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Abstract: An integrated approach which involve interpretation of Landsat ETM+, aero-magnetic and aero-radiometric data was undertaken over the eastern flank of Ife-Ijesha schist-belt, Nigeria, with an objective of delineating structural and lithological features that favour mineral deposition within the study area. The analysis of Landsat ETM+ data revealed four distinct lineament trending NNE – SSW, NNW – SSE, NW – SE and NE – SW. The lineaments density ranges between 0 and 2.67 m²; higher over and around lithological contacts and areas underlain by felsic rocks. The application of analytic signal, till derivative and 3D-euler filters on aeromagnetic data allow identification of series of anomalies suspected to be lithological contacts, alteration zones, magnetic source anomalies and overall basement characteristics. The primary trend of structural features producing magnetic anomalies is generally NE – SW, which corroborate the Landsat ETM+ result. The analysis of radiometric datasets revealed geochemical information on potassium (K), thorium (Th) and uranium (U) concentrations, and results obtained was used to identify impacts from alteration and rock contacts and define bedrock lithology within the study area. The ternary-image generated from radiometric data interpretation show distribution of the radiometric intensity which correlated well with geological structures and lithology in the area.

Keywords: Geophysical, Mineralization, Potential, Ife-Ijesha, Schist-Belt, Radiometric, Landsat, aeromagnetic

1 INTRODUCTION

Mineral exploration is capable of sustaining economic growth and industrial development of any nation. Nigeria economy depends largely on oil and gas industry at present, why opportunity availed by mining operation is yet untapped, despite the abundance of mineral deposits in the country. In most cases, the knowledge about occurrence, mineralogical composition and reserves of mineral are not fully understood [1]. Solid mineral exploration require interpretation of high-resolution airborne data which are usually targeted at delineating possible rocks, zones and structures which can serve as host [2]. Analysis of remote sensing data and imageries are efficient in delineating geology structures [7]. Magnetic surveying plays a vital role in delineating metallic and non-metallic minerals, since most minerals are usually deposited along rock contacts or features such as faults or fractures [5]. Since mineralization processes affect concentration of radiodelement in rocks, radiometric method, therefore becomes a useful tools in identification of potential mineralized zone [4]. Radiometric surveys are capable of directly detecting the presence of uranium which also assists in locating some intrusive related mineral deposit. The present research therefore focus on the analysis of Landsat imageries, aero-magnetic and aero-radiometric data of the eastern flank of the Ife-Ijesha schist belt of Nigeria with the aim of delineating structural and geological conditions relating to mineralization within the study area.

1.1 Geology and Description of the Study Area

The basement rocks of Nigeria is part of the extensive Pan-African Province of West Africa and are delimited in the west by the West African Craton and east by the Congo Craton. Nigeria basement comprises the Migmatite-gneiss complex, the Schist-belts and the Older Granites. The Migmatite Gneiss Complex is the oldest, most widespread and abundant rock type in the basement [12]. It is of Achean-Proterozoic age and a product of long, protracted and possibly polycyclic evolutionary histories. The Nigerian Schist-belts comprise of low-grade metasediments and metamorphosed pelitic and psammitic assemblages that outcrop in a series of N-S trending synformal troughs infolded into the crystalline complex of migmatite-gneises. The Pan-African Granites referred to as Older Granites include rocks of wide range of composition varying from tonalite, granodiorite, granite and syenite [14]. The Ijero-pegmatite form an intrusion into the biotite-schist that occupies the central part of the study area. The study area is an extension of the eastern end of Ife-Ijesha Schist-belt and falls within the Basement Complex of southwestern Nigeria. The study area is located within latitude 7° 38’ 50” - 7° 58’ 5” N and longitude 4° 54’ 15” - 5° 6’ 15” E (Fig. 1). According to [9], Ife-Ijesha schist belt is characterized by abundance of rocks which harbor metallic and non-metallic minerals, rare metals and gemstones among other minerals.
2 MATERIALS AND METHOD OF STUDY

Data used in this research include Landsat Imagery, aeromagnetic and georadiometric data acquired from the www.landcover.com and Nigeria Geological Survey Agency (NGSA). Enhanced Thematic Mapper Plus (ETM+) Landsat imagery covering path 190 rows 55 and Path 190 row 54 over the study area was analyzed using ERDAS 9.2 software. The Landsat imagery was filtered for visual enhancement of lineaments, while the lineaments were manually digitized and geo-referenced to WGS 1984 and UTM Zone 32N. The magnetic data analyses involved the processes of editing, application of a gridding routine, and removal of the Earth’s main magnetic field through removal of international geomagnetic reference field (IGRF) over the study area. This was followed by application of series of filters in order to improve the edge effects of magnetic anomalies, enhance shallow small-sized geologic features and making smaller anomalies more readily visible in area of strong regional disturbances. Since the study area is located an area of low latitude (between latitude 7° 30’ – 8° 00’ N), the reduction to equator transform was applied to the magnetic field intensity in order to locate the observed magnetic anomalies directly over the magnetic source bodies, [7]. A range of imaging routines involving the reduction to equator, vertical derivative, analytic signal amplitude and tilt angle derivative filtering were applied to the magnetic data to visually enhance the effects of geologic sources [5]. Airborne gamma-ray spectrometry data are the measurements of the surface concentrations of radioelements which are usually presented as colour images or contours of the spatial distribution of either single radioelement, or composite images [2]. Specialized gridding techniques provided in the Geosoft software (Oasis montaj™) were used to enhance observed radioactive distribution of the primary radioelements (potassium, uranium and thorium), and generate images and maps for easy identification and characterisation of radiometric signatures associated with mineralization, trends of structures and pattern of geologic units. A composite image (ternary) was created using Oasis-montaj™ software in which potassium, thorium and uranium were assigned red, green and blue colours respectively. The ternary image generated shows spatial distribution of the radiometric intensity which correlated well with geological structures and lithology in the area.

3 RESULTS AND DISCUSSION

3.1 Landsat ETM+

The result of the Landsat ETM+ interpretation shows frequency of lineaments in terms of lengths and trend (Fig. 2), along NNE – SSW, NNW – SSE and a dominant NE – SW (between 30° - 50°) as shown in Figures 3a and 3b. Lineament density (LD) per unit area ranges between 0 and 2.67 m². It is denser in areas underlain by felsic rocks (Quartz, muscovite, mica etc.) and shear zones (Fig. 4). These zones with relatively high LD are likely potential conduits for hydrothermal fluid and by extension probable zone for mineralization.
Fig. 3(a): Rose Diagram in terms of direction of lineaments.

Fig. 3(b) Rose Diagram in terms of Lengths of lineaments.

Fig. 4: Lineament Density Map of the Study Area.

3.2 Aeromagnetic Data Interpretation
The original Total Magnetic Intensity (TMI) grid (Fig. 5a) was processed, reduced to the equator (RTE) and filtered to enhance weak, small-sized magnetic anomalies from shallow sources and simultaneously enhancing low-amplitude, long-wavelength magnetic anomalies from deeper sources (Fig. 5b) by applying the analytic signal (AS), tilt derivative (TDR) and 3D-euler deconvolution (ED) filters.

Fig. 5(a): Total Magnetic Intensity Map of Sheet 243 and 244 (Ilesha and Ado Sheets).

Fig. 5(b): Total Magnetic Intensity Map of the Study Area.
Analytic signal filter is normally applied to delineate linear features without necessary diminishing the long wavelength anomalies [10]. This filter when applied to the TMI data helps to clearly define the edge extent and contacts between different lithologies within an area. In Fig. 6, the analytical signal map revealed rock contacts and magnetic dykes which coincides with some notable mining sites (sites A, B and C) in the central region within the study area. It is obvious that some of the identified mining sites fall on notable intrusive bodies and some others delineated from magnetic data interpretation within the immediate vicinity of the mapped structures. Several lineaments were amplified on the tilt derivative map, which were discovered to be mainly attributed to shear zones and zone of structural deformations that are related to faults, joints, alteration zones or geological contacts. Series of anomalies suspected to be fractures, faults (F - F1, F - F2), lithological contacts (C1, C2, C3, C4 and C5) and alteration zones were mapped out. The trend of structural features producing magnetic anomalies are generally oriented in an approximately NE – SW direction, in agreement with the Landsat ETM* result. There are structures of regional extent which cut-across the study area and are likely to have played a fundamental role in occurrence of some localized deposits within the study area (Fig. 7). The basement rock is highly faulted and deformed. This is attributed to the pronounced deformation and remobilization during the Pan-African orogeny [8].

Euler-3D map (Fig. 8) shows the locations, depths and geometry of geologic feature(s) which produced the magnetic anomalies displayed. The study area generally shows high density of linear features. The depth-to-top of identify features, believed to have influenced deposition and emplacement of minerals within the study area, ranges between 150 m to 900 m. The central region reveals some notable features which coincide with location of some prominent mining sites A, B, C and D within the study area.

**Fig. 6: Analytic Signal Map of the Study Area**

**Fig. 7: Tilt Derivative Map of the Study Area.**
3.3 Radiometric Data Interpretation

The analysis of radiometric datasets revealed concentrations distribution pattern of primary radioelements: potassium (K), thorium (Th) and uranium (U). The result obtained was used to delineate and characterize bedrock lithology, as well as alteration and rock contacts within the study area. High count of K (1.1 – 2.8%), Th (15.4 – 30.8 ppm) and U (3.8 – 7.8 ppm) were observed around the central region of the study area (Figure 9). The north, north central, eastern and southeastern part of the study area are characterized by high levels of potassium count (1.1 – 2.8%), while region around the west to southwestern show low potassium count (0.2 – 0.6%). Potassium occurs mainly within area underlain by feldspatic rocks. Figures 11 and 12 revealed that the concentration of thorium (13.7 – 30.9 ppm) and uranium (1.4 – 7.8 ppm) are high throughout the study area with the exception of regions underlain by felsic rocks (quartzite, granites).
The ternary-image produced from the composite analysis of the three primary radioelements (K, Th and U) was employed in refining litho-units (Fig. 12). The whitish areas in the ternary image indicates high concentration of combined potassium, thorium and uranium radioelements, resulting from felsic volcanic materials. Quartz-rich rocks appear darker than the surrounding units, indicating lower concentrations of potassium element. High count of radioelements observed between latitude $7^\circ 41' - 7^\circ 45' N$ and longitude $4^\circ 58' - 5^\circ 20' E$ can be attributed to hydrothermal alteration. About eight major rock types were recognized within the study area. Most of the active mining sites around or within the study area are located close to the boundary of rocks and alteration zones. High concentration of potassium and thorium are clearly evident in granite gneiss, as well as a smaller fraction of uranium as suggested in literatures [12]. Areas underlain by quartzite rocks show low concentration of radio-element (K, Th and U), while granite-gneiss reflects high count of these radioelements. Litho-contacts were identified based on magnetic as well as radiometric images. Magnetic maps (Figures 5b, 6, 7 and 8) revealed the presence of faults/fractures and rock contacts, in similar way, the radiometric images (Figures 9, 10, 11 and 12) revealed the overall radio-elemental distribution pattern for various litho-units (Fig. 13). Magnetic and radiometric anomalies complement one another at location of faults/lineaments, lithological contacts and alteration zones. The images are capable of delineating alteration zones which is usually associated with mineralization as confirmed by reduction of magnetic intensity around these anomalies. Minerals are usually deposited along rock contacts or features such as faults or fractures.

4 CONCLUSION
The integration of Landsat ETM+, aeromagnetic and aero-radiometric study has helped in mapping surface and concealed geological features which characterise mineralized zone within the study area. Rock boundaries, lineaments
trend, depth to source of causative body of magnetic anomaly and hydrothermal alteration zones which are potential mineralization zones were interpreted on the bases of magnetic and radiometric intensities over the study area. Results obtained assisted in providing more information on the geology and notable structural features that give credence to high mineralization potential of the eastern flank of Ile-Ijesha Schist-belt of Nigeria.

REFERENCES


