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Electromagnetic and Geoelectric Investigation of the Gurinai Structure, Inner Mongolia, NW China

Abstract

In three field campaigns between the years 2000 and 2004 geophysical measurements were conducted in the Ejina Basin, NW China. Research work in the year 2004, which is described in this paper, was concentrated on the Gurinai Structure (101°25'E, 41°N) situated in the southeastern part of the Ejina Basin in transition to the dune fields of the Badain Jaran Shamo. On satellite images the Gurinai Structure can be identified by two almost 100km long, subparallel, N-S-striking lineaments, which may indicate tectonic deformations of late Quaternary sediments. To get a coherent picture of the structure a geophysical survey employing three electromagnetic methods - magnetotellurics (MT), transient electromagnetics (TEM), and geoelectrics (DC) - has been conducted to map the subsurface resistivity at different depth scales.

The geophysical data interpretation for shallow and intermediate depth down to a few hundred meters links the subsurface distribution of electric resistivity to geomorphological units known from field work in reference with satellite images. The westerly lineament of the Gurinai Structure coincides with a subvertical change in electric resistivity. Together with geomorphological indications from fieldwork and the analysis of elevation data (SRTM), a tectonic deformation of unconsolidated sediments along a fault with an extensional component is interpreted. In the central and eastern part of the Gurinai Structure a shallow resistive subsurface layer can be traced into the first dunes of the Badain Jaran Shamo. This resistive subsurface layer is linked to the presence of fresh water, indicating infiltration from the dune field. Also, in the eastern part of the Gurinai Structure a resistive, approximately ENE-striking feature can be seen at intermediate depth, which is interpreted as a crystalline basement ridge. Towards the southern margin of the Gurinai Structure a trough-shaped unit with low resistivities and a thickness of about 1km is identified and can be explained by a sediment package saturated with fluids of high salinity or substantial amounts of clay. The strike direction of the structure can be connected to the regional pattern of tectonic faults and seismicity.

The interpretation of electromagnetic data at various depth scales contributes to the general understanding of the Ejina Basin's buildup and tectonic setting in the vicinity of the Gurinai Structure.

Key words: Gurinai Structure, Ejina Basin, Yingen Basin, Badain Jaran Shamo, NW China, Electromagnetics, Neotectonics

1. Introduction

Over the past years a multidisciplinary geoscientific investigation has been carried out in the Ejina Basin, Inner Mongolia, NW China (Fig. 1). The project's general geoscientific objective has been focusing on the study of basin sediments, which are composed of lacustrine alluvial fan deposits from the drainage system of the river Ruoshui, in order to reconstruct the paleoclimatic environmental changes. The endorheic, intracontinental basin was chosen as the target for investigations, because it contains

a substantial quaternary sedimentary record and, as part of the Alashan Plateau, was assumed to be tectonically stable (e.g. Wang et al., 1997; Wünnemann et al., 2005). Studies on sedimentary sections, which are not covered in this paper, were concentrated on locations in the vicinity of the Ruoshui's terminal endlakes Gaxun Nur, Sogo Nur and Juyanze (Mischke, 2001; Hartmann, 2003), and on core samples of the 232m deep drilling D100 in the central basin (Wünnemann and Hartmann, 2002; Wünnemann et al., 2005). Although tectonic stability of the basin was originally assumed, recent publications demonstrate an influence of neotectonic deformation processes on the sedimentation within the basin (e.g. Hartmann, 2003; Wang

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et al., 2004). Therefore, it is important to get a basic understanding of the tectonic setting of the basin to be able to distinguish between changes in the sedimentation environment induced by climatic changes and those caused by the tectonic activity within the basin.

To contribute to the general geoscientific objective, the specific task of the geophysical workgroup is the characterization of the physical properties, distribution, and thicknesses of sediments and the underlying crystalline basement in the basin. A combination of three electromagnetic methods (geoelectrics, transient electromagnetics, magnetotellurics) was used to gain information about the distribution of the subsurface electric resistivity for a wide depth range. Thus, the study covers shallow sedimentary structures at a few meters depth down to upper crustal structures at several kilometers depth reflecting various aspects of the basin's general setting. The applied geophysical methods are sensitive to the distribution of the subsurface electric resistivity at different scales and are therefore used to map this physical parameter along profile lines. Generally speaking, the data evaluation for all applied methods may have implications for the interpretation of stratigraphic, hydrologic and tectonic questions. Additionally, the use of different methods also serves to cross-check the validity and quality of all measured data.

The target of investigations in the year 2004 was the Gurinai Structure, named after a small village at the SE edge of the basin. The structure is defined by two almost 100km long, subparallel, straight lineaments, which strike approximately in N-S direction and are separated by a distance of 12km (Fig. 2). The Gurinai Structure seems to be of key interest for the interpretation of the tectonic setting in the eastern segment of the Ejina Basin, because several distinct features (Fig. 2, right) associated with the Gurinai Structure are indicative of a N-S striking structural weakness in the upper crust:

- Located at the northern end of the Gurinai Structure, lake Jingsutu is the deepest depression within the Ejina Basin. The lake is separated into two sub-basins by a 14km long, cliff-like structure. The strike direction of this structure coincides with the strike direction of the lineaments in the Gurinai Structure. Furthermore, radiocarbon datings of lacustrine deposits preserved on top of the structure (18ka) are evidence of a late Pleistocene or Holocene tectonic movement (Hartmann et al., 2004).
- At the northern margin of the Jingsutu, the *Jingsutu Structure* (working title) is defined by a 50m deep depression within the crystalline basement, which also exhibits the N-S strike observed in the Gurinai Structure. Geophysical measurements taken by our workgroup identified the structure as a westward dipping halfgraben within the basement (Becken et al., 2003), which is interpreted in terms of Mesozoic extensional tectonics in NW China. Within the halfgraben the sedimentary fill reaches a considerable thickness of at least 500m.
- To the NNE of the *Jingsutu Structure* an unnamed, circular plutonite with a diameter of 14km is situated in the

metamorphic basement. Rock samples of the plutonite and surrounding basement are currently being analyzed for composition and age.

Considering the results from geophysical measurements in the *Jingsutu Structure* north of the Gurinai Structure as well as satellite image interpretation (s.a. Hartmann, 2003; Wang et al., 2004), it was concluded that the lineaments in the Gurinai Structure might be a manifestation of neotectonic deformation processes affecting late Pleistocene and Holocene sediments in the Gurinai Structure. To validate this hypothesis, we conducted electromagnetic measurements, first concentrating on the eastern of the two lineaments, where a distinct change of topography can be observed (s. Fig. 3, top).

2. Research Area

2.1. Tectonical Framework and Topography of the Ejina Basin

Figure 1 shows portions of the general tectonic framework of Central Asia, which is presently driven by the approximately N-trending stress induced by the collision of the Indian and Eurasian plates. Differing names for the Ejina Basin - named after the provincial capital Ejina Qi - are also used, e.g. *Ejin Banner* (Wang et al., 2004), and probably *Yingen Basin* (Meng et al., 2003). The Ejina Basin, located in the northern foreland of the Tibetan Plateau, is embedded in the stress field of the largest active fault zones in Central Asia (lines in Fig. 1):

- the left-lateral Gobi Altay Fault System (Cunningham et al., 1996) and the Gurvan Bogd Fault System (Bayasgalan et al., 1999) to the N,
- the Gobi Tien Shan Fault System (Cunningham et al., 1996) to the NW (Lamb et al., 1999),
- the left-lateral Altyn Tagh Fault to the SW (e.g. Meyer et al., 1996; Meng et al., 2001),
- several fault systems in the northern Qilian Shan to the S, where both left-lateral and reverse faulting is observed (e.g. Meyer et al., 1998; Ding et al., 2004).

While recent tectonic activity of these faults is clearly indicated by seismicity, other prominent faults like the Ruqiang Fault to the W, the Tost Fault and the Gobi-Onon Fault to the NW, and the Zuunbayan Fault to the E of the Ejina Basin are considered to be Late Mesozoic by Lamb et al. (1999). They propose an interconnection between the Zuunbayan and Altyn Tagh Fault, which probably runs along the S margin of the Ejina Basin (dashed line in Fig. 1). Accordingly a Cenozoic reactivation of these faults is not generally ruled out. In a study of Johnson (2004) in the East Gobi Basin in Mongolia the Zuunbayan Fault is divided into a system of three subparallel faults, separated by a distance of ~ 40 km. According to seismic profiles and stratigraphic information from boreholes, a considerable Cenozoic tectonic activity along the North Zuunbayan Fault is deduced.

The Ejina Basin covers an area of approximately 28000km² and is bordered by the Bei Shan (*chin.*: *Shan* → mountain range) to the west, the Gobi Altay to the north, and the dune fields of the Badain Jaran Shamo to the east and south (Fig. 1). The Ruoshui (*chin.*: *Shui*, *He* → river) originates in the Qilian Shan, where it is called Heihe, and enters the basin from the southwest through a depression between the Bei Shan and the Heli Shan. North of Dingxin the river separates into the two main branches Xihe and Donghe and terminates in the end lakes Gaxun Nur, Sogo Nur and Juyanze (from west to east). Within the basin, the primarily Quaternary sediments show very little relief and exhibit a gradient of only 0.9‰ along the Ruoshui dipping towards northerly directions.

A map of seismicity (points in Fig. 1) shows locations of earthquakes in the Ejina Basin and the surrounding area as determined from local seismic stations in NW China (source: BJI, Chinese Earthquake Administration in ISC, 2005). One of these local stations is situated in Gaotai (GTA, 99°49'E, 39°25'N), SW of the Ejina Basin. Therefore, we consider the locations to be representative. However, since we do not have access to the relevant data we can give no error estimates for the locations and a thorough examination of focal mechanisms was not implemented. The map can be divided into two clusters: one cluster of events in the vicinity of the southern, and a second cluster in the vicinity of the northern margin of the basin. All earthquakes are crustal with a maximum depth of 30km and magnitudes between 3 – 5 (where specified). Comparing the two clusters, there is a slight tendency of earthquakes in the northern cluster to be more shallow (7 – 30km) as compared to the southern cluster (15 – 30km). In addition magnitudes in the northern cluster are slightly larger. Events in the southern cluster as well as events in the center of the northern cluster are aligned along several NE striking bands.

2.2. Available Geophysical Data for the Ejina Basin

Only very little unclassified, publicly available geophysical data from the Ejina Basin is attainable for reference purposes. The last segment of the global geoscientific transect "*Golmud - Ejina Transect, China*" enters the basin from SW to NE. The interpretation of geophysical data along the transect (gravimetry, magnetics, magnetotellurics, seismics, geothermics) depicts crustal and upper mantle features in a depth range between 2 – 200km (Wang et al., 1997; Zhu and Hu, 1995). Possibilities to deduce information relevant for the interpretation of the Gurinai Structure are limited, due to the different depth scale under consideration and the distance of the transect to the measurement area in the Gurinai Structure (minimum distance 70km). Towards the NW rim of the Ejina Basin three seismic profiles have been published (Meng et al., 2003). The profiles are interpreted in terms of the Mesozoic extensional evolution of the Ejina Basin, which can be found in many adjacent basins. The seismic sections give clues about the

thickness of Mesozoic sequences above the pre-Mesozoic basement, but do not resolve the uppermost Quaternary sequences.

2.3. Geomorphology of the Gurinai Structure

In this paper the term *Gurinai Structure* refers to a geomorphological unit identified on satellite images by two subparallel, straight lineaments of nearly 100km length (Fig. 2), which strike approximately in N-S direction at a distance of 12km. Based on a satellite image interpretation, Hartmann (2003) interprets the lineaments in the Gurinai Structure as sinistral strike-slip faults with polycyclic activity during the late Pleistocene and Holocene, including both transpressional and transtensional phases. The sediment deposits within the Gurinai Structure are of late Quaternary respectively Holocene age (Zhang, 1990). According to fieldwork and based on the interpretation of elevation data (SRTM), the Gurinai Structure can be divided into several morphological units running approximately in N-S direction. Along an E-W profile these units can be described as follows (s. Fig. 3):

Unit 1: Dunes of the Badain Jaran Shamo: The first dunes show elevations of about 40 – 60m above the dune base.

Unit 2: Cuesta landscape with distinct table mountains, partly of consolidated sandstones and loose sand, with a total elevation difference of 40 – 60m declining towards the west.

Easterly Lineament (EL): The lineament between *Unit 2* and *Unit 3* separates the flat lying units to the W from the ascending units to the E (s. elevation profile in Fig. 3) and possibly indicates neotectonic deformations.

Unit 3: Flat grassland area with no significant change in elevation. A number of small water holes, some containing fresh water, can be found in the eastern part of this unit. No pattern was recognized during fieldwork in the general distribution of water holes containing fresh or saline water. A visual inspection of Corona satellite images shows that the occurrence of waterholes is closely linked to the *EL*. Water samples taken from wells indicate a general increase of water salinity towards the west, which coincides with a diminishing grass covering. The eastern segment of the grassland area is used as grazing land for livestock by local farmers.

Unit 4: Small dunes with accumulation of dead tamarisks, which top the adjacent grasslands (*Unit 3*) and salt swamps (*Unit 5*) by 10 – 25m in elevation. The dunes are in parts stabilized by partially consolidated sands.

Unit 5: Salt swamps with stratifications of salt, silt and clay under the salt-crust. The salt swamps form the deepest depressions in the Gurinai Structure. They are usually 1 – 10m deeper than the next highest unit.

Westerly Lineament (WL): The lineament between *Unit 5* and *Unit 6* is interpreted from satellite images (see Fig. 2 and Fig. 3) and possibly indicates neotectonic

deformations.

Unit 6: Playa unit, which is clearly delineated on satellite images but only shows a diffuse boundary in the field. The playa-like sediments are distinguishable from *Unit 5* only by a seemingly smaller concentration of salts and an enrichment of silts and clays in the top soil. Patches of gypsum and partially consolidated sandstones similar to those in *Unit 2* and some small sand dunes ($< 5\text{m}$) can also be found. Finally, a small, diffuse uplift with respect to *Unit 5* along the westerly lineament of less than 1m is observed.

Only few geomorphological field studies were carried out in the Gurinai structure and the adjacent dune fields of the Badain Jaran Shamo. They are cited in sections 4 and 5.

3. Geophysical Methods & Data

In this section we describe the applied electromagnetic methods, the conducted field measurements, and the fundamental characteristics of the measured data¹, which are vital for a correct data interpretation in section 4.

All applied methods are sensitive to the subsurface distribution of electrical conductivity, which is controlled by the conductivities of pore fluids and matrix rocks. While all methods relate to the same physical parameter, their sensitivities to the horizontal and vertical distribution of conductivities are different. Results therefore complement each other to cover a wide depth range reaching from the near surface down to several kilometers. As the individual methods have an overlap in their depth of penetration, a comparison of results for different methods serves to validate results.

During field measurements all methods were applied at stations along the main profile, which crosses the Gurinai Structure in E-W direction, perpendicular to the assumed geological strike (profile AA' in Fig. 3).

3.1. Magnetotellurics (MT)

Broad-band MT data in the period range between 0.001 – 1000s was recorded at 18 stations along a main profile AA' (Fig. 3) in E-W direction with an average site spacing of 1km, operating up to five instruments simultaneously (4 x ADU06, 1 x Spam MkIII). In-field data processing showed that the geoelectric structure within the deeper subsurface did not comply at all stations with the previously expected strike in N-S direction. To enhance the spatial coverage for later three-dimensional interpretation of the data, additional broad-band MT measurements were carried out at a total of 19 stations along a N-S profile (profile BB' in Fig. 3) close to the easterly lineament and two short angular profiles connecting the E-W and the N-S profile (profiles CB' and CC' in Fig. 3).

¹ The strike analysis of MT data in section 3.1 is part of the doctoral thesis of Becken (2005).

Recorded time series were processed using the code of Egbert and Booker (1989) to calculate the MT impedance tensor $\mathbf{Z}$ (linear relation between horizontal electrical and horizontal magnetic field), and the vertical magnetic transfer function $\mathbf{T}$ (linear relation between horizontal and vertical magnetic field) in the spectral domain. The transfer functions depend only on the conductivity distribution of the subsurface. Hence, they are the quantities to be analyzed. A remote reference site was incorporated during processing, but generally single-site processing already yielded excellent transfer functions, owing to the absence of local noise sources in the measurement area.

In the following we will examine MT data at three representative sites (Fig. 4, Fig. 5), to establish valid interpretation approaches for the inversion of data in section 4. The sites are located in the west (s18), east (s04), and south (s21) of the measurement area and therefore serve as representatives for the other stations in the array. Additional MT data in form of pseudo sections can be found in Figure 13 and Figure 14.

At shortest periods the 1D conditions are indicated (Fig. 4): off-diagonal apparent resistivities and phases are equal, diagonal elements are negligible and induction vectors are close to zero. Generally 1D conditions are evident at all sites for periods between 0.001s – 0.1s, at some sites up to periods of 1s. In section 4 we use these MT impedances together with TEM and DC data in a 1D joint inversion to determine a set of 1D layered resistivity models and to estimate the amount of static shift in MT data.

At periods longer than 0.1 – 1s, depending on the site, magnetotelluric fields sense lateral variations of the geoelectric structure and indicate 2D/3D conditions (Fig. 4). This is manifested in splitting impedance sounding curves, associated with increasing apparent resistivities, phases typically declining below 45°, and increasing lengths of induction vectors. At a period of approximately 4s induction vectors exhibit maximum length. A preliminary first interpretation suggests that a conductive sedimentary overburden with locally varying resistivities overlays a more resistive basement. Heterogeneities within the basement as well as the basement topography may account for the observed 2D/3D effects at intermediate periods, while lateral variations of the overlying sedimentary strata do not produce significant anomalous induction fields. In this context we are interested in the depth and structure of the basement, because basement topography and thickness of sediments can help to unravel possible zones of tectonic deformation.

To distinguish between 2D and 3D induction effects, we use the impedance tensor parameterization of Becken and Burkhardt (2004). Those data representing 2D conditions will be used to derive 2D resistivity depth sections using a 2D inversion. In the analysis of Becken and Burkhardt (2004) the strike direction of a 2D regional structure can be identified - besides an inherent 90° ambiguity - from vanishing ellipticities of the columns of the impedance tensor for a range of periods. The strike direction is determined by optimization. It is important to note that the ellipticities

are not altered in case of the well known effect of galvanic distortion, reflecting in-phase charge oscillations at near-surface inhomogeneities (e.g. Groom and Bailey, 1989a). In the presence of galvanic distortion, the orientation of ellipses derived from the impedance columns is directly related to the distortion angles as defined by Smith (1995).

In Figure 5 ellipticities and distortion angles are depicted for the three representative sites. At the shortest periods, ellipticities are zero in agreement with the 1D characteristics of the associated sounding curves (Fig. 4). An exemplary investigation for site s21 shows that for intermediate periods between 0.1s – 10s, where the off-diagonal impedances split, ellipticities approximately vanish if the impedance tensor is rotated by $rot_{SP} = 3^\circ$. Hence, 2D conditions can be inferred here. In the same period range distortion angles are zero, indicating no rotation of the electric field due to galvanic distortion. At longer periods between 10s – 100s ellipticities do not vanish in any coordinate system and 3D effects are therefore inferred from the ellipticity parameterization. At the longest periods between 100 – 1000s ellipticities again approximately vanish, if the impedance tensor is rotated by $rot_{LP} = 11^\circ$, with distortion angles showing a nearly constant phase splitting, a behavior also observable at other stations (e.g. s04 in Fig. 5). While these 3D effects in the data may be explained by a 2D model with local galvanic distortion, one has to consider that the longest period data are often noisy and the corresponding error bars of ellipticities are large. A regional 2D assumption with galvanic distortion is therefore only valid within the error bars and not clearly distinguishable from induction in a 3D structure. In any case 2D inversion or 3D modeling / inversion of this period band would provide only little constraints on the deep structures due to the limited station-array dimensions with respect to the skin-depth. Therefore and since this study focuses on the upper crustal structures, the longest period data are not further considered in this paper.

Taking all MT stations into account, the period ranges yielding vanishing ellipticities and distortion angles - thus permitting a regional 2D interpretation - differ from site to site. This is due to locally varying conductivities of the upper layers (consequently varying skin depths) as well as due to the basement depth. We manually inspected the period dependency of the ellipticities at each site to define an individual cut-off period, where ellipticities start to deviate systematically from zero.

Under such 2D conditions the 90° strike ambiguity of the impedance tensor analysis can be resolved by including the vertical magnetic transfer function. In Figure 6, measured induction vectors are plotted for a period of 4s, where they exhibit maximum length. Induction vectors in the western section of the main profile (sub-profile AC) are oriented in E-W direction, while in the eastern section of the sub-profile CA' and along the N-S profile BB' induction vectors point in the N-S direction. In the central part of the MT array, induction vectors rotate along the profiles. Hence, it is obvious that the induction vectors do not reflect a simple

2D subsurface geometry.

Upon comparison of the results of the impedance tensor analysis and the behavior of induction vectors, we infer two different domains within the MT array: the MT responses in the western section are dominated by structures elongated in the N-S direction and in the eastern section a predominant strike in the E-W direction is present. At site s18 for instance, we estimate an impedance strike of -7° for periods shorter than 10s (Fig. 5). Induction vectors at this site have maximum length of 0.2 at the period of 10s (Fig. 4). They strictly point to the west at periods shorter than 10s. Hence impedance data and induction vectors are consistent and suggest a N-S strike direction. Similar results are obtained for the easterly adjacent sites s10-s17.

Along the N-S profile BB', parallel to the eastern margin of the Gurinai structure, induction vectors at a few seconds are predominantly oriented in the N-S direction (Fig. 6), which is consistent with the impedance strike estimates of sites along the N-S profile (e.g. s04 and s21 in Fig. 5). This supports the assumptions of a strike in the E-W direction in this part of the MT array. It is evident that the structure controlling the response along the N-S profile is of finite extent.

At periods of a few seconds however, the distance between the two distinct domains appears to be large enough to avoid a strong inductive coupling of the anomalous fields in either domain. This explains the consistency between the induction vectors and the impedance properties as discussed above. When taken together they support a 2D interpretation along the N-S profile (BB') and the western portion of the E-W profile (profile AC). In this framework 3D effects, as they have been identified from the impedance tensor analysis at intermediate periods and are also evident from the map of induction vectors in the central segment of the array, can be understood as coupling effects between the structures in the two domains (Fig. 7).

Therefore, we only use the MT data in the period ranges defined above along the profiles AC and BB' for a 2D inversion, as the other sites have been excluded rigorously due to the 3D effects. A common rotation angle of 0° for the profile AC and of -15° for the profile BB' has been determined from the impedance data. From rotated impedances, a distortion model - with the unresolvable gain factors (Groom and Bailey, 1989b; Smith, 1995) set to unity - was estimated from weighted mean distortion angles for each site over the respective period bands. Since at most sites diagonal elements of the impedance tensor are small (Fig. 6) and distortion angles are close to zero (Fig. 7), the removal of distortion does not significantly affect off-diagonal impedances. The main effect is the complete suppression of the diagonal elements and a slightly increased scatter of the off-diagonal elements, the latter being a result of the projection of noisier diagonal impedances into off-diagonal elements. We therefore use the rotated impedances directly for 2D inversion. In addition, we performed a 2D inversion of the data along the diagonal profile CC', using the same rotation angle for the data as for the profile BB' (-15°). However, a 2D ap-

proach is not rigorously justified for the profile CC', because the induction vectors are rotating along the profile (Fig. 6). Nevertheless the impedance data along this profile is very similar to those at profile BB' and, when using a rotation angle of -15° , the two profiles are virtually projected onto the same line. As we will see in the following section (Fig. 12), the resistivity models along these profiles are very similar, which supports the 2D approximation in that case.

To verify the interpretation of MT data and, in particular, of the behavior of the induction vectors, we perform 3D model calculations. The 3D model is constructed from a combination of the results from 1D inversion at all MT sites and 2D inversion along the profile lines AC and BB', the latter model extrapolated in strike direction using the results of the impedance strike analysis. The aim of 3D modeling is to show that the 3D effects, namely the orientation of induction vectors, can be reproduced when collocating the 2D model from the eastern and the western domain into one comprehensive model.

3.2. Transient Electromagnetics (TEM)

For field measurements we used a LAPTEM device (Geoinstruments) in the coincident loop configuration with a loop area of 10000m^2 . Transients were recorded in the time range between $50\mu\text{s} - 100\text{ms}$ yielding an approximate penetration depth between $10 - 300\text{m}$. Measurements were taken at 137 sites, with a site spacing of 100m where possible. Continuous TEM profiling with largely overlapping induction spaces between adjacent sites provides good control of data quality. In sections of the profile where dunes and tamarisks form a rather rough terrain (*Unit 4*), the desired locations along the profile line were not always accessible and site spacings had to be increased.

The TEM method as active EM method uses a transmitter coil to excite a static magnetic field. After turn-off of the primary field, the time derivative of the secondary induced magnetic field is measured with a receiver coil. Due to this inductive coupling of the method to the ground, the TEM method is inherently unaffected by static shift like magnetotellurics or geoelectrics. Sternberg et al. (1988) first showed how TEM measurements can be used to estimate and correct static shift in MT measurements, a technique that has since been used in many studies, e.g. recently in Meju (2005).

Interpretation of TEM data primarily relies on 1D inverse modeling, as can be seen in recent hydrogeological field studies (Danielsen et al., 2003; Pagano et al., 2003; Young et al., 2004; Barretta et al., 2005; Kafri and Goldman, 2005). Several TEM 3D modeling codes have been introduced in the past years (e.g. Wang and Hohmann, 1993; Druskin and Knizhnerman, 1994; Tabarovsky et al., 1995; Arnason, 1999; Commer and Newman, 2004) and have been extensively used in model studies to investigate the effects of 2D/3D structures on TEM measurements (e.g. Goldman

et al., 1994; Rabinovich, 1995; Toft, 2001); El-Kaliouby and Eldiwany (2004) also consider the effects of polarization). The modeling studies show that the 1D interpretation of TEM data in the vicinity of 2D- or 3D-structures can produce fictitious layers at greater depth, which have to be recognized and excluded from interpretation. Because the forward formulation of the 3D TEM problem is still computationally costly and no practical 3D inversion codes are readily available, interpretation usually relies on 1D pseudosections and 1D inversion, as has been mentioned above. In recent model studies, the possibilities of applying 3D inversion techniques to sets of TEM model data are investigated (e.g. Haber et al., 2004; Newman and Commer, 2005). A general overview of the current state of the art and remaining problems of 3D inversion for electromagnetic methods is given by Avdeev (2005).

In Figure 8, TEM measurements are summarized in terms of a pseudo-section of apparent resistivities. Data gaps in the central section of the profile are owed to the limited accessibility caused by dunes and vegetation. Apart from the general increase in conductivities from east to west, three significant lateral changes in the apparent conductivity are observable where the occurrence of artifacts in the 1D inversion can be expected (s. section 4.1).

3.3. Geoelectrics (DC)

A Campus Tigre device (Campus Int.) was used for complementary Schlumberger soundings with a maximum spreading of $L/2 = 237.5\text{m}$, yielding an approximate penetration depth between $1 - 100\text{m}$. DC data was recorded at MT stations along the main profile (AA'). We used the DC data together with MT- and TEM-data for a 1D joint inversion to account for static shift in MT data.

4. Results & Interpretation

In the presentation of results we proceed as follows:

- (i) For the description of shallow structures in the uppermost 300m we use the interpretations based on TEM data. For the following intermediate depth range down to 1000m we use the results of the joint inversion of MT-, TEM-, and DC-data. The joint 1D inversion is also applied to cross-check and verify measurements of the different methods and to possibly estimate the amount of static shift present in MT data.
- (ii) For deep structures we use the 2D inverse modeling results of MT data along the western section of the main profile (AC), along the N-S profile (BB'), and along the NW-SE profile (CC'). Calculations for a 3D model, which is based on the results of the previously calculated 1D- and 2D-models, are then used to investigate and explain 3D effects observed in the

data.² In this context we are particularly interested to reproduce the general characteristics of the measured induction vectors (Fig. 6).

4.1. Shallow Structures

4.1.1. TEM 1D Inversion

To describe the distribution of resistivities for shallow structures with depths of less than 300m we turn to the interpretation of TEM data, for which we use a 1D block inversion code (Weidelt, 1984). The code has been modified to account for transmitter- and receiver-effects (Panaitov et al., 2002; Effersø et al., 1999). These effects distort the measured transients and can therefore lead to misinterpretations, if not accounted for. The resistivity section based on the inversion of TEM data (Fig. 9) yields data fits with rms errors between 0.5 – 3% and can be divided into two sections: In the eastern section of the main profile (AA' in Fig. 3), resistivities generally show values of 30Ωm or higher, whereas towards the western section resistivities below 10Ωm prevail.

In the eastern section of the main profile AA' (11 – 16km in Fig. 9) the distribution of resistivities depicts a stable layering and 1D inversion is feasible. A shallow layer (S_{LQ} in Fig. 9) with an average thickness of 50m can be traced from the first dunes of the Badain Jaran Shamo (*Unit 1*) into the central portions of the grasslands (*Unit 3*). Resistivities within this layer decrease from 100Ωm in the east to 50Ωm in the west and are verified by the shallow DC data available in this section of the profile. The western boundary of the layer is linked to a distinct color change on the satellite image (turquoise to light gray in Fig. 3), and its lateral extent correlates with the existence of fresh water in shallow wells and small water holes. Mischke (1996) ¹⁴C-dated fossil root remnants at 15ka in two locations (*Unit 1*, dunes) close to the geophysical profile. Carbonates on the geophysical profile in *Unit 2* (Cuesta) are ¹⁴C-dated at 25ka by Zhang et al. (2005). Accordingly, the resistive top layer is interpreted as a series of partially consolidated, late Quaternary sandstones carrying a fresh water aquifer. The slope of elevation (Fig. 3, top) as well as the seemingly westward increasing salinity imply a westward direction of the assumed groundwater flow from the dunes (*Unit 1*) into the grassland (*Unit 3*). The dunes are therefore considered to be an important source region for the groundwater refill in the Gurinai Structure. Below the presumed aquifer at depths between 50 – 150m, resistivities around 30Ωm still support the assumption of the existence of fresh groundwater. The decrease of resistivities with depth can be attributed to increased salinization or higher concentrations of clay. The existence of shallow groundwater and its connection to the dunes in the Badain Jaran Shamo, a desert environment with a mean precipitation of 50mm/a (Geyh et al., 1996), is surprising but also supported by findings

of Jäkel (2002), who describes dunes in the Badain Jaran Shamo containing substantial amounts of groundwater. His findings coincide with observations of our workgroup at the foot of the westernmost dunes (*Unit 1*) where considerable moisture penetration of dune sands was found at only a few decimeters depth. 100km SE of the geophysical work area in the Gurinai Structure dunes retain enough groundwater to support the existence of numerous lakes embedded into the dune fields of the Badain Jaran Shamo (Hofmann, 1996).

A second distinct feature in the eastern section of the main profile AA' can be found below the shallow resistive layer S_{LQ} . The wedge-shaped layer S_{PQ-E} (Fig. 9) with resistivities of about 5Ωm is located below 150m depth. While its top is subhorizontal, the lower boundary is gently declining towards the east. Below the wedge-shaped layer S_{PQ-E} resistivities increase ($> 20\Omega m$) but are not well resolved in the inversion. Around the western margin of unit S_{PQ-E} (13 – 14km) models of 1D inversions show a considerable lateral variation below 100m depth, probably indicating artifacts caused by the 1D inversion of 2D/3D data (s. Fig. 8). Unpublished internal reports of the local government based on ground water drillings depict Neogene (i.e. young Tertiary) sediments within the Gurinai Structure in the according depth range, without giving any further specifications. In geophysical measurements in the central Ejina Basin (Becken et al., 2003), strata with similar resistivities (5 – 8Ωm) and depths (200 – 300m) can be traced along a 40km long TEM-profile. These strata in the central Ejina Basin are identified in the drilling core D100, where Wünnemann et al. (2005) found terrigenous clastic sediments with considerable amounts of clays and salts below a depth of 220m. They used magneto-stratigraphy to date the overlying sedimentary strata at 250ka and younger. In the material of the drilling core clastic strata below 220m contain no datable materials and are referred to as Pre-quaternary. Because the accumulation of sediments in the basin is a large scale process and since the resistivity and depth of layer S_{PQ-E} match the characteristics found in the vicinity of the drilling D100, we identify it as Prequaternary sediments, possibly of Neogene age. Recapitulating the eastern section of the main profile AA' shows a consistent layering as interpreted from TEM 1D inversions. Furthermore, no significant displacement across the *EL* is visible. Instead, lateral variations in the depth section of resistivities are indicated 2 – 3km further west, where units S_{LQ} and S_{PQ-E} are discontinuous.

In the central section of the profile (11 – 13km) the distribution of resistivities generally shows a greater variability. Shallow variations of resistivities in the upper 70m are linked to small geomorphological units of minor importance. Further to the west (7 – 11km), the profile line was not accessible at all locations due to sand dunes and vegetation. Resistivities show a general decrease but may not, due to the loose site spacing, be interpreted in terms of consistent layering.

In the westernmost section of the TEM-profile (3 – 7km)

² The results presented in section 4.2 are part of the doctoral thesis of Becken (2005).

very low resistivities prevail, causing a decreased penetration depth. At shallow depths a highly conductive structure S_H with minimum resistivities well below $1\Omega\text{m}$ and a thickness of about 100m is detected. They have to be interpreted as sediment packages containing substantial amounts of saline fluids as indicated at the surface by the existence of salt swamps (*Unit 5*). The structure S_H apparently consists of two branches, of which the westward dipping branch shows lower resistivities ($< 1\Omega\text{m}$) than the eastward dipping branch ($\sim 2.5\Omega\text{m}$). Since the apparent resistivity section indicates strong lateral contrasts in this section of the profile (Fig. 8), it is likely that artifacts caused by the 1D inversion are not negligible. The apparent geometry of the structure at depths $> 80\text{m}$ should therefore not be over-interpreted from the section. Instead a trough-shaped structure as depicted in the pseudo section of TEM data (Fig. 8) might better represent the true geometry. Across the WL resistivities are discontinuous in the uppermost 40m and show an increase from below $0.5\Omega\text{m}$ to $2.5\Omega\text{m}$. Increasing resistivities below the good conductor S_H are evident from the TEM-measurements and will be interpreted in the following section.

In a hydrological study, Geyh et al. (1996) show that the isotope composition of shallow groundwater in the Gurinai structure and the adjacent Badain Jaran Shamo - the analyzed water samples are taken in *Units 1-3* - is different from that of groundwater analyzed in the vicinity of the Ruoshui river, west of the geophysical array. They propose the existence of a groundwater divide between the Gurinai structure and the Ejina Basin (s. a. Geyh and Gu, 1999). Turning again to section 2.2, we see that the geomorphological change between *Unit 5* and *Unit 6* across the WL is mainly indicated by the enrichment of silts and clays in the top soil. Boyadgiev and Verheye (1996) state that the occurrence of gypsum is often connected to geological situations "... where faults and / or underground anticlinal folding structures are oriented perpendicularly to the natural flow of groundwater". From the interpretation of the shallow geophysical data in connection with the geomorphology and the satellite images (Fig. 2) we therefore conclude that the groundwater divide as proposed by Geyh and Gu (1999), coincides with the WL and is probably related to faulting.

4.1.2. 1D Joint Inversion

The analysis in section 3.1 shows that 1D characteristics of MT data can be assumed in the shortest period range, typically for periods smaller than 10^{-1}s . At stations along the main profile AA' (Fig. 3) a 1D joint inversion for these periods together with TEM- and DC-data is thus appropriate to construct sets of resistivity models, which cover the depth range down to about 1km. A joint inversion can, due to the different sensitivities of methods to model parameters, partially remove model equivalences and serves as additional cross-check for the validity and quality of measured data. Apart from the resistivity models, a joint inver-

sion is used to estimate the magnitude of static shift in MT data. Static shift, caused by near surface inhomogeneities of the conductivity distribution, can lead to a frequency independent distortion of electric fields, consequently shifting the apparent resistivities of MT data by a constant factor. Since the TEM method measures the time derivative of magnetic fields and is therefore only inductively coupled to the ground, it is inherently unaffected by static shift and can be used for its correction (Meju, 2005).

Within the 1D joint inversion we simultaneously optimize the residuals of TEM normalized voltages, DC apparent resistivities, and MT apparent resistivities and phases. Static shift is, without constraints, allowed for both MT- and DC-apparent resistivities. We use a partitioned least square optimization (Smyth, 2002), in which a linear regression is used in every optimization step to calculate linear parameters (i.e. the static shifts). The inversion can be used to produce both blocky or smooth models (Occam). In smooth inversions additional constraints are put onto the smoothness of models for regularization of the inversion process. For practical reasons, we use the MT determinant data in the joint inversion, which is, however, virtually equal to the off-diagonal elements (Fig. 4). Following the suggestions of Sternberg et al. (1988), we only use TEM data at times later than $200\mu\text{s}$.

The joint inversion at station s08 (Fig. 10) provides an exemplary demonstration of a common underground model, explaining the data of all methods if static shift is allowed. Joint inversion results for the other stations along the main profile AA' yield similar data fittings. The amount of static shift for all stations under consideration is stated in Figure 11 (top): at all but one station the static shift for the MT apparent resistivity is smaller than 0.14 decades, equaling a maximum shift factor of $10^{0.14} = 1.38$. Assuming this result to be representative of the entire measurement area, it can be concluded that static shift is not causing any serious problems in the interpretation of MT data (compare distribution of static shifts in Sternberg et al. (1988)).

Turning to the resistivity section derived from the joint inversion (Fig. 11) we recognize distinct sedimentary units in the uppermost 200m of the eastern (S_{LQ} and S_{PQ-E}) and western part (S_H) of the section, which conform with the 1D inversion results of TEM data in the previous section (Fig. 9).

Below the sedimentary strata S_{PQ-E} in the eastern section of the main profile AA', a presumably crystalline basement block B_{cr} with high resistivities above $500\Omega\text{m}$ between stations s04-s08 (Fig. 11), is laterally bounded by units B_{met} with moderate resistivities between $30-100\Omega\text{m}$. An interpretation of the units B_{met} as sediment packages, as suggested by the resistivities, poses a problem, because enormous vertical displacements along the eastern and western boundary of the crystalline block would have to be assumed. We therefore prefer to interpret these units in terms of metamorphic basement. This interpretation is supported by fieldwork of our workgroup in the *Jingsutu Structure* (item 3 in Fig. 2), where outcropping, Paleozoic

metamorphic basement was found with resistivities as low as $20\Omega\text{m}$ (Becken et al., 2003). Like in the interpretation of TEM data in the previous section, no significant lateral variations of resistivities at greater depth can be observed at the *EL*. Instead, a lateral discontinuity in the basement is indicated 4km further west at the western boundary of unit B_{cr} . We propose a hypothetical connection between the discontinuities of the units B_{cr} , S_{PQ-E} and S_{LQ} west of the *EL*, probably indicating faulting (s. Fig. 15).

The top of the westerly unit B_{met} is declining towards the west and the overlying unit S_{PQ-W} , with resistivities around $5\Omega\text{m}$, reaches a considerable thickness of at least 500m below stations s12-s14. With the same reasoning applied to the easterly unit S_{PQ-E} (s. section 4.1.1), we interpret the westerly unit S_{PQ-W} to consist of Prequaternary strata, which is mainly based on the conforming resistivities and the location of its top edge at a depth of about 100m below stations s13-s15. At stations s12-s14, increasing resistivities with greater depth are indicated by MT data (apparent resistivity and phase), but the maximum thickness of S_{PQ-W} as well as the resistivity of the presumed metamorphic basement are not well resolved in the joint inversion. Note that the resistivity of the basement in the joint inversion is largely determined by the MT responses, as the TEM- and DC-data will generally not penetrate as deep. If MT data starts to exhibit 2D effects at the periods under consideration, it is generally difficult to resolve basement resistivities within the joint inversion. The presumably Prequaternary strata S_{PQ-W} are discontinuous across the *WL*. At the westernmost stations s16-s18, 1D models show a consistent layering with increased resistivities ($15\Omega\text{m}$) below a depth of 200m, probably indicating the presence of metamorphic basement.

The geoelectric strike of the trough-shaped unit S_{PQ-W} (s. following sections) is consistent with the N-S strike of the *WL* as indicated by satellite images. Additionally local depressions like the salt swamps can be traced along the *WL* on elevation data for almost 100km (s. Fig. 2, right). In connection with the results of the TEM 1D inversion in the previous section, we therefore conclude that extensional faulting is evident along the *WL*.

4.2. Deep Structures

4.2.1. MT 2D Inversion

As a result of the strike analysis (Fig. 7), MT data is divided into two domains with different strike directions for 2D inversion: the western segment of the Gurinai Structure along profile AC with a predominant strike in the N-S direction (0°), and the eastern section along profiles BB' and CC' with predominant strike in E-W direction (-15°). A 2D regularized smooth inversion (Rodi and Mackie, 2001) with a homogeneous starting model ($\rho = 30\Omega\text{m}$) is used for subsets of data that, according to the impedance tensor analysis, exhibit 2D characteristics. Along profiles AC and BB', induction arrows and the TE- and TM-mode apparent

resistivities and phases are jointly inverted. Along profile CC' induction arrows (Fig. 6) deviate from those of a 2D structure and are therefore excluded from inversion. Thus, a 2D inversion along this profile, especially in its northern section, is problematic but can be justified by the 3D modeling in the following section. After some testing, the regularization parameter τ is set to $\tau = 30$, to achieve a good compromise between model smoothness and data fit. In the inversion, measured data is weighted with its inverse variance respectively minimum error floors of 0.01 for induction arrows, 0.02 for phases, and 0.05 for apparent resistivities. Where galvanic distortion is evident, error floors for the TE-mode apparent resistivity are increased to 0.5. The inversions yield small rms-errors between 1.5 – 2.5%. Further, the overall data-fit along the profiles indicates, with respect to the small error floors, a nearly perfect representation of data (Fig. 13, Fig. 14).

Along profile AC (Fig. 12, top) the 2D inversion identifies the same units as did the joint inversion in the previous section (Fig. 11). The presumably Prequaternary strata S_{PQ-W} reach a maximum thickness of over 500m below station s13, while the maximum thickness of the shallow Holocene sediments can be found below stations s14 and s15. Below the highly conductive sediments the structure and resistivity of the presumed metamorphic basement (B_{met} ?) is again poorly resolved and the proposed faulting along the *WL* (s. previous section) cannot be traced into the basement by the 2D inversion results. However, MT responses are predominantly determined by the extremely conductive sediments and they exhibit low sensitivities against the more resistive basement structure. Modeling studies of Ingham (2005) show that a conductive fault within a resistive basement, under a conductive overburden may only be resolved under special conditions of resistivity contrasts, geometry of the structure, and MT station spacings. However, these conditions are not fulfilled in our case, due primarily to the highly conductive overburden.

Along the profiles BB' and CC' the mean rotation angle is -15° , i.e. for the 2D inversion the profiles are projected onto a common profile line between the actual profiles. The inversion results for the two profiles are consequently very similar, differing only with respect to near surface features in the northwestern section of profile CC' (Fig. 12, middle respectively bottom). This result again supports the 2D approach. At the shallowest depth, the Late- and Prequaternary units S_{LQ} and S_{PQ-E} can be traced with varying depth extent towards the north, south, and to the west-southwest of the array. At station s03 they match the associated units as interpreted from TEM data (Fig. 9) and accordingly cover large areas of the measurement area. At greater depths toward the north and northwest the crystalline basement block B_{cr} has already been described on profile AA' and in the previous section. Towards the south and southeast two new features ($B_{r?}$ and $B_{c?}$) are identified. Since units $B_{r?}$ and $B_{c?}$ have been consistently identified on both profile lines, they are relevant data features. However, additional 2D inversions based on

inhomogeneous start models reveal that the overall manifestation of these units is not well confined, due to spatial undersampling of measurements with respect to the extent of these units. Thus, we interpret these units as basement inhomogeneities. The southernmost unit S_M exhibits resistivities well below $10\Omega\text{m}$ and a considerable thickness of about 1500m, which is well confined by the inversion. We will classify this unit in the following section.

4.2.2. MT 3D Modeling

A 3D code (Mackie and Madden, 1993; Mackie and Wannamaker, 1993) is used to calculate the MT response for 3D models, which are based on a finite difference grid with $70 \times 70 \times 35$ cells ($61\text{km} \times 61\text{km} \times 50\text{km}$), of which the central $50 \times 50 \times 25$ cells ($12.5\text{km} \times 12.5\text{km} \times 10\text{km}$) are used to represent anomalous resistivity features. Since the measurement area covers approximately $20\text{km} \times 20\text{km}$, calculations are performed for several spatially shifted grids. Only the period range between 0.2–50s is considered, where a 2D assumption is not valid at all stations in the array and 3D effects are observed in the measured data (s. section 3.1). In this context we are especially interested in explaining the general characteristics of measured induction arrows in this period range.

3D models are constructed from a plane layered earth, into which a number of bodies with constant resistivities are placed. In order to define the background structure and the bodies, the conductivity models of the previous sections are considered as slices within the 3D volume. From these slices, blocks of constant conductivity are abstracted and extrapolated in strike direction. The final 3D model (Fig. 15 and Fig. 16) consists of 19 bodies, having 12 different resistivities and aims to represent the 1D respectively 2D inversion results as closely as possible along the profiles. Some features were eliminated for 3D modeling in order to simplify the final model. Small scale variations in the upper conductive layers could not be adequately reproduced in all cases, but they are of minor importance in the period range under consideration and do not affect induction arrows, which are smooth functions in space.

There are three main units in the final 3D model (Fig. 15) that are required to harmonize the general behavior of modeled (Fig. 17) and measured induction arrows (Fig. 6), namely unit S_M in the southern segment of the array, the crystalline basement unit B_{cr} in the central and northern segment of the array, and the trough-shaped, presumably Prequaternary strata S_{PQ-W} in the western segment of the array:

In the 3D model the conductive unit S_M , with a resistivity of $1\Omega\text{m}$, has a strike direction of $N50E$ (Fig. 16) and, according to the results of 2D inversions, a thickness of 1500m (Fig. 15). With the given strike direction, the unit produces northwestward-pointing real induction arrows having maximum length at a period of a few seconds, which conforms with general spatial characteristics of the measured induction arrows (Fig. 6). The general characteristics of induc-

tion arrows with changing period (exemplarily for station s21 in Fig. 17, left), are also explained up to a period of about 10s, whereas the total length of induction arrows is somewhat overestimated. Based on seismic profiles, Meng et al. (2003) depict several sub-basins in the NW segment of the Ejina Basin with similar thicknesses and geological strike directions as compared to unit S_M . They identify these sub-basins as Mesozoic extensional basins. Hence, this is considered to be a valid interpretation in our case. Due to the abrupt increase of the sediment thickness, a normal fault is assumed at the northern margin of unit S_M (Fig. 15). In a regional context, the geoelectric strike direction can be associated with the geological strike direction of the Zuunbayan Fault System (Fig. 1), which also showed major transtensional Mesozoic activity (Lamb et al., 1999). The proposed continuation of the Zuunbayan Fault passes the measurement area to the south (dashed line in Fig. 1 according to Lamb et al. (1999)). Additionally the findings of Johnson (2004) have to be considered: she separates the Zuunbayan Fault into a system of three subparallel faults with significant lateral extent and possible Cenozoic reactivation. It is thus possible to associate the unit S_M , with the Zuunbayan Fault System. A sketch of seismicity in the vicinity of our working area (points in Fig. 1), where NE striking bands of events can be seen, supports the assumption of some neotectonic reactivation within the fault system.

The major cause of irregularly distributed induction arrows is the crystalline basement unit B_{cr} , which is embedded in a host rock B_{met} with resistivities between 25 – $100\Omega\text{m}$ representing metamorphic basement. Within the 3D model, the resistor, with its long axis oriented $N80^\circ E$, needs to be bounded to the west and may be unlimited towards the east (Fig. 15) in order to reproduce the spatial pattern of induction arrows in the central segment of the array. In the presence of unit B_{cr} , modeled induction arrows in its vicinity essentially point towards a singular point on top of the resistor, where they exhibit zero length and a turn-over in direction. The westward extension of the resistor has strong influence on the position of this singular point, which is well determined by measured data and lies in the vicinity of site s31. Thereby, and by the length of induction arrows along profile CC', the extent of unit B_{cr} is well determined. The strike direction of the basement unit B_{cr} coincides roughly with the strike direction of unit S_M suggesting that they may have to be interpreted in the same context.

The trough-shaped unit S_{PQ-W} in the western segment of the array (Fig. 15) causes induction arrows pointing in eastward direction, as observed at sites s08-s10. In the vicinity of the WL at stations s14-s18, induction arrows are comparatively small at all relevant periods in the measured data (exemplarily for station s18 in Fig. 4). A finer discretization and a refinement of bodies representing the 3D model would be needed in this part of the model to better explain the small scale variations.

To conclude the presentation of results, we again want to

point out that the 3D model was abstracted from 1D and 2D inversion results using the short-period band only. The extracted 3D model explains the general 3D characteristics of induction arrows at intermediate periods up to about 10s. We therefore assume that the most important anomalies in the upper crust are identified, and the 3D model approximately represents the actual conductivity distribution.

5. Summary & Conclusion

The results presented here most likely comprise the first geophysical measurements covering the Gurinai Structure located in NW China. In the preparation of field measurements we hoped to find indications for a neotectonic activity along the two lineaments that delineate the structure.

Along the easterly lineament the interpretation of the electromagnetic measurements can give no further evidence to support this hypothesis, because the resistivity sections show no significant displacements or discontinuities. Instead, a hypothetical tectonical boundary is detected about 2 – 4km further west, where sedimentary and basement units according to resistivity sections show lateral contrasts at all depth scales (s. Fig. 15).

Along the westerly lineament a strong increase in the thickness of Prequaternary and Holocene sediments in combination with results from sedimentology, evaluation of elevation data (SRTM) and hydrogeological field studies by other authors, are clearly indicative of neotectonic extensional faulting along an approximately N-S striking fault.

In the southern portion of the geophysical array, MT measurements have revealed an unknown, presumably Mesozoic sedimentary basin, which is interpreted in terms of the regional tectonic setting. The structure of the adjacent basement to the north is much more complex than that we envisioned based upon the satellite interpretation in preparation for field work.

To better resolve the crustal structure and to better delineate the extent of the large scale structures found in this survey, an extension and consolidation of the measurement array is needed.

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Fig. 5.

Fig. 12.

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Fig. 13.

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