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Application of Ground Penetrating Radar in delineating zones of Gold Mineralization at the Subenso-North Concession of Newmont Ghana Gold Limited

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Abstract- The growing interest in Ghana's gold mining sector due to the recent upsurge in the price of gold has impacted greatly on the economy of the country with regard to its revenue generation capacity. There is therefore the need to develop this sector. Hence, any new method which is relatively low cost and has comparable efficiency compared to prevailing conventional methods in delineating new potential gold fields would be highly recommended. This study therefore aims at using the ground penetrating radar (GPR) a hitherto unknown geophysical method in the mining industry in Ghana, to detect possible zones of gold mineralization in Ghana. The GPR survey was conducted over the Subenso-north gold deposit, a property of Newmont Ghana Gold Limited to delineate geological structures that possibly host gold mineralization. The Mala GPR equipment with 25 MHz unshielded rough terrain antenna frequency in the common offset mode was used to conduct the survey. The survey was conducted over an area of 1 km^2 with a total of 21 profiles at a 50 m profile separation. Results of the survey indicated weathered saprolitic topsoil up to a depth of about 12 m. In addition two structural patterns possibly hosting gold mineralization were delineated as S1 and S2. The S1 and S2 inferred structures were found between the depth ranges of (12 m and 42 m) and (31 m and 48 m respectively. Comparison of results from co-located electrical resistivity and chargeability measurements confirmed the mineralization trend of the surveyed site.

Index Terms- radar, mineralization, delineate, chargeability, saprolite

I. INTRODUCTION

Geophysical methods have played a major role in the discovery and development of the gold exploration sector. These methods have enhanced and increased the chances of discovery of potential gold reserves. Geophysics also gives a full insight into the depositional environment. A few of the methods commonly used for the prospecting of gold mineralization are; magnetic, gravity, resistivity, and transient electromagnetic (TEM) methods. Despite the benefits derived from the application of these methods in gold exploration they have not been extensively employed in the development of the century old mining sector in Ghana. Most companies both foreign and local in the past and present have used conventional geological mapping, drilling and other techniques based mainly on the geological structure of the formations in the exploration for gold from the reconnaissance to the exploitation stages. The main mining company in Ghana which uses the geophysical tools to aid in the exploration of gold deposit is the Newmont Ghana Gold Limited. The Newmont Ghana Geophysical crew has embarked on a number of geophysical surveys in ground magnetic, induce polarization, 3-D resistivity, transient electromagnetic and ground gravity measurements in the search of economic gold deposits. Although the used of geophysical methods have potentially contributed greatly to the success history of the company in Ghana, the potential of ground penetrating radar (GPR) in the delineation of gold targets have not been tested. Literature shows the success of this method in exploration in many fields. Over the past decades, GPR has been used extensively on quite a number of applications. For example, the GPR technique has been successfully used to explore gem tourmaline pockets and vugs (Patterson and Cook, 1999; Patterson, 2001); voids and cavities (Leggo and Leech 1983); iron oxide deposits (Van Dam and Schlager, 2000, Van Dam et al 2003), the depth of water table (Van Heteren et al 1998, Van Overmeeren 1998, Neal and Roberts, 2000) and geological structures hosting mineral deposits (Ulriksen 1982, Davis et al. 1984, Birkhead et al 1996, Hofmann et al 1997, Eisenburger and Gundelach, 2000, Franke and Yelf 2003, Slater and Niemi 2003, Da Silva et al. 2004, Leucci 2006)

Scientific publications on the use of GPR application on hard crystalline granitic rocks, for locating mineralized zones have also received less attention by many researchers and mineral prospectors as compared to the conventional gravity, electrical resistivity, induced potential and magnetic methods. This study demonstrates how the GPR can be used to delineate possible structures that host gold mineralization at the Subenso-north Concession of Newmont Ghana Gold Limited.

II. MATERIALS AND METHODS

2.1 Description of study area

The measurements were taken at the Subenso North gold mine concession of Newmont Ghana Gold Limited, a 1 km^2 block located on the Universal Transverse Mercator (UTM) coordinate of longitude 590294 north and latitude 80106 west and between Teekyere and Adrobaa in the Brong Ahafo region of Ghana (Figure 1). Road access to the project site is via bitumen sealed road from Accra to Sunyani through Kumasi. The main town in the area is Teekyere which is located just by the road side about 2.5 km from Duayaw Nkwanta. About 1 km to the south of the deposit and almost parallel to the strike direction is a feeder road which connects two main towns in the area, Teekyere on the south and Adrobaa on the north. The Project area comprises of low rounded hills with elevations ranging from 291 m to 326 m above mean sea level. Seasonal streams and tributaries of the Tano River basin drain the broad, relatively flat valleys.

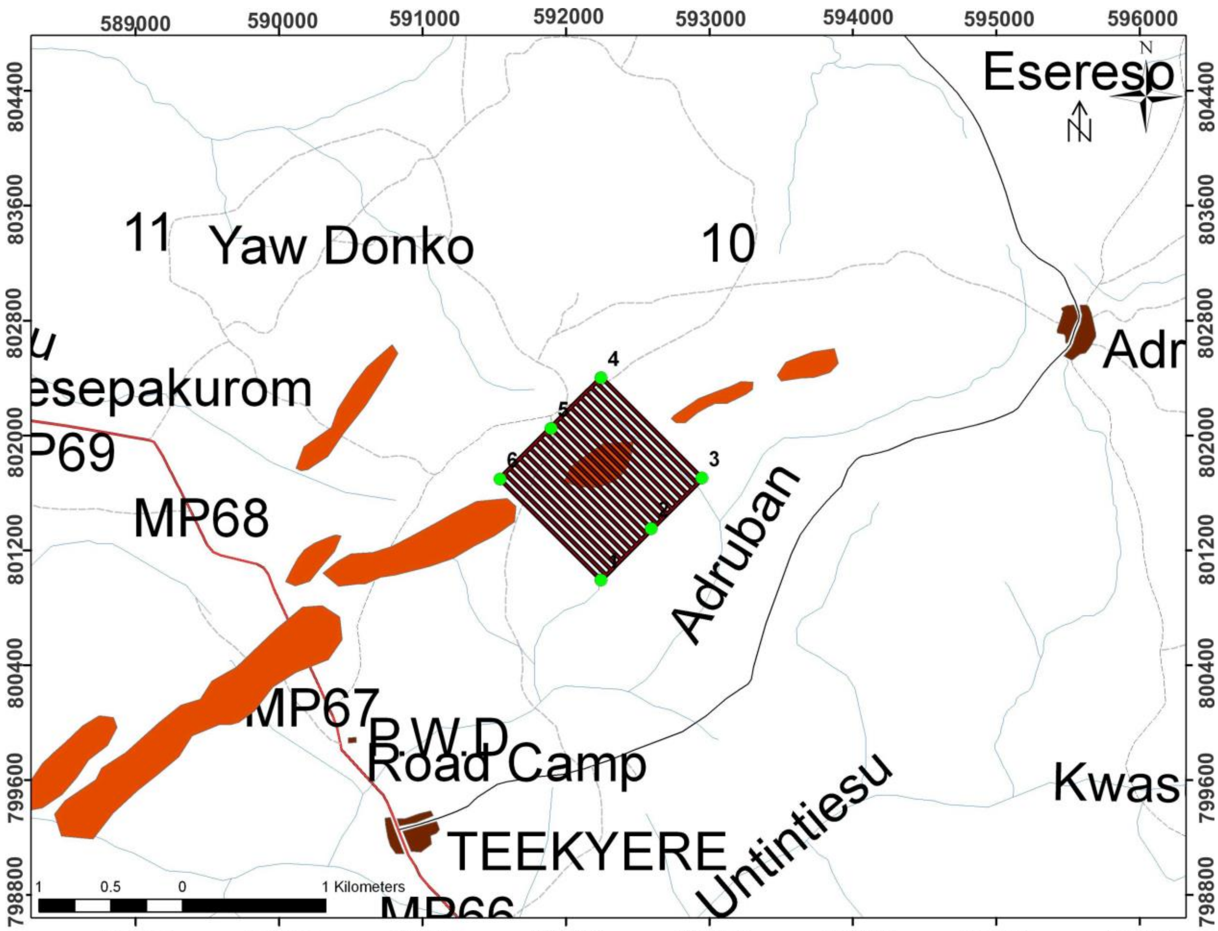


Figure 1: Location map of Subenso-North gold deposit (Cees, 2006)

2.2 Geological Setting and Mineralization

Three discrete geological zones are recognized within the Ahafo Project, relating to currently-identified mineralization styles. The Ahafo district currently consists of 12 discrete deposits, localized along multiple northeast-striking structural zones. Several additional exploration targets remain to be tested. All of the "shear zone'' type deposits appear to be part of the same system. As with many deposits located in tropical climates, a saprolite zone, typically between 5 and 50 m thick, is developed at the surface. The saprolite zone gives way at depth to a sulphide zone within which gold mineralization occurs in structurally-controlled zones of hydrothermal alteration. Most of the Ahafo deposits remain open both along strike and down dip. Excellent potential exists for connecting some of the deposits into single pits and for discovery of deposits. The deposit has dimensions of 1400 $\times$ 3-25 m and has been tested to a vertical depth of 140 m. Geologically, the Subenso-North concession falls within the Sefwi gold belt which is a 40 – 60 km wide typical Birimian volcanic belt, striking 220 km in Ghana and extends south-west to the coast in Ivory Coast (Kesse, 1985). It is located north of and parallel to the prolific Ashanti Gold Belt, which hosts many of Ghana's active producing gold mines. The Sefwi Belt (Figure 2) is dominated by mafic volcanics, metasediments and intrusive granitoids. The belt is sandwiched between adjacent sedimentary basins (Sunyani Basin to the west and the Kumasi Basin to the east) and the shared margins are highly faulted and sheared. These north-east trending marginal faults are traceable along the full length of the belt (Kesse, 1985).

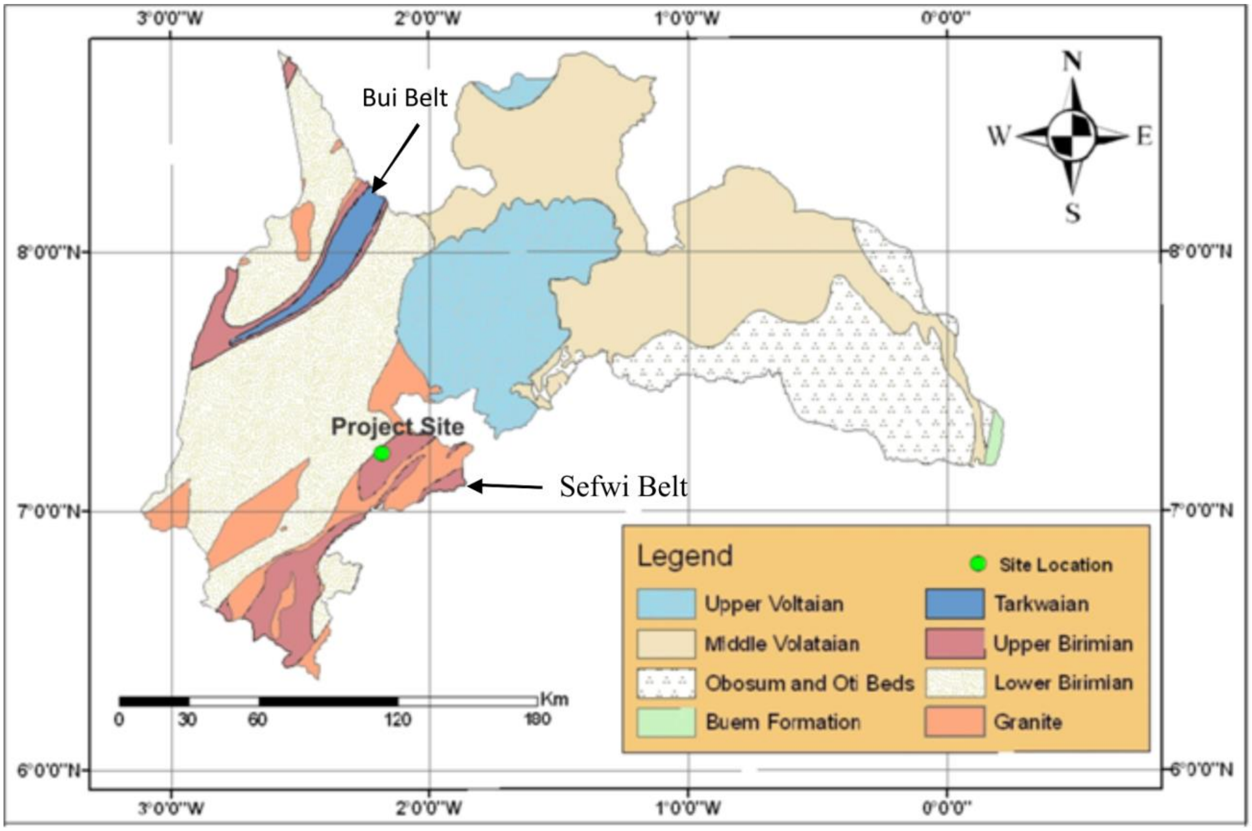


Figure 2: Geological Map of Brong Ahafo region showing the study site (Cees, 2006)

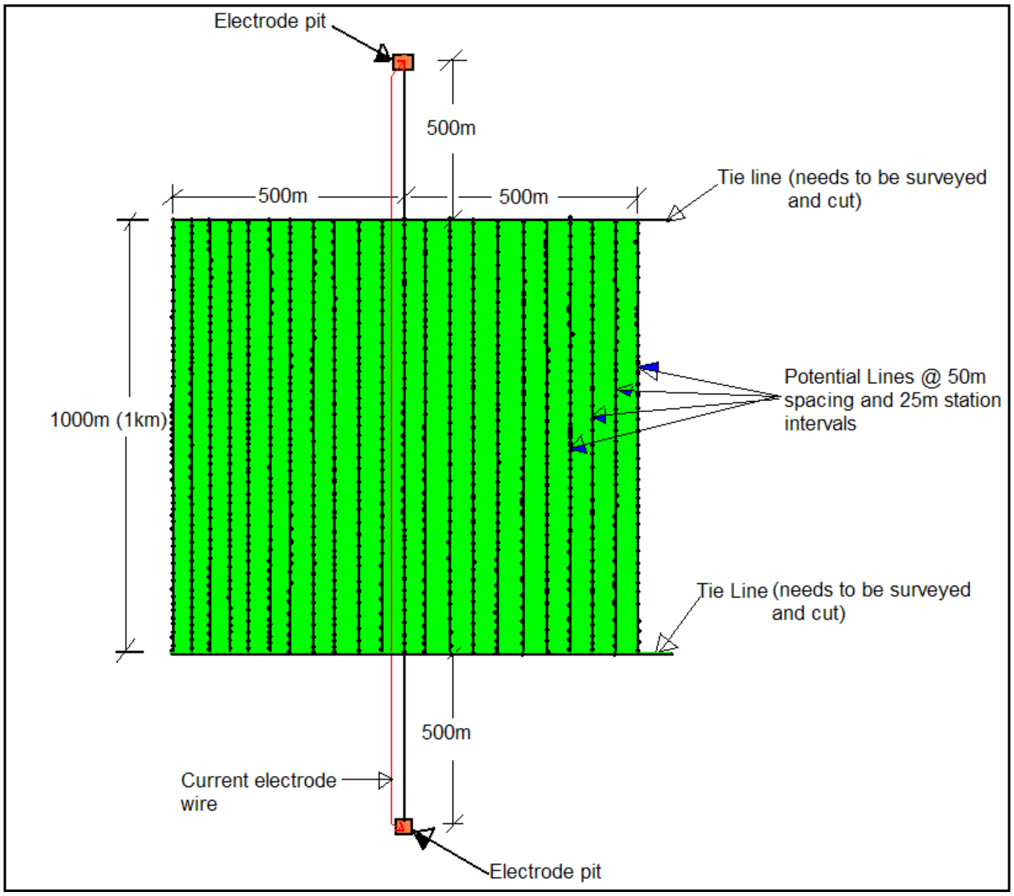
2.3 Methods

2.3.1 *GPR measurements*

The datasets were taken using the RAMAC GPR system (Figure 4) at a central frequency of 25 MHz with the rough terrain antenna (RTA) in the common offset mode. Investigations were made along a total of 21 profile lines each of length 1 km and labelled L1-L21 (Figure 3b). The ruggedly designed RTA was pulled along the profiles at pace speed. The field work took approximately 2 weeks.

2.3.2 *Induced polarization and resistivity measurements*

The induced polarization (IP) and resistivity data were collected using Incorporated Research Institutions for Seismology (IRIS) IP/Resistivity Instruments with ELREX PRO receiver and 1000 V transmitter over the 1 km^2 block in a gradient array configuration at a maximum exploration depth of 12.5 m. The survey lines were oriented northwest-southeast in order to cut across strike. The study area was divided into 21 profile lines each having a length of 1 km and inter-spacing separation of 50 m. Measurements were taken using the gradient array electrode configuration. The whole field exercise took 2 months to complete. Figure 3a shows the setup of the profiles with current injection points in red with a potential electrode separation (black dots) of 25 m. The 11th line called the "electrode line" was extended 500 m at both ends and the current electrode pit constructed for the survey. A limitation of the gradient array is that the depth of penetration is not exactly known. The subsurface resistivity distributions were mapped and where there were anomalies in resistivity, the pole dipole electrode array was used to probe the vertical extent of these anomalous zones. The pole dipole electrode array was used to survey 6 profile lines namely L6, L7, L8, L9, L10 and L11 in Fig 3a.



2.3.2 *Data*

Figure 3a: Setup of 50 m × 25 m grid for induced polarization and resistivity surveys

III. Data Processing and Interpretation

Due to the large volume of the data acquired from the field, an effective maintenance of the data was needed to ensure good data quality and interpretation. Prominent errors that occurred during data acquisition were immediately sorted out and deleted. The main aim for GPR data processing was to sharpen the signal waveform in order to improve the signal to noise ratio as reported in Akinpelu (2010). The REFLEXW Scientific software (Sandmeier, 2012) was employed for the data processing. The *dewow* tool helped to remove the low frequencies from the data. In order to bring all the traces to a common time zero position, the *static correction* or *Time-zero correction* was applied. The *background removal filter* tool was applied to remove temporally coherent noise from the data. Due to attenuation of the radar signals which is mostly caused by conductivity and geometrical spreading, the *gain tool* was applied to enhance low amplitudes from deeper depths. In this way the drastic fall of the radar signal at greater depths was compensated for. Other processing steps included time-varying bandpass frequency filter to help remove dominant frequencies seen in the data and a low cut filter to remove induction effects. Velocity estimates were made using the hyperbola fitting tool. The various subsurface structures of interest were differentiated and picked with the help of the phase follower and continuous pick tools. The resulting ASCII files containing the data of the traced structures were plotted graphically. The induced polarization and resistivity datasets were processed with the Geosoft (Oasis montaj) software to generate resistivity and chargeability image maps.

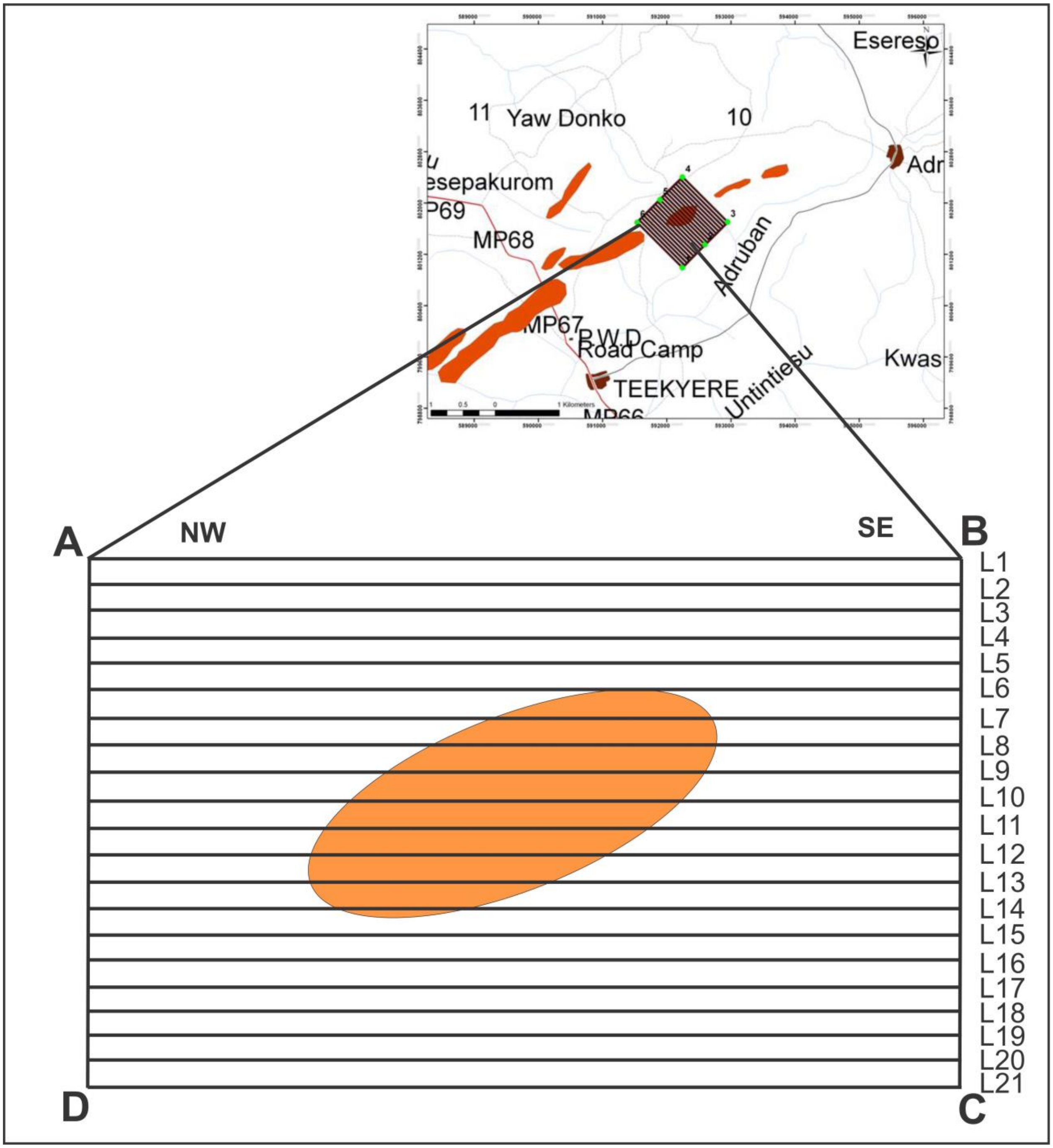


Figure 3b: Map of Subenso-North gold deposit showing the 1 km squared block ABCD with 21 profile lines L1 to L21

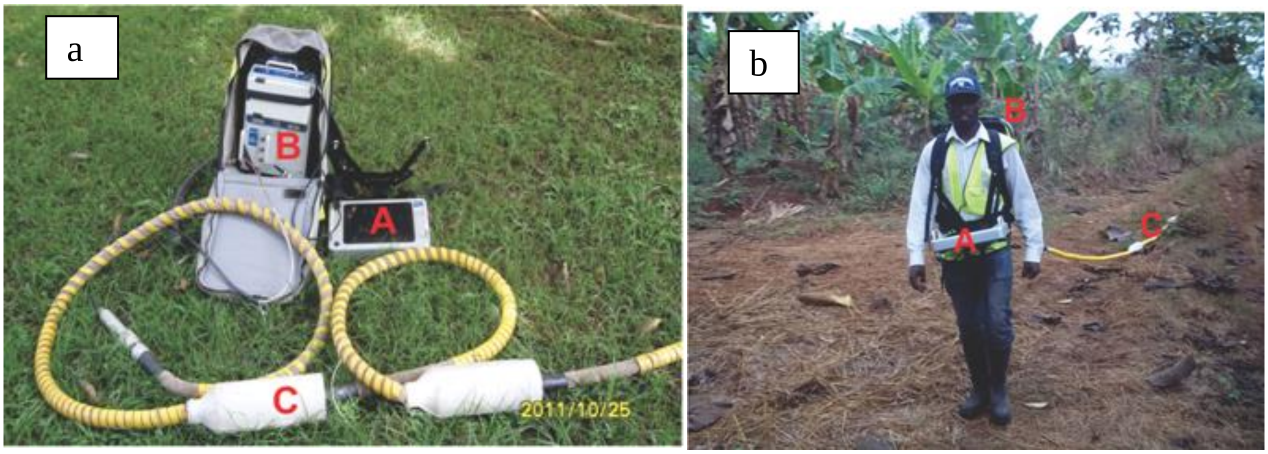


Figure 4: A: MALA GPR equipment used for the survey: A is XV monitor, B is Control unit, C is the RTA, B: GPR data collection in a continuous mode operation

IV. Results and Discussion

4.1 Interpretation of radar records

Figures 5 and 6 show the radar results of 12 profiles obtained from the study site. In all, 21 profile lines were surveyed but due to unforeseen errors in the antenna electronics coupled with a lot of noise from the roots of trees only 12 profiles will be presented and discussed. The radargrams of profiles L2 and L4 in Figure 5 and L13 and L17 in Figure 6 show possible hyperbolic diffractions between average depth intervals of 8 m and 12 m. These hyperbolic diffractions are air reflections of little geological significance. A transition zone marked D represents the duricrust-saprolite transition. The duricrust has an average thickness of about 8 m from the ground surface. Horizontal, sub-horizontal and sub-vertical reflectors also evident in these profiles were delineated and marked as S1 and S2. These are fractured and weathered zones located between the depths of about 33 m and 48 m. These are possible structures hosting gold mineralization. Fractured zones are usually weak zones that facilitate the migration and eventual deposition of hydrothermal solutions. Due to antenna reverberation and other error sources encountered in the field, some of the radar images recorded multiple reflections. Though these were suppressed traces of these are evident in the radar images of profiles L3 and L15 in Figures 5 and 6 respectively. Geologically, the multiple reflections have no meaning and do not account for any feature present within the earth surface.

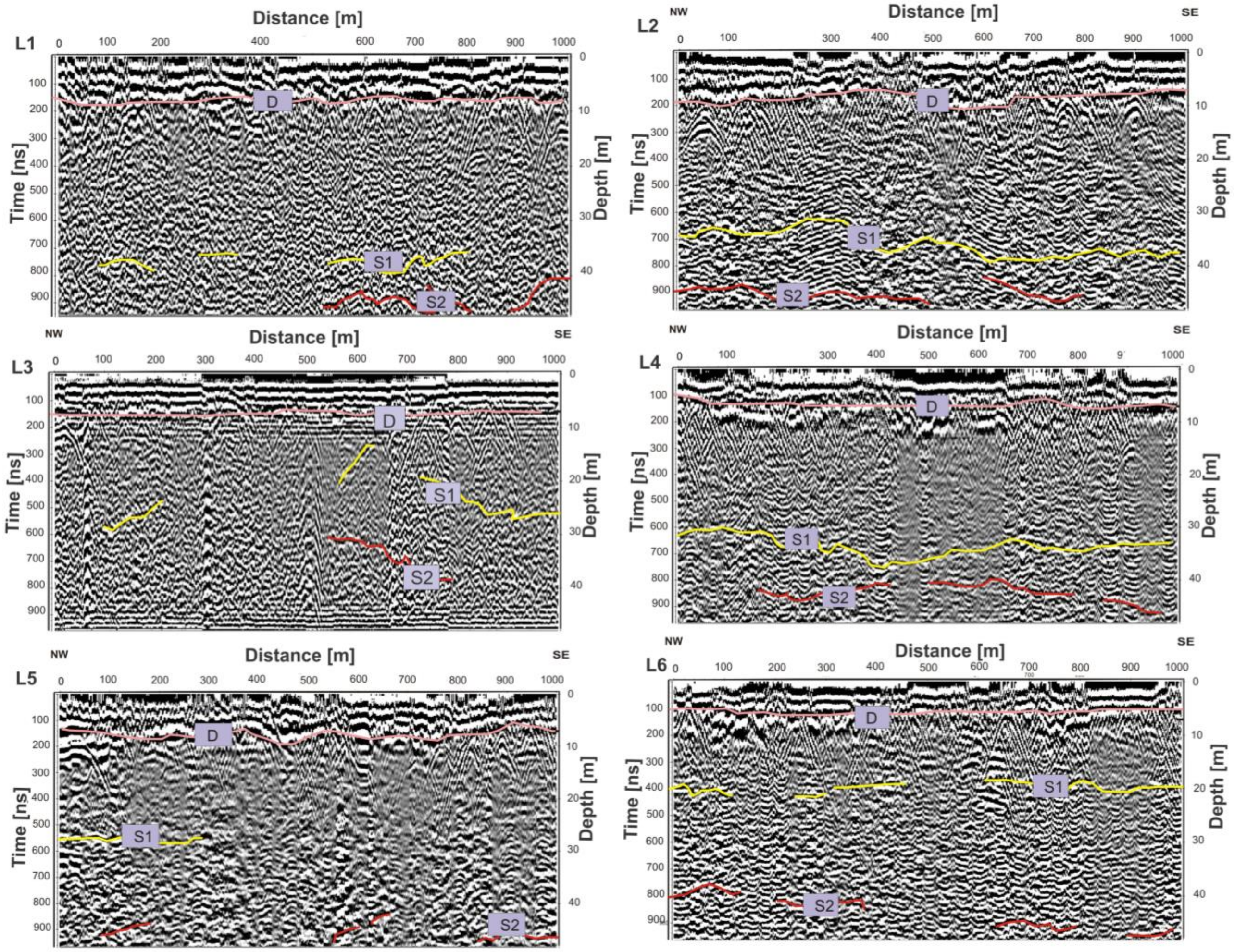


Figure 5: Radar images for profiles L1, L2, L3, L4, L5 and L6

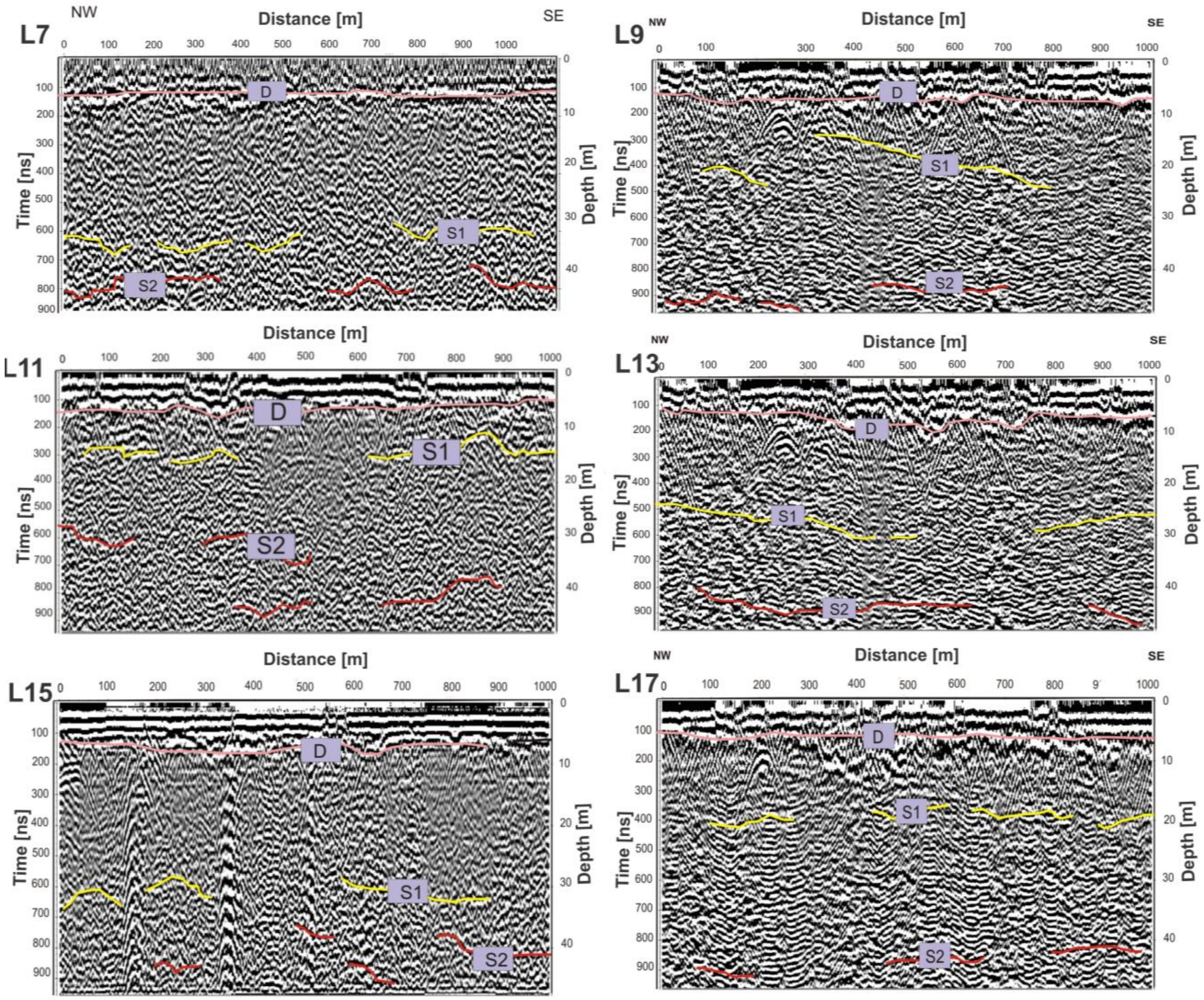


Figure 6: Radar images for profiles L7, L9, L11, L13, L15 and L17

4.1.1 *Interpretation of Inferred S2 and S1 Structural Depth Run*

Figure 7 (A) shows the S2 structures delineated between the depth range of 37.0 m and 44.5 m. In general, the inferred structures depict possible structural deformation in the NW- SE direction. There is an inferred dipping structure Z1 which occurs between the profile spacing of about 200 m and 600 m and stretches over a total distance of about 500 m. The depth range of Z1 is between 38.5 m and 44.5 m. This structural trend could be a potential zone for gold mineralization. In addition, there is a structural pattern Z2 showing a near horizontal feature between the profile intervals of 600 m and 800 m. The depth range at which the Z2 dipping structure occurs is between 42.0 m and 44.5 m and has a length of about 300 m. Figure 7 (B) shows the structures between the depth range of 15 m and 36 m. There is a possible structural deformation in the NW - SE direction which falls within the profile spacing of 300 m and 700 m. Within this range, lie dipping structures labeled Z1 and Z2 which are real representation of the trend of mineralization as mapped with the resistivity and chargeability survey (see Figure 8).

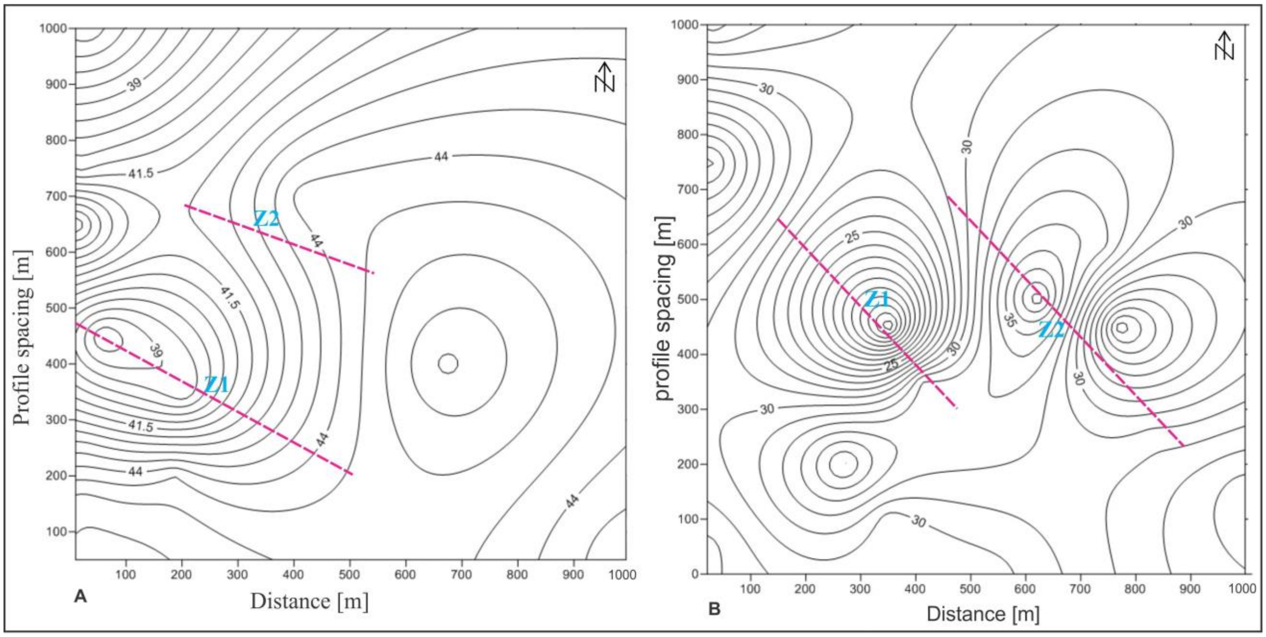


Figure 7: A) Spatial plot of inferred S2 structures and B) inferred S1 structures hosting zones of possible mineralization.

4.2. Comparison of GPR, electrical chargeability and resistivity measurements

Results from the GPR measurements were compared with that of electrical chargeability and resistivity results. Figure 8 shows the results of the chargeability and resistivity datasets respectively. The chargeability and resistivity results do not give the exact depths at which mineralization occur. The GPR results however, have shown the possible structures hosting mineralization and the depths at which these structures hosting gold mineralization can be intercepted. In Figure 8 (A) the chargeability results show a clear evidence of high chargeability values within the range 14 mV/V and 17 mV/V which is indicated in the red color code. This anomalous zone is seen to be dipping in the North West South East direction. This NW - SE trend of mineralization falls within the profile spacing of 200 m and 700 m which stretches at about a total distance of 700 m marked (M). The high chargeable zones indicate the weaker zones (conductive zones) within the saprolite which could be due to fractures, shear zones, cracks etc. These conductive zones are potential zones of gold mineralization.

Furthermore, the resistivity results shown in Figure 8 (B) show a clear evidence of high resistivity value of 2545 Ωm which is indicated in red color code. The high resistivity anomaly seen in red dips in the NW - SE direction between 200 m and 750 m. This structural trend conforms to that of the anomalous zone marked M in the chargeability results (see Figure 8)

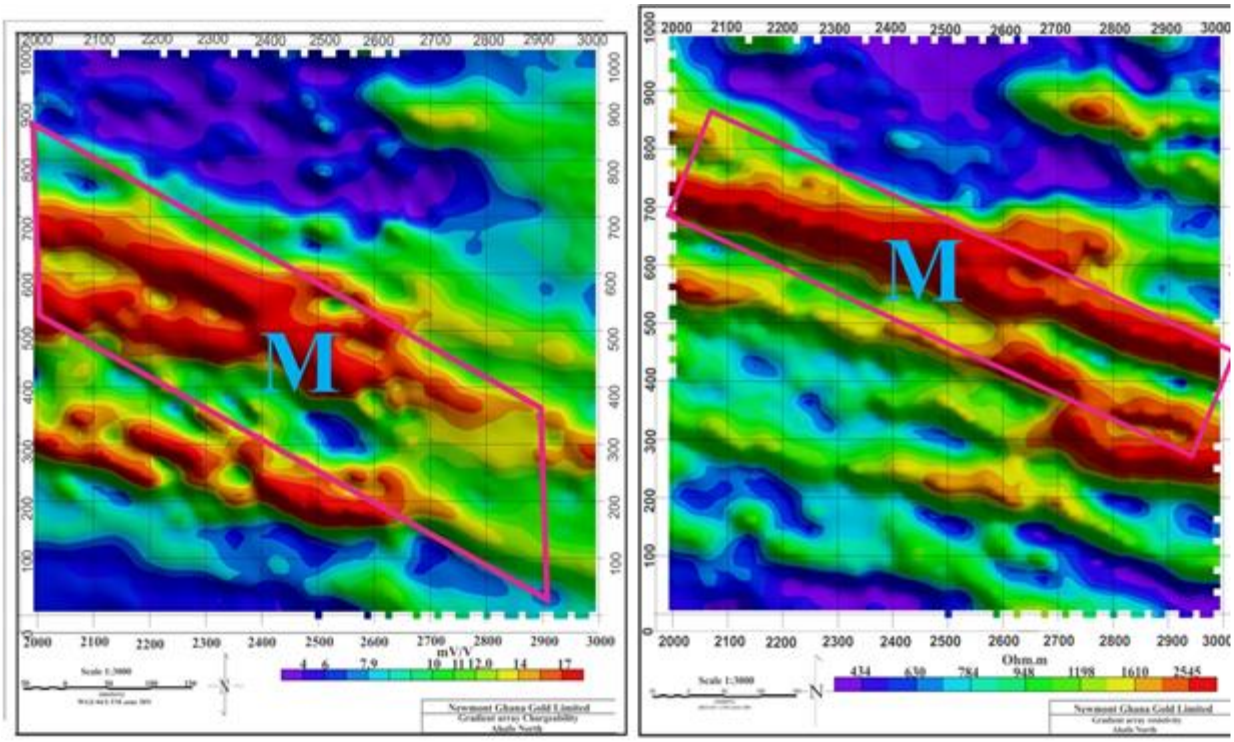


Figure 8: A) Gridded image of chargeability data B) Grid image of resistivity data

V. Conclusion

Ground penetrating radar survey has been carried out successfully to map possible structural trends hosting gold mineralization at the Subenso north concession of Newmont Ghana Gold Limited. The ground-based ground penetrating radar (GPR) survey was conducted over an already known gold deposit mapped by the Newmont Company Limited as an orientation survey to prove the efficacy of the GPR in mapping structures hosting gold mineralization. Results from the GPR compared very well with the chargeability and resistivity datasets over the study area. The GPR survey was quasi-continuous, faster and more affordable as compared to the resistivity and chargeability survey. The structures (primary lithologic unit as well as the duricrust) in the highly weathered saprolite were successfully delineated by the application of the ground penetrating radar method. The exploration depth was approximately 925 ns corresponding to 50 m with an average soil electromagnetic wave velocity of 0.1 m/ns. Two sets of inferred structural patterns were established. The structural patterns were S1 and S2. The S1 inferred structures were found between the depth range of 12 m and 42 m and the S2 a between 31 m and 48 m. Furthermore, the heterogeneous radar signatures recorded suggest that, weathering is more intense between the depth ranges of 32 m and 39 m, and 43 m and 47 m for S1 and S2 structures respectively. These sets of structures are inferred structures possibly hosting gold mineralization. The study has also revealed that, mineralization is more intense at greater depth, but decreases as close to the surface. The trend of anomalies hosting gold mineralization as predicted by the resistivity and the chargeability datasets was found to conform to the structural trend presented by the GPR dataset.

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