Reconnaissance geochemical and geophysical exploration for gold at Iri gold field, north central Nigeria

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Abstract

Field geological mapping and reconnaissance geochemical and geophysical exploration for gold was carried out at IRI Gold field north central Nigeria. Results of the geological mapping show the major lithology in the area is silicified sheared rocks and large quartz veins. Undifferentiated schist was intruded by quartzite at different locations and possibly during a major geological event which left shattering of the rocks all around two major ridges within the study area. Preliminary geochemical characterization revealed the rocks have weak geochemical anomalies of gold (Au), except in two locations where positive anomalies of gold (L3B=455ppb and L14=582ppb) were observed and identified as targets for further exploration. Interpretation of the aeromagnetic data gives the orientations of the structural features, and the major structural trend in the area is NE-SW. The lineaments extracted from the magnetic data range in length from 46.43m to about 1251.66m. Most of the lineaments extracted from the area are subsurface within the quartz-mica and migmatites while some of them have surface expressions, even though they are not clearly defined. Overall, the interpreted, geochemical signatures coincide with the geophysical signatures and were used to delineate the target prospective areas.

Index Terms: Gold mineralization, aeromagnetic data, geochemical data, schist belt, Nigeria

1. Introduction

Gold mineralization in the Nigerian schist belt is prominent. Pegmatite research in Nigeria by Ajibade[1] and Matheis *et al*.[6] used rare elements as indicators for tin mineralization without adequate information on the petrology. Most of the gold mineralization in the pegmatite is associated with sulphides and confined to pegmatite intrusions as veins. Iri, the study area, is part of the Zuru Schist belonging to the Nigerian schist belt. Artisanal gold mining has been well established in most of the localities in the study area, exploiting shallow alteration zones and quartz intruded veins and pegmatite. Pegmatites are coarse grained igneous and metamorphic rocks and represent the end product of the magmatic stage in the evolution of granitic melt. The pegmatite at Iri Village is the first mineralized pegmatite to be found in northern Nigeria and one of the few mineralized pegmatite fields in Nigeria.[6] Other pegmatite fields are at Elbe, Ijero and Jema'a. Preliminary geochemical and geophysical exploration has been carried out in the area to identify possible prospective targets. The combination of geochemical studies of rocks and sediments and the interpretation of aeromagnetic data can give information about prospective targets for detailed gold exploration in the area. This research was therefore aimed at carrying out reconnaissance geochemical evaluation and aeromagnetic data interpretation of parts of the Iri Gold field so as to identify mineralized targets.

1.1 The study area

The area is located near Iri village, in Rijau Local Government Area, North Central, Nigeria. It is located within latitude (4º 58ˈ 00"N to 4º 58ˈ 45"N**)** and longitude **(**11º 7ˈ45"E to 11º 8ˈ45"E) and covers an area of about 2.52 km^2 (see ***Figure 1***). The area can be accessed through the Minna-Kontagora and Kontagora-Rijau Roads; it can also be accessed through the Kontagora-Bin Yauri-Rijau Road and borders the town of Zuru in Kebbi State. The nearest business centres are Rijau and Zuru. The climate of the area is characterised by two distinct seasons, rainy and dry. The rainy season starts in April and ends in September. The peak of the rainfall period is between July and August. The temperature in the area varies between 30ºC and 35ºC. The coldest temperatures are experienced during the harmattan periods, when the temperature drops to 18ºC. During the harmattan, the winds are cold, dry, dusty and strong. The area is made up of typical savannah vegetation.

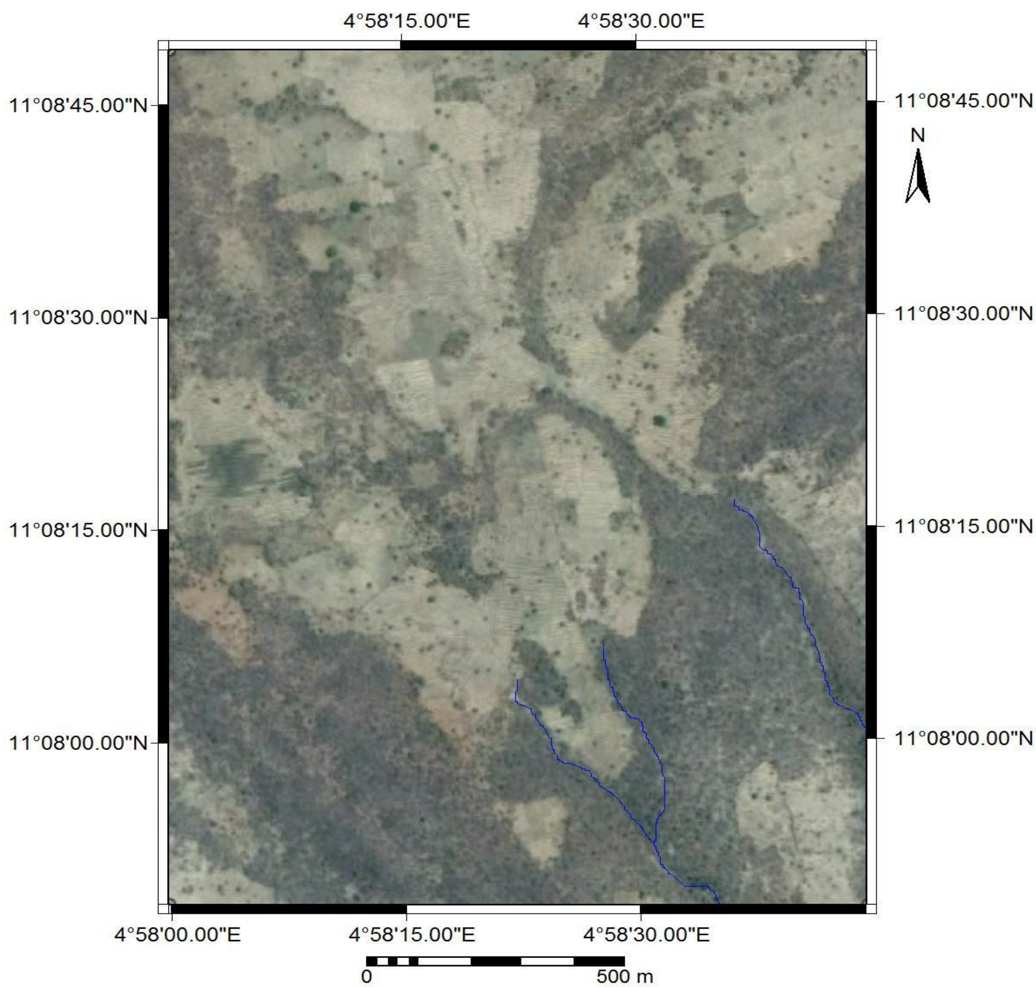

Figure 1. The study Area (modified from Google Earth, 2018).

1.2 Regional geological setting

The study area is part of the Nigerian schist belt. The Schist Belts in Nigeria comprise low grade, metasediment-dominated belts trending N-S which are best developed in the western half of Nigeria. Oyawoye[13] and McCurry[18] consider the schist belts as relicts of a single supracrustal cover. Olade and Elueze[11] consider the schist belts to be fault-controlled rift-like structures. Grant,[14] Holt[16] and Turner,[4] based on structural and lithological associations, suggest that there are different ages of sediments. Ajibade *et al*.[2] disagree with this conclusion and showed that both series contain identical deformational histories. The structural relationships between the schist belts and the basement were considered by Truswell and Cope[8] to be conformable metamorphic fronts and it was Ajibade *et al.*[2] who first mapped a structural break.

The geochronology of the schist belts remains problematic, although the ages of the intrusive cross-cutting Older Granites provide a lower limit of *ca* 750 Ma. A Rb/Sr age of 1,040 ± 25 Ma for the Maru Belt phyllites has been accepted as a metamorphic age by Ogezi[3]. The schist belt rocks are generally considered to be Upper Proterozoic. The geochemistry of the amphibolite complexes within the schist belts has also led to controversy. Klemm *et al.*[5] have concluded that the Ilesha belt may be an Achaean greenstone belt. Olade and Elueze,[11] Ogezi[3] and Ajibade[1] have favoured dominantly ensialic processes in the evolution of the schist belts, while Ajayi,[17] Rahaman[14] and Egbuniwe[7] have stressed that some include oceanic materials with tholeiitic affinities. Some metallogenetic features of the schist belts are relevant to these problems; the apparent absence of subduction related mineral deposits may be indicative of a limited role for the ensimatic processes; the distribution of primary gold occurrences in some belts but its marked absence in others may indicate that they do not represent a single supracrustal sequence.

The schist belts are confined to a NNE-trending zone about 300 km wide. The area to the west of this zone is made up of gneisses and migmatites that constitute the Dahomeyan of Burke *et al.*[10] Similarly, to the east, no schist belts are known for a distance of 700 km until in Cameroun, where a number of schist belts, considered to be Upper Proterozoic, occur in the Pan-African granite-migmatite terrain north of the Congo Craton. The schist belts have been mapped and studied in detail in the following localities: Maru, Anka, Zuru, Kazaure, Kusheriki, Zungeru, Kushaka, Isheyin Oyan, Iwo, and Ilesha where they are known to be generally associated with gold mineralization.

2. Material and Methods

2.1 Geological Mapping

Geological mapping was conducted in the area and geological information was recorded and further processed to produce the geological map, study field relations among lithological units and collect rock and soil samples for geochemical analysis.

2.1.2 Rock Sampling

Nineteen (19) rock samples (L3A, L3B, L5, L6, L9, L12, L14, L16, L18, L19, L20, L28, L29, L29B, L33, L36, L37, L38 and LDR) were collected at different locations during the geological mapping. The sampled rocks include pegmatite veins, quartz veins, quartzite and schist. At each location, the coordinates of the outcrop were recorded, hand specimen descriptions of the rocks were done and information on the texture, mineralogy and colour were recorded, the deformation structures on the rocks were observed and their orientations recorded.

2.1.3. Soils and Sediments Sampling

Twenty six (26) soil samples (L1S, L2S, L3S, L4S, L5S, L6S, L7S, L8S, L9S, L10S, L11S, L14S, L15S, L21S, L22S, L23S, L24S, L25S, L26S, L27S, L28S, L30S, L31S, L32S, L34S, and L35S) were collected in a 100 metre by 100 metre survey plan round the foot hills of the two ridges, One (1) pan concentrate stream sediment (L39BS) was collected at the stream beds of the river that drained in the area.

2.2. Geochemistry

At the sample preparation laboratory of MS Analytical in Abuja, Nigeria, all the samples collected were prepared for geochemical analysis. The procedure involved drying the samples and crushing to the particle size required. This was followed by grinding and milling of the rock samples to achieve the desired texture, and sieving of the soil and sediments. The samples were all transported to the MS

Analytical Laboratory in Canada for geochemical analysis using Au, Fire Assay, 30g fusion, AAS and Trace Level. For this purpose, the samples were crushed to pulverized fine before the analysis was carried out.

2.3. Aeromagnetic Data

The aeromagnetic data for the area covered by the study was acquired at a flight line spacing of 200 metres and a terrain clearance of 80 metres. The data available for this study was taken from the Shuttle Radar Topography Mission (SRTM), which was flown by the National Aeronautics and Space Administration (NASA) and obtained digital elevation models of the earth's surface. It is useful in surface mapping, especially in areas where a detailed geological map is not available. The data was acquired for this purpose from the Nigerian Geological Survey Agency (NGSA) Abuja, Nigeria, and is in gridded format, not flight line format.

3. Results and discussion

The sample locations map is presented in ***Figure 2***, the geological map is presented in ***Figure 3***, while the lineament map is presented in ***Figure 4***.

3.1 Geology

Two anticlinal ridges occurred in the area. They are in the south-western and north-eastern parts of the area. Regolith overburden indicating a high degree of weathering covers the bedrocks. The top of the ridges are characterized bt floated boulders of different sizes, mainly remnants of shattered quartzite. The quartzite boulders are massive, and whitish with yellow stains of iron incrustation. The textural composition of the quartzite boulders is fine grained. Isolated occurrences of Phyletic-Schist were observed in the area and believed to be intruded by quartzite during orogenic events. The schist was dark, containing mafic minerals and fine grained, dipping at 70ºE and oriented to the S-W. Pegmatite and quartz veins occur as minor intrusive bodies which could be prospected for gold mineralization. Structural analysis of the aeromagnetic data indicates that some of the rocks are well deformed and are either folded or faulted, trending N-S to NE-SW, which coincides with the disposition of the Pan African Basement structures[2]. North-East trending fractures and faults were also exposed and are exploited by most of the pegmatite veins. The lineaments extracted from the magnetic data range in length from 46.43m to about 1251.66m. The structures suggest predominantly northeast-southwest tectonic trends (see ***Figure 4***). Some of the lineaments derived from the magnetic data have surface expressions, even though they are not clearly defined.

3.2 Geochemistry

The Gold (Au) concentration maps in rocks and soils are presented in ***Figure 5*** and ***Figure 6*** respectively.

The concentration level of gold (Au) in the rock samples shows that all the samples analysed were mineralized with Au. Although the mineralization is quite above the crustal abundance of Au in normal geological materials of (4ppb),[9] it is far from the minimum value to be referred to as ore (2000ppb).[7] Therefore, the rocks show a weak anomaly, except in samples L3B and L14 (see ***Figure 7***). Possible mineralization with depth is expected. Locations L3B and L14 were identified as target areas for detailed exploration work involving pit sampling. The Au concentrations in the samples from locations L3B and L14 were 455ppb and 582ppb respectively, which are well above the Clarke value of 4ppb. Plots of the concentration of Au in both rocks and soils are shown in ***Figure 7*** and ***Figure 8***, and the target locations for further exploration were identified. The rock samples collected from L3B, L14, and L14P indicate moderate anomalies of Au. The soil samples from L2S, L14S, L24S, and L35S also indicate moderate anomalies, which coincide with the anomalies in the rocks. Comparison between the interpreted aeromagnetic data and interpreted geochemical data shows close agreement, and the results can be superimposed (see ***Figure 9***).

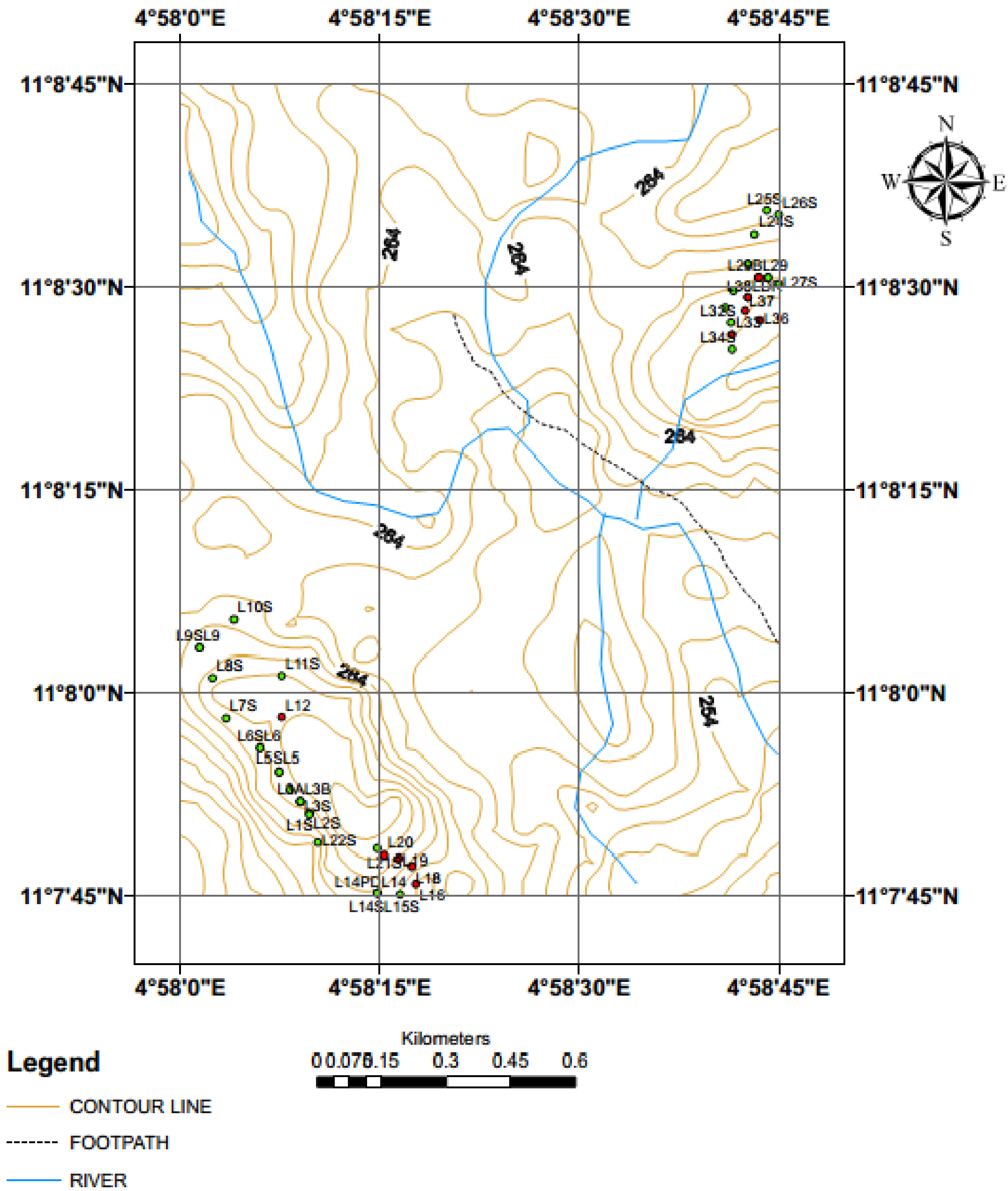

Figure 2. Sample locations map.

4. Conclusion

Preliminary geochemical and geophysical investigations conducted in the area suggest possible gold mineralization in two locations, where positive gold anomalies were identified. Prominent geological structures coupled with interpretation of the geochemical and geophysical data have been used to infer and delineate possible prospective targets. The major structural trend established from interpreting the aeromagnetic data is NE-SW, which is generally known to be associated with mineralization. The lineaments extracted from the interpreted magnetic data range in length from 46.43m to about 1251.66m. Most of the lineaments extracted from the area are subsurface within the quartz-mica and migmatites, while some of them have surface expressions even though they are not clearly defined. Magnetic lows can also mark non-magnetic, possibly mineralized shear zones or alteration zones. Most of the magnetic lineaments are within a depth of a few meters to 250 meters.

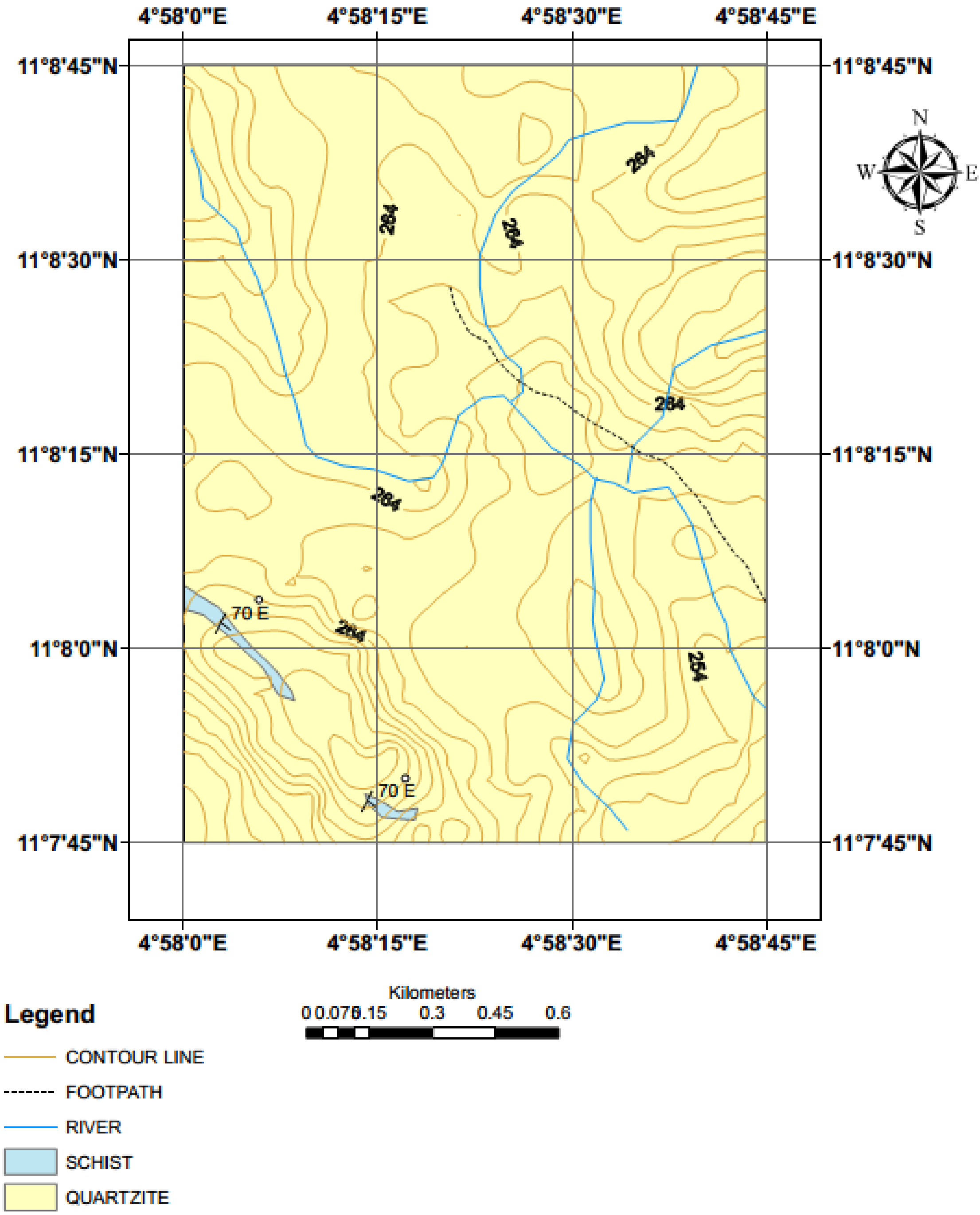

Figure 3. Geological map of the area.

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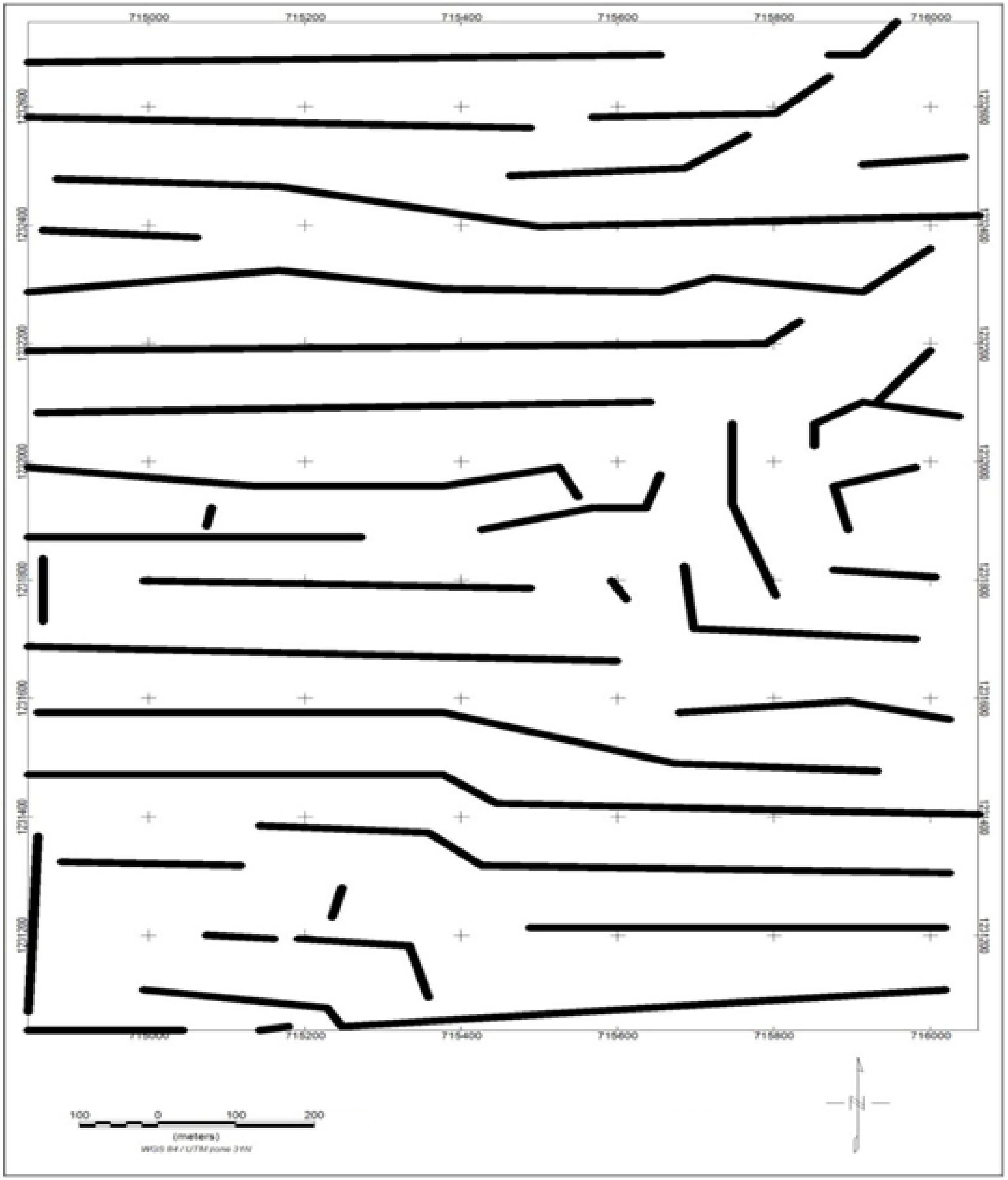

Figure 4. Lineament map of the study area.

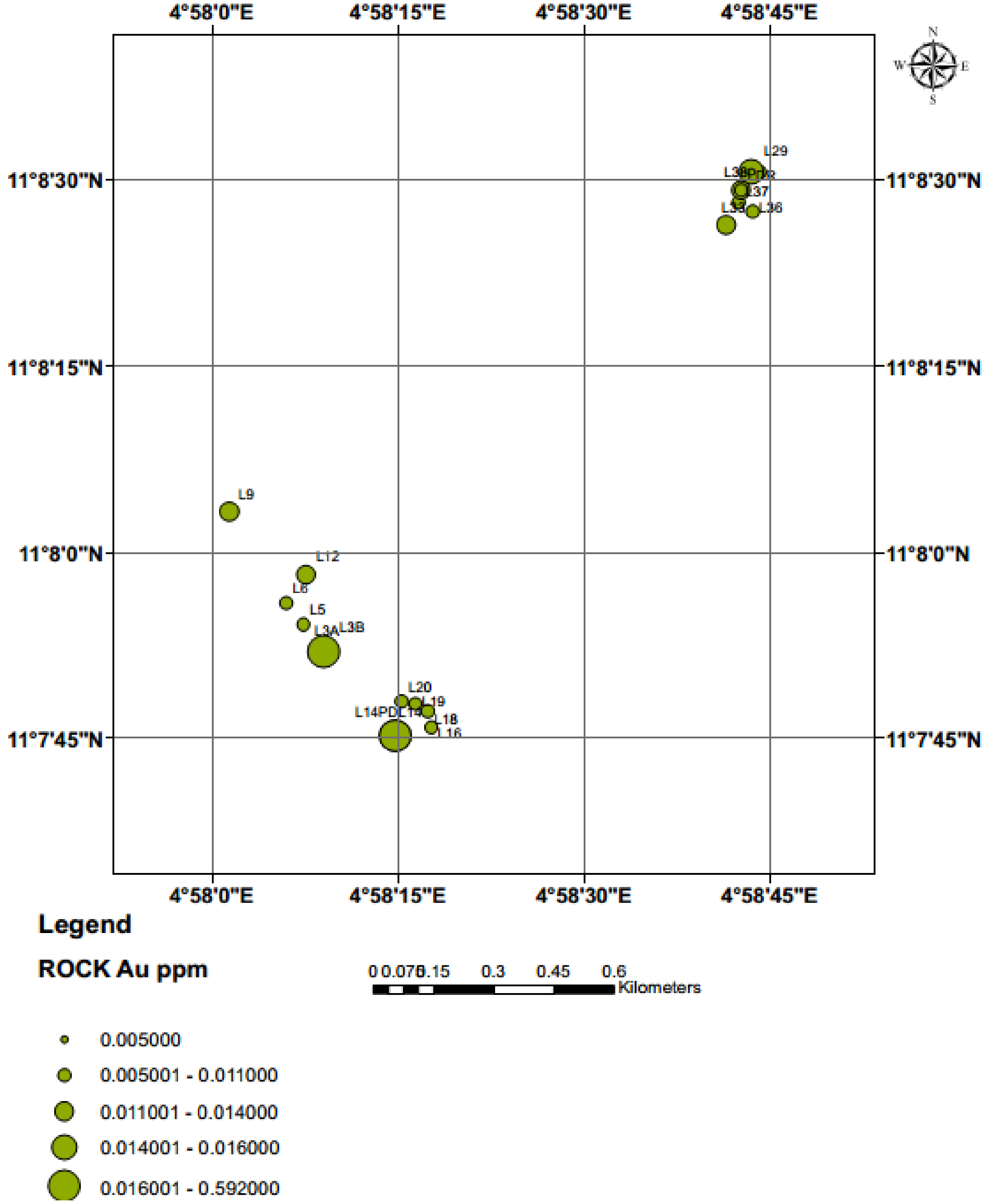

Figure 5. Gold (Au) concentrations in the rock samples collected in the area.

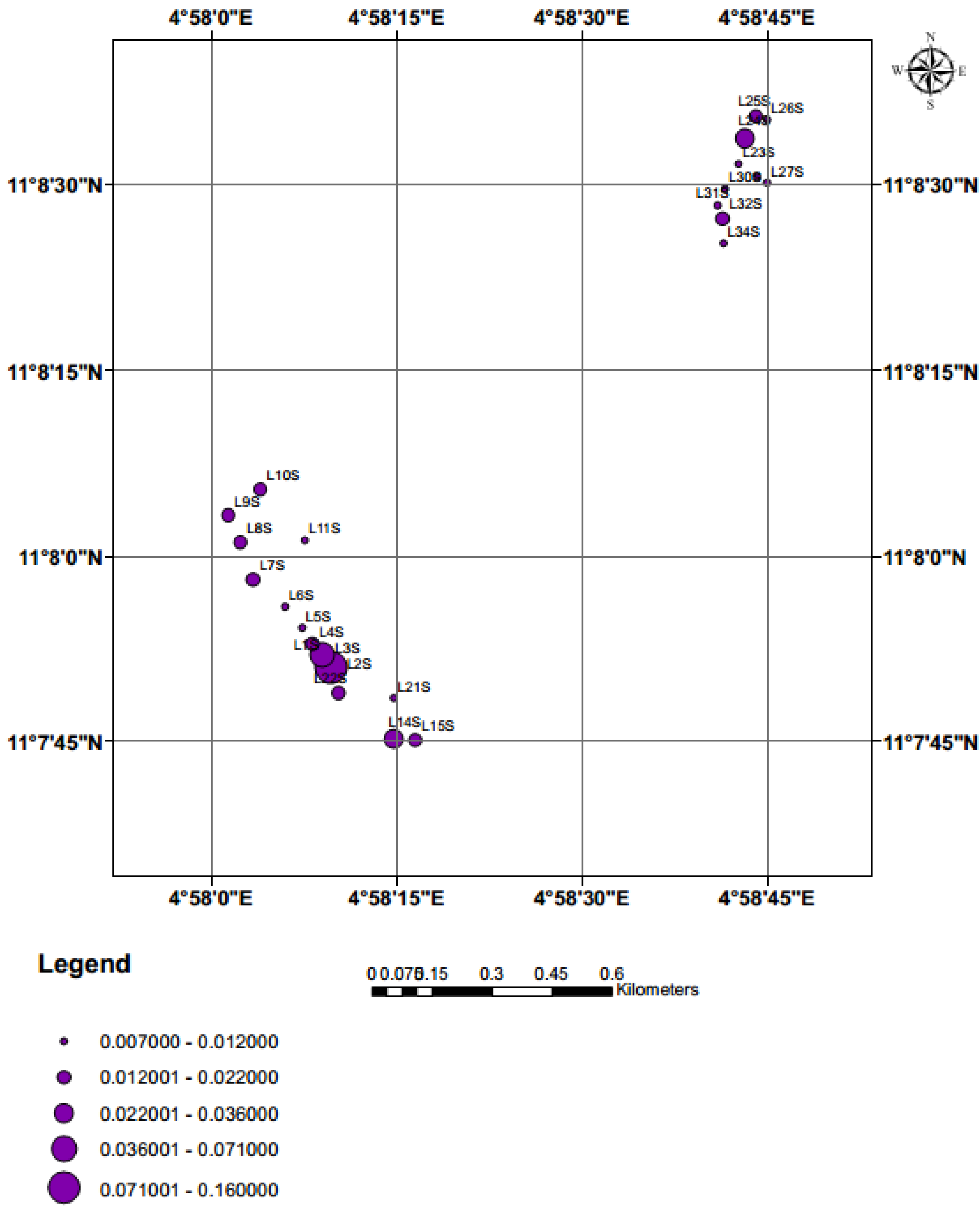

Figure 6. Gold (Au) concentrations in the sediments samples collected in the area.

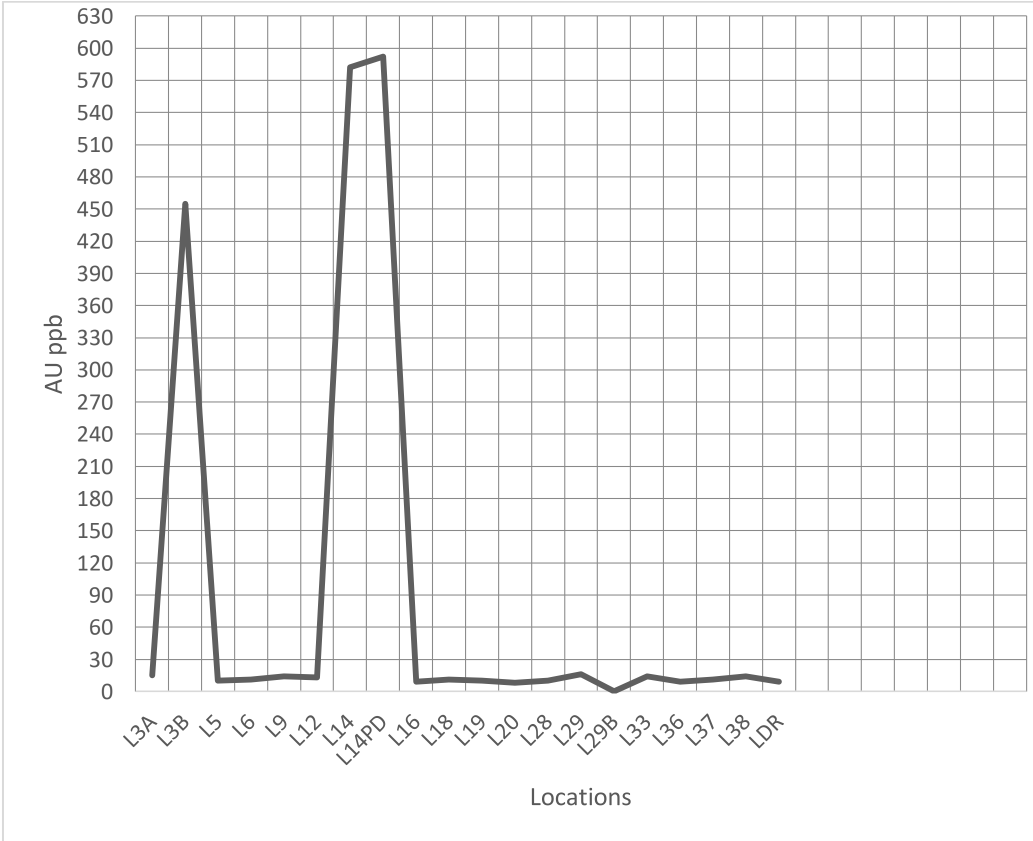

Figure 7. Concentration of Au in Rocks samples at Iri.

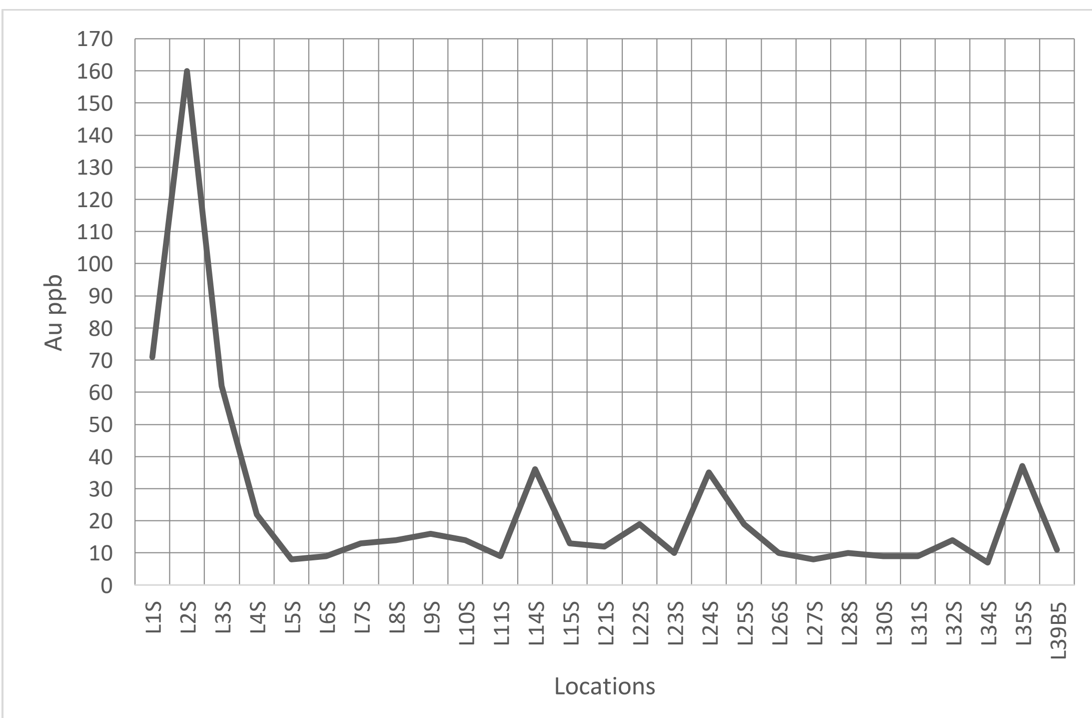

Figure 8. Concentration of Au in the soils samples at Iri.

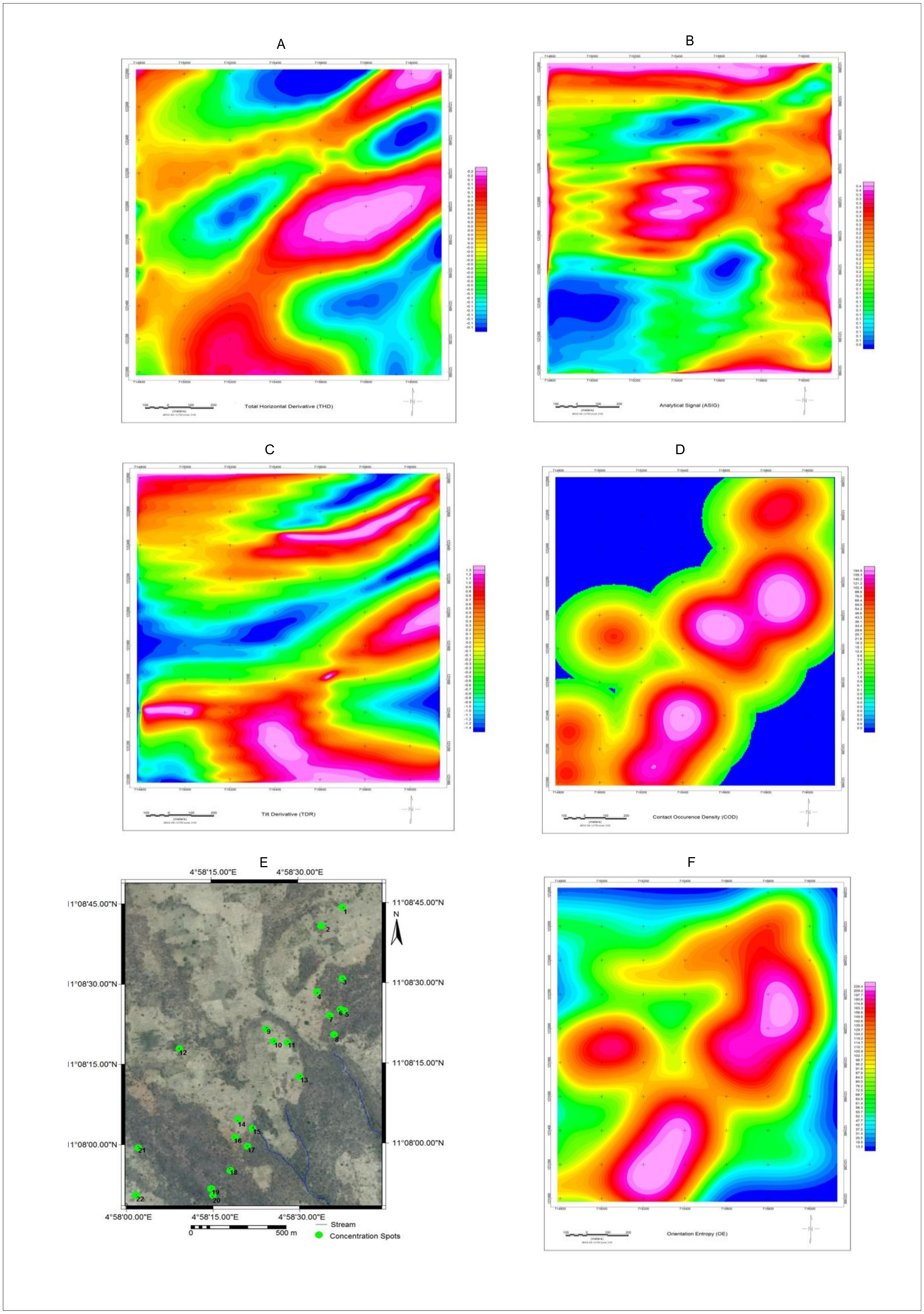

Figure 9. Interpreted aeromagnetic data.
(A) First vertical derivative, **(B)** Analytical signal derivative, **(C)**Tilt derivative grid, **(D)** Contact occurrence density, **(E)** Mineral potential map, **(F)** Entropy map with line of potential mineralization.

Table 1. Rock sample location coordinates and description.

Location	Rock Types/ Description	Location	Rock Types/ Description
L3A. N11º 51' 51.61" E004º 58' 09.7" Elevation 258m	Existing mining pit. Sample was collected at the foot of the hill. Rock type is Quartz vein, shattered, fine grained and milky white colour.	L18 N11º 07' 47.2" E004º 58' 17.4" Elevation 259m	Quartz vein intrusion in schist, the schist dips at 70ºE with noticeable shattering, probably shear zone.
L3B. N11º 07' 51.3" E004º 58' 09.7" Elevation 258m	Rock name = Quartz vein. Texture = massive appearance. Sampling was done 1.6 meter depth of an existing mining pit.	L19 N11º 07' 47.8" E004º 58' 16.4" Elevation 269m	Quartz boulder sampled, the colour is whitish and the texture is fine grained.
L5. N11º 07' 54.2". E004º 58' 07.4" Elevation 256m	Quartz intrusion with massive appearance and whitish colour. Brownish stains of iron oxidation were observed.	L20 N11º 07' 48.0" E004º 58' 15.3" Elevation 268m	Phyllite Schist. Color is dark grey with platy cleavage. Dips at 70ºE.
L6. N11º 07' 55.9" E004º 58' 06.0" Elevation 256m	Floated boulder of Quartz was sampled. The texture is fine grained, colour is whitish.	L28 N11º08'30.7" E004º58'44.2" Elevation 263m	Quartz vein with fine grained texture was sampled. Colour is whitish grey.
L9. N11º 08' 03.3" E004º 58' 01.4" Elevation 259m	Rock name = schist, color is dark grey, texture is fine grained	L29 N11º08'30.7" E004º58'43.5" Elevation 259m	Quartz vein with fine grained texture was sampled. Colour is whitish grey.
L12 N11º 07' 58.2" E004º 58' 07.6" Elevation 258m	Quartz vein sampled. Color is white to dark grey, fine-grained	L36 N11º08'27.5" E004º58'43.6" Elevation 264m	Quartz, sampled from boulders mechanically fractured. Color is whitish, texture is fine grained.
L14 N11º 07' 45.2" E004º 58' 14.8" Elevation 262m	Sampling was done at abandoned mines. Rock name = Quartz vein, texture is fine grained and color is whitish grey.	L38 N11º08'29.2" E004º58'42.7" Elevation 258m	Quartz, sampled from boulders mechanically fractured. Color is whitish, texture is fine grained.
L16 N11º 07' 45.9" E004º 58' 17.7" Elevation 261m	Shattered quartz vein with brown iron oxidation stains. Color is whitish and texture is fine grained.		