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Full Length Research

Remote sensing and geological techniques for exploration of metallic minerals in the meta-sedimentary rocks o Ogotun, Ikeji-Ile and Ipetu Area, Southwestern Nigeria

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ABSTRACT: The study area (Ogotun, Ikeji-Ile and Ipetu) belongs to the southeastern part of Ilesha schist belt, widely acclaimed as hosts to metallic mineralization and associated ore deposits. There is paucity of information on the geological and structural settings as well as mineralization history of the study area. Hence, the need for this research, to provide necessary geological information as well as reliable clues to its mineralization potentials. A Sentinel-2A Imagery of the study area was acquired and digitally processed to constitute the remotely-sensed data, followed by automatic extraction of lineaments using Envi 5.0, Geomatical, Arc Gis 10.3 and Rockwork software to generate the required lineaments, lineament density as well as the mineralogical maps of the study area. Thirty-two rock samples were systematically picked during field examination, while fifteen of the samples were carefully selected for petrographic analysis under transmitted light microscope for its mineralogical composition. Remote sensing results revealed paucity of lineaments in the study area due to the ductile nature of the rocks. Also, the major lineaments trend in the NE-SW direction while the subsidiary ones in the E-W direction has been modified by several deformation episodes. The mineralogical map from remote sensing indicated the presence of FeS2 which is an indication of iron sulphide mineralization due to supergene enrichment, while areas with higher lineaments densities were discovered not to host any mineralization because their geometrics have been destroyed by subsequent deformations. Hence, lithologic control of mineralization is confirmed. The five rocks samples whose thin sections earlier revealed opaque minerals under transmitted light were prepared for ore microscopic study and the result also confirmed the presence of chalcopyrite (CuFeS2) which is majorly hosted by the quartz-schists. Conclusively, the presence of FeS2 and chalcopyrite indicate the possibility of other ore minerals which may be present but not detected.

Keywords: Chalcopyrite, deformation, lineaments, petrography, rock units.

INTRODUCTION

Reconnaissance lithologic mapping is usually the first key that could partially unlock the hidden geological information of any area that are yet to be explored (Adepoju *et al*., 2021). However, better results can be achieved when remote sensing combined with ground truth field data are used for the extraction of such information. Mineral exploration has traditionally been based on the application of varieties of prospecting techniques, namely Geochemistry, Geophysics, Field geological mapping and remote sensing (Ayodele and Odeyemi, 2010). The results obtained from the integration of different data generated from these geoscientific techniques (Remote sensing, Geological mapping and Geochemistry) will help in generating an opinion on the likely mineralization potentials and base line geological information for future studies.

The study area lies within latitudes 07°27'N and 07°32'N and Longitudes 0 4°52'E and 0 5°2' E covering parts of Ekiti and Osun States with a total surface area approximately 170 km^2 (Figure 1). The studied area is also

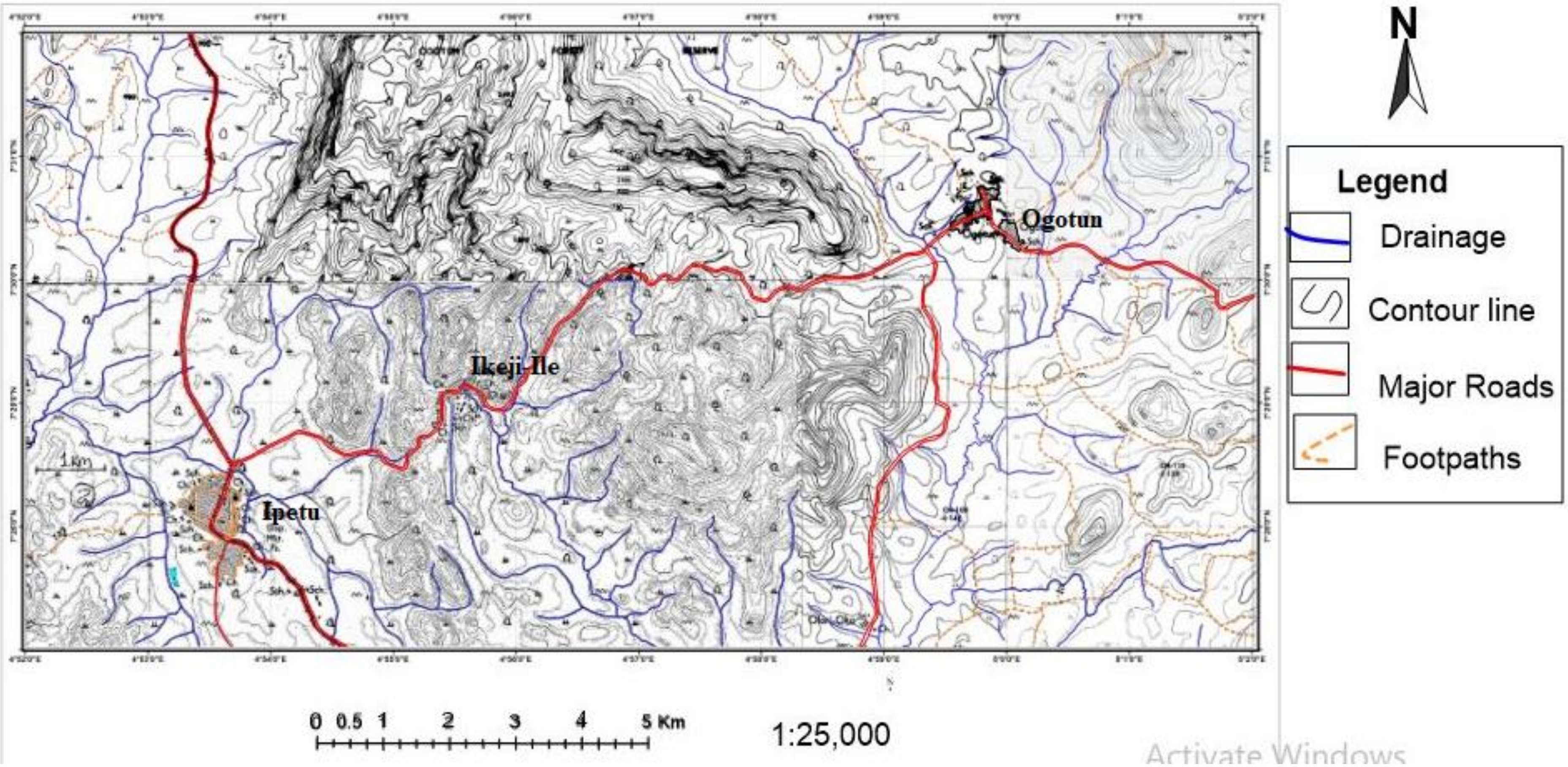


Figure 1. Topographic map of the study area.

characterized by high relief especially those places that formed quartzite ridge, quart schist and intrusion of batholitic granite with the highest ridge point varies from 200 to 350 m. The surrounding areas are characterized by presence of flood plains relative to the hills around the area. In the study area, the streams spread out from central point forming dendritic drainage pattern (Figure 2).

However, there is possibility of the study area to host some metallic minerals. The nature and the occurrences of such metallic minerals that may likely present in the study area could only be unravelled when a detailed mineral exploration program is carried out (Ayodele and Asubiojo, 2021; Olususi *et al*., 2022). Ayodele *et al*. (2017) carried out geochemical analysis using XRF on bedrocks, the geochemical result of which revealed gold mineralization in Okemesi (Ajindo) in Ilesha Schist-belt with concentration range value (10-0.05 ppm). Thus, the aim of this investigation is to reveal the nature and kind of minerals present in the study area using both geological and remote sensing techniques. This is due to non- availabilibility of any exploration reports that could serve as a reliable

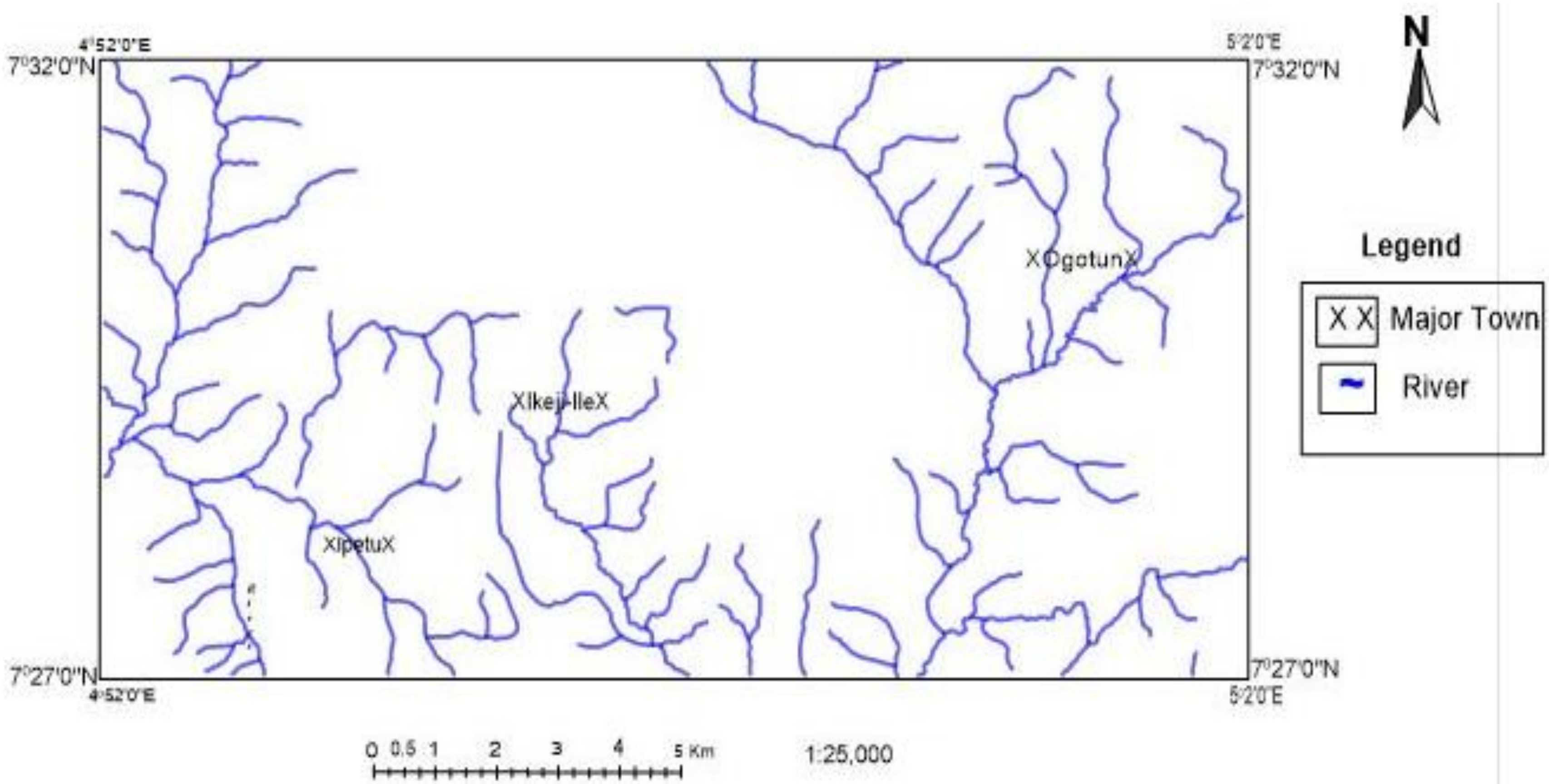


Figure 2 Drainage map of the study area.

guide on the mineralization potentials of the study area.

METHODOLOGY

A Sentinel-2A Imagery of the study area was acquired and digitally processed to obtain the remotely-sensed data, followed by automatic extraction of lineaments using Envi 5.0, Geomatical, Arc Gis 10.3 and Rockwork software to generate the required lineaments, lineament density as well as the mineralogical maps of the study area. The Sentinel-2A optical imagery which was clipped out from the (Sentinel-2A scene 2A_MSILC_20200505T100031_N0209_R122_T3 1NG1_2020505T115737) already downloaded from MSI database a multispectral Instrument has made it possible to directly download image of the sentinel already corrected for atmospheric effect via the website https://scihub.copernicus/dhus/#/ home. Image enhancement was done to improve the visual interpretability of the image by increasing the apparent distinction between the features in the scene; this was achieved with the use of Envi 5.0 software. Principal Component Analysis (PCA) method was used to generate PCtiff for the extraction of geological information. Image was further subjected to automated processing by specifying different parameter such as curve length, linking distance, kernel size, etc. using Line module of the PCI Geomatical software. The calculation of lineament related values with script files was done using Arc GIS 10.3 software. A lineament density map was produced. Then rose diagram was generated using Rockworks 17 software to determine lineaments trends and the statistical summary of the characteristic or property of the lineaments identified in the study area. Band Rationing method were used for the purpose of detecting iron bearing and hydroxyl ions minerals present in the study area.

Geological mapping of the study area was carried out on scale of 1:25,000 by traversing the length and breadth essentially on foot through existing roads, footpaths and river channels with the aid of the global position system (GPS). Rock samples were taken at sampling density of one sample per 4 km^2. A total of thirty-two (32) fresh rock samples were systematically collected with their geographical coordinates documented in the field notebook using the Global Positioning Systems (GPS). Fifteen rock samples were selected for petrographic studies which involved preparation of thin sections at the Professor Idowu Odeyemi Petrology Laboratory, Department of Applied Geology, The Federal University of Technology Akure, Ondo State, Nigeria. Fifteen rock samples were carefully selected for mineral identification under transmitted light using the Research Petrological Microscope. Also, five rock samples were prepared for polished sections because their thin sections revealed opaque minerals whose identities could not be resolved under transmitted light. Therefore, the Ore Microscope was used to analyse and identify these opaque minerals under reflected light.

RESULTS

Remote sensing

The acquired remote sensing data is the Sentinel-2A optical imagery (Figure 3) from which the data were extracted using Envi 5.0, Geomatical and Arc map 5.0 software to produce the Lineament, Lineament density and mineralogical maps of the study area. The preliminary structural information such as fracture length and density were extracted and statistically analyzed to produce the rose diagram (Figure8) mineralization. Therefore, the intensity of weathering of the rocks has created the pathway for the mineralizing fluids to settle in the rock matrix. This is reason why the rocks with higher lineament density are not hosting any metallic minerals because they are subsidiary fractures hence, the mineralization of the study area is not structurally control but lithological in nature. (Figure 6).

Band Rationing method were used to detect the iron bearing and hydroxyl ions minerals present in the study area. Ferrous Oxide and Ferrous Silicate were two prominent minerals identified in the study area (Figure 7). This is also an indication for potential gemstones mineralization in the study area.

Geological mapping and field description of the rocks

The geological and cross-sectional map of the study area are presented in (Figure 9). The map showed the dispositions of the different rock units with well delineated boundaries. Five lithologic units were identified which includes Metaconglomerates, Granites, Quartzites, Schists and Migmatites. The cross-section map confirmed folding in the study area which affected the quartzites and quartz-schists and the type of fold recognized is an antiform. The field description of the different rocks encountered are discussed below according to their ages (youngest to oldest).

Metaconglomerates

This rock type constituted an isolated, moderately high outcrop only in one location at Ipetu, south-western part of the study area. It is made up of pebbly and cobbly clasts set in a fine grain matrix. The clasts show physical stretching which is an evidence of deformation on the outcrop. The common structural features on the outcrop are foliation, crenulation and joints. The common minerals present in the rock are quartz, feldspar, biotite, microcline and opaque minerals (Figure 10d).

Porphyritic granites

This rock unit occurred as an intrusion in the study area. In most locations, it occurred as a high rising pluton, low lying flat and extensive with sparse vegetation. The occurrence is prominent at Ipetu, the western part of the study area. It also formed an isolated outcrop at Ikeji-Ile where it intruded the quartzite. Structure common to the outcrop include quartz vein, veinlet, pegmatite, dykes, exfoliation xenoliths etc. Porphyritic granite has a composition of mafic and felsic minerals, the mafic minerals are biotite and hornblende while the felsic minerals are quartz, microcline and plagioclase feldspar (Figure 10e).

Quartzite and quartz-schist

The quartzites and the quartz-schists form good topographical features which rise up to about 350 meters above the surrounding terrains forming ridges. These outcrops dominated the central to western part of the study area which covered Ikeji-Ile and Ipetu area but conspicuously absent at the eastern part of the study area

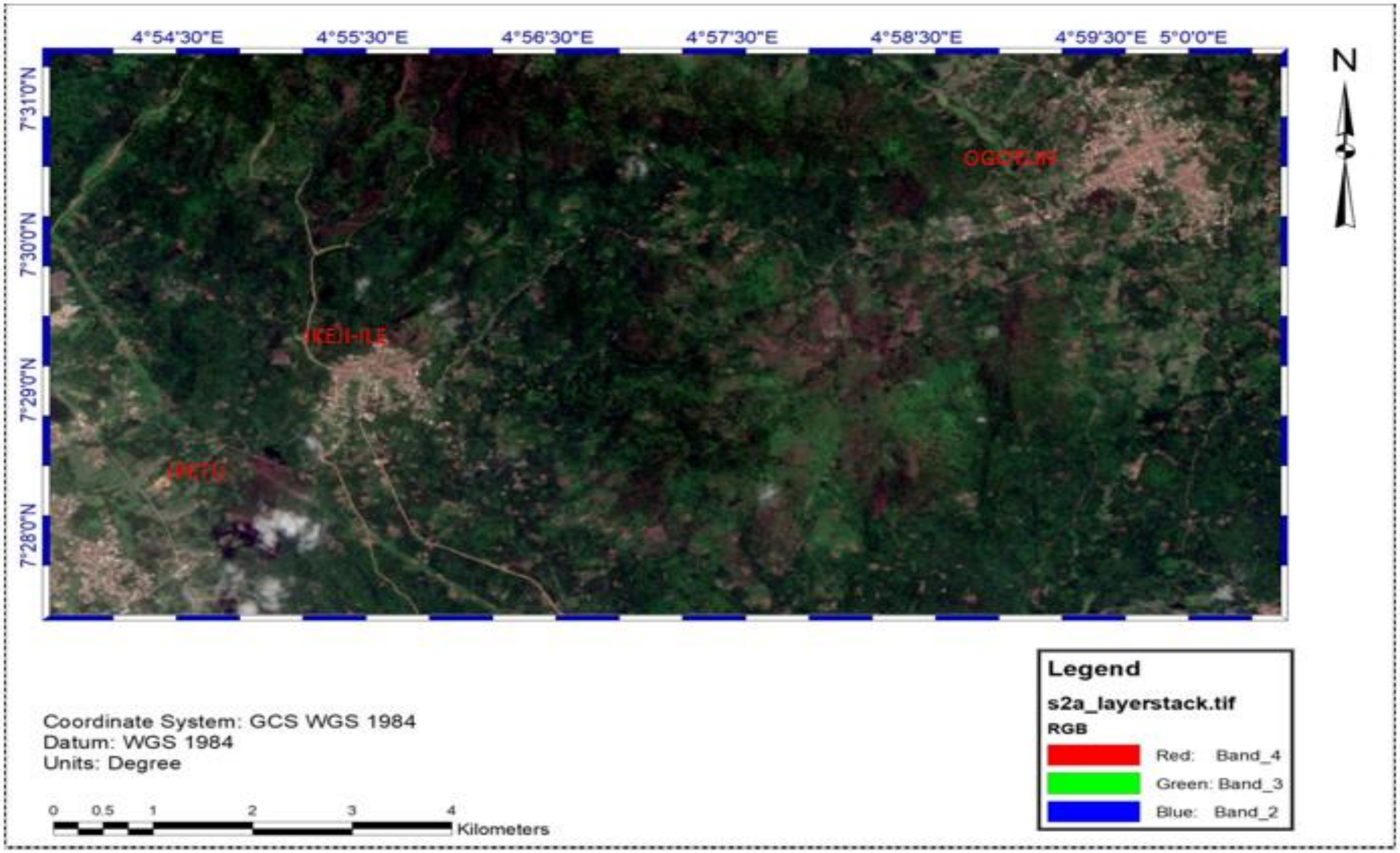


Figure 3. Sentinel-2A imagery of the study area.

particularly Ogotun area. Quartz, biotite and opaque minerals are found both as granular fine-medium grained regions, quartzites are foliated with clear exhibition of felsic with a grain-flattening. The schistose and mafic minerals alternating to each other. The mafic mineral is mostly biotite with planar fabric while the felsic mineral is quartz. Structural features such as joints, multiple joints, folds were also identified on the schistose quartzite, which are evidences of the level of deformations (locally) that affected the study area. While the massive quartzite are having a granular

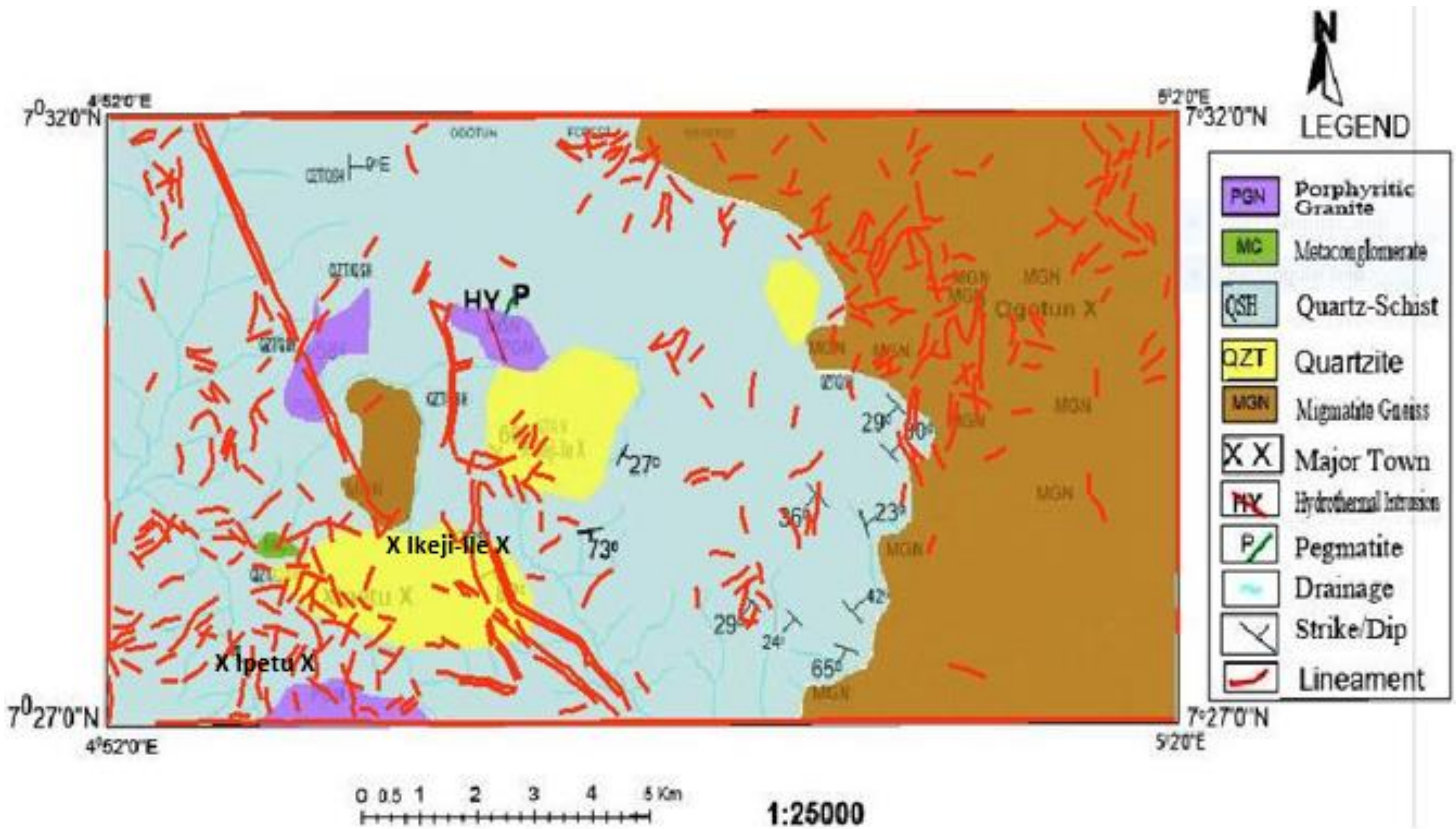


Figure 4 Geological Map of the Study area overlay with Lineaments.

texture and are friable when struck with hammer. Biotite, quartz, plagioclase and opaque (Figure10b & c) are dominant minerals.

Migmatite-gneiss

This rock type is presumably the oldest group of rocks and most widely spread of all the lithologies. It occupies about 60% of the study area and dominated the eastern part of the study area

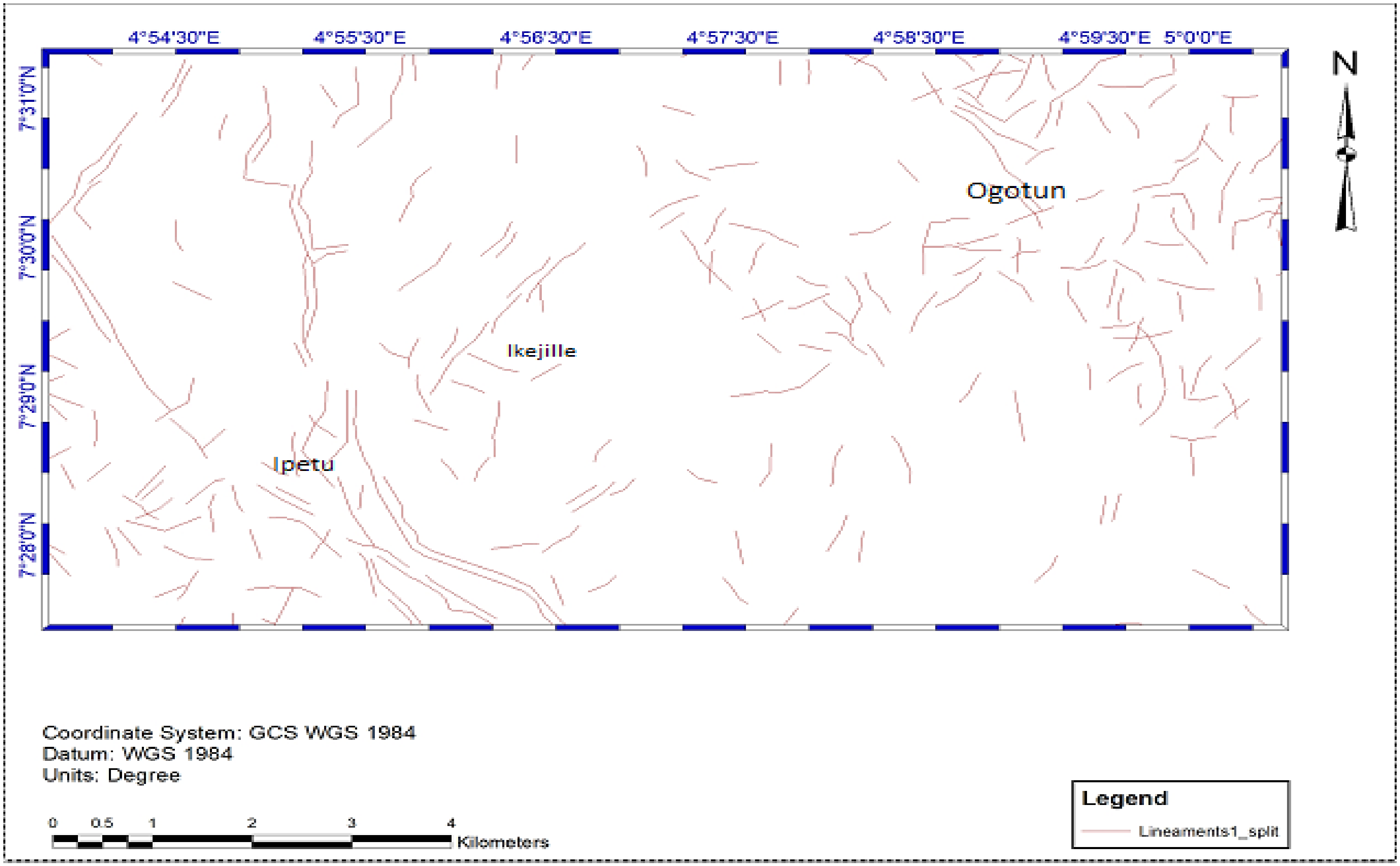


Figure 5. Lineament map of the study area.

especially Ogotun Township and its environs. It appears as low-laying outcrops in some places while it formed an isolated high hills in other areas. The rock has medium to coarse grained in nature, the gneissic part of the migmatite is characterized by conspicuous gneissic banding of mafic and felsic minerals of varying thickness while some portion of the migmatite (the granitic part) have a porphyritic texture having a fine matrix of biotite and plagioclase. The most common structural features of this rock are lineation, foliation, dykes, pegmatitic intrusions, joints, xenoliths and cavity or solution holes. The rock has a mineralogical composition of quartz, orthoclase and plagioclase feldspar, hornblende and mica (Figure 10a). Five

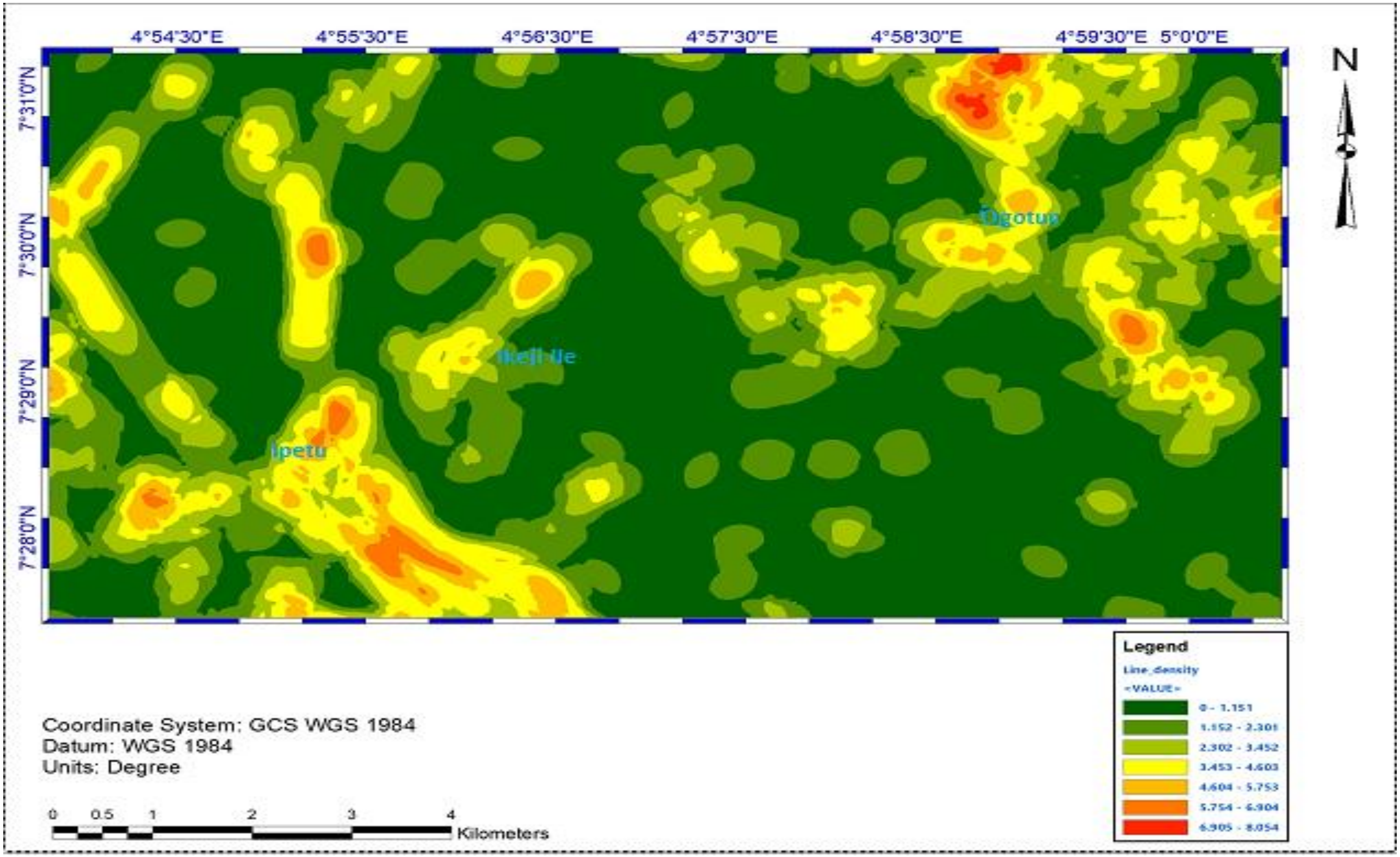


Figure 6. Lineament density map of the study area.

rock samples were prepared for polished sections and subsequently analyzed using the Reflected Ore Microscope. Three out of the thin sections were discovered to have a metallic mineral which has brassy yellow colour and was confirmed as Chalcopyrite. However, quartz-schist at Ikeji-Ile majorly hosted the Chalcopyrite while other rocks displayed a trace/minor concentration of the metallic mineral under reflected light. The detailed of the samples of the quartz-schist polished sections photomicrograph is presented in Figure 11.

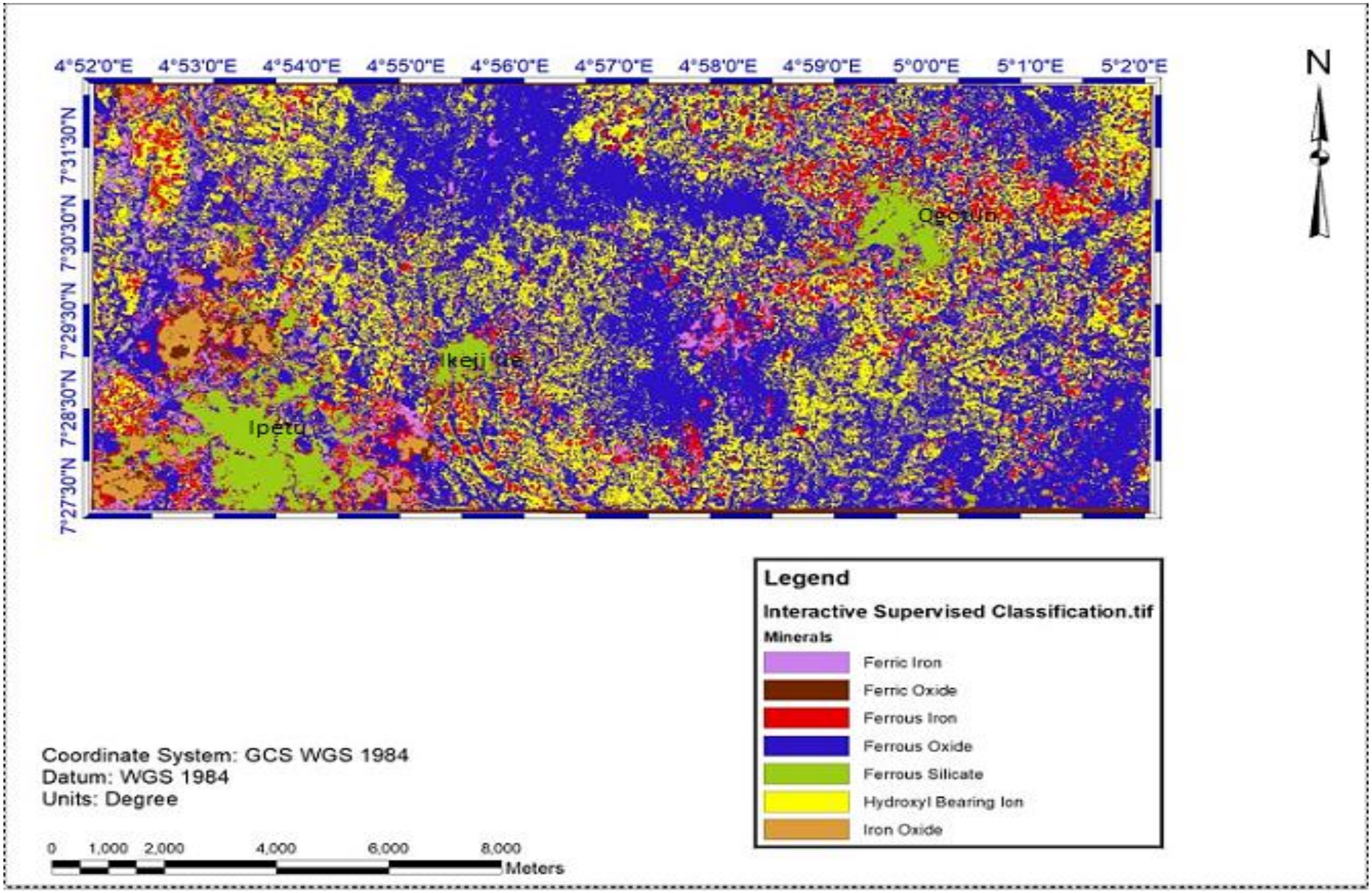
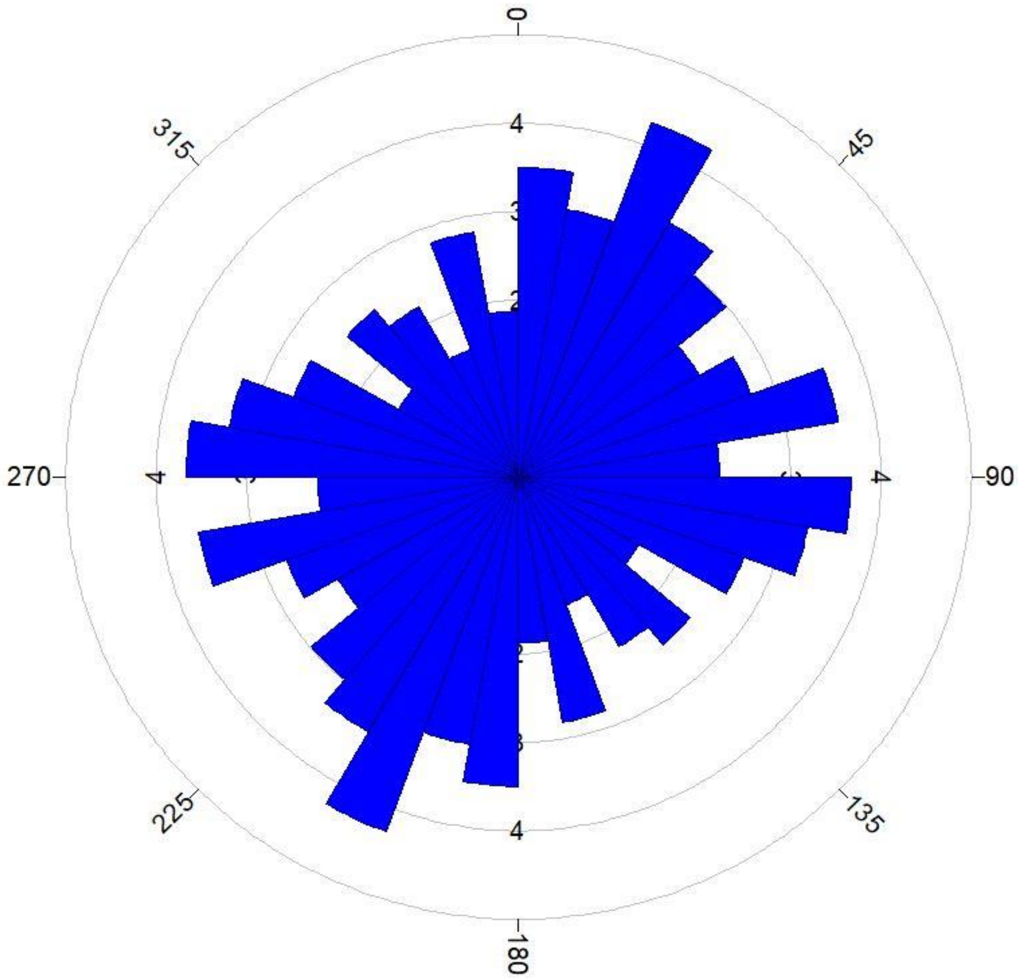


Figure 7. Mineralogical map of the study area.

DISCUSSION

Remote sensing and Geological techniques have provided the basis for mineral exploration in the meta-sedimentary rocks of the studied area which can also serve as exploration guide for future researchers. The utility of multispectral remote sensing techniques for discriminating materials was based on the differences that exist among their spectral properties, this is refer to as spectral signatures of the minerals and rocks. The Lineament map showed that the study area has low



Statistical Summary	
Calculation Method:	Length
Class Interval:	10.0 Degrees
Min.Length Filtering:	Deactivated
Max.Length Filtering:	Deactivated
Azimuth Filtering:	Deactivated
Data Type:	Bidirectional
Population:	586
Total Length of All Lineations:	501,205.17
Maximum Bin Population:	50.0
Mean Bin Population:	32.56
Standard Deviation of Bin Population:	8.72
Maximum Bin Population (%):	4.27
Mean Bin Population (%):	2.78
Standard Deviation of Bin Population (%):	0.74
Maximum Bin Length:	21,572.0
Mean Bin Length:	13,922.37
Standard Deviation of Bin Lengths:	3,872.62
Maximum Bin Length (%):	4.3
Mean Bin Length (%):	2.78
Standard Deviation of Bin Lengths (%):	0.77
Vector Mean:	39.3 Degrees
	219.32 Degrees
Confidence Interval:	29.9 Degrees
	(95 Percent)
R-mag:	0.11

Figure 8. Rose diagram of the study area.

density fractures due to the nature of the rocks and its spectral reflectance characteristics; fractures trend in E-W direction had almost been obliterated or overturned; this observation conformed with that of Oluyide (1988) and Omitogun and Ogbole (2017) that the study area had been exposed to many deformation episodes which must have obliterated or overturned the earlier structural grain of the rocks. Quartzite and quartz-schist tend to form good topographical features which rise up to about 350 meters above the surrounding terrains forming ridges. These outcrops dominated the central to western part of the study area which covered Ikeji-Ile and Ipetu area but conspicuously absent at the eastern part of the study area particularly Ogotun area. Quartz, biotite and opaque minerals are found both as granular fine-medium grained regions, with a grain-flattening.

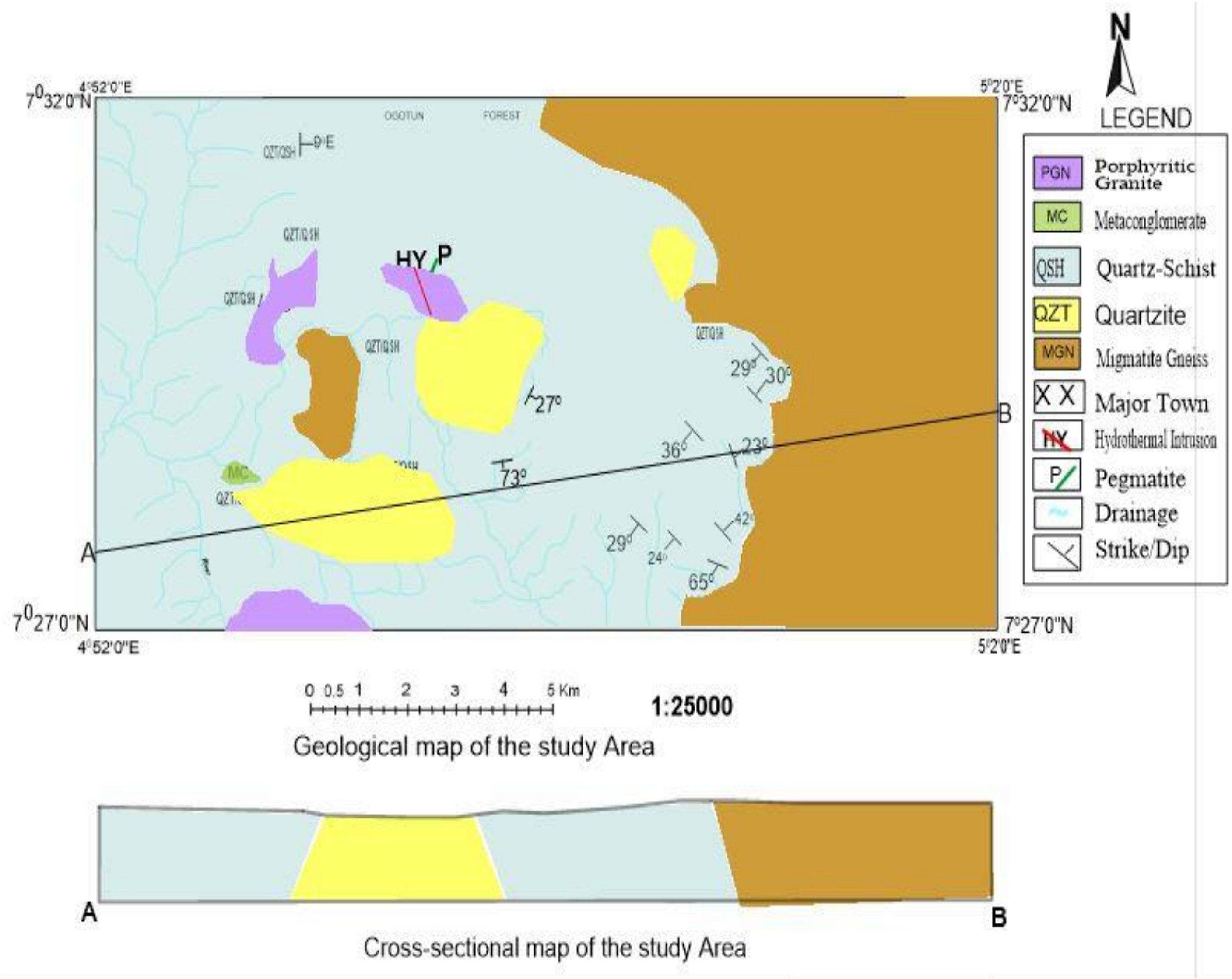


Figure 9. Rose geological map of the study area.

The schistose quartzites are foliated with clear exhibition of felsic and mafic minerals alternating to each other. The mafic mineral is mostly biotite with planar fabric while the felsic mineral is quartz. Structural features such as joints, multiple joints, folds were also identified on the schistose quartzite, which are evidences of the level of deformations (locally) that affected the study area. While the massive quartzite are having a granular texture and are friable when struck with hammer. Biotite, quartz, plagioclase and opaque (Figure10 b & c) are dominant minerals. The lineament density map observed provided information about the mineralization control of the study area. It was observed that areas with higher lineament density are not hosting mineralization. This is due to the intensity of weathering and deformation. The weathering has created pathways for the ore bearing fluids to settle at the rock matrix while the deformation has weakened the rock fabrics that were to host mineralization, hence, the lithologic control of mineralization in the study area. In addition, the rocks with higher lineament density are not hosting any metallic minerals because they are subsidiary fractures which also affirmed lithologic control of mineralization in the study area (Figure 6). Other Minerals identified are the Iron silicates (Fe_2SiO_4) which are linked with band rationing which occur as Hydroxyl bearing ions, ferrous oxide and iron oxide which suggested the possibility of gemstones mineralization. Similar studies in Efon and Okemesi area also confirmed this assertion (Ayodele and Asubiojo, 2017; Omitogun and Ogbole, 2017).

The rose diagram showed that the dominant fracture trends are in the migmatite rocks and are majorly in the NE-SW direction. The response of individual lithology to the deformational forces was different in the study area as

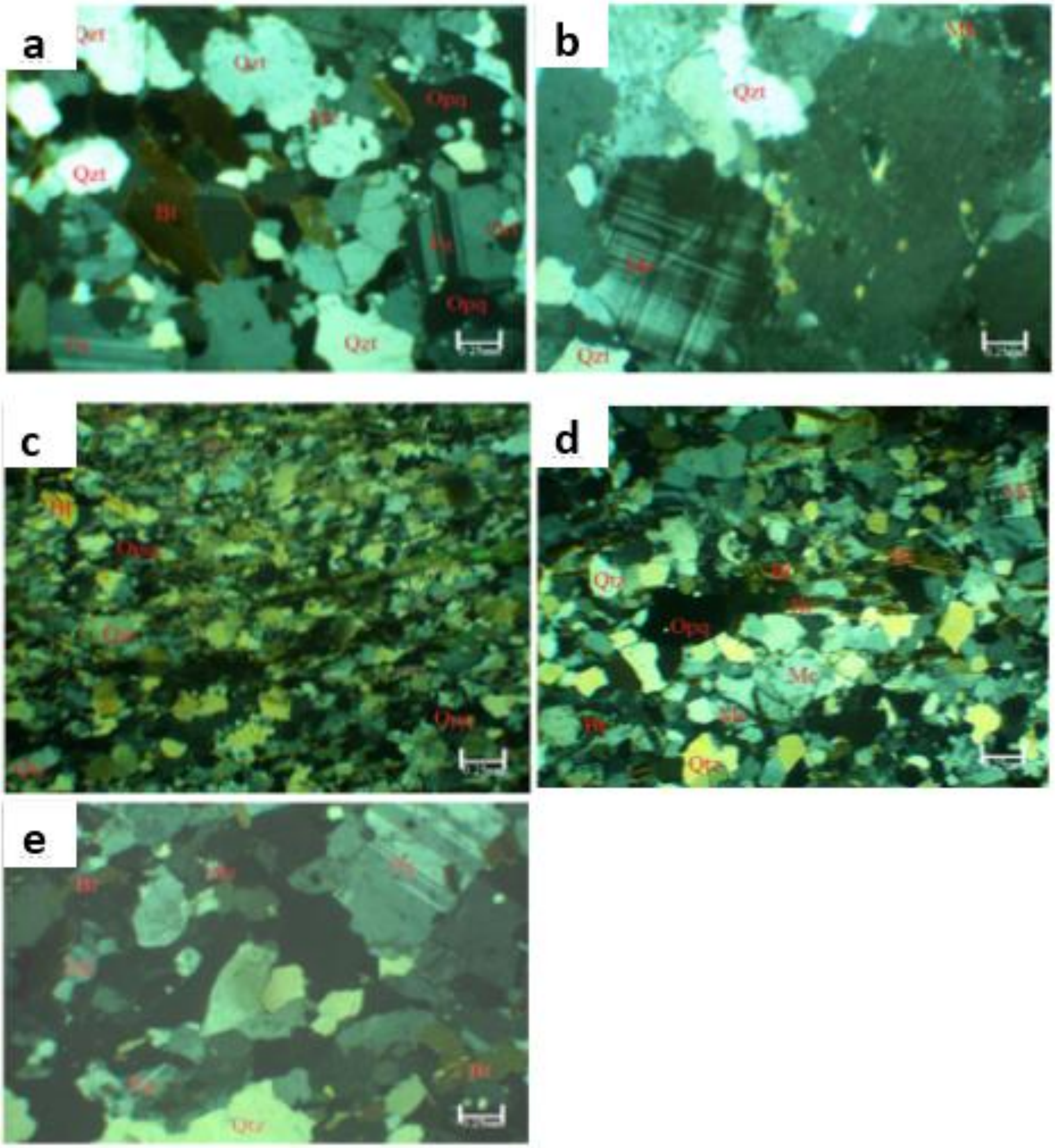


Figure 10. Photomicrographs of selected thin section: (a) Migmatite/gneiss (b) Quartzite (c) Quartz-schist (d) Metaconglomerate (e) Porphyritic Granite. **NOTE:** Qtz=Quartz, Bt=Biotite, Mc= Microcline, Pg= Plagioclase, Opq= Opaque mineral.

shown by the rose diagram. Shorter lineaments are associated with migmatite gneiss and quartz schist because they are ductile, while the longer lineaments are associated with quartzite and granite because they are brittle in nature. Consequently, the suspected hydrothermal fluids could only be lithological controlled since the structural framework for ground preparation for epigenetic mineralization has been weakened by successive deformational episodes according to the work of Olususi et al. (2022).

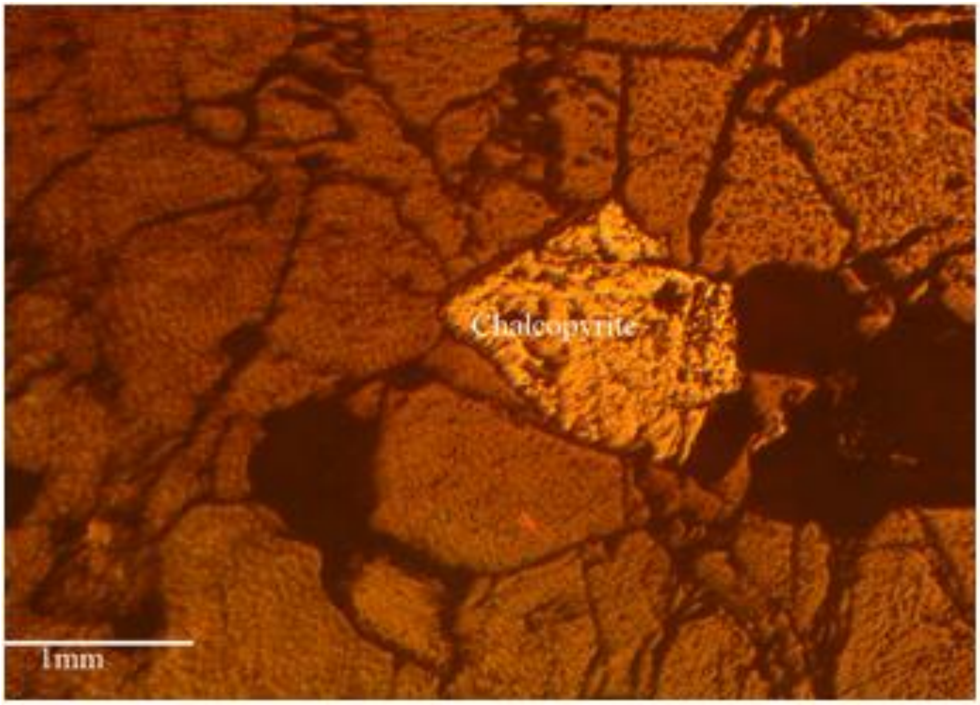


Figure. 11. Photomicrograph of polished section of quartz-schist showing chalcopyrite.

Conclusion and Recommendation

This study has demonstrated the versatility of satellite images as an important tool for geological mapping and mineral exploration. The sentinel data show improved extraction of lineaments on comparing with ASTER and Landsat by integrating edge detection algorithm and line linking algorithm. It is also useful in detecting lineaments in all directions. This study also revealed that mineralization is lithologically controlled because the structural fabrics that could hold mineralization have been completely destroyed by the deformation events the study area had witnessed in the geological past. In addition, the results obtained from the ore microscopic analysis of the polished sections of the quartz-schists and the migmatite-gneiss also confirmed sulphide mineralization (Chalcopyrite) which is a product of wall rock alteration and supergene enrichment. This study also confirmed gemstone mineralization both from remote sensing and field studies which are hosted by the complex pegmatites in Ikeji-Ile. However, the use of hyper spectral remote sensing is however desirable in the study area as this would make work easier and efficient for identifying in details most minerals that could not be identified with multispectral remote sensing such minerals are sulphides and carbonates that mostly associate with hydrothermal alteration. In addition, a much detailed geological and structural mapping of the area need to be carried out in order to have much in-depth knowledge of the tectonic evolution of the area.

CONFLICTS OF INTEREST

The authors declare that they have no conflict of interest.

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