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AIRBORNE MAGNETIC STUDY OF OTUKPO AREA

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ABSTRACT: *The study is carried out in Otukpo area of Benue State, North central Nigeria. Geologically the area is underlain by Cretaceous sediments of the Benue Trough, mainly shales, sandstones and limestones. Aeromagnetic map of Otukpo was digitized, processed and interpreted for anomalies and causes of anomalies in the area. The airborne magnetic survey provided information about folding; the differential uplift of basement resulting from magmatic intrusions, gave rise to drape folds in the overlying sediments. Airborne anomaly indications have clearly defined large igneous bodies. These intrusive rocks of intermediate basic composition occur in the Santonian and Albian shales. Two layers of sedimentary features were observed. The average thickness for the first and second observed layers is 0.37km and 1.8km respectively. The Basement depth ranges from 3 to 8.2km. Calculated magnetic susceptibility contrast of the area was 0.073-1.71 electromagnetic units. Areas of geological interest which are exploration targets were delineated. They include areas of broad magnetic intensity anomaly closures, which are zones of structural displacement associated with deep seated basement, areas of magmatic intrusions, dyke spots, fractures and fault zones. These structural studies may yield clues to the location of concealed mineral deposits.*

KEYWORDS: Aeromagnetic Map, Digitized, Processed, Sedimentary Features, Magnetic Susceptibility Contrast, Basement Depth, Thickness and Magnetic Intensity Anomaly Closures

INTRODUCTION

On a large scale, airborne magnetic studies are used for delineation of geological structures. Magnetic methods are based on measurement of small variations in magnetic field. This field is affected by any variation in distribution of magnetized (or polarized) rocks. Variations in the magnetic field may be caused by in homogeneities in composition of basement rocks or by structural or topographic relief of the basement surface. The measured variations are interpreted in terms of the probable distribution of magnetic material below the surface, which in turn is the basis of inferences about the probable geologic conditions. The interesting indications from aeromagnetic method can be selectively tested by a much expensive, but usually more certain method or in favourable circumstances, directly by drilling. In this way the more expensive exploration is concentrated in the areas that have higher probabilities of yielding favourable production of minerals associated with the area. The result of one technique may provide information which makes it possible to apply another technique more intelligently. Otukpu area (sheet 270) lies between longitude $80^{0}00^{l}$E to 8^{0} 30^{l}E and latitude $7^{0}00^{l}$N to 7^{0} 30 ^{l}N in Benue State, central Nigeria. It is endowed with tropical climate and Savannah Woodland Vegetation. The objectives of the study are to determine the local relief of the basement surface capable of producing sub surface structural relief which could be favourable for the accumulation of mineral deposits, to determine depths to magnetic sources, modeling of an individual basement feature and determination of its major geometric parameters such as inclination and susceptibility (K) of the anomaly.

Geology of the Area

The area under study is underlain by Cretaceous sediments of the lower Benue Trough located in the southern area of Benue valley. The Benue Trough has often been described as an intracontinental Cretaceous basin, occupied by up to 6,000m of marine and fluviodeltaic sediments that have been compressionally folded in a non-orogenic shield environment (Wright, 1976).The following geological formations are found in the area. They are namely; Asu River Formation, Eze-Aku Formation and the Awgu Formation. The oldest sediments present in the area belong to the Albian Marine transgression. Middle Albian transgression caused the deposition of very thick marine, dark, grey shales, siltstone and subordinate limestone of the Asu River group, which uncomformably overlie the crystalline basement rocks of pre-Cambrian age (Nwachukwu, 1972).The second cycle resulted in the deposition of Eze-Aku Formation at the end of the Cenomanian transgression that ended with a regression in the early or beginning of Turonian. The Eze-Aku Formation consists of thick flaggy calcareous and non-calcareous shales, sandy or shaleylimestones, and calcareous sandstones. It overlies the ASU River Group (Nwajide, 1986).The Eze-Aku Formation is overlain by Coniacian Awgu Shale Group. This group comprises bluish-grey, very soft, shallow marine bedded carbonaceous mudstones with occasional muddy limestone and siltstones as well as a narrow band of sandstone formation, which is generally fine to medium grained and moderately cemented (Agagu and Adighije, 1983; Agagu et al, 1985)

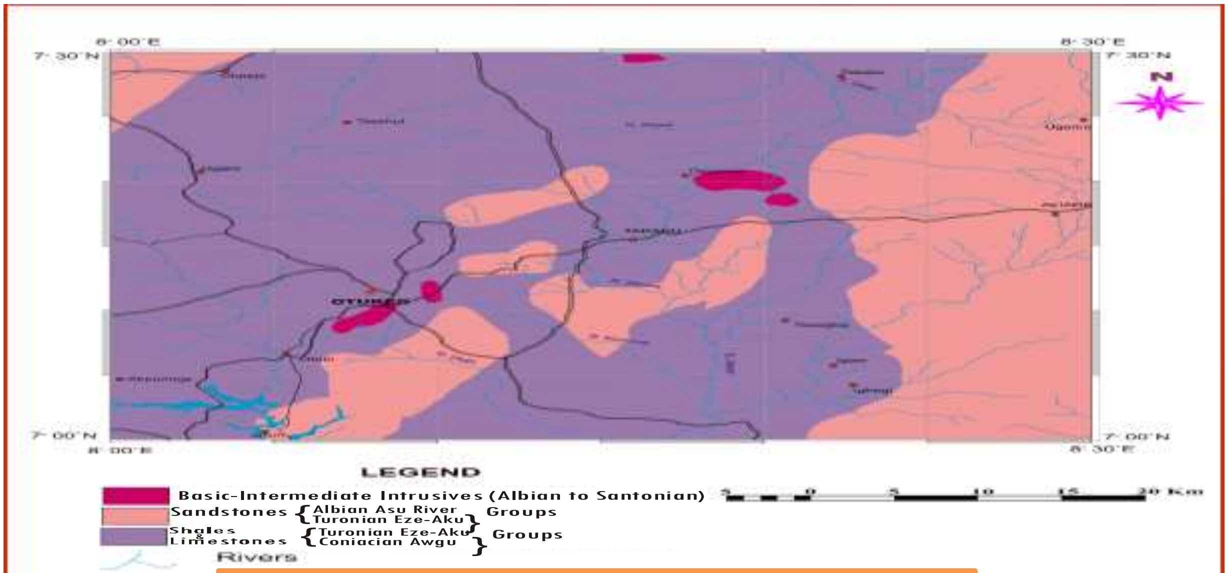

Fig. 1 Geological map of the study area

METHODOLOGY

The aeromagnetic map of the area was obtained from Geological Survey Agency of Nigeria (GSAN), Abuja. The total intensity aeromagnetic map was produced as part of nation-wide airborne geophysical survey sponsored by the Government of Nigeria. The data are published in the form of aeromagnetic map on a scale of 1:100,000 (Fig. 2).

Fig. 2. Aeromagnetic map of the area

The aeromagnetic map was digitized at an equal spacing of 1km on a 52 by 52 grid lines. The data was fed into a computer file (MS DOS) which serves as the input file for the computer program. This program calculates the longitude, latitude and the magnetic values of the coordinates as X, Y and Z which is then accepted by the contouring package 'SURFER'. This SURFER package produces a contour map that is similar to the original aeromagnetic map. This contour map produced is known as composite map (figure 3). The second stage involves residual separation. This serves as a filter which emphasizes the expression of local features, and removes the effects of large anomalies or regional influences.

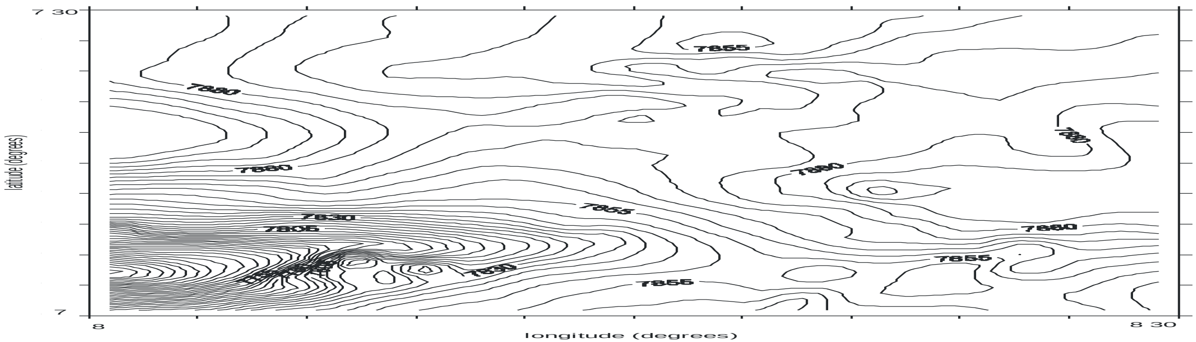

Fig. 3: Total Magnetic Field 25,000 gamma is to be added to give the actual field values. Contour

Analytical Signal Method of Regional – Residual Separation

The analytical method of determining the residual anomalies involves the use of numerical operation on the observed data to isolate the residual anomalies without relying on the visual graphical method.

The analytical method requires the magnetic values to be spaced in a regular array or grid. The polynomial fitting analytical method is based on computer program that is founded on statistical theory; since the observed data are computed by least square method to obtain a surface that has the closest fit to the magnetic field (Johnson, 1969).

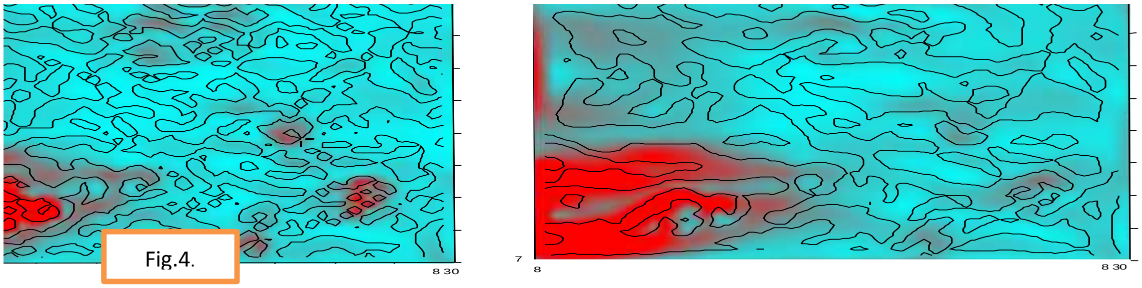

Fig.4.

Maps showing the results of the Analtytic signal technique. The results are a combination of the output from the analytic signal tecnique superimposed on the zero contours obtained by apllying a Laplacian operator. (a) The technique applied at flight height.
(b) The technique applied for the data continued 1 km above the flight height.

Fig. 5 shows the residual magnetic anomaly map of the study area with profiles taking across prominent anomalies. From this a major anomaly profile EF was modeled.

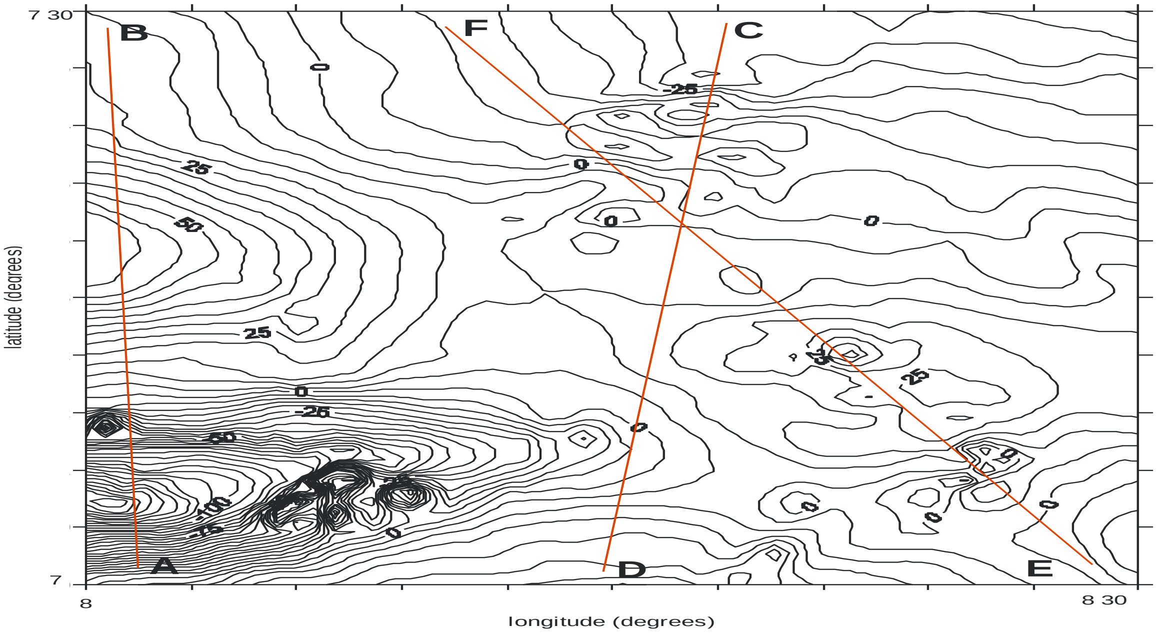

Fig 5 : Map showing profiles taking across prominent anomalies within the area of study.

Upward and downward continuation of Magnetic observation

The error curve method requires a contour map and program for continuing the mapped data upward and downward. The depth to the top of the body causing anomaly can be estimated from the result.

Figs. 6 & 7

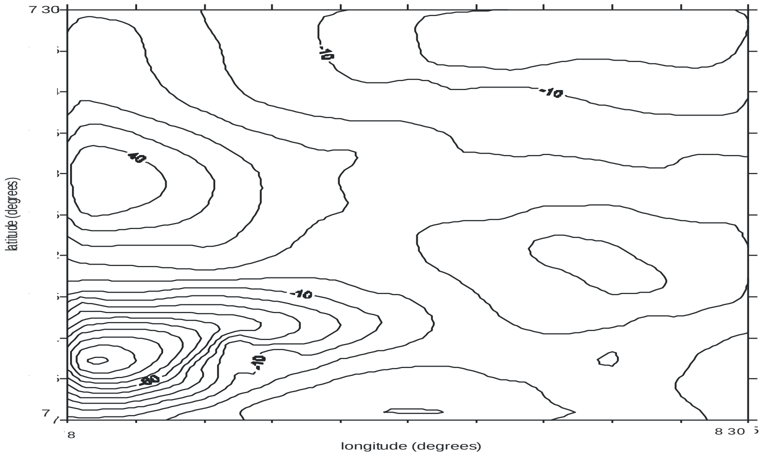

Fig 6: Upward continued field 1 km above flight height. Contour

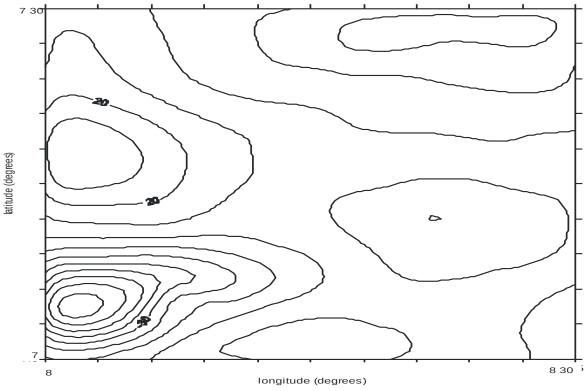

Fig 7: Upward continued field 2 km above flight height.

Depth Estimation of Magnetic Source by means of Spectral Analysis

Any process that quantifies the various amounts of light, sound, radio waves etc. versus frequency can be called spectrum analysis. It can be done on many short segments of time, or less often on longer segments just once for a deterministic function such as the Fourier Transform. The Fourier analysis of magnetic data, with the application of computerized procedure is a standard technique for analyzing aeromagnetic data. Spector and Grant (1970), Hahn et al, (1976); and many others have analyzed one and two dimensional aeromagnetic data using this algorithm. The Fourier Transform of a function produces a spectrum from which the original function can be reconstructed (aka synthesized) by an inverse transform.

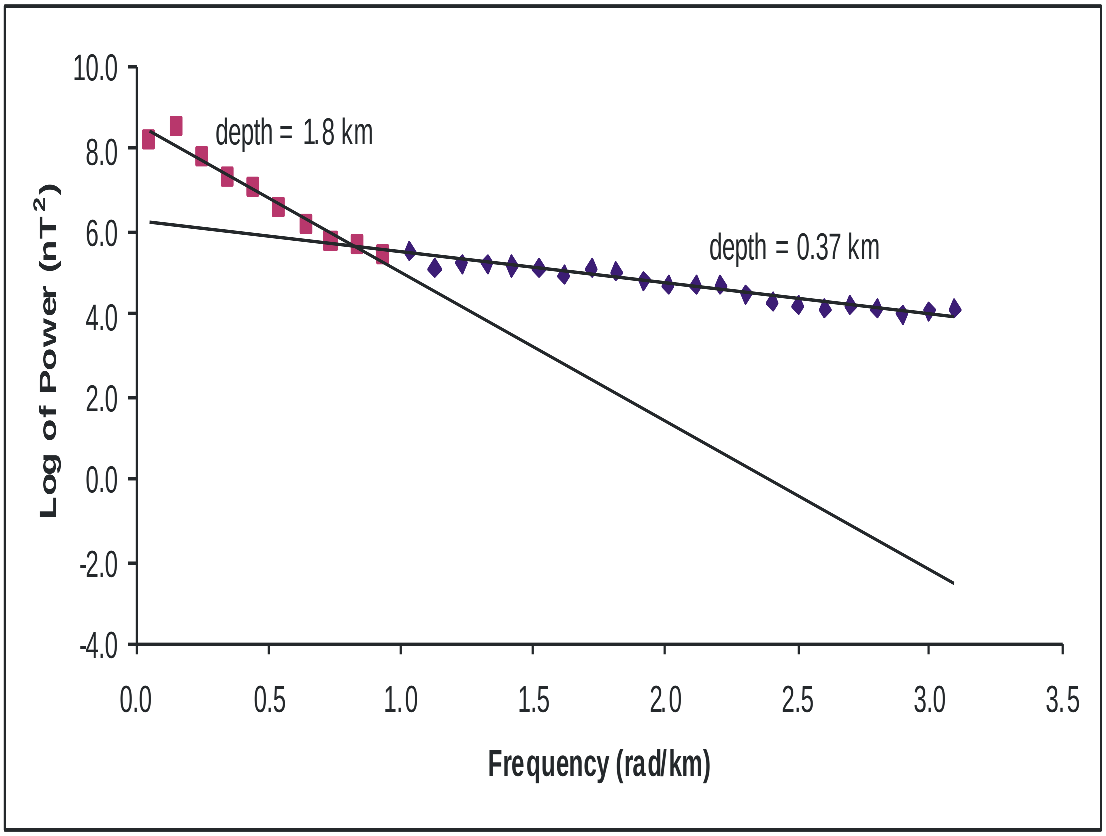

Fig 8: Power spectrum graph for the area of study. Two layers can be observed with their respective depths as shown

In graphical representations, often only the magnitude (or squared magnitude) component is shown. This is also referred to as a power spectrum. The power spectrum itself is the Fourier transform of the auto-correlation function. To estimate depth, the average amplitude together represent a spectrum which when plotted in a semi-logarithmic co-ordinate system (log amplitude versus frequency) often shows straight segments which decrease with increasing frequency. By continuing the given field downwards these straight segments become horizontal at a certain depth, the so called “white depth” (Hahn, 1965). This white depth may be used as a first estimate for the depth to magnetic bodies of the anomalous field under consideration.

Development of Model

GM- SYS Modeling Method

There are several methods of modeling in aeromagnetic interpretation. Choice of technique in any survey depends on the structures intended to model and also the purpose of the survey.The reason for this work is to first determine depth to basement and then model the shape and depth of structures in the study area. This method uses a two dimensional flat earth model for magnetic calculations; here each structural unit or block extends to plus and minus infinity in the direction perpendicular to the profile. This GM-SYS make use of interactive graphics to significantly speed up the interpretation processes.

In GM – SYS, the methods used to calculate magnetic model response are based on the methods of Talwani and Heirtzler (1964), and makes use of the algorithms described in Won and Bevis (1987). The results from GM-SYS have been analyzed and found correct by several organizations that use it for geophysical consulting work.

The development of the models involved the following steps

1. Filtering the bouguer anomaly to obtain the residual anomaly which arises from sources shallower than 4Km (Mareschal, 1985).
2. Inversion of the residual anomaly with a constant density contrast to obtain a model of the basement.
3. Adjustment of the inversion parameters and of the basin sediment density to obtain a model for basement depths which satisfies the profiles taken across prominent anomalies within the study area.

One condition for the modeling to succeed is the basin (valley) stratigraphy can be represented by two layers, Miocene and younger sediments and the Cretaceous basement with the primary density contrast between them.

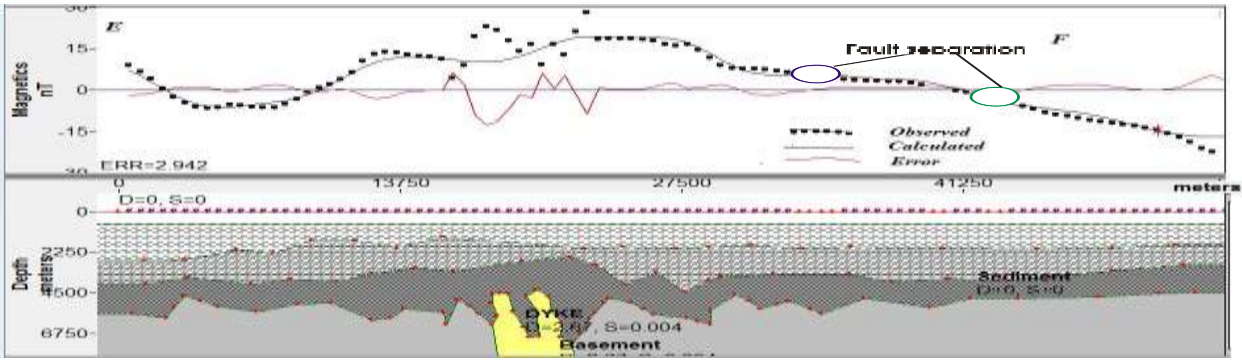

Figure 9: Model of profile EF

Interpretation of the Aeromagnetic Anomalies

The smaller local disturbances, which are of primary interest in many magnetic interpretations are known as the residual anomalies and may provide evidence of the existence of mineral ore bodies or reservoir type structures. These are established exploration targets.The interpretation, explanation and guide presented here is directed primarily towards a qualitative and quantitative interpretation for both geological reasons as well as search applications, i.e. an understanding of what causes the anomaly, its approximate depth, configuration, perhaps magnetic content or mass, and other related factors.

It is more often that estimated depths provide a good starting point for a genuine structural interpretation. Magnetic depth estimates provide insight into the evolution of more recent sedimentary features. Two layers can be observed Figure 8. The average depth to magnetic sources within the first layer of Cretaceous sediment is 0.37km while it is 1.8km at the second layer.Upward/downward continuation of magnetic observation in aeromagnetic interpretation technique is sometimes used in order to simplify the appearance of magnetic maps by suppressing local features. The proliferation of local magnetic anomalies often obscures the regional picture, but upward continuation is used to smooth out these disturbances without repairing the main regional features, figure 7.

The upward continued field in Figure 6 clearly amplifies the major anomaly which was filtered to reduce the other unwanted signals. The Bouguer anomalies show strong positive gradients which appears to be due to deeper regional features (structures deeper than the Cretaceous sediment i.e. the basement). When tectonic stresses were applied, these zones of weakness were more likely to fracture and fault. This is an area of interest to a mineral exploration geophysicist, as variation of basement composition is often correlated to basement structure.The broad magnetic closures seen in Fig. 7 are often due to changes in the rock composition within the basement. The sources of the regional magnetic anomalies in this area are interpreted as igneous activity as evident in analytical signal map in Fig. 4. This is because the area is occupied by Cretaceous sediments mainly comprising shales, sandstones and limestones considered to be non-magnetic.

In profile EF (Fig. 9), the anomaly amplitude exhibits an increase in frequency content which is indicative of the magnetic response from crustal structure. The anomalies due to structure will always exhibit higher frequencies. The suprabasement effects (basement topography) have been generated by variable lithology. The basement depth ranges from 4 to 7.3 km towards the eastern part of the intrusion.

Dyke: The sediment is intruded by a wide dyke (portion of magma which cool in cracks and vents). Such unexposed structures are potentially of economic interest. Minerals are associated with the roof zones of such intrusive and their contact zones with the host rock. The depth to the top of the dyke is 4.7km; it has a width of 3.6km and is intruded 2.8km into the sediment. Dyke rocks are not often themselves metalliferous but they have exercised a potent influence on the distribution of metalliferous deposits. Intrusive bosses, such as those of granite, are often impregnated with tin-stone near the contact with sedimentary strata. During the process of cooling, most of the water and gases are expelled as highly heated steam and gases, laden with dissolved metals, which were after wards deposited in the zone of fracture.

Calculated magnetic susceptibility contrast of the area was 0.073 – 1.71 electromagnetic units.

CONCLUSION

The interpretation and explanation of the major features revealed by this airborne magnetic survey in terms of types of likely geological formations and structures which give rise to the evident anomalies is a suitable physical approximation to the unknown geology of the locality. Basement depth (or equivalently, sedimentary thickness) is a primary exploration risk parameter. Magnetic anomaly interpretation is a major element in mineral exploration geophysics.

Thus the mean depth to the top of the basement obtained by the spectral method over and around Otukpo area may provide some useful information with regard to first order geologic interpretation, and thickness parameter useful for the indirect quantitative interpretation of magnetic data in the region.

The structural history of the area is thought to be one in which emplacement of sills and intrusive dykes have taken place. These structural studies yield clues to the location of concealed mineral deposits. Linear zones consist of weak crustal areas that have provided favourable sites for upwelling intrusive and mineralizing fluids. These areas contain faults or fractures associated with deep seated basement structures and the intersections of these features with other faults can provide favourable loci for mineralization.

Finally, the selections of exploration target zones have been established based on favourable geology and structures.These zones being areas of magmatic intrusions, the broad magnetic intensity anomaly closures, which are zones of structural displacement associated with deep seated basement; the dyke spots, the fractures and fault areas.GFG

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