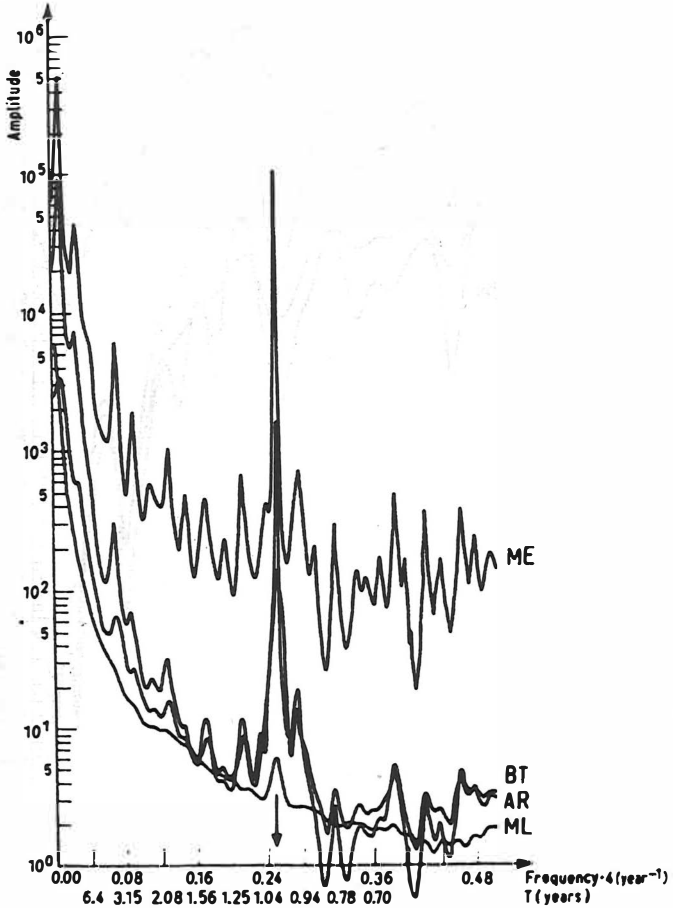

Fig. 4 Niemegk, 1890–1978, X, QuM, LAKF = 70, piecewise trend correction, comparison of spectra

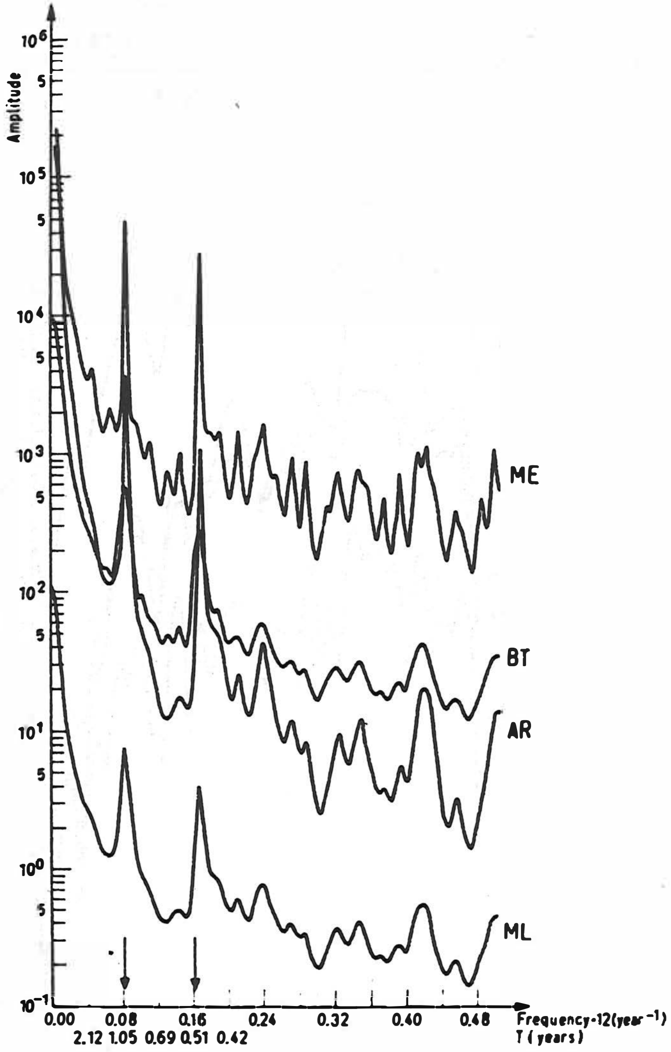

Fig. 5 Niemegk, 1947–1978, X, MM, LAKF = 70, comparison of spectra

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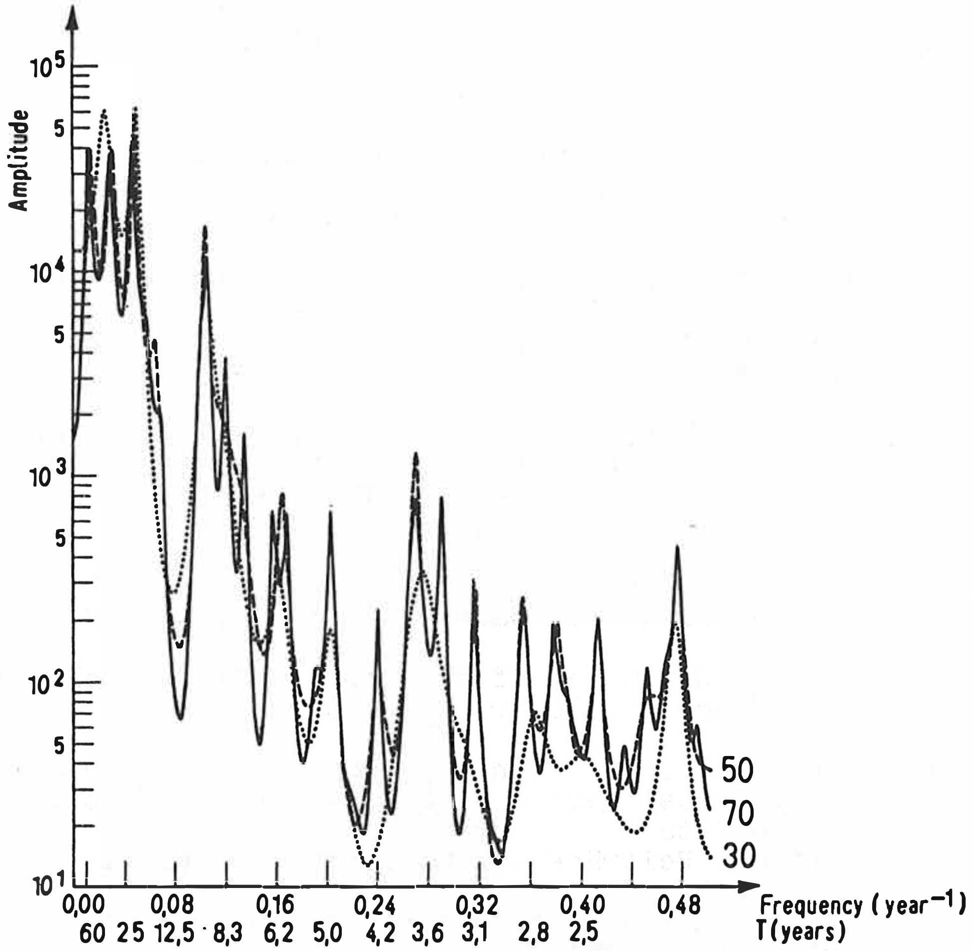

Fig. 6 Niemegk, 1890 – 1978, X, JM, ME – spectrum, piecewise trend correction, LAKF = 70; 50; 30

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References

AKAIKE, H., 1970. Statistical predictor identification Ann. Inst. statist. Math. 22, 203-217.

ALLDREDGE, L.R., 1977. Geomagnetic variations with periods from 13 to 30 years. J. Geomag. Geoelectr. 29, 123-135.

BERRYMAN, J.G., 1978. Choice of operator length for maximum entropy spectral analysis Geophysics 43 No. 7, 1384-1391.

CHEN, W.Y.; STEGEN, G.R., 1974. Experiments with maximum entropy power spectra of sinusoids J. Geophys. Res. 78 No. 20, 3019-3022.

COURTILLOT, V., LE MOUEL, J.-L., 1976. On the long-period variations of the Earth's magnetic field from 2 months to 20 years J. Geophys. Res. 81 No. 17, 2941-2950.

COURTILLOT, V., LE MOUEL, J.-L., MAYAUD, N., 1977. Maximum entropy spectral analysis of the geomagnetic activity index aa over a 107-year interval. J. Geophys. Res. 82 No. 19, 2641-2649.

CURRIE, R.G., 1973. Geomagnetic line spectra - 2 to 70 years Astrophysics and Space Sciences 21, 425-438.

CURRIE, R.G., 1974. Harmonics of the geomagnetic annual variation J. Geomag. Geoelectr. 26, 319-328.

JACOBS, F., WEBERS, W., . On applying various spectral-analytic estimation methods to geomagnetic observation data. Gerlands Beiträge zur Geophysik, in print

KANE, R.P., 1979. Maximum entropy spectral analysis of some artificial samples. J. Geophys. Res. 84 No. A3, 965-966.

RADOSKI, H.R., FOUGERE, P.F.; ZAWALICK, E.J., 1975. A comparison of power spectral estimates and applications of the maximum entropy method. J. Geophys. Res. 80 No. 4, 619-625.

RADOSKI, H.R.; ZAWALICK, E.J., FOUGERE, P.F., 1976. The superiority of maximum entropy power spectrum techniques applied to geomagnetic micropulsations. Physics Earth Planet. Int. 12, 208-216.

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SAITO, M., 1978. Possible instability in the Burg maximum entropy method.
J. Phys. Earth 26, No. 2, 123-128.

WEBERS, W., 1980. Die Frequenzanalyse geomagnetischer Variationen als Vorstufe zur geophysikalischen Interpretation.
Geodätisch Geophysikal. Veröff. NKGG der DDR, Reihe III H. 45, 135-146.

WIELADEK, R., BROMEK, A., OSTROWSKI, J., 1975.
Modified maximum entropy method of determining power spectra of stationary processes.
Publ. Int. Geoph. Pol. Ac. Sci. 96, 3-32.

PAPITASHVILI, N.E., ROTANOVA, N.M., 1979.
Metod maksimal'noi êntropii i ego primenenie k analizu vremennych rjadov geomagnitnogo polja.
Geomagnetism i a‿êronomija 19 № 3, 543-550

Резюме

Временные вариации геомагнитного поля подчиняемы отчасти внешним и отчасти внутренним источникам. При этом изучение периодических долей геомагнитного внутреннего поля имеет большое значение для исследования и характеризации физических процессов в ядерно-мантийной области Земли. Особенно спектрально-аналитические методы, как метод максимум энтропии, выгодны для определения гармонических составных частей более или менее длинных регистраций с определенными ошибками, когда временной ряд магнитных элементов в первой аппроксимации принимается за реализацию стационарного линейного случайного процесса. Оказывается, что при определении содержанных во временном ряду периодичностей высказывание о его значимости представляет значительную проблему. Применение разных употребительных спектральных определяющих методов на геомагнитный временной ряд установило разное поведение спектров. Стабильность пиков в спектрах и по отношению к параметрам вычисления и при изменениям интервала данных можно было использовать как эмпирические критерия для определения значимости пиков. Методы по сбору и элиминации 60-летнего периода с большой амплитудой значительно содействуют в нахождении значимых пиков.

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Die Sonnenaktivität (R) und ihr Einfluß auf die geomagnetische Aktivität (A_K) auf Grund der Jahresmittelwerte im Zeitabschnitt 1891 - 1975

Zusammenfassung

Im Durchschnitt ist die geomagnetische Aktivität im elfjährigen Fleckenzyklus dauernd, aber mäßig durch 8 Jahre spürbar, die restlichen 3 Jahre ist sie aber minimal.

Diese verlängerte geomagnetische Aktivität verursacht aber bei Ausführung der Bussolenmessungen mit Magnetnadeln der praktischen Empfindlichkeit ± 2′ keine wesentlichen Schwierigkeiten; für ihre Ausführung müssen wir nur das passendste Zeitintervall auswählen, so daß Vormittags- und Nachmittagsverlauf der Deklinationskurve mit einer Geraden approximierbar ist.

Die Analyse des Risikos solcher Bussolenmessungen betrifft die sechs Monate dauernde Sommersaison von April bis September in den mittleren Breiten der Nordhalbkugel.

Резюме

В среднем геомагнитная активность в II-летнем цикле частотности солнечных пятен постоянно, но умеренно заметна в течении 8-и лет, а за остальные три года она минимальна.

Однако, эта удлиненная геомагнитная активность не вызывает при проведении компасных измерений магнитными иглами практической чувствительности ± 2' никаких особенных трудностей, если только для их проведения выбрать подходящий промежуток времени, когда части деклинационной кривой первой и второй половин дня можно приблизительно определить прямой.

Анализ риска проведенных таким способом компасных измерений относится к шестимесячному летнему сезону с апреля по сентябрь на средних географических широтах северного полушария.

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Summary:

On the average the geomagnetic activity within a 11-year cycle of the sunspots frequency is perceptable permanently although moderately during 8 years while being minimal during 3 other years.

This prolonged geomagnetic activity does, however, not entail any particular difficulties when compass measurements are carried out by means of magnetic needles possessing a practical sensetivity of ± 2', if for this purpose a suitable time interval is chosen when the forenoon and the afternoon part of the declination curve may be approximated with a straight line.

The analysis of the risk of compass measurements carried out in this way refers to the six months summer season from April to September on middle geographic latitudes of the northern hemisphere.

Bei der Darstellung der Sonnenaktivität berufen wir uns nur auf die Häufigkeit der Sonnenflecken, da ja bei Erforschung der Naturerscheinungen gut organisierte und langfristige Beobachtungen von größter Bedeutung sind. Aus Veröffentlichungen der Eidgenössischen Sternwarte Zürich-Schweitzerland stehen uns die tadellos lückenfreie Daten über Jahresmittelwerte der Wolfschen Sonnenflecken-Relativzahlen R schon ab 1849 weiter zur Verfügung.

Aus dem Verlauf der Jahresmittelwerte der Relativzahlen R ist grob die zeitliche Periodizität des elfjährigen Zyklus der Sonnenflecken und dadurch im überwiegenden Maße auch die Sonnenaktivität zu ersehen.

Die Fleckenzyklen sind mit laufenden Nummern gekennzeichnet und schließen den Verlauf zwischen zwei Minima ein; Wie aus der Tabelle 1 zu ersehen ist, die elfjährige Periodizität ist nicht streng und sie dauert grob genommen von 9 bis 14 Jahre mit einem Durchschnittwert cca 11 Jahre.

Die geomagnetische Aktivität drückt man auf Grund der Potsdamer-Kennziffern K_1 als Jahresmittelwert der maximalen Amplituden-Schwankungen A_K der geomagnetischen Störungen aus. Diese Jahresmittelwerte A_K sind von 1956 bis 1975 aus alljährlichen Berichten des Adolf-Schmidt-Observatoriums für Erdmagnetismus in Niemegk, DDR berechnet; für den Zeitabschnitt 1891-1955 wurden

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Tabelle 1

R_{min}	Jahre der Minima	Zyklen Nummer	Dauer eines Zyklus in Jahren	Jahre der Maxima	R_{max}
9,6	1755				
		1	11	1761	85,9
11,4	1766				
		2	9	1769	106,1
7,0	1775				
		3	9	1778	154,4
10,2	1784				
		4	14	1787	132,0
4,1	1798				
		5	12	1804	47,5
0,0	1810				
		6	13	1816	45,8
1,8	1823				
		7	10	1830	71,0
8,5	1833				
		8	10	1837	138,3
10,7	1843				
		9	13	1848	124,3
4,3	1856				
		10	11	1860	95,7
7,3	1867				
		11	11	1870	139,1
3,4	1878				
		12	11	1883	63,7
6,3	1889				
		13	12	1893	84,9
2,7	1901				
		14	12	1905	63,5
1,4	1913				
		15	10	1917	103,9
5,8	1923				
		16	10	1928	77,8
5,7	1933				
		17	11	1937	114,4
9,6	1944				
		18	10	1947	151,6
4,4	1954				
		19	10	1957	190,2
10,2	1964				
		20	12	1968	106,5
12,6	1976				
			221		

aber die Jahresmittelwerte A_K auf Grund der „trockenen" drei-stündlicher Potsdammer-Kennziffern K_1 veröffentlichten in Tätigkeits-Publikationen der erdmagnetischen Observatorien Potsdam, Seddin und Niemegk unter der Berücksichtigung des lokalen Schlüssels von Niemegk für die Größe der Amplitude a_K

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vom Autor dieses Beitrages nachgerechnet: Tabelle 2 !

Jahresmittelwerte A_K

Tabelle 2

Jahr	A_K	Jahr	A_K	Jahr	A_K	Jahr	A_K
1891	10,0	1916	12,1	1941	14,6	1966	10,2
2	13,9	7	11,1	2	13,4	7	12,3
3	10,5	8	13,6	3	16,0	8	12,6
4	13,1	9	14,2	4	11,0	9	10,3
95	11,5	1920	11,3	1945	-	1970	10,4
6	11,2	1	11,1	1946	-	1	10,6
7	8,3	2	11,7	7	14,6	2	11,0
8	9,1	3	7,0	8	13,9	3	14,2
9	7,9	4	6,9	9	12,9	4	16,4
1900	4,6	25	8,4	1950	14,9	1975	12,5
1	3,7	6	12,9	1	17,4		
2	3,7	7	11,1	2	16,9		
3	6,5	8	12,1	3	13,6		
4	6,5	9	12,4	4	10,5		
05	8,0	1930	17,6	55	10,9		
6	7,1	1	11,1	6	14,8		
7	9,4	2	11,8	7	16,4		
8	11,0	3	10,4	8	16,3		
9	10,5	4	8,1	9	18,1		
1910	11,0	35	9,5	1960	19,0		
1	10,2	6	8,3	1	12,9		
2	5,5	7	10,0	2	12,4		
3	5,0	8	13,0	3	11,9		
4	6,9	9	13,6	4	10,3		
1915	9,7	1940	12,6	1965	8,6		

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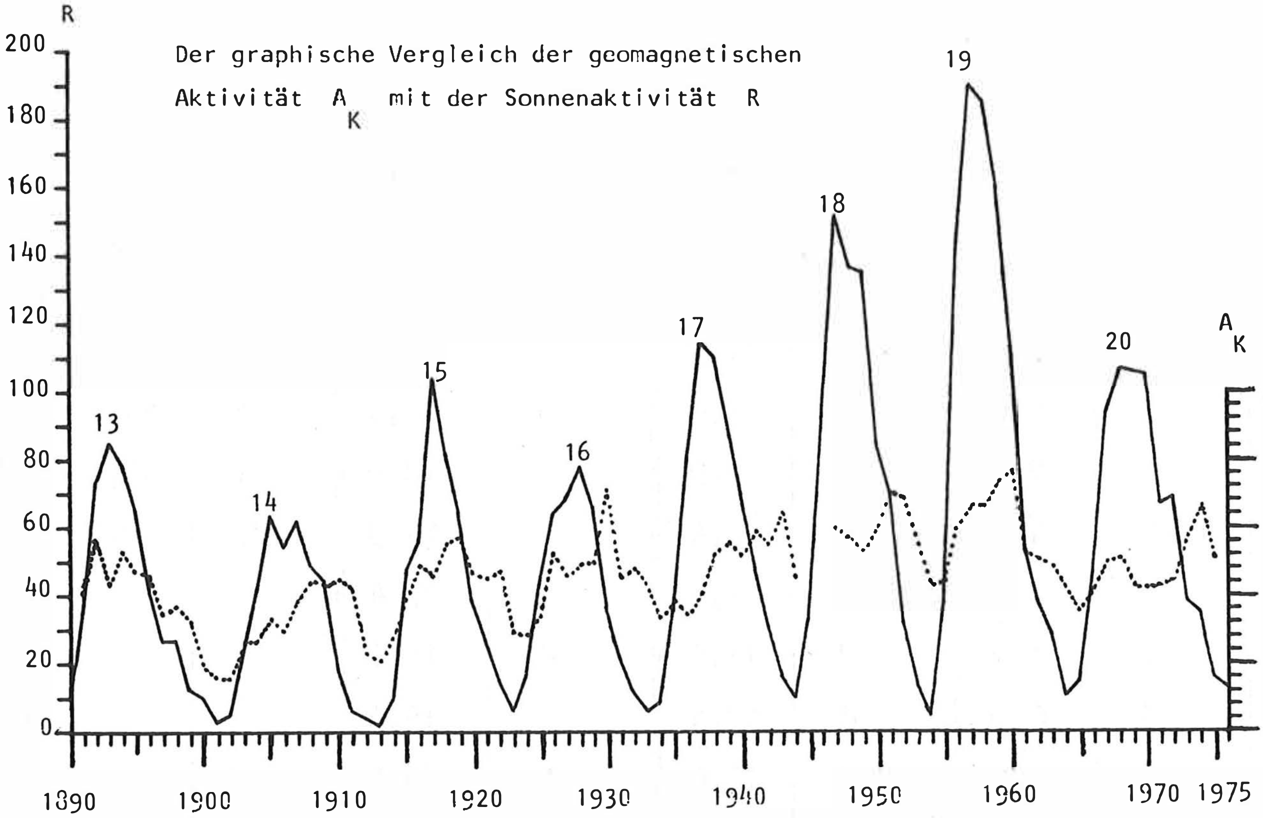
Die beiden Aktivitäten sind graphisch dargestellt. Es fehlen nur die Jahre 1945 und 1946, denn die Registrierungen der geomagnetischen Aktivität wurden am Ende des zweiten Weltkrieges Anfang April 1945 unterbrochen und Ende Februar 1946 wieder aufgenommen, da die Standard-Magnete „verlorengegangen" sind.



Aus dem graphischen Vergleich der beiden Aktivitäten in den letzten acht elfjährigen Zyklen ist zu ersehen, daß die geomagnetische Aktivität immer rückständig ist, was eine verspätete Reaktion auf der Erde bedeutet: Tabelle 3 !

Im Durchschnitt verzögern sich die Maxima der geomagnetischen Aktivität um 3 bis 4 Jahre gegenüber den Maxima der Sonnenaktivität, andererseits fallen die Minima hauptsächlich zusammen.

Das bedeutet, daß der Sonnenwind als korpuskulare Strahlung auch bei nachlassender Sonnenaktivität noch immer anwesend ist.

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Tabelle 3

Zyklen Nummer	Jahre der Maxima R_{max}	Jahre der Maxima $A_{K_{max}}$	△ max	Jahre der Minima R_{min}	Jahre der Minima $A_{K_{min}}$	△min	Dauer der geomag./ minimaler Aktivität in Jahren	
13	1893	1892	- 1	1901	1901	0	9	3
14	1905	1910	+ 5	1913	1913	0	9	3
15	1917	1919	+ 2	1923	1924	+ 1	8	3
16	1928	1930	+ 2	1933	1934	+ 1	8	3
17	1937	1943	+ 6	1944	--	-	7	-
18	1947	1951	+ 4	1954	1954	0	7	2
19	1957	1960	+ 3	1964	1965	+ 1	8	3
20	1968	1974	+ 6				9	
			+27:8≙3,4				65:8≙8	17:6≙3

So ist im Durchschnitt auf einen elfjährigen Zyklus die geomagnetische Aktivität dauernd, aber mäßig durch 8 Jahre spürbar, die restlichen 3 Jahre ist sie aber minimal.

Diese verlängerte geomagnetische Aktivität verursacht aber bei Ausführung der Bussolenmessungen mit modernen Magnetnadeln der praktischen Empfindlichkeit ± 2′ keine wesentlichen Schwierigkeiten. Solche zwei Bussoleninstrumente der laboratorischen Empfindlichkeit ± 1′ sind: Bussolen Theodolit Wild TO, Heerbrugg, Schweitzerland und die neueste Orientierungsbussole VEB Carl Zeiss JENA, des Erfinders Dr.A.Grafe von dem Adolf-Schmidt-Observatorium für Erdmagnetismus in Niemegk, DDR.

Für die Ausführung solcher Bussolenmessungen der erhöhten Genauigkeit müssen wir in sechs Monate dauernden Sommersaison vom April bis September in den mittleren Breiten der Nordhalbkugel nur das passendste Zeitintervall im bezug auf die tägliche periodische S_q-Variation und zwar vormittags zwischen 9 und 13 Uhr und nachmittags zwischen 15 und 18 Uhr nach Ortszeit auswählen !

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Dadurch weichen wir den beiden Sommerextremen des Verlaufs der magnetischen Deklinationskurve aus und stellen uns in den Zeitabschnitt mehr oder weniger gleichmäßiger Änderung, wo wir in überwiegender Mehrheit der Fälle den Vormittagsteil und den Nachmittagsteil der Deklinationskurve im Verhältnis zur praktischen Empfindlichkeit der Magnetnadel ohne weiteres mit einer Gerade approximieren können.

So kommen wir in Grenzen der praktischen Genauigkeit der Magnetnadel viel näher dem Verlauf der Deklinationskurve, als mit Monats- oder sogar mit Saisonkurve.

Für die Ausführung von praktischen Bussolenmessungen ist die ausgeglichene Kurve nicht maßgebend, sondern ihr tatsächlicher Tagesverlauf, dem sich die Beobachtungen am meisten anpassen.

Dabei können uns nur die täglichen aperiodischen Variationen der magnetischen Deklination stören. Diese zerstören in kleinerem oder größerem Maße den ruhigen Verlauf der S_q-Variation und sind vorwiegend von der Sonnenaktivität abhängig. Und in diesen aperiodischen Variationen der magnetischen Deklination steckt hauptsächlich das Risiko solcher Bussolenmessungen.

Auf Grund des Archivs ausgezeichnet gut erhaltenen Deklinations - magnetogramme der Observatorien Potsdam, Seddin und Niemegk habe ich den täglichen Verlauf der S_q-Variation in beiden für die Bussolenmessungen passendsten Zeitintervallen für den Zeitabschnitt von 85 Jahren (1891 - 1975) annalysiert und auf Grund der 31 110 Daten habe ich schließlich das gesamte Bild des Risikos festgestellt:

Auf Zeitabschnitt von 85 Jahren (1891 - 1975) kommen in sechs Saisonmonaten vom April bis September vormittags im vierstündigen Zeitintervall im Durchschnitt nur je drei (3) Totalstörungen vor oder eine (1) Totalstörung auf zwei Monate, nachmittags aber im dreistündigen Zeitintervall im Durchschnitt sechs (6) Totalstörungen vor oder eine (1) Totalstörung auf Monat; in diesen Fällen sind wir gezwungen die Bussolenmessungen wegzuwerfen.

Solcher Störungen, die uns die Bussolenmessungen wegen der Langsamkeit des Verlaufs der Änderung zwar nicht umwerfen, wir müssen uns aber hinsichtlich ihrer Berücksichtigung an die Magnetogramme

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des nächststehenden Observatoriums anlehnen, falls wir aber von dem allzuviel entfernt sind, an die selbst organisierte Begleitung der Momentanwerte des Verlaufs der magnetischen Deklination mit einem stationierten modernen Bussolen-Theodolit, sind vormittags im vierstündigen Zeitintervall im Durchschnitt fünf (5) und nachmittags im dreistündigen Zeitintervall im Durchschnitt vier (4) in einem Saisonmonat. Hier gibt es keinen wesentlichen Unterschied in der Häufigkeit zwischen Vormittags- und Nachmittagsstörungen, wann die Deklinationskurve mit einer Gerade nicht approximierbar ist.

In allen anderen Halbtagen kommt aber in 83% (25 766 untersuchten Fällen) in Betracht die Approximation des Verlaufs der Deklinationskurve mit einer Gerade, was beweist, daß das vorgeschlagene Verfahren der Korrigierung genug berechtigt ist. Dieses Verfahren der Reduktion der magnetischen Azimute in die orientierten verlangt nebst schon bei dem Theodolitenpolygon üblichen Koordinaten- und Richtungsanschluß nur noch protokollarisches Notieren auf Minute genau der ausgeführten Beobachtung nebst Datum.

Für die praktischen Messungen sind noch zwei Daten außer Durchschnitt interessant.

Im Zeitabschnitt von 85 Jahren haben wir vormittags im vierstündigen Zeitintervall :

15 Jahre ohne Totalstörungen,
20 Jahre mit je einer Totalstörung,
10 Jahre mit je zwei Totalstörungen und
7 Jahre mit je drei Totalstörungen,

also zusammen 52 Jahre, die in Durchschnitt bis drei (3) Totalstörungen pro Saison fallen.

Im Zeitabschnitt von 85 Jahren haben wir nachmittags im dreistündigen Zeitintervall :

5 Jahre ohne Totalstörung,
5 Jahre mit je einer Totalstörung,
10 Jahre mit je zwei Totalstörungen,
11 Jahre mit je drei Totalstörungen,
8 Jahre mit je vier Totalstörungen,
4 Jahre mit je fünf Totalstörungen und
11 Jahre mit je sechs Totalstörungen,

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also zusammen 54 Jahre, die in Durchschnitt bis sechs (6) Totalstörungen pro Saison fallen.

Das alles spricht wiederholt für Trennen der Ausführung der Bussolenmessungen an Vormittag und Nachmittag.

Die größte Häufigkeit 17 Totalstörungen pro Saison tritt vormittags einmal (i.J. 1930), je 20 Totalstörungen pro Saison aber dreimal (i.J. 1930., 1951. und 1952.) an.

Es drängt sich noch die Frage auf, tretten die Totalstörungen pro Saison auch paar Tage hintereinander auf ? :

je zwei (2) Tage hintereinander elfmal,
je drei (3) Tage hintereinander viermal,
je vier (4) Tage hintereinander einmal und
je fünf (5) Tage hintereinander einmal.

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SECULAR VARIATIONS AT STATIONARY FIELD AND DURING REVERSALS

Summary

The detail investigations of Matuyama-Jaramillo reversal show the presence of 600-year secular variation. The amplitude of these SV changes sharply during the reversal. It seems that the VGP shelf during the reversal is connected with these SV.

Резюме

Точные исследования обращения Матуяма-Ярамилло показывают существование 600-летней вековой вариации. Кажется, что шельф во время обращения связан с этими вековыми вариациями.

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Zusammenfassung

Detaillierte Untersuchungen der Matuyama-Jaramillo-Umkehrung zeigen das Vorhandensein einer 600-jährigen Säkularvariation. Es wird vermutet, daß das VGP-Schelf während der Umkehrung mit diesen Säkularvariationen verbunden ist.

Secular variations of geomagnetic field can be divided into four groups differing by their physical nature [1]. The shortest SV with the periods less than 30 years are referred to torsion variations. Variations of 60 till 3000 years refer to the second class. The report is devoted to the latest.

Then there is revealed variation with the period of 8,5-10 th. years, representing dynamo-mechanism own oscillation. In such a way it is considered theoretically. As the variation period is limited for the processes in the core variations with the period of more than 10 th.years are referred to the fourth class, more reliably known the variation of the order of 200 th.years. The causes of such variations are to be searched outside the core. Possibly, it is the influence of processes in the mantle on dynamo-mechanism work; characteristic time of 10^5 years allows such a supposition. Another variant is possible - the influence of outer Earth processes, connected with Earth movements and Solar activity.

Spectrum of the second class variation is discrete and includes the variations of 60, 360, 600, 900, 1200, 1800 and 3000 years. These variations are considered either as MAC-waves, i.e. inalientable part of hydromagnetic dynamo or as a result of interaction of con-

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vective flows and inhomogenitites of core-mantle boundary. However characteristics of separate variations of this group are different and it is quite possible that their nature is different too.

For example, variation of 3000 years is observed at direction of geomagnetic field but variation of about 1800 is mainly observed in the changes of intensity, variation of the same period is observed in paleoclimatic phenomena.

Variations of 600 and 900 years are not met in the same region but each of them can be together with variation of 1200 years.

Variation of 600 years can be considered as the basic one, for it is present almost at all the regions and during the whole time interval under consideration.

Variations of 60, 360, 600 and 900 years can be considered as a result of interaction of convective motions with core-mantle inhomogenities. Firstly, the centres of arising of such variations are tied to the mantle ; for the variations of 600 years - to the centres of world anomalies. Secondly, west ward drift is revealed clearly, especially for variation of 600 years.

At different sides of the centre of world magnetic anomalies (namely East-Asian anomaly) the velocity and even the direction of west-ward drift are different. It can be supposed that superposition of two processes takes place)* One of these processes is west-ward drift itself that is different rotation velocities of mantle and upper layers of the core. The second process is spreading of the flows from some obstacle on their way, namely core-mantle boundary inhomogenities. Such a supposition allows to divide these two phenomena and to estimate the motion velocity in each of them.

It should be noticed that the region of world anomaly centre is the only region, where neither SV of 600 years nor of 900 years

)* fig. 1

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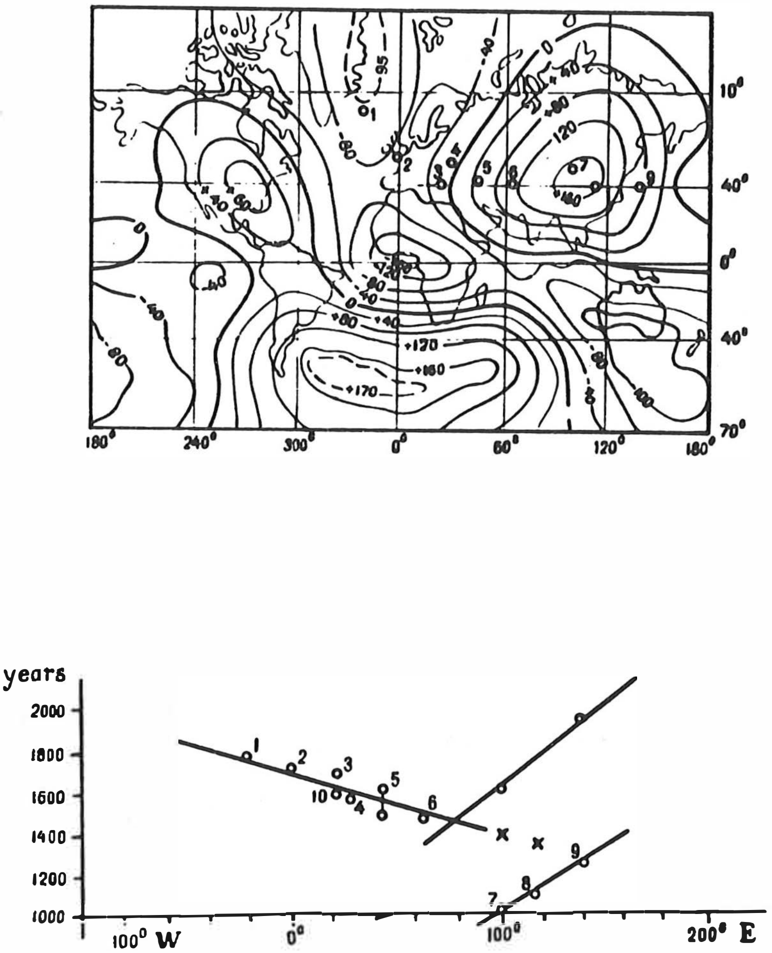

Fig. 1 The change of westward drift of geomagnetic field at the centre of world magnetic anomaly

down - The drift of the last maximum of 600-year secular variation. on absciss axis - longitudes, on ordinate axis - the year when the inclination maxima was observed at this very longitude. The figures point the places of collecting according to the map. Crosses show places, where maxima 7 and 8 should be observed, if only westward drift (without spreading) took place.

up - Geomagnetic world anomalies. The collection places are shown by figures.

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exist, but SV of 1200 years is distinctly seen (fig. 2).

All this evidences in the favour of different nature of variations with the period of 60 till 900 years and variation of 1200 years and of the connection of the first ones with the processes caused by core-mantle inhomogenities. By the way, parameters in magnetohydrodynamic equations give the periods of MAC-waves in diapason of 1-3 thousand years and hardly allow to refer variations of 600-900 years to MAC-waves.

Variation of 1200 years at world data treatment upon inclination does not show any connection with west ward drift. It reveales as synphase in global scale, what points sooner to magnetic centre displacement than to small scale turbulence in upper layers of liquid core [1].

Till nowdays we have known nothing about variations during reversals, though this information is very important for understanding of reversal mechanism.

Gurary collected in Turkmenia a rare collection, in which transitional zone is represented with 800 samples and each of them scopes the time of 25-30 years. Analysis of this collection allowed to check up the knowledge of the field character during reversals which were obtained before at less detailed collections. and receive new data. In this reversal as well as in others the field intensity is sharply decreased. The paleointensities of geomagnetic field were obtained by H_{θ} method (fig 3). The smoothed curve shows the intensity variations with the period of about 9 th.years, that is own oscillation of dynamo mechanism, which is revealed in other reversals though less reliably and is known from archaeomagnetic data. Upon the change of geomagnetic field direction transitional zone can be divided into parts corresponding to two regimes: more quiet or quasistationary regime, when VGP displacements have the

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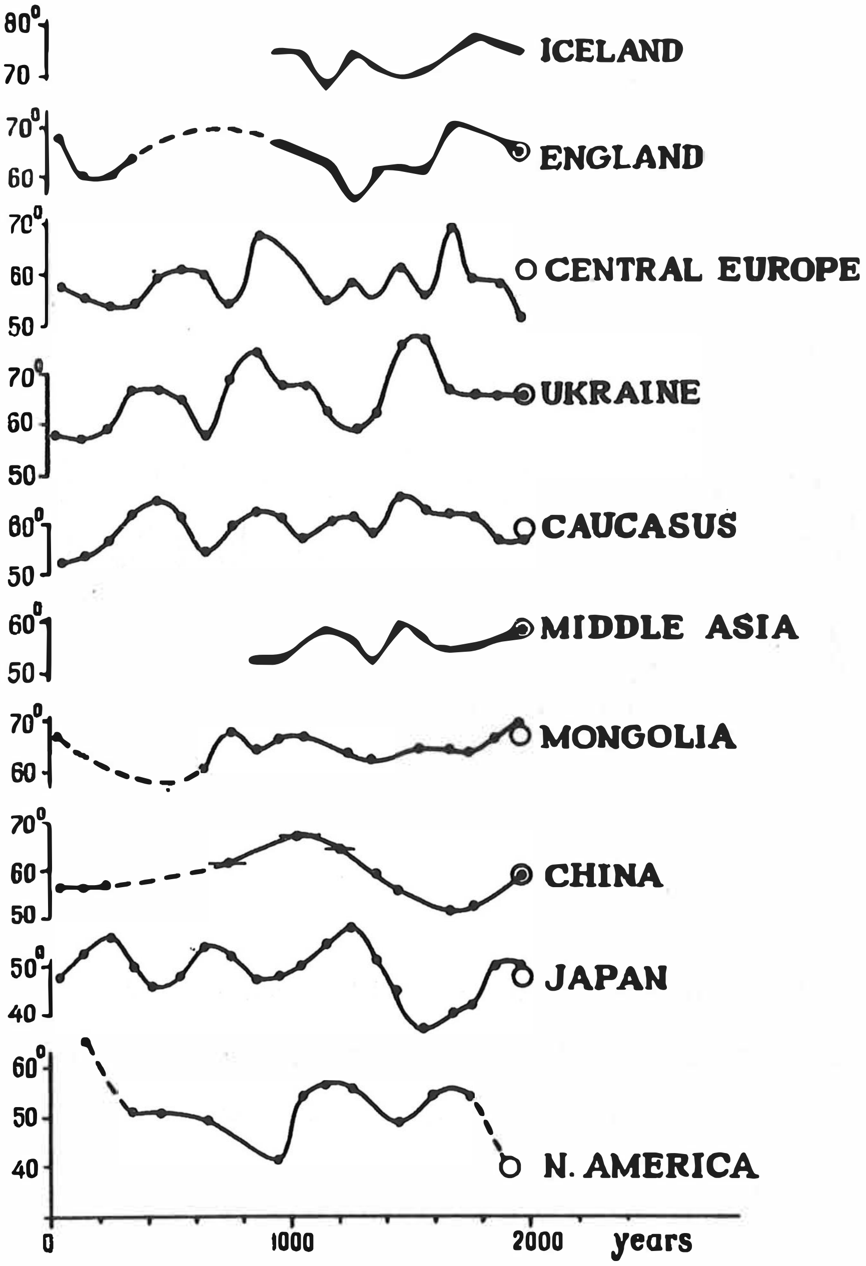

Fig.2. The inclination variations during 2 th.years in places pointed in fig.1 (according to S.P.Burlatskaya).

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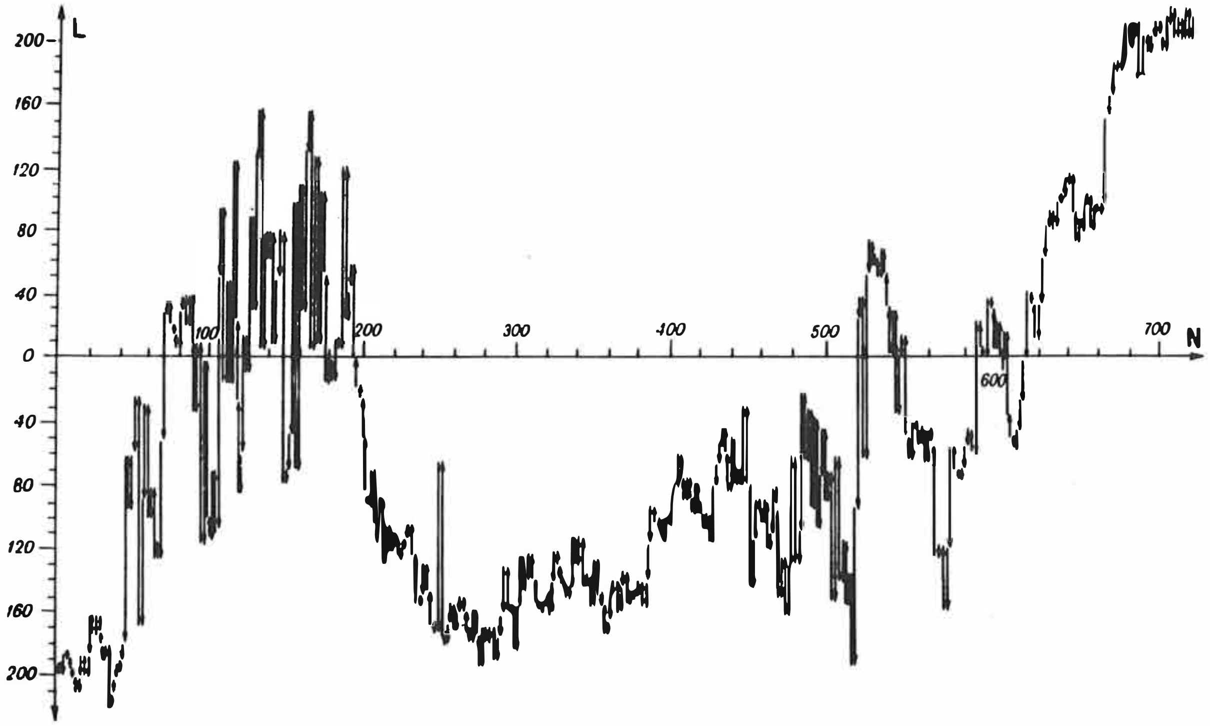

Fig.3. The VGP displacement during Matuyama-Jaramillo reversal. On absciss axis - the age in arbitrary units (the numbers of samples). On ordinate axis - the latitude of VGP position.

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character and value of SV in stationary field and disturbed one, when VGP displacements are so great, that the field direction during this regime cannot be characterized from usual points of view.

The following phenomena seem to be most interesting. Firstly, during the whole reversal both at quasistationary and disturbed regimes direction changes with characteristic time about 600 years are distinctly seen. At quasistationary regime these changes look like variations with amplitude of about 15°, that is are anological to 600 years secular variation in stationary field. At disturbed regime the time of about 600 years is the characteristic time of existence of some mean direction of geomagnetic field: during 600 years mean position of VGP remains on definite place, though some fluctuations from this position may be very large - sometimes till 120-150°. Then mean VGP position occupies a new place. The amplitude of displacement from one mean position to another can vary from 30° till 120° [2], fig. 4.

Secondly, at seeming chaotic character of displacements there exist definite mean directions or definite stable positions of VGP, where VGP remains for a long time (about 3000 years) at quasistationar regime and where it returns - not always - at disturbed regime. VGP displacement to the other hemisphere takes place during disturbed regime.

The connection is observed between different characteristics of magnetic field during reversals: large amplitudes of variations, great disturbance, i.e. sharp declination from mean position corresponds to low field intensity. At the same time, besides 600 year variation there appear shorter ones of about 300 years. As it had already been said, just at that time unreversable displacement of VGP to the other hemisphere occurs.[2], fig. 5.

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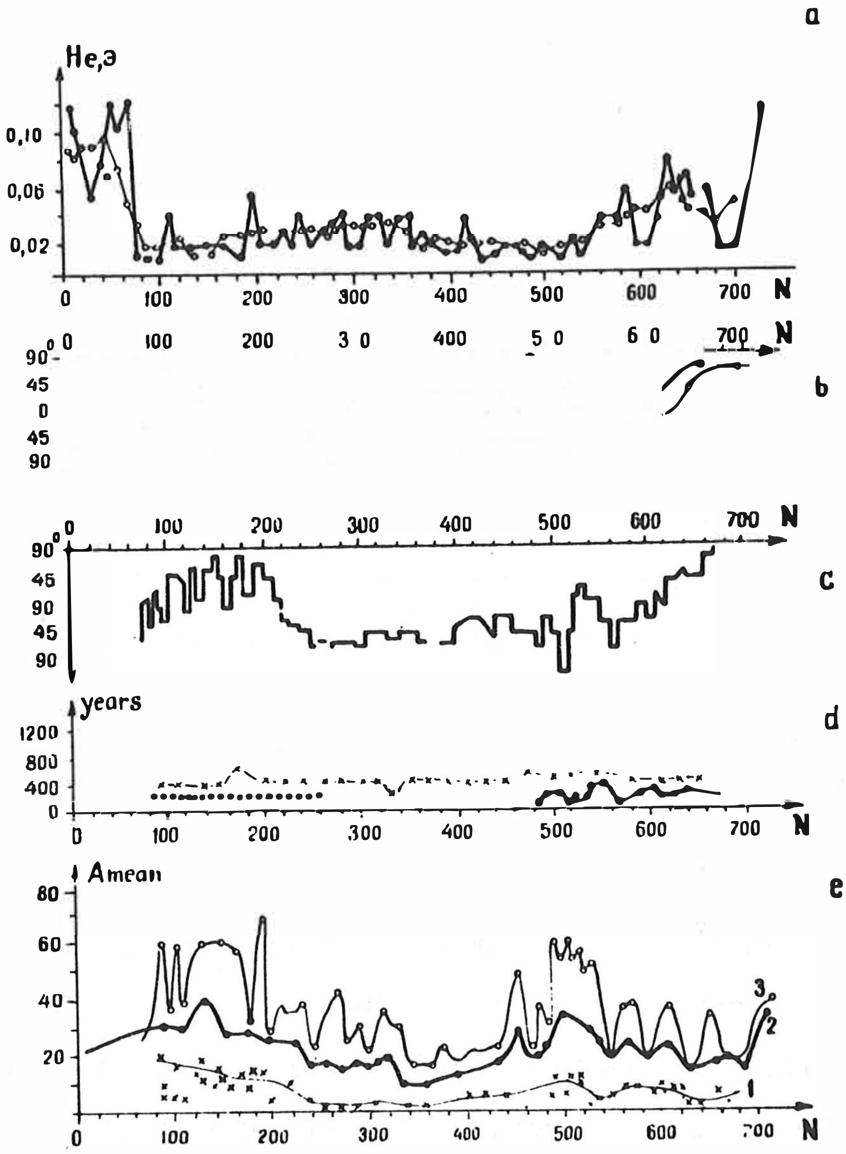

Fig. 4 The change of different geomagnetic field characteristics during Matuyama-Jaramillo reversal

a) paleointensity change (—•—•— : data upon H_e-method, —o— : running average of 5 points),

b) average position of VGP upon latitude (curve 1) and longitude (curve 2),

c) changes of periods and amplitudes of variations (sketch of fig.3),

d) periods of variations,

e) amplitudes of variations shown schematically in fig.c-curve 1; geomagnetic field activity, that is the distance between two neighbouring VGP positions, if they are less than 60° (without "excursions") - curve 2; geomagnetic field disturbance, that is the distances between two neighbouring VGP positions with any amplitude - curve 3. The main "excursions" are shown by vertical dotted lines.

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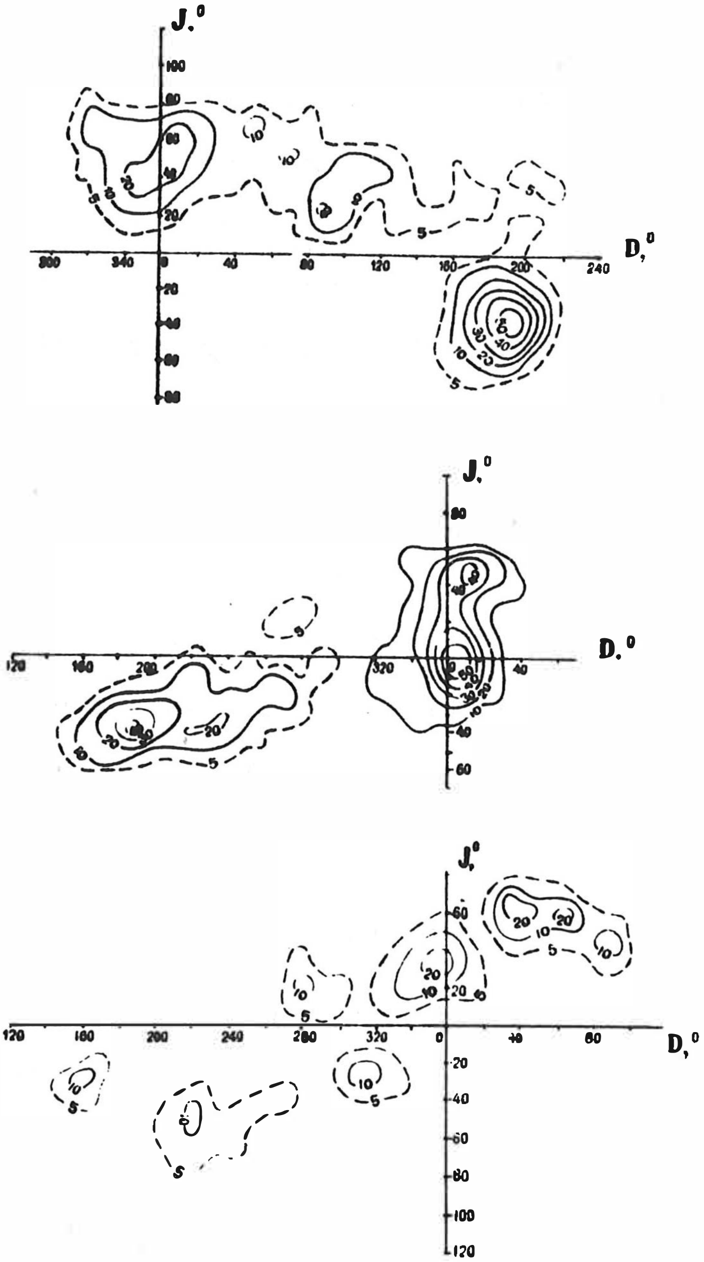

Fig.5. Distribution of VGP during reversals: a) Gauss-Matuyama, b) Matuyama-Jaramillo.

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Thus SV of 600-year takes a special place both at stationary field and at transitional regime. 600 years is, possibly, not a period, but characteristic time, namely the life time of small scale whirl. The places of these whirls arising are determined both at stationary and transitional field. At stationary field they are the centres of world magnetic anomalies, during reversals they are some other places, being stable but different for different reversals. [3].

All this allows to consider that 600-year variation is caused by interaction of convective motions with core-mantle boundary inhomogenities.

The mechanism of VGP displacement during a reversal is the same as for 600-year variations. It is likely that a reversal can occur, if a certain critical part of the volume of liquid core turns to be occupied by small scale turbulence.

Литература

I. Петрова Г.Н., Бурлацкая С.П. Современные представления о вековых вариациях. Сборник "Проблемы изучения палеовековых вариаций магнитного поля Земли". Владивосток, 1979.

Petrova G.N., Burlatskaya S.P. Modern views of secular variations. Collection "The problems of investigation of geomagnetic secular variations, Vladivostok, 1979. (Russian).

2. Петрова Г.Н., Гурарий Г.З., Рассанова Г.В. Вековые вариации в инверсии Матуяма-Харамильо. Сборник "Решение геофизических задач геомагнитными методами", ИФЗ АН СССР, 1980.

Petrova G.N., Gurary G.Z., Rassanova G.V. Secular variations during Matuyama-Jaramillo reversal. Collection "Solution of geophysical problems by geomagnetic methods", Moscow, 1980. (Russian)

DOI: https://doi.org/10.2312/zipe.1981.070.01

3. Вадковский В.Н., Гурарий Г.З., Мимиконьян М.Р. Анализ процесса смены знака геомагнитного поля. Изв. АН СССР, Физика Земли, УП, 1980.

Vadkovsky V.N., Gurary G.Z., Mimikonyan M.R. The analysis of the process of geomagnetic field polarity change. Izv. AN SSSR, Phyzika Zemli, VII, 1980.

Ю.Р. РИВИН

ДЕСЯТИЛЕТНИЕ ВАРИАЦИИ ГЕОМАГНИТНОГО ПОЛЯ ГЕНЕРИРУЕМЫЕ ВНУТРИЗЕМНЫМ ИСТОЧНИКОМ

АННОТАЦИЯ

Из анализа десятилетних вариаций геомагнитного поля, полученных разными авторами, сделан вывод о существовании двух источников таких вариаций. Один источник находится в магнитосфере, второй - в жидкой части ядра Земли.

ZUSAMMENFASSUNG

Anhand der Analyse der zehnjährigen Variationen des erdmagnetischen Feldes, die von verschiedenen Autoren erhalten wurden, wurde der Schluß über zwei Quellen solcher Variationen gezogen. Eine Quelle befindet sich in der Magnetosphäre, die zweite im flüssigen Teil des Erdkernes.

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ABSTRACT

Analysing ten-year variations of the geomagnetic field obtained by different authors it is concluded, that there exist two sources of such variations. One of them is located in the magnetosphere, the other one in the liquid part of the terrestrial core.

Введение

Первая попытка выделения десятилетних вариаций геомагнитного поля TV, как известно, предпринята Мусом (Moos, 1910). А Шмидт (Schmidt, 1916) аналогичным методом выделил десятилетние вариации в Потсдаме и Седдине. С тех пор число работ в этом направлении с каждым годом увеличивается.

Мус считал, что десятилетние вариации обусловлены воздействием на геомагнитное поле циклически изменяющейся солнечной активности. До недавнего времени это предложение Муса не подвергалось сомнению. Однако, в последние годы в результате более тщательного исследования пространственно-временных свойств десятилетних вариаций оказалось возможным сделать заключение о более сложном их составе. Выяснилось, что, наряду с вариациями солнечного происхождения, существуют десятилетние вариации иной природы.

Для того, чтобы показать это, рассмотрим сначала основные свойства десятилетней вариации коррелирующей с числами Вольфа, которую, согласно Vestine et al. (1948), будем обозначать RV.

Основные свойства вариации коррелирующей с числами Вольфа.

В первом приближении эта вариация может быть представлена в виде

$$RV(t,r) = A(t,r)\cos(2\pi t/10.3)$$

где t, r характеризуют изменение параметра во времени и пространстве (Ривин, 1979).

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Изменения амплитуды A во времени, согласно предположению о природе вариаций, должны хорошо коррелировать с изменениями амплитуды циклов чисел Вольфа W за этот же период. Поскольку в магнитном поле выделяется узкополосный процесс, естественно, что соответствующий узкополосный процесс должен быть сначала выделен в изменениях солнечной активности (которую можно считать генератором), для чего используются методы узкополосной фильтрации. Полученные после узкополосного фильтра для интервала I934-I96I гг. числа Вольфа приведены внизу рис. I . Из рассмотрения их на большем интервале известно, что у чисел Вольфа амплитуда модулирована 80-летней флуктуацией. Причем от минимума (начало нашего века) к максимуму (конец 50-ых годов) в результате модуляции амплитуда чисел Вольфа возрастает примерно в I,5 раза. Такое изменение амплитуды, следовательно, должно быть и у соответствующих геомагнитных вариаций, хотя само соотношение амплитуд циклов в магнитном поле может быть и меньше.

RV по трем компонентам, выделенные автором, приведены также на рис. I (в центре) (Ривин, I979). Как следует из сопоставления этих кривых с числами Вольфа, высказанное Мусом предположение частично оправдывается: в магнитном поле действительно существуют вариации, временные изменения которых аналогичны изменениям циклов солнечной активности. На рис. I кривая X-компоненты умножена на минус один. На самом деле такие вариации в X-компоненте проходят в противофазе к кривой чисел Вольфа.

Распределение A в пространстве исследовано Vestine et al. (I947), Yucutake (I965), Ривиным (I975,I979), Harwood et al. (I979). Показано, что оно в первом приближении может быть описано первой зональной гармоникой сферического гармонического ряда g_1^0 (рис.2).

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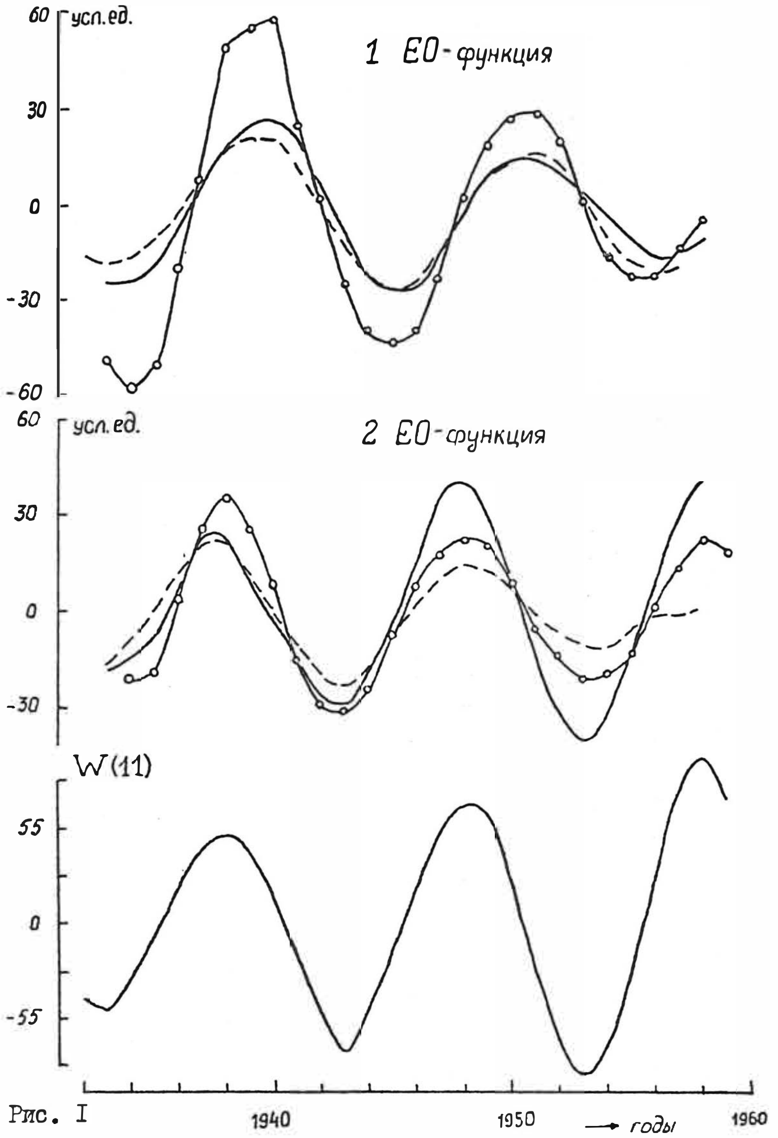

Рис. I

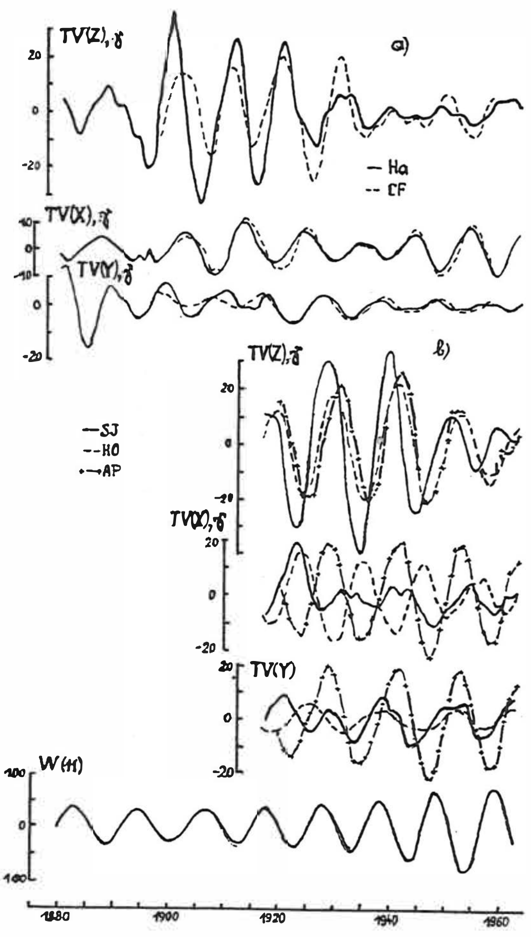

Рис. 5

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Для более точного описания необходимо учитывать также другие коэффициенты первых двух гармоник. Такой учет приводит к выделению в распределении амплитуды долготных неоднородностей, наиболее значительная из которых находится в Тихом океане. Однако, следует подчеркнуть, что при этом первая зональная гармоника преобладает по абсолютной величине над другими коэффициентами.

Как следует из рис. I, амплитуда X-компоненты RV больше, чем амплитуда других компонент. Средний период RV на рассматриваемом интервале равен I0,3 годам, что хорошо согласуется со средним периодом десятилетних вариаций солнечной активности, который на том же интервале равен I0,4 ± 0,3 года.

Из проведенного анализа основных свойств пространственно-временной структуры описанных вариаций можно сделать вывод, что эти вариации обусловлены изменениями в цикле солнечной активности основных параметров суммы полей двух токовых систем DCF + DR . В этой сумме по величине преобладает изменение поля DR , что и отражается на поведении RV .

После того, как мы рассмотрели основные свойства RV , попытаемся выяснить - все ли экспериментальные факты удовлетворяют этой модели?

Сравнение модели RV с экспериментальными данными.

Вернемся к рис. 2, который получен Yucutake (1965). На этом этом рисунке дисперсия амплитуд, особенно для Z -компоненты, очень велика, что, с одной стороны, может свидетельствовать о больших погрешностях выделения десятилетних вариаций в этой компоненте во многих обсерваториях, а с другой стороны - о некотором неучтенном

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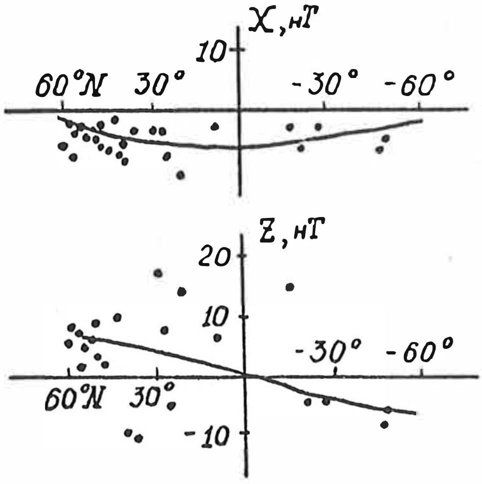

Рис. 2

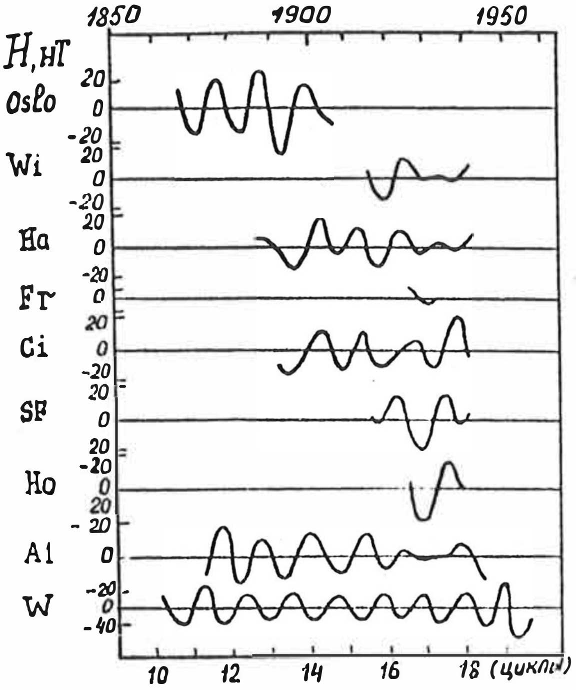

Рис. 3

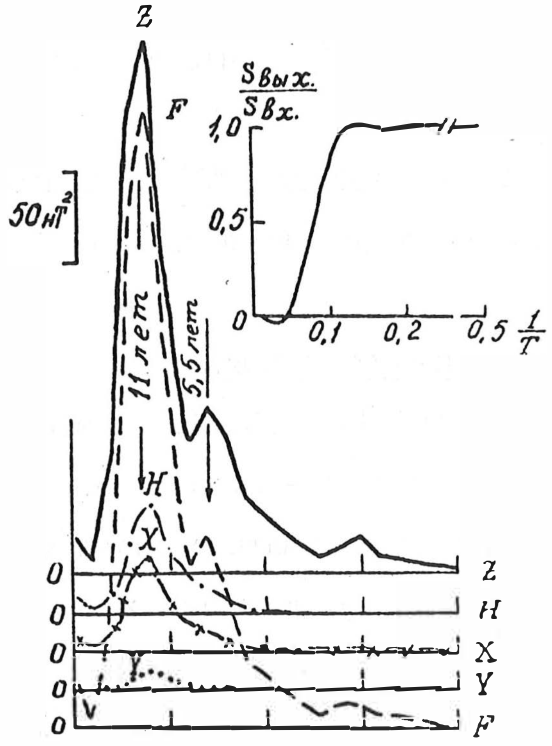

Рис. 4

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эффекте при выделении вариаций.

На рис. 3 приведены десятилетние вариации в Н-компоненте. Они получены Bhargava et al. (1971). Наиболее продолжительна и интересна здесь кривая Алибага. Она до шестнадцатого цикла чисел Вольфа идет в противофазе к ним, что согласуется с моделью RV . После семнадцатого цикла фаза этой кривой меняется на противоположную. Такое изменение фазы трудно связать с ошибками наблюдений. Как показали Yacob et al. (1969), это изменение фазы нельзя объяснить влиянием токовой системы, ответственной за Sq -вариацию.

На рис. 4 приведен энергетический спектр десятилетних вариаций Осло по данным Bhargava et al. (1970). В этом спектре амплитуда Z -компоненты больше, чем амплитуда горизонтальных компонент. Если это не является локальным эффектом, то такое соотношение амплитуд компонент Осло не соответствует модели RV .

На рис. 5а приведены десятилетние вариации в компонентах Х,У,Z , полученные в результате специальной узкополосной фильтрации данных двух старейших обсерваторий Европы (Хартленд и Шамбон-ля-Форе). Десятилетние вариации в каждой из компонент, выделенные в разных обсерваториях, довольно хорошо совпадают между собой, что позволяет говорить об их надежном выделении. Основная особенность этого графика в том, что на интервале 1890-1935 гг. амплитуда в Z -компоненте значительно больше амплитуды в горизонтальных компонентах Х, У. Возникновение в этом интервале в Z -компоненте интенсивных десятилетних вариаций сопровождается появлением соответствующих вариаций в Х,У - компонентах.

Аналогичную картину можно наблюдать на рис. 5в для трех низкоширотных обсерваторий (Сан-Хуан, Гонолулу, Апиа) в более поздние годы. Здесь опять десятилетние вариации в Z -компоненте более интенсивны, чем в Х и У; одновременные колебания отмечаются в каждой из трех компонент.

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Причина небольшого сдвига фазы десятилетних вариаций в Z -компоненте обсерваторий западного и восточного полушарий будет обсуждена ниже.

Противоречие перечисленных свойств десятилетних вариаций свойствам модели RV привело к выводу, что десятилетние вариации геомагнитного поля являются суперпозицией полей нескольких источников, имеющих очень близкие характерные времена изменений (Ривин, 1976).

Временные ряды обсерваторских наблюдений не приспособлены для разделения вариаций с очень близкими периодами при помощи частотной фильтрации. Наиболее подходящим для этой цели оказался аппарат разложения на естественные ортогональные функции, описанный, в частности, (Файнберг, 1975). Для разложения были выбраны ряды одновременных наблюдений десятилетних вариаций в X,Y,Z -компонентах двадцати шести обсерваторий в интервале 1932-1958 гг. Разложение каждой компоненты произведено независимо. Вернемся к рис. I, чтобы обсудить результаты разложения.

Первый результат, который следует отметить, - это то, что при разложении в каждой из компонент выделилось только по две значимые EO - функции.

В каждую EO -функцию выделилось довольно согласованные кривые компонент. Изменения амплитуды первой и второй EO -функций во времени различаются.

Как уже отмечалось, изменение амплитуды компонент второй EO - функции довольно хорошо коррелирует с числами Вольфа (рис. I). Их период близок к среднему периоду чисел Вольфа на этом интервале. Соотношение амплитуд и распределение их в пространстве согласуются с моделью RV . В таблице приведены соответствующие периоды и дисперсии EO -функций по компонентам.

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Таблица

	T			б	
	I	2		I	2
TV (X)	II,3	I0,0		3I2	630
TV (У)	II,8	I0,8		282	I64
TV (Z)	II,3	I0,0		I242	420
ср.	II,5±0,2	I0,3±0,2	$\sum$	I836	I2I4

У процесса, выделившегося в первую EO -функцию, изменение амплитуды во времени не согласовано с числами Вольфа; амплитуда Z -компоненты больше амплитуды других компонент; величина среднего периода больше среднего периода RV и среднего периода солнечного цикла на этом интервале; роль первой зональной гармоники при описании распределения амплитуд в пространстве оказывается очень малой, преобладают более старшие члены сферического гармонического ряда; отношение внутренней части потенциала и внешней для этого процесса, определенное по коэффициентам сферического гармонического анализа, оказывается больше единицы (Ривин, I979). Совокупность таких свойств вариаций позволяет заключить, что выделенный в первую EO - функцию процесс обусловлен источником, который находится вн внутри Земли. Будем обозначать в дальнейшем эти вариации как ITV .

Возвращаясь к рис. 5а, можно отметить, что, во-первых, ITV в Европе и районе экватора приходится на разное время, а, во-вторых, небольшой сдвиг фазы кривых на рис. 5в может быть объяснен разли-

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чием суперпозиции полей двух источников в разных точках земного шара.

Эти соображения были опубликованы несколько лет назад (Ривин, 1976). С тех пор появился еще ряд работ по этой тематике. И хотя авторы работ при интерпретации выделенных десятилетних вариаций оставались на точке зрения Муса, сам экспериментальный материал содержит факты, которые не согласуются с их интерпретацией.

На рис. 6 приведены десятилетние вариации в Z -компоненте в ряде обсерваторий выделенные Олдриджем. Модуляция амплитуды кривых в Гонолулу и Апиа здесь такая же, как ранее на рис. 5в, что не соответствует модуляции циклов кривой солнечной активности.

На рис. 7 приведена гистограмма распределения периодов, полученных методом максимальной энтропии в спектрах X, Z - компонент 38 обсерваторий на интервале 1947-1972 гг. (Courtillot et al. , 1976). Как следует из гистограммы, максимумы в X и Z соответствуют разным периодам. Наиболее вероятный период в Z - компоненте по абсолютной величине больше десяти лет, в Н-компоненте - чуть меньше. Это довольно неплохо соответствует данным таблицы.

На рис. 8 приведены десятилетние вариации в Z - компоненте, полученные (Harwood et al. , 1977). Авторы обращают внимание на аномальное поведение кривых в Гонолулу и Апиа и приходят к выводу о внутриземной природе этих вариаций. Такой вывод соответствует высказанному предположению о сложной природе десятилетних вариаций. К сожалению, кривые десятилетних вариаций в работе Harwood et al. осложнены двадцатилетней вариацией, что снижает достоверность основы для вывода авторов.

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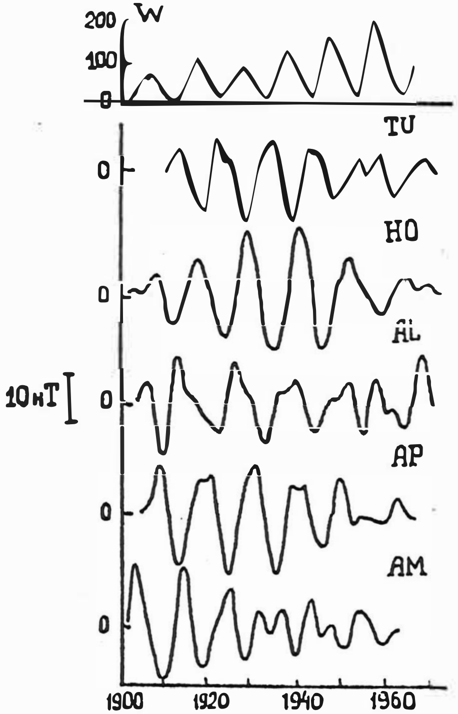

Рис. 6

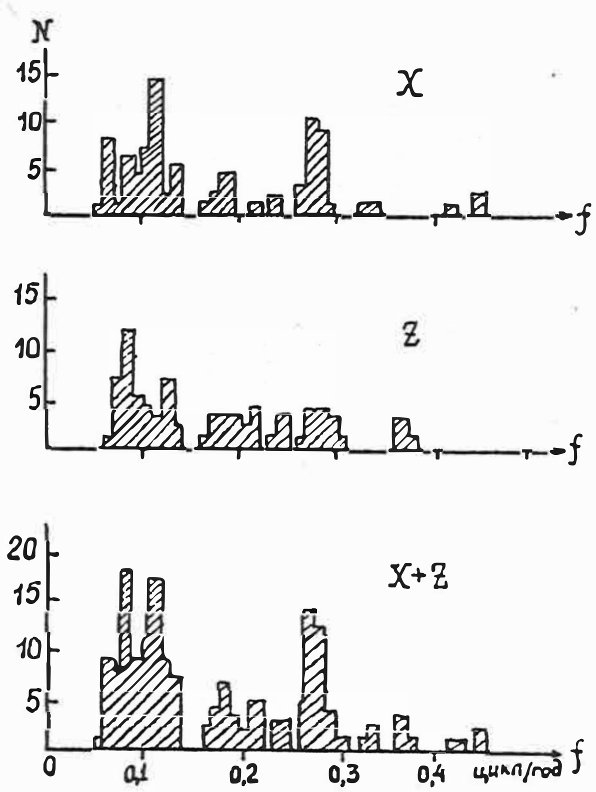

Рис. 7

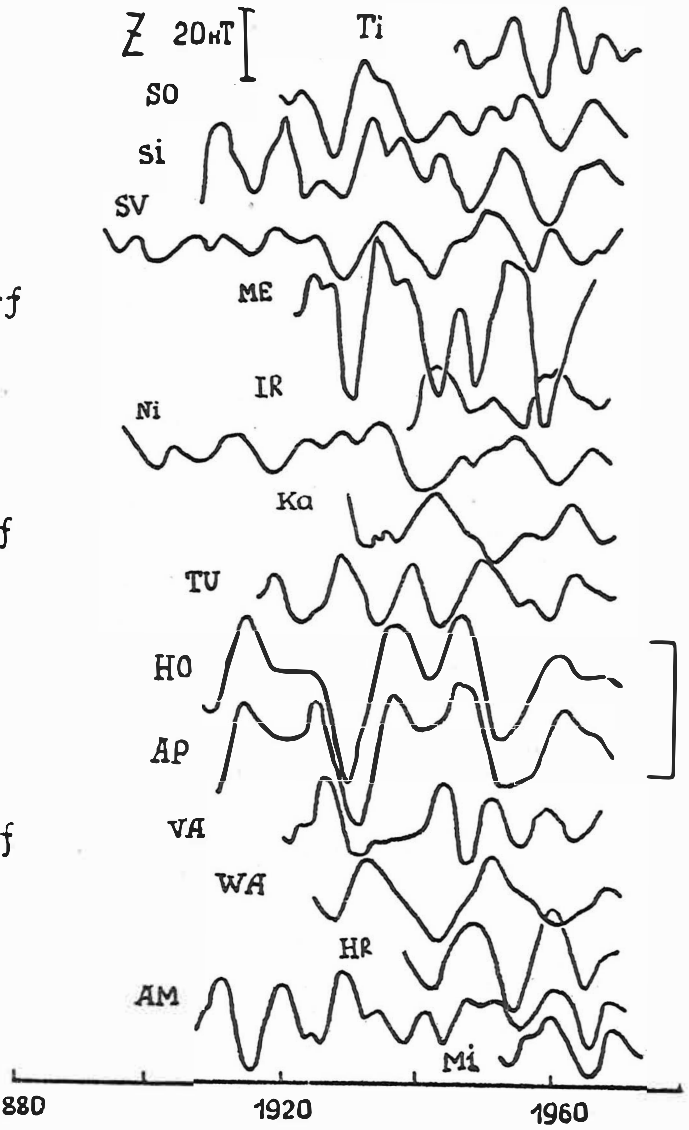

Рис. 8

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Заключение

Обнаружен ряд свойств десятилетних вариаций, которые не могут быть объяснены в рамках модели одного источника, связанного с числами Вольфа. Для их объяснения приходится предположить, что источников несколько. Метод разложения на EO -функции показывает, что существует два вида десятилетних вариаций со значимыми величинами амплитуд и различными пространственно-временными характеристиками. Десятилетние вариации внешнего происхождения, как отмечалось, безусловно глобальны. О десятилетних вариациях внутриземного происхождения из-за недостаточности данных, пока можно сказать, что они или глобальны, или крупнорегиональны.

Очень важным является вывод о том, что источник части десятилетних вариаций расположен внутри Земли. Очевидно, поскольку это динамический процесс, источник его не может быть в мантии, а находится в жидком ядре. Можно надеяться, что последующее уточнение свойств десятилетних вариаций внутриземного происхождения позволит получить больше информации о самом источнике и окружающей его среде.

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ЛИТЕРАТУРА

1. Moos N.A.F., Magnetic Observations made at the Covernment observatory, Bombay, for the period 1846-1905 and their Discussion, Part II, 1910.
2. Schmidt A., Abhandl. Kgl. Preuss. Meteorol. Inst., Berlin, 1916, 5, 3.
3. Ривин Ю.Р., Геомагнетизм и Аэрономия, 1979, 19, №1, 120- 125.
4. Vestine E.H., Lange I., Laporte L. and Skott W.E., Pub. Carnegia Inst. of Washington, 1947, No. 580, 85-92.
5. Yucutake T., J. Geomagn. and Geoel., 1965, 17, 3-4, 287-309.
6. Ривин Ю.Р., Геомагнетизм и Аэрономия, 1975, 15, № 4, 694-697.
7. Harwood J.M., Malin S.R.C., Geophys. J. Roy. Astron. Soc., 1977, 50, N 3, 605-619.
8. Bhargava B.H., Yacob A., J. of Atmosph. and Terrest. Phys., 1970, 32, N 3, 365-372.
9. Bhargava B.H., Yacob A., J. Geomagn. and Geoel., 1969, 21, N 1, 385-397.
10. Ривин Ю.Р., Сб. Пространственно-временная структура геомагнитного поля, М., Наука, 1976, ИЗМИРАН, 45-51.
11. Yacob A., Sen A.K., Indian J. Meteorol. and Geophys., 1969, 20, N 3, 283-290.
12. Ривин Ю.Р., Геомагнетизм и Аэрономия, 1979, 19, №2, 323-329.
13. Alldredge L.R., J Geophys. Res., 1976, 81, 17, 2990-2996.
14. Courtillot V., Mouël J.L., J. Geophys. Res., 1976, 81, 17, 2941-2950.

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АБСОЛЮТНАЯ МАГНИТНАЯ СЪЕМКА БОЛГАРИИ ЗА ПЕРИОД 1978 - 1980 г.

Резюме:

В 1978 и 1979 годы была проведена абсолютная магнитная съемка на территории Болгарии. Были сделаны замеры в 473 магнитных пунктах, 426 из которых на триангуляционных пунктах, а 47 были выбраны произвольным образом без стабилизации. На каждом пункте измерялось склонение - D , горизонтальная составляющая - H и полный вектор - F земного магнитного поля. Ориентация магнитных станций сделана при помощи жиро-теодолита Gi - B2 и геодезическим способом. Приведение полевых измерений из-за суточных вариаций магнитного поля сделано по записам Магнитной обсерватории Панагюрище и по записам переносимой трехкомпонентной магнитовариационной станции, которая работала в окрестностях городов Михайловград, Тарговище, Обзор и Елхово. В 1980 г. будут сделаны контрольные измерения на сети вековых пунктах. Магнитные измерения в 1978 и 1979 годы будут приведены к епохе 1980.0. Будут сделаны карты магнитного поля и анализ на ЭВМ для получения карт "нормального" и "аномального" полей.

Zusammenfassung:

In den Jahren 1978 und 1979 wurden absolute magnetische Messungen auf dem Territorium Bulgariens durchgeführt. Es wurden 473 magnetische Stationen gemessen. 426 von diesen sind Punkte des geodätischen Netzes. In jedem Punkt wurde die Deklination D, die horizontale Komponente H und die totale Intensität F des geomagnetischen Feldes gemessen. Die Orientierung der geomagnetischen Stationen wurde mit Hilfe des Girotheodoliten Gi-B2 und mit geodätischen Verfahren realisiert. Die wegen der täglichen Variationen des magnetischen Feldes erforderliche Reduktion der Feld-

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messungen wurde mit Hilfe der Registrierungen des magnetischen Observatoriums in Panagjurischte und der Registrierungen der transportablen magnetischen Dreikomponenten-Variationsstation vom Typ "Bobrov", die in der Umgebung der Städte Mihailovgrad, Targovischte, Obsor und Elhovo aufgestellt wurde, durchgeführt. Im Jahre 1980 werden Kontrollmessungen des Netzes von Säkularstationen und magnetischer Stationen "erster Klasse" vorgenommen. Alle Messungen werden auf die Epoche 1980.0 reduziert. Es werden Karten des magnetischen Feldes konstruiert und mit Computer Analysen zur Gewinnung der Karten des "normalen" und des "anomalen" Feldes angefertigt.

Summary:

The absolute magnetic measurements in 1978 and 1979 were carried out on the territory of Bulgaria. 473 magnetic points: 426 on the geodetic network and 47 free, without stabilisation, were measured. The declination - D, the horizontal component - H and the total intensity - F of the Earth magnetic field were measured on every point. The magnetic stations were orientated by giro-theodolite and geodetic way. The reduction of the measurements of the diurnal geomagnetic variations was done on the registrations of Magnetic observatory in the town of Panagjuriste and the portable tree-channel-magnetic-variation-station, situated in the suburbs of the towns of Mihailovgrad, Targoviste, Obsor and Elhovo. In 1980 control measurements on the secular and first class magnetic stations will be carried out. All magnetic measurements will be reduced to the epoch 1980. Maps of the components of general, "normal" and "anomal" geomagnetic fields will be made.

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До сих пор в Болгарии, по всей территории страны, три раза сделаны абсолютные съемки геомагнитного поля.

Первые замеры сделал проф. К.Попов в период с 1917 по 1920 г.г. В 76 пунктах, 45 из которых находятся в пределах территории Болгарии, замерены склонение D , горизонтальная составляющая H и наклонение I . Все замеры приведены к эпохе 1921.0. Следующие измерения сделаны в период 1937 - 1947 г.г. Х.Калфиным в 750 пунктах. Замерены те же самые геомагнитные элементы - D , H и I . Замеры приведены к эпохе 1940.0.

Последная геомагнитная съемка сделана К.Костовым в период 1958 - 1961 г.г. В 450 пунктах опять были замерены элементы D , H и I , а специально склонение D было измерено по более сгущенной сети - всего около 2000 пунктах. На основе этих измерений были выработаны карты общего хода геомагнитного поля и вычислено "нормальное" поле в Болгарии при помощи аппроксимации полиномом второй степени.

Теперь (1978 - 1980 г.г.) проводится новая геомагнитная съемка в Болгарии. Основная причина, ради которой пришлось провести эту съемку, состояла в том, что все геомагнитные съемки до сих пор были сделаны с меньшей точностью по отношению к нашим теперешным возможностям и что измерения не были расположены равномерно как по территории страны, так и во времени. В общем цель новой абсолютной геомагнитной съемки была следующая:

1. определить общий характер распределения элементов геомагнитного поля на территории Болгарии с достаточной высокой точностью для эпохи 1980.0 при хорошом магнитном уровне Магнитной обсерватории Панагюрище;

2. вычислить "нормальное" и выделить "аномальное" геомагнитные поля для той же эпохи;

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3. объединить все абсолютные геомагнитные измерения, проведенные до сих пор, и сделать соответствующие выводы о точности измерений в прошлом и лучше проследить вековой ход элементов геомагнитного поля на территории Болгарии за последных 50 лет;

4. измеряя некоторые из базисных пунктов болгарского "Предприятия геофизической разведки и геологии", выявить возможность объединения в одном целом (общая эпоха и единный уровень) всех до сих пор сделанных локальных геомагнитных съемках с разведовательной целью и таким образом создать хорошую основу для будущих наземных и аеро разведовательных работ.

Основная часть измерения была проведена в 1978 и 1979 г.г. В 473 пунктах, подходящим образом расположенных по всей территории страны, замерены склонение D , горизонтальная составляющая H и полный вектор геомагнитного поля F . Из всех магнитных замеров 90 % сделаны в пунктах геодезической сети. Так как южнее широты $\varphi = 42^{0}40'$ геомагнитное поле более неоднородное, то густота измерительной сети выбрана больше. Кроме того была сделана попытка охватить в выбранной сетью как можно больше из всех доступных сейчас пунктов измерения предыдущих абсолютных магнитных съемок и большую часть из базисных пунктов болгарского "Предприятия геофизической разведки и геологии", которые оно делало при проведения своих разведочных работ, в чиых окрестностях не наступили изменения среды, вызивающие исскуственное изменение магнитного поля Земли. Были замерены следующие"старые" пункты:

1. из геомагнитной съемки 1937 - 1947 г.г. - 20 пунктов;
2. из геомагнитной съемки 1958 - 1961 г.г. - 120 пунктов;
3. из базисных пунктов болгарского "Предприятия геофизической разведки и геологии" - 24 пунктов;
4. 16 вековых и 16 так назымаемых "первокласных" пунктов (эти пункты принадлежат геодезической сети Болгарии; пункты для устано-

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вления векового хода поля измеряются каждые 5 лет, а"первокласные" пункты - каждые 10 лет).

Кроме в этих "старых" пунктах, магнитные элементы были замерены еще в 277 "новых" пунктах. Они были выбраны так, что вся сеть измерения была более равномерной, но все таки гуще южнее $\varphi = 42^0\ 40'$. Густота сети, при 111 000 км^2 территории страны, 1 пункт на 235 км^2, которое отвечает среднему расстоянию около 16 км между пунктами измерений.

В 1980 году будут сделаны опять замеры на всех вековых и "первокласных" пунктах. Эти повторные замеры будут сделаны опять таки только в таких пунктах, в окрестностях которых не наступили изменения среды, вызывающие искуственное изменение магнитного поля Земли за трехлетный период проведения съемки.

Топографическая карта, которой пользовались во время съемки - М 1 : 100 000.

Состав партии, проводящей съемки, был следующий: 2 магнитолога, 1 геодез и 2 водителя автомашин. Располагала она двумя автомашинами с повышенной проходимостью. Применялась следующая аппаратура:

1. магнитный теодолит "Шульце" - полевая модель с точностью горизонтального лимба 0.2 мин.;
2. три кварцевых H- магнитометра (QHM - 1, 2 и 57);
3. два протонных магнитометра польского производства PMP-2A;
4. гиротеодолит Gi - B2 с двумя гироблоками.

Кроме этого партия имела в распоряжении все необходимые вспомагательные приборы: хронометры, гигрометры, барометры, радиоприемники и т.д.

На любом пункте магнитные измерения проводились в следующей последовательности:

1. при помощи протонного магнитометра исследовалось на однородность магнитное поле вокруг данного пункта наблюдения;

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2. измерялось мначение полного вектора поля F ;

3. измерялось значение склонения D ;

4. измерялось значение горизонтальной составляющей поля H тремя кварцевыми H - магнитометрами;

5. опять измерялось значение склонения D ;

6. опять измерялось значение полного вектора F .

На "первокласных" пунктах делались две серии замеров по выше описанной методике, а на вековых пунктах - три, двумя наблюдателями независимо друг от друга.

В большинстве случаев пункты наблюдения сориентировались двумя способами: с помощью гиротеодолита Gi - B2 и привязкой к геодезической сети. Измерения с помощью гиротеодолита выполнялись на расстояние около 200 м от пункта магнитных наблюдений. Применялся метод обратного азимута. Замеры обычно делались с помощью двух жироблоков. Точность привязки около 0.05' - 0.10'

Редукция магнитных измерений с вариаций магнитного поля до сих пор сделана по записям Магнитной обсерватории Панагюрище. Кроме того во время магнитной съемки в 4 пунктах, как указано на фиг. 1, была установлена полевая трехканальная вариационная станция типа "Бобров" - в районах городов Михайловград, Тарговище, Обзор и Елхово. Она была размещена в землянках на глубине приблизительно 1 м. Таким образом амплитуда суточного хода температуры была меньше 1^0 С. Для регистрации температуры внутри станции до вариометров была поставлена термопара, которая при помощи одним из зайчиков склонения, записывала ее изменения на той же самой бумаги, на которой записывались элементы геомагнитного поля. Эти регистрации то же будут использувани при редуцирования измерений.

На фиг. 1 указаны еще те территории, где работала партия в 1978 и 1979 г.г. и сеть вековых и "первокласных" магнитных измерительных пунктов.

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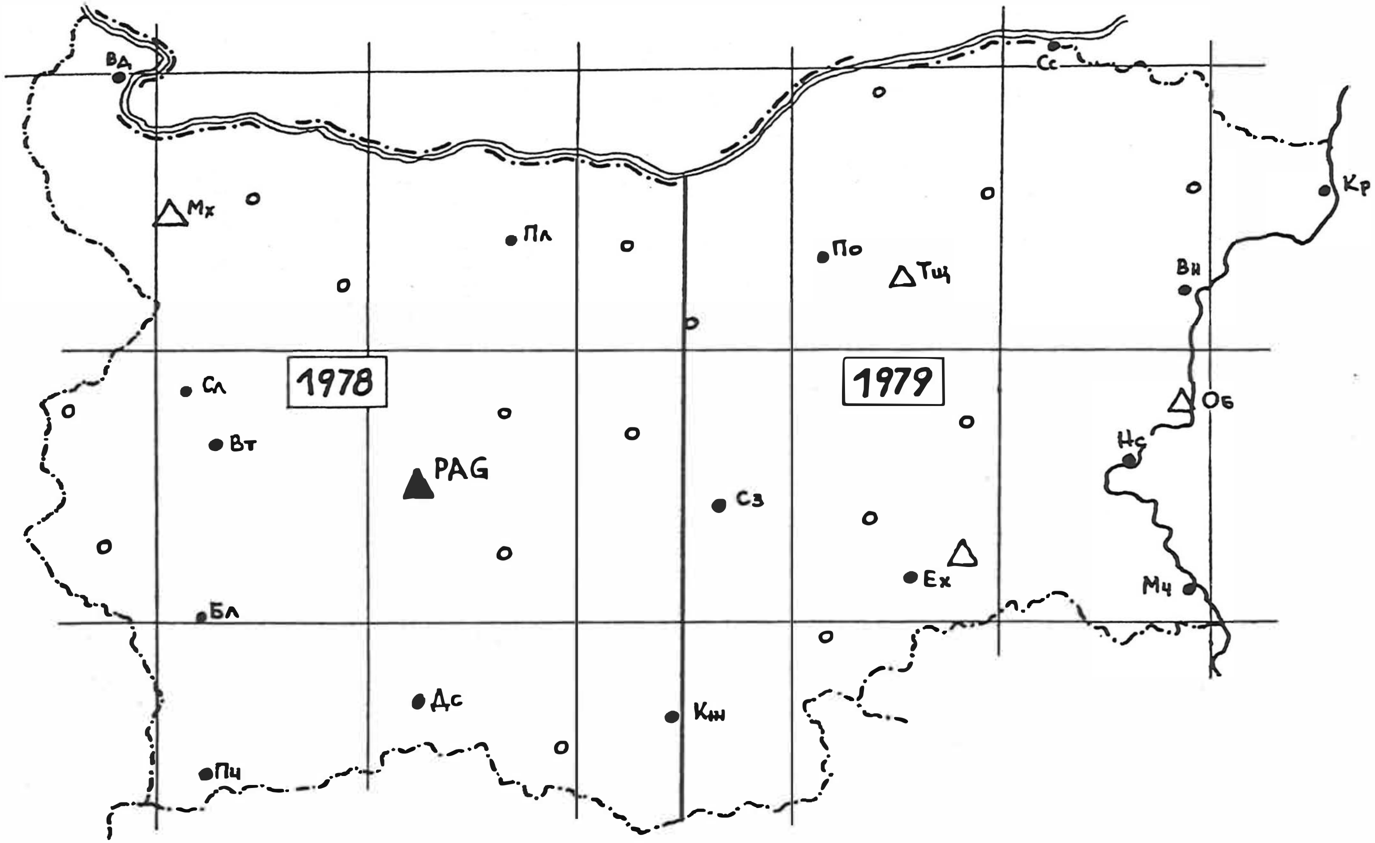

ФИГ. 1: ▲-МАГНИТНАЯ ОБСЕРВАТОРИЯ - ПАНАГЮРИЩЕ; ●-ПУНКТЫ ВЕКОВОГО ХОДА; О-ПУНКТЫ "ПЕРВОГО" КЛАССА; Δ - ПОЛЕВАЯ СТАНЦИЯ "БОБРОВ".

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Таблица 1

1977 КРАСНАЯ ПАХРА - СССР

$D_{KRA} - D_{PAG} = -0{,}6'$

$H_{KRA} - H_{PAG} = +1{,}2$ nT

$F_{KRA} - F_{PAG} = -1{,}0$ nT

СУРЛАРИ - РУМЫНИЯ

$D_{SUA} - D_{PAG} = -1{,}1'$

$H_{SUA} - H_{PAG} = +11{,}1$ nT

$Z_{SUA} - Z_{PAG} = +4{,}1$ nT

$F_{SUA} - F_{PAG} = -0{,}2$ nT

ГРОЦКА - ЮГОСЛАВИЯ

$D_{GCK} - D_{PAG} = 0{,}0'$

$H_{GCK} - H_{PAG} = +20{,}0$ nT

$F_{GCK} - F_{PAG} = -1{,}2$ nT

1978 НИМЕГК - ГДР

$D_{NGK} - D_{PAG} = -0{,}06'$

$H_{NGK} - H_{PAG} = +1{,}1$ nT

$Z_{NGK} - Z_{PAG} = 0{,}0$ nT

$F_{NGK} - F_{PAG} = +0{,}3$ nT

1979 КРАСНАЯ ПАХРА - СССР

$D_{KRA} - D_{PAG} = -0{,}7'$

$H_{KRA} - H_{PAG} = +0{,}8$ nT

$F_{KRA} - F_{PAG} = +1{,}1$ nT

ГРОЦКА - ЮГОСЛАВИЯ

$D_{GCK} - D_{PAG} = 0{,}0'$

$H_{GCK} - H_{PAG} = +18{,}0$ nT

$F_{GCK} - F_{PAG} = +0{,}9$ nT

Во время проведения съемки все приборы, принимающие участие в измерении, проверялись в Магнитной обсерватории Панагюрище. Кроме того в то же самое время и теми же самыми приборами были сделаны сравнительные магнитные измерения в следующих магнитных обсерваториях: Нимегк - ГДР, Красная Пахра - СССР, Гроцка - Югославия и Сурлари - Румыния. Результаты этих измерений даны на таблице 1. Можно еще добавить, что за последние 20 лет уровень Магнитной обсерватории Панагюрище практически не различался от уровня Магнитной обсерватории Адольф Шмидт в Нимегке, как это было и при наблюдениях в 1977 - 1979 г.г.

О погрешности измерений по предварительным подсчетам можно сказать, что их внешная наблюдательная ошибка ожидается в следующих пределах:

1. для склонения - 0.5' - 0.6';
2. для горизонтальной составляющей - 4 - 5 nT;
3. для полной сылой вектора поля - 4 - 5 nT.

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ANALYSIS OF THE MAGNETIC KNOWLEDGE OF THE WORLD OCEAN FOR SOLUTION OF CARTOGRAPHIC AND GEOLOGIC-GEOPHYSICAL PROBLEMS

Abstract

The characteristic of knowledge of the World Ocean covered by geomagnetic surveys made by Soviet and foreign research during 1953-1979 is presented. On the basis of the magnetic data analysis the schemes of the World Ocean coverage by component and modulus surveys are prepared, regionalization of the water area according to the rate of survey coverage is made and evaluation of the knowledge on different regions is given for solving some cartographic and geologic-geophysical problems.

Резюме

В работе дана характеристика изученности Мирового океана геомагнитными съемками, проведенными советскими и зарубежными исследованиями с 1953 по 1979 г.г. На основе анализа магнитной изученности построены схемы заснятости Мирового океана компонентными и модульными съемками, проведено районирование акватории по степени заснятости и дана оценка изученности различных регионов для решения некоторых картографических и геолого-геофизических задач.

Zusammenfassung

In der Arbeit wird eine Charakeristik zur Erforschbarkeit des Weltmeeres durch erdmagnetische Vermessungen, die von ausländischen und sowjetischen Wissenschaftlern im Zeitraum 1953 bis 1979 durchgeführt wurden, gegeben. Auf der Grundlage der Analyse der magnetischen Forschungen wurden Vermessungsschemata des Weltmeeres durch Komponenten- und Modulvermessungen ange-

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fertigt, eine Rayonierung der Wasserfläche entsprechend dem Vermessungsgrad durchgeführt und die Erforschbarkeit verschiedener Regionen zur Lösung einiger kartographischer und geologisch-geophysikalischer Aufgaben eingeschätzt.

Systematic research of the geomagnetic fields of oceans was initiated in 1957 according to World Magnetic Survey Project. Since that time the components and the total force are measured in the World Ocean on the water surface and at the elevation of 2-7 km as well as modulus measurements are made from satellites.

Information on the geomagnetic field is traditionally collected at the Leningrad Branch of IZMIRAN, operational schemes are prepared for component and modulus surveys of the World Ocean by Soviet and foreign scientists. At present schemes have been prepared in the scale of 1:20,000,000 generalizing the surveys made from 1958 to 1979.

The major portion of three-component and modulus measurements on the water surface has been made by Soviet non-magnetic ship "Zarja" /_ 1_/. Another type of component measurements in the ocean is presented by airborne measurements at the elevation of 2-7 km, made by the US Naval Oceanographic Office according to "MAGNET" Project, by Dominion Observatory (Canada), by Hydrographic Office of Japan. The USSR makes systematic component measurements in the Arctic from drifting stations "North Pole". The generalized scheme of the World Ocean coverage by component surveys is given in Fig. 1, where the total number of tracks is given for every 10° x 10° of area.

During 1960's the measurements of the total force of the magnetic field by a towed from the ship magnetometer were widely

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spread. In the USA much work has been done by Lamont-Doherty Geological Observatory, by the Environmental Science Service Administration, National Oceanic and Atmospheric Administration, Scripps Institution of Oceanography, University of Hawaii, Woods Hole Oceanographic Institution. Hydromagnetic modulus surveys are also made by Canada, England, France, Holland, Federal Republic of Germany, Italy, German Democratic Republic, Japan and by New Zealand. In the USSR much work has been done by the Institutes of the Academy of Sciences of the USSR.

The error of the observed values during modulus measurements equals 20-50 gammas, which is in general explained by the error of coordinating, since the instrumental error makes the first gammas, while the error of determining the ship location ranges from several hundred meters near the shore to 2-3 miles in the open ocean. During recent years coordinating was made by satellite navigation system and this provided the increase of accuracy in determining ship location in the open ocean up to several hundred meters.

The generalized scheme of the World Ocean coverage by modulus surveys is given in Fig. 2, where the total number of tracks is given for every 10° x 10° of area. Horizontal dashing shows areas for which maps of T or $(\Delta T)_a$ have been compiled, vertical dashing and dots indicate areas where areal surveys have been made by foreign and Soviet ships respectively. The total amount of modulus surveys given in the scheme makes about 15,000,000 linear kilometers.

Satellite surveys are of the utmost importance for the study of the global field characteristics and its time changes.

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Proceeding from the scheme of the World Ocean coverage by component and modulus measurements an analysis of the magnetic knowledge of the oceans has been made for a solution of cartographic and geologic-geophysical problems. The rate of coverage was estimated by the available information required to make a more precise space-time model of the main geomagnetic field, to select global and base reference fields, to detect regional anomalies and typical features in the structure of the anomalous field of different oceans.

Proceeding from the appropriate rate of survey coverage required for solving the major research problems on the space-time structure of the geomagnetic field a regionalization of the water area was made to fit every problem. The major portion of the World Ocean, in particular, the Atlantic, most of the Pacific and Indian oceans may fit for construction and precision of analytical models of the main geomagnetic field using hydro- and aeromagnetic measurements. These problems may be solved if 2 or 3 tracks more than 500 km long are available in the area of 10° x 10°. Therefore, even poorly surveyed areas of the Arctic Ocean and the southern part of the World Ocean may ensure the solution of those problems if satellite surveys and "MAGNET" airborne survey are applied.

The study of the spectral structure of the geomagnetic field shows that besides the main minimum of the spectrum within the periods from 300 to 4,000 km there exist several regional minima within the range from 60 up to 1,000 km /_ 3, 4_/, in particular, in the periods of 60-100 km, 300-450 km and 800-1,000 km. The availability of those minima provide a detection of appropriate base reference levels in order to select regional anomalies

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and to make maps of those anomalies in the World Ocean area.

To determine base reference levels within 300-400 km a dense survey is required: 5-10 interactions of the 10° x 10° areas over more than 500 km are essential. The Atlantic Ocean (except southern area), the Pacific Ocean (except $\lambda = 130^\circ - 240^\circ$, $\varphi = 20^\circ - 40^\circ$ and the southern area), the Indian Ocean (except $\lambda = 40^\circ - 130^\circ$, $\varphi = -30^\circ - -70^\circ$) are covered with surveys most densely. In the Arctic Ocean only the east area of the American Basin is studied quite sufficiently.

The study of the spectral structure of the geomagnetic field within the range from 50 km to 300 km makes it possible to obtain mid-wave levels to detect anomalies with the periods less than 50 km. Besides, these levels may be used as reference fields to complete a map for a restricted water area.

In order to solve this problem a higher rate of survey coverage is required, i.e. no less than 10-40 evenly distributed intersections of 10° x 10° area. Such regions occupy only 31% of the World Ocean area. These are central, north, south-west and south-east parts of the Atlantic, north and east parts of the Indian Ocean; south-west and Antarctic areas of the Pacific.

The study of shorter-wave anomalies ($5 \text{ km} < T < 50 \text{ km}$) is possible only in regions where areal survey is made (Fig. 2).

Numerous intersections of the tracks of different years may be applied to investigate long-period time changes of the geomagnetic field. The construction ~~of~~ and precision of the secular variation model requires the surveys of different years made along the same track which is most suitable. The regions of repeated tracks mainly pass at the shelf of Africa and in the east part of the North America, north part of the Indian Ocean, west coast of Alaska, shelf of the west Australia, Hawaii Islands and shelf of the Antarctica. Not all those areas, however, are suitable for secular variations study. Near the Islands of Hawaii and New Guinea where the anomalous field is highly differentiated, a high accuracy of space coincidence of tracks is required. In the zones of a more quiet field it is possible to use the repeated surveys of the usual accuracy, e.g., in the areas of abyssal plains of the west side of Australia and Antarctica. The areas of the ocean bottom are poorly studied from the point of view of secular variation properties.

The analysis of the World Ocean coverage by component and modulus surveys close to the Earth's surface and at the elevations of satellite flights makes it possible to expand the scope of cartographic problems which may be solved. A combined use of hydro- and airborne magnetic measurements provide a precision of the model of the main geomagnetic field and the study of regional and mid-wave anomalies distribution to detect non-homogeneity in the structure of the lithosphere of different ocean parts.

References

1. Ivanov M.M. Magnitnaya s'emka okeanov (Magnetic survey of oceans). Geomagnetism, No. 7, Moscow, "Nauka", 1966.
2. Stockard H.P.,World Magnetic Survey 1957-1969, IAGA, 1971. Final volume, 60.
3. Kolesova V.I., Petrova A.A., Efendieva M.A. In: "Problems of marine electromagnetic studies". IZMIRAN, Moscow, 1979.
4. Galbez M., Gomez I., Kolesova V.I., Petrova A.A., Portnova V.P., Pochtarev V.I. Metodika sovmestnogo analiza struktury magnitnogo

DOI: https://doi.org/10.2312/zipe.1981.070.01

i gravitatsionnogo polei na primere territorii SSSR i Kuby (Methods for a combined analysis of the structure of magnetic and gravitational fields illustrated by the territories of the USSR and Cuba). Geophys. set of papers, AN UkSSR, Kiev (presented at the International Symposium of KAPG Working Group 1.6) in Kiev, November 1979).

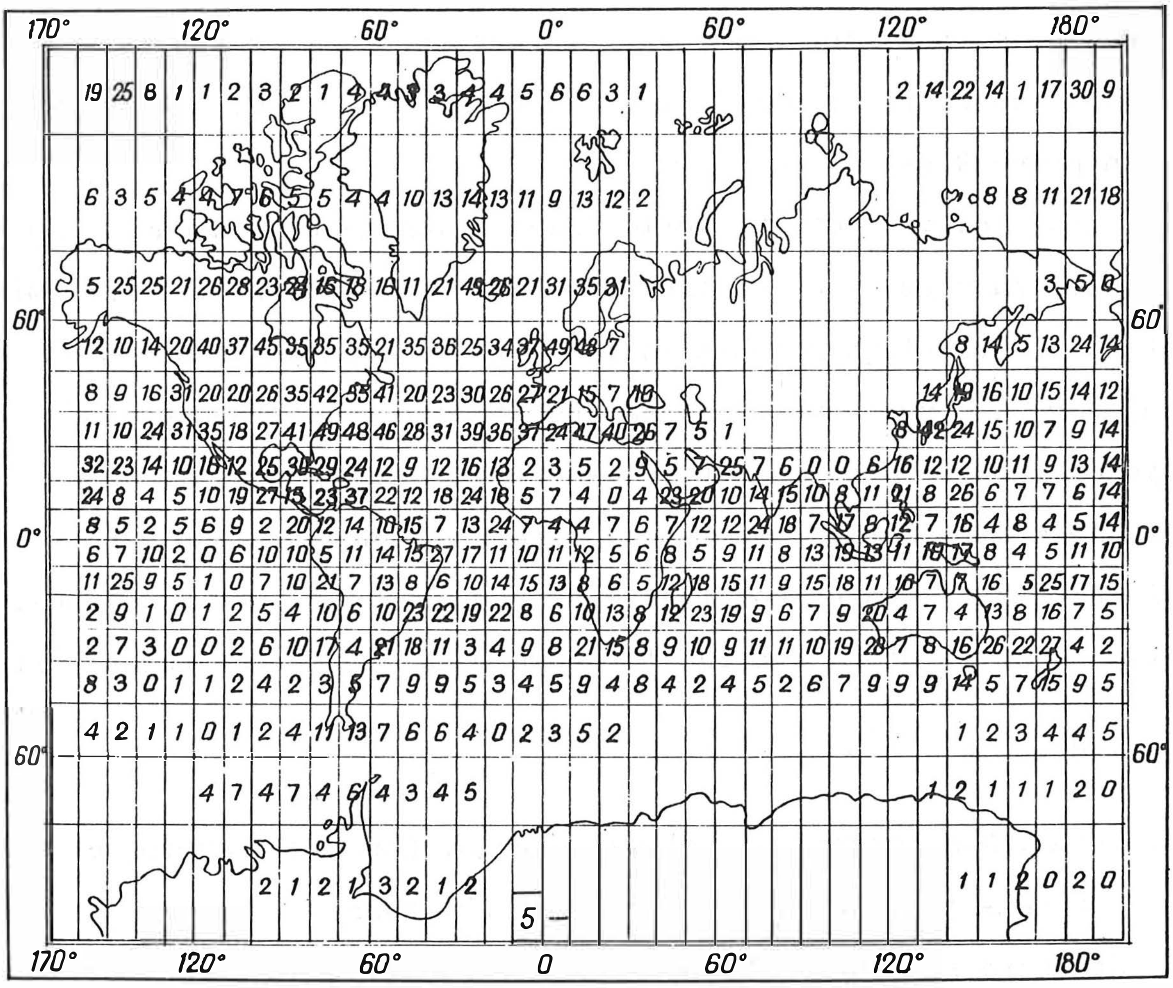

Fig. 1

Fig. 1. Generalized scheme of the World Ocean coverage by component surveys (total track number is given for every 10°x10° of area).

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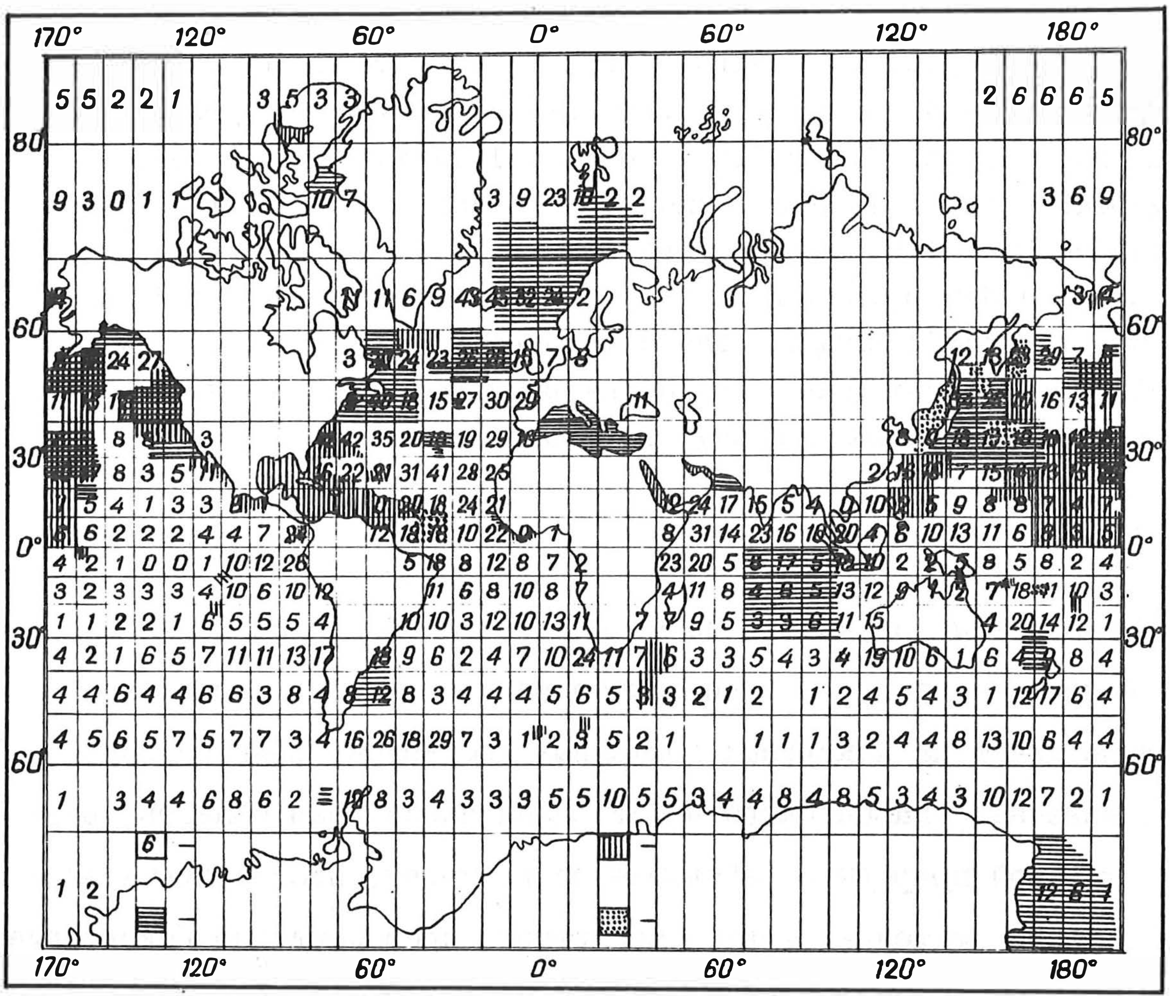

Fig.2

Fig. 2. Generalized scheme of the World Ocean coverage by modulus surveys (total track number is given for every 10°x10° of area).

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METHODS AND RESULTS OF THE GEOMAGNETIC FIELD SECULAR ANOMALIES INVESTIGATION IN THE CARPATHIAN REGION

Abstract

The investigation results of the secular variations of the geomagnetic field on the territory of Carpathian geodynamic polygon are considered. Two types of local variations in time of the geomagnetic field are found. The linear, of the Carpathian stretching anomalous region, possibly of current nature and the small in dimensions isometric anomalies are supposed to be of tectonomagnetic origin. The extension of geomagnetic investigations for search of earthquake precursors in the seismoactive Trans-Carpathian trough is proposed.

Резюме

Рассмотрены результаты изучения вековых вариаций геомагнитного поля на территории Карпатского геодинамического полигона. Выявлено два типа локальных временных изменений геомагнитного поля. Линейная, карпатского простирания аномальная область, возможно токовой природы и небольшие по размерам, изометричные аномалии предположительно тектономагнитного происхождения.Рекомендуется расширение геомагнитных исследований для поиска предвестников землетрясений в сейсмоактивном Закарпатском прогибе.

Zusammenfassung

Es werden Ergebnisse der Untersuchung der Säkularvariationen des geomagnetischen Feldes im Gebiet des Karpaten-Geodynamik-Polygons betrachtet. Zwei Typen von lokalen, zeitlichen Variationen des Erdmagnetfeldes wurden festgestellt: ein

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lineares (der Karpaten-Erstreckung folgendes), anomales Gebiet, mit möglicherweise Strom-Eigenschaften, und in der Ausdehnung kleine, isometrische Anomalien vermutlich tektonomagnetischen Ursprungs. Die Ausdehnung geomagnetischer Untersuchungen im Hinblick auf die Suche nach Erdbeben-Vorläufern in der seismisch aktiven Transkarpetensenke wird empfohlen.

The systematic investigation of the local anomal geomagnetic field variations caused by earth crust structure peculiarities and it's deep processes, is carried throughout 10 years, on the south-western slope of the Carpathians on the Carpathian geodynamic polygon territory.

The investigation is based on the principle of repeated modulus T-survey (accuracy is 0,7 - 0,9 nT) with the methods of twice a year simultaneous observation (June, October) on the network of more of 100 secular points. The matter of the methods used is to measure the modulus value T on base and series points, the feild gradient ΔT is calculated between base and series points. ΔT value time variation i.e. $\Delta\Delta T$ value will charachterize the local time variations of the geomagnetic field.

THe measurements on points are carried out with the help of proton magnetometers from USA (Geomagnetic.Pattern 816) and Soviet (T-MP) the proton magnitometers. Qvarz variometers placed in the thermostating room are used as base points.

The territory investigated contains the Trans-Carpathian deep fault along which extends the zone of deep electroconduction being source of region geomagnetic variation anomaly. The bay-shaped disturbances with the period from 15 do 150 min (1)

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are the most intensive manifestation of anomaly.

Recently the S_q-variations of the space field structure was note in the same zone.

In connection with such regional pecularities of space-time structure of the variable geomagnetic field, arised the necessity of careful investigation, registration and complete exclusion of the outer source field influence from the observed data series in order to receive the local changes of the constant geomagnetic field related directly to different processes within the crust.

From the investigation methods on polygon provide the uninterrupted 4 component measurements of geomagnetic field on one of base points what allows to exclude the investigations connected in the time with bay-passage from series of them. Moreover over some days we make the modulus measurements with period 5 to 10 minuts paralleled to that of base in a zone of largest gradient of regional conduction anomaly. A long series of investigations average, and the mean number $\Delta\Delta T$ characterise in the satisfied reliable order, the difference between the intensity field values in base and series points in a time-interval. Such methodic approaches exclude, with satisfied surety, the outer field variations from investigation results [3].

Systematic long-period investigations on polygon allow to study the space-time field peculiarities of secular variations. According to measurements resuls was made a set of $\Delta\Delta T$ anomaly maps representing the different time intervals, year field variations(the survey carried out the same months of

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current year), and that of season representing the difference between two measurement stages of a year. On the basis of these maps detail $\Delta\Delta T$ field analysis was carried out together with the data about tectonic trough, magmatism, rock crust composition and its pecularities ets. As an example we adduce $\Delta\Delta T$ maps for 2 time-period measurements, 1976-1977 and 1977-1978 years (fig. 1,2).

In the result of analysis the following $\Delta\Delta T$ field pecularities were revealed. We distingush 2 types of local anomalous changes of the field. These are a linear zone of $\Delta\Delta T$ anomalous values and local, isometric in plan, small in their area anomalies.

The region of linearly-extended anomaly of the Carpathian strech is situated somewhat to the north from the Trans-Carpathian trough and Folded Carpathians boundary. It's pasition and extension correspond to the Trans-Carpathian deep fault and Carpathian conduction anomaly which is connected and control this foult. The anomaly from south by zero $\Delta\Delta T$ isoline and from north has no exit to normal field because of points absence in Carpathian mountain part. It is characterized by large values of annual field variations achieving -7, -8 nT at a series of points. On the whole apart from some local positive anomalies isometric in plan the geomagnetic field has the general tendency to decrease every year. The maximum negative field values (to - 10 nT) during two years (1976-1978) are received in the south eastern part of this zone.

The anomaly zone is arranged for the region separating different as to structure and properties elements of the Car-

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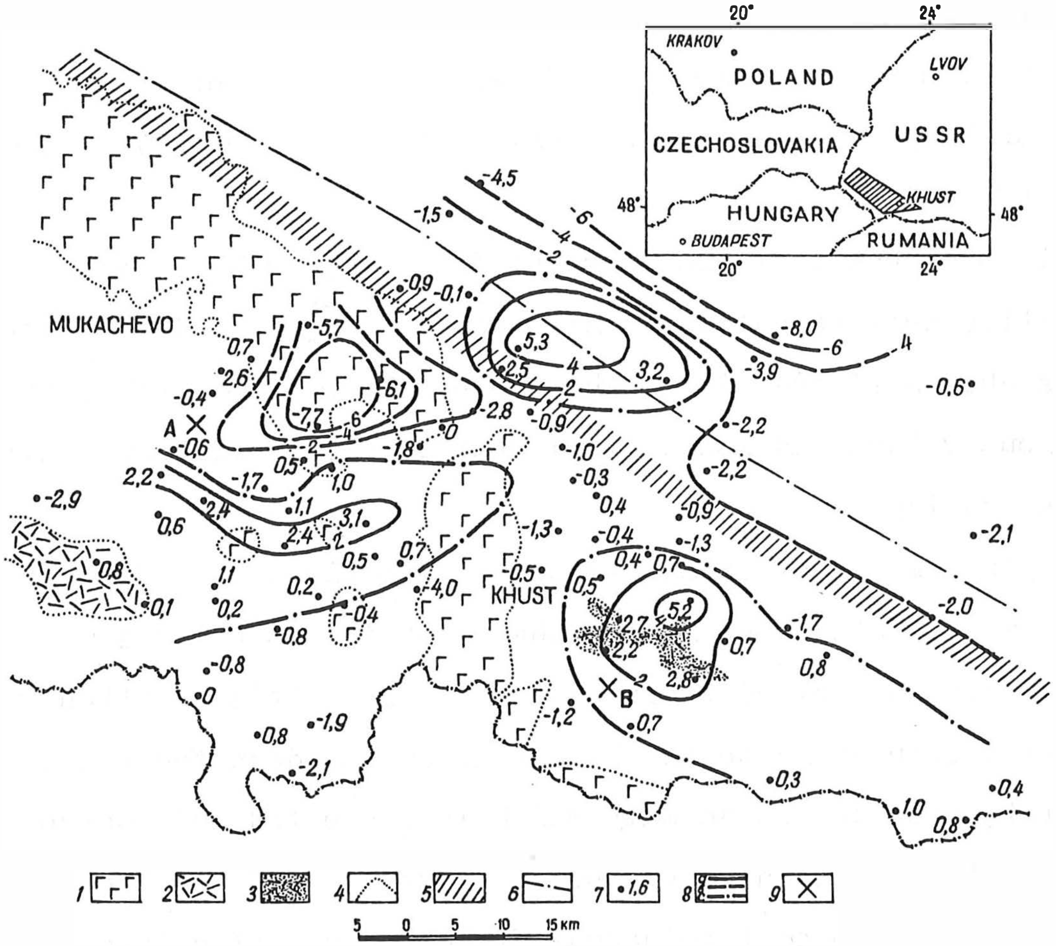

Fig. 1 Yearly magnetic field change (anomalies $\Delta\Delta T$) over the period from July 1976 to July 1977

1 - Vigorlat-Gutinskaya volcanic ridge,
2 - volcanogenic rocks of the acid composition and their tuffs,
3 - horizons of the nankovsk tuffs,
4 - boundaries of volcanogenic formations,
5 - zone of the Trans-Carpathian deep fault,
6 - the axis of the Carpathian anomaly of electroconductivity,
7 - the point of geomagnetic observation,
8 - isolines T: a - positive, b - negative, c - zero,
9 - epicentres of local earthquakes: A - 24.09.1977
B - 13.07.1978,

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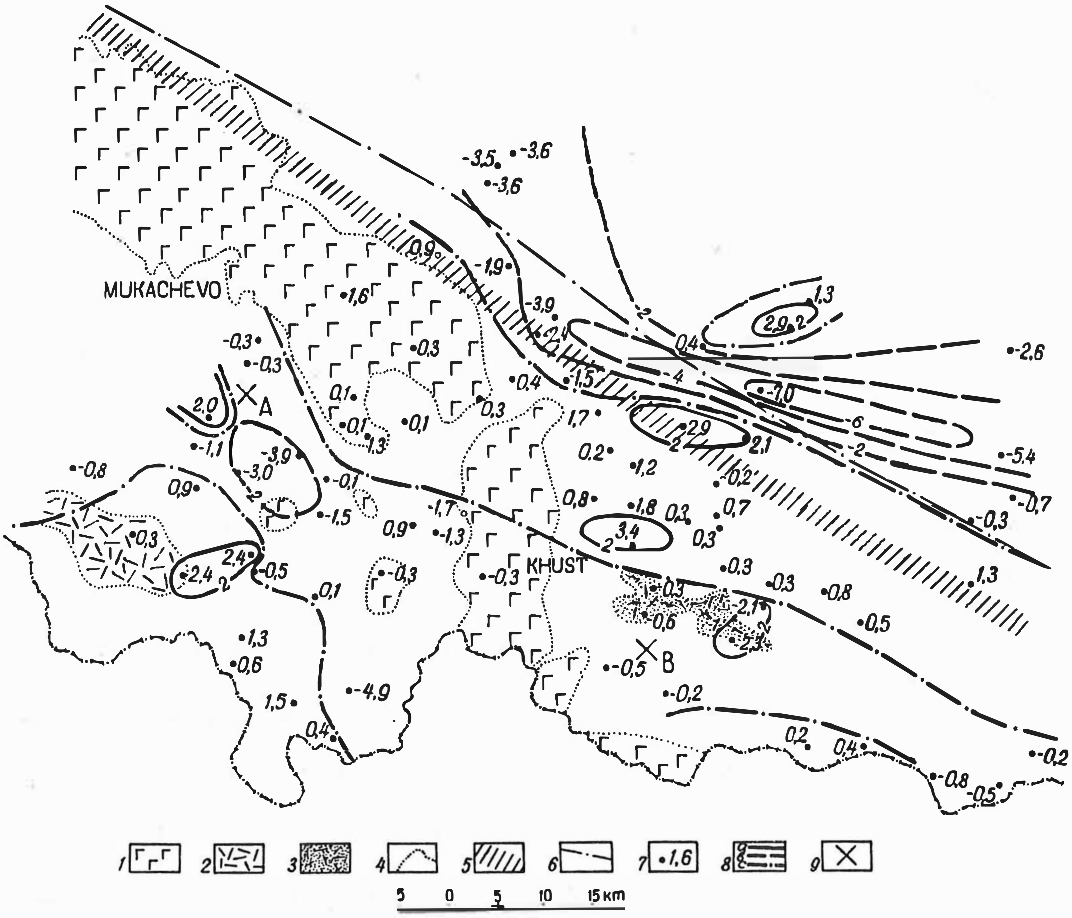

Fig. 2. Yearly magnetic field change (anomalies Δ ΔT) over the period from July 1977 to July 1978 (conventions see fig. 1).

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pathian region (i.e. Trans-Carpathian inner trough and Folded Carpathians) and for one of anomaly conduction traced all the way along the outer and Inner Carpathian boundary.

This fact underlines the important role of this structure unit in the history of the Carpathians formation. Let us remind that the inner zohe Trans-Carpathian deep-fault structure is characterized by variety and structure complexity [4].

First of all beginning from trias and to neogen inclusive the fault zone was a kind of boundary, on either sides of which conditions and sedimental accumulation nature were essentialy different. The deep faul nature is corroborated by magmatism because Vigorlat-Gutinskaya ridge is arranged for this zone. The periodicily of outpourings along the fault. testifies to the repeated tectonic activity renewal in this region and its actual tectonic activity is confirmed by quite high seismicity.

The stretch of the anomalous zone fully repeats the Carpathian anomaly axis position what testifies to those geophysic phenomena unique nature. The anomaly electroconduction axis along its stretch is moved to north-east in respect to deep fault position according to geophysical data. Probably it is connected with the fact that both the fault plane and the deep conduction zone are sloped under the Folded Carpathians to north-east.

Most likely that $\Delta\Delta T$ linear anomaly zone is of current nature and is the result of substance conduction change in commection with thermodynamical condition variation in active fault zone. Small values of local $\Delta\Delta T$ maximums and minimums periodically arising with the linear zone reflect rather parameter environment variations on small and undeep areas of active zone.

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Apart from above mentioned linear Carpathian stretch anomaly a series of local isometric in plan positive and negative

T anomalies is revealed on the Trans-Carpathian inner trough territory. These anomalies have probably undeep sources because their area values do not exceed 10-30 kilometers. They are not stable, vary in time their intensity and location.

On the whole it turned out that the discovered anomalies as a rule are arranged for the volcanogenous rocks, which are represented by andesites, andesite-basalts, lava and piroclast andesites, tuffs.

Magnetic properties of volcanegenic rocks in Trans-Carpathian are rather different. Nonmagnetic rocks within volcangenic formations are practically seldom. The assumption is arising about the tectonomagnetic nature of anomalies $\Delta\Delta T$ appearing on the polygon. Our assumptions are testified to some degree by data about seismicity over the period of the geomagnetic field meaturements. So, according to yearly measurements of the geomagnetic field from july 1976 to july 1977 a series of anomalies $\Delta\Delta T$ (fig. 1) is revealed, early described. After carrying the measurements three local earthquakes of magnitude 4 (epicenters are indicated on fig. 2) took place. The further cycle of field measurements was carried out in july 1978, and in distribution of anomalous values in the further period, i.e. from july 1977 to july 1978 the anomalies are almost disappeared or turned in quite small ones in area. It seems, the accumulation and detent of elastic stresses in the the earth's cruct trough were the cause of the change in character of the anomalous field $\Delta\Delta T$. Moreover, the field map $\Delta\Delta T$, presented on fig. 2, characterizes the quiet field of tectonic stresses. On it are seen linear anomalies of the

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current nature in the zone of Trans-Carpathian deep fault and separate residual tectonomagnetic anomalies appearing in one or two points which indicate that the detent of the stressed state took place not fully or a new accumulation period of ~~of~~ elastic stresses in the earth's crust of the trough is initiated.

Some connection of temporal changes of the geomagnetic field with trough structure is also outlined. So, on fig. 2 three zones of Carpathian stretching (devided by zerons izolines) are isolated which are distinguished in sign of the temporal geomagnetic field changes. The first (northern) is positive, the second (central) is negative, the third (southern) is positive. Such field peculiarities ΔΔT are observed at small, near to normal, values ΔΔT which really serve as a background, the normal field for local temporal anomalies. It is possible that such longitudinal zonality of temporal geomagnetic field changes of the Cappathian stretching teflects peculiarities of the earth's cruct structure of the trough and processes in it. By the way, nowadays some geologists /4/ assume that for the Trans-Carpathian trough is characteristic first of all the longitudinal zonality of structural elements. Transverse structures are more young and appeared as a result of up-and down-motions along the discrete dislocations mainly of the transverse.

The result given indicate that bodees of volcanic rocks and layer intrusions containing the ferromagnetic minerals are an original indicator of stressed state changes of rocks in Trans-Carpathian trough. Accordingly it is possible to use

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result of geomagnetic investigations for search of earthquake precursors in Trans-Carpathian conditions.

The perspectivity of study of the earth's crust structure and dynamics of processes within the earth according to geomagnetic investigations is proved by numerous physical experiments, experiments with explosions, works on the geodynamic polygons in the USSR and abroad. Apparently, the possibilities of the magnetometric method are not fully exhausted and its informativity will be higher in connection with further improvement of the investigation procedure and development of new observation systems.

References

1. Bilinskiy A.I. Electromagnetic Induction Peculiarities.- In: Carpathian Geodynamic Polygon.- M.: Sovetskoye Radio, 1978, pp. 98-101.
2. Kuznetsova V.G. Secular Variations Study of the Geomagnetic Field.- In: Carpathian Geodynamic Polygon.- M: Sovetskoye Radio, 1978, pp. 48-58.
3. Kuznetsova V.G., Maksimchuk V.Je. Possibility of the Electroconductivity Anomalies Sepazation according to Repeated High-Precision Observations of the Geomagnetic Field.- Geofiz.sb.,1979, vyp. 89, pp. 31-35.
4. Krugliv S.S. Some General Questions of the Ukrainian Carpathians Tectonics.- In: Geological Structure and Fuel Ores in Ukrainian Carpathians.- M.: Nedra, 1971, pp.288-294.

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STUDY OF SPECTRAL CHARACTERISTICS OF THE GEOMAGNETIC FIELD OF REGIONS WITH DIFFERENT TYPES OF THE EARTH'S CRUST

Резюме

В работе приведены результаты спектрально-профильного анализа (СПАН) геомагнитного поля для регионов с континентальным и океаническим типами коры, а также переходных зон. Характерные особенности спектральной структуры полей в средневолновом ($10 < T > 200$ км) и длинноволновом (200 км $< T > 600$ км) диапазонах показаны для акваторий на примере Атлантического, Тихого, Индийского и Северного Ледовитого океанов, а для материков - на примере Русской и Восточной-Сибирской платформы и Западно-Сибирской плиты.

Abstract

The results of spectral-profile analysis (SPAN) of the geomagnetic field are given for the areas with continental and oceanic crust types as well as for transient zones. The peculiarities of the spectral structure of fields with medium- ($10 < T > 200$ km) and long-wave (200 km $< T > 600$ km) ranges are shown for the water areas illustrated by the Atlantic, Pacific, Indian and Arctic Oceans and for land areas, illustrated by Russian and East-Siberia Platforms and West-Siberia Plate.

Zusammenfassung

Die Ergebnisse der Spektral-Profilanalyse des geomagnetischen Feldes (SPAN) für Regionen mit kontinentalem und ozeanischem Krustencharakter und für die Übergangsbereiche werden dargestellt. Charakteristische Besonderheiten der Spektralstruktur der Felder im Mittel- ($10 < T > 200$ km) und im Langwellenbereich ($200 < T > 600$ km) werden für die Meeresgebiete

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an Beispielen des Atlantischen, Stillen und Indischen Ozeans und des Nördlichen Eismeeres und für das Festland an Beispielen der Russischen und Ostsibirischen Tafel und der Westsibirischen Platte gezeigt.

To study spectral characteristics of the geomagnetic field of regions with different types of the Earth's crust the structure of the field has been analyzed from the hydromagnetic measurements data, from airborne surveys at the elevations of 0.5 km and 2-7 km and from satellite data of POGO and "Kosmos-321" /_ 9_/.

The studies of the continental type of the crust are illustrated by the USSR territory, while the studies of the oceanic type of the crust are illustrated by the Pacific, Atlantic, Indian and Arctic Oceans water areas /_ 1 - 5_/. The analysis of the fields structure in the zones of transition from oceanic crust to continental crust has been made for the central part of the Atlantic. The tracks of the component airborne magnetic surveys "MAGNET" in the Pacific have been used as extended profiles crossing the areas with different types of the crust.

Besides, a combined analysis of the structure of gravitational and magnetic fields has been made to study non-homogeneities of the lithosphere of the above regions and this provided to detect zones with homogeneous structure, to determine their spectral characteristics and to establish the coordinated minima in the spectrums of those fields. The results of the combined analysis made it possible to follow the peculiarities of the geomagnetic and gravitational fields of the zones connecting regions with continental and oceanic types of the crust.

To discover the main peculiarities of the structure of the geomagnetic and gravitational fields the method of the spectrum-

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profile analysis (SPAN) has been used /_ 1_/. The SPAN method is based on a successive linear filtration of the initial field spectrum with a set of narrow-banded filters with a subsequent recovery of the field by means of the inverse Fourier transform within the specified range of periods. The results of the analysis are presented in the form of an amplitude diagramme where periods are plotted on the vertical axis and the distance along the profile is plotted on the horizontal axis. The maxima of different intensities at appropriate periods and profile reaches (Fig. 1) detect individual components of the anomalous field in the diagramme. This provides a quantitative characteristic of the field structure, establishment of peculiarities of its changes along the profile, a discovery of dispersion and space properties of the anomalous fields of various regions. Thus the SPAN method provides a quantitative basis for discovery of the rate of differences and similarities in the field structure in the particular areas of the Earth's crust. A visual presentation of the magnetic field structure in the form of an amplitude diagramme makes it possible to follow the reflection of the tectonic elements of different order in the observed fields and to compare the areas of different anomalies propagation with the location of seismic boundaries and other geophysical data. This opens wider opportunities to interpret anomalies and to make geologic-geophysical models of the lithosphere.

The study of the geomagnetic field structure in different areas of the world emphasizes, on the one hand, the availability of peculiar features of the anomalous field in individual regions, and on the other hand the availability of some general laws of its structure for geological formations of different age and

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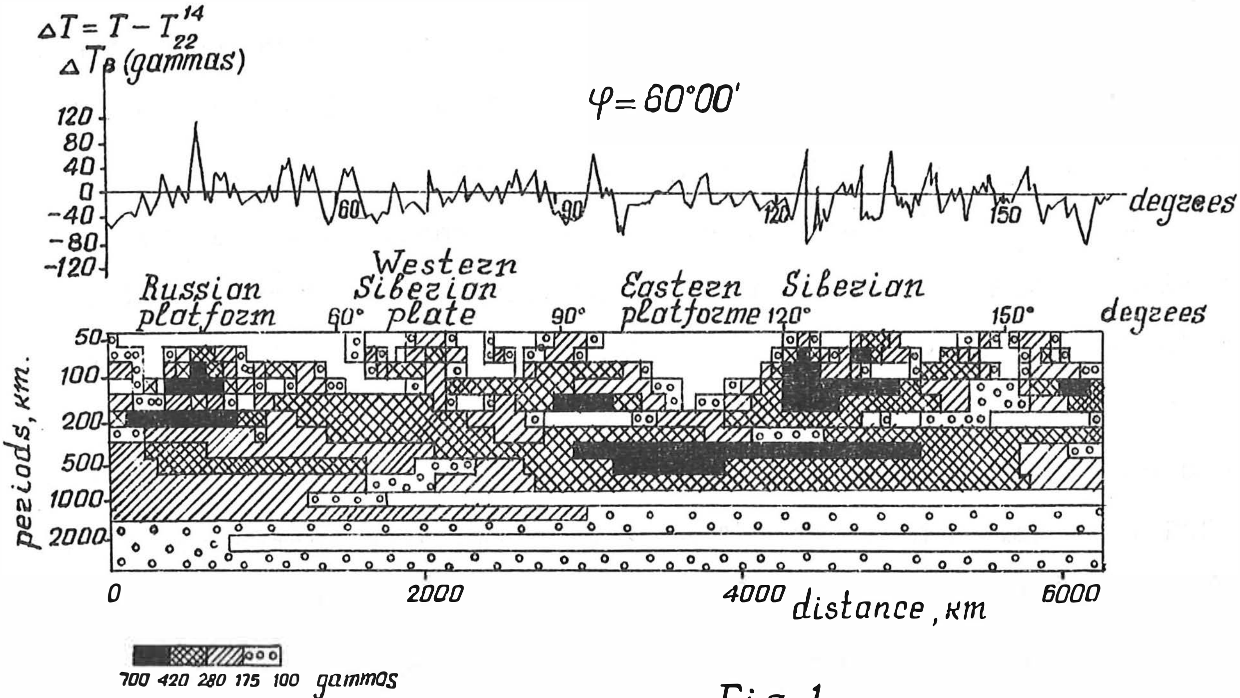

Fig. 1

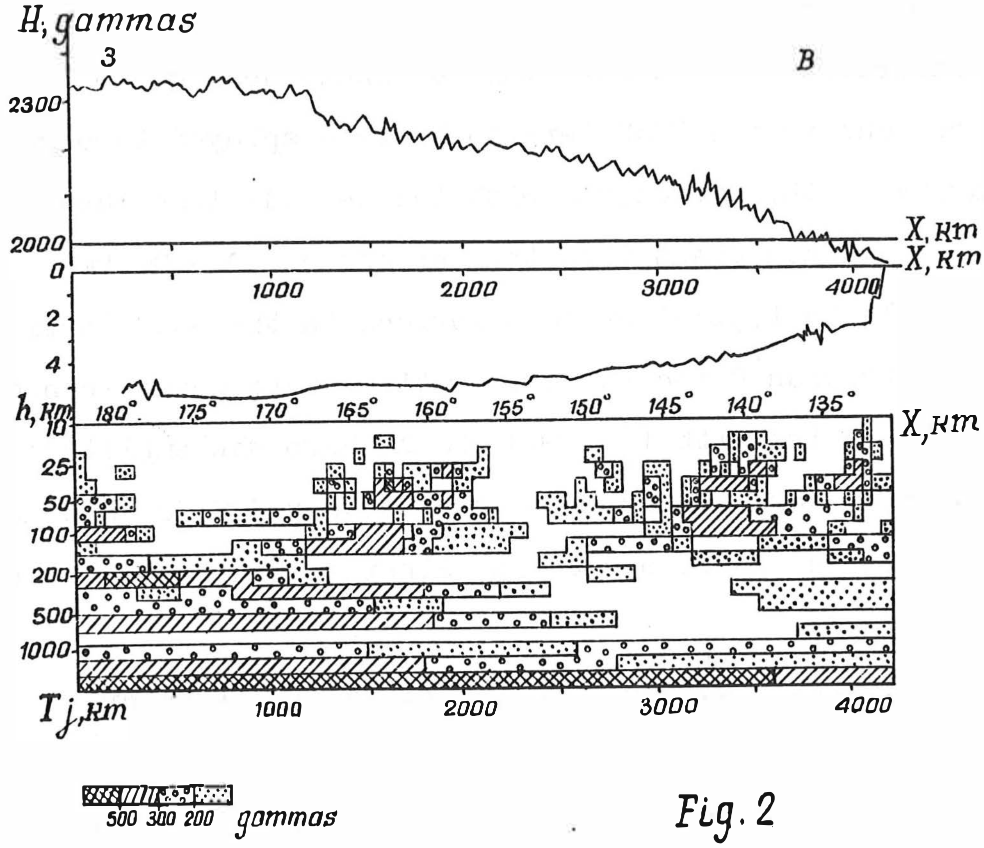

Fig. 2

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structure.

Long-wave anomalies with the periods from 100 km to 1,500 km are of principal interest for a study of large peculiarities in the structure of the lithosphere of continents and oceans.

The study of the structure of the magnetic and gravitational fields of the regions with the continental type of the crust was made for the Russian and East-Siberian Platforms and West-Siberian Plate. A combined analysis of both fields has been made along the systems of the extended latitudinal profiles crossing the entire USSR territory (φ = 55°-61° N) ∠ 2_/. The main characteristics of the spectral structure of the fields for the Russian and East-Siberian Platforms, for West-Siberian Plate and the Urals are given in Table 1. The anomalies with the periods of 40-80 km, 100-150 km, 200 km and 500-600 km are most typical of the Russian and East-Siberian Platforms (Fig. 1).

The peculiarities of the structure of individual geologic-geophysical regions in the USSR territory are displayed through a non-stationarity of the components with the periods less than 400 km. A long-wave component with the periods of 500-600 km is most stable. It is typical of most regions in the USSR territory. The West-Siberian Plate is an exception, here magnetic and gravitational anomalies with T_j = 500-600 km have the amplitude less than 200 gammas and 20 mGal. But they attain 300-500 gammas and 60-100 mGal in the Russian and East-Siberian Platforms close to the Earth's surface.

Large peculiarities of the magnetic field structure are proved by measurements made by POGO and "Kosmos-321" satellites ∠ 9_/. Anomalies with the periods of 500-600 km at the elevation

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Table 1

	Russian Platform		Urals		West-Siberian Plate		East-Siberian Plafform	
	T_j, km (T)	T_j,km(Δg)	T_j,km(T)	T_j,km(Δg)	T_j,km(T)	T_j,km(Δg)	T_j,km(T)	T_j,km(Δg)
max	18-25	-	10-20	-	15-23	-	15-23	
min	25-30	-	20-25	-	25	-	40-45	
max	35-60	40-50	25-50	-80	-80	60-80	45-90	
min	80-100	100	100	80-100	100	80-100	100	80-100
max	100-130	100-130	150-200	140-180	150	140-170	120-150	120-150
min	150-200	170-180	200	200	200	200	200-270	200-300
max	200-270	250-300	270	250-350	270	200-250	360	400-500
min	400-500	400-500	350	400	350-500	300	500	
max	490-660	500-660	500-700	500-700	500-660	350-650	650-900	600-800
min	900-1000	1000	700-1000	800-1000	850-1000	1000	900-1000	900-1000
max	1100-1300	-	1100-1300	-	1100-1500	-	1500-1600	1300-1400
min	-	-	-	-	-	1300-1700	-	1700
max	-	1500-2500	-	1500-2500	-	2200-2500	-	2500
	-	-	-	-	-	-	-	-

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of 450 km. have the intensity ranging from 4 to 6 gammas. Thus, the fields of continental regions are characterized by a complicated structure, caused by an overlapping of intensive anomalies of different classes. Regional anomalies, reflecting, probably, an existance of non-homogeneities of the lithosphere of those formations make one of the peculiarities of the ancient platforms.

The structural peculiarities of the magnetic and gravitational fields of different basins in the World Ocean are considered in the extended trans-oceanic profiles crossing the main geological structures of the Atlantic, Pacific, Arctic and Indian Oceans.

The comparison of fields in different oceans shows that the zones of all the studied mid-oceanic ridges are similar in their structure which differs by the availability of short-period and mid-wave magnetic anomalies with the periods from 10 to 50-70 km. At the same time the hollows of different basins differ greatly in some parts of the World Ocean. For example, the analysis of gravitational and magnetic fields in the Atlantic showed that the North-American and Canary hollows contain anomalies with the periods of 25-60 km, 70-90 km and 100-200 km /_ 3_/. Long-wave anomalies with T = 200-300 km and T=500 km are observed in the gravitational field only; this, probably, testifies to a shallow depth of Curie's surface extension. This field structure is typical of the major part of the bottom in the Atlantic. The areas with long-wave magnetic anomalies are the exceptions, For example, magnetic zones are located to the north from the Antilles Islands and in the West-European Hollow; the components with T = 500-600 km are typical of those zones /_ 4_/. Surveys made at the elevation of 260-280 km from "Kosmos-321" satellite proved positive regional anomalies available in those regions /_ 9_/.

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Thus, the structure of the magnetic field of the Atlantic hollow, except some areas, is characterized by the anomalies with $T < 200$ km. The similar structure is characteristic of the hollows in the west of the Indian Ocean [4].

Unlike the Atlantic Ocean, the major part of the water area in the Pacific is occupied by the regions characterized by long-wave anomalies with the periods exceeding 200 km. For example, the analysis of the gravitational and geomagnetic fields in the north-west of the Pacific resulted not only in the discovery of components with the periods of 30-70 km, 100-140 km but also 200-350 km, 500-600 km (Fig. 2) [5]. In the central and south parts of the Pacific the regional anomalies with $T > 200$ km have been detected by Japanese scientists [6]. The analysis of component and modulus measurements at the elevation of 2-7 km ("MAGNET" survey) prove the availability of large regional anomalies with $T = 500$-600 km.

The mid-ridge zone, as well as in other basins, does not contain long-wave components and is characterized by the anomalies with $T < 70$ km. A zone with similar structure is also extended northward the Pacific upraise along the west coast of the North America.

Thus, the water area of the Pacific has a heterogeneous structure of the magnetic field. A certain trend is observed, however, in the change of the spectral structure. For example, a successive crossing along $\varphi = 49°$ N of different aged areas of the ocean showed that younger east areas, i.e. younger than 50,000,000 years, are characterized by the anomalies with $T =$ 30-70 km, 100-140 km (Fig. 2). In west areas, older than

70,000,000 years, regional anomalies with T = 200-350 km and 500-600 km are observed. In the zone of transition from one area to the other at the distance of 300-400 km a great disturbance of all the components of the gravitational and magnetic fields is observed.

Thus, the spectral structure of the magnetic field in the east and west of the Pacific has different characteristics which are subject to changes, probably, because of the age of the ocean bottom.

Two different basins are located in the water area of the Arctic Ocean, i.e. Eurasian Basin (EB) and Amerasian Basin (AB) /_ 7_/. The magnetic field studies along the extended profiles, crossing the entire Arctic basin of the Arctic Ocean showed that the structure of the EB and AB fields differed greatly /_ 8_/. EB is characterized by weak-intensive linear anomalies with $T < 50$ km, while the longitudinal zonality of AB is displayed by intensive anomalies with $T < 130$ km. Moreover, the anomalies with $T > 50$ km are absent in the EB field while AB field is characterized by regional anomalies with T = 200-300 km and T = 400-450 km with the intensity up to 300-500 gammas. The analysis of component and modulus measurements made by "MAGNET" survey is in agreement with the data obtained from POGO satellite surveys. A positive anomaly with the intensity up to 7 gammas is observed in the AB area at the elevation of 450 km.

In a line-form transitional zone from AB to EB at Lomonosov Ridge the magnetic field structure is fundamentally rearranged. According to SPAN results the transitional zone between two provinces is observed all over the distance of AB and EB, being

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wider from the Asian part and narrower to Greenland.

Thus, two magnetic provinces are observed in the Arctic Ocean, as well as in the Pacific, which differ by the structure of geophysical fields significantly.

The transitional zones from oceanic basins to continents as well as the transitional zones between different-aged oceanic basins in the Pacific and Arctic Oceans are of a certain interest. A disturbance of structure in the magnetic and gravitational fields is observed in these zones; this disturbance affects all the components, regional components with the periods of 500-600 km included. It may appear, that these boundary zones are the areas with a specific crust type, referring neigher to continental type, nor to oceanic.

The comparison of regions with continental and oceanic types of crust show that despite great differences between ancient and young oceanic basins the ocean field is characterized by greater homogeneity and less complexity of the field structure compared with the continents. Moreover, the space structure of continents and oceans fields have some common properties, probably explained by similar features in the structure of the lower magnetic-active layer of the lithosphere of the Earth. In particular, the stable minimum available in the spectrum at T = 300-500 km and still deeper and more stable minimum available within 800-1,000 km is one of those features. These minima may be used as levels of field reference in different parts of the world.

References

1. Petrova A.A. A set of papers: "Problems of geophisical research of polar areas of the Earth", Leningrad, Ed. by NIIGA, 1977,

DOI: https://doi.org/10.2312/zipe.1981.070.01

p. 119-126 (in Russ.).

2. Kolesova V.I., Petrova A.A., Pochtarev V.I., Efendieva M.A. Issledovanie krupnykh regionalnykh magnitnykh anomaliy na territorii SSSR (Research of large regional magnetic anomalies over the USSR territory). Geophys. set of AN UkSSR, Kiev, presented at International Symposium of KAPG group 1.6, November 1979, Kiev.
3. Gerashchenko N.N., Verba V.V., Petrova A.A. K voprosu o magnitnoi modeli zemnoi kory tsentralnoi Atlantiki (On the problem of magnetic model of the Earth's crust in Central Atlantic), Fisika Zemli, No. 4, 1980.
4. Galbez M., Gomez I., Kolesova V.I., Petrova A.A., Portnova V.P., Pochtarev V.I. Metodika sovmestnogo analiza struktury magnitnogo i gravitatsionnogo polei na primere territorii SSSR i Kuby (Methodology for combined analysis of magnetic and gravitational structure illustrated by the USSR and Cuba territories). Geophys. set.of AN UkSSR, Kiev, presented at International Symposium of KAPG Working Group 1.6, November 1979, Kiev.
5. Kolesova V.I., Petrova A.A., Efendieva M.A. In: "Problems of electromagnetic research", IZMIRAN, Moscow, 1979 (in Russ.).
6. Nomura M. Bull. of Ocean Res. Inst., University of Tokyo, 1979, No. 11, 1-42.
7. Vakie V. Geomagnetism v morskoi geologii (Geomagnetism in Marine Geology), Leningrad, "Nedra", 1976, 191 p.
8. Petrova A.A. Geophys. set of NIIGA, vol. 13, Leningrad, 1978.
9. Katalog izmerennykh i vychislennyk znacheniy modulia napriazhennosti geomagnitnogo polia vdol orbit sputnika "Kosmos-321" (Catalogue of observed and computed values of the total force of the geomagnetic field along "Kosmos-321" satellite orbits). Moscow, "Nauka", 1976.

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ON GEOMAGNETIC FIELD LOCAL VARIATIONS RELATION TO THE CARPATHIAN REGION TECTONICS AND SEISMICITY

Abstract

The questions of the geomagnetic field local variations relations to the Trans-Carpathian trough tectonics and seismicity are considered in the paper. It is established that the Trans-Carpathians seismicity is not connected with the neighbouring territory activity, it is determined by its own earthquakes. Facts are given about the trough recent activity. The questions of Pre-Carpathians seismotectonics are treated briefly.

Zusammenfassung

Betrachtet werden Fragen der Wechselbeziehungen zwischen lokalen Magnetfeldänderungen und Tektonik und Seismizität von Transkarpatensenke. Es wird festgestellt, daß die Seismizität von Transkarpatien nicht mit der Aktivität der angrenzenden Territorien verbunden ist, sondern durch eigene Erdbeben bestimmt wird. Daten der rezenten Aktivität werden angeführt und Fragen der Seismotektonik des Vorkarpaten-Gebietes kurz behandelt.

Резюме

Рассмотрены вопросы взаимосвязи локальных изменений геомагнитного поля с тектоникой и сейсмичностью Закарпатского прогиба.

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Установлено, что сейсмичность Закарпатья не звязана с активностью прилегающих территорий, а определяется собственными землетрясениями. Приведены данные о современной активности прогиба. Кратко рассмотрены вопросы сейсмотектоники Предкарпатья.

The Carpathian region belongs/to moderate seismicity, which is determined both by local and by the Romanian (the Vrancha Mountains region), Chechoslovakian and Hungarian earthquakes. The macroseismic effect, produced by these earthquakes (of magnitude 5-7), is the same as the local earthquake intensity.

Three regions: the Pre-Carpathians, Buckovina and the Trans-Carpathians single out within the Carpathian region [2].

The question of the Carpathian region seismicity relation to tectonics and physical was treated by many authors [1 - 5].

At first there was the opinion that the Trans-Carpathian seismicity is determined by the Romanian earthquakes, what is presented in details in [1].

Further inestigations showed that the Trans-Carpathian earthquakes are not connected with the Vrancha Mountains region activity, what is testified by the direct geological relationship absence between the compared regions [1].

The Carpathian earthquake tectonic nature is recognized by the majority of authors [1 - 5]. In a number of papers on the question it is noted that the earthquakes are connected with the displacement along the main fault zones and, specifically, for the Trans-Carpathian trough:

- the Trans-Carpathian fault zone,
- the Pre-Pannonian fault zone.

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The Trans-Carpathian seismicity is caused, first of all, by the history peculiareties of the region goelogical development and is determined by own earthquakes. This principle was of great importance for establishment of the fact of existence, withen the Soviet Carpathian region, the recent tectonic activity, which is being testified by geophysical data now.

So, the equilibrium disturbance of the Carpathian region crust large blocks is testified by the gravity isostatic anomalies distribution nature.

For the folded Carpathians earth crust equilibrium at its 55 km power and the relief average height about 1 km, it is necessary to increase the relief height to 3 km. The geological and repeated levelling data testify to steady elevation of the Carpathians at 2 mm/year speed, beginning from Neogen and up to now , what, evidently, is connected with isostatic force activity.

Quite different is with the Trans-Carpathian trough. At the earth crust 25 km power to heep isostatic equilibrium conditions, the earth surface must have marks about 1,7 km while the recent relief average height makes average 200 m.

If we take into consideration only isostatic forces, the trough must he descending now. In reality, beginning from the holocene, the trough is raiseng i.e.its earth crust will deviate more and more from the equilibrium state at the speed about 1 mm/year [3]. Such directivity variety of the crust recent movements and isostatic force actions is explained perhaps, by the tectonic force influence, caused by the deep processes.

The recent trough activity is testified by its geother-

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mal regime. The geomagnetic field repeated observation data, as a result of which two regions of anomalous secular movement of small intensity and size were discovered, testify to the activation zones too.

The first anomaly was fixed near the Zalooge village and is dependent on the Borzhavsky and Latoritsky faults intersection with the Bereghovo strip of the horst elevations and the Bereghovo-Mukachevo Quarternary disturbance. The second anomaly is dependent an the active zone of the Dolghoye village, which is formed by the Borshavsky and Trans-Carpathian faults intersection with the Gutinskaya ridge transverse tectonic seam. The above anomalous regions heep their position, but change their sign and size with the time. Small anomaly sizes point at their source small depth, what agrees with the Trans-Carpathian earthquake hypocentre depths. That's why it is quite possible that anomalies are caused by the rock magnetisation variation due to variable elastic stresses [4].

THe repeated levelling data show that withein the Trans-Carpathian deep fault the differential vertical movements are absent and, at the same time, quite appreciable and usually repeating earthquakes are dependet on it. However, in spite of the limited data on the triangulation point displacement it is still possible to make some suppositions about the deformation nature in the fault zone [5]. So, on the Perechin-Dolghoye section interact four blocks with opposite motion directions, forming in the Dolghoye village region a stressed knot . Hence, on the Perechin-Dolghoye section the Trans-Carpathian fault is the extension zone. On the section from the Dolghoye village and

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further the fault is under the compression force influence (Fig. 1).

When analyzing the earth crust block horisontal motion nature of the fault and of the folded Carpathians we see that in the soulth-western part of the Chop-Mukachevo trough the compression zones are formed and in the south of the Solotvinsk depression the extension zone is formed. As a result of such movement nature observed withen the trough, the Pre-Pannonian foult is under the influence of the compression forces on one section, and on the other-under the influence of the entension ones. The earthquakes with the hypocentres at the depth of 5 km order are arranged for it.

To compare the seismicity with the trough tectonics elements, with the geophysical fields morphology and their variatione, and with after geologo-geophysical data we made the scheme of the Trans-Carpathian trough earthquake epicenters according to macroseismic and instrumental data, the scheme of diserete disturbances and block tectonics elements (Fig.2). The epicenter scheme shows that the earthquakes develop on the whole trough territory and also beyong its limits.

Considering the epicenter spatial distribution nature and the Trans-Carpathian fault zone tectonic situation, it may be taken as the Trans-Carpathians main seismotectonic line.

What concerns the earthquake epicenter totality, singles out the second large Central seismotectonic line, arranged for the fault longitudinal zone, extending from Uzhorod through Mukachevo, Khust, Tyachev to Siget. The earthquakes of magnitude 5-7 are connected with this zone of faults.

Along the Trans-Carpathian trough southern edge, the

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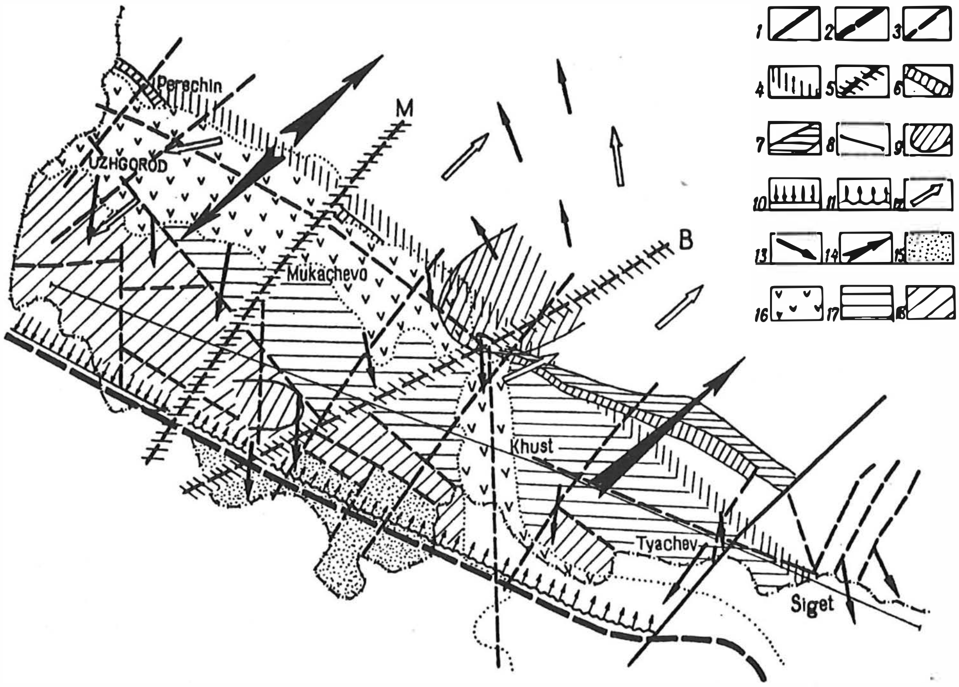

Fig. 1. The Trans-Carpathian trough earth crust deformation zones. 1 - Pannonian-Volinsky depression South-Eastern fault; 2 - Pre-Pannonian fault; 3 - discrete disturbances; 4 - Trans-Carpathian deep fault; 5 -Mukachevo (M) and Borzhavsky (B) faults; 6 -Peninsky rocks zone; 7)- Marmaroshsky rocks zone; 8 - Chop Velikiy Bichkov Deep-Seismo-Sounding (DSS) profile; 9 - geomagnetic field secular variation anomaly contours, 10 - compression zone; 11 - extension zone; 12 - linear displacement vectors of the triangulation points; 13 - Earth electromagnetic field induction vectors; 14 - earth crust large block horisontal displacement direction; 15 - Pannonian depression; 16 - Vigorlat-Gutinskaya volcanic ridge,; 17 - Mukachevo-Solotvinsk zone; 18 - Chop-Vinogradovo zone.

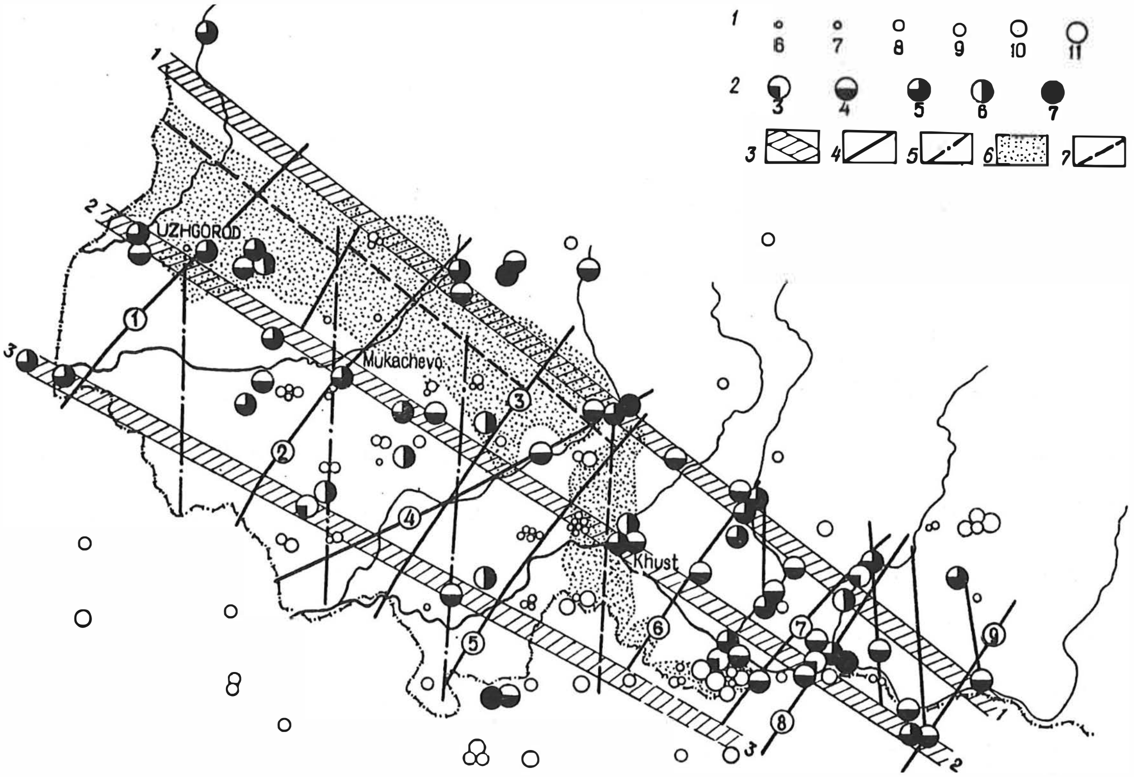

Fig. 2. The Trans-Carpathian trough seismotectonics scheme. 1 - earthquake energetic class,; 2 - intensity magnetude; 3 - seismotectonic lines: 1-1 - Trans-Carpathian deep fault; 2-2 - Central (Uzhghorod -Tiatchev zone of not deeply laying faults), 3-3 - Pre-Pannonian deep fault,; 4 - transverse faults (figures in circles): 1 - Chop fault, 2 - Latoritsa (Mukachevo) fault, 3 - Shalanno-Irshava fault, 4 - Borznava fault, 5 -Vinogradovo fault, 6 - Tereblinsky fault, 7 - Novoselitsky fault, 8 - Dubovo-Hrushevsky fault, 9 - Kobiletsko-Poliansky fault;
5 - submeridial direction discrete disturbances, 6 - Vigorlat-Gutinskaya volcanic ridge, 7 - ridge discrete disturbances.

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miocene zone of faults and buried volcanoes is observed, the earthquakes of magnitude 5-6 are connected with it and according to their totality it may be ascribed to the third Pre-Pannonian seismotectonic line (Fig.2). Besides the longitudinal seismotectonic zones, closely connected with the longitudinal structure, the transverse seismotectonic zonality is outlined too, but it is less obvious. Now we shall give a brief analysis of the Pre-Carpathian seismotectonics (Fig.3). So, within the Pre-Carpathian trough, its Inner zone, in the Dolina region a set of appreciable earthquaker was fixed. The Dolina region coincides with the Carpathian region gravity the largest depression, what testifies to a rather weakened zone, connected not only with the rock mass defects, but also with the trough development long history. The Dolina region is dependent on the Outer-Carpathian deep fault, separating the folded Carpathians and the Pre-Carpathian trough Inner zone.

The earthquakes, observed eaclier and recently in the region of Velikiye Mosty, Ternopol, Zaleschiky and Storozhynets, are situated within the Volino-Podolsky and of the East-European platform and are arranged for its various structural elements. The region seismócity is determined both by local and by the Romanian earthquakes. So, the Velikiye Mosty region earthquakes situated within the Lvov Paleozoic trough (of magnitude 6, the hypocentre at 20 km depth), was felt in Zaleschiky and Chernovtsy.

The complicated tectonic situation is observed in the Ternopol region, where in 1963 the earthquake toop place. Ternopol is situeted within the South-Western slope of the Ukrainian crystalline shield. Here a set of longitudinally limited faults of longitudinal and transverse stretch forming an active tectonic knot,is developed.

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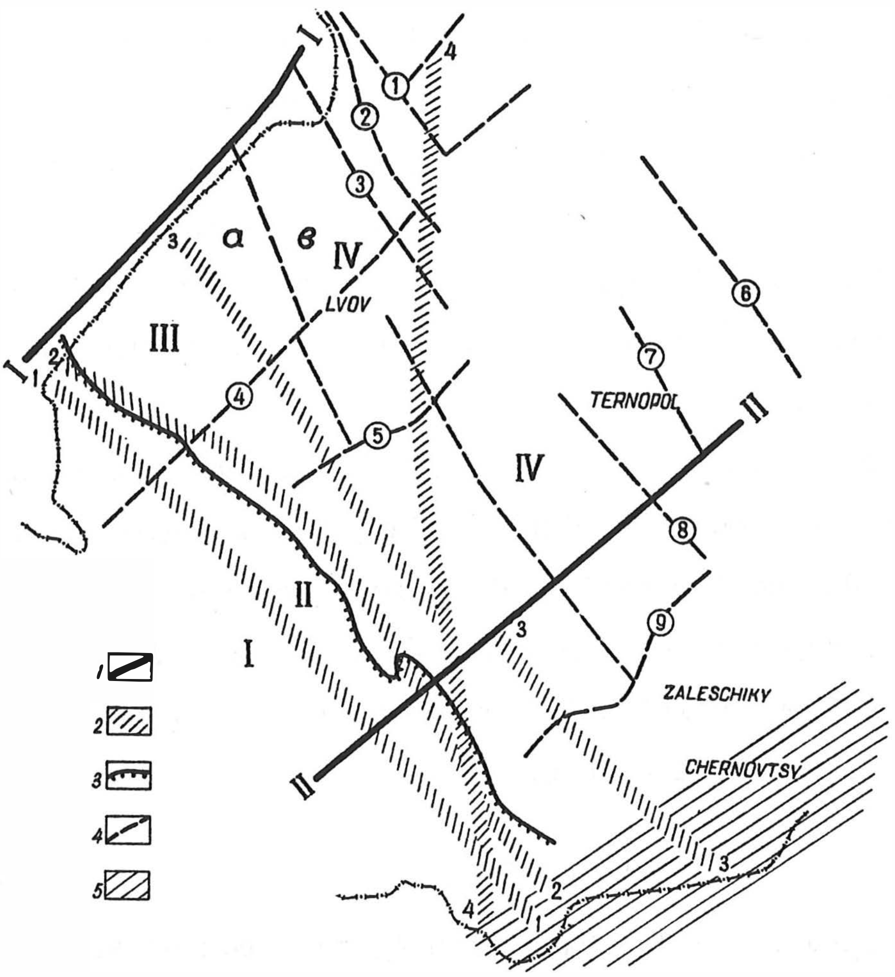

Fig. 3 The Pre - Carpathian seismotectonics elements

1. Pannonian - Volinsky transverse depression deep faults:
   I - Balaton-Koshitse-Peremishel fault, II - Shopurkino-Nadvoriansko-Monastiriysky fault (according to geophys. data)
2. deep faults:
   1-1 Outer-Carpathian (Carpathian) fault, 2-2 Pre-Carpathian fault, 3-3 Yavorow-Calushsky fault, 4-4 Radekhivsky fault,
3. Bereghovo approach line
4. faults (figures in circles):
   1 - Novovolinsky fault, 2 - Chervonogradsky fault,
   3 - Veliko-Mostovsky fault, 4 - Novo-Yarichevsky fault,
   5 - Striysko-Peremishliansky fault, 6 - Cremenetsky fault,
   7 - Ternopolsky fault, 8 - Dorokhovsky fault,
   9 - Zabolotov - Harodenkovsky fault
5. Buckovina transverse elevation:
   I - folded Carpathians, II - Pre-Carpathian trough inner zone, III - trough outer zone, IV - Volino-Podolsk and of the East-European platform.

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A similar phenomenon is also observed in the earthquake manifestation in the Zaleschiky and Storozhinets regions, situated within the Buckovinsky transverse elevation, which is on the Soviet and Romanian Carpathians boundary.

The joint analysis of the geophysical data, tectonics, and seismicity of the Carpathian region showed that the faults of different category and their intersection knots and also interfault structures are the crust stressed state discharge zones in the form of earthquakes.

Hence, on the received data basis, the close connection of seismic processes with the Carpathian region tectonics is observed, and the earthquake epicenter distribution nonuniform density depends both on total tectonophysical situation on the whole and on individual typical geologo-geophysical peculiarities of its structural elements.

Literature

1. Antipov V.I.: The Ukrainian Western region seismotectonics, Kiev, Nauk. Dumka, 1965, 56p.
2. The Carpathian geodynamic polygon. Moscow:Soviet radio, 1978, 117p.
3. Kuznetsova V.G.: On static equilibrium degree and recent vertical movement possible reasons. In: Geoph. Lesledov. Ziemn.Cory i Mantii Ukrainy.Kiev,Nauk.Dumka,1975,p.63-70
4. Melnichuk M.I.: On some deep processes manifestation peculārities in the Trans-Carpathian trough tectonics. Geoph. Zbornik Acad. Sci. Ukr.SSR, 1975, vol. 66, p.11-18
5. Melnichuk M.I.: On the Trans-Carpathian trough earth crust possible deformation zones. -In: Geol. Stroyeniye Provincii Horiuchich Iskopayemich Ukrainy. Kiev. Nauk. Dumka, 1978, p.23-32

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Some aspects of geomagnetic field modelling for past epochs

Abstract

The magnetic centre parameters are discussed on the base of spherical Harmonical analysis of the paleomagnetic and archeomagnetic data. The test calculations demonstrated that the irregular distribution of the inital data do not distort the conclusion about steady longitudinal field asymmetry in geological and ancient historical epochs.

Zusammenfassung

Aus den sphärisch-harmonischen Analysen der paläomagnetischen und archäomagnetischen Daten wurden die Parameter der magnetischen Zentren diskutiert. Die Ergebnisse zeigen, daß trotz einer irregulären Verteilung der Ausgangsdaten Aussagen über den stetigen Feldverlauf in geologischen und prähistorischen Epochen möglich sind.

Резюме

Рассмотрены параметры магнитного центра по результатам сферических гармонических анализов палеомагнитных и археомагнитных данных. Тестовыми расчётами показано, что неравномерность распределения исходных данных не искажает вывода об устойчивой долготной асимметрии поля в геологические и прошлые исторические эпохи.

The one of the most important results of geomagnetic spherical harmonic analysis (SHA) is definition of the Earth's magnetic center distribution (MC) and, as a consequence, a possibility of the investigation the geomagnetic field asymmetry. The importance of MC investigation is confirmed by the following:

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1. The field models based on SHA of historical, archaeomagnetic and palaeomagnetic data allow to compute the MC parameters and their variation for different historical epochs and geological times.
2. There is an evident similiarity in the magnetic fields of different planets, the Earth and Jupitier reveal equal (in fraction of radius) shift of their magnetic centers from the geometrical ones [1] what shows to the principal significance of the field asymmetry for theories of the field generation.
3. G. Barta [2] connected the geomagnetic field eccentricity with eccentric location of the Earth's inner solid core. The MC location within one longitudinal region could be interpreted as an evidence to that suggestion.

The main difficulties arising before SHA of the past epochs are:

a) Scarcity of experimental data, their low accuracy and poor distribution over the Earth's surface.
b) Measurements of angular values (D, I of the both) only, more seldom the field intensity module.

However a comparison between model and experimental values revealed that the results of rough SHA of past epochs contain errors comparable with those of the experimental data. Theoretical estimations of the errors of module and angular SHA confirmed that statement [3, 4] .
An effect of irregular data distribution has been investigated by the authors using analytical field model for the epoch of 1965 [5] . Two problems were discussed:

A) An effect of the data distribution, providing the data do not contain any large errors.
B) A probability of occurence of the false MC shift, as a result of combination of great random errors and poor data distribution.

The following conclusions are obtained (see tables 1 and 2)
1. The MC longitudes (λ_c) are stable enough and are maintained

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within 130° - 170°, 148° being the true value for 1965.

2. Variation in MC latitude (φ_c) and geocentrical distance (r_c) are larger and depend mainly on geometry of the mapped area, not on its dimensions. Data distribution symmetrical relative to the equator is the most favourable: data located within two narrow latitudinal bands ± (60° - 80°), only 12 % of the Earth's surface, provide better MC coordinates than the data distributed over the whole hemisphere.
3. If the analysed field is a field of central inclined dipole or dipole shifted along the rotation axis and involves a great enough random errors, an occurence of the false MC depends on the data distribution. If the data are symmetrical relative to equator, the initial model is reproduced well enough and the false shift off the geometrical center

Table 1

In-put data	Number of points	Area, % to Earth	Magnetic centre				Geomag. pole	
			δ, km	φ_c	λ_c	r_c, km	Φ	Λ
The Earth ±80°	612	100	0	17°	148°	457	79°	290°
Latitudes ±30°	252	51	59	19	150	404	80	293
±(30°-60°)	288	40	9	17	147	453	78	294
±(60°-80°)	216	12	13	18	149	460	78	295
North. hemisphere	324	50	126	9	156	544	78	296
South. hemisphere	324	50	110	8	144	369	78	293
Latitudes ±(30°-60°)	144	19	243	9	152	685	80	303
+(30°-60°)	144	19	157	4	164	434	78	284
Sector 0°-110°	204	28	121	28	143	373	76	300
0°- 60°	119	17	183	25	132	560	78	332
70°-120°	119	17	370	46	161	108	74	316
130°-180°	119	17	294	-10	172	499	73	311
190°-240°	119	17	455	-12	144	864	75	315
200°-300°	119	17	121	17	158	355	81	307
310°-360°	119	17	276	18	176	590	81	340
East. hemisphere	324	50	23	19	148	442	78	290
West. hemisphere	324	50	35	16	149	423	79	288

δ: MC shift off the "true" one according to test "The Earth"

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will be of few tens of kilometers. If the data distribution is latitudinally asymmetrical, the false shift may be great, but its direction is random and depends on the configuration of the area, being covered by these data. In case of the longitudinal asymmetry the MC reveals a tendency to move in direction, which is perpendicular to the mean sector longitude (see table 2).

Thus, the longitudinally asymmetrical data location leads to great errors in the MC coordinates; the latitudinally asymmetrical location leads to a smoothing of the North-South asymmetry, decrease of r_c and more uncertain values of MC latitude.

All said above is of importance for discussion on the rough SHA of the past epochs.

Table 2

In-put data		Magnetic Centre				Geomag. Pole	
		δ_{km}	φ_c	λ_c	r_c, km	Φ	Λ
I	The Earth ± 80°	14	88°	87°	184	89,8°	-
	Latitudes ± (30°-60°)	31	81	186	186	89,7	-
	+ (30°-60°)	164	36	156	181	88,3	274
	Sector 0°-110°	186	42	328	244	86,0	290
II	The Earth ±80°	15	45	80	15	78,8	290,7
	Latitude ±(30° -60°)	30	12	72	30	78,5	289,2
	+(30° -60°)	225	-35	100	225	76,3	281,1
	Sector 0°-110°	186	4	310	186	79,8	287,3

I Axis-symmetrical model: r_c=171 km, σ_H=2000nT, σ_Z=4000nT
II Central inclined dipole model: r_c=0 km, σ_H=2000nT, σ_Z=4000nT

A review of the palaeomagnetic SHA is given in [6, 7]. The palaeomagnetic data are presented mainly by D and I values and are located rather uniformly in both hemispheres (see table 3), Among the palaeomagnetic SHA the analyses for the quaternary period and Bruhnes epoch are the most reliable, because of better experimental information and presence of data on the world aquatories. There are 10 SHA (see table 4) for these times carried out using different methods and

Table 3

Epoch	Number of points		Element	Magnetic Center			Geomag. pole	
				φ_c	λ_c	r_c, km	Φ	Λ
Bruhnes	31 S	59 N	D, I	40°	154°	208	88,5°	40°
Matuyama	14 S	36 N	D, I	32	4	343	87	203
Cretaceous	25 S	56 N	D, I	−18	135	736	84	228
Jurassic	21 S	28 N	D, I	−39	193	1096	75	222
Triassic	27 S	41 N	I	−9	154	1000	87	154
Early Triassic	11 S	54 N	I	4	186	873	87	333
Permian	17 S	36 N	I	11	158	1000	82	32
Carboniferous	34 S	51 N	D, I	−14	157	600	81	97

different data combinations. In table 4 the result of recently published SHA of Bruhnes epoch [7] is given at the bottom of the table by a sparate line because in [8] is given only the range of the MC coordinates changes. The authors made an attempt to reveal time-variations of the MC movements during Bruhnes epoch and carried out a series of 7 analyses. Projections of the MC locations onto the Earth's surface are given in fig. 1. Content of table 3 is taken from [6], the Bruhnes epoch from [7].

In spite of significant changes in λ_c, φ_c and r_c the magnetic center for all the epochs (tables 3 and 4), independently of their polarity, is located within the middle and low latitudes and in a single meridional sector, the shift from the Earth's center is varying from 200 up to 1 000 km. It means, that the effective magnetic dipole was maintained within one region inside the Earth's core. An exception is Matuyama epoch - an epoch of reversed polarity, when MC was shifted in direction of Africa. In [6] it is suggested that this might be connected with sharp perturbution of Matuyama epoch (the upper part), what allows to consider the whole interval as a single prolonged inversion. This might lead to an increase of poloidal field symmetry and a decrease of its submission to the core asymmetry. Practically, such a situation is observed in Matuyama epoch. There are 4 analytical archaeomagnetic models for the time-interval 0-2000 years. Two of them are offered by Kolomiitzeva-Pushkov (K-P models) [9, 10] and two by Braginski-Burlatzkay (B-models) [11, 12].

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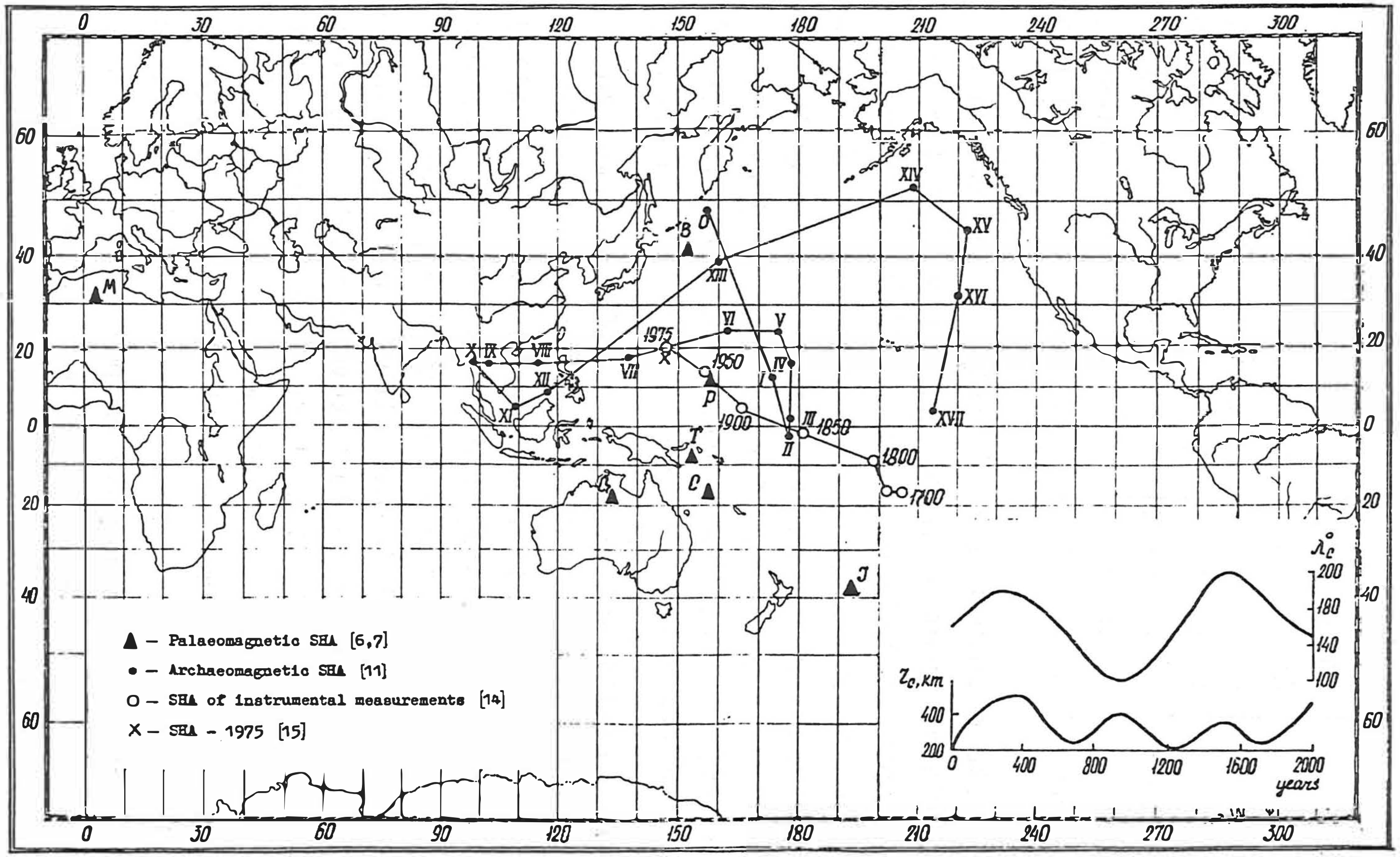

Fig. 1 Scheme of the MC projections onto the Earth's surface. Inset illustrates smoothed variations in the longitude (λ_c) and shift (r_c) from the Earth's centre.

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Table 4

Number of points, element	n	Magnetic Center			References	Epoch
		φ_c	λ_c	r_c, km		
32, I	2	33	133	242	16	Bruhnes
32, I	3	48	133	182	2	"
*90,I, 20,D	4	43	136	141	7	"
*90,I, 20,D	4	55	180	194	7	"
90, I	4	35	189	275	7	"
The mean		40°	154°	208		
80, D-I	2	17	187	206	17	Quarternary
20, D-I	2	45	166	206	17	"
32, I	2	50	137	196	16	"
32, I	3	43	171	215	16	"
25, I	2	31	143	454	6	"
The mean		37°	161°	255		
9, D-I	3	±20°	80°-160°	200	8	Bruhnes

*Different correlation of weights of D and I.

Number of the in-put points is different in different models, but not exceed 20, number of elements used is of an order of 30. The standard deviations between computed and experimental values for all the models are, practically, the same and approach to errors of the experimental data [13] .

Our further estimations are based on B-model [11] mainly.

In fig. 1 the MC path from 0 up to XVII century is given after [11] , the last centuries from 1700 up to 1975 after [14] and [15] . The MC motion has a loop-like character, in different time different directions of the motion are prevailing, but during all the 20th century MC remains within the middle-latitudinal part of the Pacific, where it was located according to palaeomagnetic data (triangles in fig. 1). The changes in longitude and r_c variations are given in the inset of fig. 1′. Changes in longitude may be presented by a cycle with time-length of about 1200 years. The cycle contains the western and

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the eastern branches. In the current epoch the MC longitude is approaching its western extremal value, that is confirmed by the fact that between the years 1965 and 1975 the MC longitude remained nearly constant. The r_c variations are presented by well-outlined oscillations of 500-600 year duration; their amplitudes lie within 200-500 km. The maximal r_c values coincide in time with the extremal western or eastern MC longitudes. It allows us to suggest their common nature. The K-P model 10 demonstrates a different pattern of the MC movement. The most characteristic feature of this movement is the westward drift, but the drift rate varies significantly over all the time-interval. However, if the MC locations when $r_c < 200$ km are rejected - in these cases definations of φ_c and λ_c may be less reliable - the K-P and B-model don't contradict one another. The understating of r_c in the K-P model may be due to the SHA procedure.

To estimate a contribution of the MC movements to the geomagnetic westward drift, the rate of quadropole field drift was computed for the western (1500-2000) and the eastern (1000-15000) branches of the MC motion using a well-known expression $\partial Z/\partial t/\partial Z/\partial\lambda$ The rates were computed separately for each phase-angle $\alpha(\lambda_1^1)$, $\beta(\lambda_2^1)$, $\gamma(\lambda_2^2)$, where phase-angle λ_2^1 represents the MC longitude, and for summary change of all these phase-angles ($\alpha + \beta + \gamma$). In the both cases (western or eastern MC motion) the rate $\beta(\lambda_2^1)$ does not practically affect the quadropole field drift ($\alpha+\beta+\gamma$) within the latitudes $\pm 30^\circ$ (see fig. 2). The summary drift depends on combination of drift rates of all three harmonics.

It seems possible to offer the following conclusions:

1. The geomagnetic field asymmetry can be followed back on the geological time scale; the asymmetry character being stable enough. The MC location mainly in the western Pacific can be considered as manifestation of this stability.
2. The MC coordinates are changing with characteristic times of 600 and 1200 years; in different epochs different directions of the movement are prevailing. A possibility could not be excluded that 600 and 1200-year oscillations are a manifestation of a single proccess.

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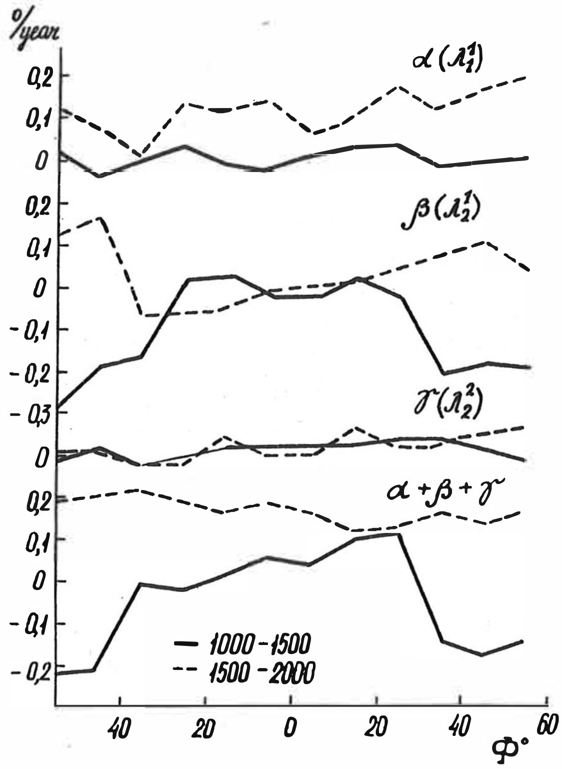

Fig. 2
The drift rates $\alpha(\lambda_1^1)$, $\beta(\lambda_2^1)$ and $\gamma(\lambda_2^2)$ of the quadropole field. The rates are averaged over latitudinal circles.

3. An effect of the MC longitudinal motion on the western or eastern drift of the quadropole field depends on geographical latitude: the effect is rather great at the middle and high latitudes and decreases sharply within latitude band + 30°. It allows us to suggest that the westward drift at low latitudes is defined mainly by the nonquadropole field drift (drift of the world anomalies), which has probably, different origin. During the last 500 year, when the data of direct measurements are available, the western drift of equatorial anomalies can be traced back quite evidently.

In conclusion we should like to emphasize once more the permanent value of Gauss-Schmidt method of spherical harmonic analysis for geophysical and geomagnetic investigations. Offered more than 150 year ago, this method remains the most perfect one to study the Earth's magnetic field as well as the fields of other planet.

DOI: https://doi.org/10.2312/zipe.1981.070.01

References

I. Долгинов Ш.Ш. Препринт, I5 (I58), I976, АН СССР, ИЗМИРАН, Москва, 3I-32.

2. Barta G.: Separata de Geomagnetica, publicação comemorativa do 50 aniversário do Observatorio Magnetico de S. Miguel, Açores. Serviço Meteorológico Nacional, Lisboa, 1962

3. Адам Н.В., Бенькова Н.П., "Итоги науки и техники", Геомагнетизм и высокие слои атмосферы, ВИНИТИ, I976, 3, 88-I22.

4. Бенькова Н.П., Пушков А.Н. "Итоги науки и техники", Геомагнетизм и высокие слои атмосферы, ВИНИТИ, I980, (в печати).

5. Бенькова Н.П.,Головков В.П., Черевко Т.Н. Геомагнетизм и Аэрономия, I979, 19, № 5, 898-903.

6. Бенькова Н.П., Петрова Г.Н., Храмов А.Н., Черевко Т.Н., Сб. "Простран. временная структура геомагнитного поля", I976, М., "Наука", 59-64.

7. Бенькова Н.П., Головков В.П., Куланин Н.В.,Черевко Т.Н. Сб. "Алгоритмы и результаты обработки в МЦД", М., I978, 34-43.

8. Коломийцева Г.И., Пушков А.Н., Филиппов С.В. Сб. "Проблемы изучения палеовековых вариаций магнитного поля Земли", I979, Владивосток, I6-22.

9. Коломийцева Г.И., Пушков А.Н. Сб. "Простран. временная структура геомагнитного поля", I975, М., "Наука", 72-8I.

I0. Коломийцева Г.И., Пушков А.Н. Сб. "Простран. временная структура геомагнитного поля", I976, М., "Наука", 52-58.

II. Брагинский С.И. Геомагнетизм и Аэрономия. I974, I4, № 3, 522.

I2. Брагинский С.И., Бурлацкая С.П. "Физика Земли", I979, № I2,59-66.

I3. Бенькова Н.П., Бурлацкая С.П., Черевко Т.Н. "Физика Земли", I979, № 3, 76-88.

I4. Бенькова Н.П., Коломийцева Г.И. "Геомагнетизм и Аэрономия", I974, I4, № 5, 88I-887.

15. Harwood J.M., Malin S.R.C., "Nature", 1976, 25, 5543, 469-471.

16. Georgi D.T. "Geophys. J. Roy. astron. Soc"., 1974, 39, 71-86.

17. Creer K. M. et al. "Geophys. J. Roy. astron. Soc.", 1973, 33. 245-332.

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NEW PALEOMAGNETIC RESULTS ON THE PRECAMBRIAN OF THE UKRAINIAN SHIELD

Summary

Some features of the Precambrian geomagnetic field are discussed on the basis of the study of more than 150 dikes in the Ukrainian Shield. The age of these is within 2700 to 900 mln y. the composition ranges from quartz porphyre to gabbro diabase.

A prominent feature of the VGP pattern as derived from the Precambrian rocks of the Ukrainian Shield is their concentration in the north of the Pacific somewhat east of the known Phanerozoic polar wandering curve relative to Europe, in the area between 160°E - 160°W longitudes and 0° - 50°N latitudes.Two groups of the poles are recognized: one of the age of 1300 - 1800 mln y at 30-50°N latitudes, the other older than 2300-2600 mln y near the equator.

The experimental results show that the poles have been calculated from the primary magnetization of the rocks bearing no indication of a remagnetization by the later geomagnetic field.

The data obtained confirm the reversed nature of the Precambrian geomagnetic field, the normal field being characteristic of the time span 1200-1800 mln y and the reversed one of 2300-2600 mln y. It is suggested, that the VGP from the Ukrainian Shield moved northward away from the equator within the time span of 2600-1800 mln y, whereas 1200-700 mln y ago it took the opposite direction.

Zusammenfassung

Auf Grund der Untersuchung von mehr als 150 Proben des Ukrainischen Schildes von 2700 bis 900 Mill. Jahren, deren Zusammensetzung von Quarzporphyren bis Gabbro-Diabas reicht, werden einige Charakterzüge des geomagnetischen Feldes des Präkambriums besprochen.

Die wichtigste Besonderheit der Verteilung der virtuellen geomagnetischen Pole (VGP) des Präkambriums des Ukrainischen

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Schildes ist ihre Konzentration im Nordpazifik, etwas östlich der bekannten VGP-Migrationskurve im Phanerozoikum relativ zu Europa - in dem Gebiet 160°ö.L. - 160°w.L. und 0°-50°n.B. Dabei stellt man 2 Gruppen von Polen fest: mit einem Alter von 1300-1800 Mill. Jahren in Breiten von 30-50°n.B. und mit einem Alter von mehr als 2300-2600 Mill. Jahren in der Nähe des Äquators.

Es wird experimentell festgestellt, daß die Pole nach der primären Magnetisierung der Gesteine berechnet sind und keine Anzeichen von Einflüssen des späteren Erdmagnetfeldes tragen.

Die gewonnenen Daten bestätigen die entgegengesetzten Eigenschaften des präkambrischen Magnetfeldes. Das normale Feld ist für den Zeitraum 1200-1800 Mill. Jahre charakteristisch und für den Zeitraum 2300-2600 Mill. Jahre das entgegengesetzte. Es wird vermutet, daß sich der VGP vom Ukrainischen Schild im Zeitraum 2600-1800 Mill. Jahre vom Äquator nach Norden und von 1200-700 Mill. Jahren in der entgegengesetzten Richtung bewegte.

Резюме

На основании изучения более чем I50 даек Украинского щита в возрастном диапазоне от 2700 до 900 млн. лет, состав которых изменяется от кварцевых порфиров до габбро-диабазов, обсуждаются некоторые черты геомагнитного поля докембрия.

Важнейшая особенность распределения виртуальных геомагнитных полюсов докембрийских пород Украинского щита - их концентрация в северной части Тихого океана, несколько восточнее известной кривой миграции ВГП в фанерозое относительно Европы, в области, ограниченной координатами: I60°в.д. - I60°з.д. и 0°-50°с.ш. Причем выделяется две группы полюсов: с возрастом I300-I800 млн. лет, тяготеющих к широтам 30-50°с.ш., и с возрастом древнее 2300-2600 млн. лет, приуроченных к приэкваториальной области.

Экспериментально показано, что полюса расчитаны по первичной намагниченности пород, не имеющей признаков влияния более позднего магнитного поля Земли.

Полученные данные подчеркивают инверсионность геомагнитного поля

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докембрия. Причем для временного диапазона I200-I800 млн. лет более характерно поле прямой полярности, а для интервала 2300 - 2600 млн. лет обратной. Предполагается, что во временном интервале 2600-I800 млн. лет полюс двигался в отношении Украинского щита от экватора к северу, а в интервале I200-900 млн. лет в противоположном направлении.

The paleomagnetic study of the Precambrian, the longest and poorest studied period of the Earth's evolution, is important for understanding geomagnetism and geology. The convincing evidence of the dipole character of the geomagnetic field in the Precambrian, knowledge of the frequency and duration of the field reversals, establishment of the morphological features would contribute greatly to the theory of the geomagnetic field. The paleomagnetic study is no less important in treating the problems of plate tectonics and geochronology, for it can assess the reality of the continental drift at the earliest stages of the evolution of the Earth and synchronous magmatic events on the regional and global scale in the paleotectonic reconstructions of horizontal and vertical deformations,etc.

Meanwhile, in studying the Precambrian paleomagnetism many difficulties are encountered related both to methodical problems and to the core of "the problem of the Precambrian paleomagnetism". These difficulties are to be overcome as soon as possible. One of the most important and complicated problems is that of separation of the primary magnetization aquired when the rock was formed. This problem is common for rocks of any age and composition, but it is especially urgent for the Precambrian crystalline rocks which have generally undergone a few stages of metamorphism and tectono-magmatic activization and have a complex natural magnetization which is the sum of several

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components of similar or different stability dependent on the composition and structure of the ferromagnetic minerals in which magnetization is concentrated.

The problem can be solved by a set of experimental tests whose techique is being intensively developed at laboratories all around the world, but still is not quite good. Therefore, the selection of the object for study is of prime importance nowadays, especially where crystalline rocks are concerned.

The first studies of the Precambrian paleomagnetism in the Ukrainian Shield were carried out at the beginning of 60's (Kruglyakova, I96I; Mikhailova, Glevasskaya, I965). Later, the work was continued by B.Ya.Savenko, who obtained the paleomagnetic characteristics of granitoids. But the main goal of the work during that period was selection of basic rocks suitable for paleomagnetic studies (Mikhailova, Karzanova, I975; Mikhailova et al., I976; Kravchenko, Mikhailova, I978; Glevasskaya Kravcheko, I979).

As a result of these investigations in the Ukrainian Shield, the rocks have been recognized whose magnetization is of primary origin. These are mostly igneous rocks, such as diallagoid pyroxenite, anorthosite, monzonite, granite, some varieties of diabase and lamprophyre. The NRM of these rocks is stable to the demagnetizing effect of the alternating field up to I000 Oe and a temperature to 500-550°C. The $I_n^*(T)$ curves for these rocks generally have a "knee" characteristic of one - component magnetization of a ferromagnetic with T_C= 500-550°C. The contribution of other magnetizations is not large and can be neglected (Fig.I).

Such magnetically stable rocks are characterized by the

$^*I_n$ = NRM

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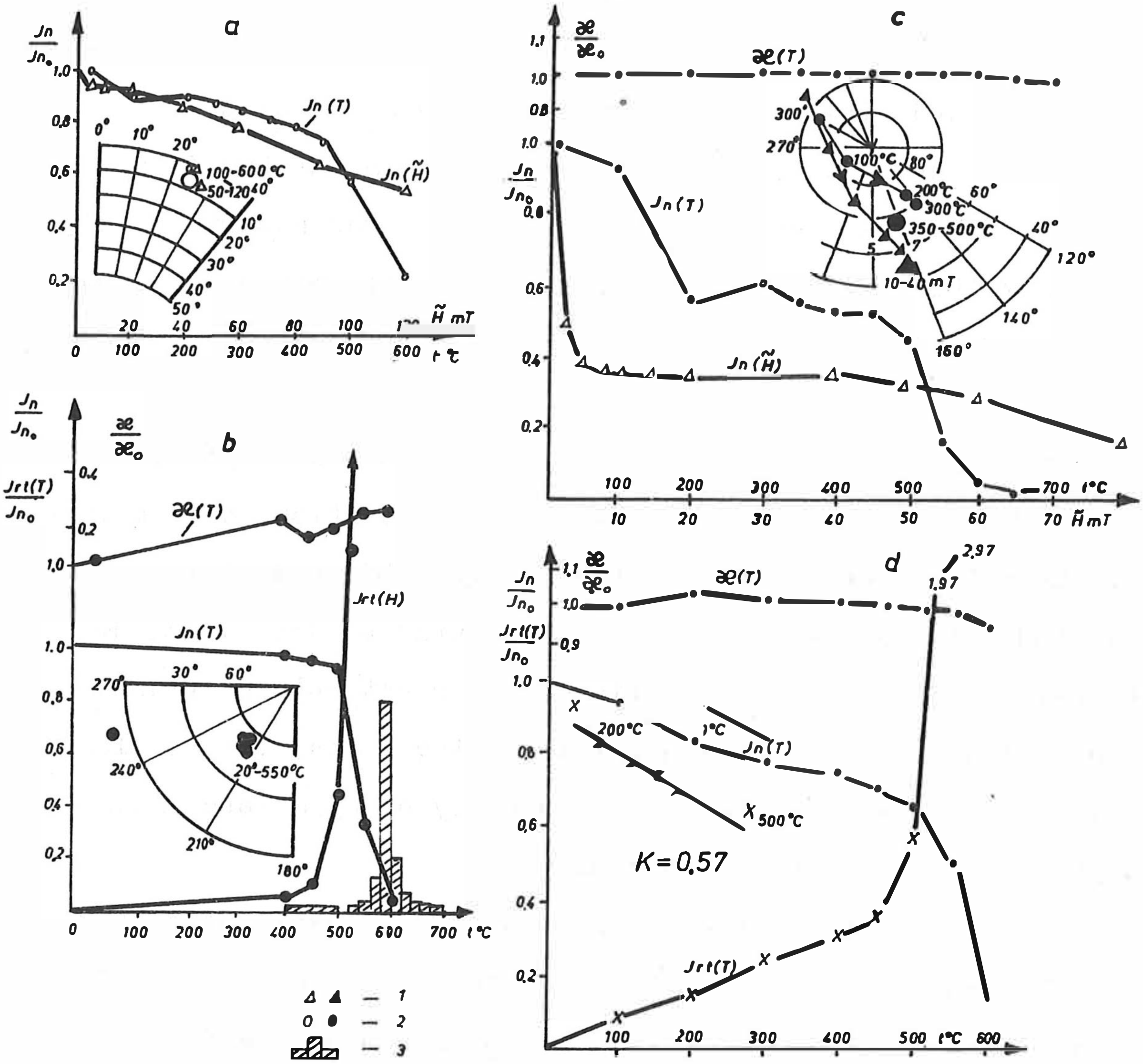

Fig. 1 Typical results of alternating field and temperature demagnetization of dike rocks in the Ukrainian Shield

a - peri-Azovian diabase

b - diabase from Middle Dnieper area (Bazavluk river)

c and d - gabbro-diabase from north-west of the shield (village of Gorodnitsa)

1 - I_n-vector position after alternating field demagnetization, big triangel denotes several stages of demagnetization

2 - same after heating, big circle - at different temperatures

3 - Curie point spectra

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presence of fine-dispersed inclusions of the ferromagnetic, generally represented by titanomagnetite with a low titanium content and T_C= 550°C or by magnetite, in the constituent minerals (pyroxene and plagioclase, sometimes mica and quartz) (Mikhailova, Glevasskaya, 1965; Glevasskaya, Kravchenko, 1979). This mineralogical feature should be considered as certain criterion of the suitability of the rock for paleomagnetic study. The use of this criterion is very helpful in studying crystalline rocks.

Among igneous rocks, dikes are most promising objects for paleomagnetic study thanks to their origin and geologic position, particularly, their location in the zones of the earth's extension, where they indicate the stage of tectono-magmatic activization. Thus, the paleomagnetic characteristic of dikes not only provides information about the ancient magnetic field of the Earth, but is also of interest in reconstructing the history of hypabissal metamorphism in shields and platforms.

In the Ukrainian Shield, dikes are found everywhere, but their highest concentration is observed in the eastern (peri--Azovian Massif), central (Middle-Dnieper area) and north-west part of the shield; here, they are grouped in belts of different width, extension and strike (Akhmetshina,1975; Krutikovskaya, et al., 1976).

The study of 150 dikes of various composition and age, sampled in the regions mentioned (Fig.2) has shown, that the greatest information capacity is characteristic of quartz porphyre, lamprophyre and diabase, that have one-component ancient remanent magnetization formed, as mineralogy shows, at the time of the rock formation. Such rocks generally have a high Q_n ratio and well-grouped directions of ancient magnetization from

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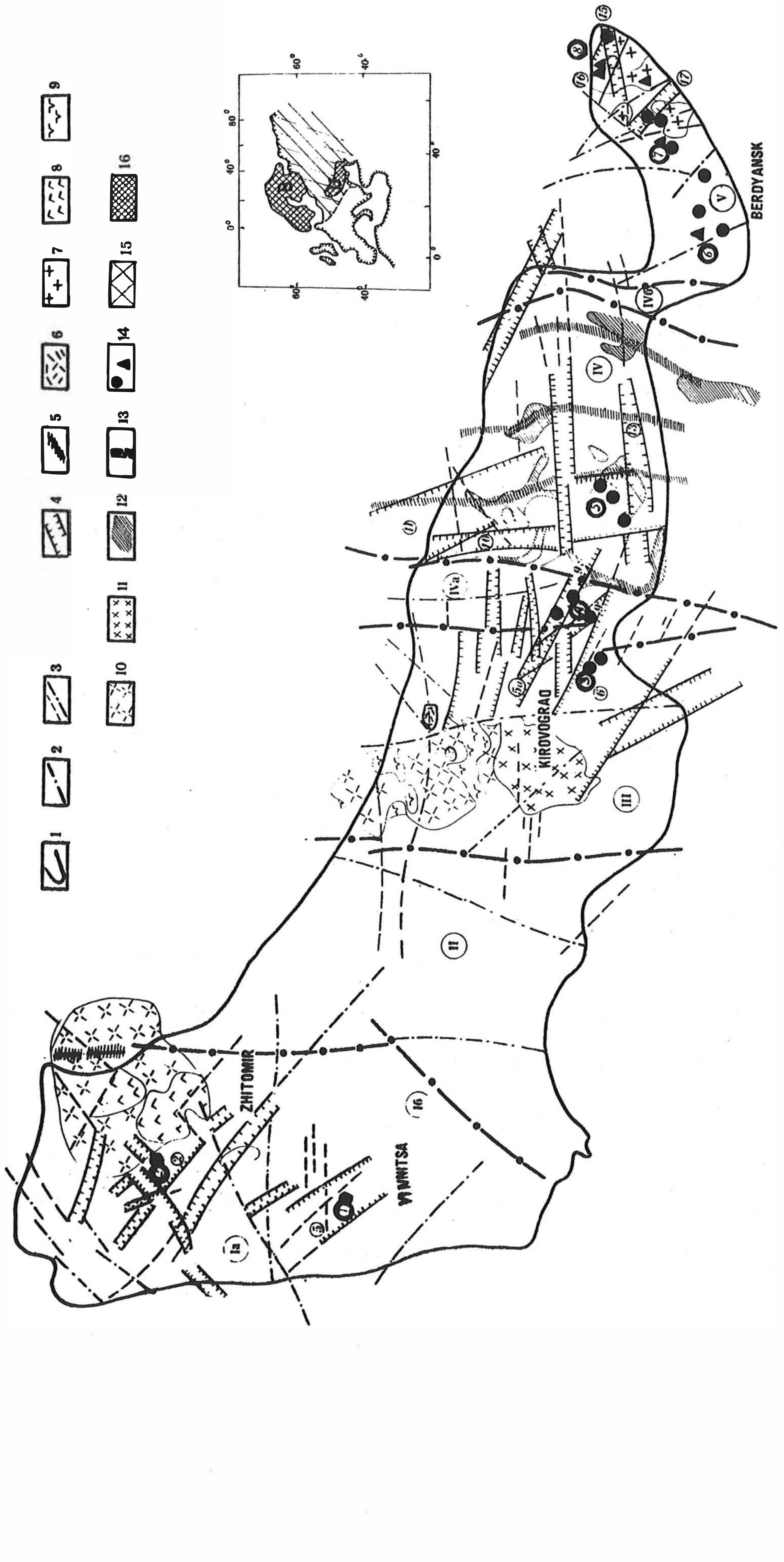

Fig. 2

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Fig.2 Paleomagnetic study of dike rocks in the Ukrainian Shield. Geologo-tectonic mapping by Z.A.Krutikhovskaya,et al., 1976 I - borders of Ukrainian Shield, 2 - first order faults, 3 - other faults, 4 - borders of dike belts, 5 - Zvizdal-Zalessky dike, 6 - Boltyshsky depression, 7 - East peri-Azovian granosienite complex rocks, 8 - gabbroid, 9 - gabbro-anorthosite, 10 - rapakivi granite, 11 - granitoid from Novoukrainsky Massif, 12 - rocks of Krivoy Rog- and Konsk-Verkhovtsevsky series, 13 - intrageosyncline faults of Great Krivoy Rog, 14 - Sampling sites for paleomagnetic studies; circles are for the author's collection, triangles - collection of N.N.Shatalov, 15 - East-European Platform; 16 - Ukrainian (U) and Baltic (B) Shields.

Circled Roman numbers designate large blocks of Ukrainian Shield: IB-Podolsky, II - Bela Tserkov-Odessa zone, III - Kirovogradsky, IV - Great Krivoy Rog, IVa- Outer West-Ingulsky zone, IVB - Orekhovo-Pvlogradsky parageosyncline, V - peri-Azovian Block.

Circled Arabic numerals show numbers of dike belts, Arabic numbers in double circles point to regions of paleomagnetic sampling: 1 - dike from Khmelnik region, 2 - area of v.Gorodnitsa, 3 - r.Ingul basin, 5 - r.Bazavluk basin, 6 - basin of r-s Berda and Obitochna, 7 - basin of r-s Kalchik and Karatysh, 8 - basins of r-s Kalmius, Gruzsky Elanchik. Enclosed is position of the Ukrainian and Baltic Shield in the structure of the East-European Platform.

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a dike or a group of dikes, that diverge from the present geomagnetic field at the sampling site (Fig. 1).

The natural magnetic parameters of dikes vary widely not only with composition but also in the same rock. Magnetic and non-magnetic varieties are encountered among mafic rocks of diabase and gabbro-diabase composition as well as among acidic rocks (orthophyre and quartz porphyre). In diabase, the I_n intensity changes from a few thousand to $1 \cdot 10^{-6}$ emu, Magnetic susceptibility also varies in a wide range, but it drops no lower than $60 x 10^{-6}$ emu, evidently, due to the contribution of paramagnetic constituent minerals in the rock magnetization.

The I_n variability exibits a certain dependence on the tectonic evolution of the rock: in the rocks of the same composition the variation is better pronounced in tectonically active regions, the secondary superimposed components, here, affecting primary magnetization stronger.

Multimethod laboratory studies involving progressive temperature and alternating field demagnetization, determination of Curie points, coercitivity spectra, saturation parameters and microscopic examination of ferromagnetic minerals, have revealed a stable magnetization component for part of the Precambrian rocks; the origin of this component and, in some cases, its contemporaneity with the rock formation have been established.

Virtual geomagnetic poles (VGP) are calculated from the primary magnetization for the time span 1.0 to 2.7 mlrd y (fig.3, table 1;Mikhailova 1976;Paleomagn.Directions a.Paleom.Poles,'79).

The prominent feature of the VGP pattern derived from dikes and other Precambrian rocks in the Ukrainian Shield is the poles

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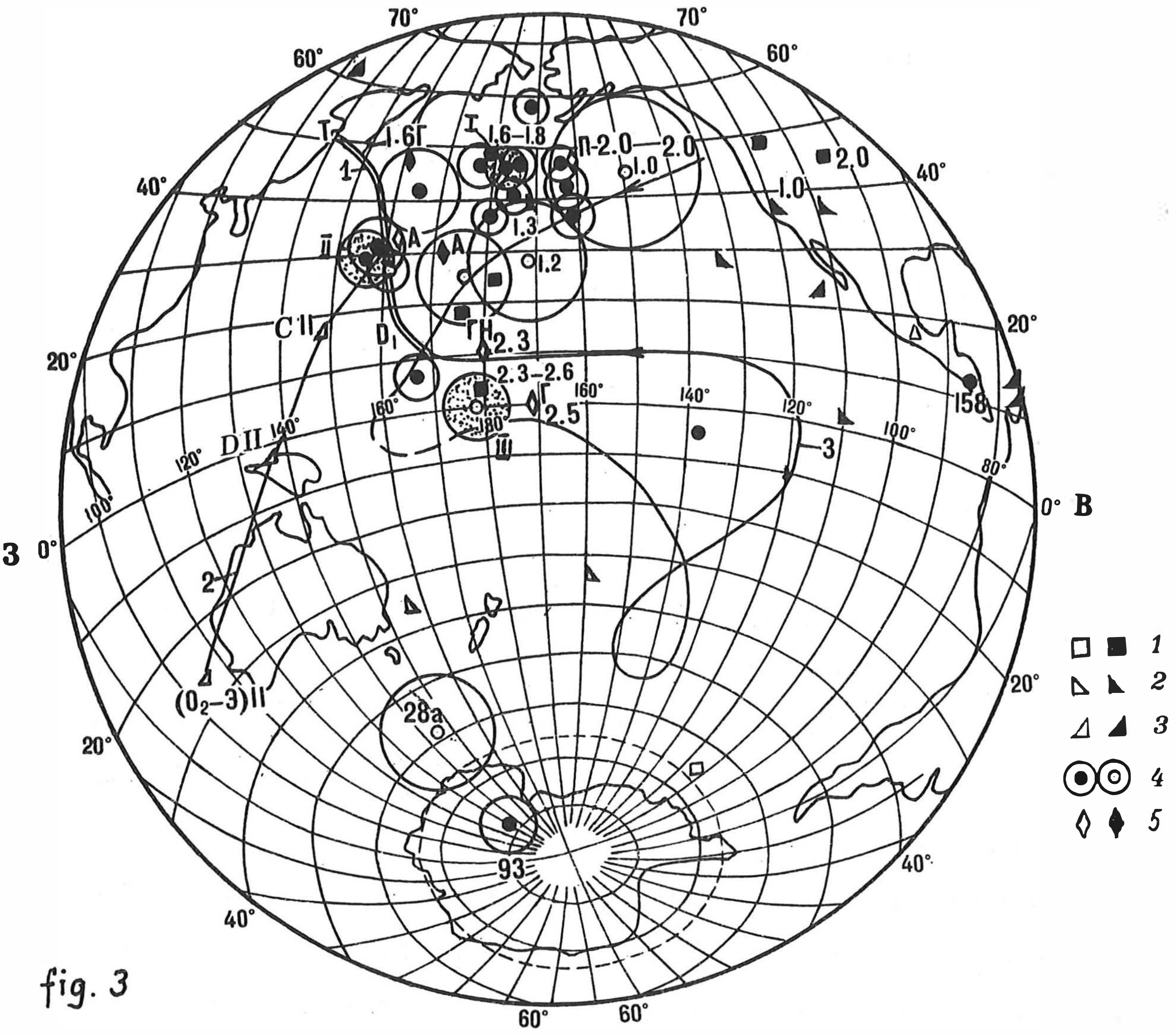

fig. 3

Precambrian Paleomagnetic Poles from the Ukrainian Shield

1 - poles from Baltic Shield rocks (solid figures are poles projected on Pacific Ocean /arbitrarily normal/; white figures are poles projected on Atlantic Ocean /arbitrarily reversed polarity/)

2 - same from rocks of Great Britain

3 - same from Czechoslovakian rocks

4 - same from dikes in Ukrainian Shield with confidence circle of 0.95; stippled confidence circles are for poles from Bazavluk dike belt (number II in fig.2);

5 - other crystalline rocks of Ukrainian Shield: A - anorthosite, - granite, H - gneiss, - pyroxenite; numbers by poles are K-Ar age of paleomagnetically studied samples;

Curves: 1 - Phanerozoic VGP apparent wandering curve by Creer, 1970; 2 - same from Khramov, 1974; 3 - same in Precambrian according to Pooter, 1975;

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concentration in the northern part of the Pacific, a little east of the apparent polar wandering for the Eurasian Phanerozoic (Khramov, I974; Creer I970). This implies in the first place that the rocks studied have been remagnetized by the Late Paleozoic magnetic field of the Earth. However, the implication is not supported by the experimental materials derived from the study of dikes and other Precambrian rocks of various composition and age (Mikhailova, I976; Mikhailova et al., I976; Kravchenko, Mikhailova, I978).

The poles presented in Fig.3 are calculated from the rocks ranging in composition with all the features indicating a stable, often one-component magnetization , or with a stable component separated by the T- and AF-cleaning. For this reason and taking into account the microscopic examination results showing the primary nature of the magnetization bearing ferromagnetic, the assumption of the Precambrian rocks being remagnetized by the later geomagnetic field is to be rejected and the poles derived should be considered characteristics of the Precambrian magnetic field of the Earth (Fig.3, Table 1).

One of the feature of the Precambrian geomagnetic field is its reversals. To emphasize the difference in the rocks polarity all the poles in Fig.3 are shown in the eastern hemisphere, the poles in the northern hemisphere (the Pacific Ocean) being attributed to the normal field and those in the southern hemisphere (the Atlantic Ocean and Indian Ocean) - to the reversed field. Although we analyse discrete fragments of the geomagnetic field pattern, one can see in the figure that in the time span of I.2-I.8 mlrd y the field was mostly

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normal, while it was mostly reversed during 3.3-3.6 mlrd y.

Fig.3 also shows that the VGP's derived fall in a swarm extended between I60°E and I60°W longitude and from the equator to 50°N latitude. Only few poles fall out of this zone for the reason that, so far, has not been explained unambiguously. In the northern portion of the swarm, there is a compact group of poles characteristic of the normal polarity field. These are derived from relatively young dikes in the Middle-Dnieper area, whose K-Ar age is I.6-I.8 mlrd y, and from other rocks in different regions of the shield (anorthosite, pyroxenite, granite) of about the same age.

The northern poles of the peri-Azovian area dated I.2-I.3mlrd y also belong to this group.

The VGP's located near the equator are also based on rocks ranging in composition (granite, gneiss, diabase). Their age is more than 2.0 mlrd y; most of the rocks have reversed magnetization.

On the whole, the poles obtained from the Precambrian rocks of the Ukrainian Shield are in satisfactory agreement with the contemporaneous poles relative to Europe (mainly, the Baltic Shield outside the USSR), which also concentrate in the northeastern part of the Pacific. However, the Ukrainian poles disagree with the apparent polar wandering for the Precambrian relative to Europe (Pooter, I975). This may result from scantiness of the information available to the author as well as to Pooter. In his analysis the latter used 26 pole determinations, I3 of which had been obtained in 60's and, to the author's mind, are of doubtful value. Besides, there are no rocks younger than I.0 mlrd y in our collection, whereas Pooter's equatorial loop

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was derived from younger rocks.

Generally speaking, only rough determination of the Precambrian polar movement relative to Europe can be obtained now using the data available. One can just suggest with care, that within the time span of 2.6-I.8 mrld y, the VGP derived from the Ukrainian Shield, moved northward away from the equator. This is supported by the results from diabase in the Bazavluk and Bobrinetsk dike belt (Fig.2), where paleomagnetically and radiometrically dated rocks show a regular northward displacement of VGP conformable with the strike of the dikes (Fig.3, pole positions are stippled and marked by Roman numbers). Their track bends about 300 mln y ago (Mikhailova, I979). Hence, it is not improbable that the pole positions I200-I300 mln y ago on the upper branch of Pooter's curve are part of the track characterizing the other half-branch with the movement from high latitudes to the equator.

It should be noted in conclusion, that the results obtained do not claim to be indisputable. This is but the first experience in systemetizing the data on the Precambrian rocks according to their paleomagnetic characteristics. These data are promising not only in deriving information on the ancient magnetic field of the Earth, but also in solving the problems of synchronization of magmatic events in shields, stratification of hypabissal rocks sequences and paleomagnetic reconstruction.

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Paleomagn. Table I.

Paleomagnetic data from the dike complex in the Ukrainian Shield

Rock and sampling area	Age of rock mln.years	Coordinates of sampling area		Paleomagnetic data Primary magnetization direction				VGP,North pole				Cleaning
		φ_N	λ_E	D	I	K	α_{95}	φ_p	$\lambda_{p.E}$	δ_p	δ_m	
Olivine diabase and lamprophyre,r.Ingul (3)	1770	48,0°	32,3°	18°	21°	34	5°	50N	184	5°	3°	T-600°C, AF-100mT
Diabase and amphibolevised diabase Bazauluk dike belt(5)	1550-1650	47,5	34,0	42	31	15	6	44 N	162	17	10	the same
Amphibolevised diabase Bazauluk dike belt(5)	2180-2200	47,7	34,0	224	54	64	10	1S	180	14	10	the same
Diabase, r.Berda, Pereasovian (6)		47,5	38,0	22	-23	9	10	36N	198	11	6	the same
Diabase porphyrite Pereasovian (6)	1050	47,5	38,0	187	-6	27	18	45 S	28	19	38	the same
Diabase, r.Obitochnaya, Pereasovian (6)	700	47,5	38,0	53	-33	48	6	9N	167	7	4	the same
Diabase, r.Obitochnaya, Pereasovian (6)		47,5	38,0	18	15	156	3	47N	194	3	2	the same
Diabase, ib.	1200	47,5	38,0	303	-22	9	27	12N	275	28	15	the same
Quartzouue porphyry r.Kalchik (7)	1200	47,5	38,0	207	16	12	15	29 S	7	15	8	the same
Lamprophyre, Vasi-Tarama,Pereazovian (7)	1040	47,5	38,0	25	21	10	22	48N	179	23	12	the same

Table 2 (Continuation)

Rock and sampling area	Age of rock mln.years	φ_N	λ_E	D	I	K	α_{95}	φ_p	$\lambda_{p.E}$	δ_p	δ_m	Cleaning
Limprophyre,r.Kalchik Pereasovian (7)		47,5	38,0	218	16	6	19	24 S	355	19	10	the same
Diabase,r.Kalchik (7)	1320	47,5	38,0	25	4	33	6	40 N	185	6	3	the same
Lamprophyre,r.Kalchik, Pereasovian (7)		47,5	38,0	17	33	82	5	57 N	186	5	3	the same
Lamprophyre, Polkovaya, Pereasovian (7)		47,5	38,0	38	19	24	19	41 N	165	20	10	the same
Diabase,r.Kalmius,Pereasovian area (8)		47,5	38,0	18	5	35	9	42 N	194	9	5	the same
Diabase,r.Kalmius, Pereasovian area (8)		47,5	38,0	242	-13	18	9	24 S	325	9	4	the same
Diabase, ib.	870	47,5	38,0	186	6	5	19	33 S	359	5	3	the same
Gabbro-diabase, in North-West Shield (I)		50,0	27,0	349	60	406	2	78 N	249	3	2	the same
Gabbro-diabase, ib.		50,0	27,0	160	64	115	4	8 N	41	6	5	the same

Note: The pole is calculated from primary magnetization based on temperature and A.F. to 1000 Oe (100 mT) demagnetization; T to 600°C according to Talhier thermomagnetic studies; numbers in brackets show the region in Fig.2.

References

Akhmetshina A.K. Analysis of the spatial distribution of dikes in the Ukrainian and Canadian Shield. In Ukrainian. I975. DAN UkSSR,ser. B, No I, p 3-5

Creer K.M. A review of paleomagnetism. I970. Earth Sci. Rev., v. 6, No 6, p 369-466

Glevasskaya A.M., S.N. Kravchenko Mineralogical basis for magnetization of gabbro anorthosite rocks of the complex Korosten Pluton, the Ukrainian Shield. In Russian. I979. Geofiz. Ghurn., No 2, p 72-78

Khramov A.N., I.G.Goncharov,et al. Paleozoic paleomagnetism. In Russian. I974. "Nyedra", Leningrad, p 236

Kruglyakova G.I. Results of paleomagnetic studies in the Ukrainian Crystalline Shield and adjacent regions. In Russian. I96I. Izv. AN USSR, ser. geofiz., No 2

Krutykhovskaya Z.A., Pashkevich I.K. ,et al. Distribution of the dike complexes in the Ukrainian Shield. In Russian. I976. Geofiz. sb. IG AN UkSSR, No 74, p 6I-74

Mikhailova N.P., A.M.Glevasskaya Magnetization of basic and ultrabasic rocks in the Ukrainian Shield. In Russian. I965. "Naukova Dumka", Kiev, pI52

Mikhailova et al; Paleomagnetic suitability of the Precambrian dike complex in the central part of the Ukrainian Shield. In Russian. In "Paleomagnetism, magnetism, geomagnetic field" I976. "Naukova Dumka", Kiev, p 42-6I

DOI: https://doi.org/10.2312/zipe.1981.070.01

Mikhailova N.P. Paleomagnetism of the dike complex in the central part of the Ukrainian Shield and some problems of studying the Precambrian geomagnetic field. In Russian. I976. Geofiz. sb. IG AN UkSSR, No 73, p 74-87

Mikhailova N.P. Paleomagnetism of diabase dikes and its role in reconstructing the Precambrian volcanism (on an example of the Ukrainian Shield). In Russian. I979. In "Global Paleovolcanic reconstructions", "Nauka", Novosibirsk, p 80-86

Paleomagnetic Directions and Paleomagnetic Poles. USSR Data. In Russian. I979. Materials of the Data World Centre, No 4, Moscow,p 88

Pooter R.P.E. Paleomagnetism of Precambrian rocks from Southeast Norway and South Sweden. I975. Phys. Earth Planet. Inter., v. I0, No I, p 74-87

Rother K., F.Wiegank Zur iterpretation der paleomagnitischen Daten von Europa. I975. Gerlands Beitr. Geophys., v. 84, No 3-4, p I79-2I4

Savenko B.Ya. Paleomagnetism of granitoids in the Ukrainian Shield. In Russian. I973. In " The present magnetic field of the Earth, paleomagnetism, magnetization of rocks", "Naukova Dumka", Kiev, p I88-I90

Spall H. Review of Precambrian paleomagnetic data for Europe. I973. Earth and Planet. Sci. Letters, No I8, p I-8

DOI: https://doi.org/10.2312/zipe.1981.070.01

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THE ROLE OF PYRRHOTITE MAGNETIC PROPERTIES IN THE STUDY OF THE FORMING OF ROCKS

Summary:

There was offered a method of determination of repeated heating of rock upon pyrrhotite magnetic properties.

As an example the results of study of rocks of two sections were considered. It has been shown that the study of pyrrhotite magnetic properties allows to determine: succession magnetic of intrusions, to determine whether the rock is useful for paleomagnetic investigation etc.

Zusammenfassung:

Es wird eine Methode zur Bestimmung wiederholter Erhitzung von Gestein auf magnetische Eigenschaften von Pyrrothin vorgestellt.

Als Beispiel werden die Ergebnisse von Gesteinsuntersuchungen an zwei Profilen betrachtet. Es stellte sich heraus, daß die Untersuchung magnetischer Eigenschaften von Pyrrothin die Bestimmung einer magnetischen Folge von Intrusionen zuläßt, und auch die Bestimmung, ob das Gestein für paleomagnetische Untersuchungen nützlich ist usw.

Резюме:

Представляется метод определения повторного нагревания горной породы о магнитных свойствах пирротина. Как пример рассмотрены результаты исследований на двух профилях. Показалось, что исследование магнитных свойств пирротина допускает определение магнитной свиты интрузий, и определение пригодности для палеомагнитных исследований и т. д.

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The study of condition of formation of rocks includes the determination of physical and chemical conditions where the rock was during its evolution. Determination of the rock's temperature regime and, namely, the processes of ore occurence is of great interest. As iron sulphides are widely spread at ore deposits, they were tried to be used for determination of metamorphic processes temperatures. So, the presence of association of cubanite, petlandite and cobaltine points to temperature occurences of the order of 300°C [1]. Solid solution of halko-pyrrite-cubanite takes place at 250-300°C [2]. Hexagonal pyrrhotite occurs at the temperature of more than 320°C [3].

It was considered that monoclinic pyrrhotite occurs at lower temperatures than hexagonal one. However lately it has been shown that monoclinic pyrrhotite can be synthezied at temperatures of 325-415°C [4] and $400 < t° < 700°C$ [5]. Thus the presence of monoclinic pyrrhotite cannot show low temperature process. P.Arnold [6] obtained the dependence of pyrrhotite composition on the temperature of the mineral forming but this "thermometer" cannot be used at temperature region lower than 300°C.

In rock magnetism there were made attempts to determine temperature of ferromagnetic minerals magnetization. All offered methods were based on the study of natural remanent magnetization, determination of its kind, characteristics of stability and coercive spectrum. None of the above methods allows to distinguish the primary and secondary heatings of a rock, though identifica-

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tion of secondary heating is principle in many cases. Hereby the methods connected with laboratory heating excluded using the rocks in which mineralogical changes develop during the experiment. On the contrary the study of mineralogical changes during heating was the basis of our method. From this point of view pyrrhotite proved to be very useful mineral thanks to it characteristic changes at definite temperatures [7,8]. In our paper [9] the advised method is described.

In fig. 1-3 the curves of changes of saturation parameters of Is, Irs and Hc's at succesive heatings are represented. Hereby definite temperatural prehistory was given to each sample (see the captures). It may be considered that the rock containing pyrrhotite suffered the secondary heating, if: 1) at curve Is/Iso (t^o) there are observed a weak "peak" or "step" at temperature region of 210-260^{o}C (case of λ -pyrrhotite) and a bend of about 325^{o}C (T_c) (fig.1), 2) curves of the changes of saturation parameters of Irs and Hc's during heating differ of similar curves of the initial sample (fig. 2-3). It is enough to identificate a repeated heating in order to solve the following problems: succession magmatic and metamorphic processes, succession of intrusions [10], to determine whether the rock is useful for paleomagnetic investigation etc. The temperature of the repeated heating allows to approach to the determination of the temperature metamorphic processes [10].

As an example, we shall consider two sections including contacts of metamorphic rocks (metamorphic sediments with pyrrhotite mineralization) with peridotites and gabbroids.

In fig.4 there are Is/Iso(t^o) curves collected from country rocks on the boundary with peridotite body. As it is seen , pyrrhotite significantly changes approaching the body (thickness 120 m).

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Obviously the baked contact takes place here, and, this peridotite body is younger than pyrrhotite mineralization.

In fig.5 in schematic form there are represented the results of the study of pyrrhotite magnetic properties on the contact with gabbroide intrusion (thickness 124 m). As can be seen from the figure, pyrrhotite both higher and lower than the body in question does not change while approaching it. Pyrrhotite does not carry any features of heating (instensity of λ-peak does not change). So, pyrrhotite was not heated by intrusive body, hence, pyrrhotite mineralisation is younger than this body.

Thus the fact that pyrrhotite magnetic properties significantly change during heating allows to determine: succession magmatic and metamorphic processes, succession of intrusions, to determine, whether the rock is useful for paleomagnetic investigation etc. The temperature of the repeated heating allows to approach to the determination of the temperature of metamorphic processes.

References

1. Bessmertnaya M.S., Chvileva T.I. et al. Determination of ore minerals in polished sections on reflection and solidity spectra. Moscow, "Nedra", 1973.
2. Ramdor P. Die Erzmineralien and ihre Vermachsungen, 1960.
3. Desborouch G.A., Carpenter R.H. Phase relations of pyrrhotite. Econom. Geol. 60, p.1431-1450, 1965.
4. Likhachev A.P., Chuvikina N.G., Kozhevnikova L.I. On hydrothermal synthesis of monoclinic pyrrhotite at temperatures above 320°. Dokl. AN SSSR, v.202, No.2, p.426, 1972.
5. Bezmen N.I., Egorov V.K. et al. Well-regulation of vacancies in high-temperature iron sulphides. The 5th International con-

DOI: https://doi.org/10.2312/zipe.1981.070.01

ference on Mössbauer Spectromentry Abstracts, Bratislava, 1973.

6. Arnold P. Equilibrium ratios between pyrrhotite and pyrrhite. Coll. "Problems of endogene deposits", Moscow, "Mir", 1970.
7. Brodskaya S.Yu., Vetoshkin I.D., Zherdenko O.N. Connection between magnetic properties of pyrrhotites and their compositions. Izv. AN SSSR, Phyzika Zemli No.3, 1973, p.112-121.
8. Brodskaya S.Yu., Gendler T.S. On λ -type pyrrhotite changes within the range of γ-transition. Izv. AN SSSR, Phyzika Zemli No.12, p.103-113, 1979.
9. Brodskaya S.Yu. Pyrrhotite as a geothermometer indicating reheating of rocks. Izv. AN SSSR, Phyzika Zemli, No.3, p.48-56, 1980.
10. Brodskaya S.Yu., Kuzmicheva E.V. et al. Magnetic properties of pyrrhotites and conditions of formation of Holodninsk deposite. Izv. AN SSSR, Phyzika Zemli No.6, p.426, 1976.

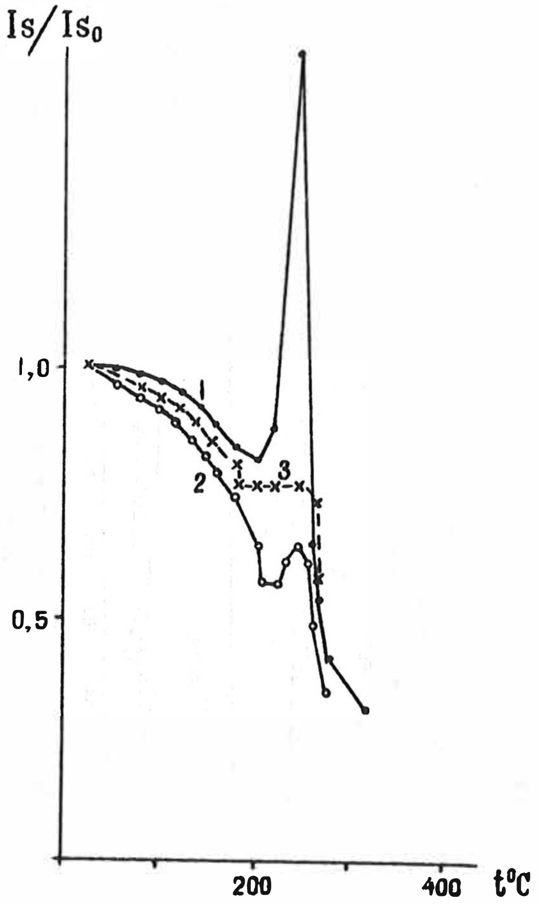

Fig.1. The curves of Is/Iso(t°) in dependence on different temperature prehistory:

1) initial sample,
2) after heating till 250°C,
3) after heating till 450°C.

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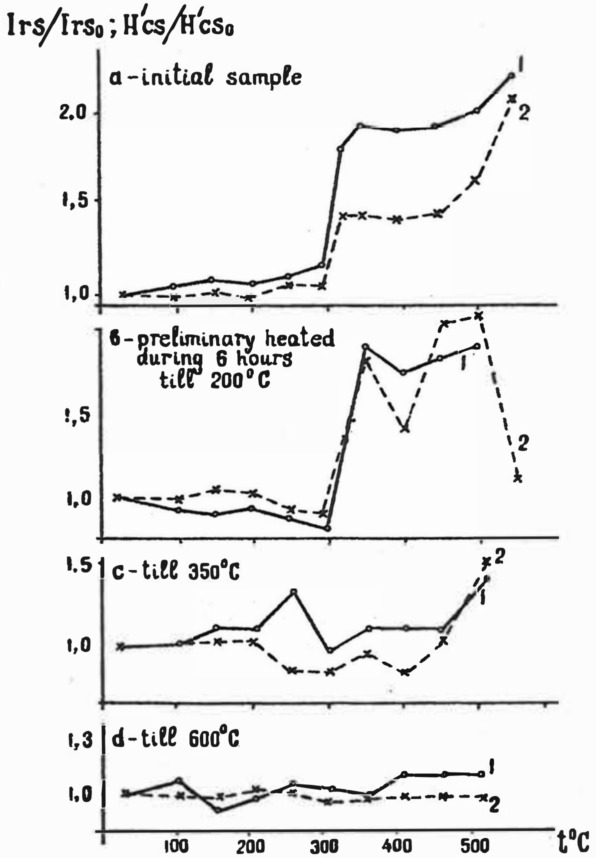

Fig.2. The curves of the changes of saturation parameters of Irs and Hc's of monoclinic pyrrhotite with different temperature prehistory.

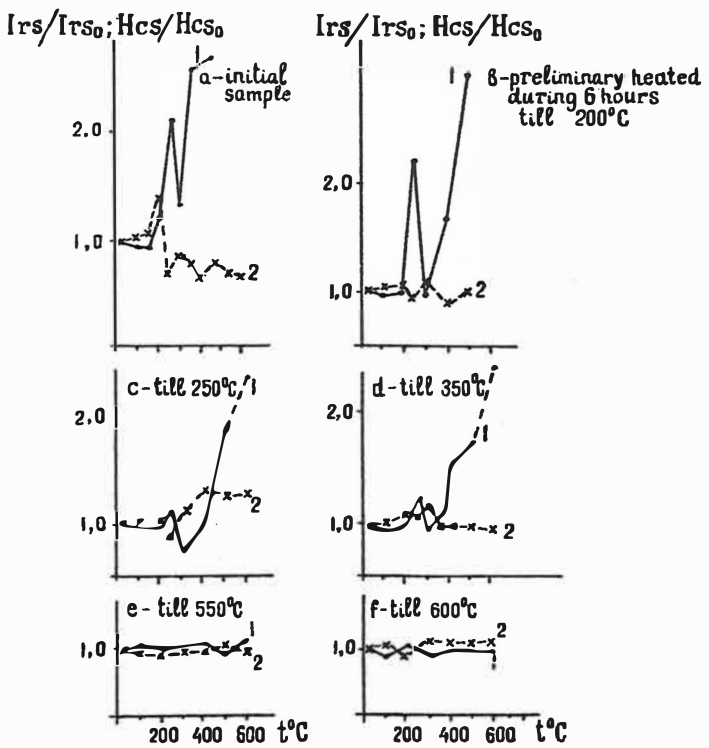

Fig.3. The curves of the changes of saturation parameters of Irs (1) and Hc's (2) of hexagonal pyrrhotite λ-type with different temperature prehistory.

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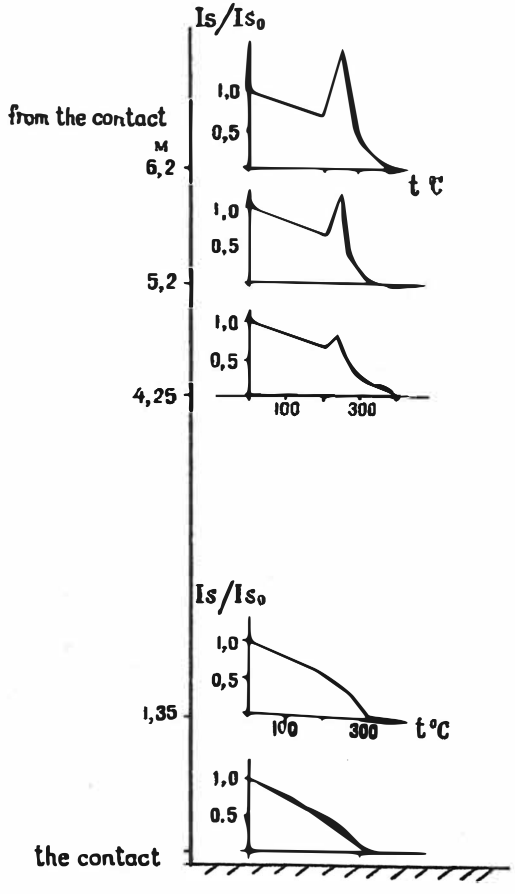

Fig.4. The curves of thermomagnetic analysis of samples of rocks collected on the boundary with peridotite body.

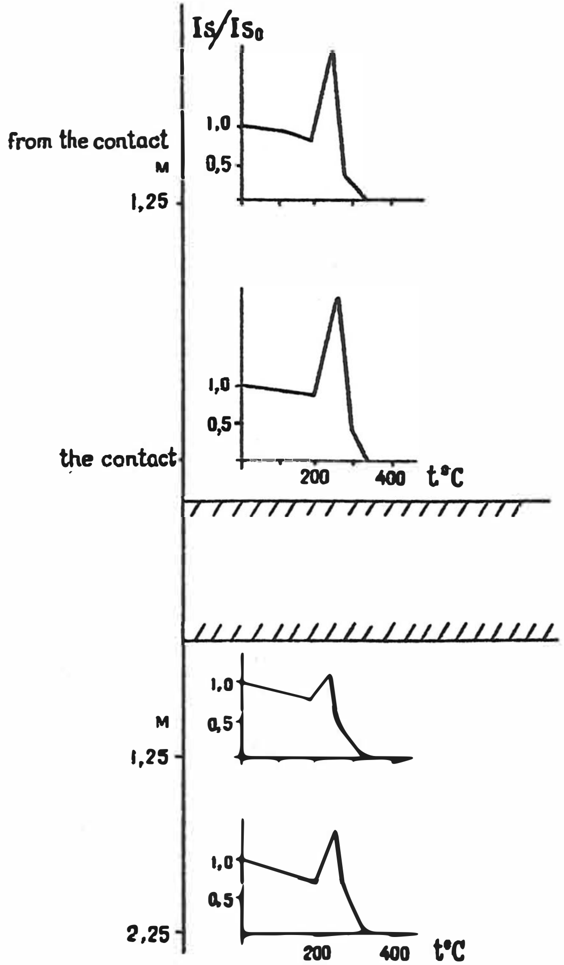

Fig.5. The curves of thermomagnetic analysis of the samples of rocks collected on the boundary with gabbroide body.

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G.F.Zagniy

THE PATTERN OF THE ARCHAEOSECULAR VARIATIONS OF THE GEOMAGNETIC FIELD FOR THE LAST 5500 YEARS

SUMMARY

The variation curves for the strength, inclination and declination of the geomagnetic field in the Ukraine and Moldavia for the last 5500 years.are shown. The 1200-yr. period is the main one for and caused by eastward precession excentric dipole. 500-600-yr. variations are generated by stationary sources of the non-dipole field.

РЕЗЮМЕ

Приведены кривые изменения напряженности, наклонения и склонения геомагнитного поля на Украине и в Молдавии за последние 5500 лет. Показано, что 1200- летний период является основным периодом и изменения всех компонент и обусловлен прецессией эксцентричного диполя в восточном направлении. 500-600-летние вариации генерируются стационарными источниками недипольного поля.

ZUSAMMENFASSUNG

Im vorgelegten Vortrag werden die Kurven der Veränderung der Intensität, der Inklination und der Deklination des geomagnetischen Feldes während der letzten 5500 Jahre in der Ukraine und der Moldauischen SSR demonstriert. Es wurde gezeigt, daß die 1200-jährige Periode die Hauptperiode der Veränderung aller Komponenten ist. Diese Periode wird durch die Präzession des exzentrischen Dipols nach Osten bedingt. Die 500 - 600-jährigen Variationen werden durch stationäre Quellen des nichtdipolaren Feldes generiert.

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By the present time, a large body of factual information on variations in inclination and strength of the geomagnetic field in the past have been accumulated in certain regions of the globe. However, the results obtained are not sufficient for solving the problem of the main period of the field variations and their separation into components of different duration. Practically no information is available concerning variations in declination , the study of which, even in the regions involved in a thorough archaeomagnetic study, could gain more information and lead to essentially new results on the geomagnetic field behaviour in time and the mechanism of this behaviour.

In this connection, this archaeomagnetic study is aimed at obtaining new results on variations in the geomagnetic field components.

To determine inclination and declination in the past, measuremants were made on more than 3000 oriented samples covering a time span of 5500 years.

The directions of the mean vectors of remanent magnetization for each object have been derived with high accuracy: α_{95} does not exceed 2° for 71% of determinations and is no more than 3° for 96%.

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The strength variation curve for the time span under consideration is constructed on the basis of 985 independent determinations of the coefficient K (F_a/F_o) by different techniques.

Since the field components are dependent not only on time, but also on geographic coordinates, all the results on declination (D) and inclination (I) determinations are reduced to the reference point (Kiev) using the virtual geomagnetic dipole technique.

The reduced archaeomagnetic data have been grouped within I00-years intervals and mean values of the field parameters, as well as their errors, calculated for each interval.

Fig. I shows the variation curves for the strength (a), inclination (b) and declination (c) of the geomagnetic field over the last 5500 years.

During this period of time K (F_a/F_o) changes noticeably from 0.85 to 2.I. The I-value varies widely from $5I^o$ in the 35-th century B.C. to 76.5^o in the 20-th century B.C. Both the inclination and strength mean values grow as the present time is approached while the variation amplitudes somewhat decrease.

The D-value changes from 20^oW to $I8^oE$, except for the abnormally high value of $5I^o$ in the 8-th century B.C.

Comparison between the variation curves for strength and inclination of the geomagnetic field shows not only synchronism in wave-like fluctuations of these components, but also the general trend of their variation. The similarity of the curves cannot result from causal factors but is due to reasons of the genetic nature.

The spectral analysis of the secular variation curves for the geomagnetic field components over the time span of 5500

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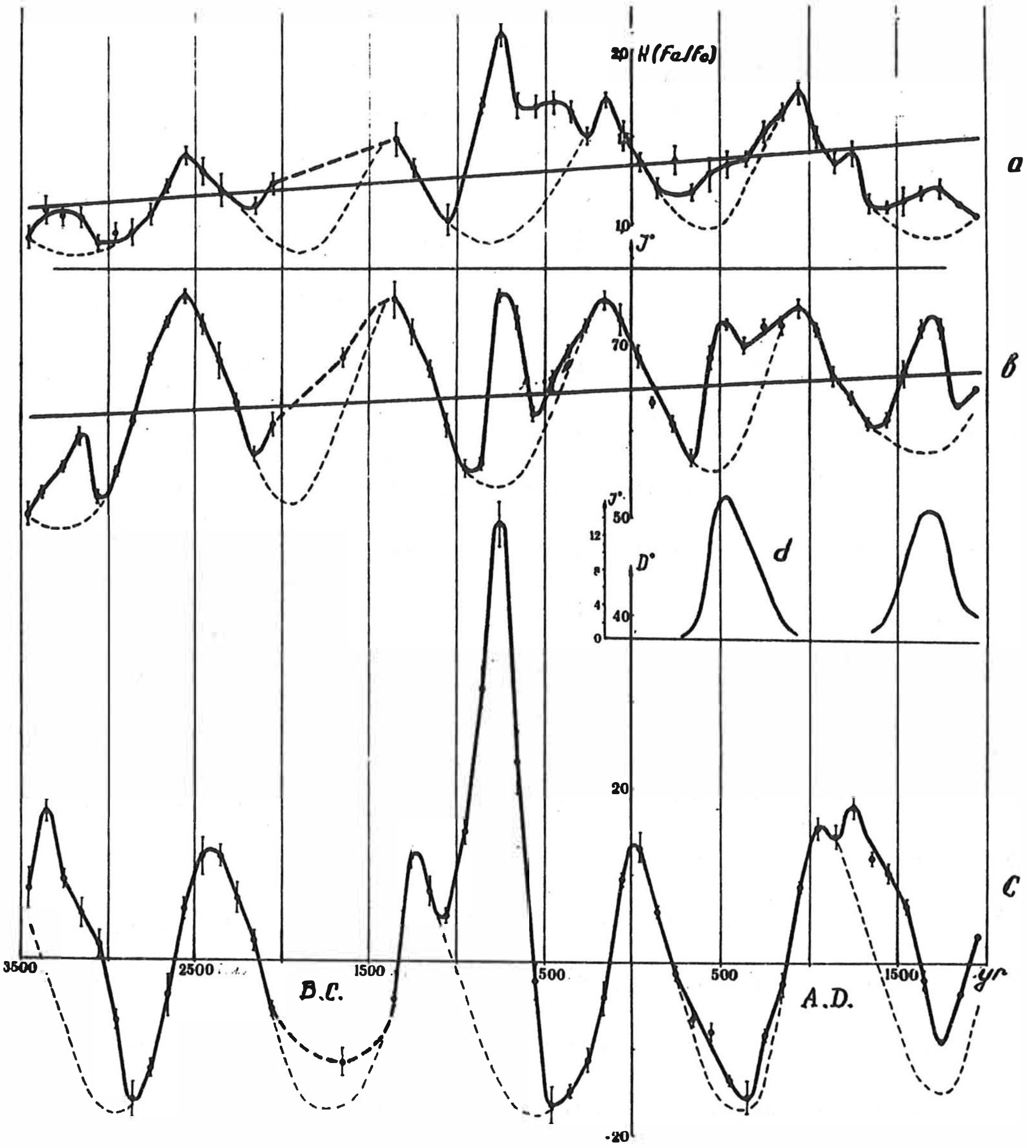

Fig. I. Secular Variation of the Geomagnetic Intensity (a), Inclination (b) and Declination (c) in the Ukraine and Moldavia for the Last 5500 Years.

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years has made it possible to recognize the main period of their variation to be I200 yr. This period is common for all the components of the geomagnetic field (strength, inclination and declination).

As seen in Fig. I, the main period shown in a dotted line is overlapped by short-living fluctuations lasting for 500-600 years. These are nonperiodical variations in the form of one-act outbursts reoccuring about every I200 yr.

Thus, the variations of the geomagnetic field components in the Ukraine and Moldavia for the last 5500 yr. include the main I200 - year period, trend and short-time 500-600-year cycles.

To find out whether the geomagnetic field pattern for the last 5500 years is due to global or regional effects and to construct a model for the source of its variations one should analyse information from the whole Earth.

To begin with, let us consider the evidence on the past behaviour of the field that can elucidate its spatial spectrum. The study of secular variations during the Late Pleistocene from the Ob' river alluvium has established a I200-yr. period for fluctuations of the geomagnetic field elements / 7 /.

The same period resulted from studying the Narita sediments in Japan / 9 /. The spectral analysis of the global I-curve irrespective of the above results produced a clearly pronounced component of about I200 years / 5 /.

Thus, at least four independent sets of data from the regions rather far from each other evidence on the fluctuation of the field components with a period of I200 yr. It implies that the I200-year period is a global feature of the geomagnetic field.

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The problem of the 600-year period variation is more difficult to solve. Nevertheless, the fact that no such variation is [illegible] revealed for the last two thousand years over the vast territory of Mongolia and Middle Asia / I, 4 / suggests, that 600-year period fluctuations are of a regional nature.

This conclusion is supported by the analysis of the virtual geomagnetic pole (VGP) wandering paths calculated for the Ukraine, Moldavia and Japan. According to our data, VGP moves by loop-like curves in opposite directions (Fig.2). It moves clockwise only when 500-600-year period variations appear on the inclination and declination curves, the duration of the clockwise movement and the loop radius depending on how good are these cycles on the D-curve. The data from Japan also show, that VGP moves both clockwise and anticlockwise / 6 /, the time of the switch in direction and dimensions of the clockwise loops disagreeing with our data. This proves the existence of the short cycle sources restricted in space and operating independently from each other.

On leaving the 500-600-year cycles out of the curves derived and then recalculating the VGP coordinates one finds, that for the time span in consideration VGP moved only anticlockwise. Taking into account the Rancorn rule by which the VGP wandering direction corresponds with that of the source drift in the core, we believe that the dipole axis is precessing eastward at a speed of 0.3^{o}/yr. The shortening of the long axes of closed loops, eastward displacement of their centeres andthe presence of a trend are indicative of the north- and eastward shift of the main dipole, i.e. of its eccentricity.

The eastward precession of the eccentric dipole on the

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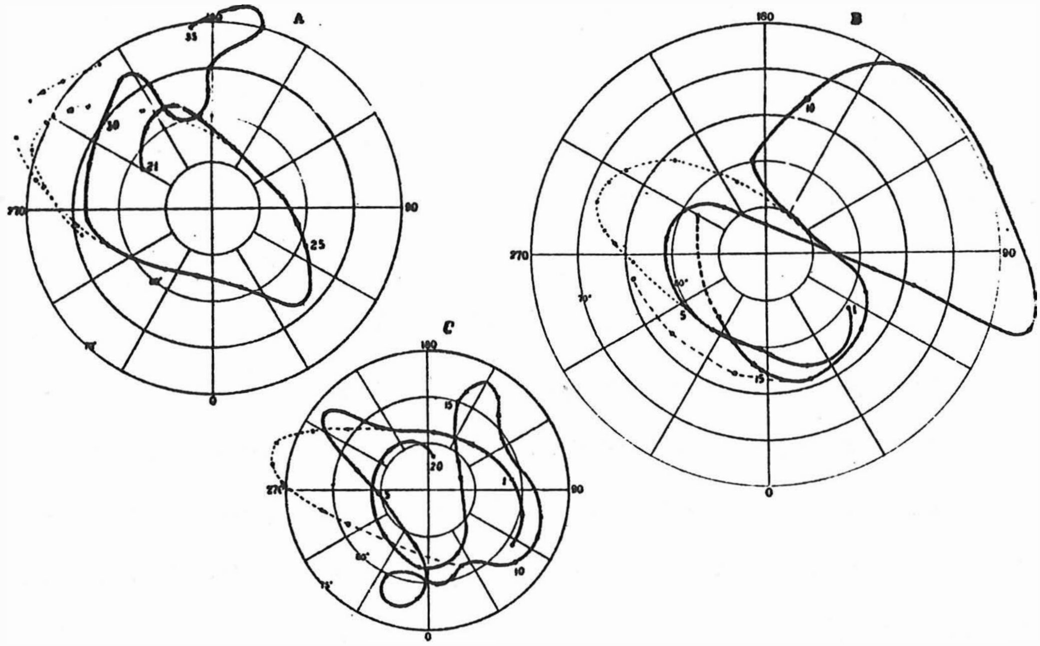

Fig. 2. Virtual Geomagnetic Pole Positions of the Ukraine and Moldavia for Every 100 years. The Data is Shown in Hundreds of Years B.C. (A, B) and A.D. (C).

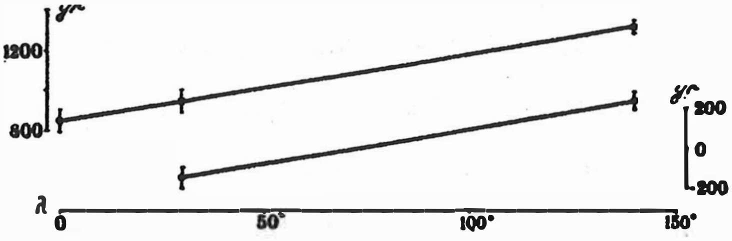

Fig. 3. Illustration of the East Drift of Dipole Field According to Archaeomagnetic Data.

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Earth's surface shows in the dependence of the appearance time for an extremum value on longitude: the farther east the observation point, the later the appearance of a certain feature of the I - curve. The analysis of the phenomenon involved the archaeomagnetic measurements of inclination and declination in widely separated regions (England, the Ukraine and Japan / 2 /).

Fig. 3 shows, that there is linear dependence the inclination global component and longitude of the observation site. This confirms the fact of the eastward precession of the main dipole.

The author has tried to determine the epicentre of the latest 600-year variation using direct measurements at the observatories of London, Paris and Rome / 3, 8 / as well as archaeomagnetic results on inclination reported by other investigators / 2 /. All the information is displayed in Fig. 4. As seen, the maxima of all the curves occur about A.D. 1700 within the accuracy of the dating and I - determination. The deviation of the observed field from that of the axial dipole is measured in arbitrary units on all the sites. The region of maximum distortion of the axial dipole field points to the epicentre of the source of a 600 -year cycle.

The fact, that the limit I -value is achieved simultaneously over a vast territory, points out that the source of shorttime cycles is immobile.

The stationary sources of the nondipole field are, evidently, located at the core - mantle boundary and go through the stages of origin , evolution and disintegration. These sources cause global anomalies. They ars manifested on the I - curves as bellshaped variations lasting 500-600 years. They can be more or

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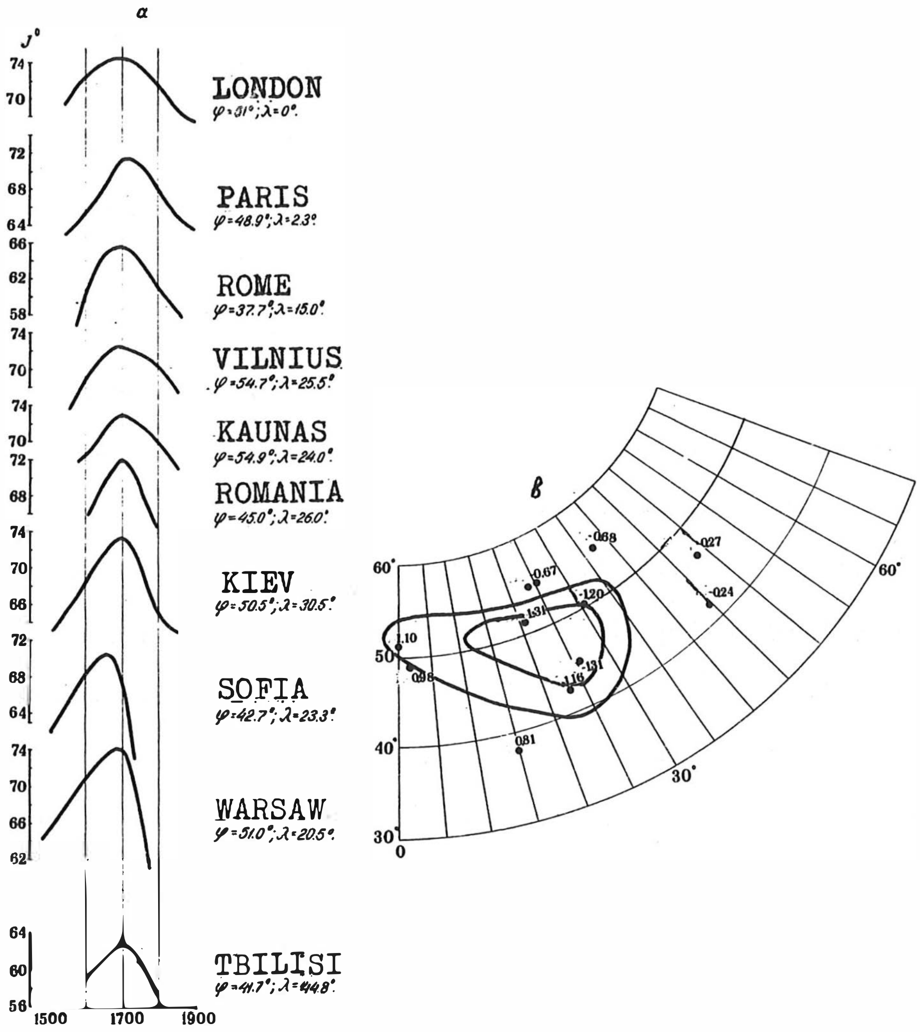

Fig. 4. Inclination Variability in the Different Points of the Earth (a); Definition of the 600-yr. Variation Centre(b). Inclination Data by Bauer, I899; Vestine et al.,I947; Bucur, I967; Tarhov,I965; Kovacheva, I968; Burlatskaya et al.,I970; Tchelidze, I97I / 2, 3, 8 /.

less pronounced on the field strength curve as well, depending on the intensity of the global anomaly. At this time, the D-value is controlled by the relative positions of the main and radial dipoles. According to the archaeomagnetic data for the last 5500 yr in Europe, the global anomaly made its appearance and disappearance four times at minimum. Its life time was 500-600 yr.

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Thus, the geomagnetic field variations for the last 5500 yr, studied archaeomagnetically, can be described in terms of the following model. Within the Earth, there is the main eccentric dipole precessing eastward at a speed of 0.3 °/yr to cause variations with a period of I200 yr. Without changing the precession amplitude and frequency, the main dipole moves northeastward forming the trend. At certain points of the core-mantle boundary, stationary sources of the nondipole field (of the global anomalies) origin, whose life-time is 500-600 yr. These variations are superimposed on the main I200-year period in the form of separate cycles.

In terms of stationary sources of the nondipole field, the drift of the global anomaly centers can be considered a particular case of interaction between the field from the stationary sources and that from the eccentric dipole drifting eastward at a rate of 0.3 °/yr.

The drift direction depends on the phase relationship between the fields from the dipole and nondipole sources: the westward drift is observed when the sources are out of phase - the European and East-Siberian anomalies - and the drift is eastward when they are in phase - the North-American anomaly-, the rate of the drift being different in any specific case.

REFERENCES

I. Ayuushzav G., Burlatskaya S.P., Dodon G. Variability of the Geomagnetic Field in the Mongolia for the Last 2000 Years. - In book: 8-th Conference Abstracts, Part I, Constant Geomagnetic Field, M.I970, p.73-74.(in russian)

DOI: https://doi.org/10.2312/zipe.1981.070.01

2. Archaeomagnetic Determinations of Geomagnetic Field Elements. World Data. Materials of the World Data Center B. Soviet Geophysical Committee of the Academy of Sciences of the USSR. Moscow, I977. (in russian)

3. Bauer L.A. On the Secular Variation of a Free Magnetic Needle. Phys. Rev. I899, N 3, p.34-48.

4. Burlatzkaya S.P.,Nechaeva T.B.,Tarhov E.N. The Archaeosecular Variation in the Geomagnetic Field in the Middle Asia. - In book: 8-th Conference Abstracts, Part I, Constant Geomagnetic Field, M. I970, p. 56-57. (in russian).

5. Burlatskaya S.P. About the Peculiarities of the Secular Variation Spectrum of the Geomagnetic Field for the Last 8500 Years.- Geomagn. Aeronom.,I978,v.I8,N 5,p.9I6-9I9(in russia

6. Hirooka K. Archaeomagnetic Study for the Past 2000 Years in Southwast Japan. - Memoirs of the Faculty of Science. Kyoto Univ.Ser. Geol.Miner.,I97I,v.38,N 2,p.I67-207.

7. Kulykova L.S.,Pospelova G.A. Secular Variation of the Geomagnetic Field in the Late Pleistocene From the Ob' river Alluvium. - Paleomagnetism of the Mesozoic and Kainozoic in the Siberia and Far East. Novosibirsk, I976, p.96-II3. (in russian)

8. Vestine E.H., Laporte L.,Cooper C.,Lange I.,Hendrix W.C. Description of the Earth^s main Magnetic Field and its Secular Change,I905-I945.- Publ.Carneg.Inst.(Dept. of Terrestial Magnetism),I947, N 578.

9. Yukutake T. The Westward Drift of the Magnetic Field of the Earth. - Bull. Earth. Res. Inst.,I962,v.40,N I,p.I-66.

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Beitrag zur Stratigraphie des höheren Känozoikums auf paläomagnetischer Grundlage

F. Wiegank

Die besondere geologische, geographische, klimatische und biogeographische Situation der Gegenwart ist das offensichtliche Ergebnis des Zusammenwirkens krustendynamischer, geologischer und paläoklimatischer Prozesse unserer jüngsten geologischen Vergangenheit, des höheren Känozoikums. Einer teilweise recht detaillierten Kenntnis der besonderen geologischen, paläogeographischen, paläoklimatischen und paläontologischen Verhältnisse dieses bis in die Gegenwart reichenden Zeitabschnitts, die auf einer mehr als 100jährigen intensiven interdisziplinären internationalen Forschung fußt, steht jedoch ein höchst lückenhafter Einblick in die verursachenden Prozesse und ihre zu vermutenden Wirkungszusammenhänge gegenüber. Solange diese Wirkprinzipien nicht erkannt, in ihren Zusammenhängen analysiert und in ihrer Wirkung abschätzbar sind, muß uns mithin unsere geologische Gegenwart letztlich unverständlich bleiben.
Eine Grundvoraussetzung hierfür ist die Rekonstruktion des Ereignisablaufs, der Ereignisfolge zur Bestimmung der zeitlichen Zusammenhänge von Ursachen und Wirkungen, von möglichen Relaxationen und ihren Bedingungen. Aber gerade die für diese Rekonstruktion nötige Ereignisdatierung der geologischen, paläoklimatischen und paläontologischen Zeitreihe bereitet für das höhere Känozoikum, für das Quartär wegen der stark eingeschränkten Anwendbarkeit physikalischer Datierungsverfahren (^{14}C, K/Ar) große Schwierigkeiten. Die zyklische Wiederholung der andere Geoprozesse beherrschenden oder mit ihnen gekoppelten Klimaschwankungen bedingt wegen der Ähnlichkeit der mit einer Periode von etwa 100×10^3J aufeinanderfolgenden Ereignisse, daß diese oft nicht mehr unterschieden werden können, so daß selbst die Bestimmung der Anzahl der Ereignisse (z.B. Warmzeiten) bisher nicht eindeutig möglich war. So gehen bis heute die Auffassungen über Gleichzeitigkeit, Anzahl und Intensität der Klimaschwankungen im

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höheren Känozoikum auseinander, ist ein Vergleich der nordischen und alpinen Vereisungen noch immer unsicher.

Erste Möglichkeiten für einen überregionalen Vergleich und für die Aufstellung eines fundierten globalen Korrelationsschemas für das höhere Känozoikum zeichneten sich ab, als nach der Anwendung des paläomagnetischen Datierungsverfahrens auf Tiefsee-Sedimente auch in kontinentalen feinkörnigen Sedimentserien die Identifizierbarkeit absolut datierter Polaritätsgrenzen erwartet werden konnte.

In wenigen Jahren konnten durch gezielte Untersuchungen von rasch sedimentierten Lößserien und limnischen Abfolgen auf dieser Basis neue wesentliche Erkenntnisse über den zeitlichen Rahmen und die Frequenz der Klimaschwankungen im höheren Känozoikum gewonnen werden, wobei sich die internationale Zusammenarbeit innerhalb des IGCP Projektes "Quartäre Vereisungen der Nordhalbkugel" und im Rahmen der KAPG der Akademien sozialistischer Länder als sehr nützlich erwies.

Gleichzeitig wurden neue Beiträge zur Feinstruktur des Paläomagnetfeldes (PSV und Exkursionen) geliefert.

Vor dem Hintergrund dieser Entwicklung wurde auch am ZIPE 1975 mit der systematischen Untersuchung jungkänozoischer Lockersedimente im Gebiet der DDR und - auf der Grundlage von Akademievereinbarungen - in der VR Bulgarien begonnen.

Damit wurden Voraussetzungen möglich, das auf dem Boden der DDR aufgestellte klassische Gliederungsschema der nordischen Vereisungen in einen weiteren überregionalen und globalen Rahmen zu stellen. Diese Untersuchungen wurden gleichfalls im Hinblick auf die weitere Präzisierung der paläomagnetischen Zeitskala und der Analyse ihres Periodenspektrums durchgeführt.

Die Ergebnisse dieser Untersuchungen können wie folgt zusammengefaßt werden:

1. Ein großer Teil der bisher untersuchten etwa 30 Profile ließ sich anhand magnetostratigraphischer Charakteristika stratigraphisch genauer einstufen bzw. in das Datierungsraster der Polaritätsskala einordnen.
2. Wichtige Abschnitte des regionalen stratigraphischen Schemas des höheren Känozoikums der DDR können auf der Basis der bisher registrierten magnetostratigraphischen Kriterien global korreliert werden.

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3. Die Untersuchungen ergaben eine in Abhängigkeit von der petrographischen Beschaffenheit, von den Sedimentationsbedingungen und von der postsedimentären Gesteinsgeschichte unterschiedlichen Schärfe der stratigraphischen Aussage der bearbeiteten Ablagerungen. In zahlreichen Profilen ist die primäre Remanenz durch Verwitterung und Bodenbildungen sekundär überprägt worden. Die paläomagnetischen Daten enthalten in diesen Fällen Informationen über die Zeit der sekundären Veränderungen und das einwirkende Milieu, deren Nutzung jedoch die Erweiterung des bisher angewandten Methodenspektrums erfordert.

Im einzelnen können die untersuchten Profile auf der Grundlage der verfügbaren stratigraphischen Information nach paläomagnetischen Kriterien wie folgt eingestuft werden:

1. Pliopleistozäne Schotter bzw. Dolinenfüllungen der Vorrhön (Haselbach, Kaltensundheim, Sülzfeld) mit wechselnder bzw. positiver Polarität sind der mittleren bzw. höheren Gauss-Epoche zuzuordnen und etwa zwischen 3 bis 2,4 x 10^6 J alt.
2. Präglaziale Zersatzkiese (Bittstedt), Zersatzgrobschotter und Terrassenablagerungen des südwestlichen Thüringer Waldes und des Werratales (Gerstungen, Breitungen, Schwallungen) bzw. des Elbesystems (Klotzsche, Kleingießhübel, Wehlen) lassen sich anhand der paläomagnetischen Charakteristika nicht in allen Fällen stratigraphisch sicher einordnen. Die fraglichen Sedimente sind z. T. stark verwittert und meist positiv polarisiert. Die normale Polarität könnte sowohl während der Gauss-, der Brunhes-Epoche oder während der positiven Events der Matuyama-Epoche entstanden sein. Einzelne negative Proben mit hoher Stabilität und anomales Verhalten bei der Abmagnetisierung lassen darauf schließen, daß das Material mit großer Wahrscheinlichkeit primär negativ polarisiert war und postgenetisch unter Einwirkung eines positiven Magnetfeldes verwitterte.
3. Für die oberpliozänen Zersatzkiese (Bittstedt) muß danach eine primär positive, für die hangenden Zersatzgrobschotter eine primär negative Polarität angenommen werden. Unter Einbeziehung anderer stratigraphischer Kriterien müßten die Zersatzkiese dann der Gauss-, die Zersatzgrobschotter,

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wie die Schotter des Jüngeren Senftenberger Elbelaufs, bereits der Matuyama-Epoche zuzurechnen sein.
Mit dieser Interpretation steht die Einstufung der Zersatzkiese ins Prätegelen und der Zersatzgrobschotter in das Eburon im Einklang. Doch bleiben für die Zersatzgrobschotter noch die Alternativen Tegelen B oder C4c, wenn nicht gar das obere Prätegelen offen.

4. Die Ablagerungen des Bautzener Elbelaufs bei Kleingießhübel sind insgesamt inhomogen unten wechselnd, oben positiv polarisiert, was einer Einstufung nach terrassenstratigraphischen Gesichtspunkten (WOLF, 1978) ins Tegelen B nicht wiederspricht.
5. Die neue Großsäugerfundstätte Meiningen (Werraschotter) ist basal negativ, im mittleren und hangenden Teil positiv polarisiert.
Da nach Kleinsäugerfunden ein präcromerzeitliches Alter angenommen werden muß, dürfte der registrierte Polaritätswechsel der unteren Grenze des Jaramillo-Events entsprechen.
6. Der wichtigste magnetostratigraphische Leithorizont des Pleistozäns, die Grenze zwischen der paläomagnetischen Matuyama- und des Brunhes-Epoche (M/B-Grenze, $700x10^3$ J) wurde bisher in den Richtprofilen Voigtstedt und Mahlis registriert. Ihr Nachweis ermöglichte unter Berücksichtigung des geologisch-paläontologischen Inventars eine Präzisierung der Gliederung des Cromer-Komplexes. Die Lage der M/B-Grenze innerhalb der beiden Profile bestätigt die nach geologischen Befunden in England und den Niederlanden vermutete Aufgliederung dieses Komplexes in 4 selbständige Warmzeit/Kaltzeit-Folgen. Damit konnte das im Mittelpleistozän bestehende Defizit zwischen der Anzahl der Klimazyklen in kontinentalen und marinen Ablagerungen ausgeglichen werden.
7. In Geschiebemergeln der Elster-, Saale- und Weichselkaltzeit wurden Zonen anomaler Polarität registriert, die einerseits auf Anomalien des Magnetfeldes z.Z. der Moränenbildung, andererseits auf den Sedimentationsprozeß während des Austauens der Moräne aus dem Gletscher zurückgeführt werden könnten.
Für die erste Annahme spricht der Nachweis anomaler Magnetisierung auch im Schlepp (Eisstausee-Schluffe) der Saale-I-Moräne. Dagegen zeigten die unmittelbar vor den Elster-Moränen abgelagerten Bändertone kein ausgeprägt anomales Verhalten, während die Moränen i.a. geringere und negative Inklinations-

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werte aufweisen. Die Klärung dieses Problems erfordert die Bearbeitung weiterer geeigneter Profile.

8. Untersuchungen nordbulgarischer Lößserien ergab, daß offenbar die gesamte Lößfolge einschließlich des cromerzeitlichen Fossilbodens FB_7 - bis auf einzelne kurze Events und Exkursionen - positiv polarisiert ist. Im Profil Kosar Belene könnte sich im basalen Teil des ältesten Bodens der Übergang zur Matuyama-Epoche abzeichnen. Daraus kann abgeleitet werden, daß in Südosteuropa die Lößsedimentation erst mit Beginn der Brunhes-Epoche, d.h. etwa 1 Mio J. später einsetzte als in Zentraleuropa.
9. In jungen Lößen der VR Bulgarien konnte weiter bei Russe und Silsitra das Blake-Event (114 - 108 x 10^3J) nachgewiesen werden, aus dessen Position auf der Basis der Sedimentationsrate das Alter der hangenden und liegenden Fossilböden abgeschätzt werden konnte, die danach mit den letztinterglazialen Meeresspiegelhochständen der Barbados-Terrassen III und II korreliert sind. Hierdurch wird die globale Koinzidenz paläoklimatischer Ereignisse 1. Ordnung dokumentiert.
10. In Kooperation mit dem ZGI Berlin und dem VEB Geophysik Leipzig wurden zwei Tiefsee-Kerne bearbeitet. Ein Kern aus dem Azorenbecken wurde magnetostratigraphisch interpretiert. Die registrierten Zeitmarken erlaubten wichtige Aussagen zur Sedimentation.

Damit haben sich die Voraussetzungen für den Vergleich der geologischen, paläoklimatischen und paläontologischen Zeitreihe im regionalen und globalen Maßstab erheblich verbessert und erweitert. Auf der Basis solcher Datierungen konnte nunmehr mit der quantitativen Analyse der die quartäre Entwicklung bestimmenden Prozesse begonnen werden. Das betrifft sowohl die Periodizität der Klimaschwankungen wie ihre zeitliche Kopplung mit der Variation der Sedimentation in kontinentaler und mariner Fazies oder die Frequenz der Faunenwellen und die Evolutionsrate. Insbesondere machte der globale Vergleich enge Beziehungen zwischen der Änderung der paläogeographischen Bedingungen (Drift, Spreading, Meeresströmung), der progressiven und episodichen Abkühlung der Weltmeere, dem Aufbau der antarktischen Eiskalotte, der wachsenden Aridität und der Beschleunigung der Evolutionsrate

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deutlich. Damit führt die Frage nach den die globale Situation im Quartär bestimmenden Wirkprinzipien 1. Ordnung weit in das Tertiär hinein. Es zeichnet sich ab, daß enge Zusammenhänge zwischen Änderungen des Konvektionsregimes in der Kruste und im oberen Mantel, Plattentektonik, Riftaktivität, Tektogonese, Orogenese, Paläogeographie, Paläoökologie und Evolution bestehen, woraus neue methodische Ansätze für die Untersuchung der Antriebsmechanismen der planetaren Entwicklung hergeleitet werden können. Für eine detaillierte Untersuchung dieser Zusammenhänge ist eine Ausdehnung der paläomagnetischen Korrelations- und Datierungsverfahren auf das gesamte Tertiär dabei unumgänglich.

Zusammenfassung

Für die Analyse der die geologische Entwicklung sensu lato bestimmenden geophysikalischen und geologischen Wirkprinzipien ist die Datierung der regionalen geologischen, paläoklimatischen und paläontologischen Zeitreihe eine Grundvoraussetzung. Der globale Vergleich solcher Ereignisfolgen ermöglicht, zeitliche Zusammenhänge und damit Kausalbeziehungen zwischen geologischen, paläogeographischen, paläoklimatischen und paläontologischen Prozessen zu untersuchen. Es wird ein Überblick über den Stand der diese Zielstellung verfolgenden magnetostratigraphischen Arbeiten im höheren Känozoikum der DDR gegeben. Von mehr als 30 untersuchten Profilen konnte der überwiegende Teil durch die Bestimmung magnetostratigraphischer Merkmale zeitlich genauer gefaßt werden. Durch die Identifizierung der Brunhes/Matuyama-Polaritätsgrenze in zwei Richtprofilen kann das Korrelationsschema des höheren Känozoikums der DDR mit der globalen Entwicklung verglichen werden. Es ergibt sich weitgehende Übereinstimmung hinsichtlich der Anzahl und Intensität der klimastratigraphischen Merkmale vergleichbarer Zeitabschnitte.

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Abstract

For analysis of geophysical and geological principles influencing the geologic development not strictly speaking, dating of the regional geologic, paleoclimatic and paleontologic time series is a basic assumption. By means of a global comparison of such series of events it is possible to investigate temporal relations and therewith causal relations among geologic, paleogeographic, paleoclimatic and paleontologic processes. There is given a survey on the level reached of magnetostratigraphic works in higher Caenozoic of the GDR concerning this aim. The vast majority of more than 30 profiles investigated could be seized temporarily more exactly by determination of magnetostratigraphic aigns. By identification of the Brunhes/Matuyama polarity border in two directional profiles the correlation scheme of higher Caenozoic of the GDR can be compared with the global development. There is resulting a vast correspondence with respect to number and intensity of climastratigraphic characteristics of comparable periods.

Резюме

Для анализа определяющих геологическое развитие геофизических и геологических принципов действия в широком смысле, датирование регионального геологического, палеоклиматического и палеонтологического временных рядов является основной предпосылкой. Глобальное сравнение таких последовательностей событий разрешает исследовать временные взаимозависимости итак причинные связи между геологическими, палеографическими, палеоклиматическими и палеонтологическими процессами. Дается обзор об уровне магнитостратиграфических работ в высшей кайнозойской эре ГДР, занимающихся этой целью. Большую часть более 30 исследованных профилей можно было охватывать временно точнее определением магнитостратиграфических признаков. При помощи идентификации границы полярности Брунэс/Матуяма в двух профилях направления схема корреляции высшей кайнозойской эры можно сравнить с глобальным развитием. Оказывается значительное соответствие относительно числа и интенсивности климастратиграфических признаков сравниваемых периодов.

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Literatur

BERGGREN, W.A.; VAN COUVERING, J.A.: The Late Neogen. Biostratigraphy, geochronology and paleoclimatology of the last 15 millionyears in marine and continental sequences. Paleogeography, paleoclimatology, paleoecology, Amsterdam 16 (1974), S. 1-216.

BUCHA, V.; ŠIBRAVA, V.: On the correlation of Quaternary stratigraphy stages in the northern hemisphere. IGCP Project 73/1/24, Rep. No. 4, Stuttgart 1976, Prag (1977), S. 91-101.

KENNETT, J.P.; BURNS, R.E.; ANDREWS, J.E.; CHURKIN, M.; DAVIES, T.A.; DUMITRICA, P.; EDWARDS, A.R.; GALEHOUSE, J.S.; PACKHAM, G.H.; VAN DER LINGEN, G.J.: Australian-Antarctic continental drift, palaeocirculation changes and Oligocene deep-sea erosion. Nature physical sci., London 239 (1972), S. 51-55.

KUKLA, G.J.: Pleistocene land-sea correlations. I. Europe. Earth sci. rev., Amsterdam 13 (1977), S. 307-374.

WIEGANK, F.: Paläomagnetische Datierung und Korrelation paläoklimatischer Ereignisse des Mittel- und Jungpleistozäns. Z. Geol. Wiss., Berlin 5 (1977), S. 705-716.

WIEGANK, F.: Palaeomagnetic dating and correlation of Quarternary deposits in the GDR. IGCP Project 73/1/24, Rep. No. 5, Novosibirsk 1978, Prag (1979), S. 254-262.

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EXCURSIONS OF THE GEOMAGNETIC FIELD DURING BRUNHES EPOCH

Abstract

As a result of detailed paleomagnetic investigations of pliocene-quarternary sediments of some regions of the USSR it has been stated that during Brunhes epoch there existed short-term inversions that did not take place - excursions of the geomagnetic field. In the summary paleomagnetic section of Brunhes epoch one can distinguish as many as 12 excursions, the most surely stated of them are the last four ones: ~12, ~ 25, ~ 43 and ~100 thousand of years ago. Discovered are some general and characteristic features of excursions, those features served as a basis for the assumption concerning the nature of excursions.

Резюме

В результате детального палеомагнитного изучения плиоцен-четвертичных отложений нескольких районов СССР установлено, что в эпоху Брюнес существовали кратковременные несостоявшиеся инверсии - экскурсы геомагнитного поля. В сводном палеомагнитном разрезе эпохи Брюнес выделяется до I2 экскурсов, наиболее надежно установленными из которых можно считать последние четыре: ~I2, ~25, ~43 и ~I00 тысяч лет тому назад. Выявлены некоторые общие и характерные черты экскурсов, на основании чего сделано предположение о их природе.

Zusammenfassung

Als Resultat detaillierter paläomagnetischer Untersuchungen der Pliozän - Quartär - Ablagerungen in einigen Gebieten der UdSSR wurde festgestellt, daß in der Brunhesepoche kurz-

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fristige nichtrealisierte Inversionen - Exkursionen des geomagnetischen Feldes existiert haben. Im paläomagnetischen Sammelprofil der Brunhesepoche lassen sich 12 Exkursionen nachweisen, von denen die letzten vier, vor ~12, ~25, ~ 43 und ~ 100 Tausend Jahren, als die gesichertsten bestimmt wurden. Es wurden einige allgemeine und charakteristische Züge der Exkursionen festgestellt, auf Grund derer Vermutungen über ihre Natur getroffen wurden.

Lately a new branch has been quickly developing in paleomagnetism - the study of a finer space-time structure of an ancient geomagnetic field, of secular variations, the study of the process of reversals and short-term aborted reversals - excursions. New paleomagnetic data are an effective source of information about processes taking place in the external part of the core; they supply us with information necessary to develop the theory of hydromagnetic dynamo. They are no less important for practical goals of stratigraphy and geochronology, and they are particularly important for dismemberment and correlation of quaternary sediments.

To study excursions of the geomagnetic field during Brunhes epoch, detailed paleomagnetic investigations of quaternary continental sediments and bottom silts in several regions of the USSR have been performed. The investigations have been conducted in both one sedimentary environment on parallel sections and on exposures which are very distant from one another: in the Carpathians (4 sections) (Adamenko, Pospelova, Gladilin et al., 1980), in the Middle Dniester (2 sections) (Kulikova, 1980), in Western Siberia (8 sections) (Pospelova, 1971; Pospelova, Gnibidenko, Adamenko, 1976; Kulikova, Pospelova, 1979), in the southern part of the Okhotsk Sea (5 cores) (Pospelova et al., 1976). Spots investi-

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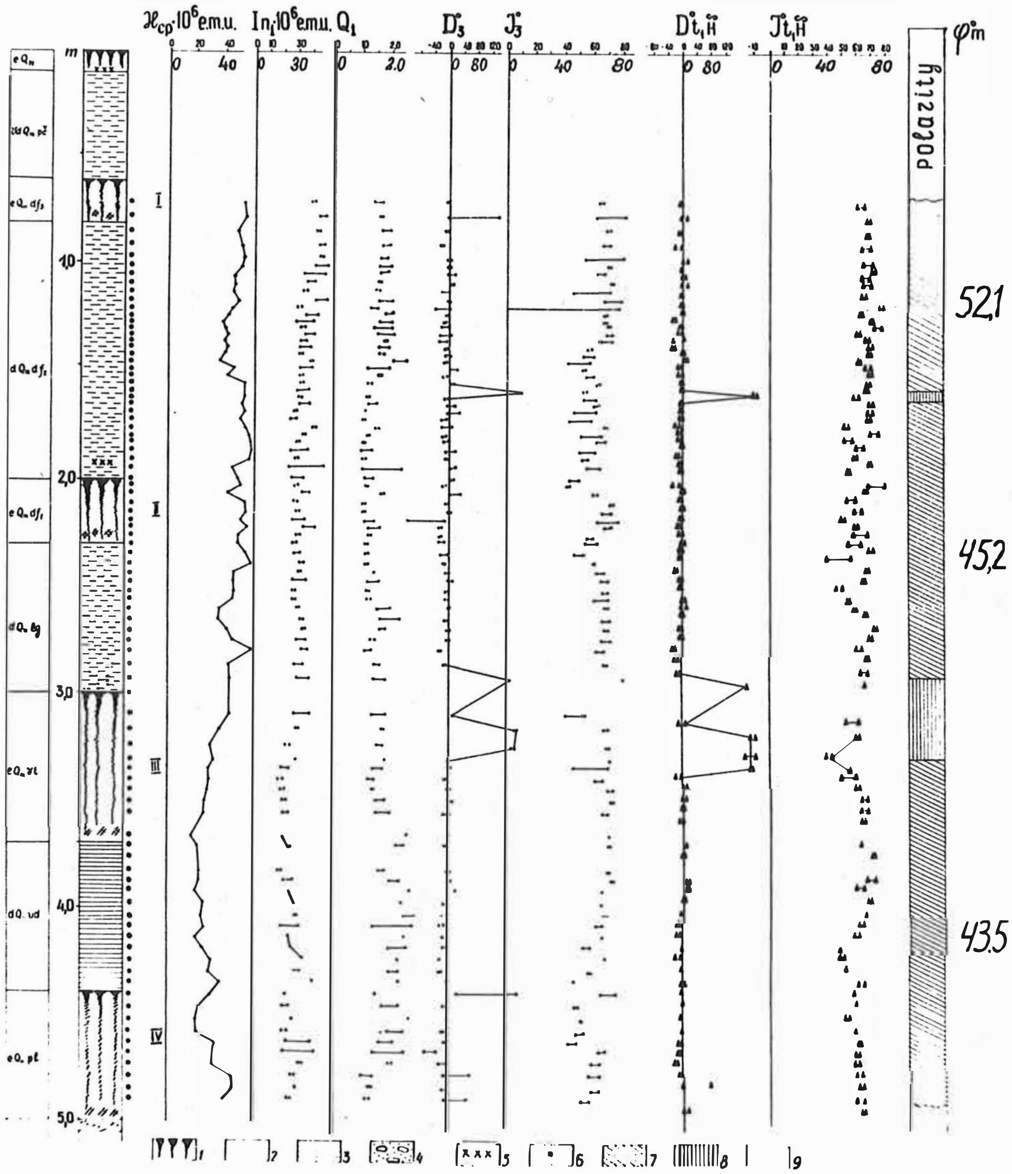

Fig. 1.

Lithology, magnetic characteristics and paleomagnetic section of the Beregovo II exposure.

1 - fossil soil, 2 - loessial loam, 3 - clay, 4 - gravel, 5 - cultured stratum, 6 - the point of sample selection, 7 - zone of normal polarity, 8 - paleomagnetic anomaly, 9 - non-investigated part of the section.

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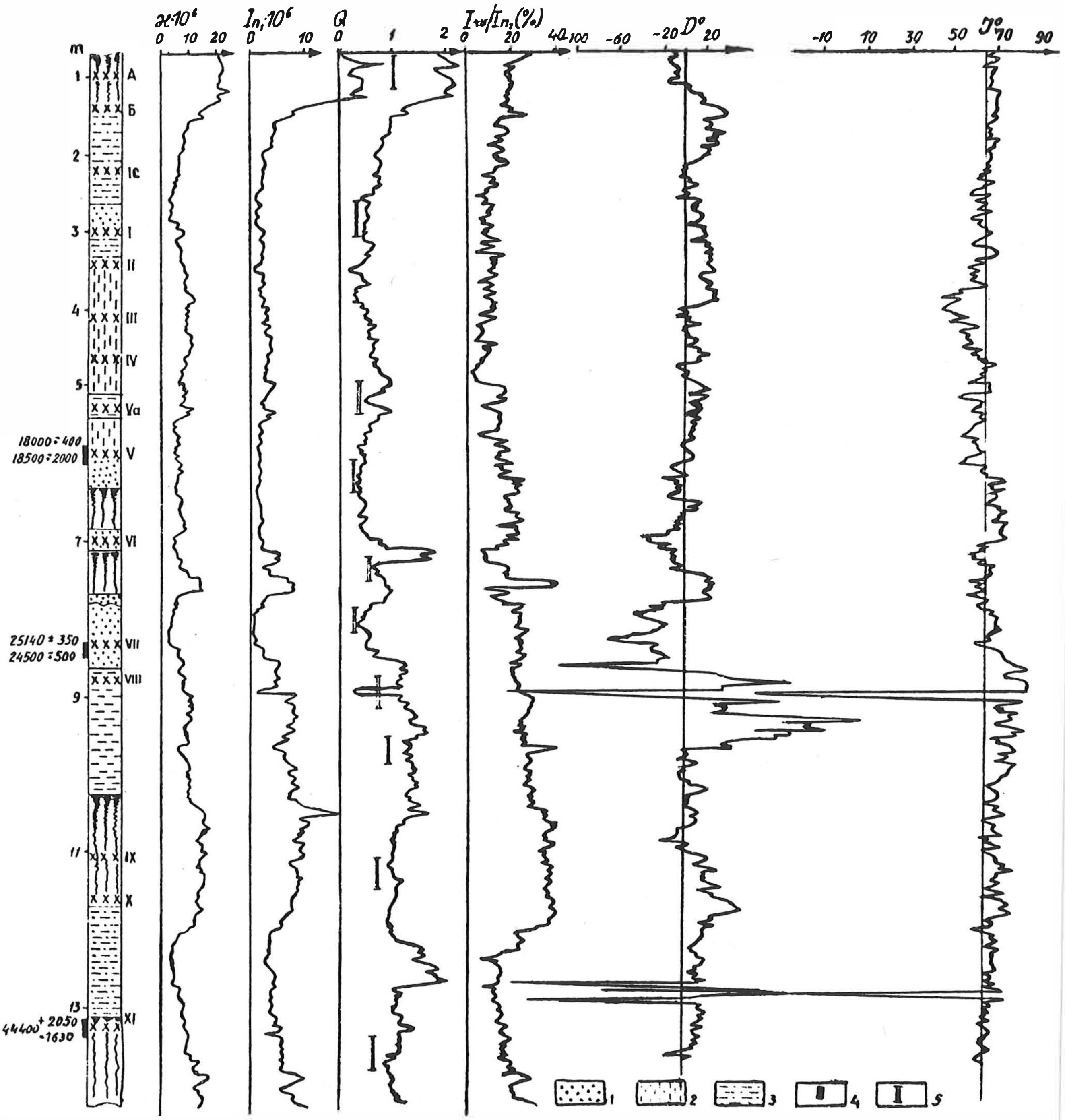

Fig. 2.

Lithology and magnetic characteristics of rocks in the summary section Korman IV.

1 - sand, 2 - loess, 3 - loessial loamy sand, 4 - radiocarbon dates, 5 - resedimentation factor.

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gated are located near latitude 50° North but are distant by longitude for 124° which makes ~ 13000 kilometers.

Some of investigated sections (Molodova V, Korman IV in the Middle Dniester, Kargapolovo and Belovo in Western Siberia) have no less than two dated horizons with the absolute age being defined by radiocarbon and thermoluminescence methods. In the rest of the exposures there are no definitions of the absolute age. But in bottom cores of the Okhotsk Sea micropaleontologic and palynologic analyses allowed us to securely estimate the time interval under study. In sections of the Carpathians and Western Siberia on the basis of complex geologic, paleontologic, archaeologic and paleomagnetic data dismemberment and correlation of sections have been performed and the age of sediments has been approximately defined.

The main part of rocks under study, bottom silts of the Okhotsk Sea and alluvial sediments of the Ob' discovered by Kargapolovo exposure excluded, is presented by loessial loams and clays separated by fossil soils. Some of sections have been continuously tested with the step 3÷3.5 cm, others - with the step 15 cm, still others - with the step 30 cm. On the whole, nearly 6000of oriented sample rocks have been selected and investigated.

In general the investigated rocks are weakly magnetic. Magnetic susceptibility ($\varkappa$) in the average is $10 \div 40 \times 10^{-6}$ e.m.u., natural remanent magnetization (I_n) does not exceed 40×10^{-6} e.m.u. with the exception of parts with hightened values $\varkappa$ and I_n which are timed, as a rule, to horizons of fossil soils, and of rock of the Kargapolovo section whose $\varkappa_{av}$ is 150×10^{-6} e.m.u., In_{av} - 80×10^{-6} e.m.u. Some of sections are rather homogeneous by scalar magnetic parameters (Figs. 1, 2), others have a wider range of changing magnetic parameters (Figs. 3, 4). Values of Königsberger

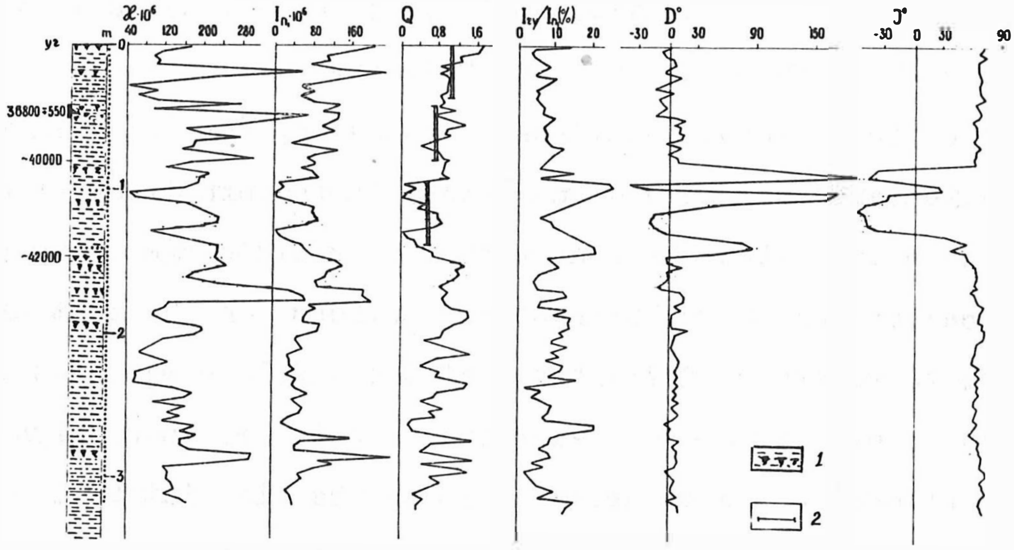

Fig. 3. Lithology and magnetic characteristics of rocks of some part of the summary section Kargapolovo. 1 - humussial loam, 2 - sparseness of magnetic parameters on a stratigraphic level.

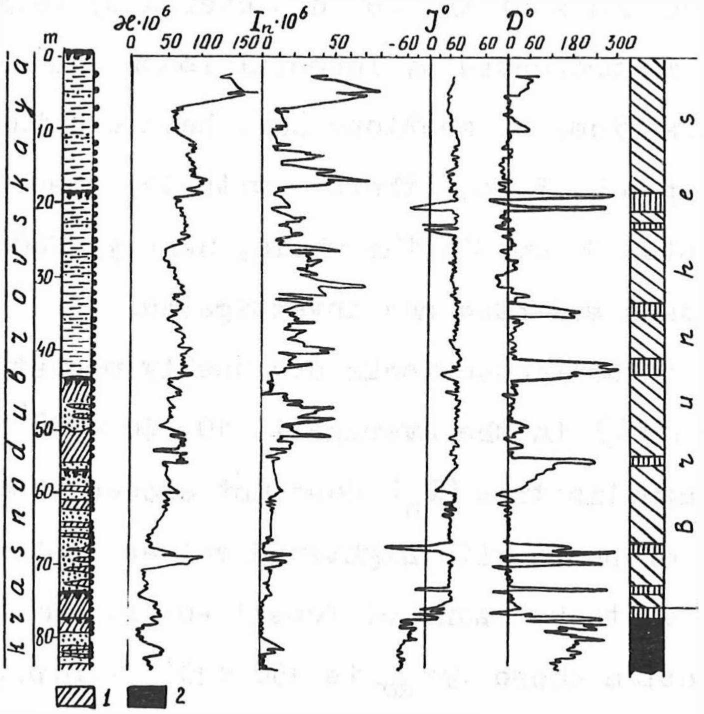

Fig. 4. Lithology, magnetic characteristics and paleomagnetic section of the exposure Elunino I. 1 - compact loam, 2 - zone of reversal polarity.

factor (Q) vary from 0.1 to 6.5. The maximal values of Q are, in general, typical of fossil soils. Viscous remanent magnetization (I_{rv}) of the most part of the rocks makes 5÷10% of I_n rocks, that of a smaller number of rocks is 40% of I_n. To single out the primary remanent magnetization (I_n^o) from the general vector I_n, necessary laboratory magnetic cleanings of rocks have been used: all samples of the collections underwent time magnetic cleaning (τ), 70 % of samples underwent the cleaning by the alternating magnetic field ($\tilde{H}$) and temperature (T).

Both by the first measurements of the vector I_n and after magnetic cleanings having been performed, the character of the change of the direction of I_n in sections has been in general preserved. In all the sections marked are two regimes of behaviour of the direction of the vector I_n. Against the background of small oscillations of declination and inclination values, thin horizons representing paleomagnetic anomalies are fixed. As paleomagnetic anomalies we took the horizons of rocks whose data showed the virtual geomagnetic pole (VGP) to be to the south of latitude 45°. In the sections of the Middle Dniester, two paleomagnetic anomalies for each, have been marked (Fig. 2), 4 paleomagnetic anomalies have been noticed in the Carpathians in the summary section Beregovo, 5 anomalies in Koroljevo, 6 - in Nizhny Koropetz (Fig. 5). Altogether 9 paleomagnetic anomalies in the Ukrainian sections have been marked, some of them, positively marked in two or more sections, can be said to be stated for sure, others demanding further confirmance. 2 anomalies have been found out in the cores of the Okhotsk Sea (Fig. 6), 1 anomaly - in the Kargapolovo section (Fig. 3), as many as 8 paleomagnetic anomalies - in the sec-

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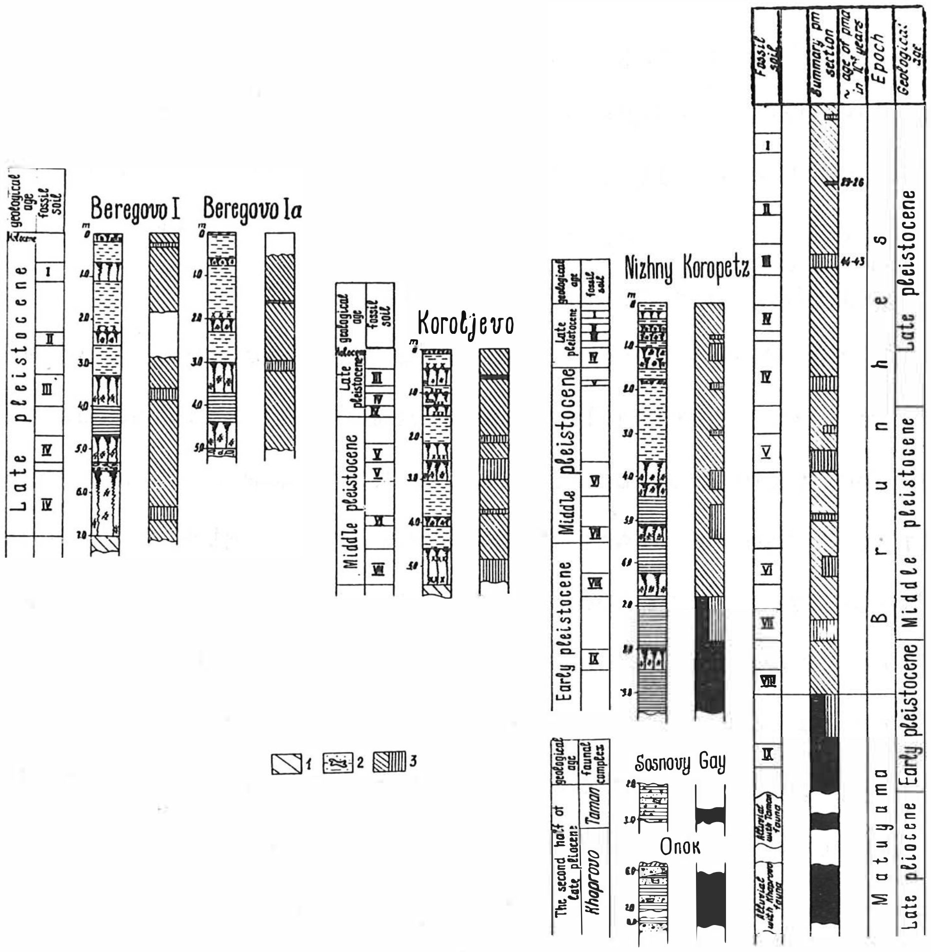

Fig. 5. Summary paleomagnetic section of pliocene-quaternary sediments in the Carpathians.

1 - socle presented by weathering rind of dacite,

2 - fauna, 3 - assumed paleomagnetic anomaly.

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tions of near-Ob' plateau of Western Siberia, 7 of them being discovered in the same section (Fig. 4). Separated and correlated at a large area of the near-Ob' plateau (more than 10000 km^2) paleomagnetic anomalies have different reliability degree. Mostly positively stated are considered to be 2 anomalies in the time interval of 100 ÷ 200 thousand years ago.

To state the nature of paleomagnetic anomalies special expeditionary and laboratory investigations have been done. As a result it was stated that there are no mechanical and physico-chemical causes for paleomagnetic anomalies to appear. The dependence of horizons with anomalous magnetization on the lithology of rocks was not discovered. Anomalously magnetized horizons have been traced both in soil horizons and in the beds of loam and clay. Rocks with normal magnetization I_n and with the anomalous direction of I_n do not differ by the structure and size of magnetic minerals investigated by mineragraphic, X-ray structural and magnetic analyses. Differences in the nature of I_n confirmed by experiments on laboratory resedimentation in both the rocks are also lacking. On the other hand, one can observe accordance of time and stratigraphic position of anomalies in parallel and distant sections. All that allows us to interpret the abovementioned paleomagnetic anomalies as a real geophysical phenomenon conditioned by changes of the geomagnetic field.

Thus we may draw a conclusion that excursions of the geomagnetic field did exist during Brunhes epoch. In the summary paleomagnetic section of Brunhes epoch 12 excursions have been singled out (Table 1). The last four of them: ~ 12, ~ 25, ~ 43 and ~ 100 thousand years ago - can be considered the most surely stated ones; the excursion of ~ 200 thousand years ago and the first one after

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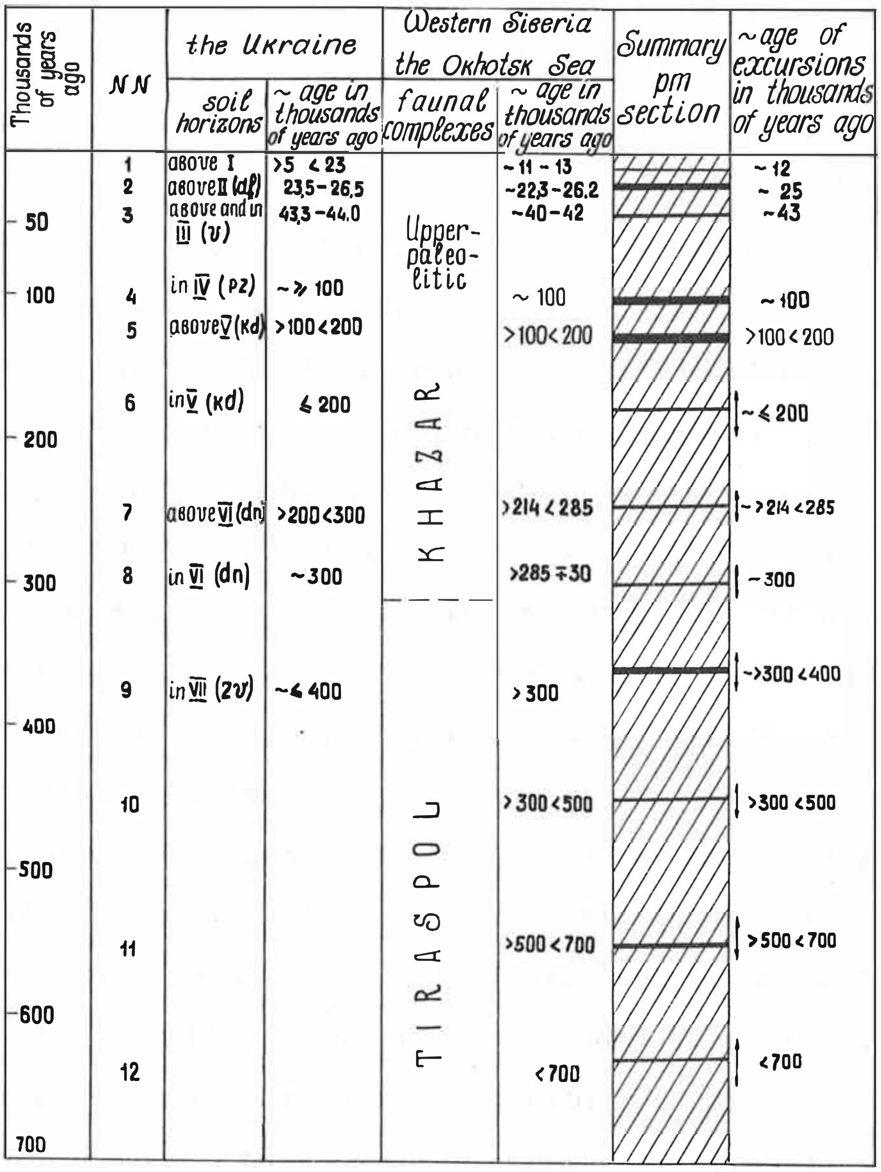
Table 1



Thousands of years ago	NN	the Ukraine		Western Siberia the Okhotsk Sea		Summary pm section	~age of excursions in thousands of years ago
		soil horizons	~ age in thousands of years ago	faunal complexes	~ age in thousands of years ago		
	1	above I	>5 < 23	Upper-paleolitic	~ 11 – 13		~ 12
	2	above II (df)	23,5 – 26,5		~22,3 – 26,2		~ 25
50	3	above and in III (v)	43,3 – 44,0		~40 – 42		~43
100	4	in IV (pz)	~ ≥ 100		~ 100		~ 100
	5	above V (kd)	>100 < 200	KHAZAR	>100 < 200		>100 < 200
	6	in V (kd)	≤ 200				~ ≤ 200
200							
	7	above VI (dn)	>200 < 300		>214 < 285		~ >214 < 285
300	8	in VI (dn)	~300		>285 ∓30		~300
	9	in VII (zv)	~ ≤ 400	TIRASPOL	>300		~ >300 < 400
400							
	10				> 300 < 500		>300 < 500
500							
	11				>500 < 700		>500 < 700
600							
	12				< 700		< 700
700							

TABLE 1.

Comparison scheme of excursions discovered in the Ukraine, Western Siberia and the Okhotsk Sea for Brunhes epoch.

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the Matuyama-Brunhes reversal are said to be the lest positively stated. That is, during Brunhes epoch there occured no less than at least 10 excursions of the geomagnetic field, the greater part of them being traced in different spots of the Earth remoted for thousands of kilometers. Comparison of the obtained data with those of literature in general confirms the global character of the excursions' revealing (Svytoch et al., 1978; Tretyak, Volok, 1976; Bucha, 1976; Nöel, Tarling, 1975; Smith, Foster, 1969; Verosub, Banerjee, 1977; Wiegank, 1979 and many others). During the last 700 000 years the frequency of excursions' revealing does not satisfy the periodicity law and makes in the average 10^5-10^4 years.

The analysis of the excursions stated on natural exposures and boreholes shows that each of the excursions is, at least short-term, complete reversal of the geomagnetic field; before and after this reversal one may observe perturbations of the field with great variations of declination and inclination (Table 2). The duration of excursions on the basis of their age being precisely determined, and on a rough approximate estimation (judging by the thickness of paleomagnetic anomalies) makes from 700 to 6 000 years. The main part of excursions has the duration of ~ 2 000 years (Table 2). The duration of excursions of about 10^3 years is close to the duration of reversal process in the transition of the geomagnetic field from one polarity to the other.

The fact that excursions take place against the background of lowered values of I_n, Q, of the resedimentation coefficient P, laboratory field He for which $I_{ri} = I_n^{\circ}$ (Fig. 7), is an interesting peculiarity of excursions. However, such a behaviour is not fixed on all the sections studied. In the cases when an excursion is

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Table 2

N of excursion	~ age in thousands of years ago	Duration in thousands of years	Certainty			Thickness of PMA in cm	Estimation of field intensity	Amplitude of PMA	VGP	
			number of exposures	number of samples	Laboratory investigations				Lat.°	Long.°
1	~12	~2	3	9	τ, $\tilde{H}$, T, P, $I_{rs}(t)$ $I_r(\bar{\bar{H}})$, X-ray	7-20	decrease I_n; no change	100°-135°	up to -45	45 E.L. 140 W.L.
2	~25	3	6	67	τ, $\tilde{H}$, T, P. X-ray	4-100	increace with short-term decrease I_n, Q, P	85°-177°	up to -87	60 E.L. 120 W.L.
3	~43	0,7-2	7	113	τ, $\tilde{H}$, T, P	4-70	decrease Q, I_n, P no change	105°-174°	up to -84	
4	~100	~5	8	38	τ, $\tilde{H}$, T, He, P, $I_{rs}(t)$, $I_r(\bar{\bar{H}})$, X-ray	7-100	decrease I_n, Q; lowered Q, I_n, He	72°-120°	up to -30	95 E.L. 54 W.L.
5	>100<200	~5	8	32	τ, $\tilde{H}$, T, He, P, $I_{rs}(t)$, $I_r(\bar{\bar{H}})$	7-50	Sharp decrease I_n, Q; lowered Q, I_n, He, P	70-136°	up to -46	100 W.L. 170 W.L.
6	~ ≤ 200	?	2	24	τ, $\tilde{H}$, T, P	17-45	min I_n; decrease Q	104	up to -14	110 E.L.
7	~>214<285	~1	6	18	τ, $\tilde{H}$, T, He	10-15	decrease I_n with further increase; no change			
8	~300	~2	5	25	τ, $\tilde{H}$, T, He, P, $I_r(\bar{\bar{H}})$, $I_{rs}(t)$	45-50	lowered I_n, Q	85°-140°	up to -50	102 E.L.
9	~>300<400	~6	8	55	τ, $\tilde{H}$, T, He, P, X-ray	23-80	lowered I_n, Q; max I_n	112°-157°	up to -67	15 E.L.
10	>300<500	~1,3	2-3	16	τ, $\tilde{H}$, T, He, P, $I_r(\bar{\bar{H}})$, $I_{rs}(t)$	15-20	lowered I_n, Q	93°	up to -3	140 W.L.
11	>500<700	~1,8	4-5	16	τ, $\tilde{H}$, T, P, I_{ri}, X-ray	10-20	lowered I_n, Q	117°-150°	up to -60	120 E.L.
12	<700	~1	1-3	10	τ, $\tilde{H}$, T, P, I_{ri} $I_r(\bar{\bar{H}})$, $I_{rs}(t)$, X-ray	10-15		72°-120°	up to -30	100 W.L.

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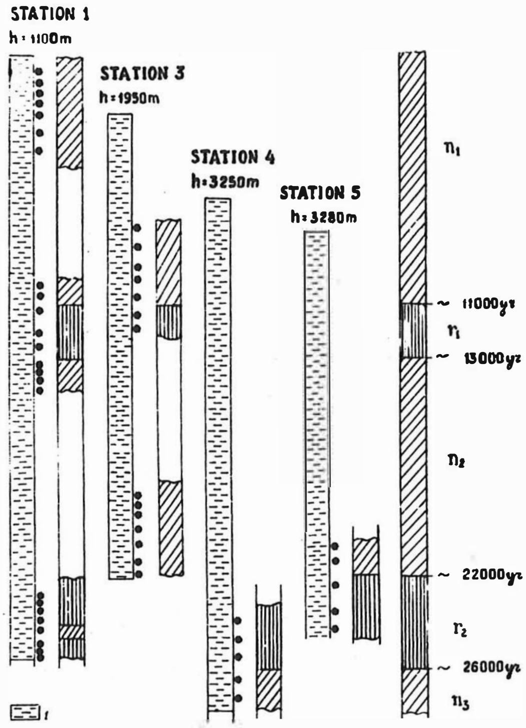

Fig. 6. Comparison scheme of paleomagnetic sections in the studied cores of the Okhotsk Sea.

1 - bottom clay silts, h - the depth of core selection.

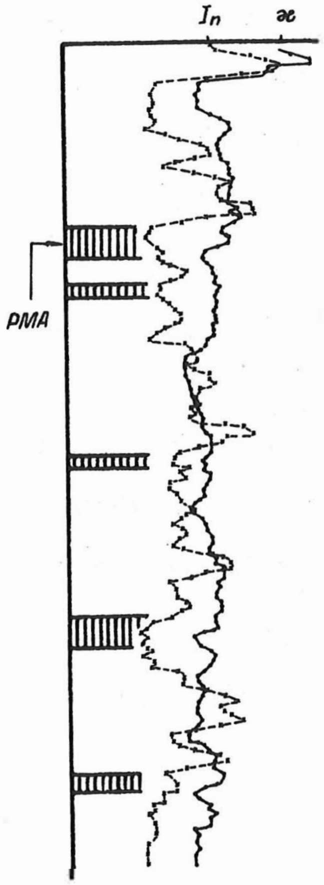

Fig.7. Change of the geomagnetic field intensity by the data of Elunino section.

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studied on large actual material, one can easily see that just at the moment of a short-term complete reversal field sharp decrease of I_n, Q, P (see Figs. 2, 3) takes place. That is, perturbations in the direction of the field are also accompanied by sharp perturbations in the geomagnetic field intensity characterized by its decrease during the excursion with the preceding and following increase (Table 2).

Open so far is the question of characteristic features of each excursion. The difficulty is that the impresiveness of the material at hand is different for different sections. One may get an impression that an excursion of the same age discovered in different spots of the Earth has common features in the character of VGP path. For example, during the excursion of ~ 25 000 years ago the path of VGP has the directed transition from the region of the Arctic Ocean to Africa and backwards, with the sharp jump to the South Pole, according to the data of both the Dniester, the Carpathians and the Okhotsk Sea (Fig. 8). As for excursions of different age, they differ in the type of VGP path with some modification. We could only give the final answer after additional investigations. According to the data of the Kargapolovo excursion which has been more thoroughly investigated, the average velocity of VGP during the excursion is rather high, more than 50 km per year.

To explain the mechanism of excursions' formation, different models have been proposed (Barbetti, McElhinny, 1976; Verosub, Banerjee, 1977; Petrova, 1980 etc.). From the aforementioned material one can see that the singled out peculiarities in the behaviour of the geomagnetic field during an excursion, in principle, well

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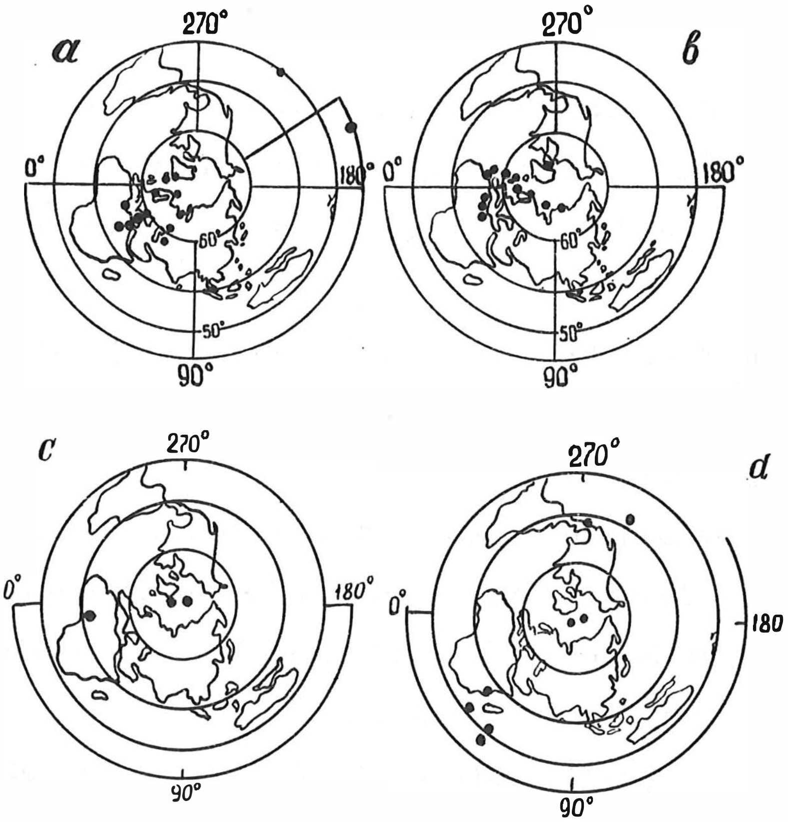

Fig. 8. VGP of the excursion of ~ 25000 years ago.
a - according to the data of Korman IV section, b - according to the data of Molodova V section, c - according to the data of the Beregovo section, d - according to the data of the cores in the Okhotsk Sea.

agree with some characteristic features of the field during reversals (Burakov, Gurary, Khramov et al., 1976; Petrova, 1977 and others). Possible is the assumption of the same nature of phenomena taking place in the dynamo mechanism. The role of the trigger mechanism is performed by secular variations conditioned by the processes on the core-mantle boundary.

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REFERENCES

Adamenko O.M., Pospelova G.A., Gladilin V.N. et al. Key magnetostratigraphical sections of anthropogenic sediments of the Carpathians. Proceedings of the USSR Academy of Sciences, geological series, 1980 (to appear).

Kulikova L.S., Pospelova G.A. Short-term reversal of the geomagnetic field of ~ 40 thousand years ago. - Proc. of the USSR AS, Earth Physics, 1979, No. 6.

Kulikova L.S. Selection of magnitochronological markers according to results of paleomagnetic investigation of late-pleistocene sediments in sections Molodova V and Korman IV. In: Geochronology of the quaternary period, Nauka, Moscow, 1980.

Petrova G.N. Geomagnetic data on Earth core. Proc. of the USSR AS, Earth Physics, 1977, No. 11.

Petrova G.N. Earth core by geomagnetic data. Ch. 1, 1980 (to appear).

Pospelova G.A. Anomalous behaviour of the geomagnetic field in pliocene-pleistocene. - Geology and geophysics, 1971, No. 6.

Pospelova G.A., Gnibidenko Z.N., Adamenko O.M. Magnitobiostratigraphical key section of the Neogene-Quaternary deposits from the South of Western Siberia. Proceeding of the USSR AS, geological series, 1976, No. 9.

Pospelova G.A., Gnibidenko Z.N., Larionova G.Ya. et al. Paleomagnetic investigations of sedimentary formations of mesozoic and cenozoic periods. In: Methods and results of complex geophysical investigations of the Earth crust in Siberia. Published by the Institute of Geology and geophysics, Siberian Branch of the USSR Academy of Sciences, Novosibirsk, 1976.

DOI: https://doi.org/10.2312/zipe.1981.070.01

Svytoch A.A., Boyarskaya G.D., Voskresenskaya T.N. et al. Section of the latest sediments in the Altai territory. Published by Moscow State University, Moscow, 1978.

Tretyak A.N., Volok Z.E. Paleomagnetic stratigraphy of pliocene-quaternary sedimentary rocks of the Ukraine, "Naukova Dumka", Kiev, 1976.

Barbetti M.F., McElhinny M.W. The Lake Mungo geomagnetic excursion. Philosophical transactions of the Royal society. A., 1976, v. 281, No. 1305.

Bucha V.V. Variations of the geomagnetic field, the climate and weather. Studia geophys. et geod., 1976, 2.

Burakov K.S., Gurary G.Z., Khramov A.N. et al. Some peculiarities of the virtual pole positions during reversals. J.Geomagn. and Geoelectr., 1976, 28.

Nöel M., Tarling D.H. The Laschamp geomagnetic event. Nature, 1975, v. 253, No. 5494.

Smith J.D., Foster J.H. Geomagnetic reversal in Brunhes normal polarity epoch. Science, 1969, v. 163, No. 3867.

Verosub K.L., Banerjee S.K. Geomagnetic excursions and their paleomagnetic record. Rev.Geophys. and Space Phys., 1977, v. 15, No. 2.

Wiegank F. Palaeomagnetic dating and correlation of quaternary deposits in GDR. Quaternary glaciations in the Northern Hemisphere. Project 73/1/24, INQUA, Prague, 1979.

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THE ROLE OF STONY METEORITES IN THE STUDY OF EXTRATERRESTRIAL MAGNETISM

Abstract

Data on statistical analysis of natural remanent magnetization I_n and magnetic susceptibility æ for 400 samples of stony meteorites of L and H types and of samples of meteorite shower Pultusk are given. The results show that I_n is quite stable and is of an extraterrestrial origin. The comparison of summary distribution of $Q_n = I_n/0.5$ æ value for stony meteorites, lunar rocks and earthen basalts showed that the magnetization of stony meteorites is less susceptible to other influences than lunar rocks.

Резюме

Приводятся данные статистической обработки значений естественной остаточной намагниченности I_n и магнитной восприимчивости æ для 400 образцов каменных метеоритов L и H типов и образцов метеоритного дождя Pultusk . Результаты показывают, что I_n очень стабильна и имеет внеземное происхождение. Сравнение сводного распределения величины $Q_n = I_n/0.5$ æ для каменных метеоритов, лунных пород и земных базальтов свидетельствует о том, что намагниченность каменных метеоритов менее подвержена внешним воздействиям, чем лунных пород.

Zusammenfassung

Die Daten der statistischen Analyse der natürlichen Restmagnetisierung I_n und der magnetischen Suszeptibilität æ werden für 400 Proben der Steinmeteoriten-Typen L und H und für Proben des Meteoritenregens Pultusk vorgestellt. Die Ergebnisse zeigen, daß I_n sehr stabil und extraterrestrischen Ursprungs ist. Vergleiche der Summenverteilungen von $Q_n = I_n/0.5$ für Steinmeteoriten, Mondgestein und irdischen Basalt zeugen davon,

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daß die Magnetisierung von Steinmeteoriten äußeren Einflüssen weniger unterworfen ist als Mondgestein.

Magnetic properties of stony meteorites of different types (1-3) received the most serious study. The results obtained confirm that such studies may be conducted on the basis of the method of investigation the magnetic properties for paleomagnetic research.

Some additional data about the magnetic properties of stony meteorites can be obtained from the study of distribution of values $Q_n = I_n/0.5$ æ, where I_n - natural remanent magnetization, æ - magnetic susceptibility of the sample of meteorite. It is known, that Q_n is the characteristic value in the rock magnetism.

Distribution of Q_n values is presented for 193 samples of meteorites type L (contain of kamacite is to 12 wt %), for 92 samples of meteorites type H (contain of kamacite is to 25 wt.%) and 120 samples of meteorites of meteorite shower Pultusk (type H), there are the samples of one meteorite body, size of which is $70x70x70 \ cm^3$ according to the quantity of material gathered on the Earth. The distribution of Q_n is presented in fig. 1; as can be seen from fig. 1, the curves are practically identical.

To compare the kind of the distribution the statistical characteristics of Q_n distribution for each of these types were calculated. As the distribution differs from normal distribution and the number of samples is vast 4 statistical characteristics, i.e. Q_n - average value, dispersion S, asymmetry A and excess E, are calculated by the "method of classified data" with the help of usual formulae of mathematical statistics (4). The data are presented in Table 1; the characteristics are identical for all

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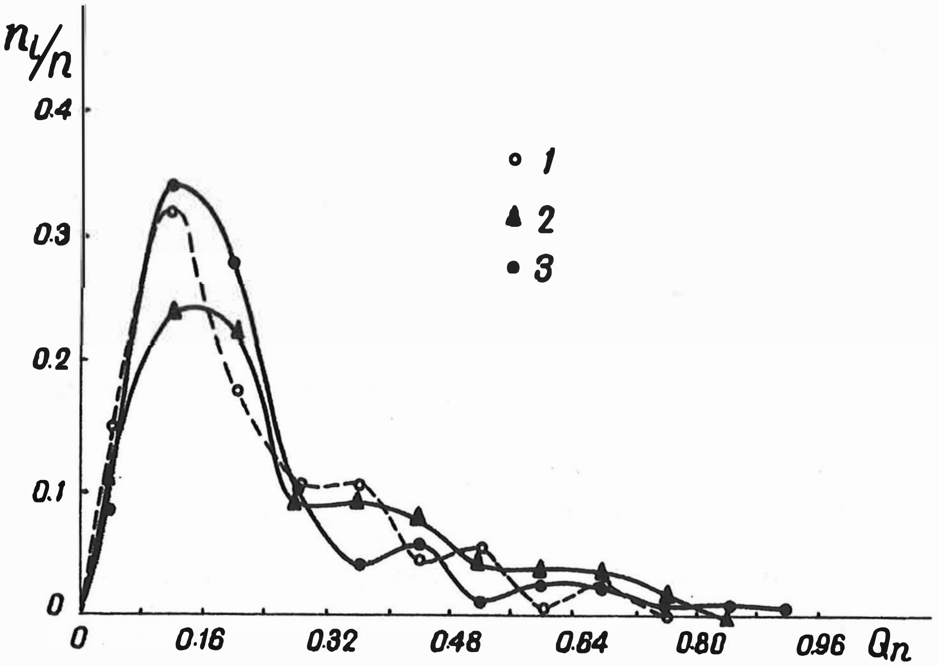

Fig. 1 Distribution of values of $Q_n = I_n/0.5$ æ for meteorites of different types. 1 - type L (n = 193), 2 - type H (n = 93), 3 - Pultusk (type H, n = 120).

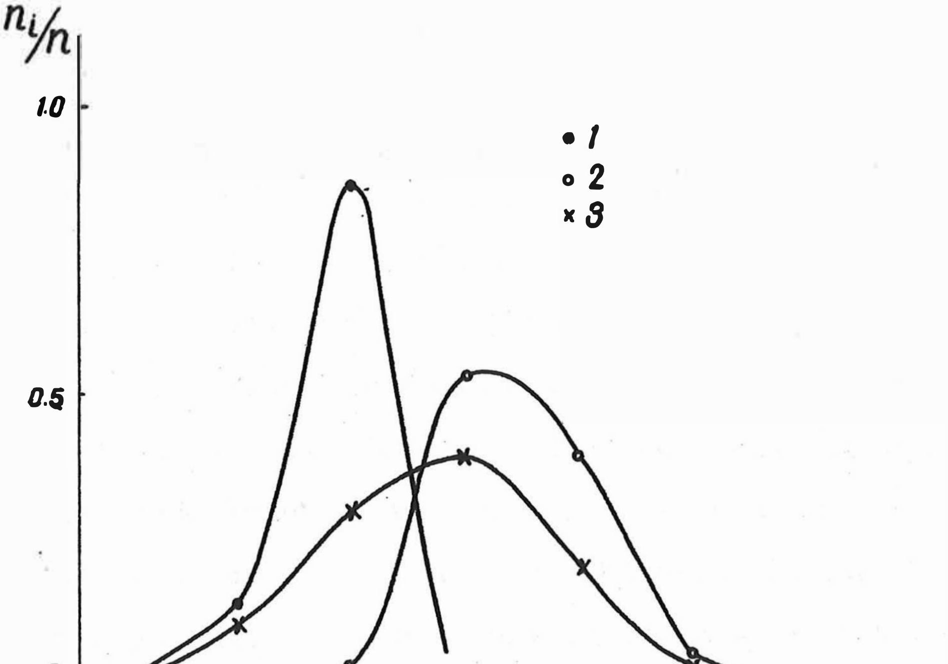

Fig. 2 The comparison of distributions of Q_n values for meteorites, lunar rocks and basalts. 1 - meteorites (n=400), 2 - lunar rocks (n = 38), 3 - basalts (n = 1730).

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types of meteorites - that is the distribution of magnetization for meteorites of type L and H fallen on the Earth in different places at different periods of time is similar to that of one meteorite body. Such a similarity is likely to confirm the uniform nature of magnetization I_n and its extraterrestrial origin.

Table 1

Statistical Characteristics of Q_n Value Distribution for Stony Meteorites of Different Types

Type	Number of samples	Q_n	S	A	E
L	193	0.22	0.17	1.0	0.6
H	92	0.27	0.18	1.0	0.9
Pultusk (type H)	120	0.22	0.15	1.4	2.9

Carbonaceous chondrites C are too few in number to provide any reliable statistics. As each of the samples is unique it is very important the date of the investigation of magnetic properties of the samples of carbonaceous chondrites from different collections. The values of magnetic properties of carbonaceous chondrites we obtained and those from literature when compared prove to be next to identical - the dispersion of values does not exceed 1 order. Such similarity of I_n values for samples preserved in the different collections of the world and measured in different laboratories is the sign of high stability of I_n and the uniform nature of it. In other words the magnetization I_n might appear at the time when all the samples of one carbona-

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ceous chondrite had been the parts of one intact meteorite body which means before it arrived on the Earth.

For ordinary chondrites such comparison is not easy to conduct due to the variability of meteorites in collections. The comparison for some particular samples gives the identical values of magnetization I_n.

In the process of investigation some of the samples of stony meteorites were cut into some oriented parts to compare the distribution of the direction of I_n vector along the sample. The data are presented in Table 2.

Table 2

Q_n Values and Direction of I_n for the Parts of one Stone Meteorite

Type	Name and number	Q_n	Inclination, J,°	Declination, D,°
C III	Allende 1	2.3	30	89
	Allende 2	2.0	35	79
	Allende 3	3.5	20	95
L	Farmington 1	0.14	-39	135
	Farmington 2	0.15	-24	168
	Farmington 3	0.13	-21	148
L	Kunashak 1	0.60	8	350
	Kunashak 2	0.54	16	3
H	Hessle 1	0.11	10	265
	Hessle 2	0.03	30	290

In spite of the fact that the shapes of samples are not isometrical and the angular values of inclination J and declination D

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are similar for the parts of one meteorite. For lunar rocks the data did not show the uniform distribution of I_n along the sample. That can be accounted by unusual conditions on the surface of the Moon (6, 7). Table 2 does not give the data for the rocks as it is obvious that the follow the same pattern as that of meteorites.

Summary distributions of Q_n value for stony meteorites were compared to those for lunar rocks (8-10) and rocks-basalts (11). Such comparison shows a sharp increase of the distribution of Q_n for stony meteorites.

Having summarised the data about magnetic properties of meteorites of all types together with the results of statistic analysis we come to the conclusion that the natural remanent magnetization I_n is quite stable and has extraterrestrial origin. Unlike lunar rocks, whose magnetization is changing under the influence of specific Moon conditions, the magnetization of stony meteorites is less susceptible to outer influences. The results obtained in the study of magnetism of stony meteorites help us to understand the physical conditions at the time of its origin and make it possible to evaluate the ancient magnetic field using paleomagnetic research methods.

References

1. Gus'kova E.G. Magnetic properties of meteorites. Leningrad, Nauka Press, 143 p. (English translation, NASA TT F792, 1976).
2. Brecher A., Ranganajaki R.P. Paleomagnetic systematics of ordinary chondrites. - Earth Plan.,Sci. Lett., 1975, 25, 1, 57-67.
3. Nagata T. Magnetic classification of stony meteorites. - Mem. Nat. Inst. Polar.Res., 1979, No. 15, 273-293.

DOI: https://doi.org/10.2312/zipe.1981.070.01

4. Pustylnik E.I. Statisticheskie metody analisa i obrabotki nabliudenii. Moskva, Nauka, 1968.

5. Gus'kova E.G. Namagnichennost uglistykh chondritov. Meteoritika, 1976, 35, p.78-87.

6. Gose W.A., Pearce G.W., Strangway D.W., Larson E.E. Magnetic properties of Apollo 14 breccias and their correlation with methamorphism. - Proc. 3 Lun. Sci. Conf., 1973, 3, 2387-95.

7. Pearce G.W., Gose W.A., Strangway D.W. Magnetic studies of Apollo 15 and 16 lunar samples. - Proc. 4 Lun. Sci. Conf., 1974, 3, 3045-76.

8. Gus'kova E.G., Gorshkov E.S., Ivanov A.V., Pochtarev V.I., Florensky K.P. Magnitnye svoistva lunnykh porod, dostavlennykh ALS "Luna-16" i "Luna-20". Kosmich. issled., 1975, XII, 5, 748-57.

9. Brecher A., Menke W.H., Morash K.R. Comparative magnetic studies of some Apollo 17 rocks and soils and their implications. - Proc. 5 Lun. Sci. Conf., 1974, 3, 2795-2814.

10. Nagata T., Sugiura N., Fisher R.M., Schwerer F.C., Fuller M.D., Dunn J.R., Magnetic properties of Apollo 11-17 lunar materials with special reference to effect of meteorite impact. - Proc. 4 Lun. Sci. Conf., 1974, 3, 2827-39.

11. Belokonj V.I., Kochegura V.V., Scholpo L.E. Metody paleomagnitnykh issledovanii gornykh porod. Leningrad, Nedra, 1973, 248 p.

DOI: https://doi.org/10.2312/zipe.1981.070.01

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TITANOMAGNETITE OXIDATION AND MAGNETISM OF OCEANIC BASALTS

Abstract

Magnetic properties of oceanic basalts from Atlantic and Pacific are due to titanomagnetites and the products of their oxidation, both if these products have only one phase and several phases. The composition of primary titanomagnetites determined by microprobe and thermomagnetic analyses is homogeneous for basalts under thermotreatment (T=1000°C) in neutral medium. Hereby Fe is carried out from titanomagnetites. Such a process is possible in nature at low temperature oxidation.

Резюме

Магнитные свойства океанических базальтов Атлантического океана и Тихого океана базируют на титаномагнетитах и их продуктов окисления, когда эти продукты имеют и только одна фаза и некоторые фазы. Состав первичных титаномагнетитов, определенный микрозондированием и термомагнитными анализами, для базальтов под тепловой обработкой / T = I000°C/ в нейтральной среде однороден. Fe отведен от титаномагнетитов. Такой процесс возможен в природе при окислениях под низкими температурами.

Zusammenfassung

Die magnetischen Eigenschaften ozeanischer Basalte aus dem Atlantik und dem Pazifik sind zurückzuführen auf Titanomagnetite und ihre Oxydationsprodukte, wenn diese Produkte nur eine oder auch verschiedene Phasen haben. Die Zusammensetzung primärer Titanomagnetite, die durch Mikrosondierungen und thermo-

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magnetische Analysen bestimmt wurde, ist für Basalte unter Hitzebehandlung ($T=1000^{0}C$) im neutralen Medium homogen. Hierbei ist Fe von Titanomagnetiten abgeleitet. Solch ein Prozeß ist in der Natur bei Oxidationen bei niedrigen Temperaturen möglich.

It is known that primary titanomagnetites in oceanica basalts are considerable altered. In most cases it is low temperature oxidation process leading to arising of titanomaghemites, more rarely - it is unmixing.

Our investigations have shown that the degree of these alterations especially singlephase oxidation depends on alterations of basalts as a whole. Strongly developed processes of oxidation on the final stage lead to unreversible alteration of composition of primary TM grains because of more active removal of iron ions from TM grains in the process of their alteration.

Investigation of basalts altered in different degree and titanomagnetites from these basalts was carried out on a collection of basalts of different ages, obtained by drilling and dredging in different parts of Atlantic and Pacific. One of the methods for determination of composition of TM in basalts was their high temperature treatment in neutral media or vacuum. The conditions of treatment were as follows: $T= 1000^{0}C$, time duration 15-30 minutes. Curie points were measured before and after temperature treatment. Besides the magnetic parameters reflecting concentration and coercivity of magnetic grains were measured. For pilot samples alterations in TM grains were studied with the help of raster-type electron microscope and X-ray phase analysis. The composition and homogenities of grains were determined, besides thermomagnetic analysis by electron microprobe "Camebax".

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According to magnetic characteristics before and after high temperature treatment all the samples were divided into four groups (table). The first group samples are the petrographically fresh basalts, usually completely crystallized, containing large homogeneous grains of titanomagnetite (more than 40 μm). Their Curie points are 110-150°. They correspond to Curie points calculated upon microprobe data (table) and are close to the middle Curie point calculated for oceanic basalts according to world data which is 130°C. The thermomagnetic curves are reversible. Curie points do not change after thermotreatment. Magnetic parameters reflecting structural peculiarities of grains are typical for multidomain grains. The samples of the second group are usually petrologically fresh and well crystallized basalts. But in distinction from the first group the measured Curie points of these basalts differ from the calculated ones. In process of high temperature treatment the homogenization occurs, as a result of which calculated and measured Curie points drow together (table).

According to electron microscopic and magnetic data the second group can be divided into two subgroups.

Subgroup IIa contains grains of titanomagnetite which are highly homogeneous upon microprobe and electron microscope data. Measured Tc are usually less than 250°C, thermomagnetic curves are close to reversible, the samples are magnetic soft. Calculated Tc are lower than the measured one. This fact coupled with grains homogeneity point to singlephase oxidation. In O'Reilly and Readman's diagram intersection of isolines of Tc and lattice parameters show that the oxidation degree does not exceed 0.4.

Curie points of subgroup IIb are higher than 250°. Thermomagnetic curves are close to the reversible ones. Many grains

Table

Typical characteristics of samples of oceanic basalts before and after thermotreatment

Group	Sample	Curie point, T_c, ^oC			$\frac{I_s^{hom.}}{I_s^{init.}}$	$\frac{I_{st}}{I_s^{init.}}$	$\frac{I_{rs}}{I_s^{init.}}$	Z
		calculated initial	measured initial	measured after treatm.				
I	412-78	135	150	140	0,5	0,95	0,09	0,1
IIa	407-8	125	210	110	0,51	1,06	0,11	0,35
IIb	418A-465	160	350	130	0,5	0,84	0,03	0,1
III	417D-94	160	280	350	0,6	1,5	0,2	0,45
	417D-122	90	350	500	0,8	1,3	0,12	0,8
IV	1028	-20	320	575	13,6	7,0	0,3	0,9

$I_s^{init.}$ - saturation magnetization initial; $I_s^{hom.}$ - saturation magnetization after high temperature treatment in argon or vacuum (T=1000°C, T= 15-30min.).

I_{st} - saturation magnetization after thermomagnetic analysis (heating in air to 600°C);

I_{rs} - remanence initial; Z - singlephase oxidation parameter.

have unmixing structure what can be seen distinctly with the help of electron microscope (fig.1). Upon O'Reilly and Readman diagram the degree of their oxidation is very low, less than 0.1. This fact allows to suppose that unmixing and singlephase oxidation do not coexist in the same grain.

After thermotreatment Curie points in both subgroups decrease to 100-180° and become close to the calculated ones and to Curie points of I group (table). It means that both rather low singlephase oxidation and unmixing do not disturb the composition of primary titanomagnetites grains and do not prevent the reconstruction of primary titanomagnetites by homogenization processes.

The fourth group includes basalts with features of high alterations. As a rule, they are pillow-basalts with very fine sceleton grains and many thin fractures (fig 2). Their magnetic characteristics are very typical for pillow-lavas with strong singlephase oxidation: a) magnetization is lower than for I group; b) thermomagnetic curves are of P-Neel-type character (fig 3), as for I and II groups. It means that all these curves have maxima, but for I and II groups maxima are in the temperature intervals lower than 20°C, while for IV group the samples maxima are in the interval of 100-200°C; c) usually T_c are 300-400°, but thermomagnetic curves are irreversible and after heating till 600° a mineral appears with Curie point exceeding 500°C, that is magnetite. Saturation magnetization increases hereby 3-10 times; d) the samples of this group are magnetically harder than of the others ones; e) there are no unmixing features.

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The degree of singlephase oxidation exceeds 0.8; f) calculated Curie points are lower than for the other groups (table).

By thermotreatment magnetic minerals of these basalts are being destroyed. Instead of homogenization arising of magnetite takes place and magnetization increases 3-10 times. As it can be seen under electron microscope titanomagnetite grains become coroded and are of highly inhomogeneous structure (fig.4).

There are also samples which characteristics are intermediate between the second and fourth groups. It is the third group in the table.

Thus we can see that the composition of primary titanomagnetites in oceanic basalts is highly homogeneous comparing with continental and volcanic basalts. Tc of oceanic basalts are always close to 150°C, for the others Tc varies in wide limits. As a rule increasing of Ti-contents in titanomagnetite grains reflected in decreasing of calculated Tc is connected with the removal of Fe-ions from titanomagnetic grains. This process is developing parallelly with singlephase oxidation of titanomagnetite. Till oxidation degree 0.4 the removal of Fe from grains is unsignificant. It is confirmed by similarity of titanomagnetite composition of samples from I and II groups. Higher than 0.4 degree of oxidation is coupled with significant alterations of rock as a whole and titanomagnetite composition. In this case thermotreatment does not cause homogenization of titanomagnetites, and titanomagnetite grains became unmixing instead of homogeneous.

Two peculiarities were noticed while investigating the range of basalts by thermotreatment: calculated T_c and measu-

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red I_s after thermotreatment are lower then the ones before treatment, this difference for T_c reaches 80°C, for I_s exeeded twice and more.

In order to clear up the above regularities the behaviour of Fe and Ti at the contact of titanomagnetite and silicate grains was studied by electron microprobe (fig. 5). The following two variants were analyzed. 1) TiO_2 content in titanomagnetite after thermotreatment does not change (sample 428A-4-1-13);2) TiO_2 content in titanomagnetite increasies (sample 418A-465). In the second case there is distinctly seen that Fe and Ti are carried out off titanomagnetite (fig. 5). That is why titanomagnetite grain is relatively enriching by Ti(Ti is carried out lesser than Fe, fig. 5).

Besides, there was experimentally estimated the removal of the substance through gas phase outside the sample. For this purpose the content of sediment at the ampule walls after treatment of basalt samples was investigated. Small crystalls of iron oxides were watched on the ampule walls. Upon the data of atomic adsorption analysis the content of Fe carried out through gas phase is less than 0,1 mg (the samples weight are 200-500 mg).

Thus, decreasing of T_c and I_s is due to preferable removal of Fe from titanomagnetite into two ways: 1) diffusion of Fe from titanomagnetite into surrounding silicate grains and 2) removal of Fe through gas phase from the sample.

The income of the first process is significant more than the second one. Obviously, similar processes happen in the nature during low-temperature alteration of rocks. Laboratory thermotreatment can be considered as a model of the latter. Evidently, increased content of Ti in titanomagnetites from basalts of IV group is a result of such processes.

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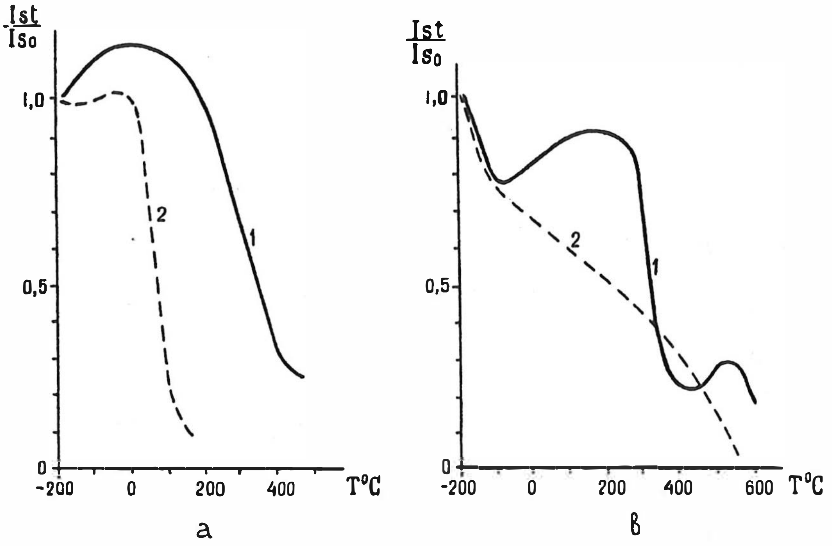

Fig.3. Thermomagnetic curves: a) subgroup IIb (sample 418A-465), b) subgroup IV (sample 1011-3): 1) initial state, 2) after thermotreatment.

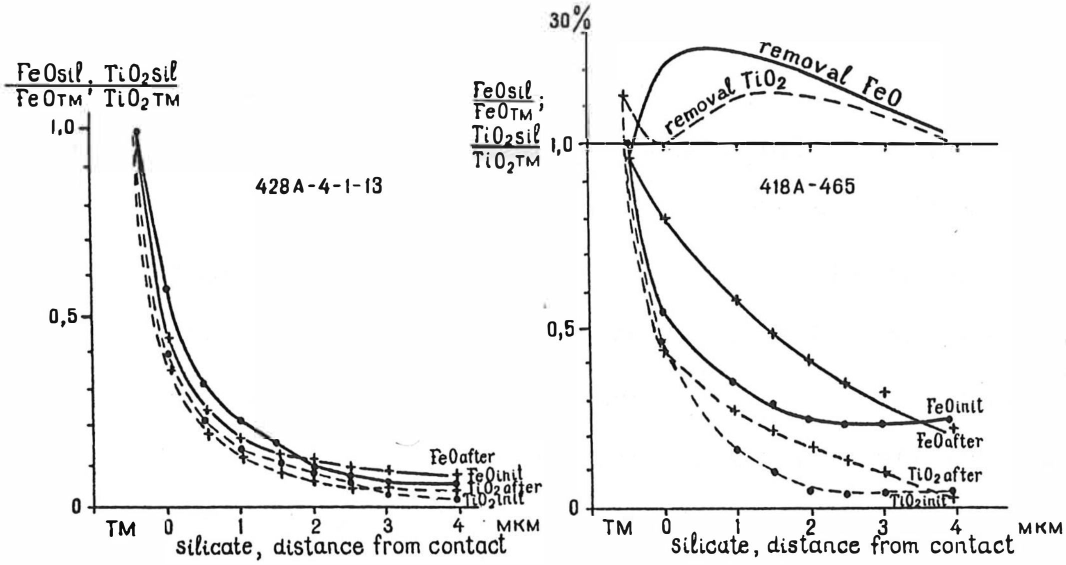

Fig.5. Distribution of FeO and TiO$_2$ in silicate before and after thermotreatment at the contact with titanomagnetite, reflecting the removal of Fe and Ti ions from titanomagnetite grain.

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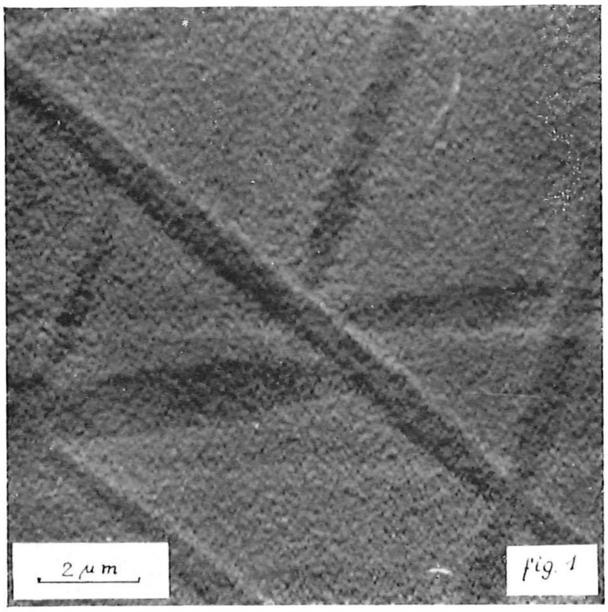

fig. 1

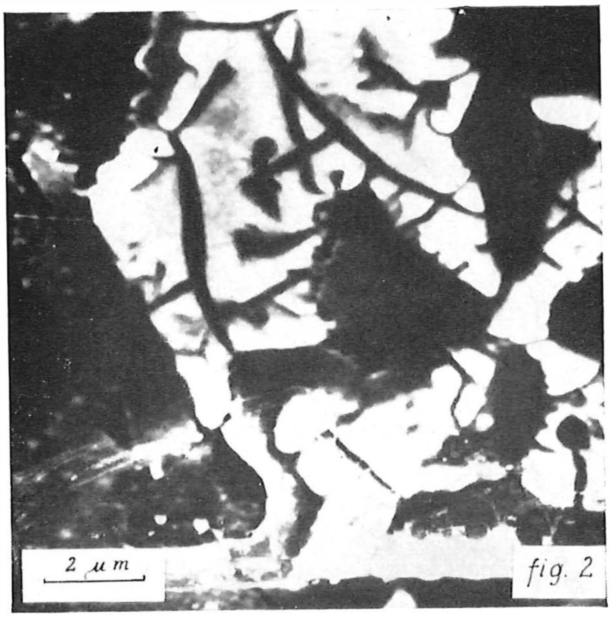

fig. 2

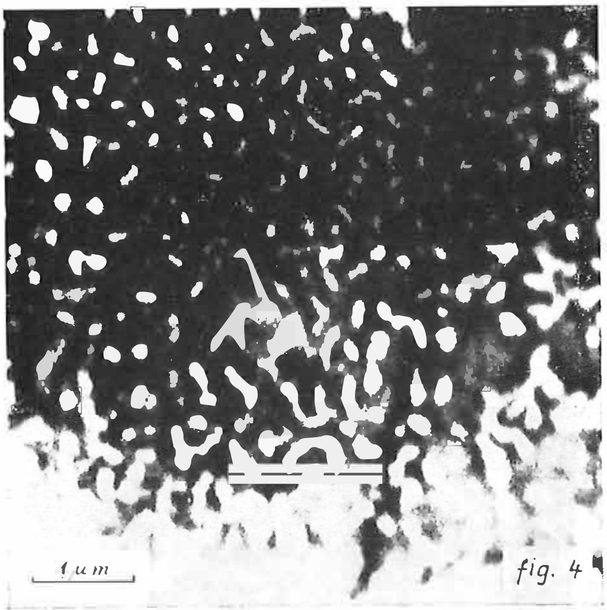

fig. 4

Fig. 1.

The hemoilmenite lamellae in titanomagnetite grain (electron-microscope photo, sample 418 A-465).

Fig. 2.

Skeletal titanomagnetite with many cracks (electron-microscope photo, sample 1011).

Fig. 4.

Development of small areas of low titanium magnetite (light) in titanomagnetite grain during thermotreatment (electron microscope photo, sample 1436).

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