

*Short communication***A high conductivity anomaly on the West African craton (Mali)**

M. Ritz

Office de la Recherche Scientifique et Technique Outre-Mer, Boîte Postale n° 1386, Dakar, Sénégal

Key words: Magnetotelluric – Mali – West African craton – Electrical conductivity – Crust**Introduction**

The geophysical section of Office de la Recherche Scientifique et Technique Outre-Mer (ORSTOM) in Senegal has been conducting magnetotelluric (MT) soundings for several years on the West African craton and on its eastern and western borders. Up to the present, the interpretation of the data throughout Senegal, Upper Volta and Niger has shown characteristic models of platforms and continental shields with the first conductive layer situated in the upper mantle at a depth of 80–130 km (Ritz, 1982). On the Canadian shield, Kurtz and Garland (1976) find a conductive layer at a depth of 170 km. Tammemagi and Lilley (1973) place their conductive layer at a depth of 230 km on the Australian shield and, on the Kaapvaal craton, Van Zijl (1977) describes the presence of a conductive layer in the upper mantle at a depth of 90 km. However, an increasing number of soundings suggests regions of high conductivity at depths ranging from 10 to 40 km so that a tectonic province without this conductive zone is beginning to be considered an anomaly. Thus, in the southeastern section of the Canadian shield, MT soundings conducted by Dowling (1970) establish a conductive zone at a depth of 8–15 km. Geomagnetic depth soundings (GDS) made in the western section of the American platform also show conductive zones in the crust (Camfield et al., 1971). Van Zijl (1977) finds a conductive layer at a depth of approximately 35 km on the Rhodesian and Kaapvaal cratons. The absence of a conductive layer in the crust of the West African craton in Senegal, Upper Volta and Niger can be regarded as irregular (Ritz, 1983). We have, therefore, conducted an MT sounding in the centre of the West African craton at Bafo (latitude 13° 25', longitude 6° 16' W) in the southwestern part of the Segou basin, Mali (Fig. 1). The equipment used has been described in a previous article (Ritz, 1982).

A synthetic geological and geophysical picture

From the geological point of view, most of Mali belongs to the West African craton, which was definitively stabilized during the Eburnean orogeny ($1,850 \pm 250$ m.y.). Birrimian

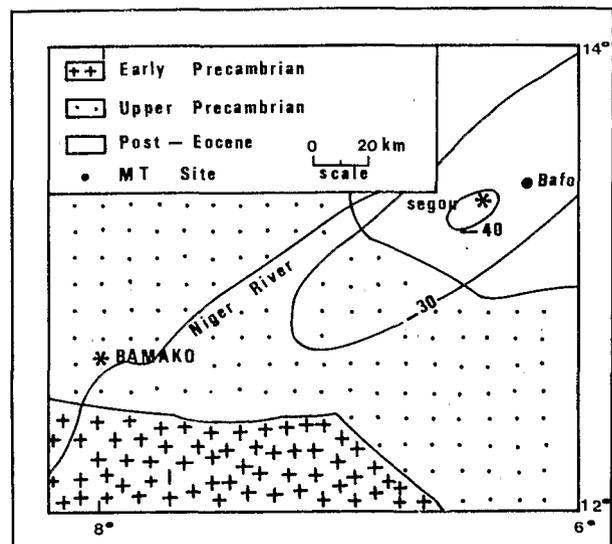


Fig. 1. Generalized geological and Bouguer gravity map of the Segou area. Gravity contours in milligal

rocks are by far the most plentiful in the Precambrian basement. Elsewhere the basement is concealed by a more recent sedimentary cover. Sedimentary rocks consist of series of the Infracambrian age, of the "Continental terminal", a limnic and fluvial formation of Tertiary age and Quaternary dunes (Dars, 1961). The fundamental tectonic structure of the studied area can be assimilated to a large synclinal structure (Reichelt, 1972). However, the geological information about the Segou basin is poorly known. The basin is characterized by Palaeozoic sandstones and Infracambrian sediments which rest on a Birrimian basement comprising highly metamorphosed sedimentary rocks and different intrusive rocks (Dars, 1961).

The Bouguer gravity anomaly (Fig. 1) shows that the Segou basin is dominated by a major east-northeast trending negative anomaly. It is centred in the vicinity of the MT site (Bafo), and is as much as 40 mgal in magnitude. This axial minimum coincides with a large "lineament band", Bamako-Segou (Simon et al., 1982). The Bouguer anomaly along a NW – SE profile is shown in Fig. 2. This "low" is most probably due to the thick sedimentary deposit in the basin. A single density contrast of 0.26 g/cm^3 was used for the basement in a model employed in the computa-



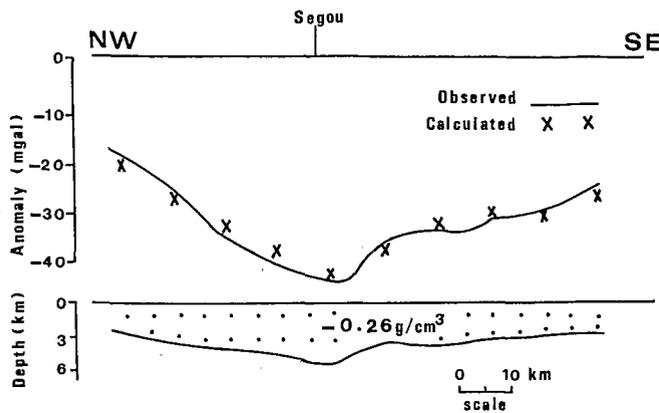


Fig. 2. Observed Bouguer anomaly and schematic interpretational model along a NW-SE profile

tion of depth to the basement (Rechenmann, 1957). The result showed that with a single density contrast there is a close fit between the observed and computed gravity anomaly profile. The gravity anomaly indicates sediments 5 km thick in the deepest part of the basin (Fig. 2).

Results

The variations of the electric and magnetic fields have been measured in the period range extending from 6 to 2,000 s at Bafo. The analysis techniques are those described by Vozoff (1972) and will not be discussed here. Generally, two apparent resistivity curves (and phases) resulted for a site, due to the effects of inhomogeneous structures. The apparent resistivities and the phases in the directions of the principal axes of anisotropy, the direction of the major axis of anisotropy and the preferential direction of the flow of the telluric currents as a function of period are shown

in Fig. 3a-c. The data between 6 and 100 s on both major and minor curves are nearly the same. The apparent resistivity curves display increasing anisotropy with increasing period. It should be mentioned that the minor curve has important error bars for periods longer than 100 s (not presented). It can be seen that the major axis of anisotropy is orientated north-south at Bafo. The separation between apparent resistivities in the principal directions for periods longer than 100 s is an indication of two- or three-dimensional structures. We assume that the apparent anisotropy detected at Bafo is caused by a conductivity inhomogeneity. The problem is to decide which of the two curves best represents the electrical conductivity structure under Bafo. Studies made on the behaviour of the MT fields in the presence of two-dimensional inhomogeneities show that for sites on or off a buried conductor, the maximum apparent resistivity curve is more representative (Patrick and Bostick, 1969). As a result, on the conductive side, this curve will tend to overestimate the resistivity. However the maximum curve is more accurate for a one-dimensional interpretation.

As a first step, major data from Bafo were inverted to a resistivity-depth function by applying the Bostick transform (Bostick, 1976; Goldberg and Rotstein, 1982). This method is an inversion technique applied to the observed data which yields a smoothed variation of the resistivity with depth directly. The result of this transformation is presented in Fig. 3d. The major data were also fitted to layered models according to a linearized, least squares inversion modelling scheme (Jupp and Vozoff, 1975). A low resistivity layer is found, whose upper surface is between 4.5 and 6.5 km in depth and which is about 6 km thick. There is a transition to a highly conductive layer at a depth of 48–60 km (Fig. 3d). Although the model gives results which correspond to the field results, there is a high degree of nonuniqueness of the selected model, since we only considered the MT response at a single site.

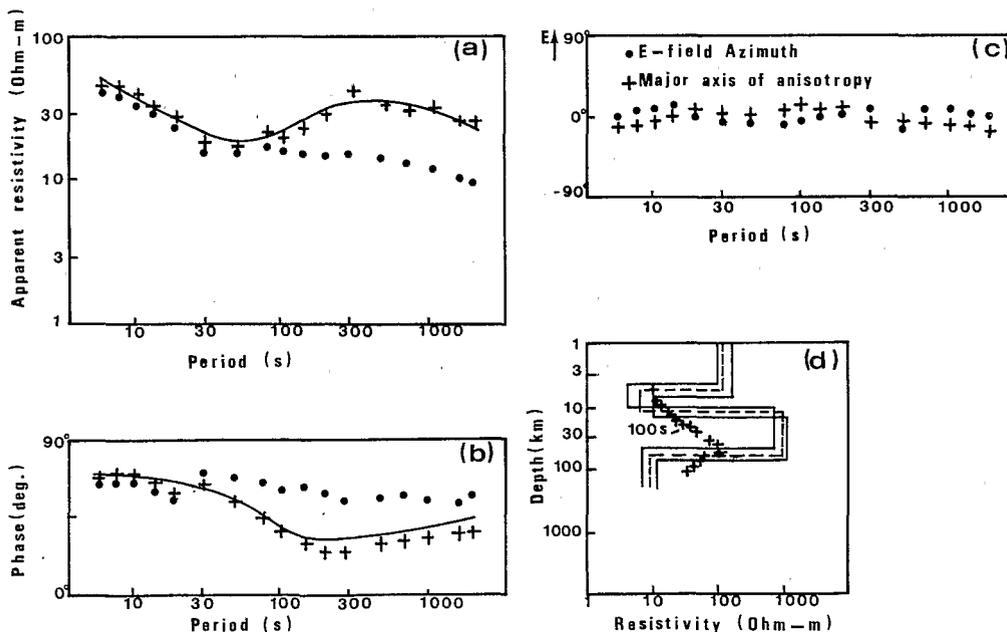


Fig. 3. Rotated major (*crosses*) and minor (*dots*) magnetotelluric responses for Bafo (a and b). *Solid curves* on the major data represent theoretical curves calculated from 1-D model. *c* The directions of the major axis of the impedance tensor and the angles of polarization of the telluric current. *d* One-dimensional model for Bafo, the *dashed line* represents the best-fitting 4-layer model and the *solid lines* the bounds of acceptable models. A depth-resistivity diagram (Bostick, 1976) is presented, marked by *crosses*

The conductive zone found between 5 and 10 km in the upper crust is rather unexpected. Gravity surveys indicated sediments 3–5 km thick in this area, underlain by a crystalline basement. To a first approximation, it appears that the basement is fractured and if the fractured zone is filled with water, it will form a low resistivity zone.

Discussion

The explanation usually given for the existence of layers of low resistivity in the crust is based on hydration processes, with or without partial melting. A temperature of more than 700° C is needed for partial melting of water-saturated rocks at lower crustal levels (Hyndman and Hyndman, 1968). In the case of hydrated basalts, melting could begin at 800°–900° C; the resistivity is then in the region of 10 ohm-m (Volarovitch and Parkhomenko, 1976; Pham Van Ngoc et al., 1980). Since the conductive zone begins at a depth of about 5 km, a geothermal gradient of approximately 160° C/km would be required if partial melting were responsible for the conductive layer at this depth. Such a temperature gradient should create hot springs, but this does not seem to have been noted in this region. Such high temperature gradients are to be found in rift zones (Iceland: Beblo and Björnsson, 1980; Afar: Berkthold et al., 1974; Kenya: Rooney and Hutton, 1977). Unfortunately, in this region no measurement of heat flow has been obtained. The only measurements of heat flow made on the West African craton are those by Chapman and Pollack (1974) in Niger. They found values that were very low, and lower than the continental average (18–22 mWm⁻²). On the other hand, temperature in the range of 800° C at the level of the conductive zone in the crust may appear exaggerated in a stable shield region. The conductive zone in the crust could then be attributed to the hydration process of Hyndman and Hyndman (1968).

Anomalously high conductivity near the top of the crust can also be connected with the presence of well-conducting minerals, like sulphide and graphite. Such zones have been found in crystalline shields at depths of 5–8 km (Dowling, 1970; Lilley and Tammemagi, 1972; Sternberg and Clay, 1977; Adam et al., 1982). The presence of graphite in rocks leads to a considerable increase in the conductivity which can reach a resistivity of the order of 10 ohm-m (Kotvun, 1976).

It appears, however, that definite conclusions seem to be still premature or largely speculative because of the lack of other geophysical and geological findings in the region. More detailed results may be reached in the future by additional MT soundings.

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