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# TWO-DIMENSIONAL RESISTIVITY INVESTIGATION OF CASSITERITE DEPOSIT AT PINGEL VILLAGE, MAGAMA GUMAU, BAUCHI STATE, NIGERIA.

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## ABSTRACT

Two-dimensional geoelectric resistivity survey was conducted at the mining site in Pingel village, Magama Gumau, Bauchi state, Nigeria. The survey was undertaken to characterize the cassiterite deposit in the area. The Schlumberger array was used-and a total of five profiles were taken across the study area and the result of the 2D resistivity survey revealed the occurrence of three to four layers in the geoelectric models. The first layer consists of earth materials with resistivity values mostly less than 120 Ωm, and is inferred to consist of clayey sand and laterite with an average thickness of 4.5 m. The second layer has resistivity range of 60 Ωm to 250 Ωm and may consist of weathered and fracture rocks with cassiterite composition at approximately 7.0 m depth. The third layer is characterized by highly resistive values that is greater than 800 Ωm, at a depth stretching beyond 7 m. The high resistivity values could be associated with the fresh basement.

**Keywords**: Cassiterite, lithology, Geoelectric, Schlumberger array

## INTRODUCTION

Tin is one of the metals known to mankind since the earliest times (Umeshwar, 2011; Kinnaird, 2016). It was possibly one of the first metals used by man as an ingredient of bronze (alloy of copper and tin). Bronze objects such as weapons, tools and jewelry, with 10-14% tin have been found in excavations of different ancient civilization. A bronze rod found in Egypt has been dated back to 3700 B.C. Tin has also been found in the tombs of ancient Egyptians and was exported to Europe in large quantities from Cornwall, England during the Roman period (Umeshwar, 2011). Tin deposits are abundant in China, Malaysia, Indonesia, Peru, Thailand, Brazil, Bolivia, D.R. Congo, Australia, Nigeria, Myanmar (Burma), Russia, Zimbabwe, Rwanda, South Africa, United Kingdom, Mongolia, Colombia, Germany, Canada, Mexico and Morocco (Sainsbury, 1969; Olade, 1980; Carlin, 2012; International tin research L.t.d, 2016). The estimated total world reserve of tin metal as at 2017 is over 4.80 million tonnes and global production amounted to 290,000 tonnes with China being the largest producer (100,000 tonnes) and Nigeria contributing about 2,400 tones. About 80% of tin mined in Nigeria is from secondary deposits found downstream (tin placer deposits) derived from primary tin lodes and granitic rocks (Imeokparia, 2015).

Cassiterite, stannite and cylinderite are the major ore minerals of tin. Tin ores occur mainly in veins, stockworks, disseminations, pegmatites, replacements and placers. Primary tin deposits are formed by magmatic, hydrothermal and/or replacement processes. Secondary deposits are the products of weathering of primary deposits, and the subsequent transportation and deposition of the resulting sediments in a new environment. Cassiterite are trapped in the topographic lows within drainage basin sinks. Resident of Magama Gumao, who live around the drainage sink engage in exploration of these Cassiterite deposits. Like in most mining sites in Nigeria, the search for this mineral in Pingel village is done mainly by artisan miners. These miners employ the technique of 'trial by error' to search for minerals by indiscriminately digging mining pits. This approach is cumbersome, time-consuming, inaccurate and may even be harmful to miners, hence the need for appropriate scientific approach.

According to Pratt *et al.* (1992), the Nigerian younger granite is a petro geologic supermarket. Cassiterite is one of the most important mineral types of the Nigerian younger granite environments. Cassiterite mining is seen to be the major source of employment for residents of the Nigerian younger granite province. Cassiterite is used to prevent rusting or corrosion by simply using it to coat other metals like tin can. It can and equally be used to form many useful alloys such as soft solders, pewter, bronze and phosphor bronze. Circuit-boards for televisions, computers, microwave ovens etc. contain tin because it has a low melting point which makes it ideal for this purpose. If the experiments for electric car use in countries like China and Germany are successful, this could further increase the demand for tin (Akanbi *et al.*, 2012). Thus, the demand for Cassiterite has led to a continuous search for economically viable deposits. Although several works concerning Cassiterite mineralization in Nigeria have been documented, no known work has been done to suggest the best resistivity configuration for delineation and characterization of Cassiterite mineralization.

Geophysics is a discipline that gives information about the earths subsurface without necessarily indulging in the invasive digging of the earth's surface. Its' survey involves measuring the physical properties of the ground (or structure) to determine any variations (anomalies) in the background readings. For geophysical technique to be useful in mineral exploration, contrast must exist in the physical properties of the rocks concerned that are related directly or indirectly to the presence of economically significant mineral. Also, the suitability of a method depends on the sites' peculiar conditions and the composition of target features.

For the purpose of this research, Electrical resistivity method was used to characterize cassiterite (tin ore) in Magama Gumau-Pingel, Toro local government, Bauchi state, Nigeria. This technique has been chosen because it has proven successfully in identifying earth materials with metallic composition, on the basis of resistivity contrast that exist between tin ore deposit and surrounding formation (Saad *et al*, 2012).

**Location, Vegetation and Geology of the Study Area**

The study area is situated in Pingel village, Toro local government area of Bauchi state Nigeria; approximately one hour thirty minutes' drive from Magama-Gumau military check-point along Bauchi-Zaria road. Its geographical coordinates are Latitude $10^0$ 20′00″ N to $10^0$ 22′ 00″ N and Longitude $9^0$ 5′ 00″ E to $9^0$ 7′ 00″E (Figure 1). The area is characterized by two season, wet and dry. The wet season lasts between April and October, with August having the highest precipitation while the dry season extents from November to March. The mean annual surface temperature varies from about $25^0$C to $35^0$C. The temperatures generally fall in July and August periods of the year corresponding to the peak of rainy season, as well as in December and January periods corresponding to the peak of harmattan in the area. The vegetation here is that of Sudan Savannah characterized by grasses, shrubs, thorns and scattered trees.

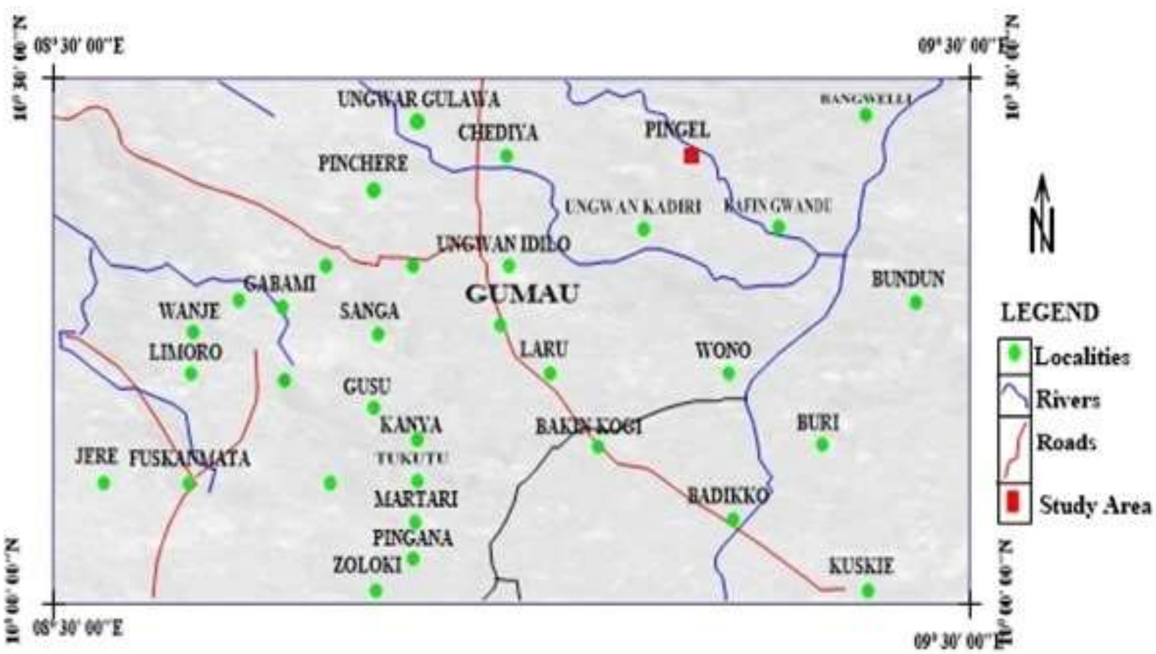


Fig. 1: Location map of the study area.

The rocks in the study area, which is situated at the Younger granite province, is intruded into an undifferentiated amphibolite grade basement composed of migmatites and granitic gneisses (Ajakaiye, 1974). Three major igneous units common to the younger granite suite make up the exposure and exhibit sharp mutual contacts (Raeburn *et al.,* 1927; Turner, 1972; Jacobson and MacLeod, 1977). In chronological order these are volcanics, biotite granite and albite riebeckite granite. Remnants of an initial volcanic phase are preserved as a narrow outcrop of explosion breccia 600 m long and up to 60 m wide composed entirely of basement rock fragments up to 0.3 m in diameter along the southern flank of the complex (Jacobson and MacLeod, 1977). The main intrusive forms 80% of the exposed complex and is nonporphyritic fine- to medium-grained biotite granite which has a homogeneous macroscopic texture and composition (Jacobson & MacLeod, 1977). Its well-developed north-northwest joint system controls drainage in the immediate vicinity of its outcrop (Ajakaiye, 1977). The most prominent of this lineation occurs as a broad steep-sided flat-bottomed valley up to 1 km wide containing an underfit stream which drains to the northwest from the central part of the biotite granite exposure. Preliminary interpretation of aerial photographs of this feature suggests that it may be a fault or shear zone (Ajakaiye, 1977). The biotite granite is the source rock for the tin deposits mined on a very small scale in the area although Raeburn *et al.,* (1927) noted that the complex exhibited excessive tin mineralization for its outcrop size. Tin deposits are typically associated with biotite granite throughout the Younger Granite Province.

A later intrusion of albite riebeckite granite, which is somewhat arcuate and poorly exposed, flanks the biotite granite on its east side. It is extremely variable in texture but is compositionally homogeneous except in the degree of late stage albitization (Jacobson and MacLeod, 1977). Contacts with the basement rocks to the east are poorly defined. Several felsitic dikes (mostly biotite microgranites) associated with the biotite granite (Jacobson and MacLeod, 1977) cut the granite as well as basement rocks adjacent to the southern and eastern margins of the complex. The sequence of extrusive and intrusive igneous events in the province is well documented (Turner, 1963, 1972) and consists of an initial predominantly acidic volcanic phase accompanied or immediately followed by the formation of a peripheral vertical-sided ring fracture which broke the surface and which was filled, in most cases, with granite porphyry upon subsidence of the rock's interior to the ring fracture. A long waning felsic intrusive phase followed. In the case of the study area, the present outcrop limits give the probable extent of the associated initial ring fracture. Ring fracture followed by cauldron subsidence is considered to be the major mode of intrusive emplacement for the younger granites and is thought to give rise to plutons roughly circular in plan with generally steeply dipping contacts (Turner, 1963, 1972; Black & Girod, 1973; Jacobson & MacLeod, 1977). Once ring fractures are created ring dikes can be produced by cauldron subsidence, block or piecemeal stoping (Billings, 1945), reduction of magma chamber pressure to produce settling of the central block (Anderson, 1936) or upward removal of host-rock debris within the fracture by gas coring or volcanic activity (Turner, 1963). Figure 2 is the geological map of the study area and environs showing the various rock units.

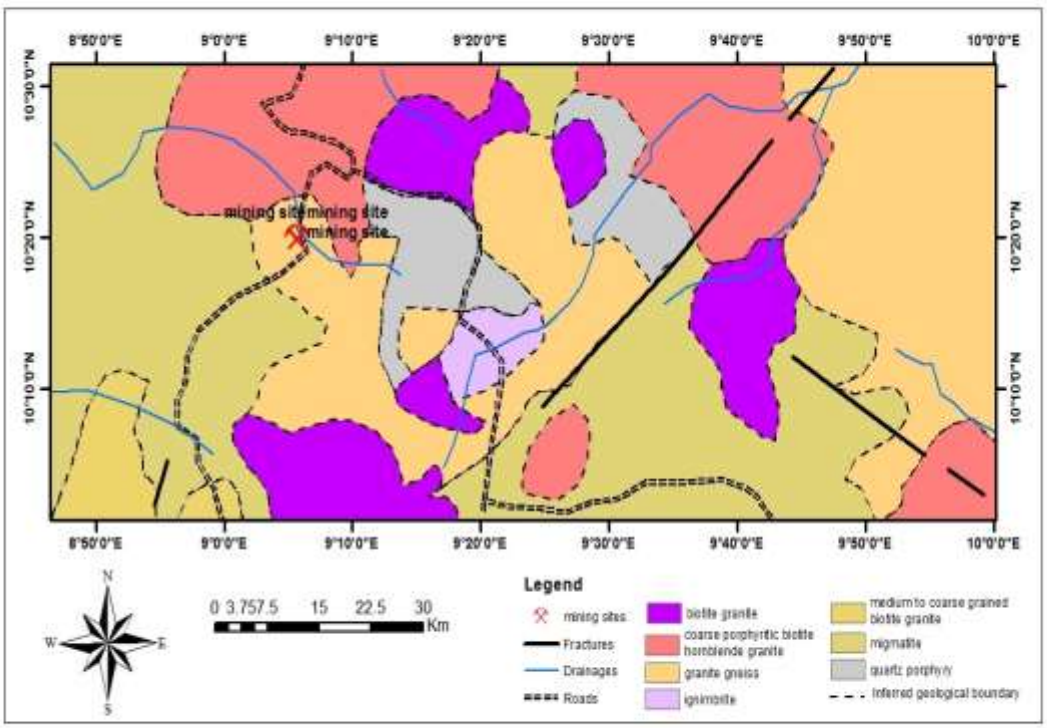


Fig. 2: Geological Map of the Study Area. (Source: Nigerian shape file, Nigerian Geological Survey Agency 2014).

## MATERIALS AND METHODS

### Data Acquisition and Processing

The Electrical Resistivity method employs artificial source of current, which is introduced into the ground through current electrodes. The procedure then is to measure potentials between the potential electrodes in the vicinity of the current flow. From these measurements, the resistance is computed and converted into apparent resistivity, from which the true resistivity of the subsurface is estimated by inversion using the RES2DINV computer program. Several arrangements of the current and potential electrodes are possible but for the purpose of this research the gradient electrode arrangement is employed.

2D Electrical resistivity data set were acquired along five profiles with the Schlumberger array using a multi electrode system. Electrode spacing of 2 m for 42 electrode systems was utilized which sums the total length each traverse covered to be

315 m. Three Profiles (Profiles 1 to 3) were laid parallel to each other, 5 m apart while the other two, Profiles (4 and 5), were laid perpendicular to Profiles 1 to 3. Profile one, two and three are trending in the west-east direction and profile four and five trend in the north-south direction. The test profile is trending in the NE-SW direction.

Prior to data inversion, the apparent resistivity data set were inspected in accordance with the suggestion of Loke (2002) for bad datum point and such points were deleted. The 2D ERT of each profile was inverted using the RES2DINV software (Geotomo software).

**Interpretation of Results**

To obtain such geological results, available and reliable geological controls are necessary for a reliable interpretation of geophysical data. Such controls are often obtained from borehole data, results of previous works within such an area and a good knowledge of the geology of the area. A borehole log in the study area was used as control (figure 3). The top soil comprises mainly of the overburden (laterite and clay), cassiterite bearing layer and the granitic rock.

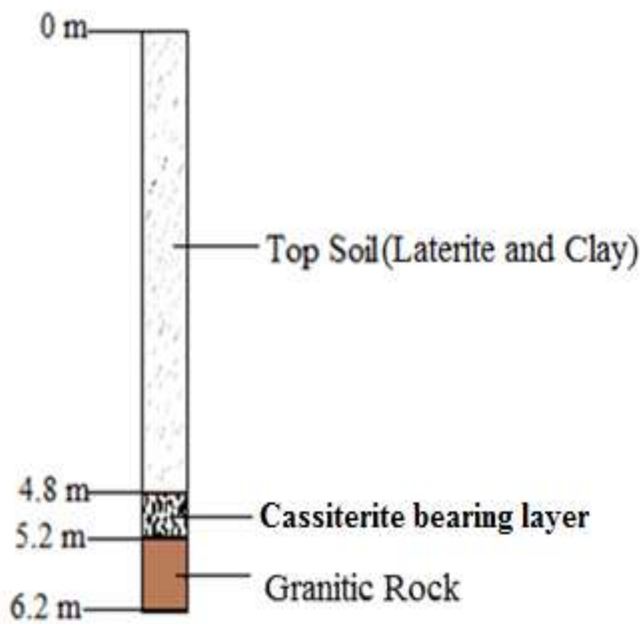


Fig. 3: Lithological log of Pingel Village (Center for geology and geodesy, Toro).

Figure 4 to 8 shows the 2D pseudo-sections for each of the profiles. All the profiles show the inversion result with an absolute error (RMS) of 4.2% for profile 1, 3.5% for profile 2, 4.9% for 3, 3.9% for profile 4 and 3.9% for profile 5. Thus, indicating that a good fit between the measured and calculated apparent resistivity data has been achieved.

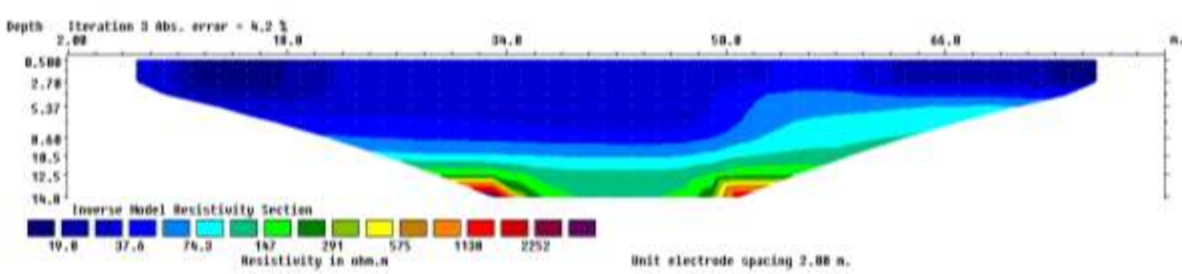


Fig. 4: Result of 2D Inversion of the Schlumberger Configuration Data along Profile 1.

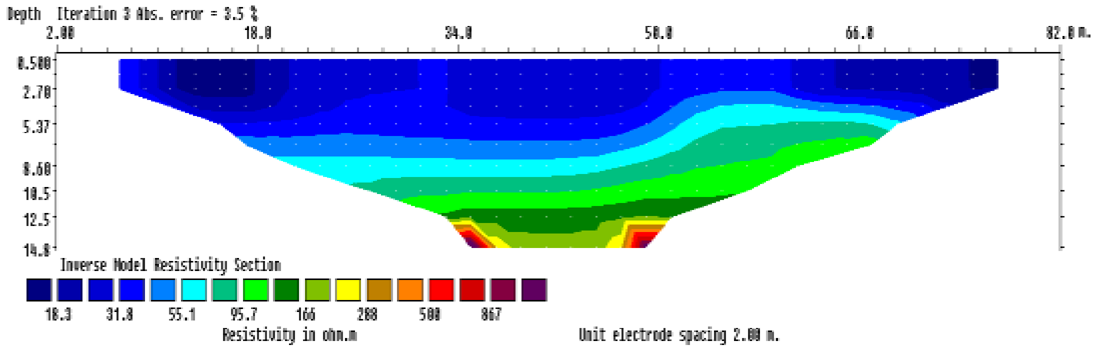


Fig. 5: Result of 2D Inversion of the Schlumberger Configuration Data along Profile 2.

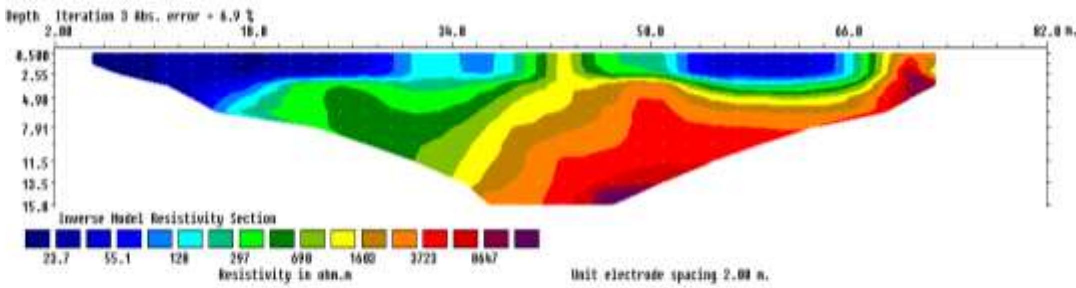


Fig. 6: Result of 2D Inversion of the Schlumberger Configuration Data along Profile 3.

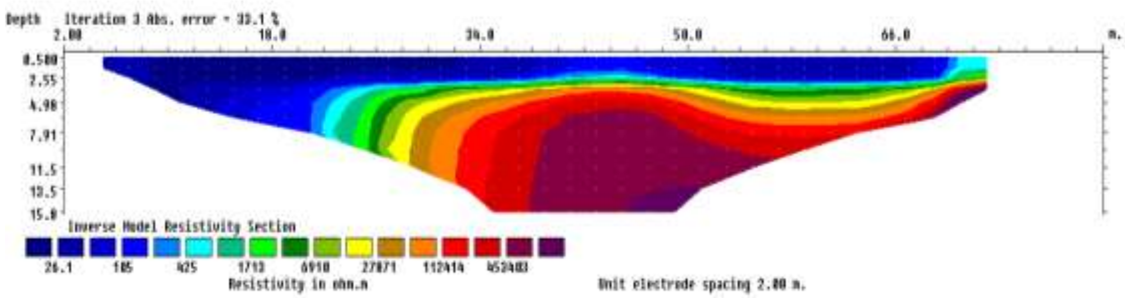


Fig. 7: Result of 2D Inversion of the Schlumberger Configuration Data along Profile 4.

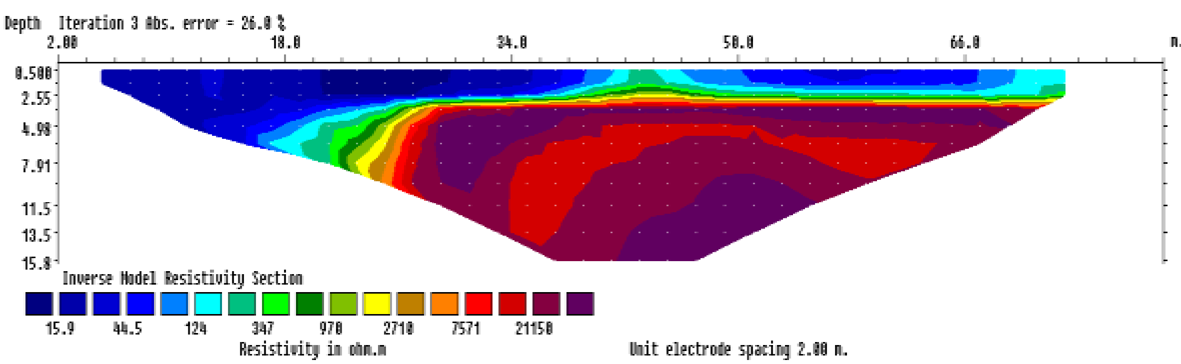


Fig. 8: Result of 2D Inversion of the Schlumberger Configuration Data along Profile 5.

## DISCUSSION

Lithological information and representative resistivity values of earth materials used in this study in classifying the geologic layers were derived from Akanbi *et al.*, 2017, and are as follows; 1 to 300 Ωm- overburden resistivity; 300 to 400 Ωm- weathered granite; 400 to 600 Ωm- cassiterite bearing layers; > 600 Ωm- granitic rocks and fresh basement. Cassiterite is dispersed in multitudinous, narrow greisen veins and quartz stringers in the roof zones of biotite granite intrusions, and usually entrapped within parent rock beneath an impermeable cover of roof rock dykes i.e. the biotite granite intrusions (Macleod *et al.*, 1971; Obaje, 2009). Erosion of these rocks over time would have rapidly uncovered some extensive area of cassiterite bearing granite and thus facilitate wide distribution of cassiterite in the surrounding drainage system.

Two-dimensional electrical resistivity survey was then conducted within the unexplored/unexploited area of the Cassiterite mining site. Data was obtained along a total of five profiles using the Schlumberger array.

The result of the 2D electrical resistivity inversion reveals three to four layers in the surveyed area. The first layer (topsoil) consists of earth materials with resistivity values mostly less than 120 Ωm. This layer is inferred to consist of consolidated materials mainly clayey sand and laterite deposit in composition. It has an approximate thickness of 4.5 m. The second layer has resistivity values ranging from 60 Ωm to 240 Ωm and may consist of weathered and fractured rocks with cassiterite composition at approximately 7.0 m deep.

The third layer is composed of highly resistive materials, generally greater than 800 Ωm, at depth stretching beyond 7 m. The high resistivity values in the third layer could be associated with the fresh basement.

Suspected igneous intrusions and fractures were observed within the subsurface along the profiles three and five. This suggest a possible relationship between these fractures and igneous intrusions. The probable depth to cassiterite bearing layer is 4 – 7 m from the surface, with resistivity range of 500 Ωm – 700 Ωm.

Considering profiles one, two and four, the probable depth to the cassiterite bearing layer is 4 – 7 m. Suspected igneous intrusions were also observed along profiles one, two and four, which could be dykes forming intrusion of biotite granites and cassiterite occurs only in association with biotite-granite. The cassiterite deposit has a thickness of about 3 m across all five profiles and this deposit is just beneath the weathered basement.

## CONCLUSION

The 2D electrical resistivity sections revealed suspected igneous intrusions and fractures which are structures relevant to cassiterite mineralization. It also revealed the average depth to cassiterite bearing layer and to the basement.

The result further revealed the occurrence of four layered geoelectric sections within the study area. The top layer consists of low resistive materials, probably clay with mean thickness of 4.5 m. The second layer, just below the top layer, is inferred to be the weathered basement, containing the cassiterite bearing layer. It consists of materials with varying resistivities between 50 Ωm to 250 Ωm at depth of approximately 6.0 m. This layer is inferred to be the host for Cassiterite mineralization. The third layer is the fresh basement having resistivity values greater than 800 Ωm.

Based on the finding of this study, it can be concluded that the study area has high cassiterite potential and if the mining activities are well coordinated, it can generate income for the rural dwellers as well as the state at large.

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## REFERENCES

Ajakaiye DE (1983) Deep structures of alkaline ringcomplexes from geophysical data. In: Abstract, international conference on alkaline ring complexes in Africa. Zaria, Nigeria

Akanbi, E.S, Ugodulunwa F.X.O and Gyang B.N (2012). Mapping Potential Cassiterite deposit at Naraguta area north central Nigeria using geophysics and geographic information system Journal of mining and geology volume 13, 21-26.

Akanbi, E.S, Ugodulunwa F.X.O and Gyang B.N (2017). 2-D Electrical Resistivity Survey for Cassiterite Potential Mapping in Jos-Bukuru Area, North Central, Nigeria. Journal of Geography, Environment and Earth Science International 10(1): 1-12.

Carlin JF. (2012). Tin: Statistics and Information. United States Geological Survey Mineral Commodity Summaries, pp. 170-171.

Imeokparia EG. (2015). The Applied Geochemist and the Challenges of Georesource Evaluation for Sustainable Development and Environmental Management. Inaugural Lecture delivered at University of Benin, Benin City, Edo State, Nigeria.International Tin Research Institute Ltd. (ITRI Ltd.). (2016). Report on Global Tin Resources & Reserves (Security of Long-term Tin Supply). 20.

Kinnaird JA, Nex PAM, Milani L. (2016). Tin in Africa. Episodes 39(2): 361-380. https://doi.org/10.18814/epiiugs/2016/v39i2/95783.

Macleod WN, Turner DC, Wright EP. The geology of the jos plateau; General Geology Bulletin Geological Survey, Nigeria. 1971; 32:118.

Olade MA. (1980). Geochemical characteristics of tin-bearing and tin-barren granites, northern Nigeria. Economic Geology 75: 71-82. https://doi.org/10.213/gsecongeo.75.1.71.

Obaje N. G. (2009). *Geology and Mineral Resources of Nigeria*. Springer-Verleg Berlin Heidelberg.

Pratt, L.M., Comer JB, Brassell SC (1992) Geochemistry of organic matter in sediments and sedimentary rocks. SEPM Short Course 37:100 pp.

Saad .R.,Adli, and Mohamed, A.S.(2012). The Study of Iron Ore Prospect using 2-D Resistivity and Induced Polarization Method Electronic. *Journal of Geotechnical engineering*. vol.17.bund.

Sainsbury CL. (1969). Tin Resources of the World. US Geological Survey Bulletin 1301, p. 55.

Turner DC. (1983). Upper Proterozoic Schist Belts in the Nigerian Sector of the Pan-African province of West Africa. Prec. Res. 21: 55-79. https://doi.org/10.1016/0301-9268(83)90005-0

Umeshwar P. (2011). Economic Geology (Economic Mineral Deposits). 2nd ed. CBS Publishers and Distributors, p. 319.