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Analysis of Self-Potential Data at a 0.6 km^2 Swath of the Southern Phase II Development, Gidan Kwano Campus, Minna, Northcentral Nigeria

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Abstract

A segment of northeast-southwest rock-body has been discerned at the Gidan Kwano Campus of the Federal University of Technology, Minna, Nigeria; this rock-body can be correlated with the Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt. Thus, this study is concerned with the analysis of a body of self-potential (SP) data-field at the upslope of these discerned fault-traces with a view to detailing its possible mineralisation character. The SP survey was at 5 m ground-interval for the 600 m southeasternmost reaches of the area of survey where the landform slope is greatest; this survey was accomplished by the ABEM Terrameter SAS 4000. Qualitative analysis of the SP data-field of this study proceeded by the route of producing contour maps for the four distinct depths of survey for this study and these are the 5-m, 10-m, 15-m, and 20-m depths. Only at Profile 14 Station 3 (P14-3: latitude $9^0 31'04.28''$ and longitude $6^0 26'21.12''$) can a prominent negative SP anomaly be identified with a maximum SP value at the 5 m depth-mark corresponding to -183 mV. This prominent negative SP anomaly occur along a flat dip; any such prominent negative SP anomaly on a flat dip is indication of mineralisation. This study recommends that a detailed geological work be conducted at the location of P14-3 to determine the surface characteristics of the source of the prominent negative SP anomaly. Also, detailed induced polarisation and vertical electrical sounding geophysical surveys should be conducted as follow-up studies at this location.

Keywords: Self-potential; millivolt; anomaly; dip; mineralization; fault-line; schist-belt

Introduction

The principal conclusion of the work of Jonah and Olasehinde (2017A) was the discernment of northeast-southwest (NE-SW) subsurface fault-traces that are characterised by clusters of groundwater prospect locations. These discerned subsurface fault-traces can be correlated with the Kazaure-Karaukarau-Kushaka-Ilesha Schist Belt on account of their trend (the NE-SW orientation), their geographic attribute (occurrence mapped west of 8^0 longitude), and positional locator because the NE-SW line drawn from the Kazaure schist body through to the Ilesha schist body actually cuts through the southern reaches of the Gidan Kwano Campus (GKC), Federal University of Technology (FUT), Minna, where the fault-traces have been mapped. According to a myriad of local geological literature on the schist belts of Nigeria (Obaje 2009, especially), these belts are associated with gold mineralisation. Thus, this study is concerned with the analysis of a body of self-potential (SP) data-field at the upslope of these discerned fault-traces with a view to detailing its possible mineralisation character. Moreover, ABEM (1999) recommends the use of the Terrameter SAS 4000 in the SP mode for ground mineralogical survey. Actually, from field observations, there are comparatively more outcrop protrusions at the upslope of these fault-traces which is coincident with the southeastern portion of a particular swath of land called Phase II Development of the GKC; this Phase II Development is an appropriately-defined 8 km^2 area, contiguous with the developed portion of the GKC of the FUT Minna where expansions to the existing students' hostel facilities and other structures are planned in accordance with the groundbreaking launch in 2011 indicated by the stone plaque at the point of latitude $9^0 31' 53.7''$ and longitude $6^0 26' 23.5''$. Thus, this study is concerned with the analysis of acquired SP data at the southeastern 0.6 km^2 corner of the Phase II Development, Gidan Kwano Campus, Minna, Northcentral Nigeria.

According to Kearey and Brooks (1984), the self-potential (or spontaneous polarisation) method is based on the surface measurement of natural potential differences resulting from electrochemical reactions in the subsurface. Typical SP anomalies may have ans amplitude of several hundred millivolts with respect to barren ground. They invariably exhibit a central negative anomaly and are stable over long periods of time. They are usually associated with deposits of metallic sulphides, magnetite, or graphite. According to Dobrin (1981) self-potential anomalies (often hundreds of millivolts in magnitude) can be detected by non-polarising porous electrodes connected to the respective terminals of a millivoltmeter. The potentials can be measured along profiles with pairs of such electrodes maintained at uniform separation. With this arrangement, gradients are usually mapped rather than actual potential differences. Equipotential lines are sometimes determined by maintaining one electrode in a fixed position and finding the line along the surface for which no potential difference is observed between it and a movable probe.

If the discerned subsurface fault-traces of interest in this study can be correlated with a prominent schist belt, then question has arisen about the mineralisation potential of this emplaced and easily-fractured schist rock segment. Actually, dedicated subsurface surveys for mineralisation potentials of the GKC have never been undertaken before and so the problem of a lack of database for subsurface mineralisation potentials of the GKC would have been solved at the completion of this study, albeit over a comparatively small tranche of 0.6 km^2 (the GKC is just a little over 100 km^2 in size according to Adesoye 1986).

The aim of this study is to make informed inference about the mineralogical nature of the upslope of the discerned subsurface NE-SW fault-traces at a 0.6 km^2 tranche of the GKC based on the analysis of self-potential data acquired over that tranche. The following key objectives of this study are required to achieve this broad aim: Qualitative analysis of the SP data whereby the full-body of the SP data-field would be contoured to look for trends defined by SP clusters across the extent of study. This analysis would be aided by productions of four contour maps at 5 m, 10 m, 15 m, and 20 m electrode-spreads; these would be the "iso-potential" maps at these depths. Production of typical point-to-point one-dimensional (1-D) model representations whereby typical 1-D model representations for each location of the SP survey would be produced in strong analogy to the typical log-log WinResist® plots familiar from the analysis of resistivity sounding surveys. Herein, then, SP data could now be plotted on any convenient co-ordinate showing SP millivolts (mV) versus depth of survey (once again, the maximum electrode-spread for the SP survey is 20 m). It was mentioned in Adesoye (1986) that there was no trace of mineralisation on any of the outcrops seen at the GKC, and that study recommended that subsequent subsurface studies be conducted to fully establish the mineral potential or otherwise of the GKC. Furthermore, Obaje (2009) posited that the schist belts of Nigeria are associated with gold mineralisation. Thus, at the completion of this study, a positive contribution to the mineralogical knowledge base of a small portion of the GKC would have been made. There are seven cross-profiles, each 100 m in length that are of interest for this study. Along each profile SP information was acquired for a maximum of 20 m electrode-spread at station-interval of 20 m. Thus, there are 357 planned total stations earmarked for this SP study.

Area of Study

The core 0.6 km^2 (0.6 km x 1 km) tranche areal extent of this study is subsumed in the wider 8 km^2 Phase II Development; this 8 km^2 swath of land is ideal for the University's near-term and mid-term facility expansion programmes (Jonah *et al.*, 2015A, 2015C, 2015D, 2015E; Jonah and Olasehinde, 2015B; Jonah and Jimoh, 2016A; Jonah and Saidu, 2016B; Jonah, 2016C; Jonah and Olasehinde, 2017A; Jonah and Adamu 2017B; Jonah *et al.*, 2018A; Jonah *et al.*, 2018B). On the ground, this 8 km^2 areal extent is a perfect rectangle with its ends corresponding to the following georeferenced co-ordinates: $09^0 30'57.8''$N, $006^0 25'39.0''$E (most extreme southwest); $09^0 30'57.8''$N, $006^0 26'43.8''$E (most extreme southeast); $09^0 33'07.4''$N, $006^0 26'43.8''$E (most extreme northeast); $09^0 33'07.4''$N, $006^0 25'39.0''$E (most extreme northwest); see Figure 1.

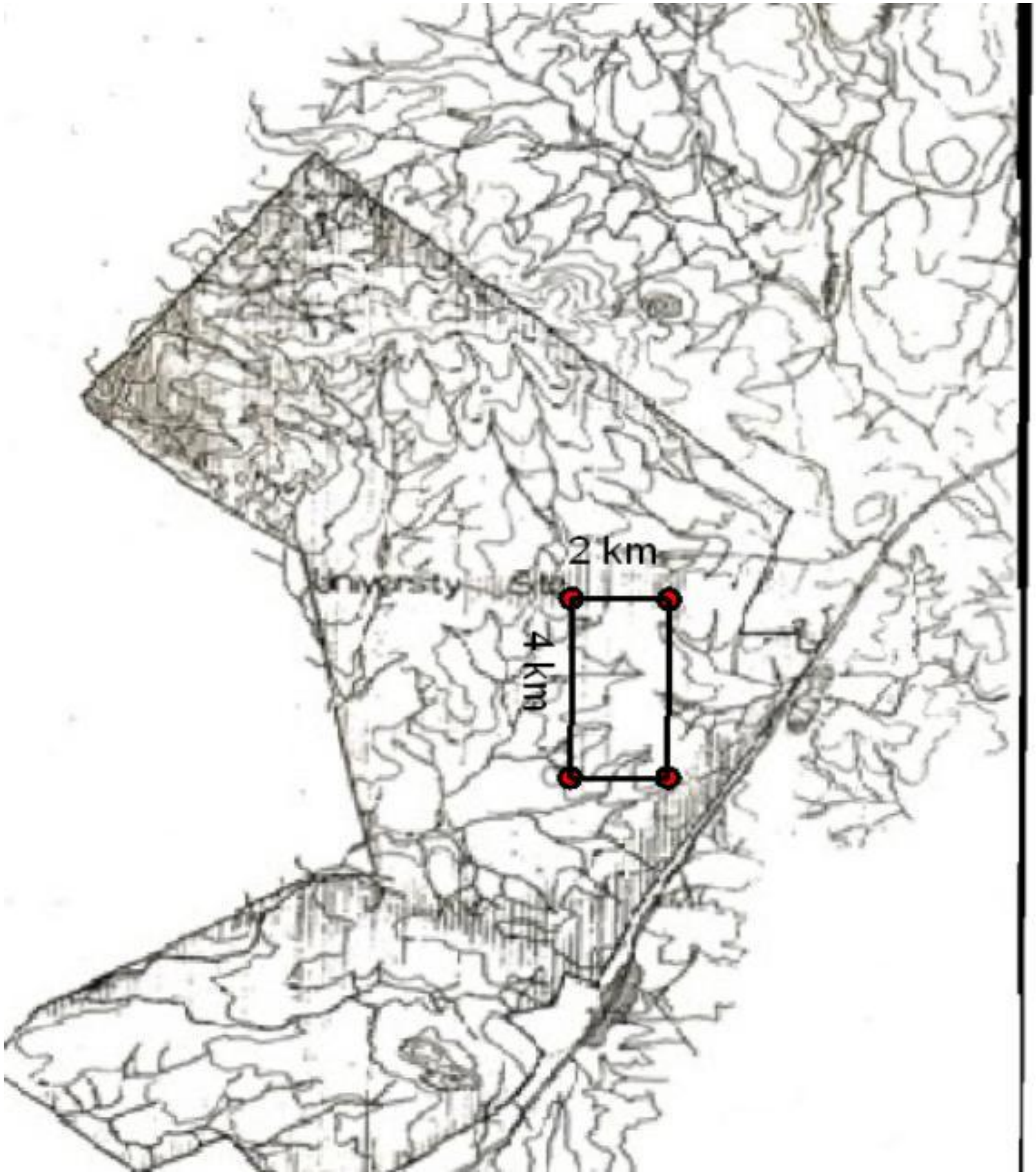

Fig.1. Location most suited for Phase II development at the Gidan Kwano Campus

Accurate traverse fixing is desirable to build a grid for the 8 km^2 swath and georeferencing of survey stations is desirable to independently verify the results of this study. At 100 m separation, a total of 21 profile lines were identified in the longitudinal traverse sense and a total of 41 profile lines were identified in the transverse traverse sense. This traverse fixing scheme results in 21 x 41 = 861 principal survey stations. This grid representation is shown in Figure 2. Each of these principal survey stations was visited whence its latitude, longitude, and elevation information (x, y, z) were measured and duly recorded. On the ground, against the backdrop of a satellite imagery map showing Phase I (obviously, the present developed portion), the locations of the principal stations are as shown in Figure 3. The map of Figure 3, configured in the Geographic Information System (GIS) environment, was manipulated such that the principal 100 m-interval points of survey of the SP study (which, incidentally are also the principal 100 m-interval points of the vertical electrical sounding, VES, and the induced polarisation, IP, studies) are highlighted in green against the red-dot original station-designations. However, for the SP survey, for every 100 m-interval there are five 20 m sub-interval stations that were surveyed. The core 0.6 km^2 tranche at the southeastern corner of the 8 km^2 swath is highlighted on the map of Figure 4.

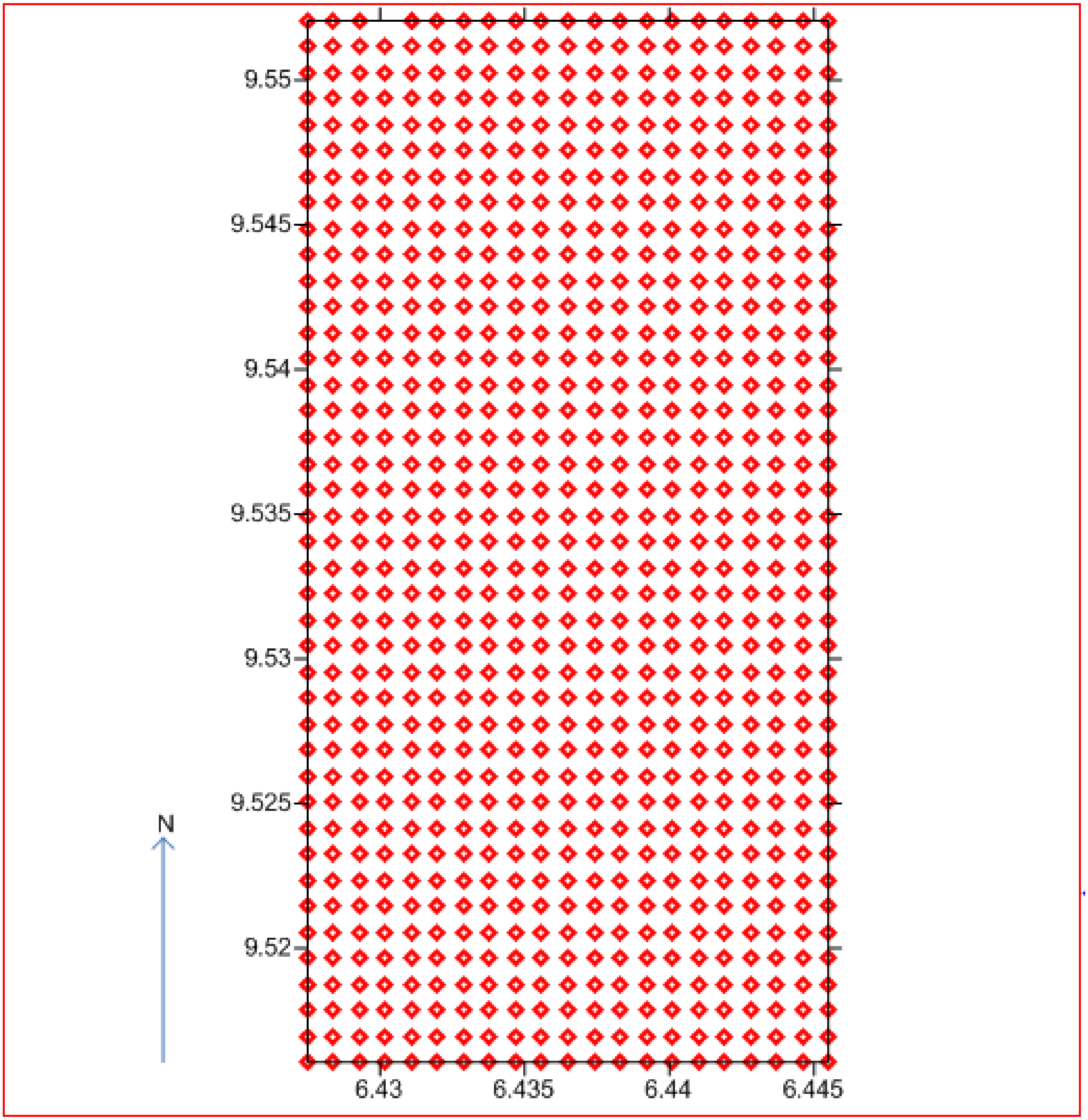

Fig.2. Grid representation of principal stations of area of study

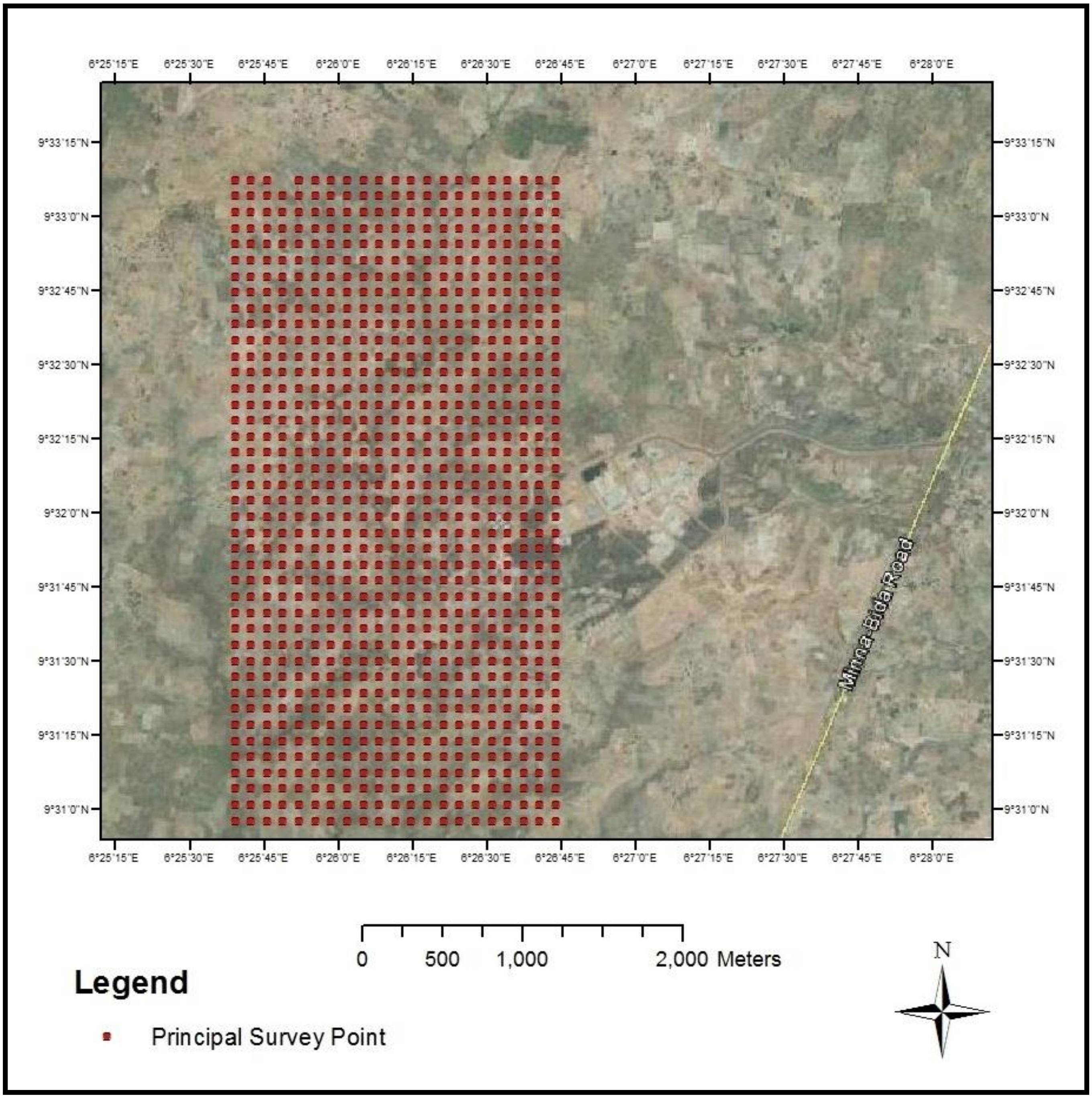

Fig.3. Locations of the principal stations against the backdrop of a satellite imagery map showing

Phase I

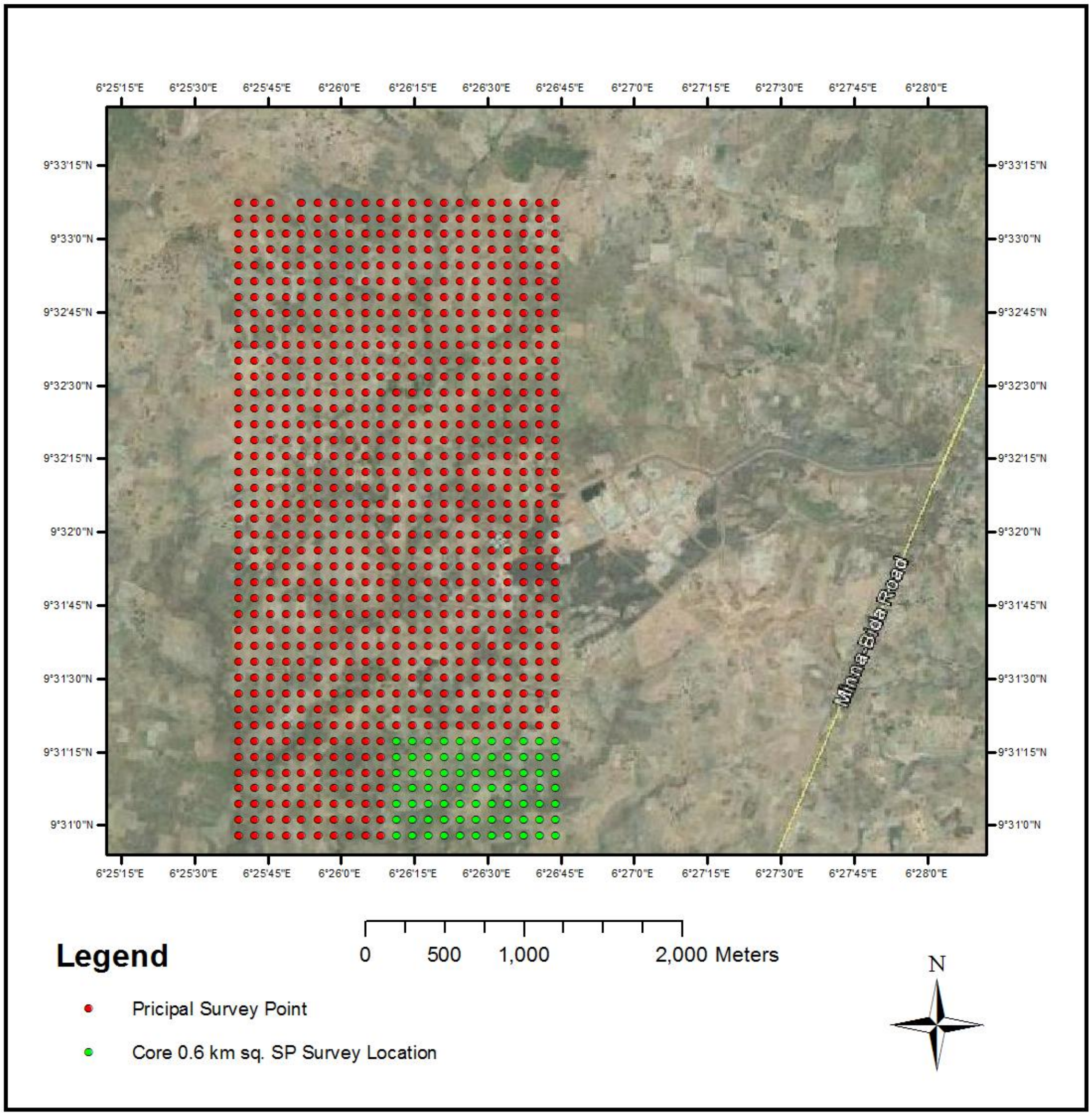

Fig.4. Core 0.6 km^2 tranche at the southeastern corner of the 8 km^2 swath

Brief Literature Review

Parasnis (1986), p. 104, pointed out that the self-potential method, as its name implies, is based upon measuring the natural potential differences which generally exist between any two points on the ground. The potential differences, partly constant and partly fluctuating, are associated with electric currents in the ground. The constant and unidirectional potential differences between any two points can arise due to various electrochemical mechanisms. Ranging normally from a fraction of a millivolt to a few tens of millivolts self-potentials sometimes attain values of the order of a few hundred millivolts and much more. Such large anomalous potentials are often (but not always) observed over sulphide and graphite ore bodies, magnetite and several other electronically conducting minerals. Large SP values are also found on coal and manganese deposits. Unless superimposed by other self-potentials these "mineral potentials" are invariable negative with respect to a point far away from the mineral occurrence when the dips are steep but they may be flanked by positive maxima. Positive principal SP maxima on the ground surface over the above minerals are found in the case of flat dips. Distinct, although considerably smaller in magnitudes, are the anomalies often observed on other features like quartz veins, pegmatite, etc. These are positive. Parasnis (1986), p. 105, also noted that the measurement of self-potentials is quite easy. The author stated that any millivoltmeter with a surface over the above mentioned minerals are found in the case of flat dips some 10-15 cm into the ground and read off.

Adeyemi *et al.* (2006) discussed the spontaneous potential and electrical resistivity response modelling for a thick conductor in their work published in the Journal of Applied Sciences Research, pages 691 to 702. The authors carried out direct laboratory modeling of the spontaneous potential (SP) and electrical resistivity responses of a thick conductor with different attitudes with the objective of obtaining characteristic signatures that may be diagnostic of similar geological targets. They pointed out that the method of investigation involved the burial of the conductor at different angles of inclination in sand within a model tank. It is understood that this study proceeded by taking measurements across the conductor and the data obtained were used to generate profiles; furthermore, the profiles were then interpreted qualitatively and semi-quantitatively. The authors stated that the results indicated, on the one hand, SP profiles delineate the conductor better giving the location, information on the magnitude and direction of inclination, and quantitative estimation of the depth of burial and on the other hand the resistivity profiles indicated the direction of inclination and location of the conductor. The authors concluded that the SP method is suitable for the investigation of sheet-like targets of different attitude, since the results are amenable to both quantitative and qualitative interpretations.

Fedi and Abbas (2010) discussed the fast interpretation of self-potential data by DEXP method at the Society of Exploration Geophysicists (SEG)'s Annual Meeting held at Denver, Colorado. The authors pointed out that the method of Depth from Extreme Points (DEXP) was used for self-potential (SP) data interpretation; they also provided a description on how to estimate in a fast way the depth to the source, the structural index and the shape factor of the causative sources. They observed that the method was demonstrated for synthetic examples and the result showed great agreement with the true model parameters. Finally, they reported that the method was applied to real data from a Malachite Mine, Jefferson County, Colorado, USA, and the estimated depth and structural index were in a good agreement with the known geology.

Layout of Survey and Progression

Kearey and Brooks (1984) indicated that the depth of penetration of the SP field technique is limited to about 30 m and that the method is actually generally suited as a subordinate ground reconnaissance procedure in conjunction with magnetic, electromagnetic, and geochemical techniques (although, for this present study, the SP method was employed as a subordinate technique to the more deep-penetration IP method). Thus, a maximum of 20 m station-spacing was chosen for this study configured for taking readings at every 5 m interval; since the core 0.6 km^2 area of study tranche of the present study is subsumed in the wider 8 km^2 Phase II Development swath, the first principal SP profiles actually begins from P11-1 (Station 1 of Profile 11 of that 8 km^2 layout); on that 8 km^2 layout, principal profiles are in a north-south trend with the first profile being the westernmost dot-line as seen in Figure 4. The study progression was defined by assigning the five SP sub-stations between the principal stations of Figures 2 and 3 their appropriate co-ordinates in the latitude-longitude system as well as their equivalent values in the Universal Traverse Mercator (UTM) system because the locator co-ordinates for each of the principal stations are already known; by this means, then, the SP data acquisition process proceeded with minimal hitch. The SP field equipment consisted simply of a pair of electrodes connected via a high-impedance millivoltmeter that is built-in in the ABEM Terrameter SAS 4000.

Results

Data Processing. Qualitative analysis of the SP data-field of this study proceeded by the route of producing contour maps for the four distinct depths of study of this study and these are the 5th, 10th, 15th, and 20th metre marks. The suite of Rockworks® and Surfer®13 was employed to produce the SP contour maps for the four distinct depth intervals.

Qualitative Analysis of the SP Data. The SP contour map for the 5-m depth-mark is shown as Figure 5, for the 10-m depth-mark as Figure 6, for the 15-m depth-mark as Figure 7, and for the 20-m depth-mark as Figure 8.

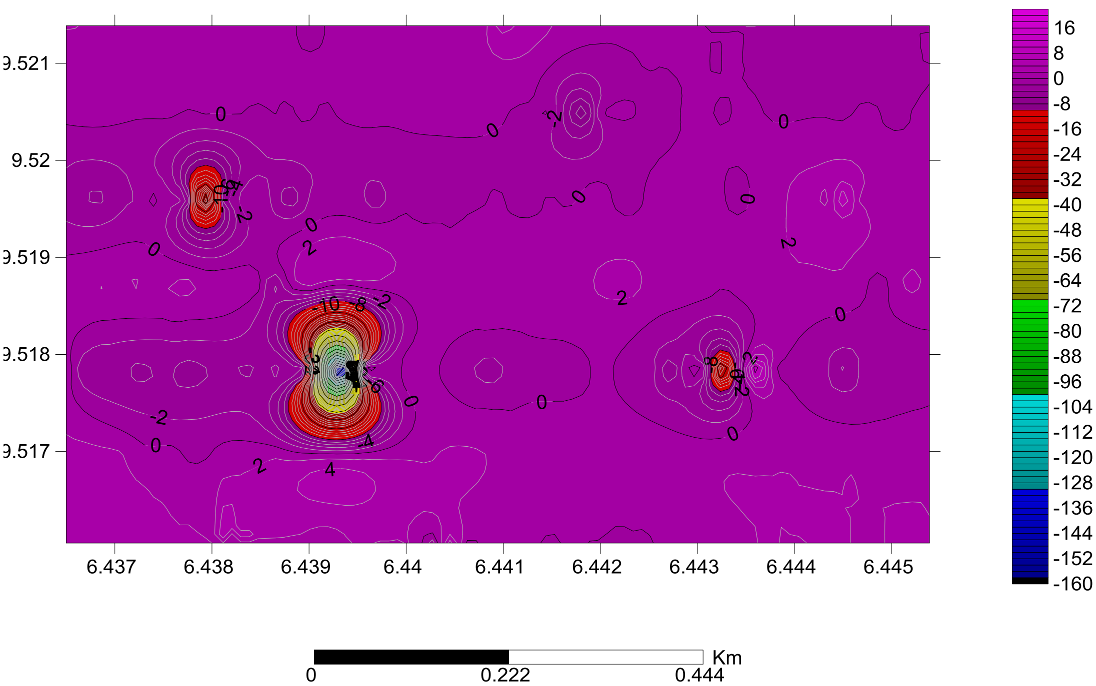

Fig.5. SP Contour map for the 5-m depth-mark

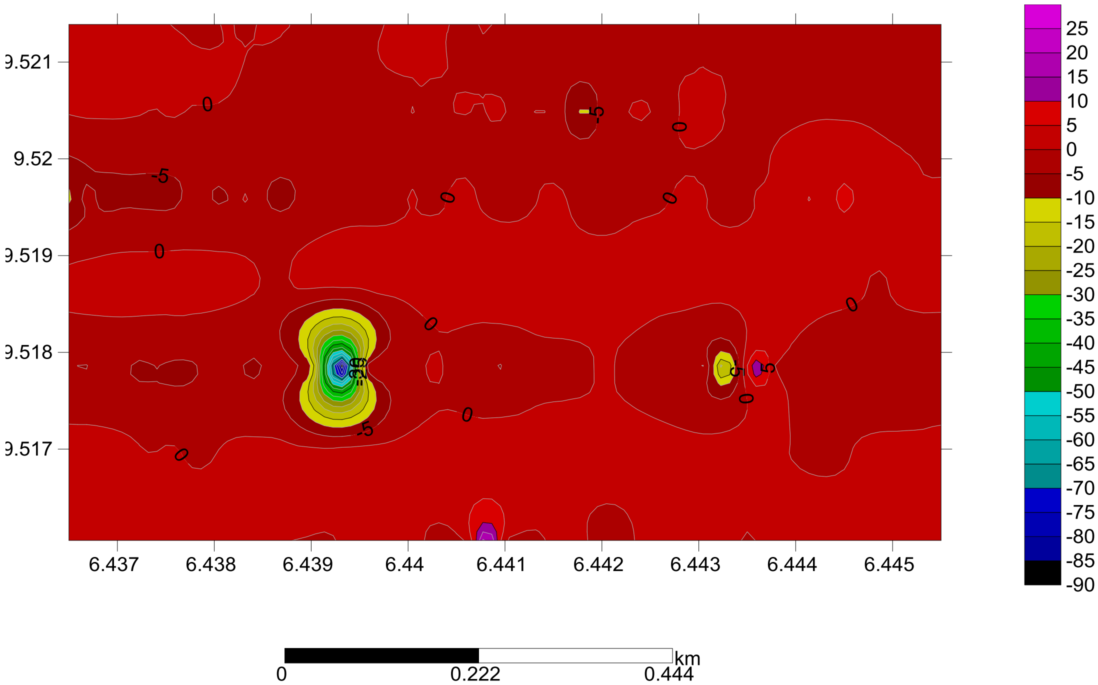

Fig.6. SP Contour map for the 10-m depth-mark

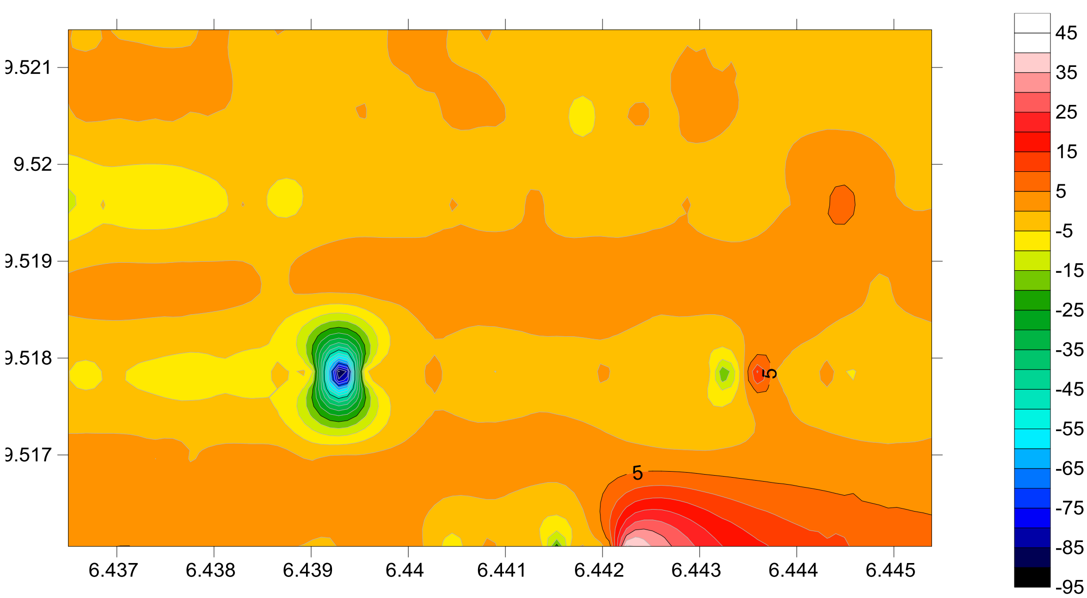

Fig.7. SP Contour map for the 15-m depth-mark

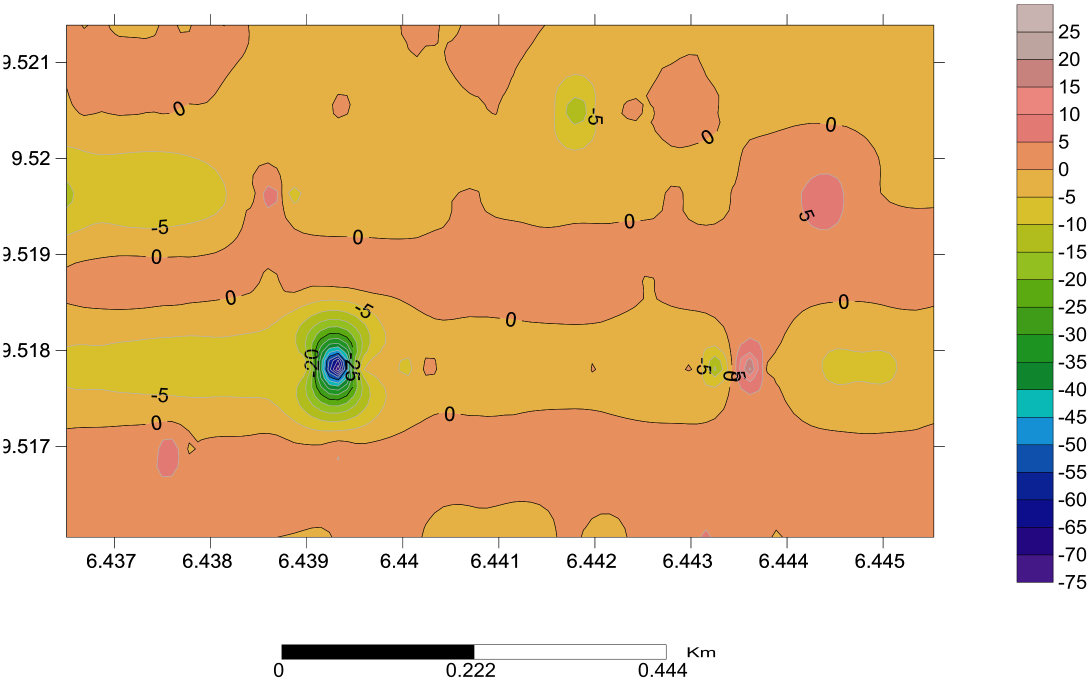

Fig.8. SP Contour map for the 20-m depth-mark

Production of Typical Point-to-Point One-Dimensional (1-D) Model Representations. The SP values and depth values were imported into Microsoft Excel whence the data were segmented such that the range of SP values for the five sub-stations between principal stations plus the coincident sub-station that is usually the first of the next principal station and the sixth of the previous principal stations was shown on the y-axis and the depth intervals on the x-axis. For each plot of the 20 m sub-stations between principal stations there are six colour-coded plots for the six sub-stations implied to earlier. The 1-D model representations for the three zones of significant negative SP anomalies (P12-5, P14-3, and P18-3) are shown in Figures 9 to 11.

Discussion

Qualitative Analysis of the SP Data:

The SP Contour map for the 5-m depth-mark:- This map (Figure 5) shows a nearly uniform distribution of homogeneous material throughout the extent of the area of study characterised by positive SP values in the small tens of millivolts. However, three zones of negative SP anomalies are also observed on this map with values ranging from -16 mV to -160 mV; these SP anomalies occur at Profile 12, Station 5 ($09^{0}31'10.76''$; $006^{0}26'14.64''$), Profile 14, Station 3 ($09^{0}31'04.28''$; $006^{0}26'21.12''$), and Profile 18, Station 3 ($09^{0}31'04.28''$; $006^{0}26'34.08''$) but the largest negative SP anomaly of over -160 mV is observed at Profile 14, Station 3.

The SP Contour map for the 10-m depth-mark:- This map also shows a nearly uniform distribution of homogeneous material characterised mainly by SP values between -10 mV and +5 mV throughout the extent of the area of study. However, just one zone of prominent negative SP value can be made out at Profile 14, Station 3 having a value of – 99 mV.

The SP Contour map for the 15-m depth-mark:- The pattern of anomaly occurrence for the 10 m depth mark, especially with respect to the single zone of prominent negative SP value, can be followed through to the 15 m depth map, although the largest negative SP value is -110 mV.

The SP Contour map for the 20-m depth-mark:- At this depth, it is only the anomaly at Profile 14, Station 3, of -83 mV, that can be made amongst a uniform spread of material.

Production of Typical Point-to-Point One-Dimensional (1-D) Model Representations: It is seen in Figure 9 that the prominent negative SP anomaly for P12-5 manifests only at the 5 m depth mark as can be corroborated in Figures 5 to 8. Figure 10, for P14-3, is the location where prominent negative SP anomaly manifests at the four depth-segment of survey, from the 5 m mark through to the 20 m mark; the negative anomaly high can be seen at the 5 m depth mark, and the fact that prominent negative SP anomaly manifests at all depth points is also corroborated in Figures 5 to 8. What was a prominent negative SP anomaly at P18-3 seen at the 5 m depth-mark tapered off significantly at the 10-, 15-, and 20 m depth-marks, although the anomaly maximum is greater than -40 mV as is seen in Figure 11. In each of Figures 9 to 11, the anomaly maximum occurs at the 5 m depth-mark.

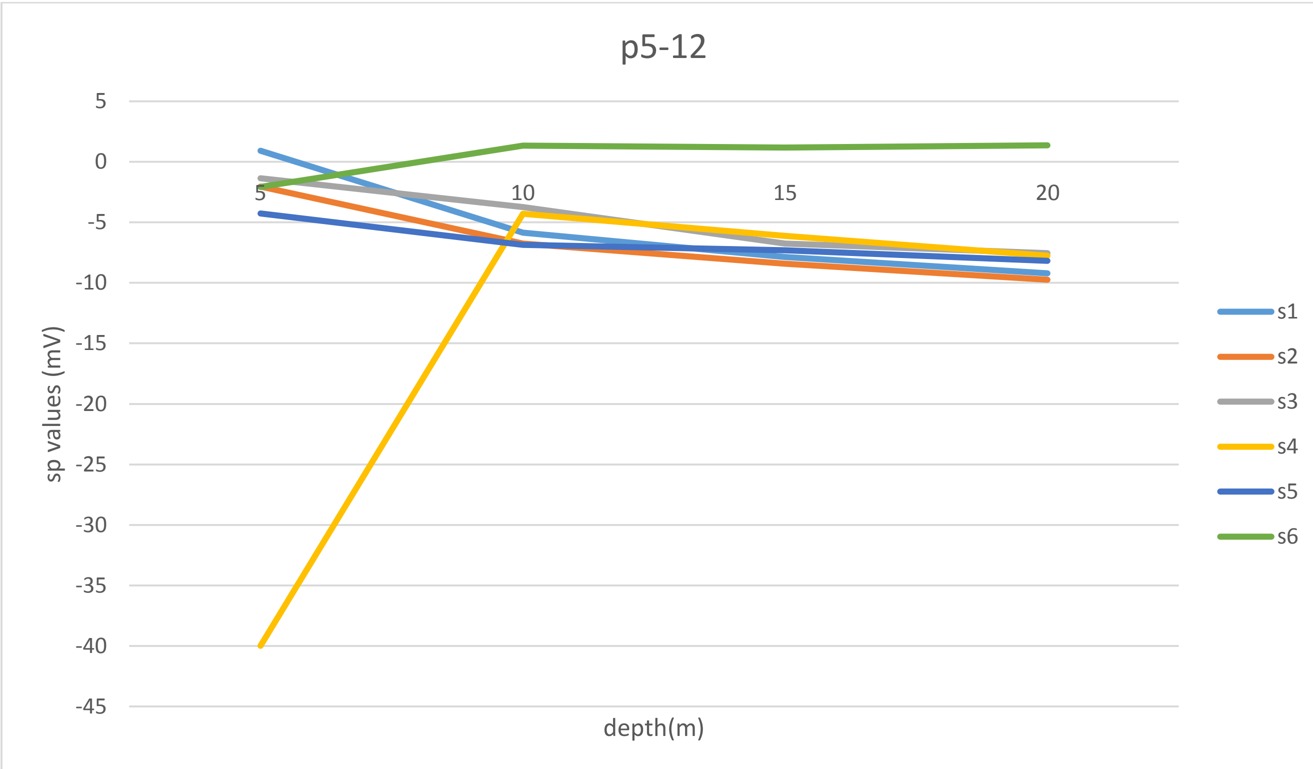

Fig.9. 1-D model representation for P12-5

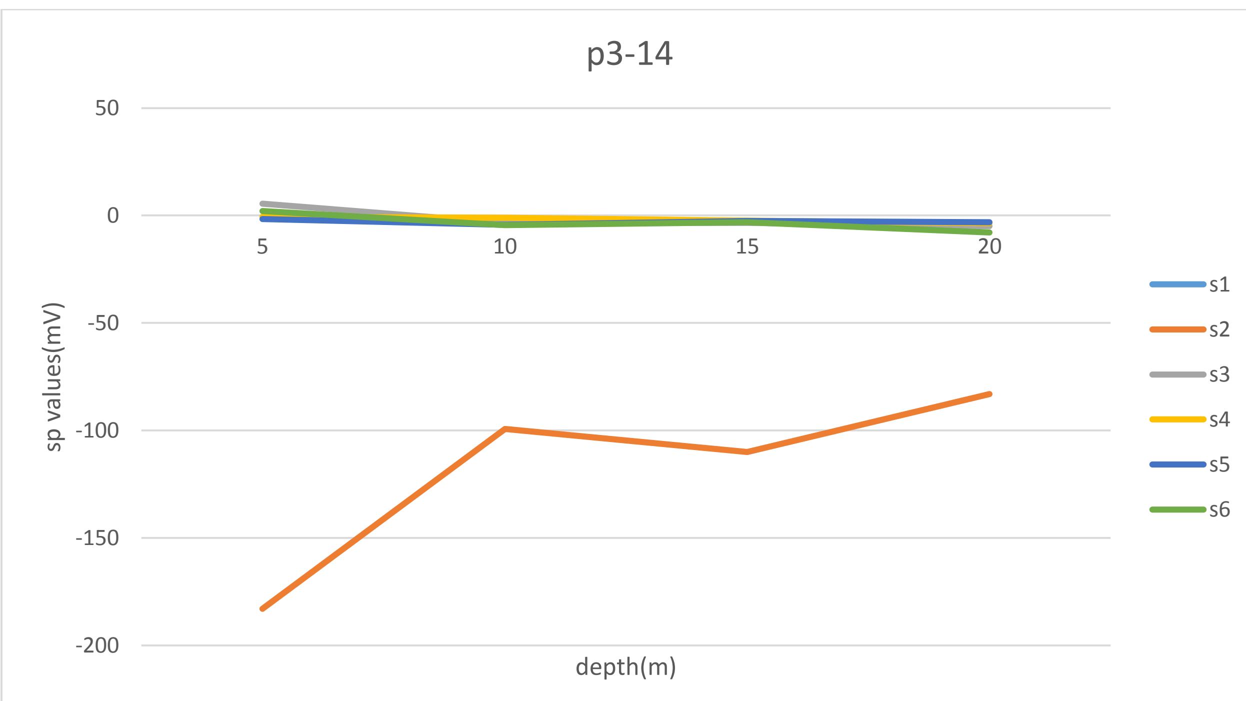

Fig.10. 1-D model representation for P14-3

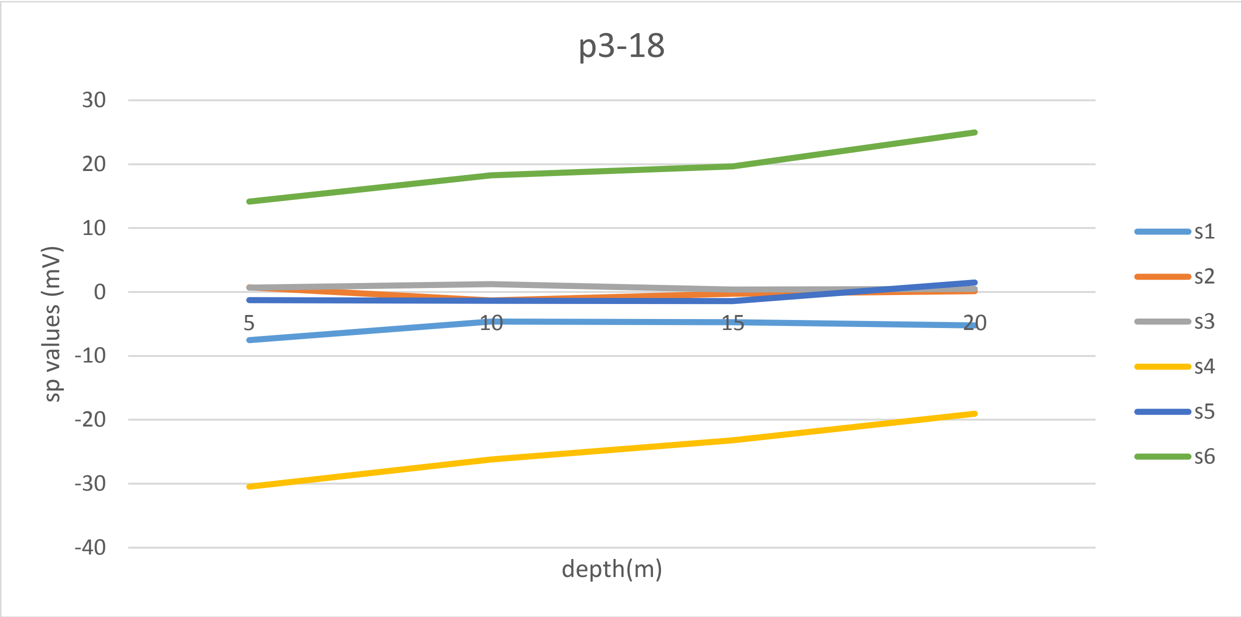

Fig.11. 1-D model representation for P18-3

Conclusion

Only at P14-3 can a prominent negative SP anomaly be identified for the four distinct depths of survey for this study with a maximum SP value at the 5 m depth-mark corresponding to -183 mV. An examination of Table 1, culled from the Appendix, indicates that this anomaly actually occur at Station 2 of P14-3 (in reality, Sub-Station 2, Station 3, Profile 14). Table 1 also shows that a positive SP value flanks this prominent negative anomaly as its right-handed maximum at Sub-station 3. The fact that this positive SP maximum and the prominent negative SP anomaly occur along a flat dip can be inferred from the work of Jonah *et al.* (2015D) that showed that the landform of the larger 8 km^2 dips in a southwesterly direction, as is seen in Figure 12. Any such prominent negative SP anomaly on a flat dip is indication of mineralisation.

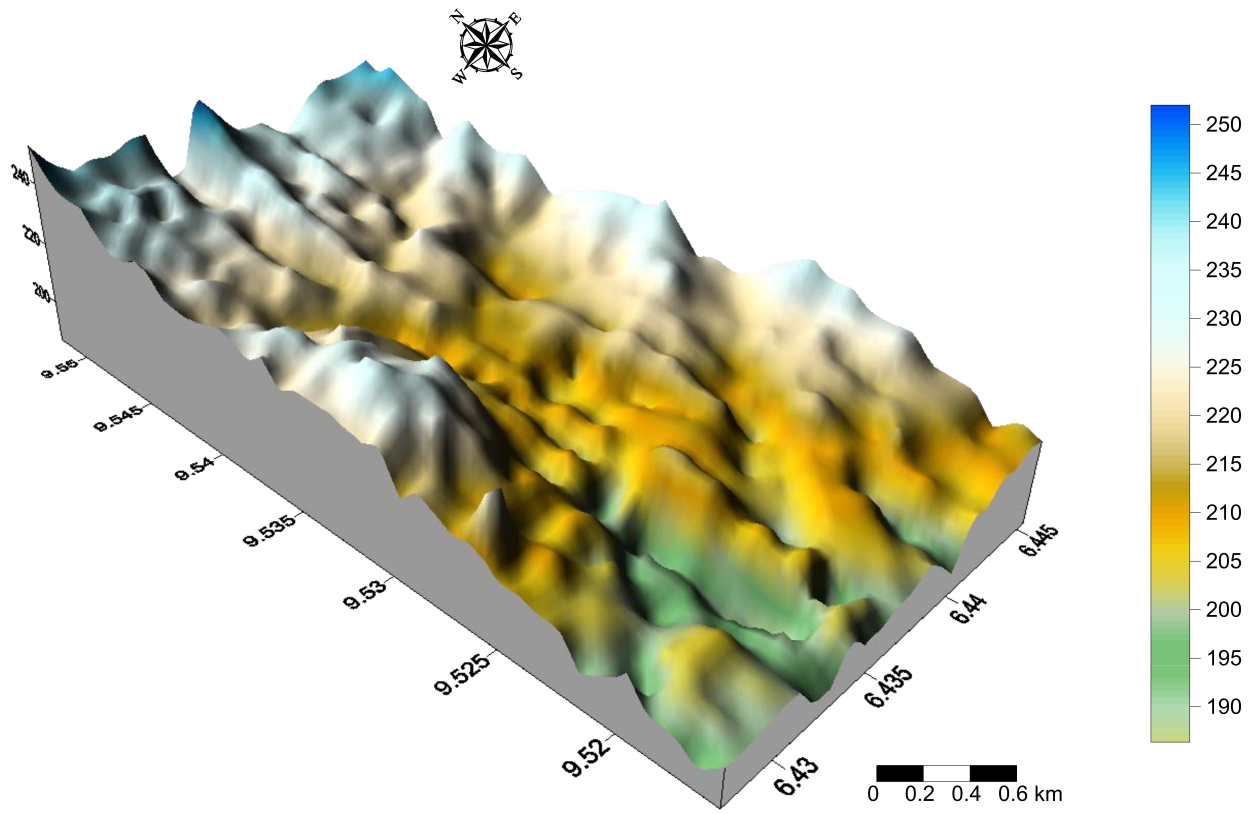

Fig.12. Landform of the larger 8 km^2 dips in a southwesterly direction

Table 1. Field SP data for sub-stations of Station 3, Profile 14

GEOELECTRICAL DATA RECORD SHEET

TYPE OF SURVEY: Self Potential.**EQUIPMENT:**ABEM Terrameter SAS 4000.**GPS UNIT:**Garmin GPSmap76 **PLACE:..**Gidan Kwano Campus…**WEATHER:**……..**TRANSVERSE TRAVERSE:.TT3**
LOCATION: (i) **N:…………**(ii) **E:**……….....**ELEVATION: .... DESIGNATION: P14-3**
OPERATOR:……………..…**RECORDER:**……… …… ……**DATE:**………. **TIME:**………………

SP@ 5m

STATION 1	STATION 2	STATION 3	STATION 4	STATION 5	STATION 6
x =9^{0}31'04.2''	x =9^{0}31'04.2''	x =9^{0}31'04.2''	x =9^{0}31'04.2''	x =9^{0}31'04.2''	x =9^{0}31'04.2''
y = 6^{0}26'21.0''	y = 6^{0}26'21.6''	y = 6^{0}26'22.3''	y = 6^{0}26'22.9''	y = 6^{0}26'23.6''	y = 6^{0}26'24.2''
z =	z = 200m	z = 204m	z = 205m	z = 205m	z = 204m
SP =	SP = -0.183V	SP = 5.573mV	SP = -0.574mV	SP = -1.640mV	SP = 2.128mV
SD =	SD = 0.45%	SD =	SD = 39%	SD = 16%	SD = 79%
STACKS =	STACKS =2	STACKS =	STACKS =4	STACKS =4	STACKS =4

SP@ 10m

STATION 1	STATION 2	STATION 3	STATION 4	STATION 5	STATION 6
x =9^{0}31'04.2''	x = 9^{0}31'04.2''	x =9^{0}31'04.2''	x =9^{0}31'04.2''	x =9^{0}31'04.2''	x =9^{0}31'04.2''
y =6^{0}26'21.0''	y = 6^{0}26'21.6''	y = 6^{0}26'22.3''	y = 6^{0}26'22.9''	y = 6^{0}26'23.6''	y = 6^{0}26'24.2''
z =	z = 200m	z = 204m	z = 205m	z = 205m	z = 204m
SP =	SP = -99.31mV	SP = -3.363mV	SP = -1.109mV	SP = -4.346mV	SP = -4.501mV
SD =	SD = 0.20%	SD = 18%	SD = 19%	SD = 72%	SD = 25%
STACKS =	STACKS =2	STACKS =4	STACKS =4	STACKS =4	STACKS =4

SP@ 15m

STATION 1	STATION 2	STATION 3	STATION 4	STATION 5	STATION 6
x =9^{0}31'04.2''	x =9^{0}31'04.2''	x =9^{0}31'04.2''	x =9^{0}31'04.2''	x =9^{0}31'04.2''	x =9^{0}31'04.2''
y = 6^{0}26'21.0''	y = 6^{0}26'21.6''	y = 6^{0}26'22.3''	y = 6^{0}26'22.9''	y = 6^{0}26'23.6''	y = 6^{0}26'24.2''
z =	z = 200m	z = 204m	z = 205m	z = 205m	z = 204m
SP =	SP = -0.110V	SP = -3.363mV	SP = -2.372mV	SP = -2.520mV	SP = -3.158mV
SD =	SD = 0.86%	SD = 18%	SD = 11%	SD = 4.4%	SD = 15%
STACKS =	STACKS =3	STACKS =4	STACKS =4	STACKS =4	STACKS =4

SP@ 20m

STATION 1	STATION 2	STATION 3	STATION 4	STATION 5	STATION 6
x =9^{0}31'04.2''	x = 9^{0}31'04.2''	x =9^{0}31'04.2''	x = 9^{0}31'04.2''	x =9^{0}31'04.2''	x =9^{0}31'04.2''
y = 6^{0}26'21.0''	y = 6^{0}26'21.6''	y = 6^{0}26'22.3''	y = 6^{0}26'22.9''	y = 6^{0}26'23.6''	y = 6^{0}26'24.2''
z =	z = 200m	z = 204m	z = 205m	z = 205m	z = 204m
SP =	SP = -83.09mV	SP = -4.903mV	SP = -3.556mV	SP = -3.112mV	SP = -7.955mV
SD =	SD = 0.57%	SD = 4.7%	SD = 2.8%	SD = 3.3%	SD = 38%
STACKS =	STACKS =2	STACKS =4	STACKS =4	STACKS =4	STACKS = 4

Since the SP schedule of this study was conducted for a qualitative format, this study recommends that a detailed geological work be conducted at the location of P14-3 to determine the surface characteristics of the source of the prominent negative SP anomaly. Also, induced polarisation (IP) and vertical electrical sounding (VES) geophysical surveys should be conducted as follow-up studies at this location.

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