Journal of Geology and Mining Research Vol. 5(2) pp. 38-57, February 2013
Available online http://www.academicjournals.org/jgmr
DOI: 10.5897/JGMR12.016
ISSN 2006 – 9766 ©2013 Academic Journals

Full Length Research Paper

Interpretation of aeromagnetic anomalies and electrical resistivity mapping around Iwaraja area Southwestern Nigeria

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Accepted 27 December, 2012

Aeromagnetic, ground magnetic and vertical electrical sounding (VES) methods were used to delineate the basement structures around Iwaraja area, southwestern Nigeria. In doing this, an aeromagnetic sheet 264 of the Geological Survey of Nigeria (GSN) and digitized aeromagnetic map from Nigeria Geological Survey Agency (NGSA, 2008) were interpreted. Also sixteen ground magnetic profiling were carried out, mostly in the E-W direction. A total of sixty seven vertical electrical soundings using Schlumberger electrode configuration was occupied. Qualitative interpretation of the aeromagnetic and ground magnetic profiles suggest varying magnetic intensities from different sources producing the anomaly. Quantitative interpretation aided by the manual half slope and automated Euler deconvolution techniques yielded information on depth to fracture, ranging between 6 and 38 m. Vertical electrical sounding results helped in the delineation of four subsurface geologic layers, also basement depressions that coincides with fracture zones were mapped in the area. The top soil layer resistivity ranges from 50 to 2359 Ωm. The weathered layer (clay, clayey sand, sand and sandy clay) resistivity ranges from 35 to 4935 Ωm while the fractured basement ranges from 152 to 981 Ωm and the fresh basement resistivity ranges from 1132 to 22821 Ωm. A major basement ridge (Rs_1) trending approximately in the NE-SW direction was also delineated.

Key words: Basement structures, anomaly signature, Euler deconvolution, aeromagnetic, Iwaraja, depth to fracture zone.

INTRODUCTION

The study area falls within the Ife-Ilesha schist belt, southwestern Nigeria which is noted for mineralization. It is about 9 km east of Ilesha (Folami, 1992) on latitude 7° 37^{1}10$^"$ – 7° 37^1 37$^"$ N and Longitudes 4°49 ^{1} 19$^"$ – 4° 49^1 58$^"$ E (Figure 1). Geological and geophysical mapping over the years in Iwaraja area showed that some of the crystalline rocks present have been tectonically disturbed (Hubbard, 1960, Rahaman, 1976) which have led to the development of several structures such as folds, faults, fractures, cavities and depressions. The use of aeromagnetic study in the area supports its classification as a highly mineralized zone (Folami, 1992, Kayode, 2006) with the delineation of Iwaraja fault that is believed to be over 250 km long trending NNE-SSW and stretching through Ijebu-Ode, Ifewara, Iwaraja and Okemesi (Hubbard, 1960). Very low frequency electromagnetic method and electrical resistivity imaging using vertical electrical sounding technique have been used in the characterization of the overburden materials and to delineate concealed basement structures within the bedrock (Adelusi et al., 2009). The present research work involves the use of aeromagnetic, ground magnetic and electrical resistivity methods in mapping rock boundaries, lateral and depth extent of geologic units, for the purpose of subsurface geologic mapping and identification of fracture zones that could act as depo centers for mineral accumulations.

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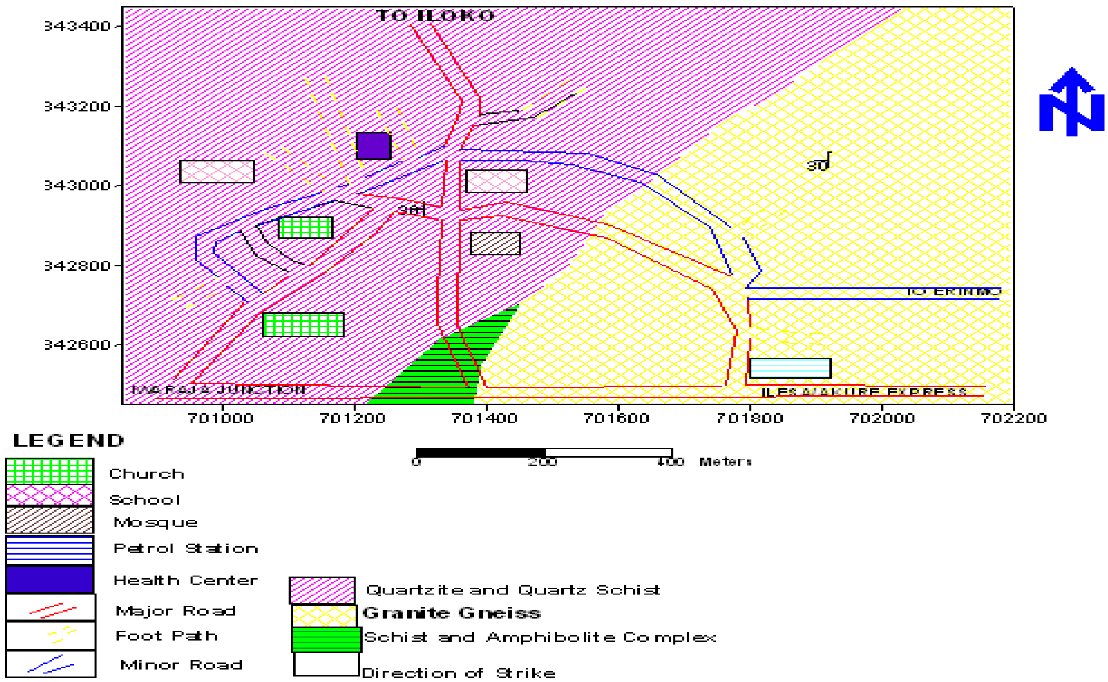


Figure 1. Location Map of Iwaraja showing the geology of the area.

Geology

Iwaraja is underlain by Precambrian rocks typical of the basement complex of southwestern Nigeria (Rahaman, 1988). The main rock types found are undifferentiated schist including some gneiss, schist and amphibolite complex, quartzite and quartz schist and granite-gneiss (Figure 3). The topography is gentle except for some outcrops of granite gneiss that is quite extensive towards the eastern flank of the area (Kayode, 2006).

MATERIALS AND METHODS

An aeromagnetic map and digitized aeromagnetic data of Iwaraja area (Geological Survey of Nigeria1965; Nigeria Geological Survey Agency (NGSA 2008) were acquired and processed for interpretation (Figure 2 and 3b). The aeromagnetic map was gridded with the aid of software Surfer 8 (Figure 3a) while digitized aeromagnetic data was processed using Oasis Montaj^{Tm} (2012) (Figure 3b). A total of sixteen traverses were occupied along the N-S, S-N, and E-W directions (Figure 4). Closely spaced stations of 20m interval were adopted for the magnetic survey to allow high resolution of near surface structures. The ground magnetic survey involved measurement of total field component of the earth's magnetic field along the sixteen established traverses using the GEM-8 Proton Precision Magnetometer. The magnetic data acquired were corrected for drift.

Electrical resistivity investigation of the subsurface involved determination of the distribution of ground resistivity based on its response to the flow of electric current injected during surface measurement (Osinowo et al., 2011). Vertical electrical sounding (VES) survey is a measure of variation of electrical resistivity with depth. This is achieved by a gradual increase in the current electrode spacing about a fixed center of electrode spread. Sixty seven vertical electrical soundings were carried out along traverses previously occupied by the ground magnetic method utilizing the Schlumberger electrode configuration. Electrode spacing (AB/2) was varied from 1 to 100 m. The vertical electricity sounding data were obtained using ohmega terrammeter. The VES data interpretation involved the convectional preliminary partial curve matching (Patrax and Nath, 1998). The model derived from the manual interpretation was iteratively adjusted, using WinRESIST version 1.0 (Vander Velper, 2004) software to get a better fit in each case.

RESULTS AND DISCUSSION

Interpretation of aeromagnetic profiles and corresponding geomagnetic sections

The aeromagnetic map (Figure 3b) shows a major magnetic low intensity trending approximately NE-SW which correspond to the Iwaraja fault. Also, ten traverses were established in the E-W direction on the gridded aeromagnetic map. These were plotted as profiles (Figures 4) and the profiles were qualitatively and quantitatively interpreted. The qualitative interpretation of the aeromagnetic profiles shows varying amplitude of the anomaly signature which suggests varying magnetic intensities from different sources producing the anomaly. Quantitatively, these magnetic profiles were interpreted one after the other using the Manual Half Slope method and Automated Euler deconvolution techniques. The

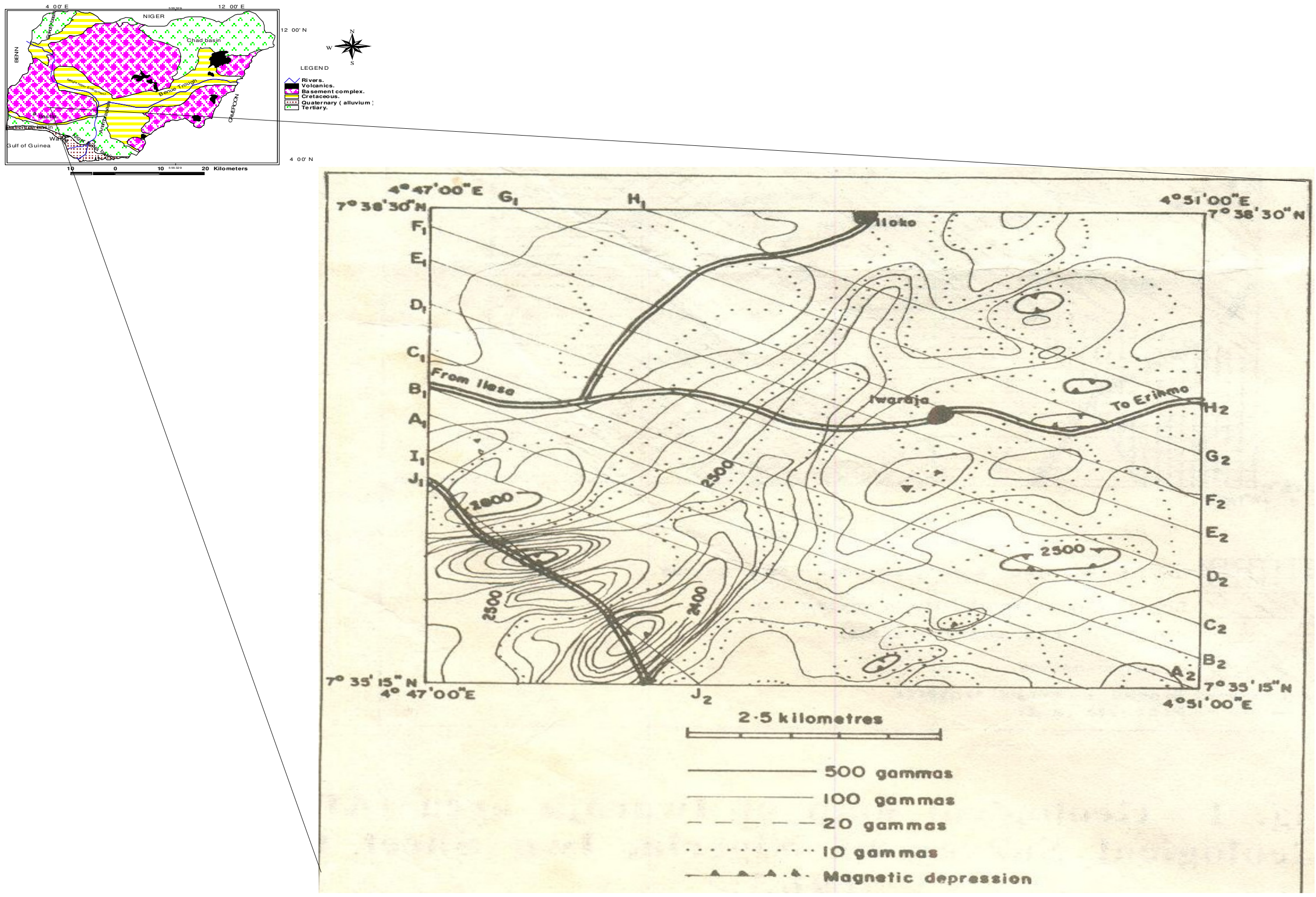


Figure 2. Undigitized aeromagnetic map of Iwaraja area (After Geological Survey of Nigeria, 1965); Inset, geological map of Nigeria.

quantitative interpretation enabled the estimation of depths and generation of geologic sections. Figure 5 along traverse AT1 has magnetic intensity values ranging from 2350 to 2700 gammas. The magnetic intensity contrast which is an indication of a probable fracture zone or contacts between rock units occur at distance between 500 and 1500 m. The half slope method gave depth estimates of 24, 6 and 9 m at distances 900, 1750 and 2250 m respectively while the Euler deconvolution method gave depth estimates of 13, 10, 12 and 18 m at distances 500, 1750, 2250 and 2700 m, respectively. The probable zones delineated by the two techniques coincide with the contacts between the undifferentiated schist, quartzite and quartz schist and the granite gneiss except for the zone occurring at distance 2700 m on the Euler deconvolution geomagnetic section which falls within the quartzite and quartz schist. Figure 6 along traverse AT10 shows a constant magnetic intensity value of 2900 gammas between 0 and 1000 m. Magnetic intensity contrast occurs at 2900 and 2650 gammas and at distances 1000 and 2000 m, respectively (figures 7a-j). The magnetic intensity contrast is indicative of a probable fracture zone along the traverse.

The geomagnetic sections produced from the depth estimated by the manual half slope and automated Euler deconvolution techniques were useful in the delineation of the two and four probable fracture zones respectively (Figure 8). The half slope method gave depth estimates of 13 and 19 m at distance 1375 and 1750 m, respectively while the Euler deconvolution method gave depth estimates of 19, 10, 12 and 11 m at distance 500, 1250, 1500 and 1700 m, respectively. The zones delineated by both methods are indicative of geologic contacts between rock units along the traverses.

Interpretation of the ground magnetic profiles and sections with their corresponding geo-electric sections

Ground magnetic profiles, geomagnetic sections, and geoelectric sections were produced from the data acquired through the ground magnetics and electrical resistivity methods, respectively. Qualitative interpretation of the ground magnetic profile reveals that varying amplitude of the anomaly signature which suggests

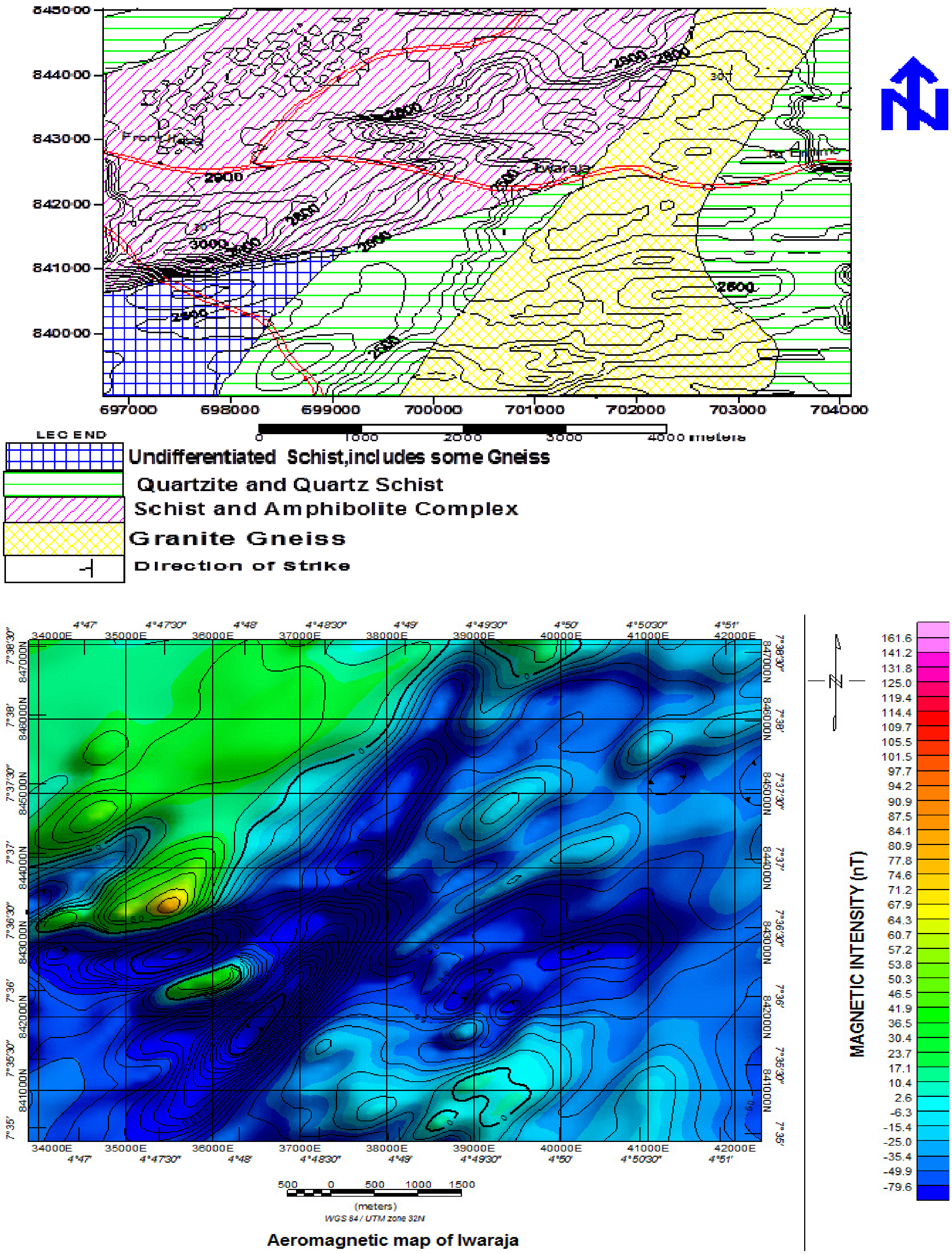


Figure 3. (a) Gridded aeromagnetic map of Iwaraja area. (b) Digitized aeromagnetic map of Iwaraja after NGSA, 2008 (Source: Sheet 265, NGSA (2008).

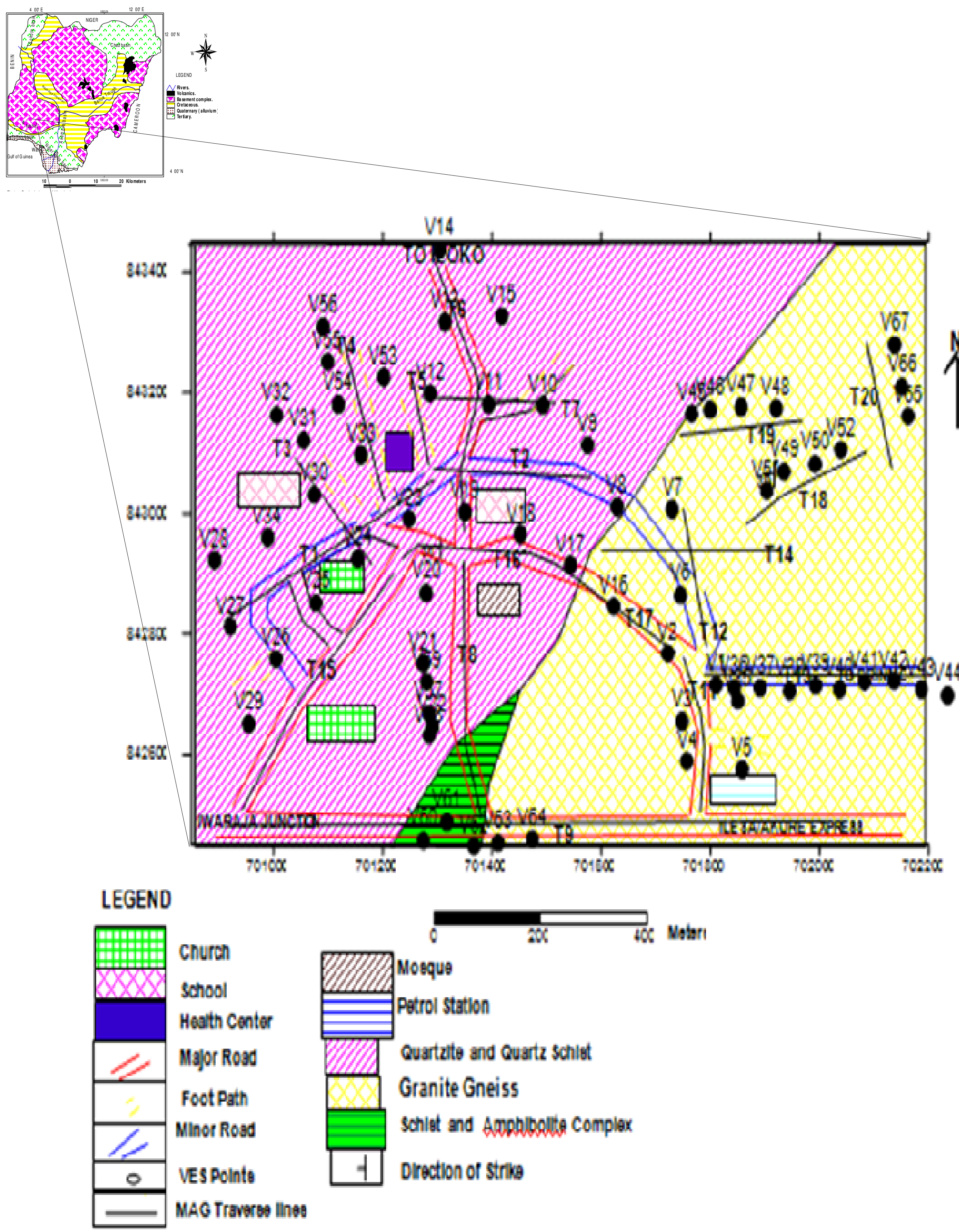


Figure 4. Location map of Iwaraja showing magnetics and VES traverse points with geological map of Nigeria inserted.

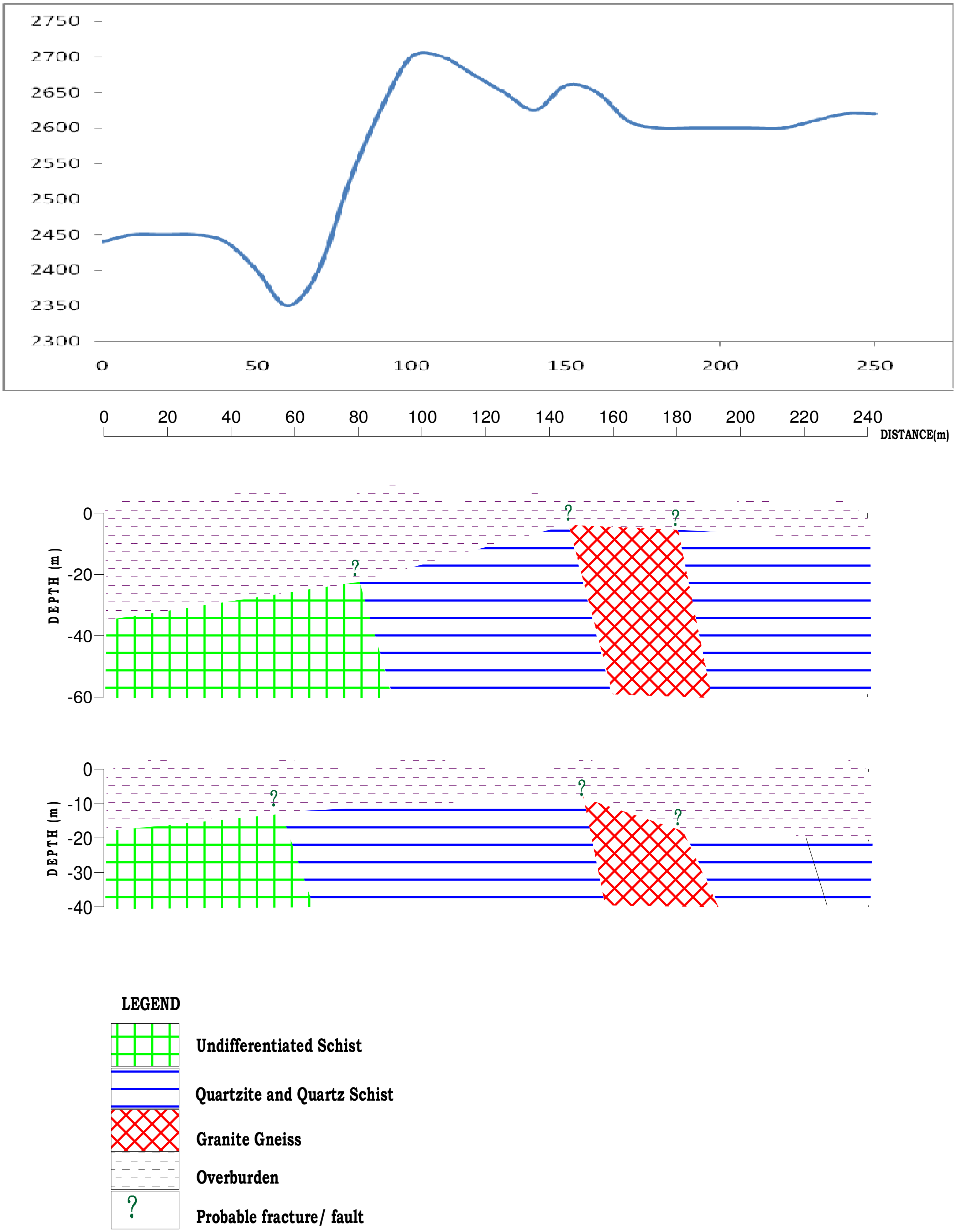


Figure 5. Aeromagnetic profile and corresponding geomagnetic sections on traverse AT1 in Iwaraja Area.

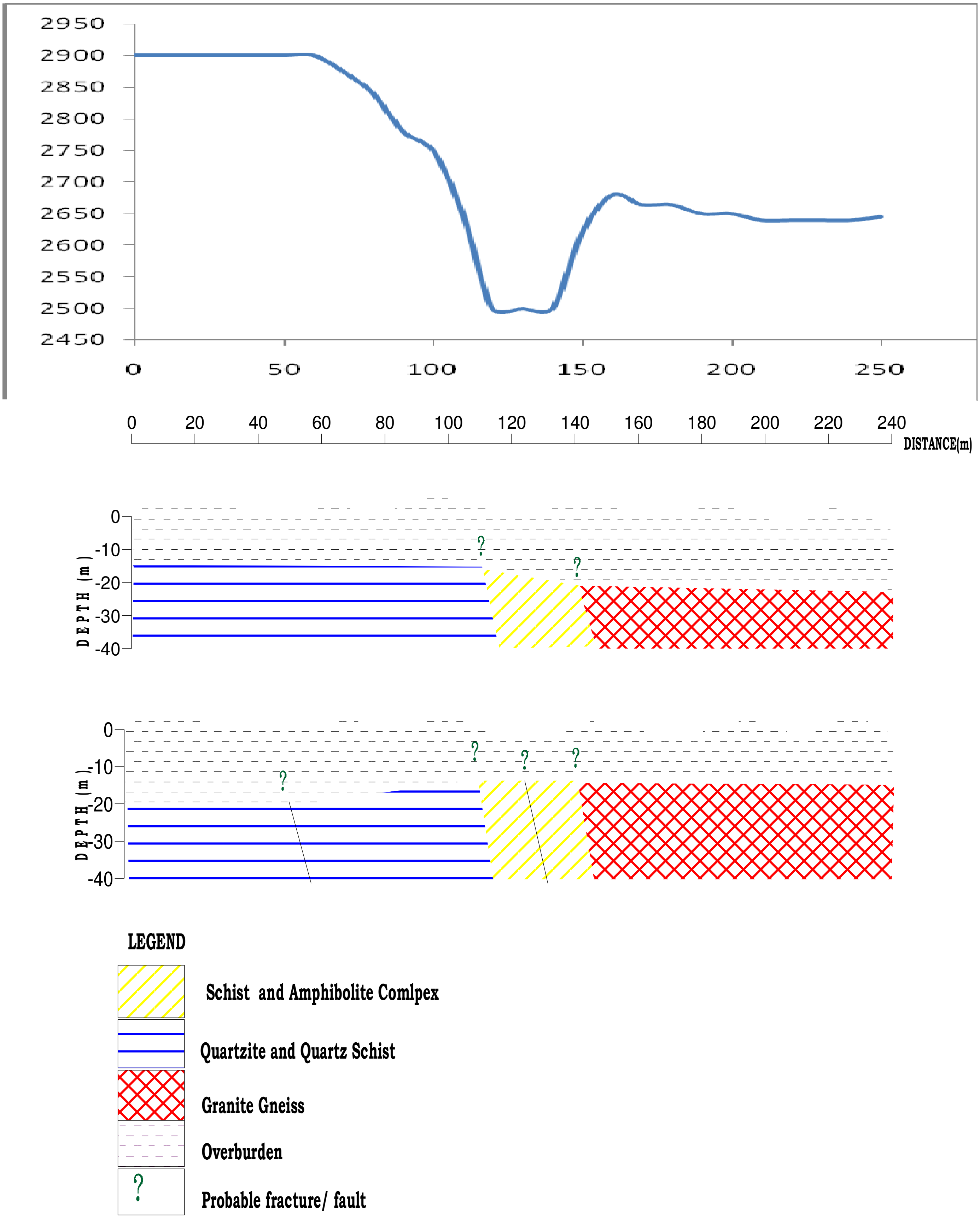
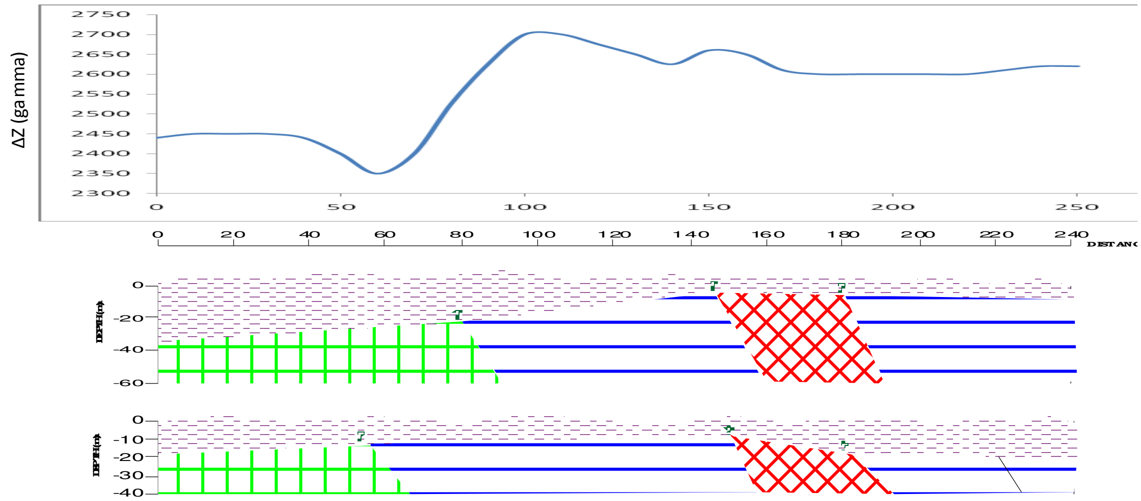
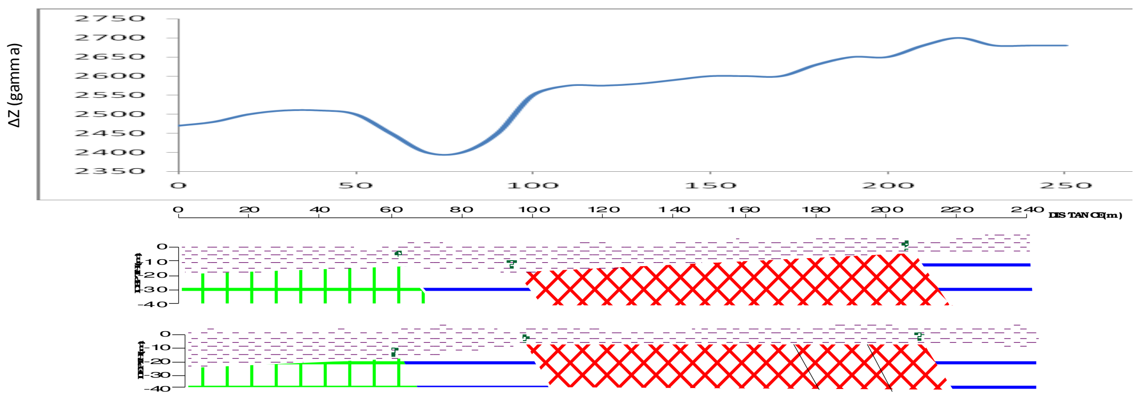


Figure 6. Aeromagnetic profile and corresponding geomagnetic sections on traverse AT10 in Iwaraja area.


ΔZ (gamma)
2750
2700
2650
2600
2550
2500
2450
2400
2350
2300
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180 200 220 240
-20
-40
-60
-10
-30


ΔZ (gamma)
2750
2700
2650
2600
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2500
2450
2400
2350
0
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100
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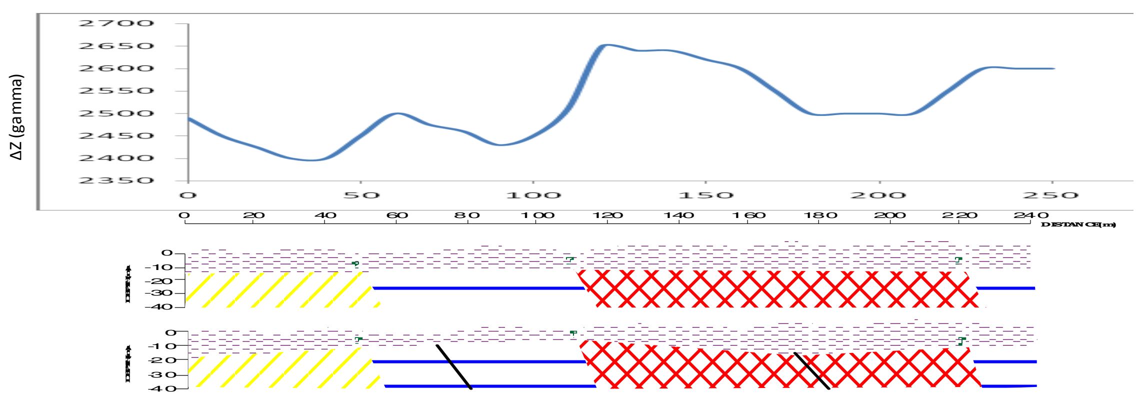
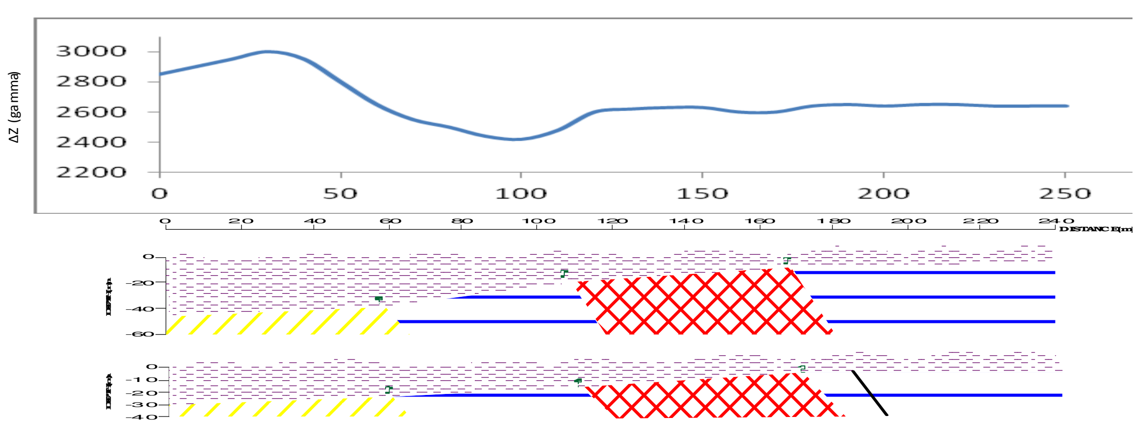
200
250
0 20 40 60 80 100 120 140 160 180 200 220 240


ΔZ (gamma)
2700
2650
2600
2550
2500
2450
2400
2350
0
50
100
150
200
250
0 20 40 60 80 100 120 140 160 180 200 220 240


ΔZ (gamma)
3000
2800
2600
2400
2200
0
50
100
150
200
250

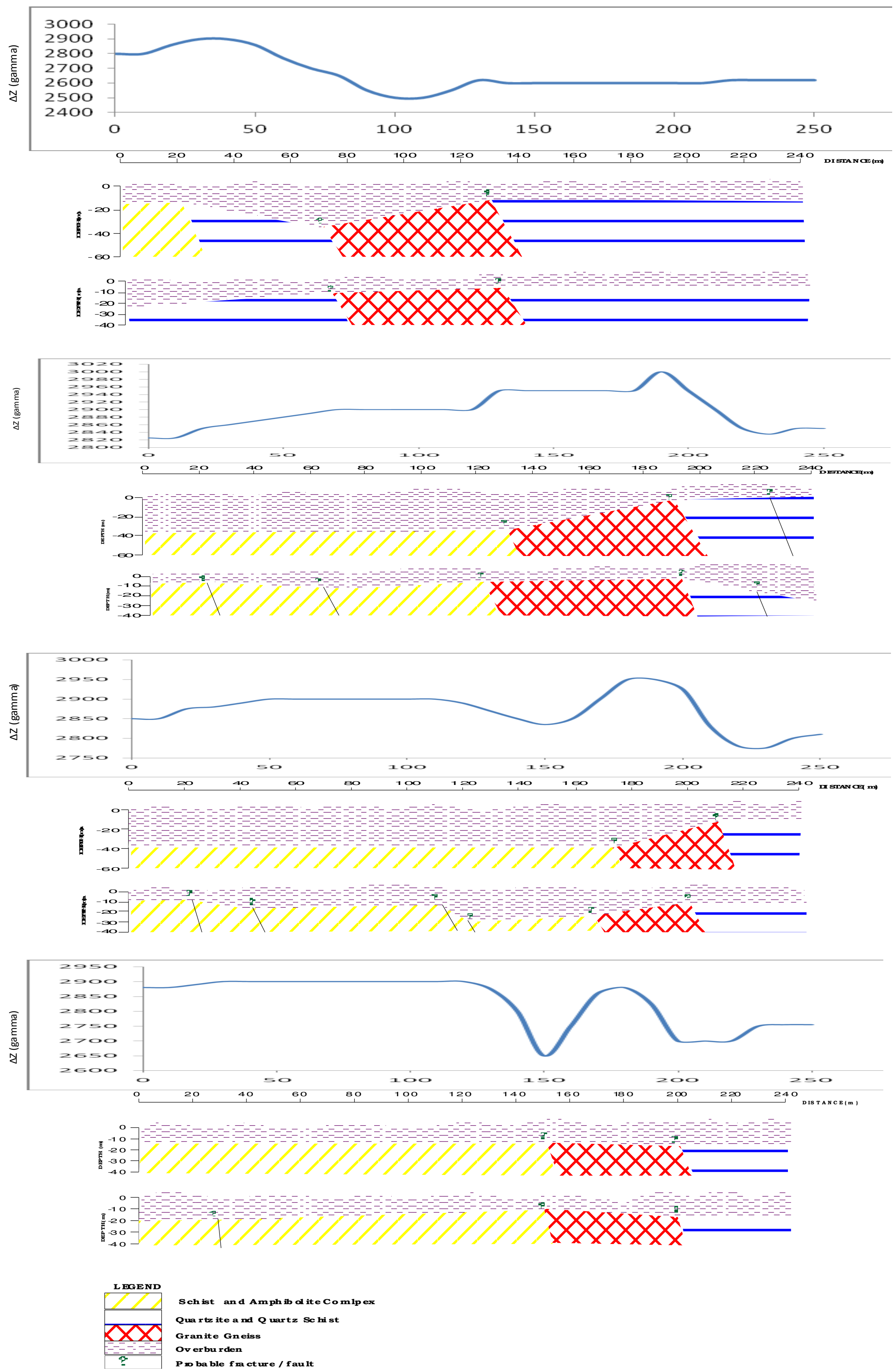


Figure 7. Aeromagnetic profile and sections obtained from half slope method and Euler deconvolution methods on AT1 - AT8.

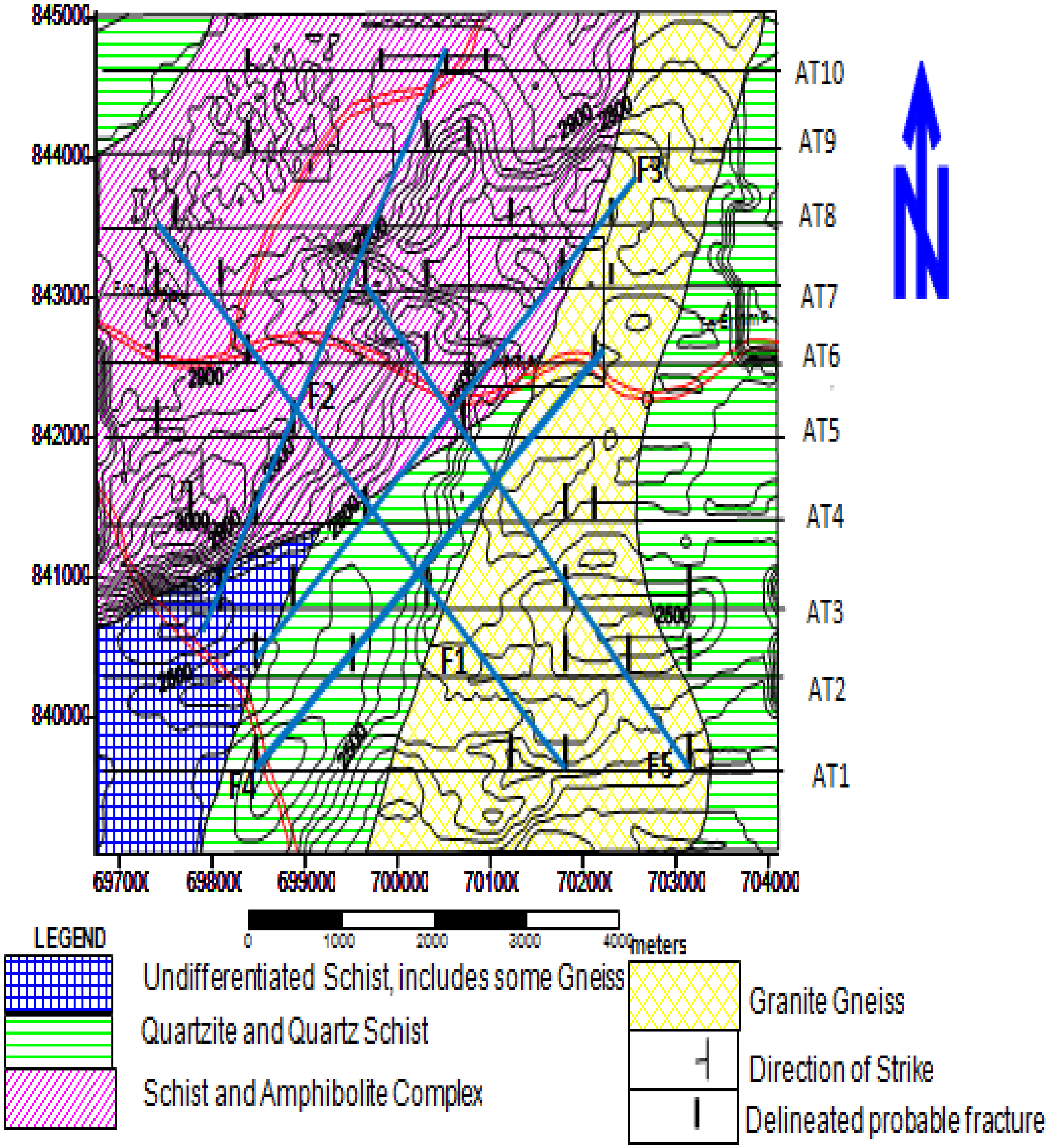


Figure 8. Showing delineated trend of fracture zones in Iwaraja area obtained from aeromagnetic interpretations.

possible fracture zones. Quantitatively, the magnetic profiles were interpreted one after the other using the manual half slope and automated Euler deconvolution techniques. The quantitative interpretation enabled the estimation of depths and generation of geologic sections.

Interpretation of geo-electric parameters obtained from the VES helped in the production of geo-electric sections and subsurface characterization along the traverses. Figure 9 shows the ground magnetic profiles and sections with their corresponding geo-electric section

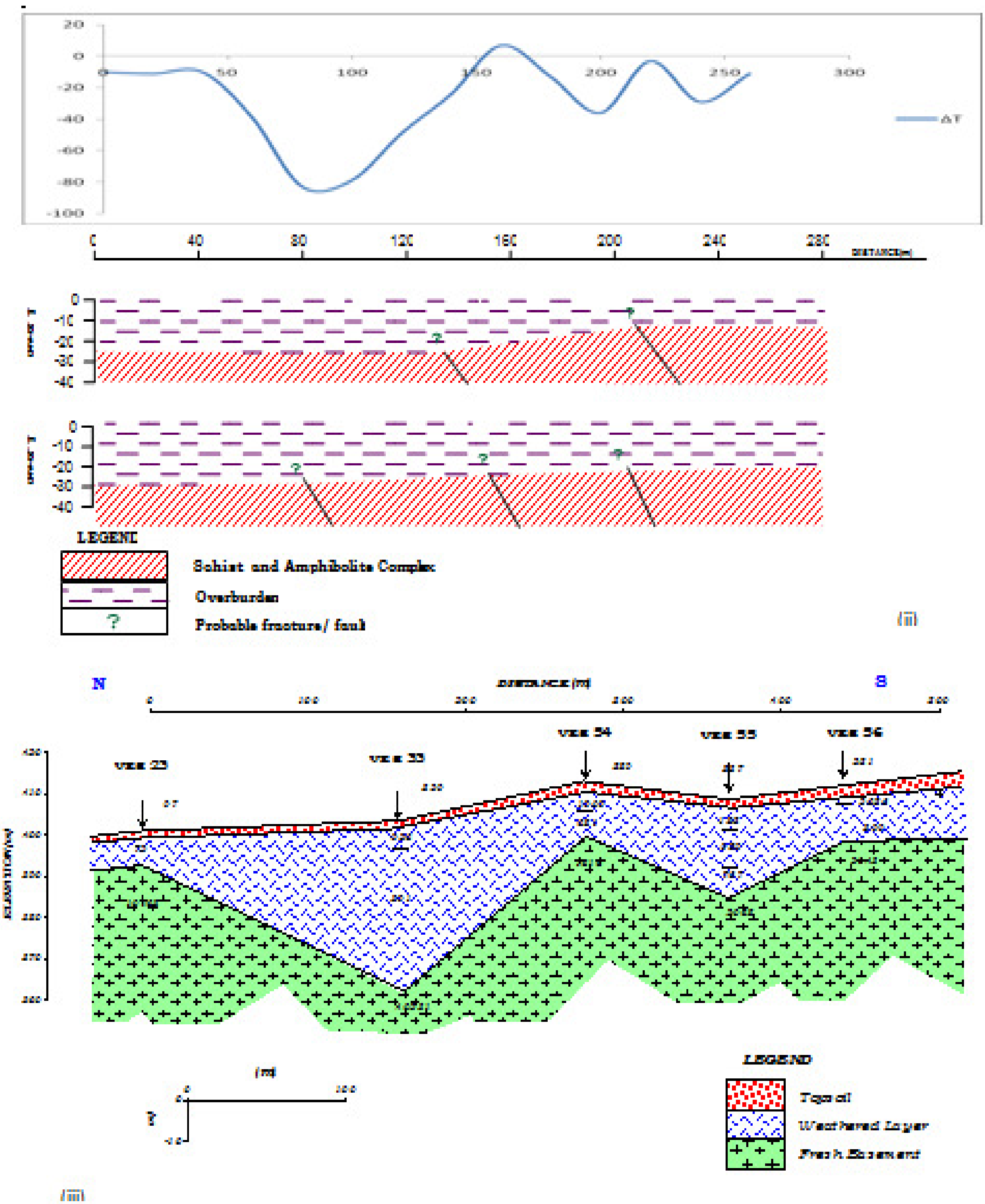


Figure 9. (i), Ground magnetic profile and the corresponding geomagnetic sections obtained from half slope and Euler deconvolution methods; (ii), Geo-electric section along traverse 4.

along traverse 4.

The traverse length is about 250 m in the N-S direction. The magnetic profile shows a magnetic intensity contrast -10nT and 7nT at distance of about 50 and 160 m, respectively. The magnetic intensity contrast is indicative of probable fracture zones. Geomagnetic sections were produced from the depths estimated by the half slope and Euler deconvolution techniques. The half slope method was used in delineating two probable fracture zones of depth 25 m at distance 120 m and depth 13 m at distance 200 m.

The Euler deconvolution technique was used in delineating three probable fracture zones of depth 30 m at distance 80 m, depth 25 m at distance 120 m and depth 20 m at distance 200 m. The probable fracture zones occur within the schist and amphibolite complex.

The geo-electric section along traverse 4 was occupied by VES 23, VES 33, VES 54, VES 55 and VES56. The section reveals three subsurface geologic layers which consist of top soil, weathered layer and schist and amphibolite complex fresh basements. Figure 10 reveals the ground magnetic profiles and sections with their corresponding geo-electric section along traverse 8. The traverse length is about 400 m in the N-S direction. The magnetic profile along this traverse reveals a generally low magnetic intensity values ranging from -1100 to -400 nT (figures.11a-p). This low magnetic intensity suggests a highly fractured zone. Magnetic intensity contrast is observed at distance of about 30, 100 and 200 m, respectively.

Distance from 250 to 450 m shows continuous anomaly signatures. Geomagnetic sections obtained from the half slope technique and automated Euler deconvolution method of depth estimation was used in delineating four and five probable fracture zones, respectively. Half slope method gave depth estimates of 13 m at distance 30 m, 6 m at distance 100 m, 13 m at distance 200 m and 25 m at distance 300 m, while the Euler deconvolution method gave depth estimates of 20 m at distance 100 m, 15 m at distance 160 m, 26 m at distance 200 m, 26 m at distance 300 m and 35 m at distance 350 m. The probable zone delineated at distance 300 m coincide with geologic contact between the schist and amphibolite complex with quartzite and quartz schist. The geo-electric section along this traverse has a length of about 400 m and was occupied by VES 20, VES 21, VES 59,VES 57, VES 22 and VES 58. The geo-electric section was used in delineating four subsurface geologic layers of top soil, weathered layer, schist and amphibolites complex fractured basement and the quartzite and quartz schist fresh basement.

The basement is highly fractured between 0 and 220 m thereby suggesting that the fracture zones are within the fracture basement whose resistivity ranges from 413 to 2694 Ωm. The distinct depression observed between distance 200 and 350 m coincides with fracture zones delineated by the magnetic profile and sections.

The fractured basement along the geo-electric section between 0 and about 200 m also agrees with the distance of 50 and 100 m delineated as fracture zones by the manual half slope method. These observation shows that the delineated fracture zone in this case falls within the weathered layer and the probable fracture zones coincides with depressions along the traverse. The topography is stable beneath VES 20 and VES 21 and later becomes undulating towards the southern part of the traverse. The interpretation of the different sections and profiles obtained from the ground magnetic and VES along traverse 8 suggests a high degree of fracturing especially at distance 50, 110 to 180 m and 300 m to about 390 m as delineated by all the methods.

Isopach map of the overburden of the study area

The distribution of the thickness of overburden obtained from the geo-electric parameters helped in the generation of the isopach map of overburden in Iwaraja area. Figure 12 shows the presence of moderately thick overburden at the North Eastern and North Western flank of the study area underlain by granite- gneiss and the schist and amphibolites complex. At the boundary between schist and amphibolite complex and granite –gneiss exist a moderately thick overburden of about 30 m thick. Some moderately thick overburden of about 25 m thickness is also observed at the southern part at the boundary between quartzite and quartz schist and schist and amphibolite complex. These areas of moderate to thick overburden are marked as depressions (Figure 12). A total of eight depressions were mapped in the study area as Ds_1 to Ds_8. A major thin overburden (about 10 m) is found almost at the central portion of the study area straddling the whole area approximately in the NE - SW direction. This thin overburden corresponds to a major ridge Rs1. Four ridges were identified in the area as R_1 to R_4.

Correlations between fracture zones delineated by aeromagnetic method and other geophysical methods

Traverse AT7 on the aeromagnetic map coincides with a part of traverse 13 on the ground at Northing’s 843000 and Easting’s 701550. Probable fracture/contact zone with estimated depth of 38 and 18 m by the half slope and Euler deconvolution techniques respectively were delineated along traverse 7 at a distance of 170 m. This delineated zone coincides with the area delineated as probable fracture/contact zone along traverse 13 with estimated depths of 20 and 6 m respectively by the half slope method and Euler deconvolution method, respectively at a distance of 40 m. The delineated zone is located at the contact between the schist and amphibolite complex and the granite gneiss. This reveals that areas

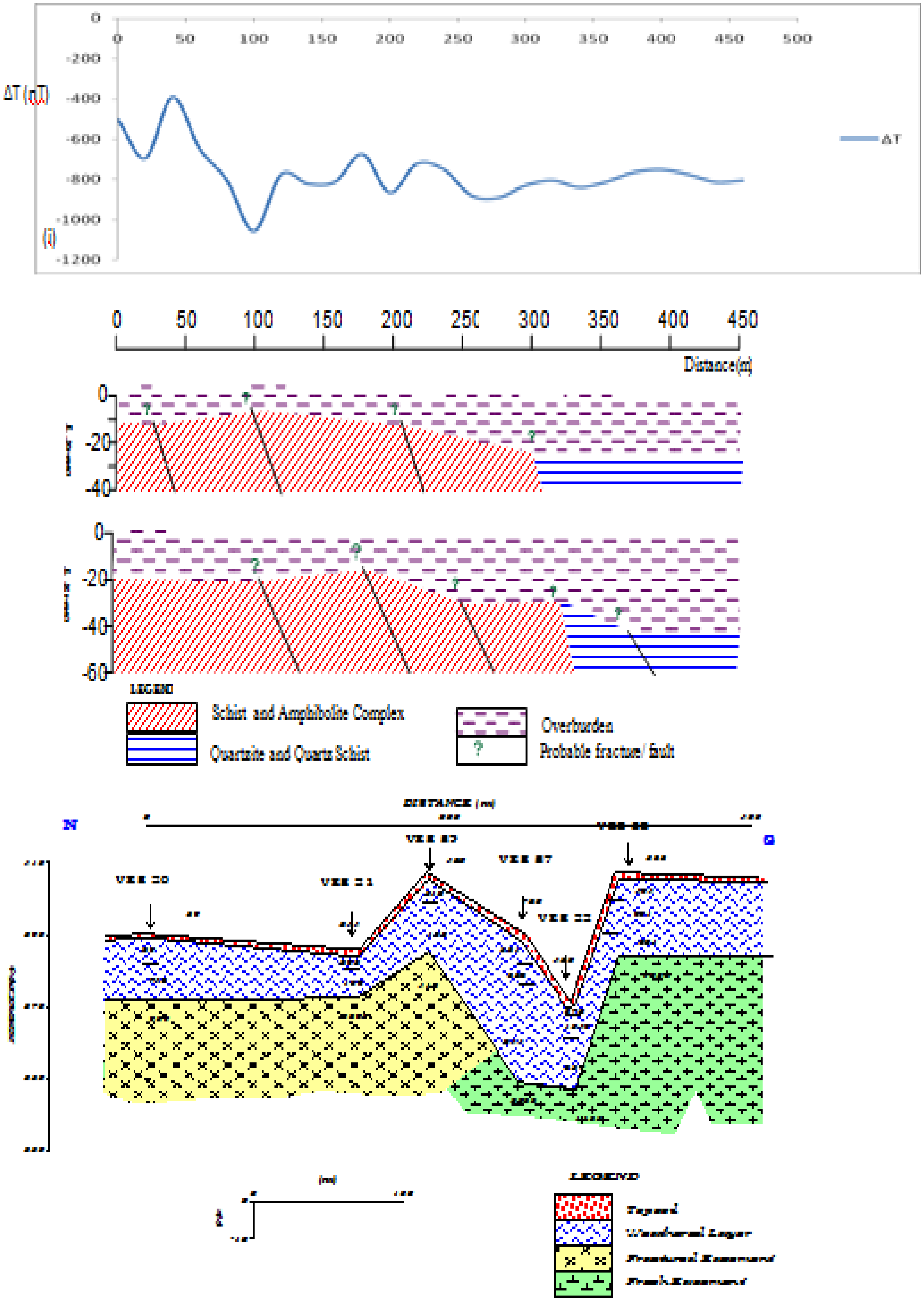
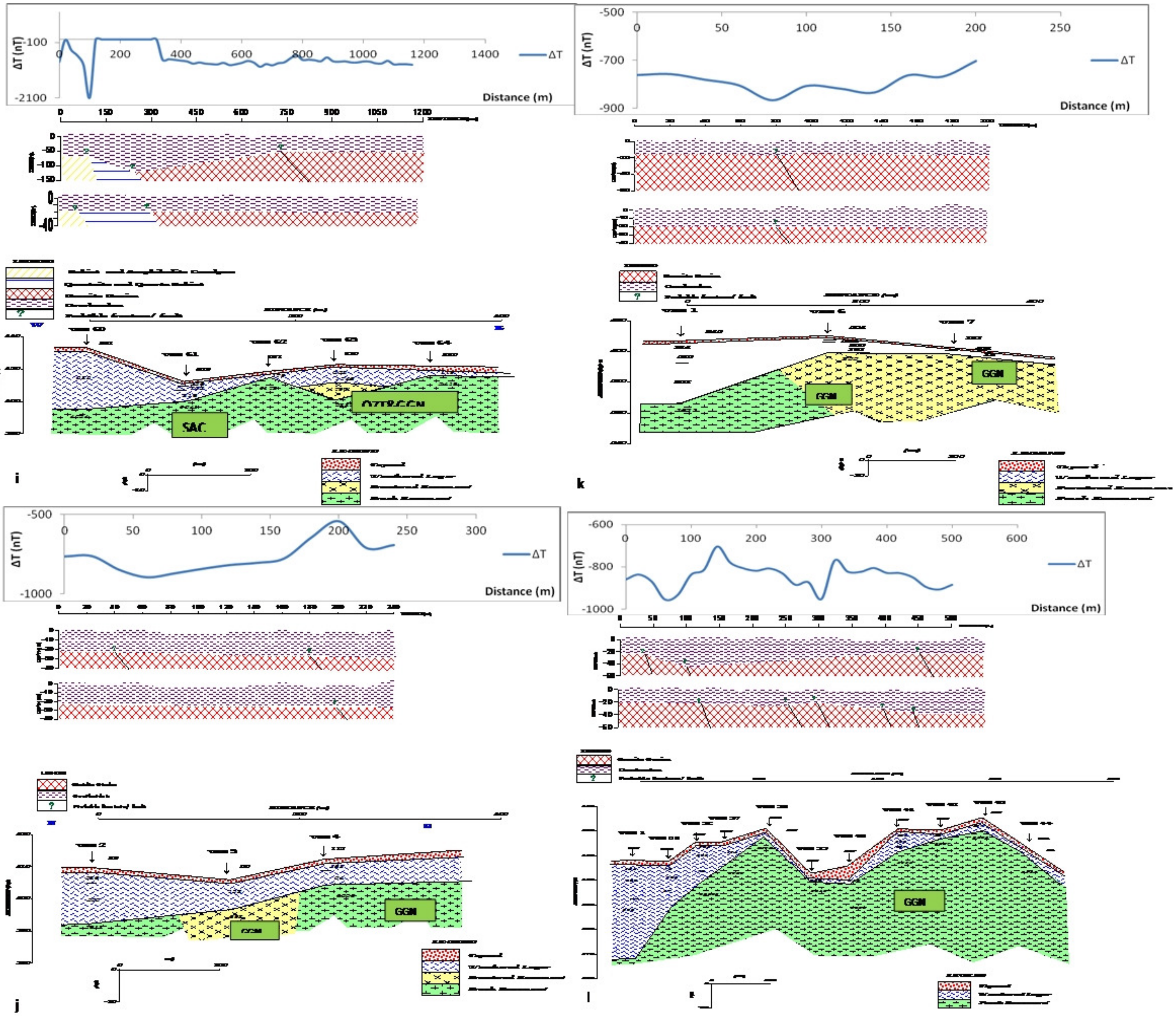
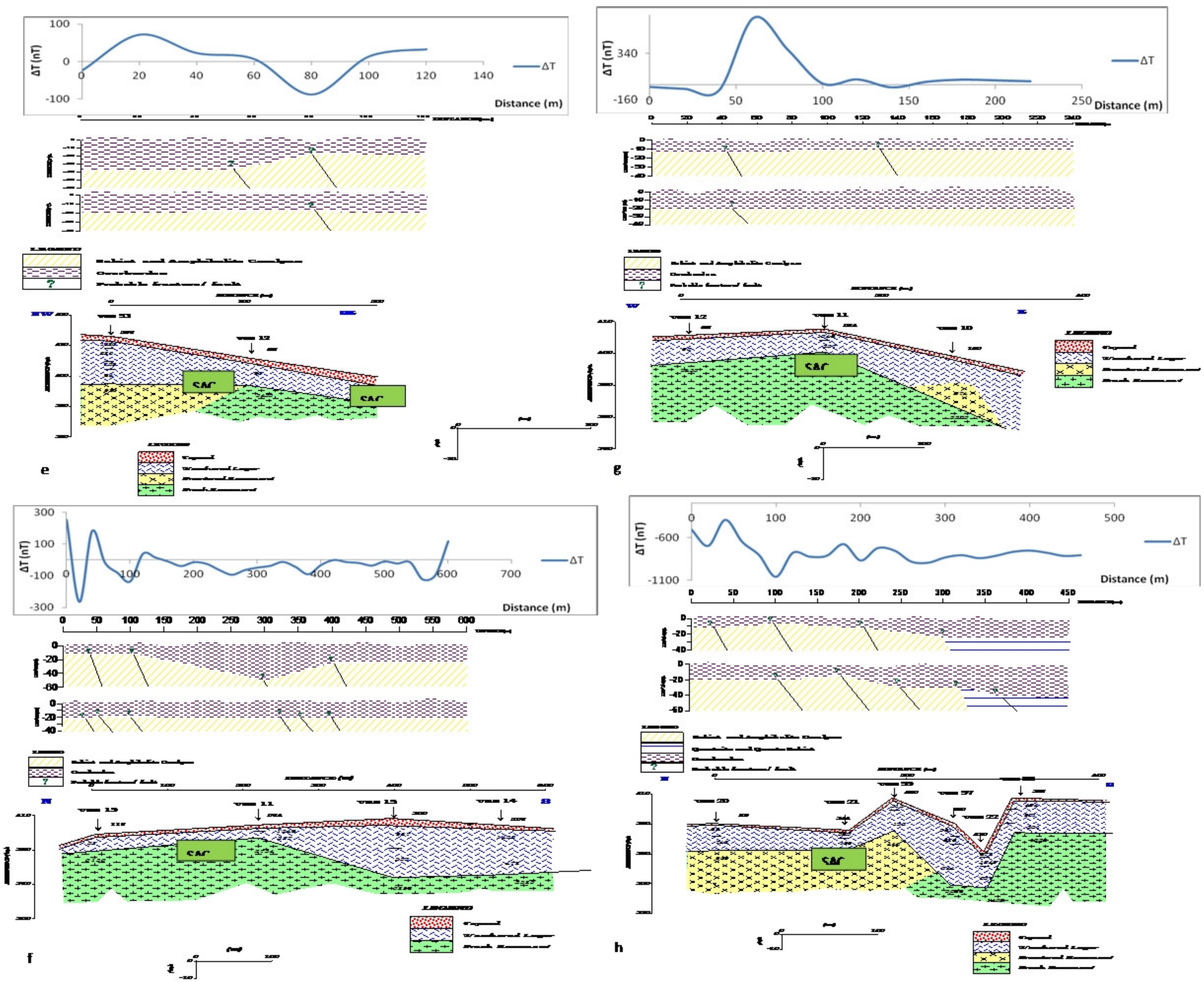
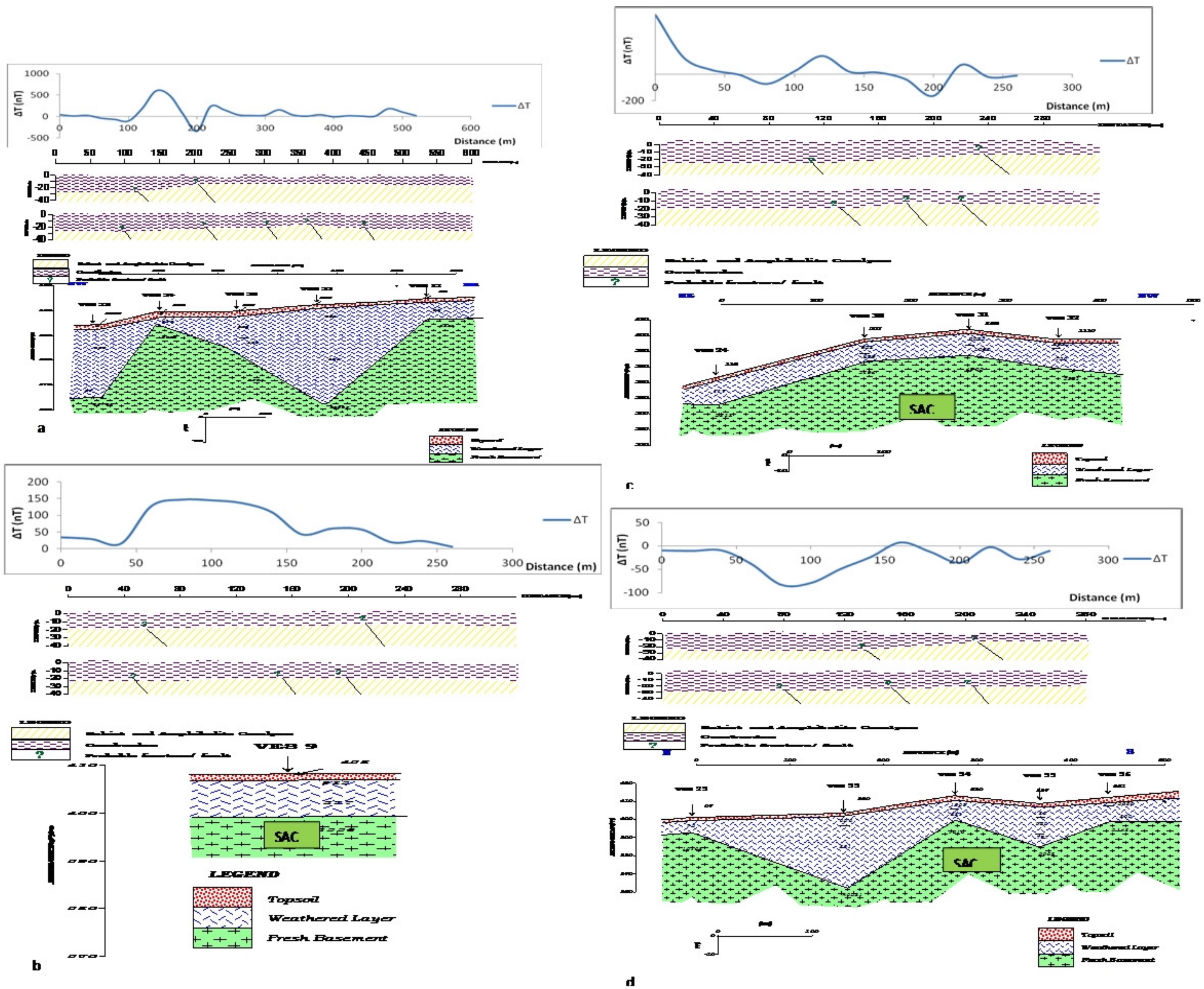


Figure 10. (i) Ground magnetic profile and the corresponding geomagnetic sections obtained from half slope and Euler deconvolution methods; (ii), Geo-electric section along traverse 8.


ΔT (nT)
Distance (m)
ΔT
SAC
OZT&GGN
GGN
i
j
k
l


ΔT (nT)
ΔT
Distance (m)
100
0
-100
0
20
40
60
80
100
120
140
340
-160
50
150
200
250
300
-300
400
500
600
700
-600
-1100
SAC
e
g
f
h


ΔT (nT)
ΔT
Distance (m)
a
b
c
d
VES 9
SAC
LEGEND
Topsoil
Weathered Layer
Fresh Basement

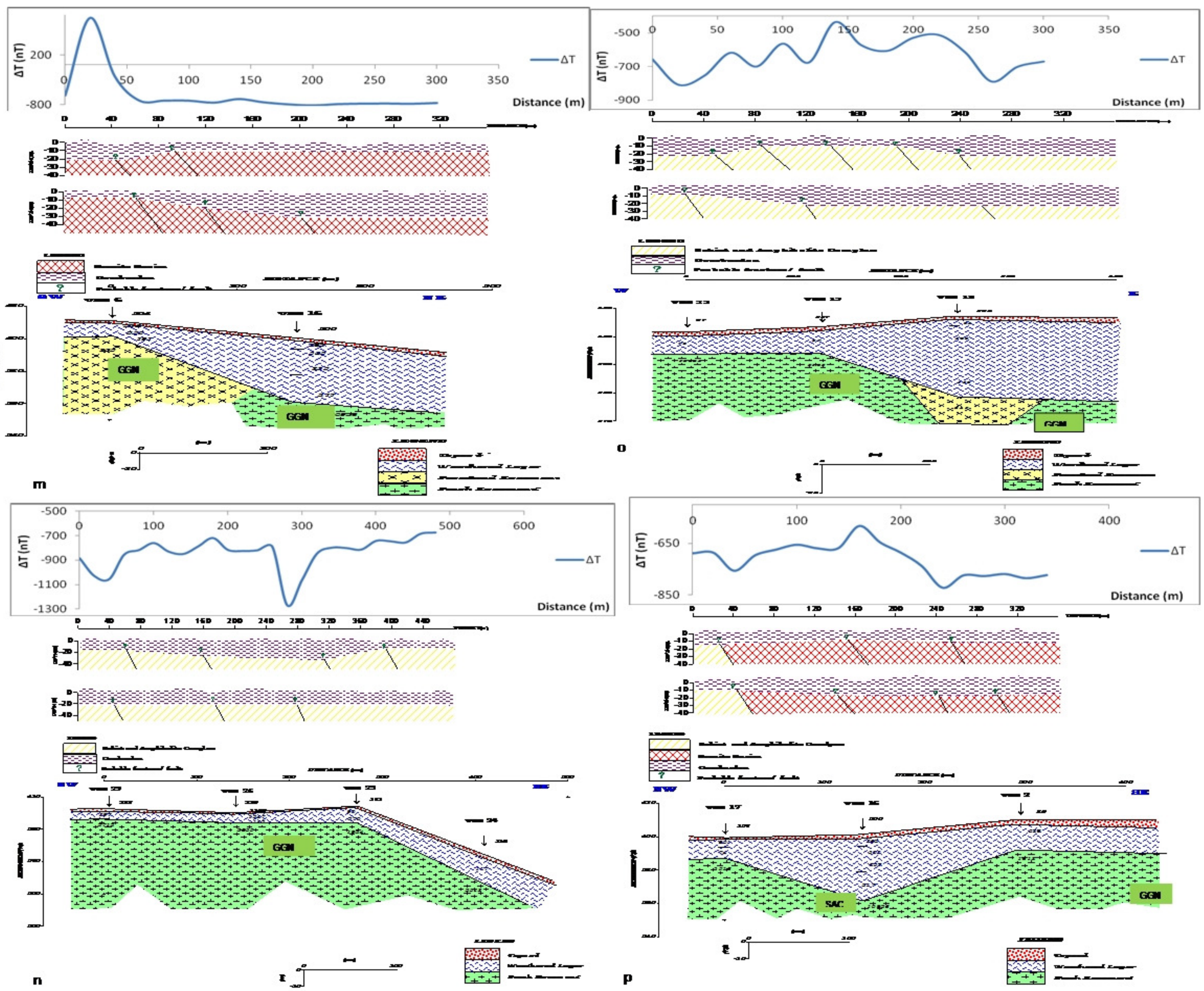


Figure 11 (a-p). (i) Ground magnetic profile and the corresponding geomagnetic sections obtained from half slope and Euler deconvolution methods; (ii), Geo-electric section along traverse 1-10.

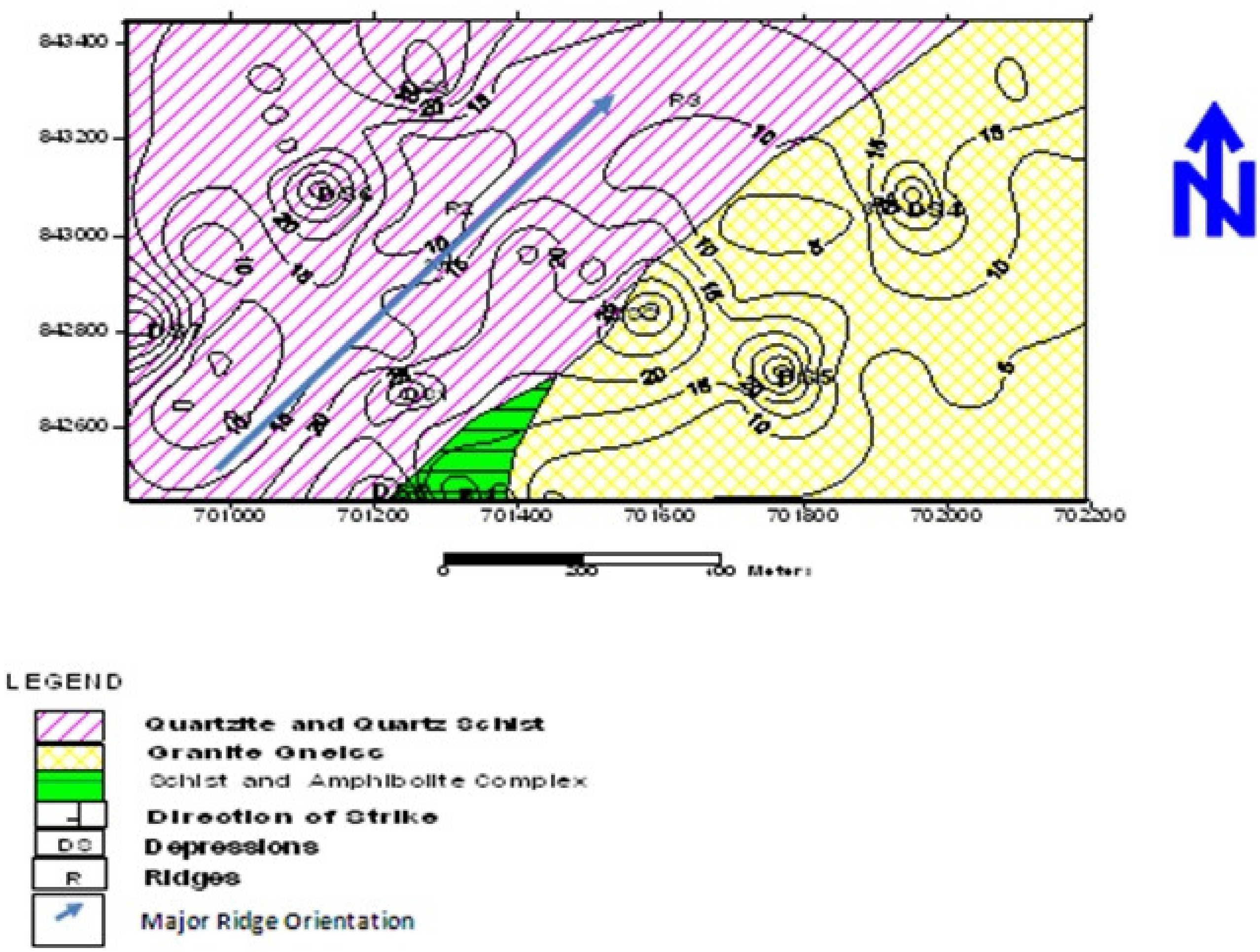


Figure 12. Isopach map of the overburden in Iwaraja.

where the aeromagnetic method show magnetic intensity contrast correspond with areas of magnetic intensity contrast on the ground magnetic profile and it also agrees with conductive zone delineated by the VLF-EM profile and section along traverse 13 (Figure 13). Therefore, the correlation along traverse 7 on the aeromagnetic profiles and sections with traverse 13 on the ground magnetic profiles and sections with their corresponding geo-electric section shows that all the geophysical methods employed in this study are compliementary and they serve as an important tools in delineating basement structures.

Conclusion

Integration of aeromagnetic, ground magnetic and vertical electrical sounding methods has been used to delineate fracture zones around Iwaraja area. Ten aeromagnetic profiles, sixteen ground magnetic profiles and sixty seven vertical electrical sounding data were acquired using digitized aeromagnetic map of Iwaraja, GEMproton precession magnetometer and Ohmega resistivity meter, respectively. The aeromagnetic profiles interpreted qualitatively and quantitatively using the manual half slope method and automated Euler deconvolution software enabled the delineation of five fracture zones denoted as F_1 to F_5 and trending in the NE-SW and NW-SE direction. F_1 and F_5 trends in the NW-SE direction cutting across the granite gneiss, quartzite and quartz schist and schist and amphibolites complex.F_2, F_3 and F_5 trends in the NE-SW direction. F2 occupies the schist and amphibolites complex and the undifferentiated schist. F3 cuts across the quartzite and quartz schist, schist and amphibolites complex and granite gneiss while F_4 cuts across the quartzite and quartz schist and granite gneiss. The ground magnetic method delineates series of fracture zones with depth ranging between 6 and 38 m. The electrical resistivity method delineated four sub-surface geologic layers and mapped a major ridge R_S and depressions denoted as D_{S1} to D_{S8} in the area. The geophysical methods employed are found to be complimentary.

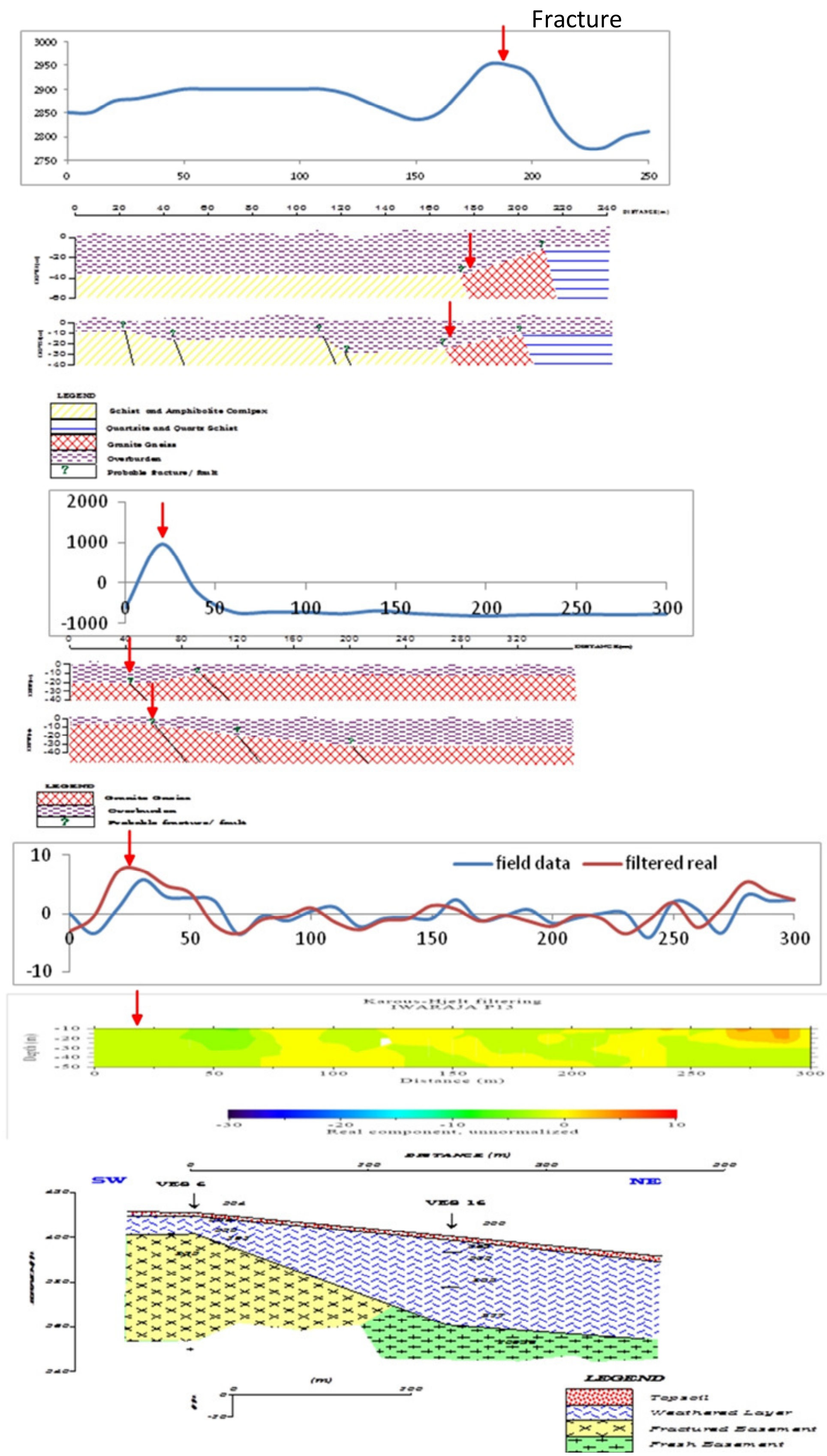


Figure 13. Profiles and sections showing correlations between fracture zones delineated by aeromagnetic method and other geophysical methods along traverse AT7 and traverse 13.

ACKNOWLEDGEMENTS

Messrs A., Afolabi A. and Adegbuyiro O. Akinlalu, assisted during the data acquisition. Their participations are gratefully acknowledged.

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