Detection of Concealed Mineral Deposits using Magnetic Data in part of Osun State and its Environs, South-western Nigeria

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Abstract. Magnetic data of part of Osun State and its Environs, Southwestern Nigeria has been studied with the aim of identifying structures concealing mineral deposits through some enhancement techniques. These techniques are Analytic signal, Euler deconvolution, Center for exploration targeting and porphyry analysis. In this work we have applied Analytic signal to identify edges and distribution of magnetic sources that are equivalent to concealed mineral deposits, Euler deconvolution was used to identify and estimate depth to various magnetic source geometries using prescribed structural indices of 0.0, 1.0 and 2.0 respectively and lastly, the center for exploration targeting and porphyry analysis was used to obtain magnetic lineaments and porphyry intrusivesthat may serve as structures concealing mineral deposits. From this study, we were able to identify several volcanic intrusions which appeared beyond surface exposure and at the same time of Cenozoic era. These intrusions resulted from the high magnetic content which serves as a contributing factor for the presence of positive magnetic anomalies in the area. In conclusion, we have been able use magnetic data of Osun State and its environs to delineate structures concealing mineral deposits.

Keywords: Magnetic data, enhancement techniques, Intrusions and Osun State and its Environs.

1. Introduction

Magnetic data has been used extensively in the investigation of subsurface geology on the basis of magnetic anomalies present in the magnetic field of the earth which result from the properties of susceptibility contrast of the underlying rocks [1]. Applications of magnetic surveys is not limited to detections of hidden ore sources in the mineral’s investigation [2] only but has also received a nod in reconnaissance survey for studying of faults [3], geothermal and hydrocarbon signatures [4]. In aeromagnetic data interpretation, part of its objective is to obtain the topmost depth of the magnetic sources which is equivalent to the sedimentary thickness in the case of an Inland basin and more importantly detection of magnetic sources which may be as a result of intrusive sources present in the rocks. These intrusives exhibit more magnetic properties than the underlying lava flow [5]. [6] reported that intrusive rocks reveals high magnetic intensities as a result of the presence of strong magnetic mineral contents and that higher wave number magnetic anomaly are characteristics
of low intrusions coming from igneous rock while low wave number anomalies are associated with intrusions covered by thick basins [2]. The mineral potential in this study as reported in the work of [7] that the area is made up of abundance of rocks which house metallic, non-metallic minerals, rare metals etc. Some the rocks include quartzite, amphibolites schist, and quartz schist. Their economic importance cannot be over emphasized for example, amphibolites is regarded as a local host of gold mineralization while Quartz schist and schist are used for carving materials and cutting softer stones respectively. In a recent development, the Minister of Mines and Steel Development, Mr. Olamilekan Adegbite has expressed Federal government readiness to partner with the State of Osun and its environs on the proper exploration of its abundance mineral resources. He made this call in Osun when he visited the governor Mr. Adeboyega Oyetola in his office while drumming support for Segilola mining firm in the bid to unlock the mining potential in the state [8]. Although registered mining firm and some other illegal miners have been on the full exploration scale but this exploration of minerals are only limited to the south-western portion of the study area while other parts are yet to be explored. Therefore, this work is focused in the updating the existing information on the geology of the area via the enhancement techniques.

2. Geology and Tectonic settings
The study area lies within the Precambrian basement complex which is one of the three major lithologies (namely Polymetamorphic Migmatite-gneiss complex, low grade sediments-dominated Schists and the syntectonic to late tectonic granitic rocks) components that makes up the geology of Nigeria. [9] reported that this area forms part of the Pan-african mobile belt and lies between the West Africa and Congo cratons. The basement complex of is made up of four major lithological units, namely: The migmatite – gneiss complex (it is the most widespread of the component units in the basement complex of Nigeria), The Schist Belt (metasedimentary and metavolcanic rocks, phylites, schists, pelites, quartzites, marbles, amphibolites), The Older Granites (Pan African granitoids granites, granodiorites, syenites, monzonites, gabbro, charnockites) and Undeformed Acid and Basic Dykes (muscovite-, tourmaline- and beryl-bearing pegmatites, apllites and syenite dykes; basaltic, doleritic and lamprophyric dykes). Among these major lithological units, the study area is situated between the Schist belt and Migmatite-Gneiss complex of the south western basement complex with lithological variations of coarse to fine grained clastics, pelitic schists, phyllites, banded iron formation, carbonate rocks (marbles / dolomitic marbles) and mafic metavolcanics (amphibolites), younger metasediment rock, Banded gneiss and granite gneiss. Also, of the four important fault systems in Nigeria (Ifewara, Zungeru, Anka and Kalangai fault systems) only Ifewara fault zone is located within this study area (Fig. 1).
3. Material and Methods

3.1 Data Acquisition and Analysis

The Magnetic data (Fig. 2) used in this work was acquired from the Nigeria Geological Survey Agency (NGSA). The data was acquired via an aircraft flown at a height of 80 m with 500 m line spacing, 80 m mean terrain clearance and the tie line spacing of 500 m. Regional correction through the International Geomagnetic Reference Field (IGRF 2010) was isolated from the data. Reduction to the Equator (RTE) correction, as used by [4], was performed on the data because of so that the peaks of total magnetic anomalies due to subsurface are shifted from directly over the source and the anomalies becomes highly asymmetric [10].
Fig. 2. The Magnetic intensity (TMI) map of the study area
Fig. 3. The Reduction to the Equator (RTE) maps of the study area.

4. Results and Discussion

In order to identify structures concealing mineral deposits in this area, we have applied the enhanced techniques on the RTE magnetic data (Fig. 3) Analytic signal [11; 12] was applied to the magnetic data and the result (Fig. 4) shows an enhanced picture of high frequency anomalies in the area. Also on the map are three main magnetic domains: (i) a domain of magnetic intensity maxima (with gradient 0.105 – 0.436 nT/m) which can be regarded as outlines of magnetic sources. Some of these maxima are noticeable in the Northwest, Southwest, North central and Southeastern portion of the study area; (ii) a domain of intermediate magnetic intensities with gradient ranging from 0.043 – 0.096 nT/m; and (iii) a domain of low magnetic intensities with gradient located between 0.010 – 0.040 nT/m. In the first gradient, the majority of maxima are trending in the NE-SW directions while minor maxima are observed to be trending in NW-SE. These two groups of maxima can be associated with intrusive bodies (e.g. Porphyritic granite) rich in ferromagnesian-bearing rocks with low amount of felsic minerals [13]. In contrast, the low and intermediate magnetic-intensity zones might be reflections of downward faulted blocks of the basement complex full
with sediments or possibly set of tectonic pattern controlling the overlying sediments. Rocks associated with these zones are metavolcanic, metasediments and granites and this is because the rocks contain more than 60% quartz [14]. The map also shows networks of magnetic discontinuities that might represent fracture zones that could be targets for minerals prospection.

![Analytic Signal map](image)

**Fig. 4** The result of the Analytic Signal map

Also, the Euler deconvolution method developed by [15], [16] was applied to the RTE grid in order to identify and obtain depth to various magnetic source geometries using prescribed structural indices of 0.0, 1.0 and 2.0 respectively [16]. In view of this S.I = 0 and 1 gives a better solutions than 2.0 and this is because the solutions are clustered and distributed all over the study area. This clustering and distribution of all solutions obtained for S.I = 0 and 1 (Fig. 5 and 6) represents lithological features which confirmed highly deformed muscovite schist rocks while the granite gneiss rocks are possible intrusive dykes. The depth to delineated structural features obtained using Euler deconvolution technique varies from 185 m to 800 m is a suggestion of that mineral deposits are structurally controlled within the area.
Fig. 5 Euler deconvolution for S.I = 0.0 showing the nature and distribution of magnetic sources with depth.
More so, the CET grid analysis was applied to RTE map in other to detect structures within the map through the steps described by [17] that include textural analysis which estimates variations in magnetic data followed by the phase symmetry detects any laterally continuous line - line regions of discontinuity and lastly amplitude thresholding used to enhance lineaments through the suppression of signals at the background and noise to produce a lineament map (Fig. 7). These lineament features corresponds to structures (e.g. faults and fractures), lithological boundaries and hidden ores which shows how the basement rocks in the area are controlled structurally. It can also be observed from the lineament map that majority of the prominent structures are trending in Northeast-Southwest while less ones are trending in Northeast-Southwest, East-west and North central directions. These trends reveal the effects of deep heterogeneity of the earth’s crust which represents fractures - faults which affects the both the basement and the overlying sediments [18].

Fig. 6 Euler deconvolution for S.I = 1.0 showing the nature and distribution of magnetic sources with depth
Fig. 7 The result of the lineament map of the study area

And lastly, the CET porphyry technique was applied to RTE map which depicts porphyry features that are dyke-like in nature within the map through the steps described by [17]. The steps include circular feature detection, amplitude and contrast transforms and produced the center for exploration porphyry enhancement map (Fig. 8). The CET porphyry technique is used to map circular, semi circular or near circular features with their boundaries interpreted as zones of weakness and these zones of weakness help in detecting porphyry - like intrusive bodies [19].

This map depicts porphyry features that are dyke-like in nature trending NE-SW, NE, SW and NS direction and they all characterize the point of reference of the mineral potential zones of the area [20]. Also, it can be observed that this enhanced CET porphyry map shows a good correlation with the Analytic signal map (Fig. 3) in form of the locations of porphyry intrusives present in the study area.
Fig. 8 Center for exploration porphyry enhancement map
5. Conclusion and Recommendation

The magnetic data of part of Osun state and its environs Southwestern Nigeria has been studied with the aim of identifying structures concealing mineral deposits through some enhancement techniques. The high frequency low magnetic sources are associated with the mineral deposits occurrences in the region of study. This work has been able to update the existing information on the geology of the area via the enhancement techniques by superimposing the lineament map and Center for exploration porphyry enhancement map on the geological map of the area (Fig. 9).

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