An Integrated Technique in Delineating Structures: A Case Study of the Kushaka Schist Belt Northwestern Nigeria

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Abstract

A combined GIS, aeromagnetic and remote sensing techniques were used in the Kushaka schist belt with the aim of assessing their usefulness in delineating geologic features within Kushaka schist belt northwestern Nigeria. The area has been known to host important mineralization notable of which are gold and rare earth metal pegmatite. The techniques proved to be useful in identifying known and new structures in the study area especially when they are used together. Over 100 new lineaments were interpreted, five of which were later confirmed to be minor fault system. Analytical signal function indicates that with the exception of the Kalangai fault system the rest of the known and new faults systems are shallow (probably upper crustal).

Keywords: Lineaments, Faults, Kalangai Fault system, Analytical Signal, DEM, Aeromagnetic, Landsat ETM+.

Introduction

The Kushaka schist belt occupies a belt of about 50 km wide and stretching from the Minna area up to the Tsohon Birnin Gwari area of northwestern Nigeria (Fig.1). The rocks lie in a number of isoclinal fold structures trending NNE, which give rise to a strong foliation parallel to the axial planes of the folds (Truswell and Cope 1963). Many granitic plutons intrude the metasedimentary succession (schist, phyllites, banded iron formations), and the whole series is cut and displaced by Kalagai Fault (Fig.1). The area is known is well known to host gold mineralization as well as other minerals such as rare earth metal pegmatite The regional and local controls of most of the mineralization in this area are primarily structures e.g gold (Garba,1992, 2000, 2002; Akande *et al*.,1988). The role of fractures in mineralization is dual, as channel ways for the mineralization solution and as loci of deposition of mineralization. Regional features are of fundamental importance in selection of targets for mineral exploration, while localize features such as contact zone and shear zone are responsible for the localization of the ore deposit. These geologic features could be either directly observed or interpreted from data sets such as aeromagnetic and landsat imageries. The present study is aimed at assessing the usefulness of these multidisciplinary data sets in delineating these features as well as other structures which could be associated with mineralization in the study area. The present levels of knowledge of mineralization in the study area, couple with the availability of these data sets form the bases for choosing the area for the application.

Regional Geology and Structure

The basement complex of northwestern Nigeria is part of the Neoproterozoic to early Phanezoic terrain separating the West Africa and Congo craton. This vast terrain consist of reactivated older crust in which Archaean (ca 2700 Ma) and Palaeoproterozoic (ca 2000 Ma) isotopic ages have been recorded (Grant, 1970; Grant et al., 1972; Oversby, 1975). The Pan African event (600±150 Ma) was the latest reactivation that affected the whole region (Turner, 1983; Fitches et al., 1985; Wright et al., 1985). The terrain is therefore referred to as the Pan African shield.

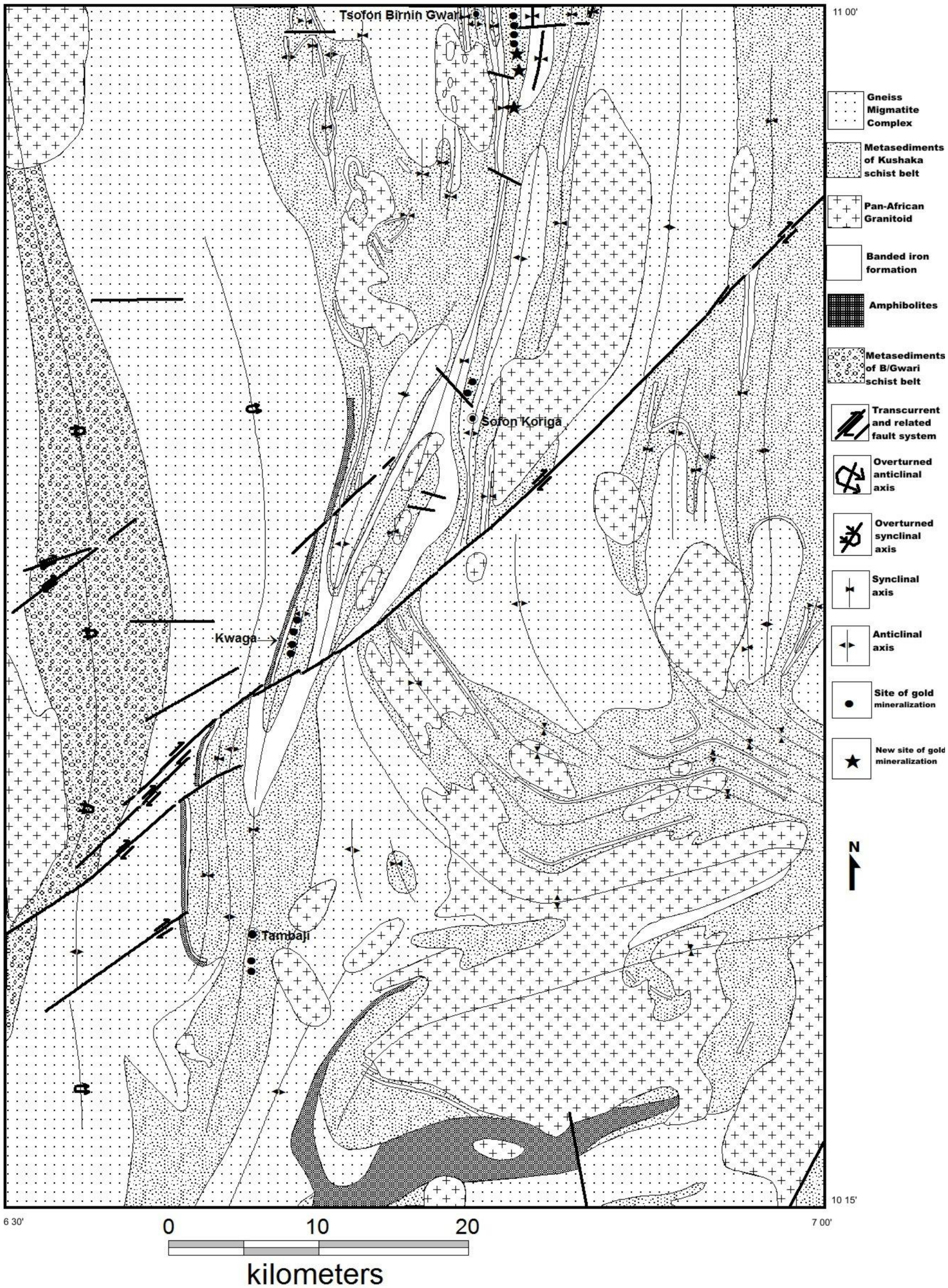

Fig.1:Geology of the Kushaka schist belt (northwestern Nigeria) with areas of gold mineralization (modified after Truswell and Cope,1963) in Garba,2002.

The Pan African event imposed a generally north- south foliation and cleavage trend in rocks and brought about the emplacement of granitoids in the region (Turner, 1983; Fitches et al., 1985). The Pan African shield in Nigeria is usually divided into three lithostratigraphic units:

i) The basement gneisses and migmatites, with supracrustal relics yielding in many places Archaean and Palaeoproterozoic ages. Metamorphism is generally in the amphibolites-facies grade.

ii) The schist belt, are mainly north-northeast trending belt of low to medium grade deformed supracrustal assemblages (with minor volcanic units). They are considered to be late Proterozoic cover with metamorphic grade mainly within green schist-facies in northwestern Nigeria.

iii) The Pan African granitoids (Older Granites) are mainly syn- to late- tectonic intrusions of granites, tonalites, granodiorite, diorites, some gabbros, syenites and charnokites. They range in size from small subcircular stocks to large batholithic bodies emplaced into both basement gneisses and supracrustal rocks during or just after the main phase of Pan African deformation (Fitches et al., 1985; Wright et al., 1985). Some contacts with the host rocks show narrow thermal aureoles (Fitches et al., 1985). Many of the granitoids plutons give ages in the range 750 – 450 Ma (Van Breemen et al., 1977; Ogezi, 1977; Holt, 1982).

Two major transcurret fault systems with dextral displacements are known in the Precambrian basement. They trend in the NE-SW direction displacing earlier structures in the order of tens of kilometers. The two fault systems are known as the Anka fault and the Kalangai-Ifewara fault (Fig.2) and are often associated with locally developed subsidiary (NW-SE) sinistral fault and are considered to be conjugate system of late Pan-African brittle deformation that occurred after about 530 Ma on a continental scale (Ball, 1980). The close association of ultramafic and related rocks with the fault systems suggests that they might be crustal sutures (Wright, 1976; Ajibade and Wright 1989). A collision-type orogeny has been suggested (Ball, 1980; Wright et al., 1985), involving the

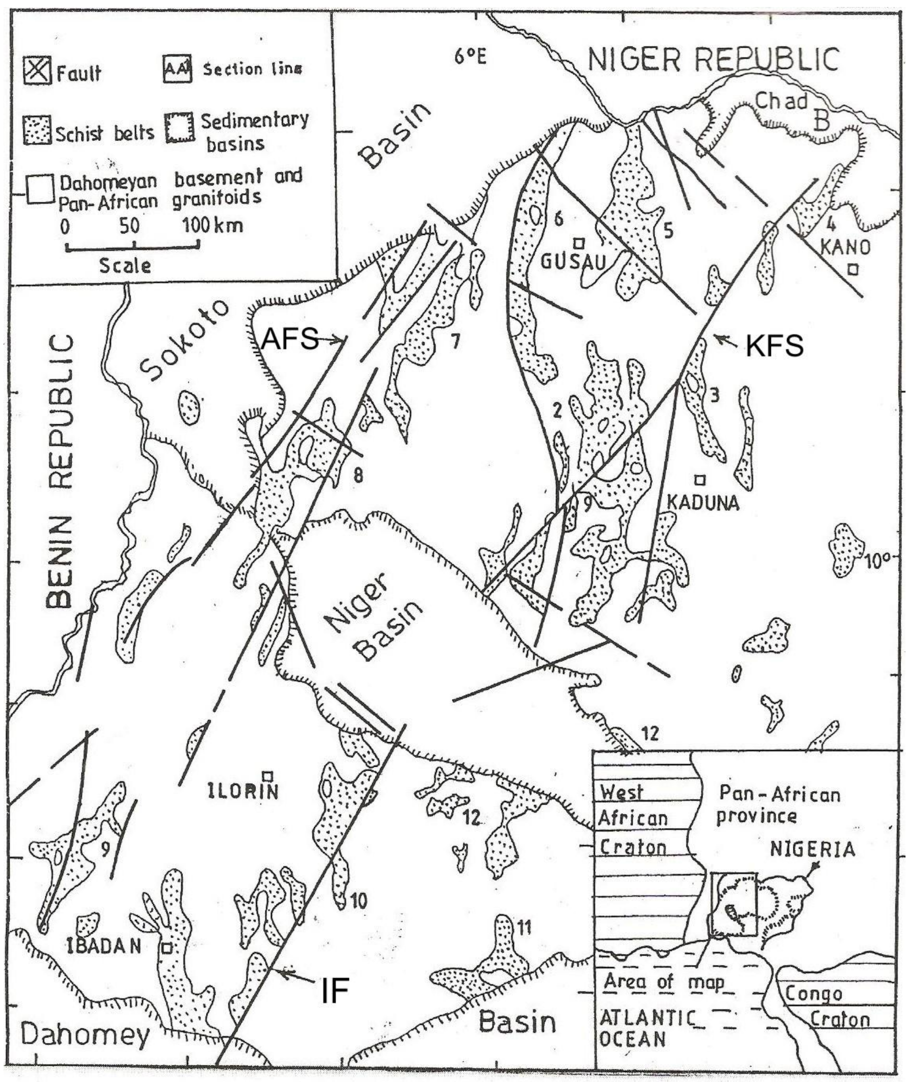

Fig.2: Regional geology and structure of western half of Nigeria, showing locations of key sites of gold Mineralization (modified after the !:2 000 000 Geological Survey of Nigeria, 1994, map) 1, Maru (Duki and Maraba); 2,Anka (Kwali and Jameson); 3, Anka (Zuzzurfa and Kuba); 4, Malele; 5, Bin Yauri; 6,Tsohon Birnin Gwari; 7, Kwaga; 8, Gurmana; 9, Okolom-Dogondaji and 10, Iperindo. AFS = Anka fault system, KFS = Kalangai fault system, IF = Ifewara fault.

Pan-African region and the West African craton, in which a subduction zone dip eastward beneath the Pan-African region. Deformation and metamorphism followed the continental collision at around 660 Ma with considered to be the basement *sensu stricto*, and most radiometric ages lie in the range 600 + 150 Ma, dating the imprints' of the consequent crustal thickening in the Nigerian region (Turner,1983). The period 650-500 Ma was characterized by extrusion of post-tectonic alkaline to calc-alkaline volcanic and brittle deformation, as the last manifestation of the Pan-African orgeny(McCurry and Wright, 1977).

Material and Methods

Two different aeromagnetic data sets were acquired from the Nigerian Geological Survey Agency (NGSA) and were used in the present study. The first data set is a 3-dimensional (3D) total magnetic intensity field with horizontal gradient enhanced raster image prepared especially for structural interpretation. The second data set contains corrected residual aeromagnetic field data of the area which allows calculations and conversions, unlike the raster image. The data was used to carry out analytical signal function analysis in order to delineate as well as check the continuity of structures of interest. A single scene of Landsat enhanced thematic Mapper plus (ETM+) Path 189 / Row 053 date 2000, and Digital Elevation Model (DEM) data covering the study area were also used in the present study. The data was processed using different techniques ranging from contrast enhancement, band rationing, shaded relief and principle component analysis. Several digital image of the study area were generated from the landsat data ranging from a single band images to multiple band images. False Colour Composite image (742 in RGB) was found to be suitable for this study as it highlights most of the lineaments and hence was used in the present study. The Digital elevation model (DEM) contains elevation data of the terrain of the study area. The model has been largely used in lineaments extraction and is adopted in this study. Lineaments deduced from the aeromagnetic data, landsat ETM+ and digital elevation model are presented in figure 3, 4 and 5 while the analytical signal solution function is presented in figure 6.

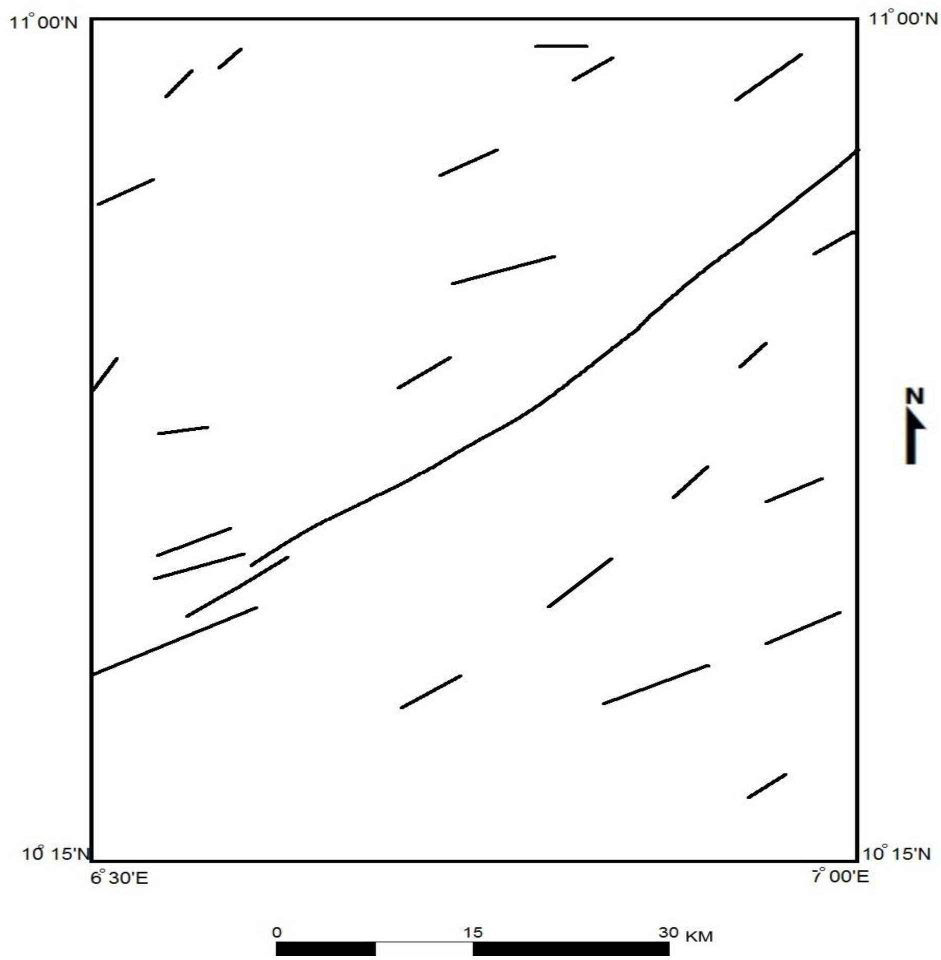

Fig.3: Lineaments deduced from 3D total magnetic intensity field raster image.

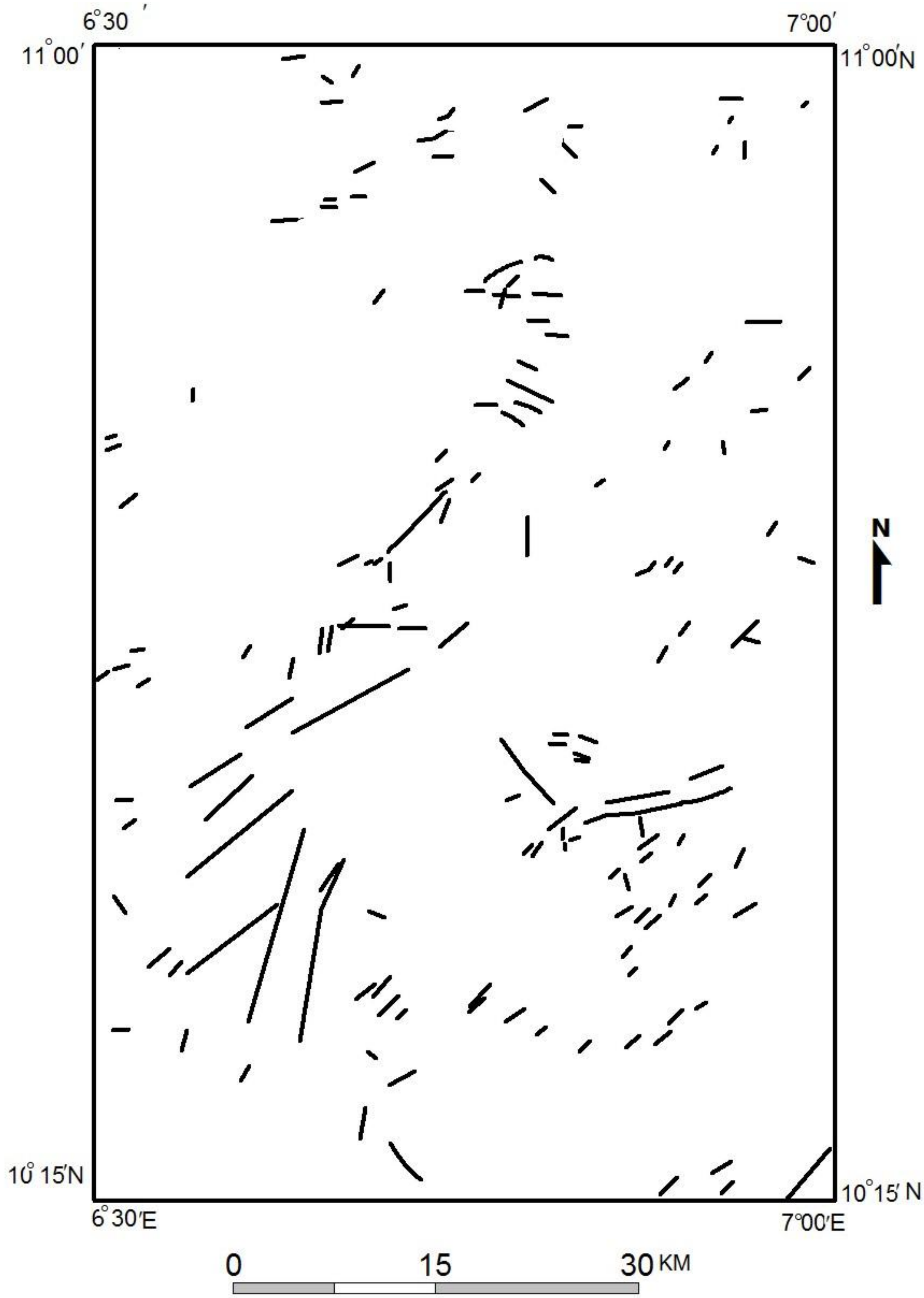

Fig.4: Lineaments deduced from Landsat ETM+

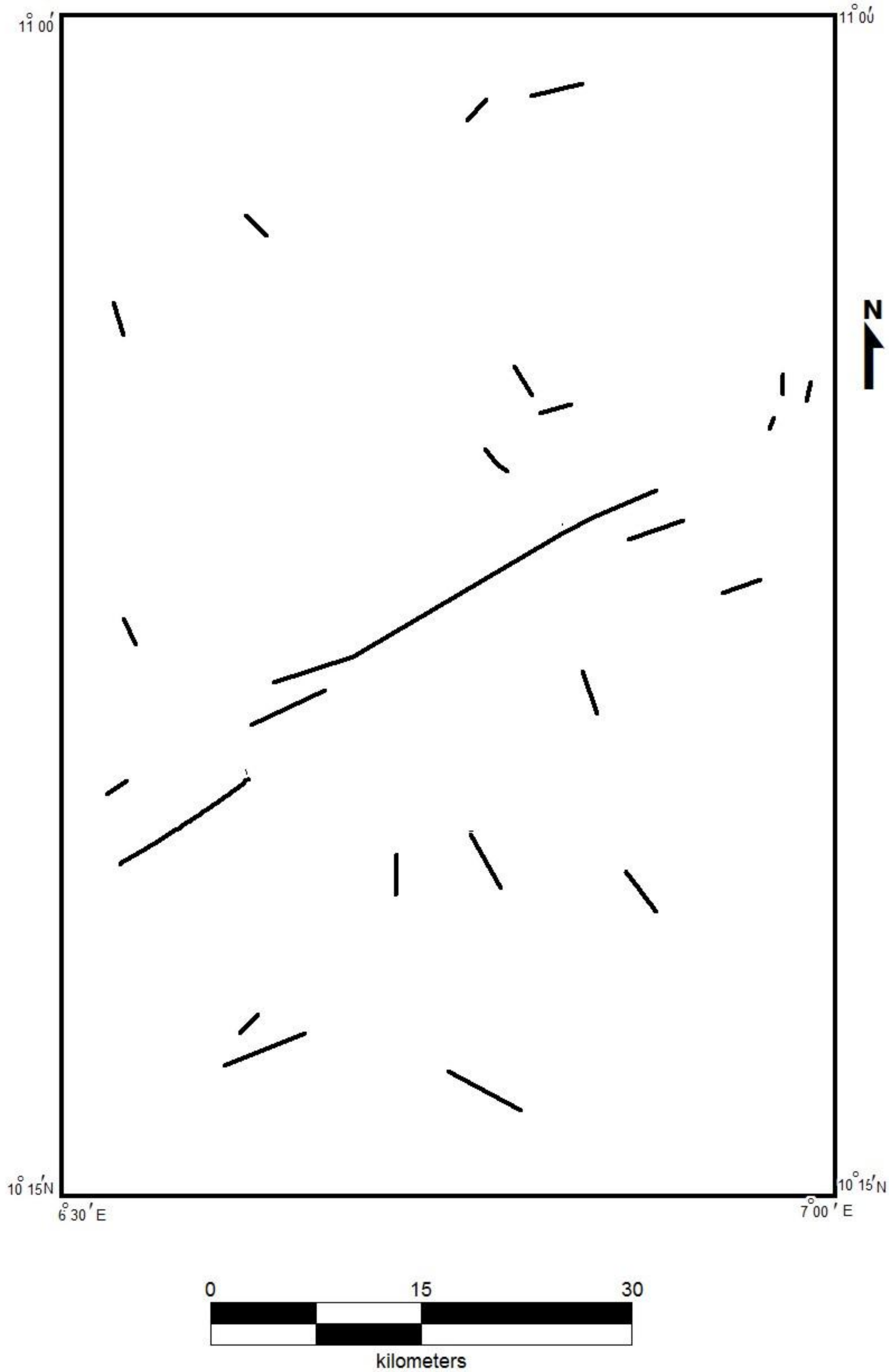

Fig.5: Lineaments deduced from digital elevation model (DEM)

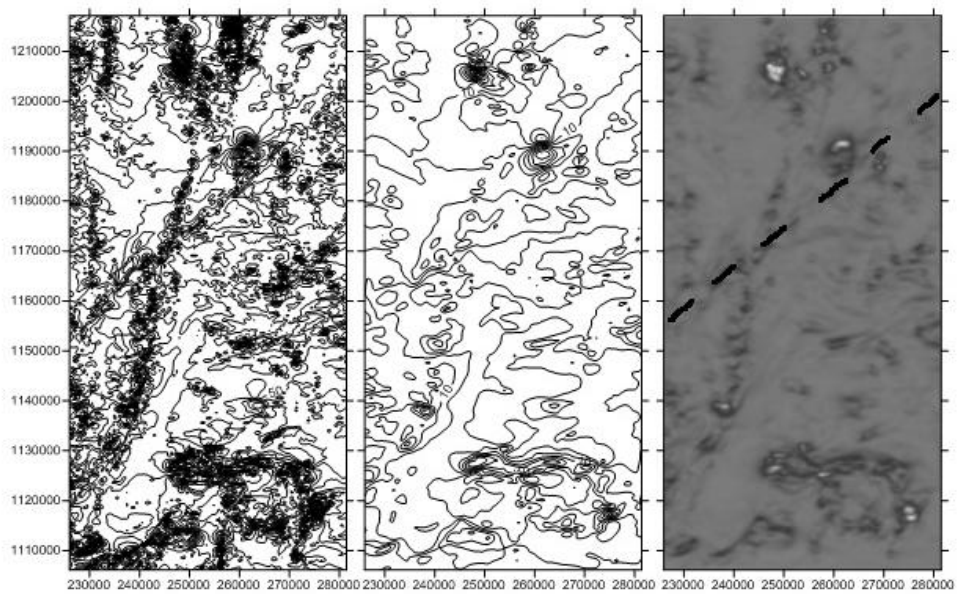

Fig.6:a) Residual magnetic field data of the study area
b) 500 meters upward continued residual magnetic field
c) Analytical signal function of the upward continued field data

Note: The difference between figure **a** and **b** as a result of filtering effect caused by the upward continuation.

Results and Discussion

There is a good correlation between the lineament map produce from the three data sets. The three lineament maps (Aeromagnetic, Landsat and DEM) were combined together to produce a composite lineament map (Fig.7). Some of the interpreted lineaments correspond to known structures within the study area. These structures were first isolated and the rest were interpreted based on existing knowledge of structures in the area and additional fieldwork. Field expression of the interpreted lineaments corresponds to ridges, furrows and tracks, while others correspond to tributaries of rivers and strike direction of some geologic features within the study area. The analytical signal function map indicates that with the exception of the Kalangai fault system most of the interpreted lineaments are shallow. Five out of the 114 newly interpreted lineaments were later confirmed to be minor fault system in the area (Fig.8).

Three conspicuous short wavelength high intensity anomalies can be observe at the extreme northern part in the residual aeromagnetic data of the study area (Fig.6a), this can be attributed to the Pan-African granitoids and the banded iron formation (BIF) in that area. Another such anomaly occurs in southern part and can be attributed to the large intrusion of the granitoid in that area. The anomalies appear to be deep seated as indicated by the upward continued map and the analytical signal function map (Fig.6b,c). Correlation between the newly interpreted lineament and areas of gold occurrences shows no any significant spatial relationship, However, the data used in the study has prove to be useful in identifying known and new geologic features in the area especially when they are combined.

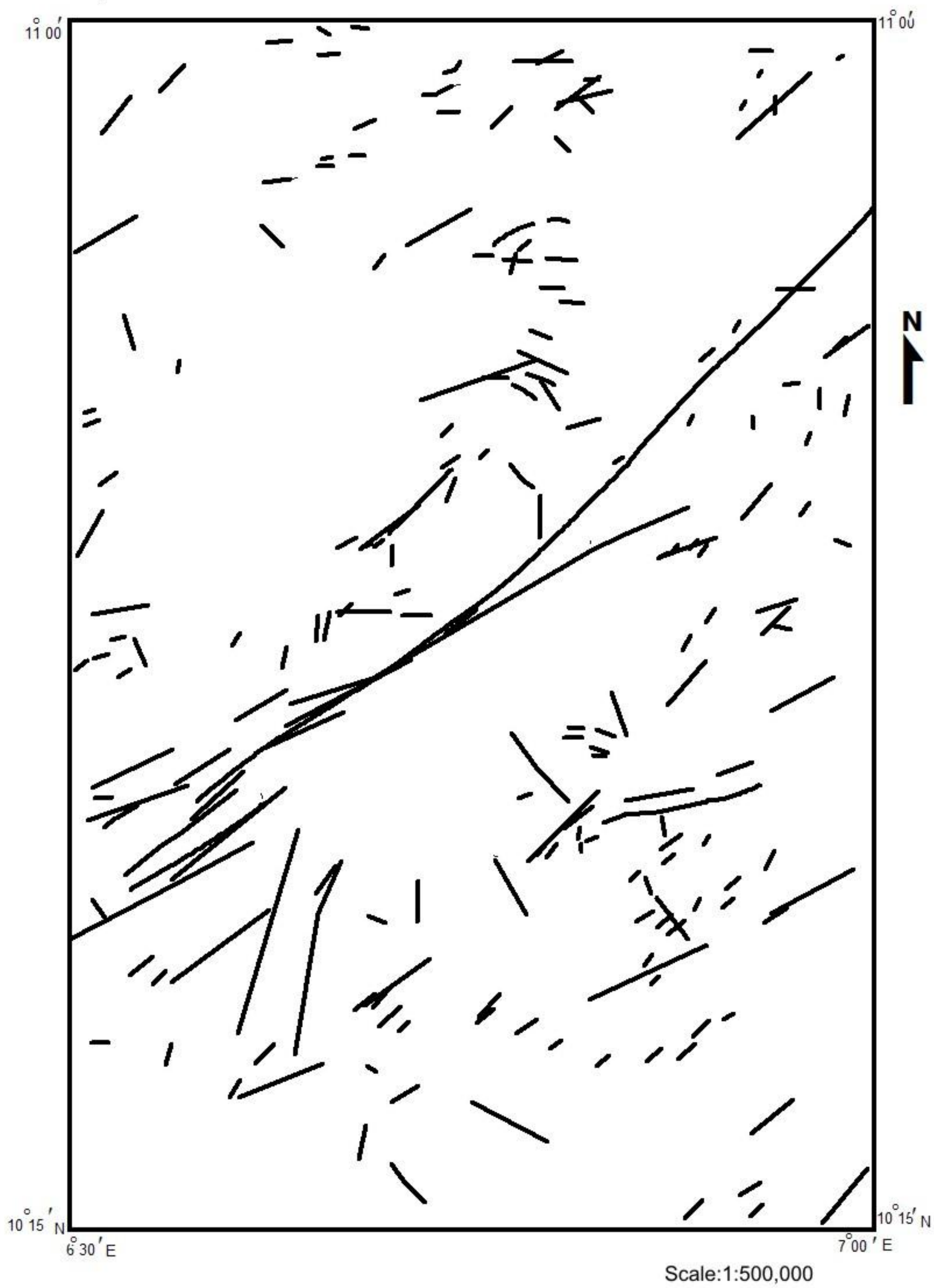

Fig.7:Composite lineament map of Aeromag, Landsat and DEM of the study area.

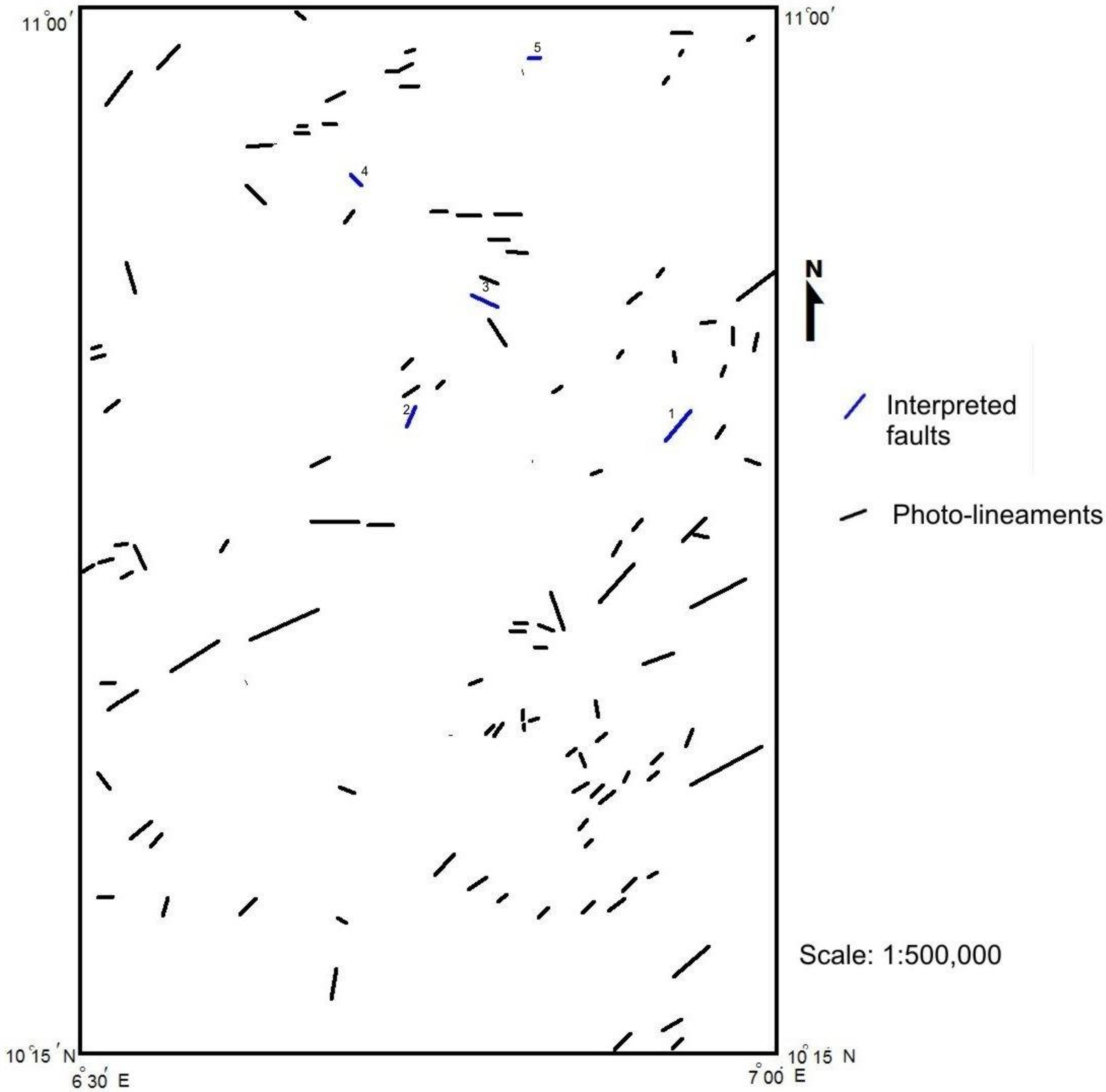

Fig.8: Composite map of newly interpreted lineament within the study area

Conclusion

The present study has shown that the use of these multi-disciplinary data sets in delineating subsurface and surface structures in the study area prove to be useful. The study has also shown that the Kalangai fault system is deep seated (probably deep crustal) further supporting the fact that the gold mineralizing fluid in the area evolve from deep crustal reservoir and subsequently channelled through the fault system hence the fault acted as a channel way, while most of the interpreted and known structures of interest are shallow (probably upper crustal). Five new subsidiary fault systems were identified in the study area.

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