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Search of Clay Deposits in a Dual Geological Environment in the South-Southern Part of Nigeria

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Abstract. The presence of clay deposits in the south-southern part of Nigeria was investigated using the electrical resistivity method. The vertical electrical sounding was adopted for the investigation using the Schlumberger electrode arrangement. Resistivity soundings were collected from several locations, which were evenly distributed within the study area to explore the clay deposits. Models were generated for computer iterative technique. Borehole data were also collected using spontaneous potential logging method, as well as driller's log in some selected sites within the study area, so as to correlate surface measurements with borehole records. Analysis based on five depth-related resistivity contour maps, as well as selected cross-sectional profiles, confirm the existing dual regional geological environment of the area. Finally, it was established quantitatively that there were comparatively larger clay mineral deposits in the sedimentary environment than in the basement complex areas.

Keywords: clay deposits, vertical electircal sounding, Schlumberger electrode arrangement, dual geological environment, Nigerian clay

Introduction

The mining and production of individual minerals for the use of various industries is an activity that has not received adequate entrepreneurial attention in Nigeria. This has its historical basis in the fact that virtually all Nigerian industrialists depend on foreign sources for both the plants and equipment, as well as the raw materials, for their industries. With the current drive towards the attainment of self-reliance in the local sourcing of industrial raw materials, it has become possible to set up profitable ventures for the supply of raw materials as the feedstock to industries without direct involvement in actual manufacturing. There are hundreds of various non-metallic minerals that have applications in the industrial sector. Clay falls into one of the industrial minerals that are needed for the manufacturing of several industrial products. The study of ground resistivity is commonly used in shallow depth geophysical prospecting where the electrical property of rocks and soils, which varies over a wide range, is measured. This electrical exploration method utilizes artificial electric currents to explore the properties of the earth's interior and to search for natural resources such as water, clay and other minerals.

Zodhy (1973) and Zodhy *et al.* (1974) gave details on the use of resistivity method for obtaining information on the subsurface geology. Chilton and Foster (1995) have successfully utilized the resistivity techniques in assessing water supply potential in basement aquifers.

Location of study area. The study area lies within the latitude 6^0 47´N and 7^0 35´N and longitude 5^0 46´E and 6^0 45´E. Resistivity sounding data were collected from 24 towns and these locations were evenly distributed within the study area as shown in the base map (Fig. 1). The resistivity data were used to explore the clay deposits in the area. The topography of the area may be generally described as 'rugged'. It is characterised by irregular depressions and elevations. In general, the western and eastern portions are characterized by undulating hills and ridges, more especially the western portion, which is aligned to the course of River Ule and its tributaries. The central portion is characteised by fairly lowland with an average elevation of 122 m above the sea level. The eastern part of the study area is bounded by River Niger. Other major rivers within the area are Onyami, Orle, Edion Obe and Udo. The rivers appear to be structurally controlled, and their down-cutting action has given rise to deep valleys and gullies, especially along outcrops of weak lithologies.

Local geology. The area under study is underlain by basement complex rocks of Pre-Cambrian to Upper Cambrian age and Cretaceous to Tertiary sedimentary rocks (Fig. 2). The basement complex comprises chiefly of undifferentiated basement rocks, undifferentiated meta-sediments, and older granite. In the sedimentary area, five lithostratigraphic units were observed, which were: (i) Nkporo shale group (shale and mudstone); (ii) upper and lower coal measure (coal, sandstone and shale); (iii) Ajali formation (false bedded sandstones); (iv) Imo clay-shale group (clays and shales with limestone); and (v) Bende Ameki group (clay, clayey sands and shale).

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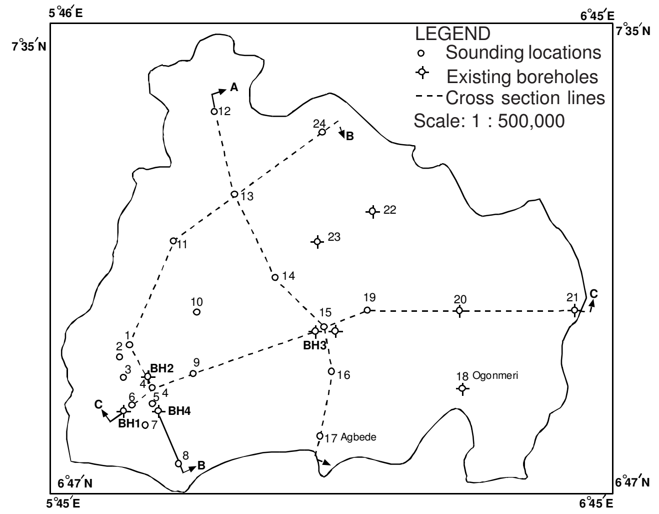

Fig. 1. Basement of study area showing sounding points, existing boreholes, and cross sectional lines.

Theory. The resistivity transform function is usually preferred to the apparent resistivity as a basis for interpretation, because it has a significant advantage, in that, it may be calculated more easily for theoretical models. Koeford (1965) decomposed the field curve into a sum of partial apparent resistivity functions and then obtained the equivalent transform curve as a sum of corresponding partial transform functions. Chan (1970) calculated the resistivity transform directly by numerical integration. Ghosh (1971a) used electric filter theory to determine a digital filter, which allowed each transform value to be expressed simply as a weighted sum of field apparent resitivity values.

$$T(i) = \sum_j a(j)\rho_a(i-j)$$

$i = 1, 2, \ldots\ldots\ldots\ldots\ldots, m$

where:

a (j) = filter coefficients

m = the number of field data

Forward filter coefficients for both Schlumberger and Wenner arrays at a sampling interval have been published (Ghosh, 1971a):

$$\Delta x = \frac{1}{3}\ln(10)$$

field curves were sampled at:

x = 1, 2.15, 4.64, 10, 21.5, ……., etc.

where:

x = half current spacing for Schlumberger configuration

x = distance between adjacent electrodes for Wenner spread

Subsequently, Ghosh (1971b) used linear filter theory to solve the inverse case of obtaining apparent resistivity data from transform data:

$$\rho_a(i) = \sum_j b(T)\,7\,(i-j)$$

$j = 1, 2, \ldots\ldots\ldots, m$

where:

b (j) = inverse filter coefficients

Again, the sampling interval was 1/3ln10. However, the significance of this inverse filter is that theoretical apparent resistivity curves may be calculated quickly and easily for horizontally-stratified models of the earth by using theoretical transform data generated by a recursion formula.

Materials and Methods

The present work was carried out in parts of south-southern part of Nigeria. Resistivity sounding data were collected along many profiles scattered in position to give good geophysical knowledge of a region that has a dual geological setting. The Schlumberger array system was adopted in view of its reliability and cost effectiveness. Oseimeikhian and Asokhia (1994) have given details on field procedure and practice. The direction of expansion of the cables was, however, constrained by topography though it is desirable that array should be expanded parallel to probable strike so as to minimize the effect of non-horizontal bedding. The Abem Terrameter SAS 300B was used for surface investigation as well as for logging. Non-polarizable copper electrodes in copper sulphate solution were used in logging, while stainless steel electrodes were used for surface investigation.

Results and Discussion

Identification of field curves. The major observed apparent resistivity curves within the study area were: H- curve, Q-curve, KQ-curve, HK-curve, QH-curve, KH-curve, HA-curve and KHKH-curve types. Ujuanbi (2000) has given detailed description of these curve types.

Geological interpretation of vertical electrical sounding results correlated with borehole records. In the sedimentary southwestern part of the study area, clay deposits were encountered, which have been mapped into different geological formations. Some of the locations within this sedimentary environment are whown in section B-B (Fig. 3). At Eme-ora, this clay outcropped at the surface, which was over-

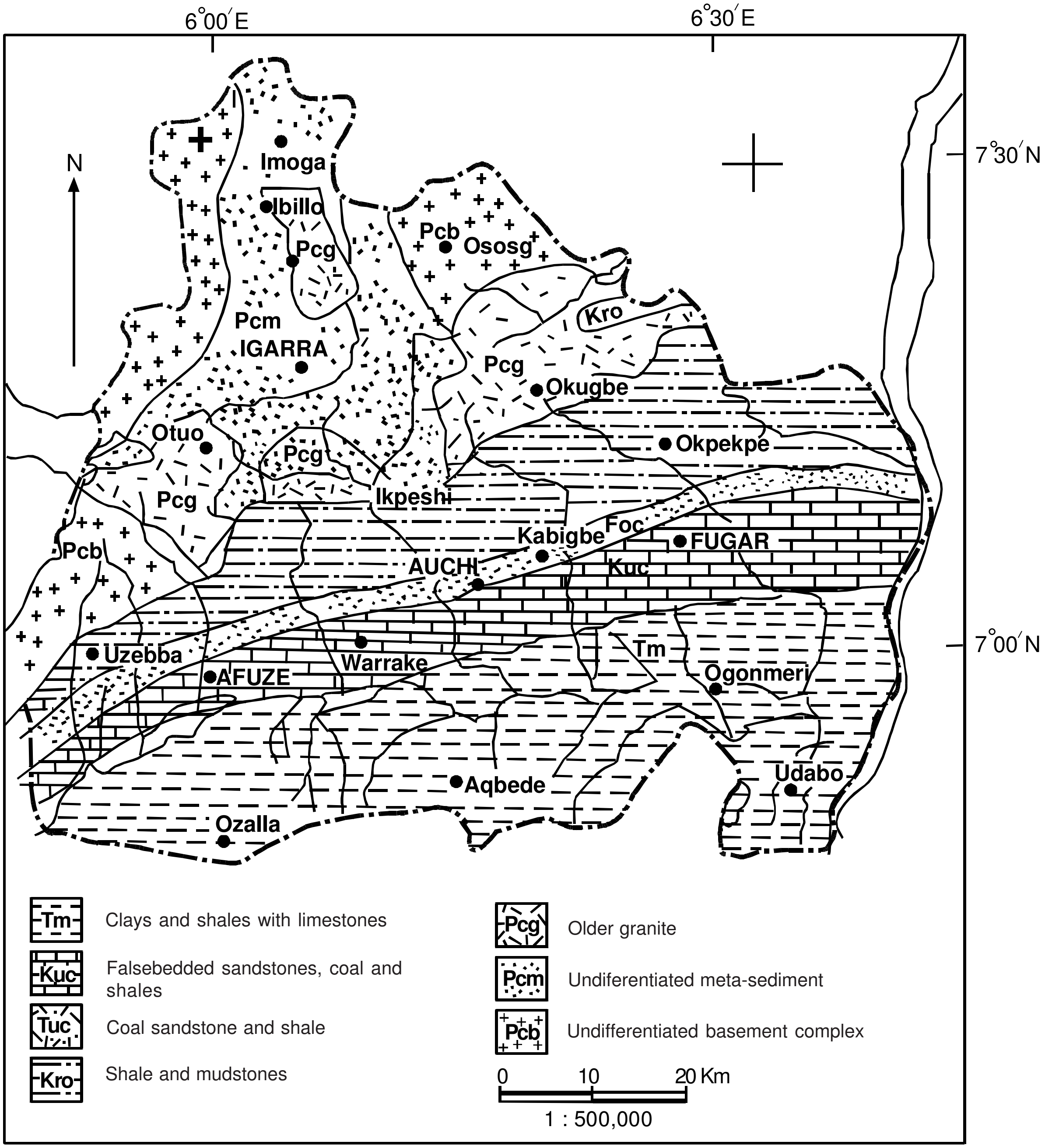

Fig. 2. Geological map of Edo North, South-southern Nigeria.

lain by superficial sand layers of thickness ranging between 0.6 m and 0.7 m at (Oke-ora and Uhonmora) and 4.6 m at Agbede and Ogonmeri in southeastern part of the study area. However, Agbede is shown in section A-A (Fig. 4). Other locations in this section were Aviele, Auchi, Ikpeshi, Igarra and Ososo.

At Ozalla, the overburden sand presented a much higher thickness of over 35 m. It is worthy to note that at Eme-ora and Agbede, the clay deposit was not fully penetrated because of the large thickness of the clay and the fact that accuracy decreases with depth in resistivity sounding. After probing to a depth of about 55 m at Eme-ora and at Agbede, the clay layers were still continuous. This was correlated by borehole log at Eme-ora (Fig. 5). This Agbede clay tagged Imo clay/shale had a southern dip and was also encountered in the southern portion at Ogonmeri.

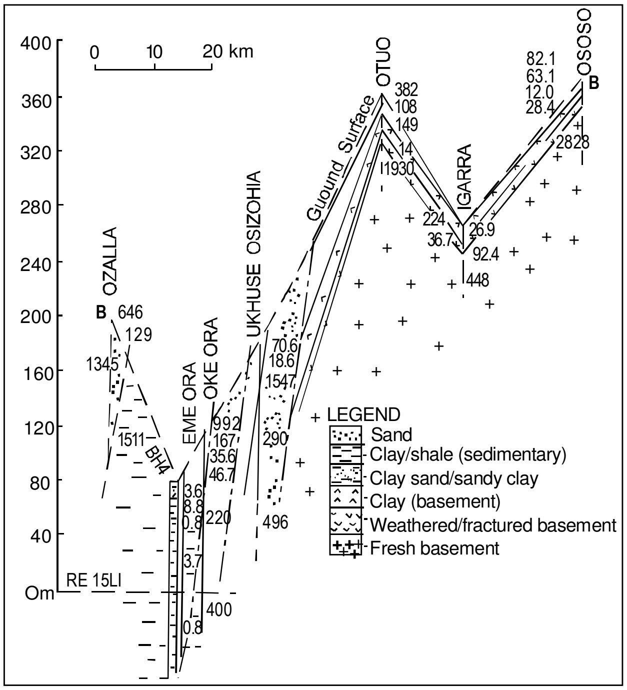

Fig. 3. Cross section B-B showing geological interpretation of vertical electrical sounding (VES) observations as correlated with borehole records; vertical scale applies to surface points at VES and borehole locations only; subsurface depths are exaggerated by a factor of 2.

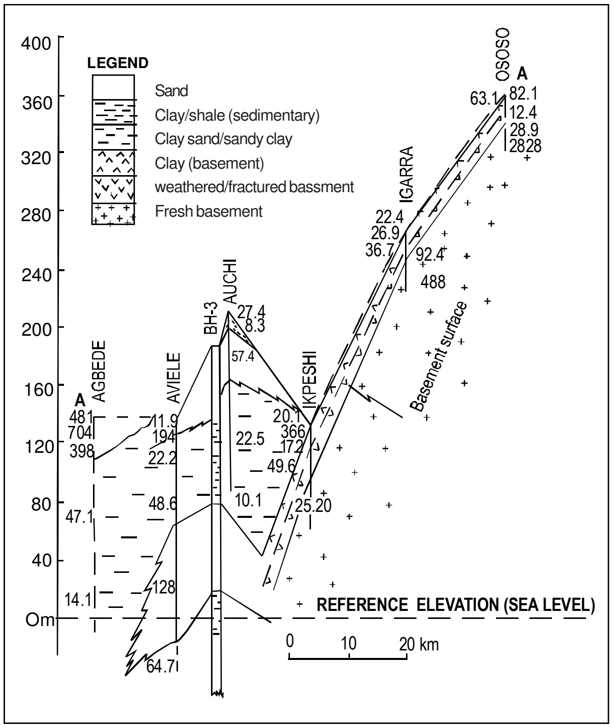

Fig. 4. Cross section A-A showing geological interpretation of vertical electrical sounding (VES) observations as correlated with borehole records; vertical scale applies to surface points at VES and borehole locations only; subsurface depths are exaggerated by a factor of 2.

At Afuze and Aviele, the surface was underlain by a resistive (sandy) material of thickness 5 m and about 3 m, respectively. This surface sand layer was underlain by clay body whose thickness was well over 30 m at Aviele, where it bore a sand mixture in the lower depth. At Afuze, this clay extended to the substratum above a thickness of 40 m. Borehole information from Auchi (Fig. 6) confirmed the interrupted subsurface stratification at these sites. It may be noted, however, that geologically, the Afuze sand/shale bodies belonged to the false bedded sandstone and upper coal measure formation, which directly underlies the Imo clay/shale formation.

Auchi, Fugar and Agenebode have been indicated in cross section C-C (Fig. 7). Other locations in this cross section profile were Sabongida-ora, Oke-ora, Afuze, Ikabigbo. At Auchi, Fugar and Agenebode, the surface material was clayey. However, at Auchi where this surface clay/shale material was being mined, the thickness was about 4.2 m, whereas at Fugar and Agenebode, the thicknesses were 13.4 m and 8.5 m, respectively. It is also noteworthy that this clay/shale material found at Auchi and Fugar was underlain by false bedded sandstone (Ajali) formation exposed at Afuze and Aviele.

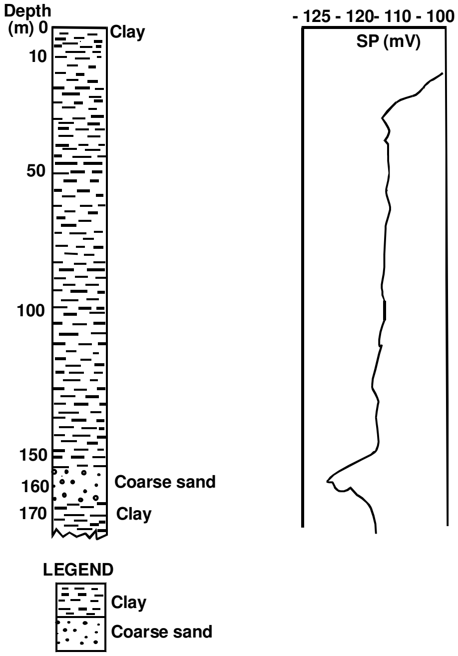

Fig. 5. Driller's log/spontaneous potential logging in Eme-ora.

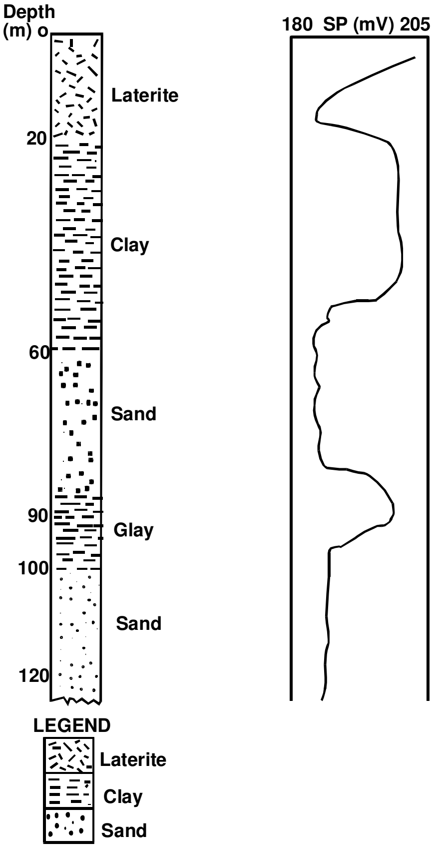

Fig. 6. Driller's log/spontaneous potential logging in Auchi.

At Ikabigbo, this surface clay layer was completely absent, possibly due to erosion. This exposed clay presented shale condition at Auchi that assumed very plastic behaviour at its exposure at the River Ojo valley, between Ikabigbo and Fugar. Although road failure in this area was ascribable to the presence of this plastic clay, it is also believed to be of an economic occurrence that could sustain the production of bricks and other clay related products.

At Uzebba, within the depth of 47.2 m penetrated, no clay layer of appreciable thickness was encountered. At Ukhuse, conductive clayey material of up to 5 m was encountered from the surface, which was immediately underlain by a very resistive layer believed to be dry sand below which lie fairly conductive layers which together with the substratum could be interpreted as clay sand.

Within the basement area, namely, Ikpeshi, Okpella, Atte, Otuo, Igarra, Ososo and Ibillo, distinct clay layers of thickness between 3.1 m to 13 m from the surface were encountered. The above stated results are also expressed in the resistivity contour maps of depth horizon of 1 m, 3 m and 10 m, respectively (Fig. 8, Fig. 9 and Fig. 10), whereas con-

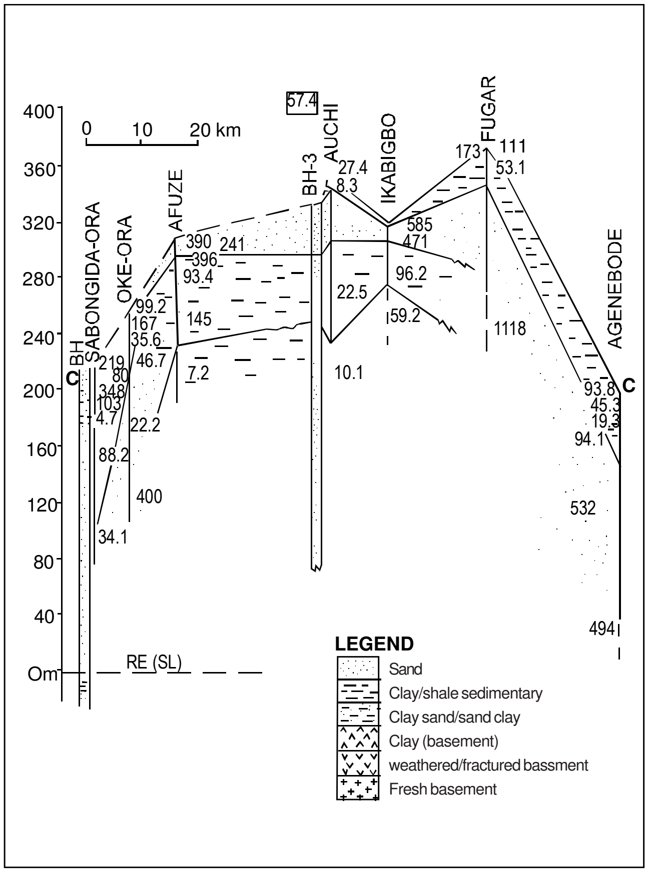

Fig. 7. Cross section C-C showing geological interpretation of vertical electical sounding (VES) observations as correlated with borehole records; vertical scale applies to surface points at VES and borehole locations only; subsurface depths are exaggerated by a factor of 2.

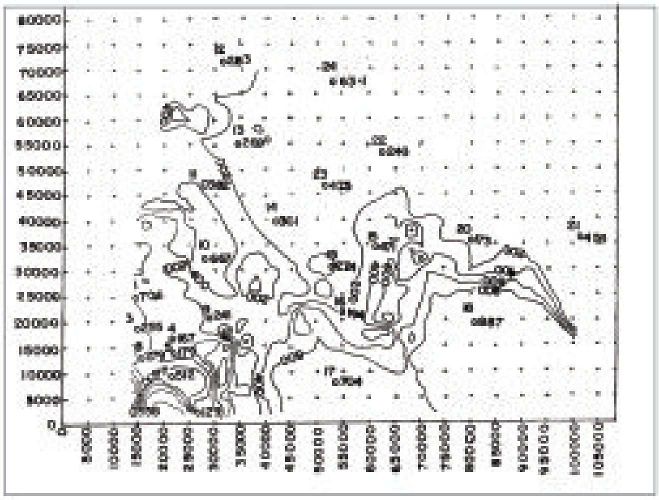

Fig. 8. Resistivity contour map of depth horizon of 1 m.

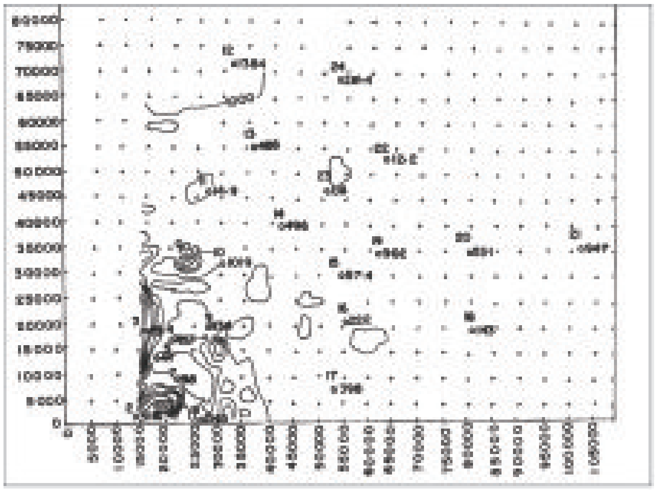

Fig. 9. Resistivity contour map of depth horizon of 3 m.

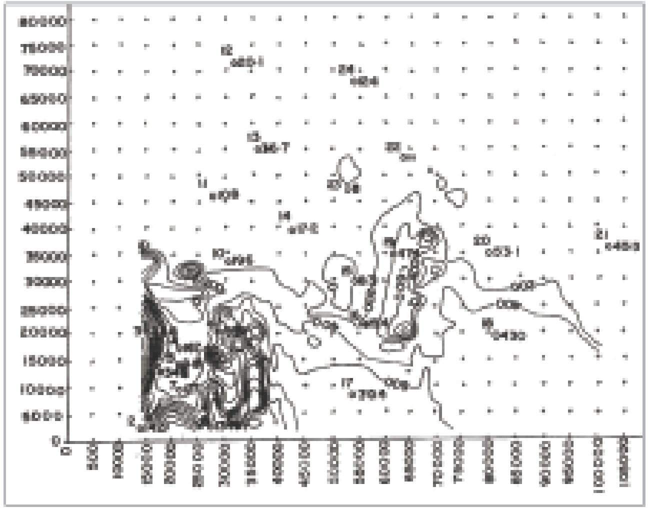

Fig. 10. Resistivity contour map of depth horizon of 10 m.

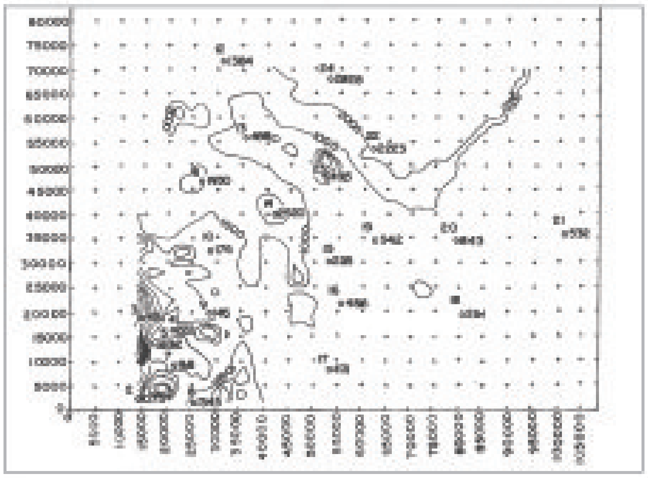

Fig. 11. Resistivity contour map of depth horizon of 30 m.

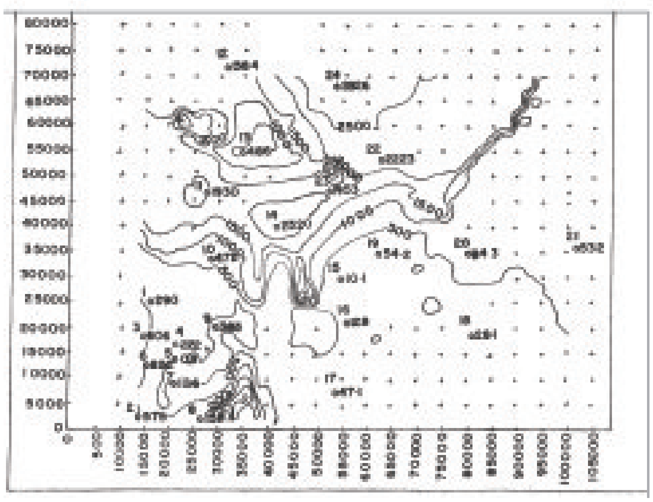

Fig. 12. Resistivity contour map of depth horizon of 50 m.

tour maps shown in Fig. 11 and Fig. 12 are for depths 30 m and 50 m, respectively, which are mainly applicable to locations within the sedimentary environment. In addition, within the basement area, the surface clay layers directly overlie the weathered or fractured basement zone, which in turn precedes the unweathered basement environment and are by no means continuous over the entire area since their occurrence is frequently interrupted by fresh intrusions. In parts of the study area between Igarra and Ososo, economic exploitation of this clay body by local inhabitants for pottery is a common sight.

Acknowledgement

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