

# On the Application of the Magnetic Method in the Mapping of Mineralized Pegmatites in Mica Schist underlain Basement Complex of Southwest Nigeria

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## ABSTRACT

Mineralized pegmatites are of economic interest and are sought after targets in mineral exploration. They are linear features whose delineation is based on the physical, electrical, and electrochemical properties of the mineral constituents. We utilized the magnetic susceptibility contrasts between iron-rich black tourmaline embedded pegmatites and a mica schist host rock to map the intrusive bodies as magnetic lineaments. The reduced to equator magnetic data acquired along thirteen inline and cross-line traverses, at 5 m intervals, were subjected to Total Horizontal Derivative (THD), Analytical Signal (AS) and Euler Deconvolution (EUD) filters for magnetic lineament delineation using the maxima of the THD and AS maps and alignments of EUD clusters. Thirty-two lineaments with lengths ranging from 12-55 m and orientations of E-W (major), WNW-ESE, NW-SE, ENE-WSW and NNE-SSW (minor), were delineated. Thirteen (13), or 41%, of these magnetic lineaments correlated with geo-referenced field observed pegmatite veins and locations of concentrations of quartz/feldspar boulders. Other delineated lineaments are suspected to be embedded within weathered mica schist. It is concluded that the magnetic method can be effective in mapping mineralized pegmatites in areas where the intrusive bodies are concealed within weathered mica schist.

(Keywords: linear feature, mineralized pegmatites, magnetic lineaments, mica schist, Nigerian Precambrian Basement Complex)

## INTRODUCTION

Pegmatites occur as intrusive bodies within the Nigerian Precambrian Basement Complex rocks especially within the over 400 km long NE-SW

trending Schist Belt extending from Ago-Iwoye in the southwest to Bauchi in the northeast and within the southeastern Basement Complex region around Obudu Hill (Okunlola, 2006; Akintola and Adekeye, 2008; Akintola *et al.*, 2012; Jimoh and Olatunji, 2020). They occur as dykes, stringers, and veins intruding discordantly into granite, gneiss, and mica schist with diverse structural orientations ranging from N-S to E-W, NE-SW, NW-SE and NNW-SSE (Okunlola, 2006; Okunlola and Akintola, 2007; Akintola *et al.*, 2011; Tanko *et al.*, 2015; Adetunji *et al.*, 2016; Jimoh and Olatunji, 2020). The width extent varies from few centimeters to up to tens of meters (50 m) and could range in length from few meters (up to 10 m) to as long as 2 km (Okunlola, 2006; Tanko *et al.*, 2015; Adetunji *et al.*, 2016; Jimoh and Olatunji, 2020).

In most places, pegmatites occur as vertically or steeply dipping intrusive bodies, most especially within pelitic to semi-pelitic schists, and sometimes as flat lying near horizontal body as observed in Oke-Ogun pegmatite field (Okunlola, 2006). The main mineral constituents of pegmatite include quartz, feldspar, and mica. Its accessory minerals could include tourmaline (green, pink, blue and black), beryl, chrysoberyl, lepidolite, apatite, monazite, cassiterite, nigerite, columbo-tantalite, chiolite, zinnwaldite, fluor, axinite, spodumene, garnet and zircon (Read, 1973; Kinniard, 1984; Adekoya *et al.*, 2003; Okunlola and Ogedengbe, 2003; Akintola and Adekeye, 2008; Akintola *et al.*, 2011; Akintola *et al.*, 2012).

Pegmatites, therefore, host both metallic and non-metallic minerals including rare metals such as tantalum (Ta), niobium (Nb), tin (Sn), tungsten (W), columbite (Cs), and lithium (Li), which make the intrusive bodies of economic interest and a sought-after target. Okunlola (2006) classified pegmatites based on two broad lithological

associations – pegmatite veins intrusive into pelitic to semi-pelitic schists with minor associated calc gneiss, amphibolite and dolerites and pegmatite veins intrusive into gneisses, granites, and metavolcanics. The mica schists serve as host to pegmatite veins which are rarely exposed except at mine sites and erosion created channels and gullies (Jimoh and Olatunji, 2020). These pegmatite veins are the focus of this study.

The Ilesha Schist Belt is noted for its mineralization potentials including gold, gemstones and talc. The gemstones, including tourmaline, beryl, cassiterite, are hosted by pegmatite veins within the schist. While the veins are sometimes exposed by erosional features (channels and gullies) and mining excavations, they are most times concealed within weathered schist. The uncontrolled (unguided) nature of artisanal mining of pegmatite veins has led to landscape devastation. There is therefore the need to identify and delineate mineralized pegmatite veins prior to mining to minimize this environmental impact.

By the nature of the mineral constituents of pegmatite – quartz (the main component), feldspar, and mica and the coarse texture of the minerals, pegmatite veins usually display high resistivity relative to its host. Quartz, the major mineral component of pegmatite, is very resistive. Pegmatites and quartz veins are also known to give relatively high positive polarity natural potential (SP) anomaly (Reynolds, 1997).

When it is mineralized with accessory mineral such as iron-rich tourmaline (schorl) and garnet, the magnetic and electromagnetic methods could also be used as an indirect method in the delineation of pegmatite veins, most especially where they are concealed. Iron-rich black tourmaline is a common accessory mineral (gemstone) in the pegmatite veins hosted by the mica schist of Ife area. This study therefore intends to investigate the effectiveness of the magnetic method in the delineation of pegmatite veins within the Ife mica schist. The study will assume veins of pegmatite as linear features because their linear extents are most times order of magnitude greater than the width extents.

## SITE DESCRIPTION

### Geographic Location and Geomorphology

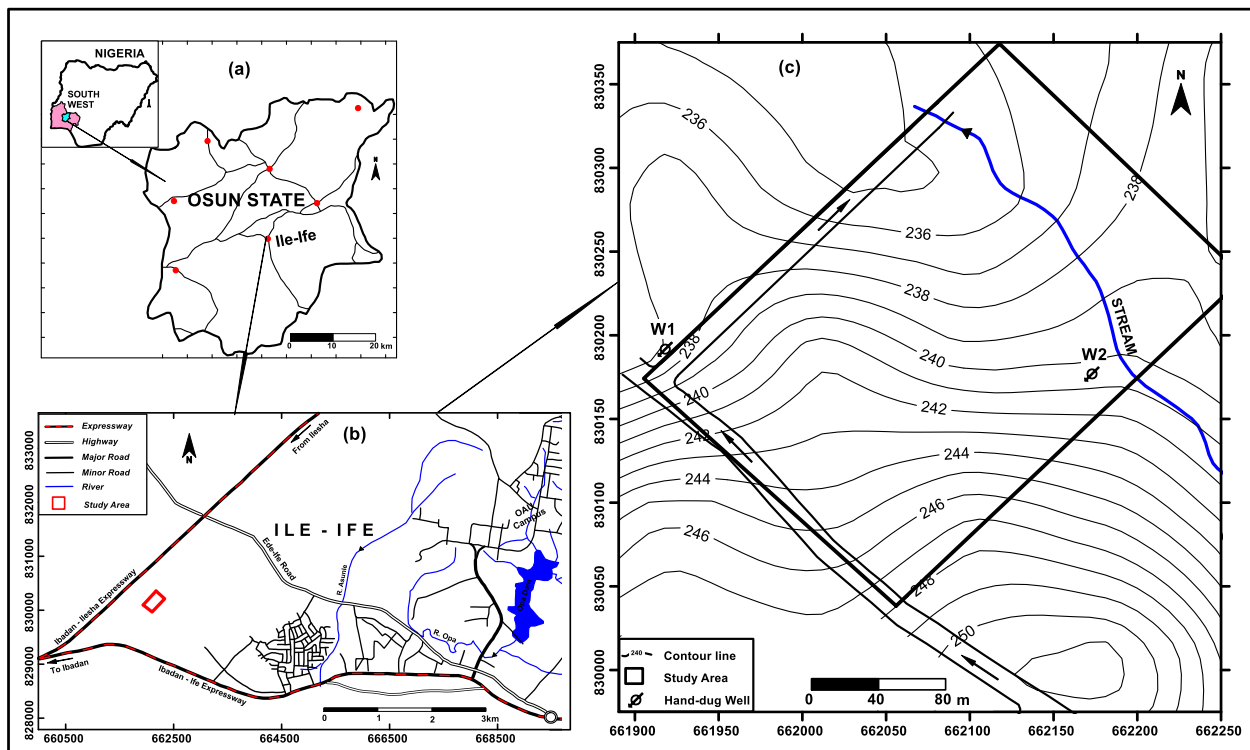
This pilot study was carried out in Fasina area of Ile-Ife in Ife Central Local Government Area of Osun State, Southwest Nigeria (Figure 1). The site is bounded by the geographic coordinates of Northings 829922 mN and 830336 mN and Eastings 661900 mE and 662272 mE in the Universal Traverse Mercator (UTM) Zone 31N (Minna Datum) coordinate system (Figure 1c). The site has a gently undulating topography with elevations varying from 235 m a.s.l. within the stream channel at the northeastern flank to 247 m a.s.l. on the southern edge (Figure 1c).

### Geology and Soil

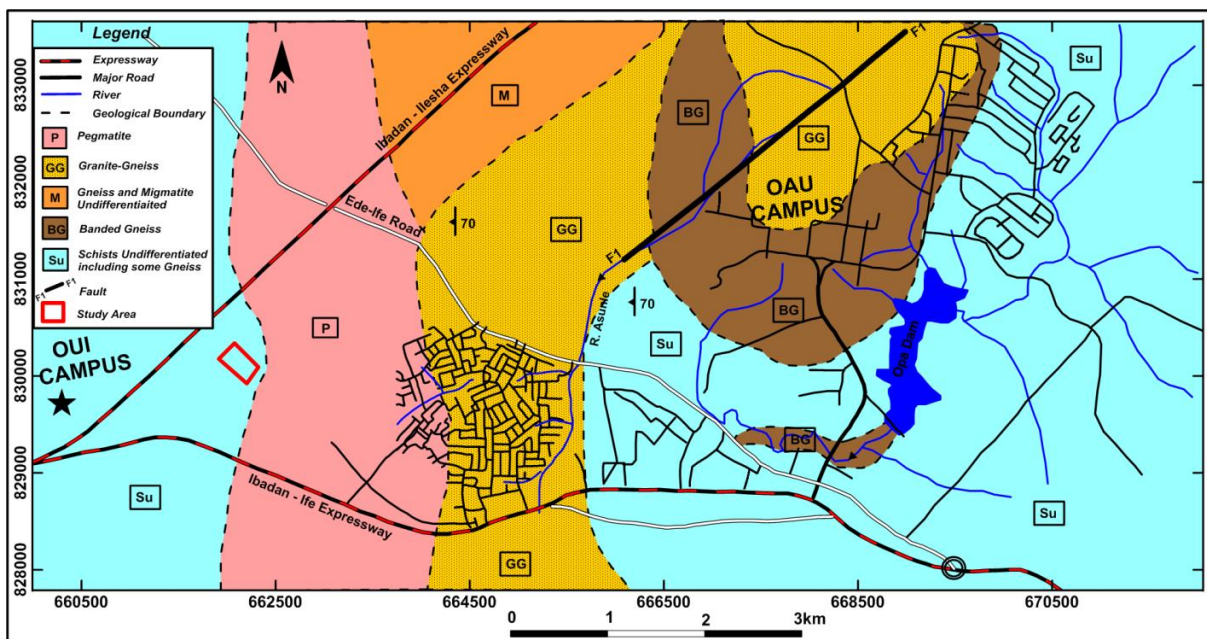
Ile-Ife falls within the Precambrian Ilesha Schist Belt comprising amphibolite, amphibole schist, pelitic schist, grey gneiss, granite gneiss and intrusive pegmatites and dolerites dykes (Olorunfemi *et al.*, 2020) (Figure 2). The survey area is underlain by mica schist. No outcrop of the basement rock was found. However, dug out chips of weathered rock from a newly dug well (W1) (Figure 1c) with relics of planar structure typical of mica schist, confirmed a mica schist basement bedrock.

Mica schist underlain areas are characterized by deep weathering depth and lateritic surface and near-surface subsoil. The referenced well penetrated about 10 m thick red lateritic soil. The mica schist is suspected to be pegmatized with exposed veins of pegmatites embedded within and cross cutting weathered mica schist along erosion-created channels (Figure 3a); concentrations of boulders of quartz and feldspars (Figure 3b) at several locations and a low-lying pegmatite ridge (Figure 3c) within the site. It is suspected that some of the exposed pegmatites may have been mined for gemstones.

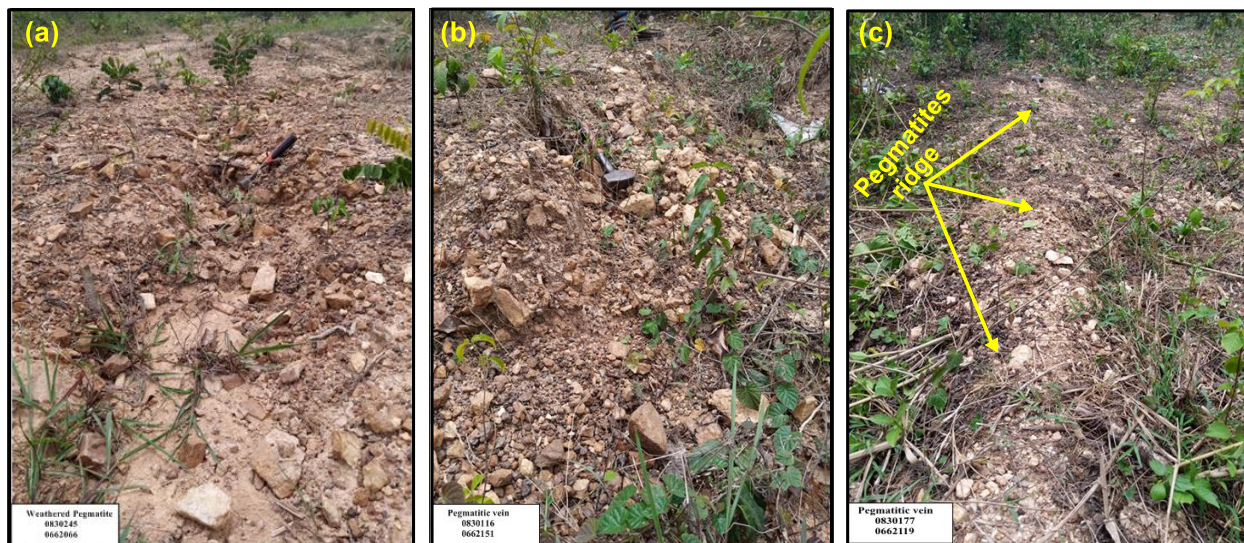
The soils belong to the Egbeda Soil Association characterized by fine textured, brown to brownish red, fairly clayey to clayey lateritic soils overlying red, brown, yellow and white mottled clay to depths exceeding 5 m in places, typical of mica schist underlain area (Smyth and Montgomery, 1962).



**Figure 1:** Location Map of (a) Osun State showing Ile-Ife (with map of Nigeria as inset) (b) Ile-Ife showing the Study Area and (c) the Study Area with Superimposed Topographic Contour Lines.



**Figure 2:** Generalized Geological Map of part of Ile-Ife showing the Study Area. (Boesses, 1989; NGSA, 2006)



**Figure 3:** (a) Erosion Exposed Weathered Pegmatite (b) Quartz and Feldspar Concentrations from Weathered Pegmatite and (c) Low Relief Pegmatite Ridge.

## METHODOLOGY

The geophysical survey involved the magnetic method. A base station was established at a magnetically quiet location close to the investigated site where variations in the Earth's total magnetic field were monitored at regular intervals of about thirty minutes and virtually at the beginning and end of the occupation of each traverse line.

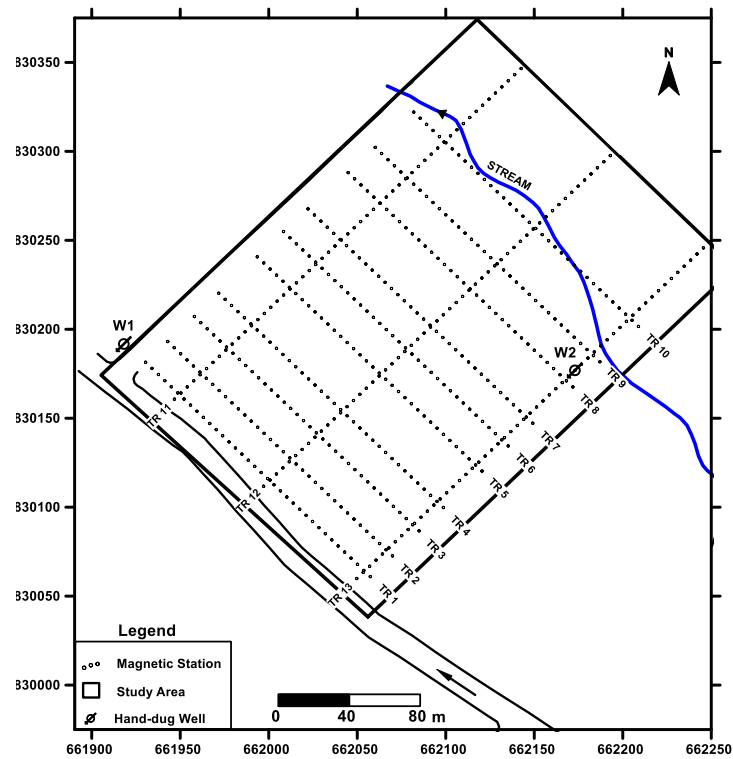
The magnetic variation curves generated from the mean of repeated (three times) measurements at the base station were used for diurnal variation correction. The total field component of the Earth's magnetic field intensity was measured at 5 m interval with GEM GSM -19T Proton Precision Magnetometer along thirteen traverses ranging in lengths from 175 m (134° inline Traverses TR 1 – 10) to 300 m 046° cross-line Traverses TR 11 – 13) (Figure 4). The field observed magnetic data (mean of two repeat readings) along the investigated traverses were corrected for diurnal variation and offset following standard procedures and subsequently reduced to the magnetic equator to center anomalies on causative bodies and correct for non-zero magnetic inclination (magnetic inclination (I) at the survey site is -11.44°).

Total Horizontal Derivative (THD), Analytical Signal (AS) and 3D Euler Deconvolution filters

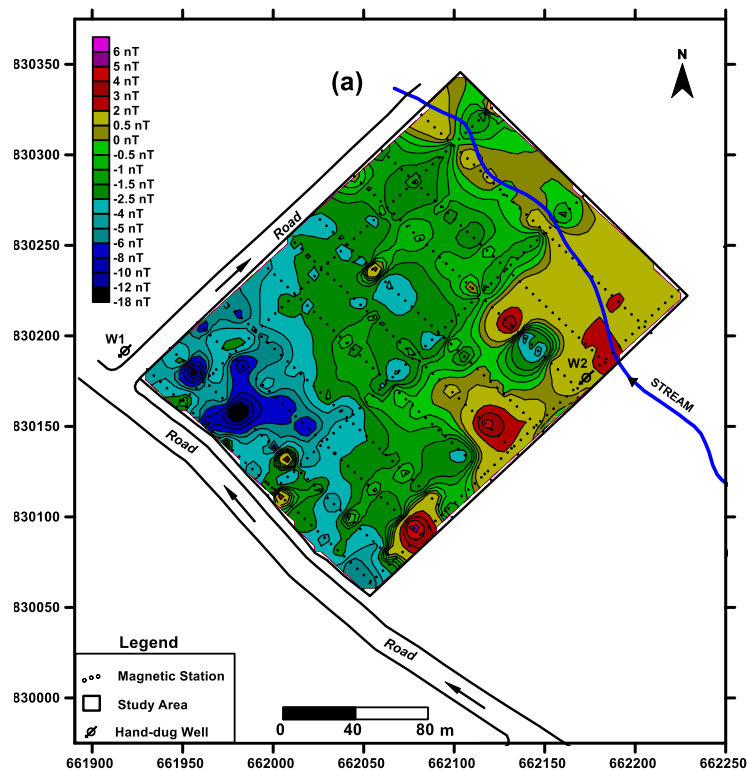
were applied to the reduced to magnetic equator data for data enhancement to enable the magnetic data to be interpreted for magnetic lineaments and possible structures. The maxima of both the THD and AS maps are effective in the mapping of edges of 2D bodies (Roest *et al.*, 1992) and hence relevant in magnetic lineament mapping. The Euler Deconvolution technique estimates depths to magnetic sources (Reid *et al.*, 1990). The alignments of Euler clusters can also be used to map magnetic lineaments.

## RESULTS AND DISCUSSION

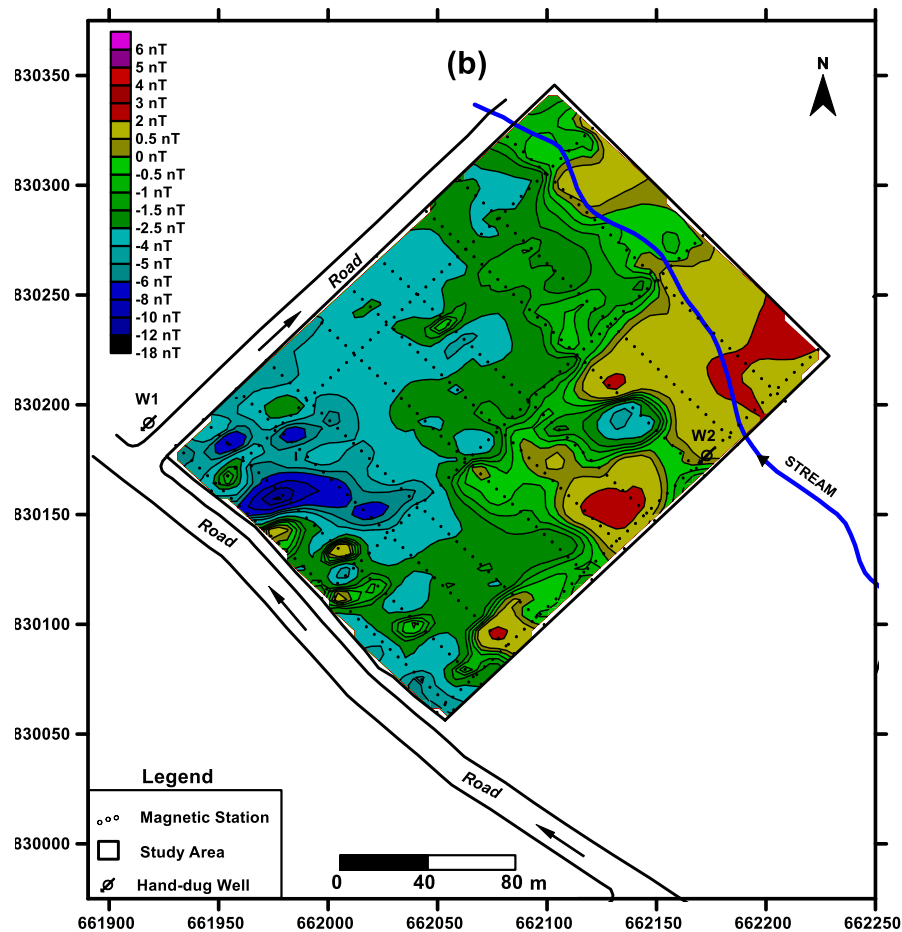
The residual Total Magnetic Intensity (TMI) and the Reduced to the (magnetic) Equator (RTE) maps are shown in Figures 5a and b with intensities varying from -18 nT to 6 nT. The generally uniform (small variation) low amplitude negative polarity magnetic intensities (0 to -18 nT) within the site is attributable to the monolithic (mica schist) basement bedrock and the significant depth of burial. The observed localized positive polarity magnetic intensity closures (0 to 6 nT) in the southern/southeastern parts are not geology related but created by artefacts – abandoned components of block making machine and corrugated iron sheet constructed shed hosting a block making machine and a power generator.



**Figure 4:** Data Acquisition Map of the Study Area showing the Magnetic Profiles.



**Figure 5(a):** Residual Total Magnetic Intensity (TMI) Map.



**Figure 5(b):** Reduced to the Equator (RTE) Map.

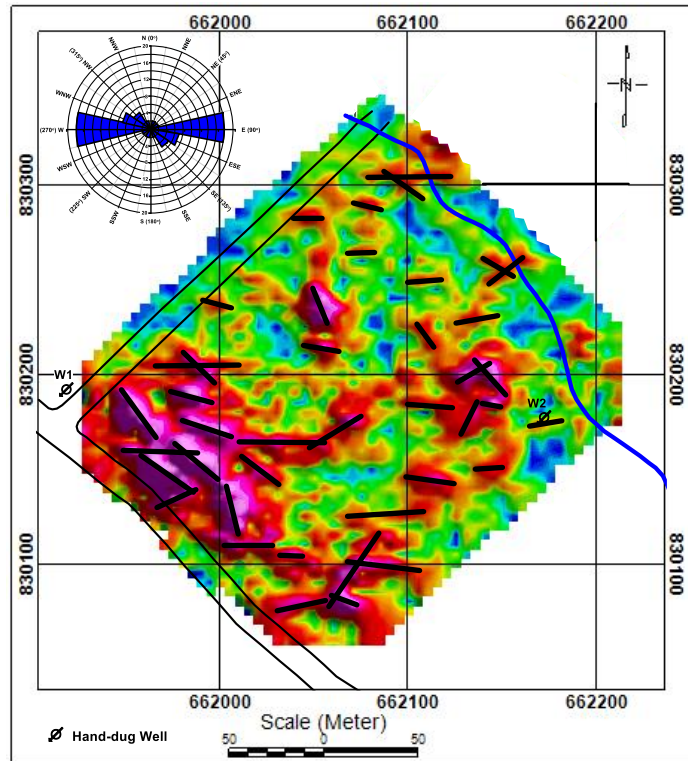
The THD map is presented in Figure 6. The map was interpreted for magnetic lineaments based on delineated anomaly maxima (anomaly peak in dark straight lines). The magnetic lineaments range in lengths from 12 m to 45 m and vary in orientations from E-W to WNW-ESE and NW-SE.

The AS map (Figure 7) was also interpreted for magnetic lineaments by delineating the anomaly maxima in dark straight lines. The lineaments range in lengths from 12 m to 55 m while the orientations range from E-W to NW-SE, WNW-ESE, ENE-WSW, and NNE-SSW. The AS derived lineaments are fewer than the THD derived ones but significantly overlap in lengths and orientations with the THD.

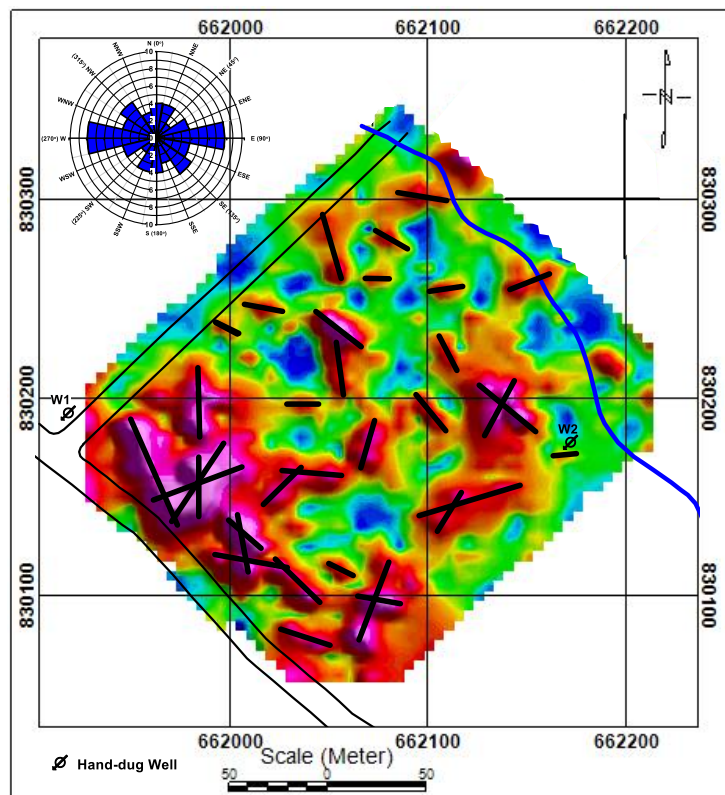
The EUD solution map for structural index of 0.5, tolerance of 30% and window size of 15 is

presented in Figure 8. The source depth ranges from <5 m to 5-10 m with the latter dominating. The depths to magnetic sources are generally less than 10 m. The overburden thickness observed from well (W1) is in excess of 10 m which implies that the delineated magnetic lineaments are essentially embedded within the weathered mica schist and not basement bedrock related.

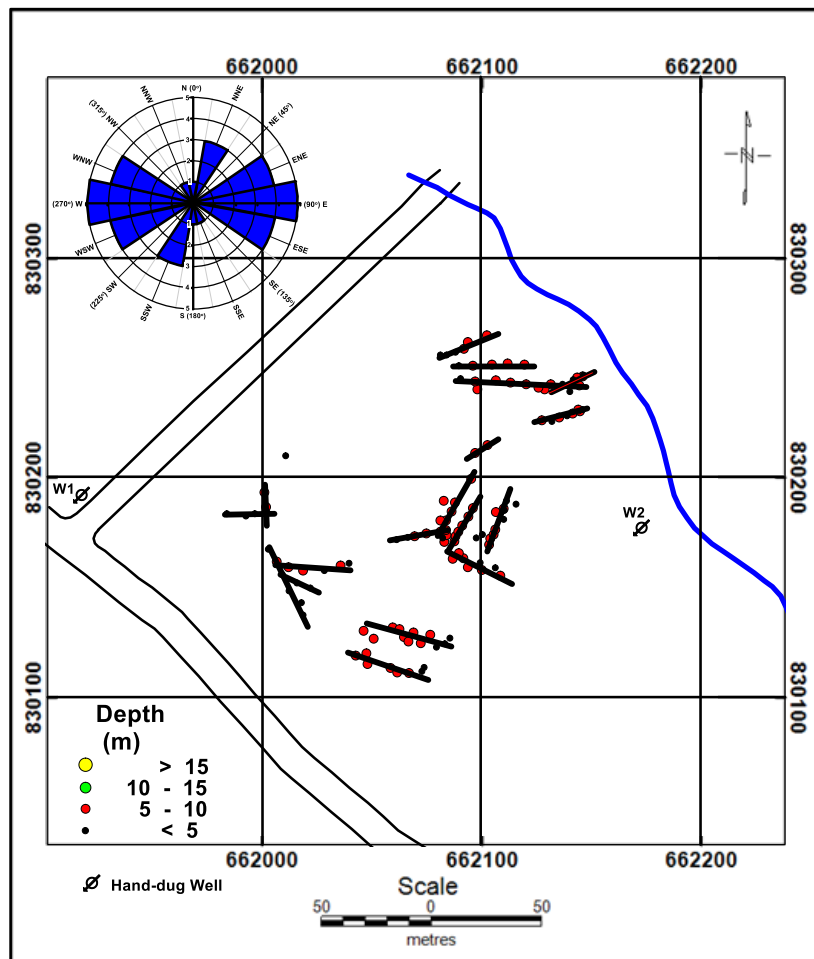
The Euler solution cluster linear alignments are delineated in dark straight lines. The lineament orientations vary from E-W to WNW-ESE, ENE-WSW, NNE-SSW, and NNW-SSE. The suspected lineaments are fewer than the THD and AS derived lineaments with very few overlapping lineaments.



**Figure 6:** Total Horizontal Derivative (THD) Map with Superimposed Magnetic Lineaments.



**Figure 7:** Analytical Signal (AS) Map with Superimposed Magnetic Lineaments.

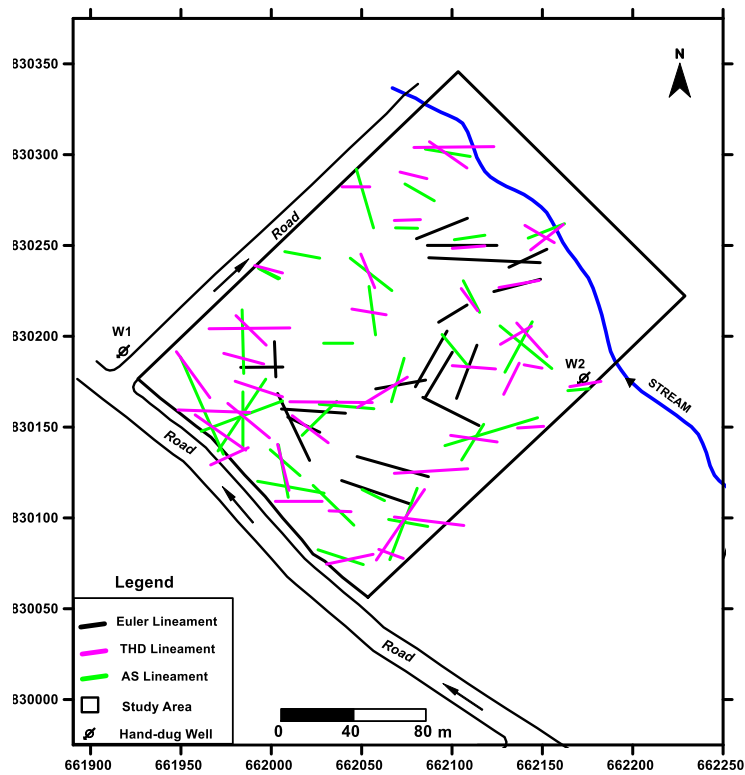


**Figure 8:** Euler Deconvolution (EUD) Solution Map with Superimposed Magnetic Lineaments.

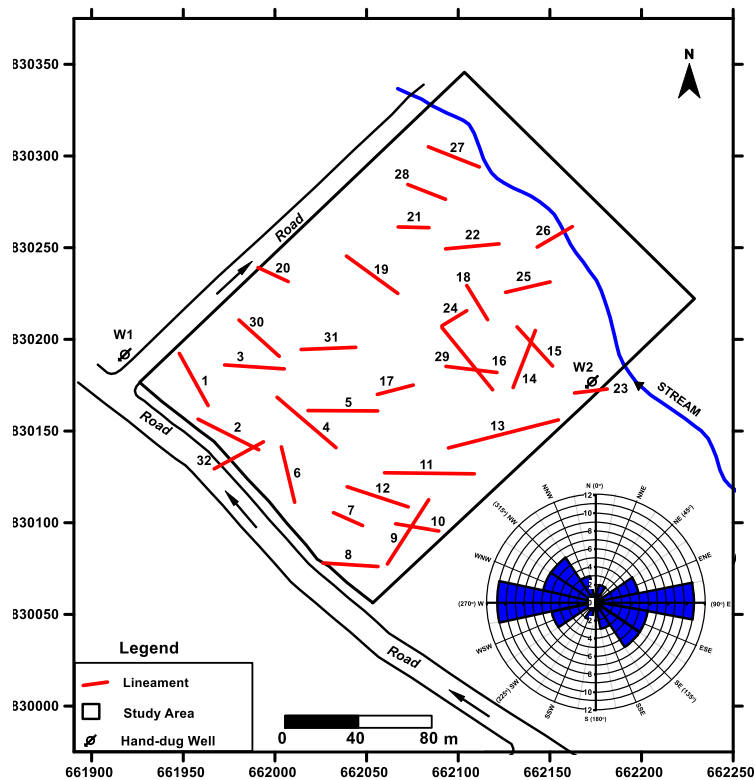
Figure 9 shows the superimposed THD, AS and EUD derived lineaments map. The THD and AS derived magnetic lineaments show significant overlap while few of the EUD derived lineaments overlap with THD and AS derived lineaments.

The composite magnetic lineament map (Figure 10) was generated from Figure 9 and was based on overlapping lineaments from any two or all of the THD, AS and EUD derived. In all, thirty-two (32) magnetic lineaments were delineated with lengths ranging from 12 m to 55 m with major E-W orientation and minor WNW-ESE, NW-SE, ENE-WSW, NNW-SSE, and NNE-SSW orientations.

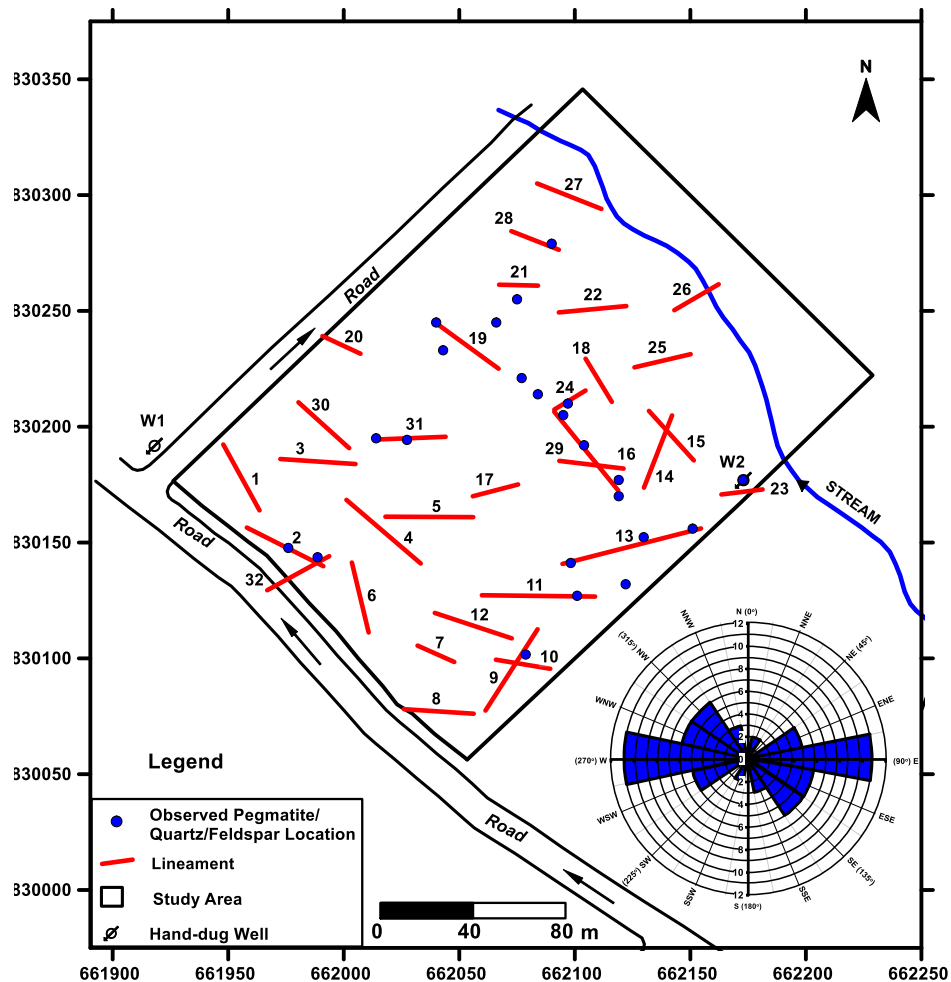
These orientations are in agreement with the observations of Okunola (2006), Akintola *et al.* (2011), Tanko *et al.* (2015) and Jimoh and Olatunji (2020). Field observed locations of exposed pegmatite veins and quartz/feldspar boulders concentrations were geo-referenced and their locations superimposed on the composite magnetic lineament map (Figure 11). The geo-referenced locations (as blue dots) fell on or very close to thirteen delineated lineaments numbers 2, 9, 11, 13, 16, 19, 21, 23, 24, 28, 29, 31 and 32. The other identified lineaments are suspected to be concealed within weathered mica schist.



**Figure 9:** Map showing Superimposed THD, AS, and Euler Deconvolution (EUD) Derived Lineaments.



**Figure 10:** Composite Magnetic Lineament Map.



**Figure 11:** Lineament Map of the Study Area with Superimposed Locations of Observed Pegmatite Veins and Quartz and Feldspar Boulder Concentrations (blue dots).

## CONCLUSION

Pegmatite veins are host to metallic and non-metallic minerals that are of economic interest and hence are sought after targets in mineral exploration. They are linear features whose delineation is based on the physical, electrical and electrochemical properties of the mineral constituents. We utilized, in this paper, the magnetic susceptibility contrasts between iron-rich black tourmaline often embedded in pegmatites and a mica schist host rock to map the intrusive bodies as magnetic lineaments.

The reduced to equator magnetic data at 5 m station interval, along thirteen inline and cross-line traverses, were subjected to Total Horizontal

Derivative (THD), Analytical Signal (AS) and Euler Deconvolution (EUD) filters to enable the delineation of magnetic lineaments as maxima of the THD and AS maps and alignments of EUD clusters. The EUD map enabled the estimation of depths to magnetic sources.

Thirty-two magnetic lineaments at depths of less than 10 m with lengths ranging from 12-55 m were delineated. The orientations of the lineaments range from E-W (major) to minor WNW-ESE, NW-SE, ENE-WSW, NNW-SSE, and NNE-SSW directions. These directions corroborate the works of Okunola (2006), Akintola *et al.* (2011), Tanko *et al.* (2015), and Jimoh and Olatunji (2020). Thirteen (13) or 41% of these magnetic lineaments, on ground truthing,

correlated with geo-referenced observed pegmatite veins and locations of concentrations of quartz/feldspar boulders. Other delineated lineaments are suspected to be embedded within weathered mica schist.

The study concluded that the magnetic method can be effective in mapping mineralized pegmatites in areas where the intrusive bodies are concealed within weathered mica schist.

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## SUGGESTED CITATION

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