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A magnetotelluric traverse across the Mauritanides orogenic belt (West Africa)

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Summary. Magnetotelluric measurements, with reference magnetometers for study of the anomalous geomagnetic variation field, were made in the period range 10–10 000 s at 10 sites crossing the main geological zones of eastern Senegal (West Africa). The results indicate that the electromagnetic fields are controlled by the dominant structural trends of the Mauritanides orogenic belt. Apparent resistivities reflect the major structural units identified from surface geology. Data in the principal directions for most of the stations exhibit anisotropic behaviour, and at certain sites the magnetotelluric responses are affected by surface distortion effects. The study of the geomagnetic variation field indicates the presence of a concentration of telluric current flow beneath the craton. A lack of obviously conductive geological structures at the surface suggests that this flow of telluric current may be attributed to increased electrical conductivity in the crust. The quantitative interpretation of the magnetotelluric results is given in terms of 1-D and 2-D resistivity models. It is shown that the data require the presence of a highly anomalous crustal structure (40 Ωm) dipping to the east from a small depth beneath the outcropping margin of the West African craton. In the Mauritanides, the crust is resistive (3000 Ωm) to a depth of 30 km, and overlies a conducting layer of 10 km thick. In the depth range 250–300 km, resistivities decrease to less than 50 Ωm. This may coincide with the top of the asthenosphere. The geoelectric model is discussed in relation to the general geological background of the region considered.

Key words: magnetotelluric data, current channel, orogenic belt, craton, resistivity structure, West Africa

1 Introduction

In 1979, the Institut Français de Recherche Scientifique pour le Développement en Coopération (ORSTOM) undertook a magnetotelluric (MT) survey to examine the resistivity of the Earth's crust and upper mantle in the Mauritanides orogenic belt in eastern Senegal (West Africa). Recordings were made at seven sites (Fig. 1) in the period range 10 to 1000 s

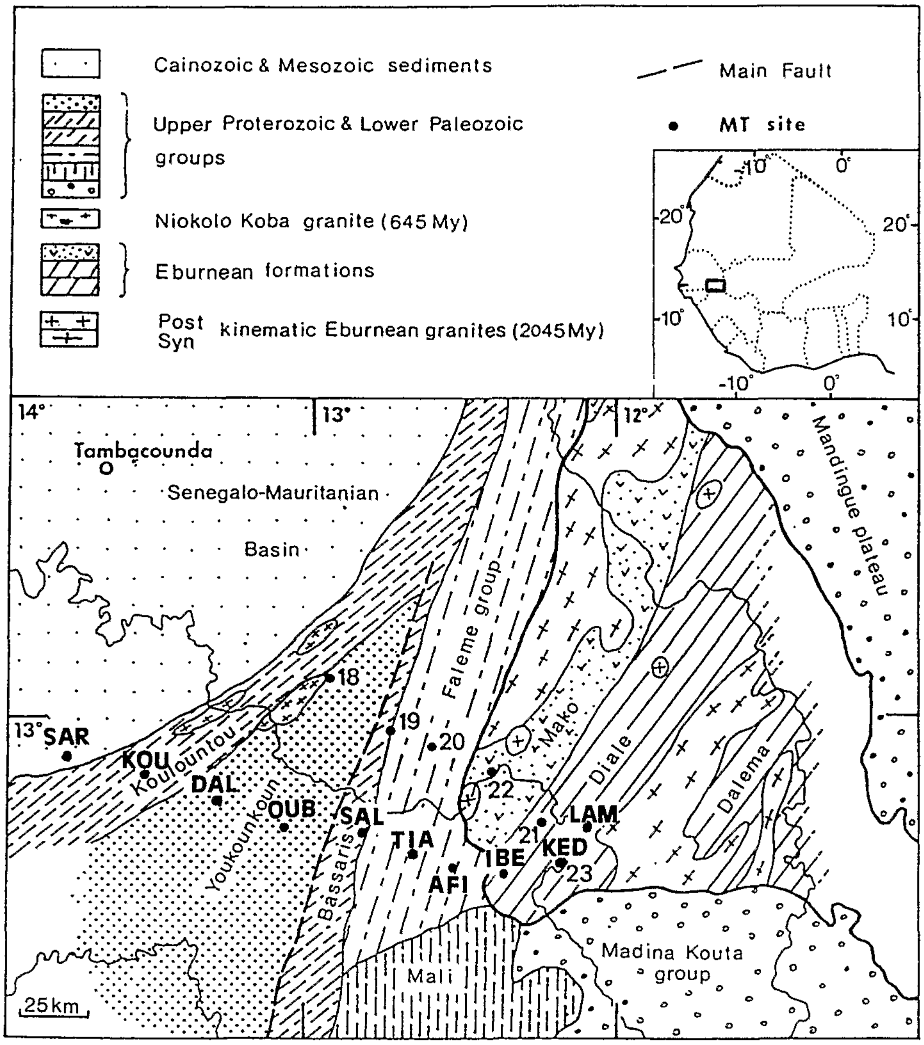

Figure 1. MT site locations defining traverse crossing the main geological zones of eastern Senegal. Data from sites 18–23 were interpreted by Ritz (1984).

(Ritz 1984). Two-dimensional (2-D) computer model results have revealed the presence of several areas where electrical resistivity is abnormally low at crustal and upper mantle depths and the existence of lateral electrical conductivity inhomogeneities within the lithosphere. Although the tectonic structure of the Mauritanides is difficult to explain due to the complex geology, geoelectric models for the crustal part have a value in enlightening structural geological problems (Ritz & Robineau 1986). Our previous MT results place significant constraints on the structural units of the Mauritanides belt and thus on acceptable tectonic models. However, because of the lack of long-period MT data, the exact location of the asthenosphere boundary could not be specified. Acquisition of data in the period range 1000–10 000 s would be very valuable in these studies for evaluating the electrical properties of the deep lithosphere and thereby fixing the top of the asthenosphere. As there is evidence of a close correlation between electrical resistivity anomalies and past tectonic

Table 1. Location of the stations

Station name	Code name	Latitude N	Longitude W
Sare-Oura	SAR	12.87	13.75
Koulountoun	KOU	12.83	13.50
Dalaba	DAL	12.75	13.28
Oubadji	OUB	12.67	13.07
Salemata	SAL	12.64	12.81
Tiankoye	TIA	12.58	12.66
Afia	AFI	12.55	12.53
Ibel	IBE	12.51	12.38
Kedougou	KED	12.56	12.19
Laminia	LAM	12.63	12.10

activity, it was decided to undertake new electromagnetic induction studies in eastern Senegal. These comprised differential geomagnetic sounding (DGS) and MT studies using Mosnier variometers (Mosnier & Yvetot 1972) and a period band of 10–10 000 s. The present paper reports on the MT and DGS results at 10 stations (Table 1) constituting an approximately EW traverse from Laminia (LAM) to Sare Oura (SAR). The east end of the profile falls in the West African craton (Fig. 1). The tectonic significance of the conductivity distribution in eastern Senegal will be discussed in a later paper.

2 Geological and geophysical background

In eastern Senegal, two different tectonic zones coexist (Fig. 1). To the east, the West African craton which is an old metamorphic and granitic basement, with structures inherited from the Eburnean orogeny (2400–1800 Ma). Its surface is covered by slightly or not deformed Upper Proterozoic formations (Bassot 1966; Bessoles 1977). To the west, the mobile belt, bounding the craton, consists of sedimentary and igneous formations of the basement and its cover which have been folded and more or less metamorphosed. In our study area, the West African fold belt, or Mauritanides belt, originated during the Pan-African event (Villeneuve 1984) and four lithostructural units can be distinguished (Bassot 1966) as shown in Fig. 1. The sites AFI, TIA, SAL, OUB, DAL and KOU were situated on these units.

Villeneuve (1984) proposes to separate the orogenic belt into two zones. The central zone, including the Faleme and Bassaris groups, is marked out by a tholeitic volcanism interbedded with volcano-detrital sediments. It could correspond to the passive margin of the West African craton. The western zone (Koulountou and Youkounkoun groups), displaying calc-alkaline material is interpreted as the active margin of another continent, a Pan-African suture separating the two zones.

The eastern sites (IBE, KED and LAM) were situated in the West African craton, on the Diale group, which is characterized by the predominance of flysch facies. The structure of the sedimentary formations of Eburnean age in the region has a dominantly NE–SW trend.

Various seismic and gravity studies have been undertaken in eastern Senegal. Gravity coverage shows large variations of Bouguer anomaly across the Mauritanides, –40 to 40 mgal from east to weat (Crenn & Rechenmann 1965). For Guétat (1981), the negative Bouguer anomaly observed on the external part of the belt is partly due to a thickening of the crust. It is also suggested by seismic studies (Dorbath *et al.* 1983). In a recent gravimetric interpretation, Ponsard (1984) individualizes two crustal blocks separated by a west-dipping suture plane, resulting from the Pan-African collision of the West African craton with a western continent. The suture is underlined by a dense body between 2 and 20 km below the Koulountou group. The seismological study of eastern Senegal (Dorbath *et al.* 1983) has shown the existence of a prominent seismic discontinuity, dipping to the east, which extends downward from the surface to a depth of 150–200 km. It cuts the surface at about 120 km west of the margin of the craton. The authors suggest that the major discontinuity indicates the trace of a Precambrian suture.

3 MT results

A four-channel digital MT system was used in this survey similar to that described by Ritz & Vassal (1986). The field tapes were analysed following standard procedures described by Vozoff (1972) and Thayer (1975). The results are tensor-rotated apparent resistivities and phases with their error bars which represent two standard deviations, rotation angle of the principal axes and skew factor in the period range 10–10 000 s. Selection was undertaken by using data with predicted coherence greater than 0.9. The equatorial electrojet (EEJ) runs about parallel to the actual traverse, approximately 130–150 km south of the MT line (Vassal & Villeneuve 1986), and the non-uniform geometry of the inducing magnetic field of the daytime EEJ may influence the MT observations. Consequently, we have used night-time observations to compute the various MT parameters.

At most of the stations, the direction of the principal axes of the impedance tensor is constant for periods larger than 100 s while it tends to rotate at some sites (LAM, AFI, TIA and SAL) for shorter periods. Table 2 shows the major principal directions at each site for data averaged in the period range 100–3000 s. It is apparent that the direction of the major

Table 2. Orientation of the principal axes of the impedance tensors (clockwise from north)

Station	SAR	KOU	DAL	OUB	SAL	TIA	AFI	IBE	KED	LAM
Orientation	25°	−55°	30°	20°	−64°	−58°	−68°	−65°	20°	35°

impedance axis changes in a systematic fashion between each site. This rotation is often abrupt and is probably due to the geological complexity of the region. For a 2-D structure, the major principal direction is parallel to the strike on the conductive side, and perpendicular to the strike on the resistive side (these directions are here on referred to as TE and TM). Consequently a strong change in the direction of the major axis between sites certainly indicates the proximity of a major lateral contact, and structural boundaries can then be identified immediately (Table 2). However, by rotating the impedance tensor, two principal directions are obtained. It is not known which of the two principal directions represents the electrical strike direction, and geological controls must be adopted to define the regional strike. Several dominant surface structures, considered to be associated with the evolution of eastern Senegal, have been identified by Villeneuve (1984). In the study area the dominant trends are north–north-easterly. Based on the geological preference for N–NE trending structures, the electrical strike direction for each site has been selected from the two possible azimuths. At LAM, KED, OUB, DAL and SAR, the major resistivity axes are assumed to be parallel to the electrical strike; for all other sites, the major resistivity axes are assumed to be perpendicular to the electrical strike. The average strike obtained at each site from the principal impedance directions approximately aligns with the dominant surface structures, with mean direction of about N28°E. Note that this direction is roughly perpendicular to the MT traverse.

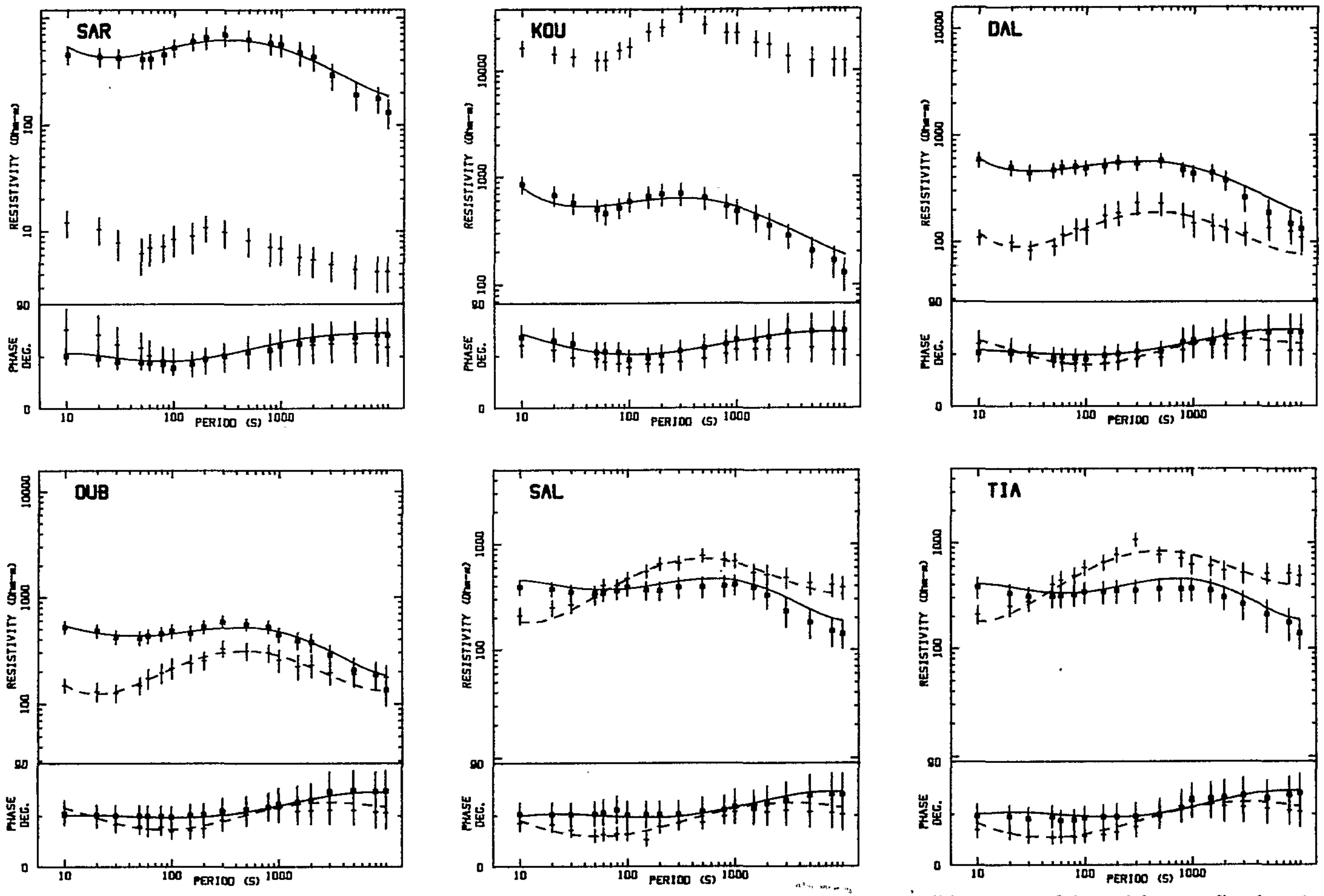

Figure 2. TE (dots) and TM (crosses) directional amplitude and phase responses for the MT data. The solid curves are 2-D model curves fitted to the TE data, and the dashed curves are 2-D model curves fitted to the TM data. The solid curves at sites KOU and SAR are 1-D model curves fitted to the TE data. Error bars are two standard deviations. Models are shown in Fig. 5.

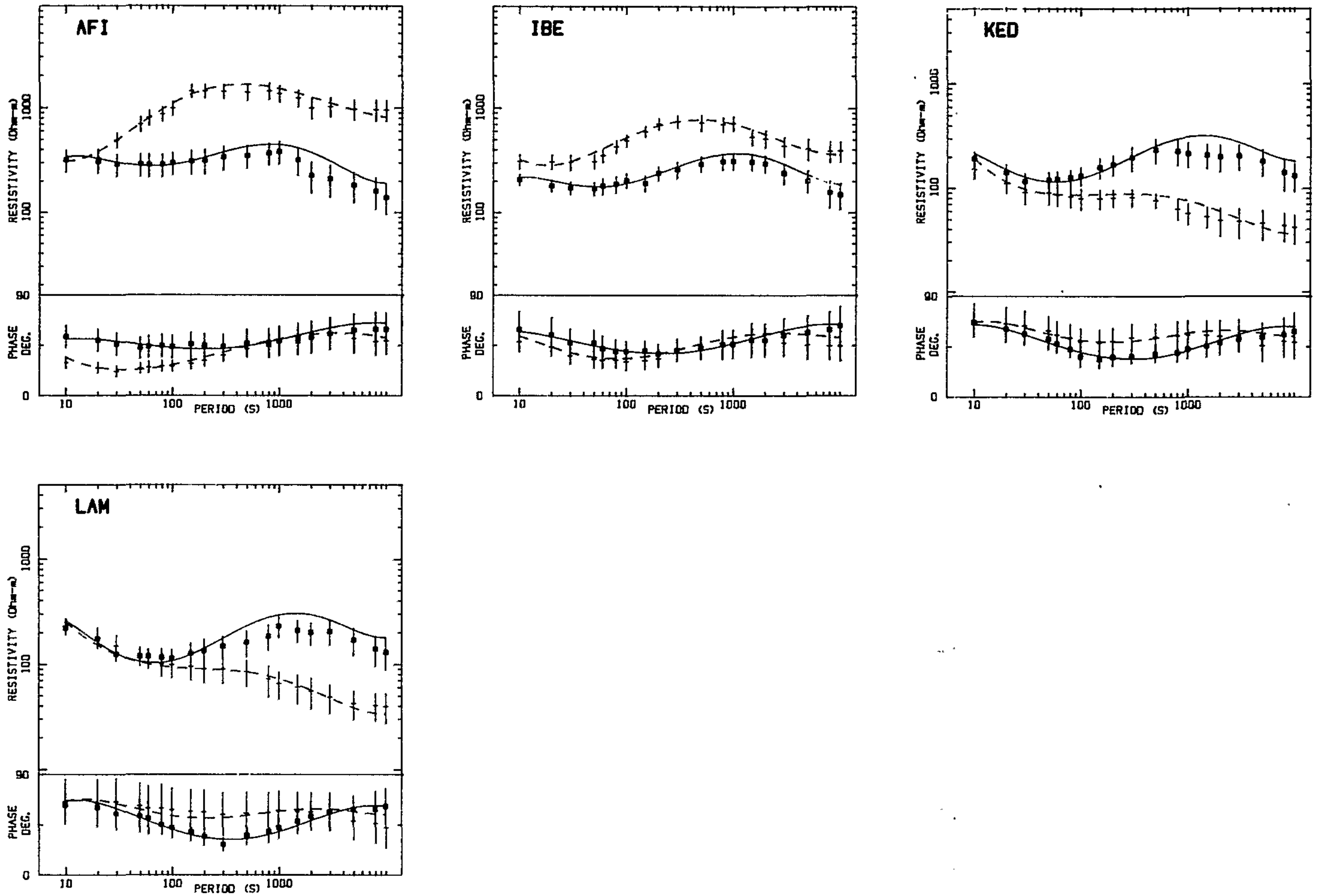

Figure 3. Continuation of MT responses.

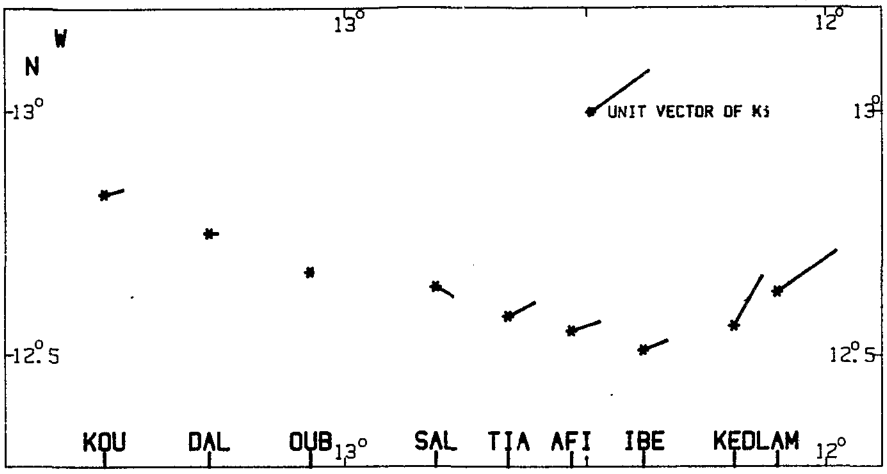

Figure 4. Variation of the K_i differential magnetic vector along the traverse for periods in the 500–2000 s range. In each station, the vector indicates the direction of the anomalous current flow and its length is proportional to the intensity of the anomalous field. The vector K_i is included between 0 and 1. Large value of K_i indicates the presence of a concentration of geoelectric current into regions of anomalously high electrical conductivity.

Information about the MT responses (TE and TM directional amplitude and phase data) from all sites in eastern Senegal is given in Figs 2–3. Several important facts are immediately evident from an inspection of the MT responses. Of particular significance is the fact that both orthogonal components of apparent resistivity are divergent at most stations. This anisotropy is thought to be the effect of the major structural complexity of the study area. The results from these sites are discussed region by region.

3.1 CRATON SITES

Data obtained at sites LAM, KED and IBE are considered to be representative of the Diale group. The sites LAM and KED are remote from the craton–orogenic belt boundary, and TE and TM responses are nearly coincident at periods less than 100 s. At longer periods the data are anisotropic in that the TE and TM estimates are dissimilar. The anisotropy ratio (ratio of major to minor resistivities) increases with increasing period until about 3000 s. The MT responses at IBE are different from those measured at LAM and KED. The TM apparent resistivities at station IBE are larger than those at sites LAM and KED. The TM apparent resistivity curve increases with the period from 30 to 500 s and it decreases for longer periods. It should be mentioned that the TE apparent resistivities at IBE are not significantly different from those at LAM and KED and the shapes of the TE curves are very similar. The TE phase decreases steadily from about 60° at 10 s period to less than 45° at 200 s where it begins to gradually increase to nearly 60° at the longest periods. For the long-period data, the degree of anisotropy is smaller at IBE than the anisotropy observed at other sites inside the craton.

3.2 MAURITANIDES SITES

Stations which display the Mauritanides response are AFI, TIA, SAL, OUB, DAL and KOU. The MT estimates from these six stations are, in general, different to each other in both amplitude and phase responses (Figs 2–3). The large variation in MT responses at the various sites can be attributed to the geological complexity of the region. On the other hand, MT responses can be regarded as representative of the major structural units of the orogenic belt. The most important characteristics of the results presented in Figs 2–3 are the following:

(1) The tensor apparent resistivity curves in the principal directions for all the stations in the Mauritanides exhibit anisotropic behaviour. The degree of anisotropy varies from site to site. In particular, the orthogonal components of apparent resistivity are highly divergent in the region of the Koulountou group (site KOU); the major apparent resistivity curve (associated with the TM direction) reaches values greater than 10 000 Ωm and is the largest encountered. The degree of anisotropy is minimum at SAL and TIA.

(2) The high degree of polarization of the electric field is reflected in the large error bars on minimum apparent resistivities and in the large values of phase estimates.

(3) The dependence of the TE apparent resistivity curve on the period is similar for most of the stations. The TE curve is large in the period range of about 100–800 s; it decreases toward longer periods and remains constant or increases slightly for shorter periods.

(4) For sites OUB and DAL the apparent resistivities both (TE and TM curves) appear to converge at long periods.

3.3 SENEGAL BASIN SITE

The apparent resistivity curves at the one station in the Senegal basin, SAR, display a very high degree of anisotropy, with the ratio of major to minor resistivities being more than 50 to 1. The minor resistivity estimates at this site are very different from those from LAM–KOU; the minor resistivity is less at all periods than that observed at any other location. At short periods, the minor apparent resistivity is of the order of 10 Ωm. It decreases from about 10 Ωm at 200 s period to less than 5 Ωm at long periods. These low values can be attributed to the three-dimensionality of finite length structures (Wannamaker, Hohmann & Ward 1984).

4 DGS results

Field procedure in DGS surveys consists of recording horizontal magnetic signals simultaneously at reference stations and field stations (Babour & Mosnier 1977). The regional telluric current system is controlled by the electrical resistivity structure. Contrasts in the resistivity structure result in local variations in the density of telluric current flow and, consequently, in local variations in the geomagnetic variation field. The geomagnetic field of the electric currents, which are induced additionally in the geoelectric structure, is superimposed locally onto the large-scale geomagnetic field. Consequently, the differences, ΔH_i and ΔD_i, between the homologous components of the field recorded at a given time at a reference station S_0 (where the density of the telluric currents is assumed uniform) and at the remaining S_i stations, allow measurements of the excess or lack of density of the telluric currents at the S_i stations with regard to S_0. The amplitude of the anomalous field is a random function of time, which can be normalized by using a second S_j reference station (Babour & Mosnier 1977). A coefficient,

$$K_i = \sqrt{(\Delta H_i^2 + \Delta D_i^2)}/\sqrt{(\Delta H_j^2 + \Delta D_j^2)}$$

can be introduced, independent of time and proportional to the anomalous field in each station i.

Both local induction due to a nearby electrically conductive structure and the regional current channelling by a local conductor of currents generated by induction on a scale much larger than the region under investigation will cause an anomalous geomagnetic variation field (Dupis & Théra 1982; Fischer 1984).

The study of the records of the geomagnetic variation field in eastern Senegal shows that significant differences exist between the stations of the traverse. The telluric currents circulating at LAM and KED inside the craton are more intense than those circulating at other sites. Station OUB can be taken as the first S_0 reference station and LAM as the second S_j reference station. Thus, the K_i coefficient varies between 0 and 1. Fig. 4 shows the anomalous telluric current distribution responsible for differential fields along the traverse. In most cases the vectors tend to peak in the 500–2000 s range. The K_i vectors are not significant for periods longer than 2000 s. Note that the DGS measurements were restricted to the long-period data. The simultaneous measurements were not made at SAR and reference sites of both horizontal magnetic components because some H and D component recorders failed at some sites.

The most obvious feature of the anomalous current distribution (Fig. 4) is the large difference in amplitude of the differential vectors between stations outside the craton and stations within the craton (except IBE). There is no significant anomalous response associated with the stations KOU, DAL, OUB and SAL. A very small anomalous response is observed at stations nearest to the craton (TIA–IBE). There is an anomalous response at stations KED and LAM inside the craton with a north-easterly trending current path; it is approximately coincident with the main structural trends of the Eburnean units of the craton suggesting that the induced telluric system is controlled by local geological structure. Within the range TIA–AFI–IBE, the vectors deviate from the general trend. The Mauritanides appear to be a non-conducting barrier, deflecting the telluric current flow in the craton. What is remarkable about the anomaly inside the craton is that there is no direct geological evidence of a coincident conductive structure at the surface to concentrate electric currents strongly. One can reasonably suppose that the telluric current concentration is caused by fundamental geoelectric structures in the crust (or upper mantle). The anomalous current distribution suggests a conductive fabric throughout the craton parallel to the dominant structural trends of the region. Finally, it appears from our results that the dominant feature is the boundary between the West African craton and the Mauritanides orogenic belt, with current flowing beneath the craton but avoiding the Mauritanides. Additional profiles of geomagnetic variations are necessary to adequately map the craton current channel.

5 2-D and 3-D effects

The skew parameter, a measure of two-dimensionality (Swift 1967), was calculated. At most of the sites along the profile, the skew factor is less than 0.25 until about 500 s where it begins to increase to nearly 0.4 at the longest periods indicating some 3-D characteristics. Nevertheless, the skew values can be biased by the presence of coherent noise, and hence, their absolute levels alone should not serve as solitary criterion ruling out a 2-D structure. Perhaps the large skew values arise from very local structures channelling the telluric currents.

The MT data in the far West (Fig. 2), especially for KOU and SAR, show a pronounced parallel split between the TE and TM amplitude curves, but the phase values are practically unaffected throughout the period range (except for SAR for periods below 50 s). This bilateral splitting is caused by shallow 2-D or 3-D inhomogeneities. In such environments, there is a constant bias on the impedance tensor because of static electric field distortion (Berdichevsky & Dmitriev 1976), which is seen only on the amplitude data. In the case of a measuring site outside the inhomogeneity, both the TE and TM amplitude curves will be biased bilaterally, one up and one down. Unfortunately, without knowledge of the characteristic signs of the heterogeneity, it is difficult to determine the extent of the bilateral displacement of the TE and TM curves. Sites KOU and SAR are typical of this bilateral splitting caused by shallow features off to the side of the site location.

6 Interpretation

The complexity of the structure in the survey area is indicated by diverging components of apparent resistivity, significant changes in the character of the MT estimates from east to west, strong rotation of the direction of the major impedance axis between sites, surface distortion in the MT response, non-zero values of the skew parameter and the presence of a telluric current concentration beneath the craton. At all the Senegalese MT sites, the resistivity structure appears to be at least 2-D. However, along the profile the TE data show a good consistency from site to site (Figs 2–3), and the similarity of the responses suggest that the TE mode for KOU and SAR is less affected by surface distortion effects. For these sites, the TE data appear more accurate for a 1-D interpretation. The data for all other sites are interpreted to be 2-D in character, so that a line from LAM to DAL direct would be at right angles to the strike. This assumption is supported by the electrical strike directions at stations along the traverse line which are approximately parallel to each other and are consistent with the regional strike of eastern Senegal; this regional strike (N 28° E) is roughly perpendicular to the MT traverse.

Modelling of the MT data was then done using a combination of forward 1-D and 2-D (Wannamaker, Stodt & Rijo 1985) computations to estimate actual resistivities and phases, and subsequently to establish the electrical characteristics of the major structural zones encountered. A starting 2-D model was defined using the 1-D models computed at each site (except KOU and SAR) and other geophysical information with geological constraints provided by surface mapping. Repeated adjustments were then made to the starting model at seven periods (10, 30, 100, 300, 1000, 3000, and 10 000 s) to obtain a model which fitted the MT estimates at stations east of KOU. In general, significant lateral changes in resistivity are required to accommodate data from neighbouring stations. The resulting 2-D geoelectric model and models of 1-D resistivity distribution at KOU and SAR, calculated from apparent resistivities and phases of the TE mode, are given in Fig. 5. The responses of these models at all sites are shown with the observed apparent resistivities and phases in Figs 2–3. The agreement is reasonably good between observed and computed responses but the 2-D model results sometimes depart from the resistivity estimates above periods of 500 s. This coincides with the period where the skew begins its increase. The MT results can be used to explain causes of the anomalous geomagnetic field in the eastern part of the traverse (Fig. 4). The conductive structure inside the craton probably provides the main electrical conduit for the anomalous currents. It is possible from the calculation of the magnetic field for different periods and several sites to obtain the same type of data as was obtained experimentally with DGS (the E along-strike component of the 2-D model is used). On the basis of the geoelectric model we are presently proposing, calculations show that the magnetic induction in local structure is very strong at LAM and KED. The theoretical values of the anomalous magnetic field are in sufficient agreement with the experimental values. It should be stressed that the uniqueness of the model cannot be guaranteed because of the number of assumptions involved. The selected model is only one of many possibilities that may produce

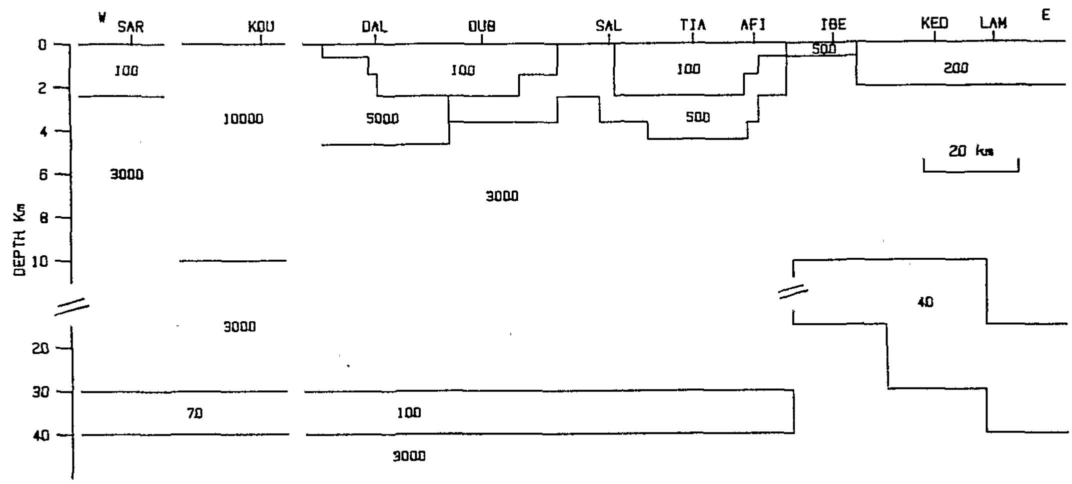

Figure 5. Two-dimensional geoelectric model of possible crustal structure in eastern Senegal beneath the MT line shown in Fig. 1. The 2-D model was designed to fit only sites LAM–DAL and was connected to 1-D models for the rest of the sites (KOU and SAR) in this presentation. Numbers are interpreted resistivities in Ωm. The first rapid decrease in mantle resistivity occurs in the depth range 250–300 km.

similar or better results. While this model is non-unique it is subject to constraints which will be briefly noted:

(1) The most important feature is the contrast in resistivity between the craton and mobile belt regions. In the craton, the model indicates a low-resistivity region in the lower crust. The depth of the top boundary of this low-resistive feature is between 10 and 15 km with resistivity of 40 Ωm. This conductor thickens to the east. The resistivity value for the lower crust in the craton is lower than usually assumed for a stable continental crust (Jones 1981). In the mobile belt, the model shows a resistive curve (3000 Ωm) underlain by material of 100 Ωm. Dorbath *et al.* (1983) infer a crustal thickness of 40 km in eastern Senegal from seismic data and consequently the 100 Ωm layer is located at the base of the crust.

(2) From sounding DAL to sounding KOU on the west portion of the profile (mobile belt), a highly resistive near-surface material (5000–10 000 Ωm) is encountered. The resistive body dips toward the west. The thickness of this feature is about 10 km at sounding KOU.

(3) The uppermost mantle is resistive (3000 Ωm) to a depth of about 130 km, and overlies a less resistive layer (500 Ωm), of poorly defined thickness, 120–170 km. At depths in excess of 250 km there is a general trend toward lower resistivities, the transition from 500 Ωm to about 50 Ωm occurring in the depth range 250–300 km.

Although the structure of the region is highly complex, the model can be used to identify the major geological units.

The resistive layer (3000 Ωm) which can be followed across the entire profile is thought to correspond in part to the Precambrian granite basement. The presumed basement sinks under the Mauritanides belt between depths of 3 and 10 km and reappears eastwards (craton) and westwards (Senegal basin) under thin sedimentary formations. An abrupt change is evident near site DAL. Within the Mauritanides under sites AFI, TIA, SAL, OUB and DAL, the near-surface zones have resistivities in the range 100–500 Ωm. In this region, the model shows trough structures filled with moderate resistivity material of about

100 Ωm forming a marker at depths near 2500 m. This medium possibly represents flysch deposits correlating with the Youkounkoun and Faleme synclinoriums. The layer immediately underlying the uppermost sediments has a resistivity of 500 Ωm and a maximum thickness of 2500 m, it is assigned to the basal volcanic complex. The 500 Ωm substance trends to the surface near site SAL and corresponds to an outcropping highly faulted horst of Bassaris group rocks. From sounding DAL to sounding KOU, the Youkounkoun group–Koulountou group boundary is indicated by a strong increase in resistivity from 100 Ωm (site DAL) to about 10 000 Ωm (site KOU). However, this region is extremely disturbed and interpretation remains contentious.

Previous to this investigation, a geoelectric traverse cutting across the Mauritanides immediately to the north of the present traverse (Fig. 1) has already been interpreted (Ritz 1984). The results along the northern traverse provide a good basis for comparing the features along this traverse with those of the present traverse in the south. Although in detail some differences exist between the two traverses, the electrical characteristics of the belt structural units, and the variation in thickness of major units appear to be similar. The Koulountou branch is characterized by a highly resistive body, at least 10 km thick. However, an important widening and a steep west-dipping of this unit can be observed on the southern traverse (Fig. 5). Faleme and Youkounkoun synclinoriums are easily recognized on each traverse, but the southern one clearly spreads out southward. They are characterized by low resistivity material of about 20–100 Ωm. These trough structures are underlain by a layer of higher resistivity (approximately 500 Ωm), roughly 2 km thick, which outcrops in the Bassaris range. If the outcrop of the basal volcanic complex reduces northward, on the other hand its lateral extension beneath the Youkounkoun group seems to increase.

Both models show the presence of regions of high conductivity at both crustal and upper mantle depths, in particular the present study confirms the existence of a good conductor under the craton from a depth of about 10 km to about 40 km. The high level of consistency between the two geoelectric models seems to support the assumption of a rather general 2-D character of the cross-section along the actual traverse.

7 Discussion

We realize that there are severe limitations to the application of the MT method in a region which is apparently subjected to channel currents. However, the telluric current concentration appears to be negligible beneath the Mauritanides (Fig. 4). This appears to render tenable the hypothesis that the observed MT anisotropy at sites IBE–DEL is caused by the geological complexity of the Mauritanides system. It thus appears that the anisotropy can reasonably be explained by induction on a regional scale. The interpretation is based on the construction of 1-D and 2-D models explaining the observed features. Exploiting other independent geophysical and geological information, we propose models of possible geoelectric structure along the profile. Within the craton, the MT and DGS measurements can be accounted for very well by inductive excitation in a 2-D structure but a contribution from injected currents unrelated to regional induction cannot be ruled out. The 2-D model obtained from the MT observations confirms the contrast in resistivity in the crust between the craton and Mauritanides regions. Thus, the concentration of telluric current flow beneath the craton at sites KED and LAM may be attributed to abnormally low resistivity layers in the crust. We do not claim uniqueness in any way but believe that this model is representative for at least the Mauritanides region.

Comparison of the MT model with the expected geological structure shows good agreement for most major features of the resistivity distribution, including estimated electrical strike directions. On the other hand, significant contrasts in resistivity are sufficient to resolve the principal structural features by their electrical responses. However, electrical resistivities are not uniquely associated with the major geological units. Perturbation in MT response are introduced by the physical environment. In particular, there are many types of rock contained in each geological unit, and a simple representative value of resistivity may not always be appropriate. The Koulountou group is most readily identified; it is characterized by extremely high resistivities (> 5000 Ωm). But, resistivities for the Youkounkoun and Faleme groups are more difficult to resolve.

An important discovery is the presence of two conductors in the crust, one at depths between 10 and 30 km under the craton and the second at the base of the crust beneath the orogenic belt. Highly conducting zones detected at depths of 20–40 km in the crust of both orogenically active areas and stable shield areas have been interpreted as evidence of water at depth (Van Zijl 1977; Connerney, Nehut & Kuckes 1980). The strong contrast in resistivity between the craton and orogenic belt regions is surprising considering the plausible mechanisms by which significant lateral variation of resistivity could have been expected to develop in this region. Nevertheless, a very significant result of this study is that the zone where electrical resistivity is abnormally low (40 Ωm) is found at the edge of the craton. This implies a close association between the conductivity anomaly and the former plate boundary area, where incorporation of ancient oceanic crustal material might occur in the present continental crust (Drury & Niblett 1980; De Beer, Van Zijl & Gough 1982). The suture zone will without doubt produce a resistivity contrast comparable to the one under discussion (Stesky & Brace 1973). It is, however, likely that if buried oceanic material does exist in the region, it most probably will be highly metamorphosed and as such will bear little ressemblance to the original material. Lee, Vine & Ross (1983) have suggested that low resistivity in presently stable continental areas may result from a combination of basic rock type and high pore-fluid pressure. On the basis of MT data alone, it is not clear how this zone was formed or what property or material in this zone gives rise to the low resistivity.

At depths in excess of 130 km there is a general trend towards lower resistivities, the transition from 500 Ωm to about 50 Ωm occurring in the depth range 250–300 km. It is suggested that the lithosphere derived from this work has a thickness of the order of 250–300 km. From surface heat flow measurements, Chapman & Pollack (1974) have suggested that the lithosphere is very thick beneath West Africa, probably more than 400 km, and that the asthenosphere is absent or at least not well developed. Additional MT measurements are required to determine if the lithosphere thickens uniformly to about 300 km in eastern Senegal as supported by our results.

Acknowledgments

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