



RESOLVING OPTIMUM MAGNETIC SIGNATURES FOR DRILL-HOLE TARGETING IN GOLD EXPLORATION – A CASE STUDY FOR MBUDZANE IN GWANDA, ZIMBABWE

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ABSTRACT

Optimum magnetic signatures for drill-hole targeting in gold exploration in Mbudzane were resolved from induced polarisation-resistivity and magnetic anomalies. Total magnetic field and a gold-in-soil map showed the area is magnetically quiet with high anomalous values along old gold workings. Induced polarisation was carried out along a grid for lines of 500m length, 50m separation and a baseline oriented at 330°. The survey comprised a gradient array and three real sections. The magnetic survey was conducted over the same grid as the induced polarisation. Stations were set at 5m intervals for a line spacing of 50m. The results show intense anomalies that suggest different degrees of magnetic alteration and a set of conjugate lineaments and faults that possibly control the mineralisation in Mbudzane. The tilt derivative of the reduced-to-pole image resolves the separation between anomalies, giving information on the faulting. High chargeability is confined to the sheared and silicified mafic schist. The gradient resistivity image revealed contact between rock formations. Real section IP shows coincident low chargeability – low resistivity anomalies close to the surface. Chargeability intensity increases with depth, suggesting incipient development of disseminated sulphide replacement zones. A strong correlation between ground magnetic inferred contacts and apparent resistivity-chargeability anomalies forms the basis for suggesting a new drill-hole targeting. They dictate both the depth and angle at which drilling should be carried out. These results should be applicable to any region where drill-hole targeting in gold exploration may be required.

Keywords: Drill-Hole targeting, Anomalous zones, Chargeability, Resistivity, Magnetic signature, Real section.

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1. INTRODUCTION

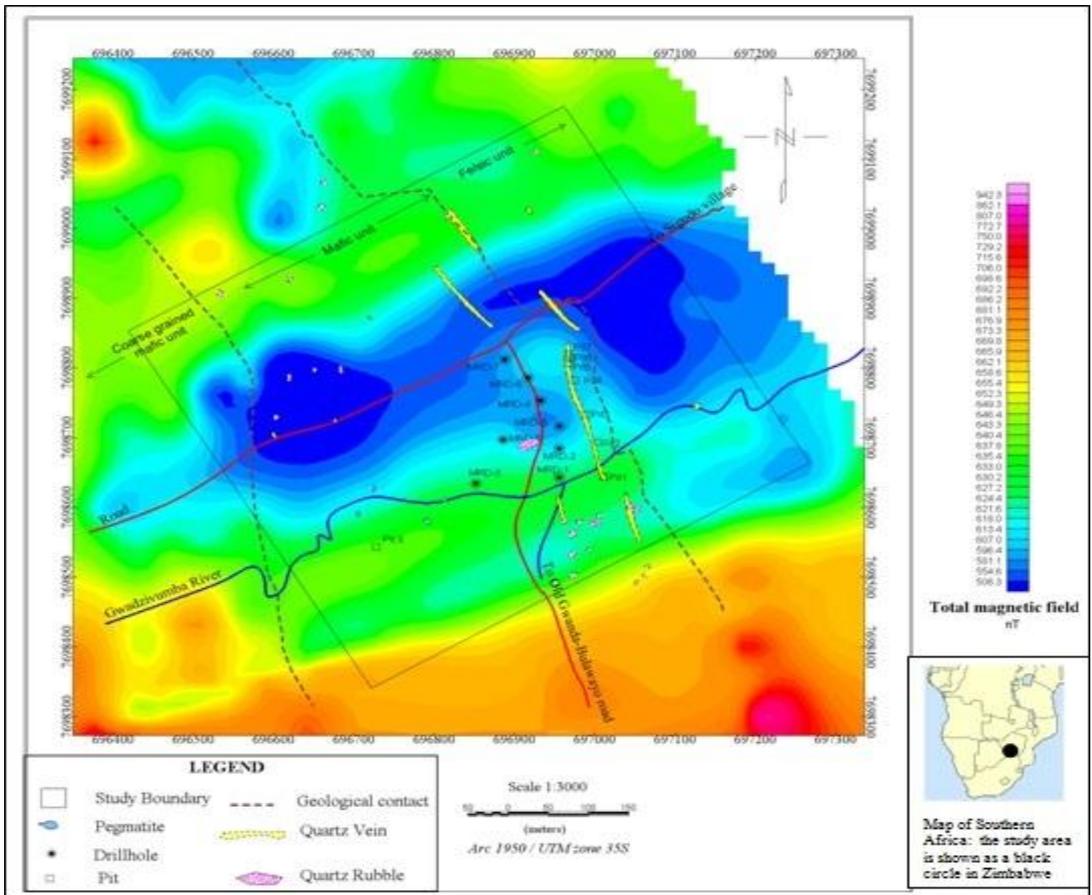
The location of an economic mineralized zone may be achieved with well planned drill-hole targeting. Various geophysical methods are used in drill-hole targeting. The choice of the method depends on the type of mineralization, cost, availability, effectiveness and the required accuracy. In this study, induced polarization / resistivity and magnetics were used to optimize magnetic signatures that are required in drill-hole targeting in Mbudzane, in the Gwanda greenstone belt in Zimbabwe. A geology map for Mbudzane already exists and there is a vast bank of raw geophysical data in the data-base.

Mbudzane is located about 25km to the north of Gwanda town in the Gwanda greenstone belt. The Gwanda greenstone belt is a known gold mineralized zone (Tyndale-Biscoe, 1940; Fuchter, 1990; Dirks and Mikhailov, 2000). The eastern part of Mbudzane covers a number of small-scale gold workings, pits and trenches. All workings are now dormant, except for some minor illegal gold-panning activity. Mbudzane gold workings were probably stopped because the bulk of the gold in the area is not free milling. The hardness of the quartz and the silicified mafic schists in the area may have contributed to the difficulties in ore extraction. The infrastructure in the area shows that at the time of mining, it must have been done by a "small-scale owner". There are eight shallow pits and trenches trending northwards. The pits cover a total strike length of 150m with depths down to 5m. Most of the pits are accessible, suggesting they could have been developed for prospecting purposes. There is no existing record of the workings. However, from the size of the pits, about 375 tones of ore may have been extracted.

2. BACKGROUND

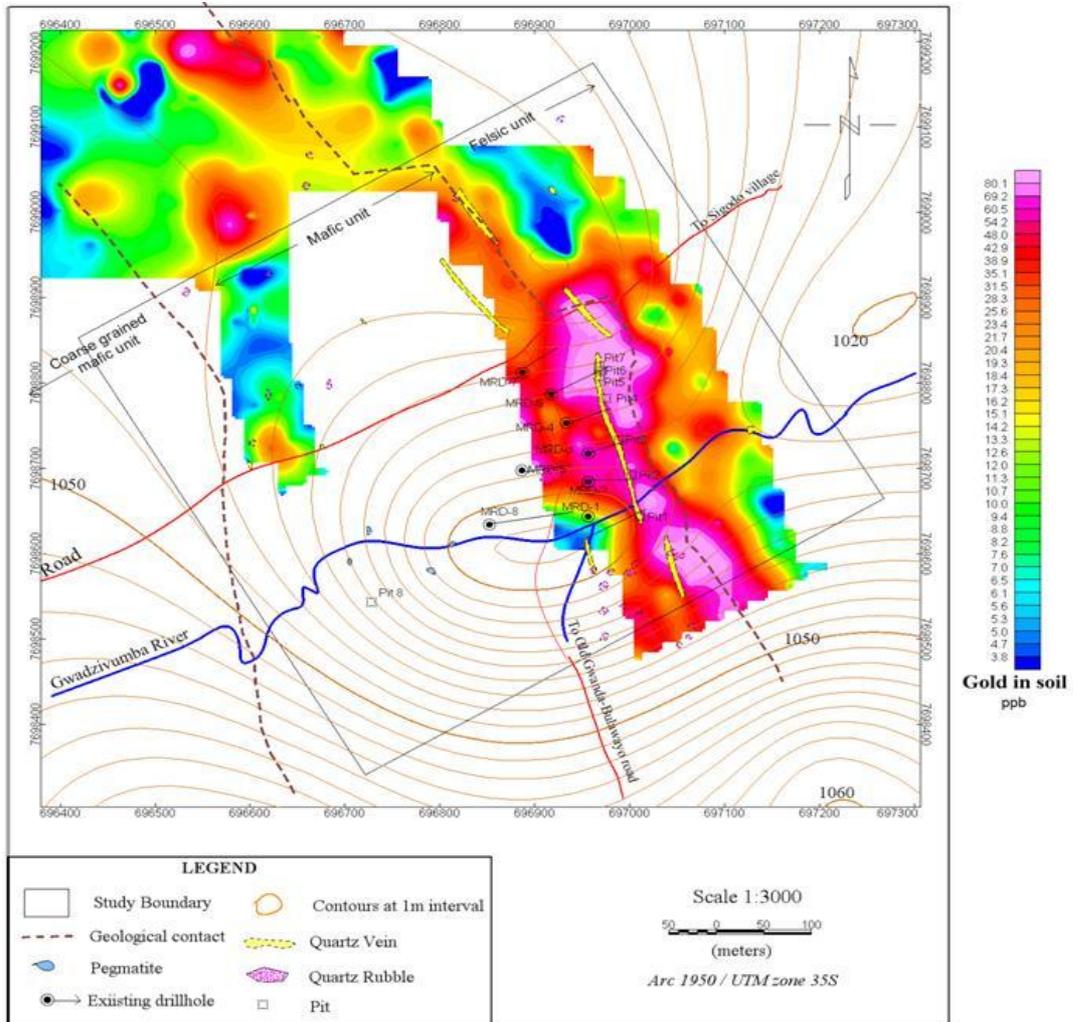
A ground magnetic survey was done in Mbudzane under the Exclusive Prospective Order (EPO) 629 (Ndebele, 1992). Data was collected at 10m station intervals for a line spacing of 50m. Total magnetic field readings were taken from each station using two Geometrics G-816 proton precession magnetometers. One magnetometer was used as a base station to monitor diurnal changes, while the other was a rover unit taking readings over the grid. The results showed the magnetic expression for Mbudzane to be generally quiet (Fig.1). This was attributed to the presence of granite in the area.

Figure- 1. Ground magnetic image (total field) derived from the 1992 magnetic survey data (Courtesy of Blanket Mine Exploration Department). An area of low magnetics trends across the middle of the study area in a SW-NE direction. The magnetic expression for the area is generally quiet. The area comprises felsic schists to the east, coarse-grained mafic in the west and mafic schists in between the two assemblages. The squares numbered Pit 1 to Pit 8 are the old gold workings, while MRD-1 to MRD-8 are locations where holes were drilled in 2004, following recommendations from EPO 629 project.



The remainder of the data collected under EPO 629 project comprised mainly metal in soil geochemical data, geological mapping and structural data from air photo interpretation, ground and airborne geophysical data. Statistical analysis of gold-in-soil data determined a background value of 29 ppb Au with anomalous values in excess of 68 ppb Au for the area. Several anomalies along a 400m long zone were centered over the old workings on a quartz vein in the extreme southeast of Mbudzane(Fig.2). The zone lies in the study area and was recommended for further exploration work (Thomson and Nyagumbo, 2004). In this study, attention is focussed upon this area.

Figure- 2.Gold in soil image of Mbudzane area. The image was constructed from geochemical data obtained from earlier studies (Courtesy of Blanket Mine Exploration Department). The average value of 29 ppb AU was obtained for the area. Various anomalous values were obtained over the old gold workings. In some spots, high values in excess of 68 ppb Au were obtained. Specks of visible gold were also seen in some soil samples.



A detailed 1:250 scale mapping was done along the quartz vein in the target area. During the mapping exercise, grab sampling indicated gold bearing mineralization similar to the Blanket Mine disseminated sulphide replacement (DSR) ore bodies. A value of 6.19glt was obtained and an average for five samples collected from Pit 1 collar was 3.21glt. These samples were banded, silicified, quartz veined hornblende/biotite schist. The sulphides present are predominantly arsenopyrite, pyrite and subordinate pyrrhotite. Specks of quartz visible gold were seen in a few of the samples. A single grab sample from the outcropping vein gave 4.72glt gold (Thomson and Nyagumbo, 2004).

In 2004, Blanket Mine carried out an eight-hole 800.05m core-drilling program on the Mbudzane rock block. Six holes (MRD-1 to MRD-6) (Fig. 2) were drilled towards the east target to test an exposed quartz vein system and the mafic / felsic schist contact order (a strike length of 150m), to shallow depths of 40m. Two holes (MRD-7 and MRD-8) tested the system at depths in excess of 190m. The program was successful in outlining a small panel of low grade gold-bearing mineralization in the area. Three of the eight holes returned sub-economic intersections from the

main and the foot-wall zones (Thomson and Nyagumbo, 2004). The shoots were sub-parallel. They trend north-northwest and dip southwest at 65° . The main zone is defined by a quartz vein, bound by sulphide mineralization (arsenopyrite, pyrite and pyrrhotite) in silicified mafic schists. In the east, the foot-wall shoot is on the contact between mafic and felsic development. Despite the poor gold bearing mineralization, the two shoots are persistent and cover a total strike length of 120m. A gold-in-soil anomalous zone occurs along the geologic strike where old pits are located (Fig. 2). This information provides a good clue for a follow-up and further investigation using geophysical exploration methods.

3. FIELD WORK

During this study, two geophysical surveys were carried out in Mbudzane: Induced Polarization (IP) survey and ground magnetic survey.

3.1. Induced Polarization

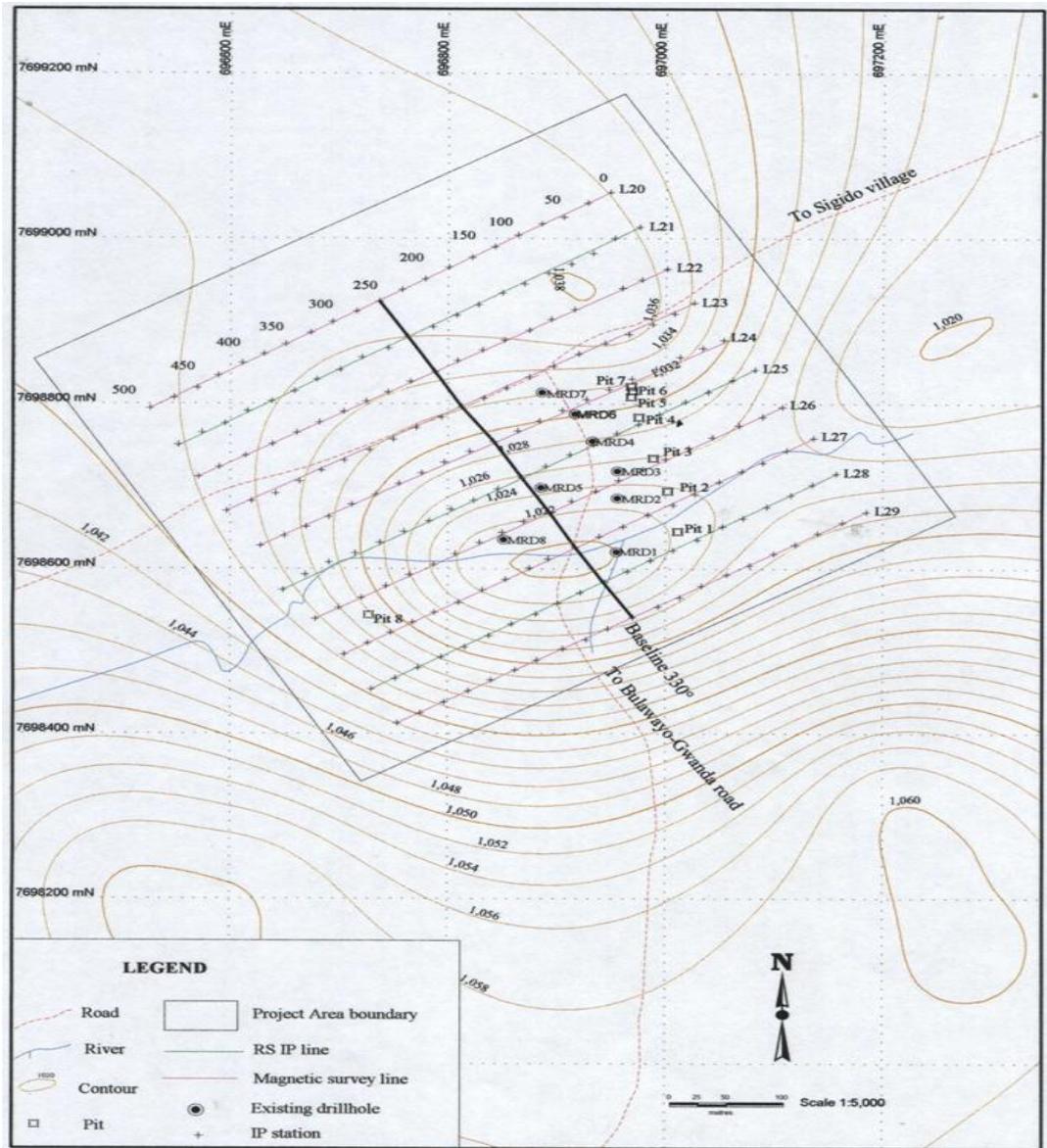
An IP survey was carried out on a cut grid with survey lines 500m long, 50m apart and a baseline orientation of 330° (Fig. 3). The survey consisted of a gradient array and three real sections. A Phoenix 3KW transmitter was used for current transmission while a six channel EDA IP-6 receiver was used to measure IP readings. The gradient array survey was conducted using a dipole of size 25m and a station spacing of 25m. Real section IP lines were surveyed over lines 21, 25 and 28 (Fig. 3) to define gradient array anomalies. Depths of 50m, 100m, 150m, 200m and 300m were investigated.

3.2. Ground Magnetism

A ground magnetic survey was done on the previously-cut IP grid (Fig. 3). Stations were marked at 5m intervals for a line spacing of 50m. Two Geotron G5 proton precession magnetometers were used for the survey. These magnetometers have a resolution of 0.1nT and a non-volatile CMOS memory with a capacity of 7500 readings (Breiner, 1973). One of the magnetometers was used as a base station reference instrument and set up at a magnetically quiet location. The position was chosen for its low magnetic gradient and was far away from man-made objects. This condition assists in the correction of diurnal and erratic variations in the readings. The base station magnetometer was set to automatically record at one minute intervals. The second magnetometer was used as a roving unit. Since the work took four days to complete, as a daily routine, the two magnetometers were checked and synchronized for correct time before work commenced. Using the roving unit, readings were taken every 5m along 10 lines on the previously-cut IP grid for a line length of 500m and 50m line separation. At the end of each day, data was downloaded on to a computer to await processing and analysis. A total of 1000 readings was recorded.

Figure- 3. Contours of the study area showing the altitude above sea-level. The grid used for the IP / Resistivity and the ground magnetic surveys is shown. Real section IP survey was done

along lines L 21, L 25 and L 28. The Baseline was taken along a line striking 330° and at the centre of the study area. While the gradient array survey was done using a dipole size of 25m at station spacing of 25m, the ground magnetic survey was carried out at 5m intervals on 50m line spacing.



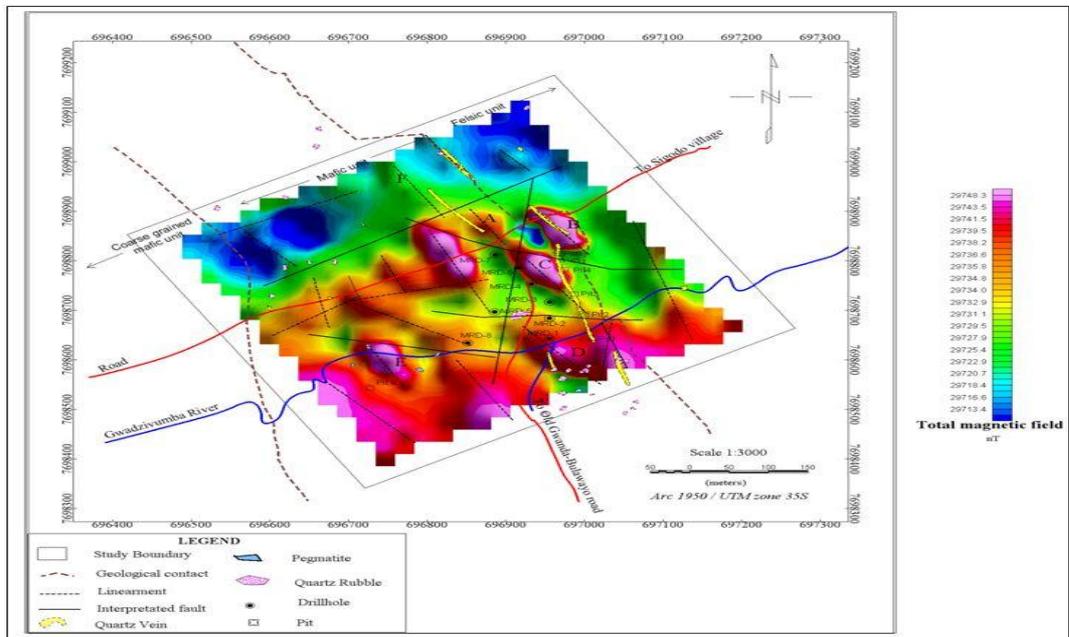
4. RESULTS

4.1. Ground Magnetics

Processed total field magnetic data show predominantly NW-SE trending magnetic-high lineaments concordant with mapped geologic strike but disjointed by a set of conjugate lineaments trending to the East(Fig. 4).A prominent magnetic low to the extreme north of the

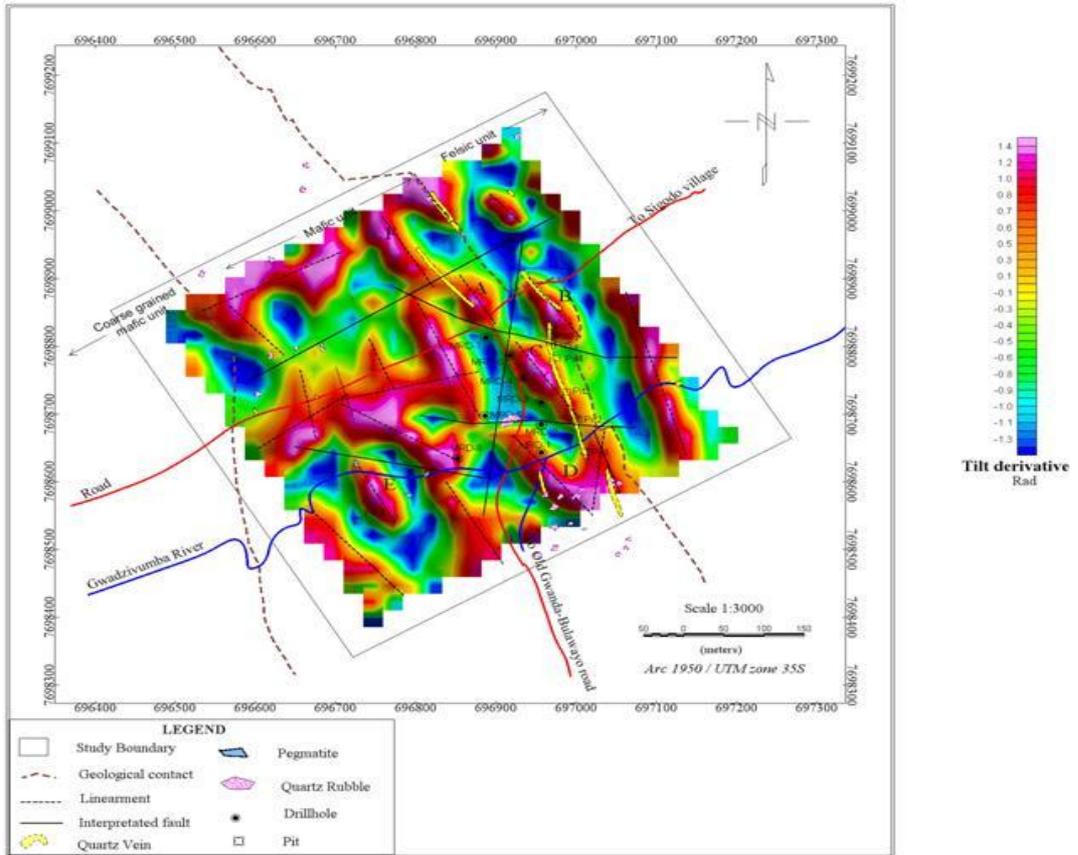
area clearly traverses the geological strike. These are reflections of a deep-seated granitic rock. Irvine and Smith (1990) suggested a similar structure. Assuming a high signal to noise ratio, it may be seen from the dynamic range that the area is in general, magnetically quiet with some magnetic high signatures that range from generally subdued to clearly distinct intense anomalies that suggest different degrees of magnetic alteration.

Figure- 4. Total magnetic field image obtained from data taken during this study. Both the geological contact, lineaments and interpreted faults are shown. Areas with significant quartz rubble are closely associated with the quartz veins.



The image also shows a set of conjugate lineaments (dotted black lines) (Fig. 4) and faults (solid black lines) that possibly control the mineralization existing in the area. The tilt derivative of the reduced to pole (RTP) image (Fig. 5) resolves the separation between anomalies and gives more information on the faulting in the survey area. It shows several breaks in magnetic lineament patterns that suggest the existence of fractures and faults within the contact zone of mafic and felsic units. Distinct anomalies, A, B and C, lie in a mapped quartz vein. This may be due to magnetic alteration that gave rise to the formation of secondary magnetite. Anomaly F may also be due to the same source as it has similar magnetic signature and lies within the same geological set up. Anomaly E is found near the mapped granitic pegmatite. It could be due to the alteration of the mafic schists resulting from some intrusive event.

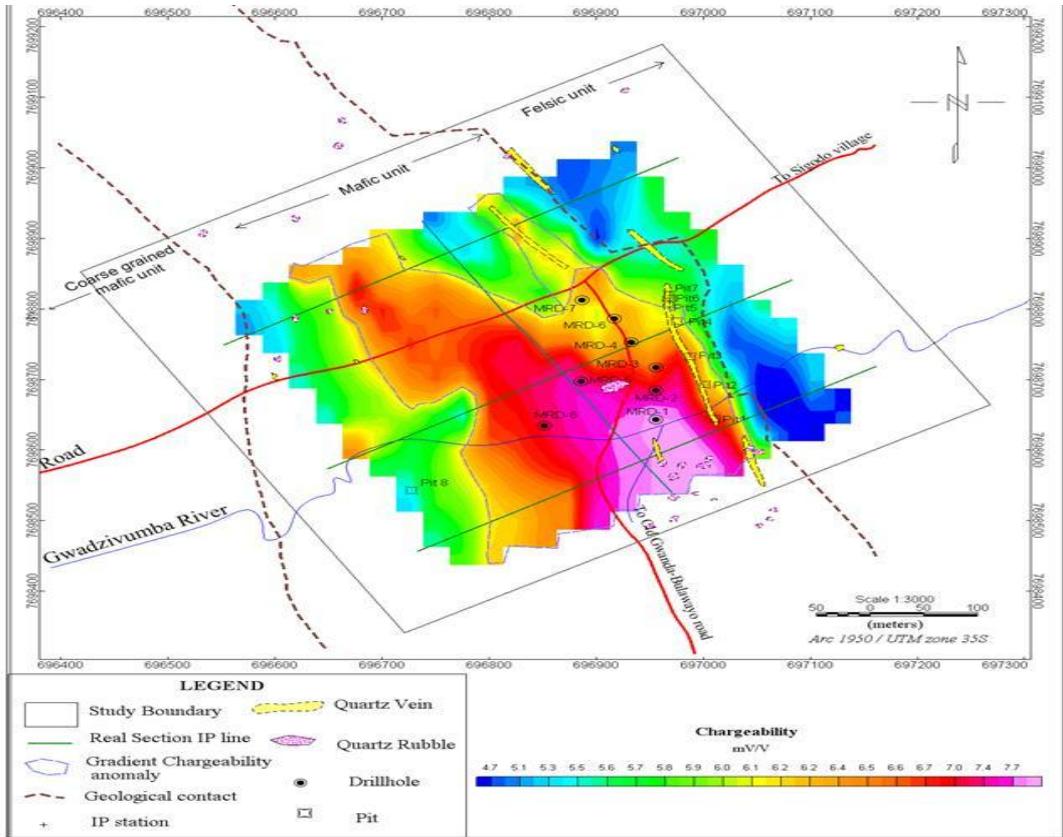
Figure-5. The tilt derivative of the reduced to pole (RTP) magnetic field image of Mbudzane (colour shaded). High values are closely associated with the observed lineaments, suggesting the tilt derivative of the RTP to be a useful tool in delineating lineaments in the area.



4.2. IP-Gradient

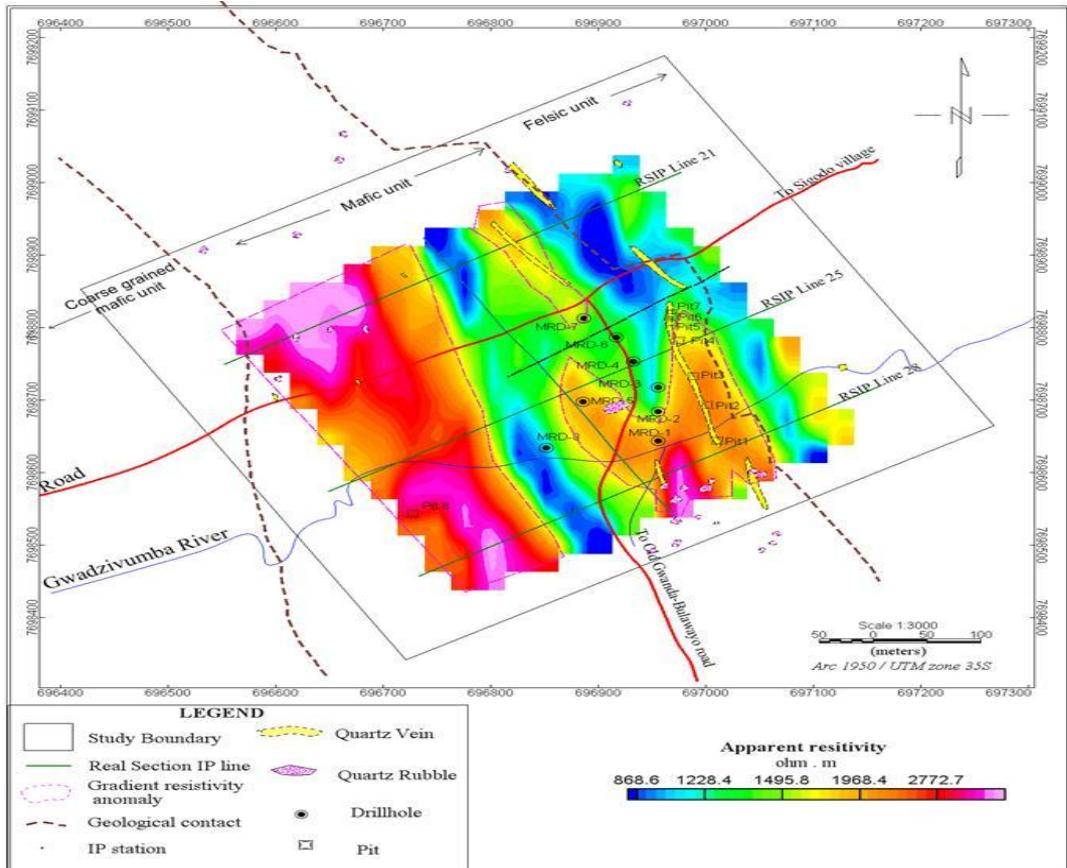
IP data yielded a gradient chargeability image (Fig. 6) that confirms a change in lithology. High chargeability is confined to the mapped sheared and silicified mafic schists. Fuchter (1990) suggests that typical geological models for gold exploration in the area show that gold mineralization is found disseminated in

Figure- 6. IP gradient chargeability image of Mbudzane. High chargeability values in excess of 7.5 mV/V are observed in the southern portion of the area just to the east of the Baseline. The three RSIP lines are shown as green lines.



such geological units. The gradient resistivity image (Fig.7), shows lateral variations in rock units. The image obtained confirms the contact between the rock units shown in Fig. 6. In comparison with the known geology of the area, the mapped quartz vein lies within the central high resistivity anomalous zone. This zone may be faulted and is shown in the figure by a dotted black line. The quartz vein comprising mainly silica showed non-conductivity. This may be due to shearing and silicification. The surface expression of the results from the gradient IP data show that major anomalies are characterized by partially coincident high chargeability-strike. Both the chargeability and the resistivity anomalies are open ended; hence, the entire extent of the anomaly coverage cannot be established.

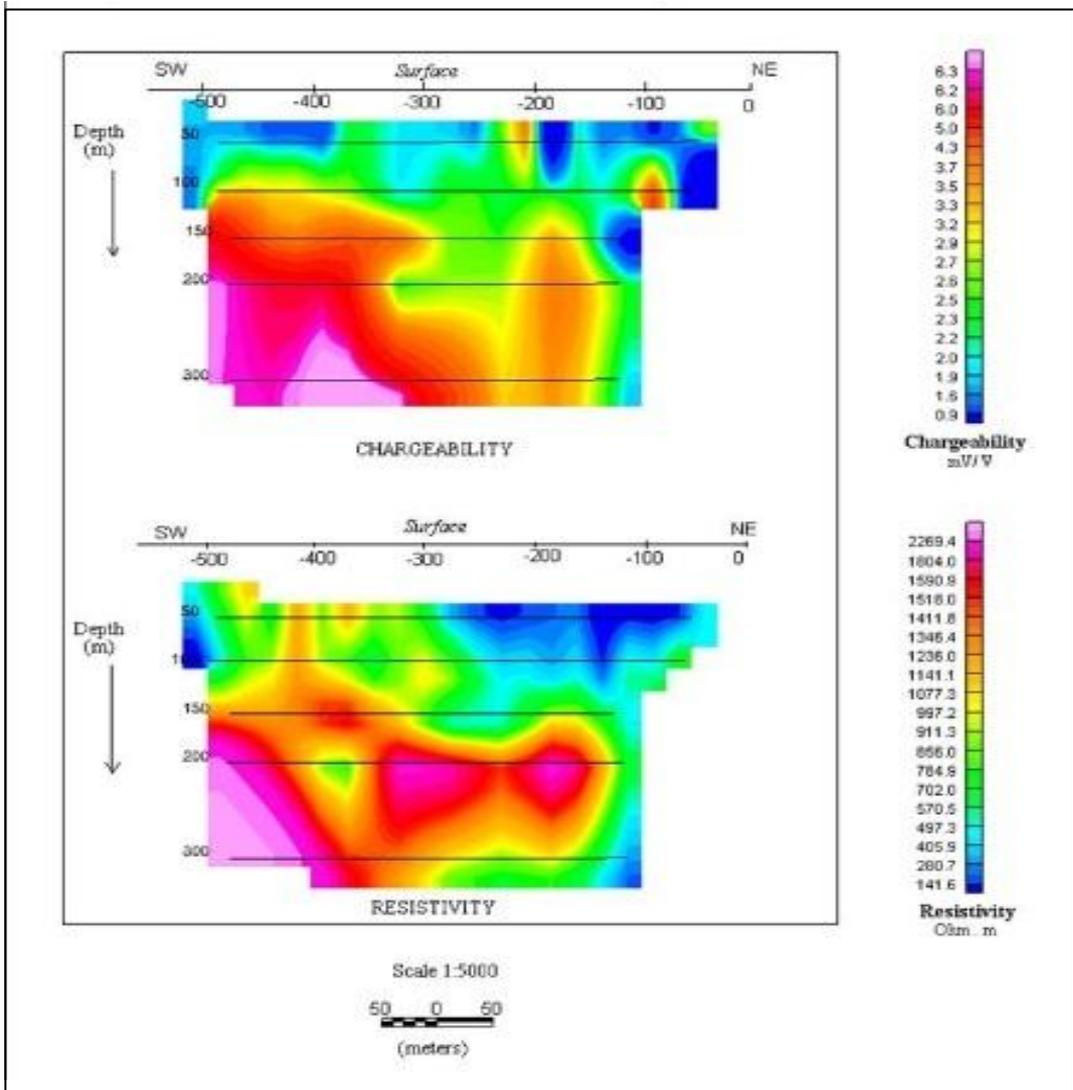
Figure- 7. IP gradient apparent resistivity image of Mbudzane. Apparent resistivity is shown in shaded colour while the gradient resistivity anomalies are shown by dashed lines.



4.3. Real Section

Real section induced polarization (RSIP) carried out along lines 21, 25 and 28 identifies the vertical development of the anomalies mapped on the surface by the gradient IP method. The images (Figs.8 (a), (b) and (c)) suggest at least two deep-seated (>150m) coincident high chargeability-resistivity anomalous zones that are open ended at sounding depths of 300m. All the RSIP images show coincident low chargeability-low resistivity anomalies close to the surface. The intensity of the chargeability increases with depth. This may represent incipient development of disseminated sulphide replacement zones.

Figure- 8. (a). RSIP results along line 21. Values are given for a depth of 300m. The figure above shows the chargeability while the one below gives the resistivity. Observable are zones of anomalous values along the IP grid which correspond to those along the same line for resistivity.



The RSIP image anomalies are potential indicators of disseminated sulphide mineralization in Mbudzane. The low anomalies near the surface in all RSIP images may be due to the oxidized zone with clay minerals (Kaolinite, Montmorillonite and Illite). Figure 9 shows the definition of anomalous zones as interpreted from both gradient and RSIP results.

Figure- 8. (b). RSIP results along line 25. Special to note, is the zone between 300n and 400m to the SW where high anomalous values are modelled at depths in excess of 160m.

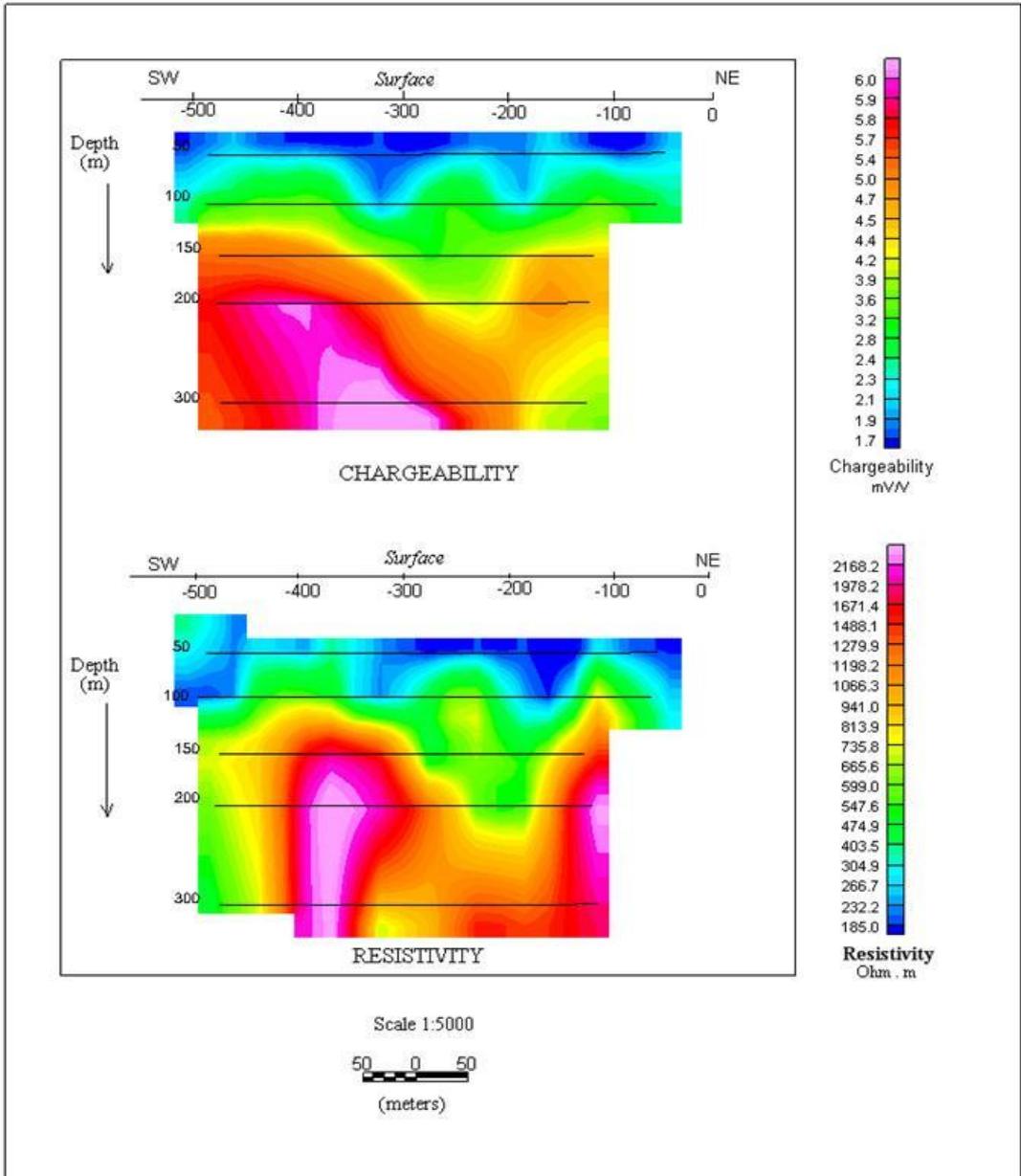
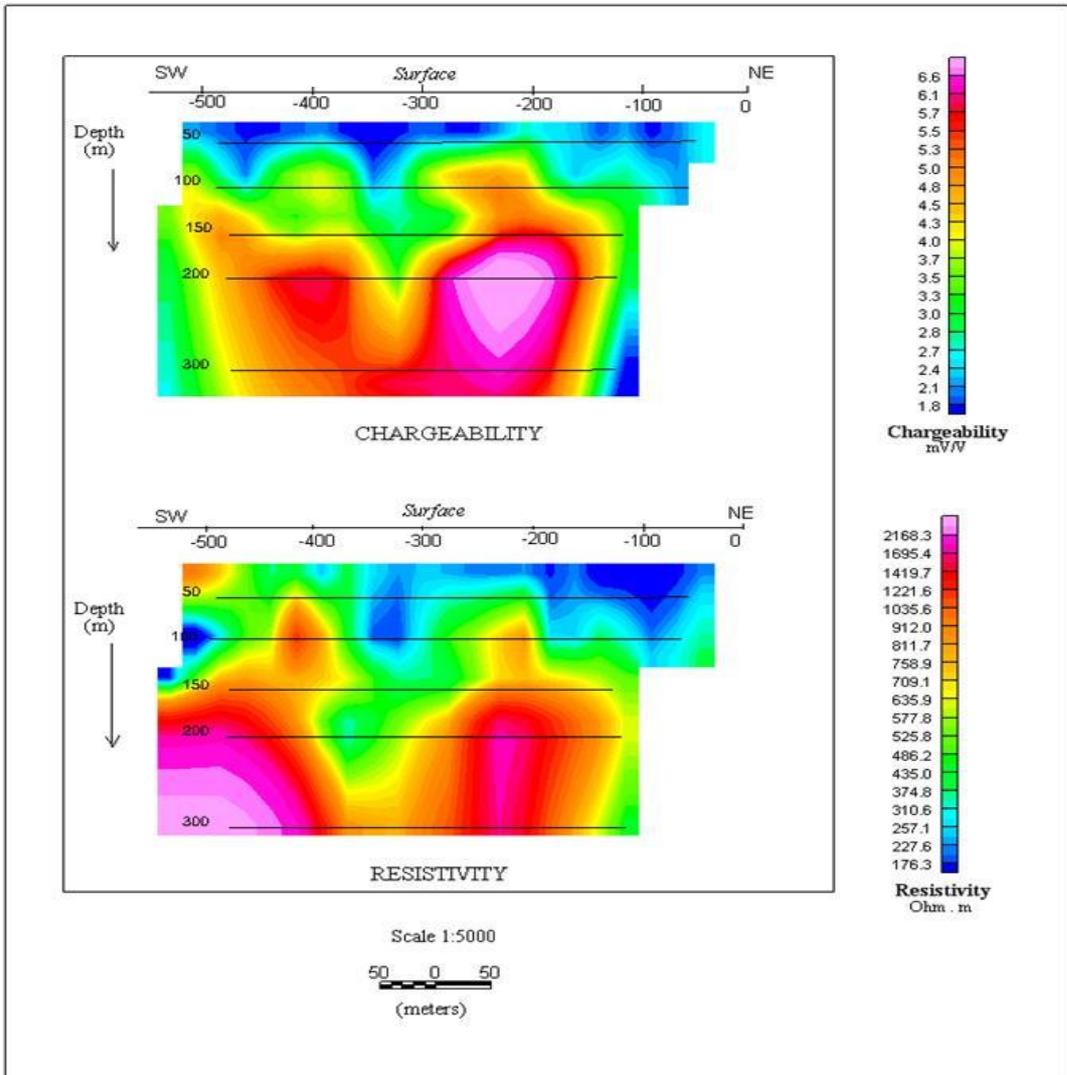
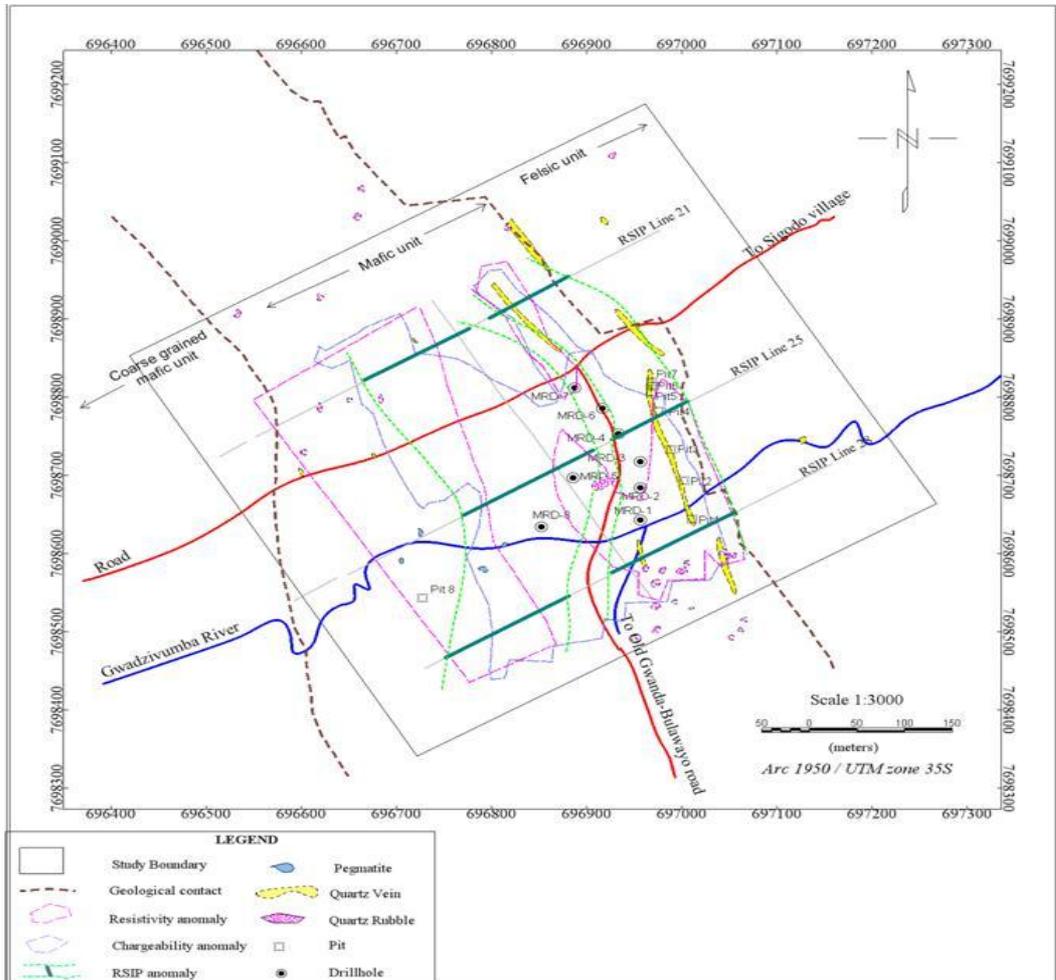


Figure- 8. (c). RSIP results along line 28. High chargeability and resistivity values are modelled for corresponding distances between 120m and 280m and between 360m and 460m, at depths in excess of 150m.



The highest chargeability zone occurs in the south-eastern end of the grid where RSIP results are indicative of deeper sources. The gradient IP method maps the entire lateral extent of the anomaly to greater depths, due to the weighted distance average method used.

Figure 9. This map gives a summary of the chargeability, resistivity and RSIP anomalies, and the overall IP interpretation image of Mbudzane. Areas of particular interest to note are those where resistivity and chargeability anomalies either intersect or overlap.

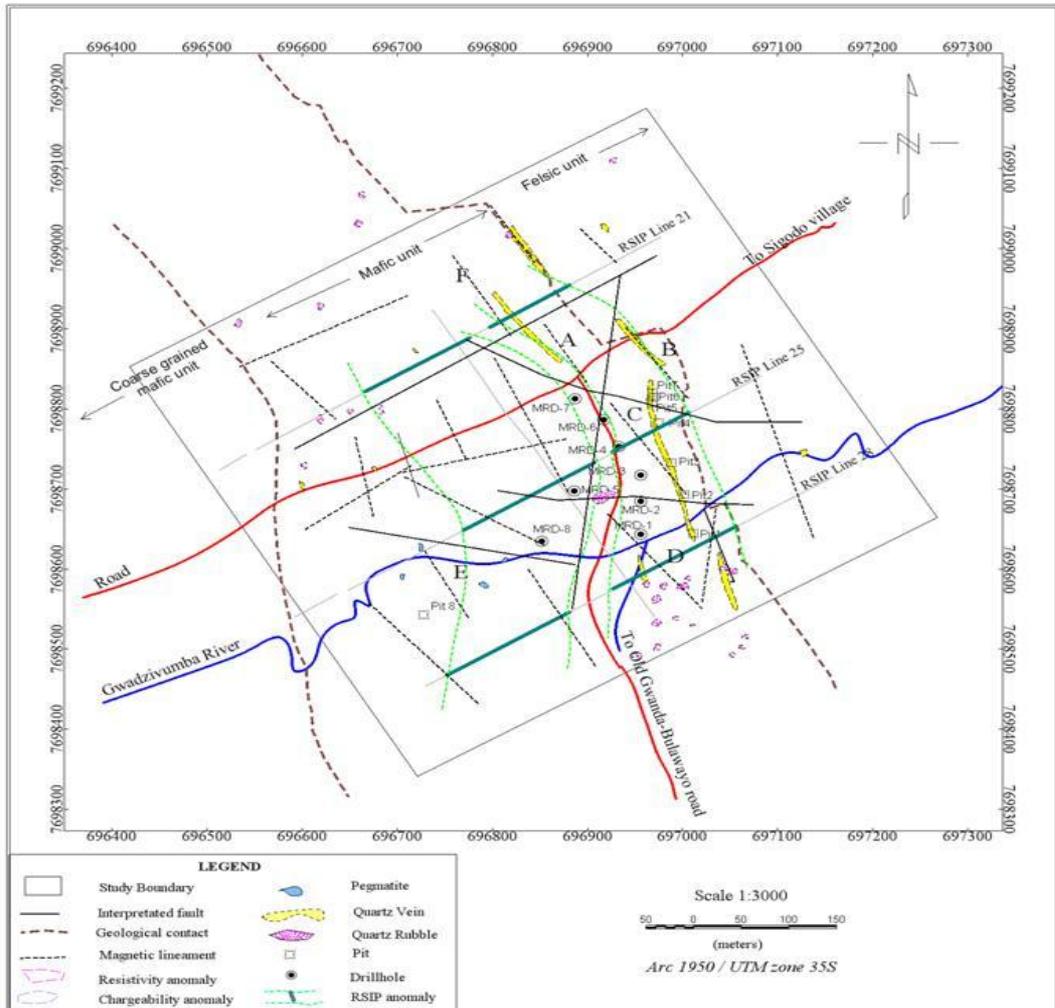


5. HOLE TARGETING

There is a strong correlation between ground magnetic survey inferred contacts and the apparent resistivity and chargeability anomalies. The high magnetic field anomaly in the hornblende schist coincides with IP anomalies. Figure 9 shows the position of the magnetic inferred contact with respect of the IP chargeability anomaly. There are relatively high chargeability values of 8ms coincident with high apparent resistivity values of 2 kΩm. Such high values are typical of metallic sulphides. The magnetic anomaly shows signs of faulting at the same point as the chargeability anomaly, suggesting faulting of the central part of the grid. Figure 10 gives an overall summary of geophysical structural image interpreted from the magnetic and IP

anomalies. The main faults trend south-easterly with two distinct faults trending north and north-easterly.

Figure 10. The geophysical structural image of Mbudzane. The resistivity, chargeability and RSIP anomalies are superimposed over the lineaments as derived from the results of Fig. 6.



The IP / resistivity results show that it is possible to delineate various geologic units in this area, using this method. The gradient array method provided a surface map showing lateral distribution of chargeable and apparent resistivity zones. This information is important in updating existing geology maps. The RSIP array resolved the vertical development of the gradient anomalies seen at the surface, down to 300m. For Mbudzane, this depth of investigation is optimum. Any increase in the survey parameter (for example, current electrode separation) greatly reduces the data quality. Magnetic data is a powerful tool in determining surface expression of magnetic alteration but fails to resolve vertical anomaly development with respect to depth. In this study, it succeeded in outlining conjugate faults in Mbudzane. Contact between

the mafic and felsic schists, believed to be in prior existence, were confirmed. The inferred faults and contact have a control on the mineralization in the area. Gold found in the area may have come to the subsurface by hydrothermal processes through these points of weakness in the rock structure (Jackson, 1997). The close association of gold deposits with small intrusions of granite or other acid igneous rock is well known. Such intrusions are logically interpreted as peaks rising from a large mass below (Macgrego, 1951). The magnetic anomaly which transgresses geologic strike could be a deep seated intrusive granitic dyke. Irvine and Smith (1990) gave such a suggestion. During intrusion, the granite mass could have caused the development of the mapped transgress faults. From the geophysical response observed, these are very much a possibility. The faults may have been the passage of the gold bearing hydrothermal fluids while the quartz vein may have precipitated after this intrusion event to eventually reach the surface.

The optimum survey parameters that may be used for drill-hole targeting are 5m station intervals at 50m line spacing. Values below these tend to introduce short wavelength noise as a result of high sampling frequency between anomalies. Geochemical data was used as a quick way to define areas for detailed exploration, hence, identifying the study area. It was however not possible to use geochemistry in the form of gold-in-soil alone for drill-hole targeting because 'soil anomaly is a landscape expression of a three dimension dispersion train that has its roots at the much sort after mineral occurrence' (Hoffman, 1986).

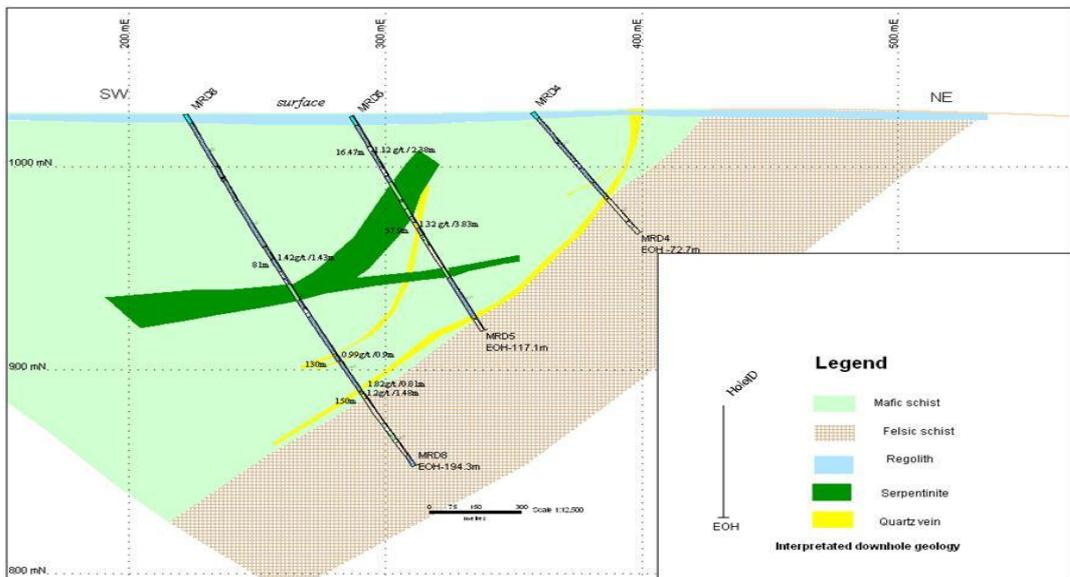
The structural control of the gold mineralization in Mbudzane is confined mainly to the quartz vein system that is located near the contact between the mafic and felsic schists. The quartz vein system gave a good IP and magnetic signature that was used to locate targets for new drill-holes. The RSIP array was able to resolve the vertical development to a depth of 300m of the gradient anomalies that are seen at the surface. This depth of investigation is optimal for Mbudzane. Any depth values in excess of 300m require higher values of current electrode separation, resulting in significantly reduced data quality.

Data from the 2004 drilling program was used to project drill-hole cross-sections. Holes lying along RSIP line 25 were used to create a down-hole geology model (Fig 11). The model shows a geological sequence that is capped at the surface by a regolith, underlain by mafic schists that are intruded by serpentinites and quartz veins. Felsic schists lie below the mafic schists for the three existing holes (MRD-8, MRD-5 and MRD-4) that were drilled in 2004. Both the mafic and felsic schists thicken southwest-wards

These results suggest targeting of new holes that extend to depths of chargeable zones. Eight new holes are proposed, all sited on the RSIP lines. Figure 12 shows the surface plan of the proposed drill-hole targets. The cross-sectional projections are shown in Fig. 13(a) to Fig. 13(d). The holes will target the down dip extension of the geophysical anomalies. Such anomalies are usually associated with disseminated sulphide replacement type mineralization. Incorporating available geological and geophysical information, a total of 3130m is proposed to be drilled for all the 8 holes in search of locations for economic gold deposits.

Target hole A aims at testing the combined RSIP chargeability and resistivity anomalies (MBZ-A) in the mafic unit at a depth of 230 m on RSIP line 28 (Fig. 13c), while hole B will test the combined RSIP chargeability and resistivity anomalies (MBZ-C) that showed the highest chargeability intensity of 7.0 ms on RSIP line 28. Holes should be drilled to depths of 400 m at 70° and 60° dip angles, respectively (Fig.13c). Target hole H

Figure- 11. Interpretation of drillhole geology. This model is constructed from data that was obtained in the 2004 drillhole project (Courtesy of Blanket Mine Exploration Department). The model establishes the geological profile as obtained from the drill-holes MRD-8, MRD-5 and MRD-4. The mafic schists thicken southwest-wards.



will aim at testing the western extension of the possible DSR shoot which is probed by target hole A. Target hole C will be used to check the geophysically interpreted fault and its probable control on the mineralization in the area. It will also test the coincidence of the high chargeability-high resistivity anomalies on the RSIP line 25 (Fig. 13b). This hole should be drilled to 450m depth at a dip angle of 58°.

Hole D aims to test the extreme north-end of the exposed quartz vein system at depth where chargeability anomaly is moderate. It will also verify the depth extension of the sub-economic gold mineralization that was observed in previous holes (MRD-8 and MRD-5). This hole is on RSIP line 25 (Fig. 13b) and should be drilled to a depth of 300m at a dip angle of 65°.

Target hole E is designed to test the combined RSIP chargeability and resistivity anomalies along the western portion of RSIP line 21 (Fig. 13a). The hole will assist in the understanding of geologic constitution of the mapped coarse-grained mafic unit and its probable role in the observed geophysical signatures. The hole should be drilled to a depth of 360m at an angle of 70°. Target hole F is located 50m to the east of target hole E. This hole tests the extent of the anomaly that is being tested by E, but at a greater depth. Target hole G is planned to test the

combined chargeability and resistivity anomalies (MBZ-B) along the eastern portion of RSIP line 21 at an estimated depth of 220 m. Drilling at an angle of 65° is recommended to a depth of 320 m.

Figure 12. Drillhole target zones. The map shows the locations of the IP anomalies on the surface and the proposed locations of 8 new drill-holes (marked A to H) along the three RSIP lines 21, 25 and 28.

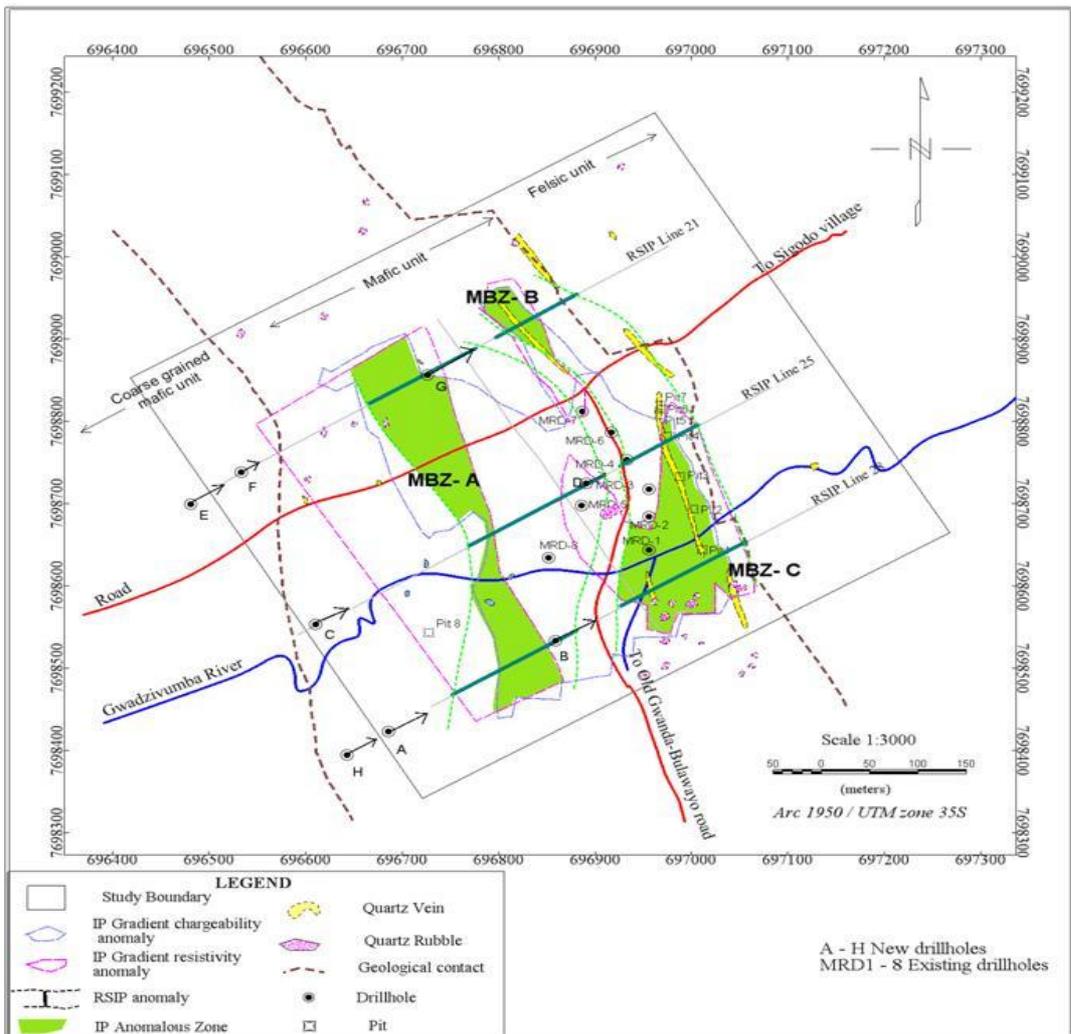


Figure- 13. (a). Projected drillhole for RSIP line 21 on a chargeability image. Holes E and F are modelled at a dipping angle of 70° while G is set at 65°. The holes will test areas of high anomalies at depth as observed along line 21.

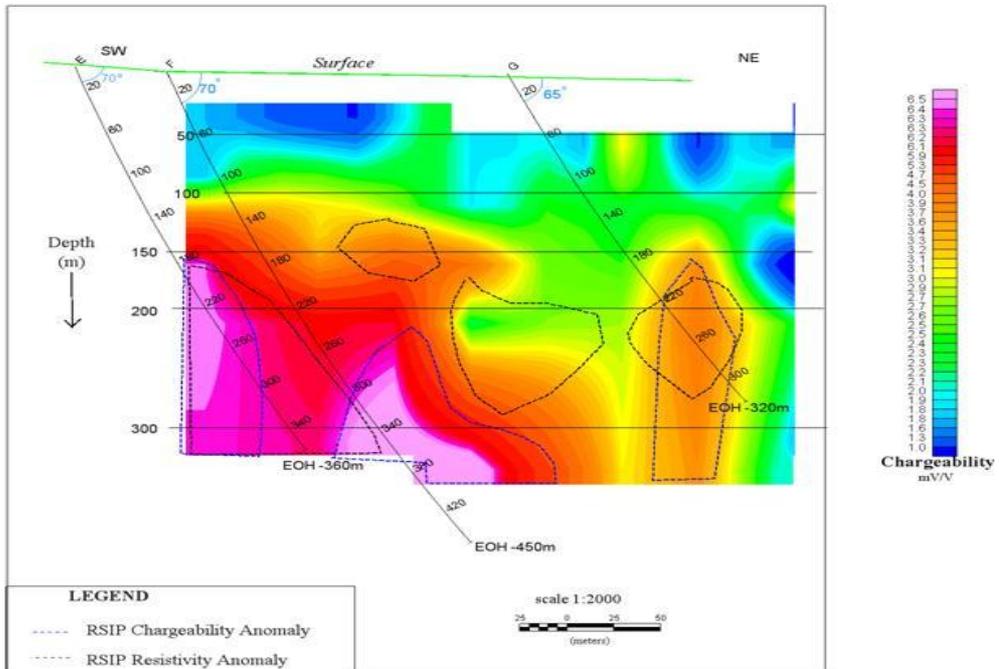


Figure 13 (b). Projected drillhole for RSIP line 25 which should be drilled to a depth of 300m at a dip angle of 65°. This hole would test the mineralisation that was observed in previous holes (MRD-8 and MRD-5).

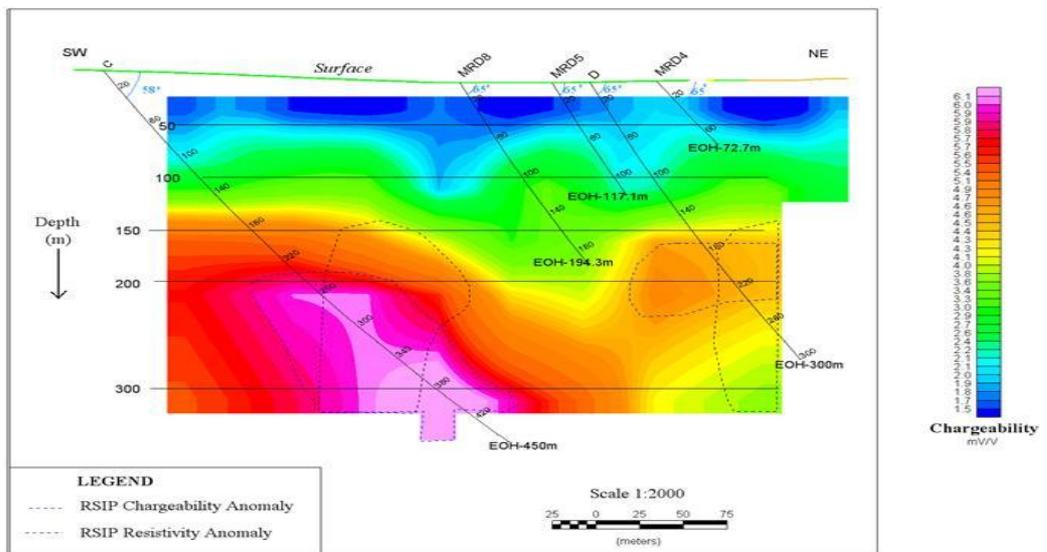


Figure 13 (c). Projected drillhole for RSIP line 25 on a chargeability image. Holes C and D at dipping angles of 58° and 65° respectively, will test zones of anomalies along line 25. Three hole (MRD-8, NRD-5 and MRD-4) drilled in a previous project are also shown relative to the zones of anomalies obtained in this study.

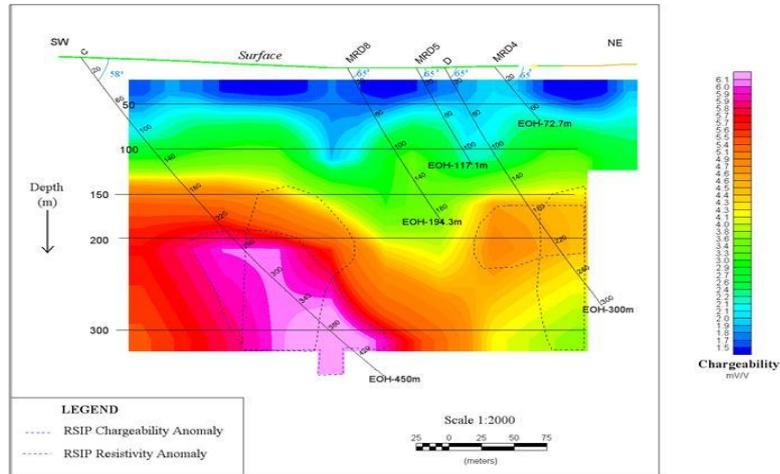
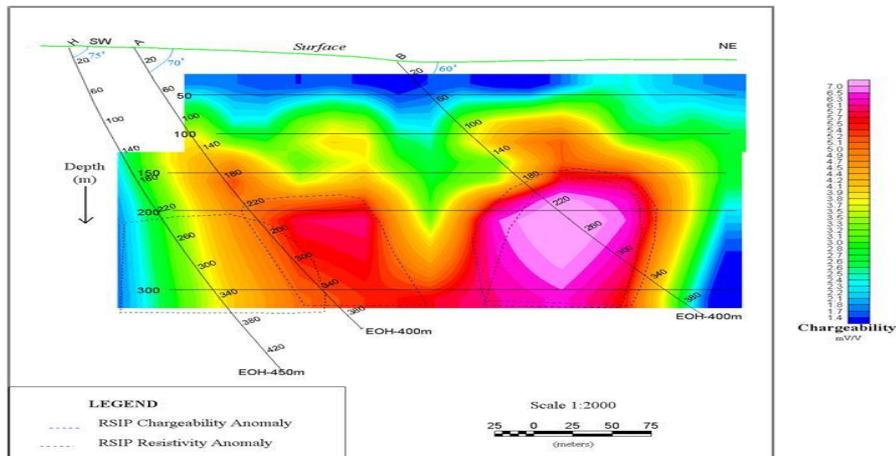


Figure 13 (d). Projected drillhole for RSIP line 28 on a chargeability image. Holes A, B and H are modelled at dipping angles of 70° , 60° and 75° respectively. The holes will test anomalies along line 28 at depths in excess of 150m.



6. CONCLUSIONS

Mbudzane comprises rock formations with varying response to geophysical exploration methods. Data from IP survey showed that RSIP is superior to gradient in defining deeply seated chargeable zones to optimize drill-hole targeting. Gold mineralization in Mbudzane is disseminated sulphide replacement (DSR) which probably fissured through the contact between mafic and felsic to the sub-surface by the hydrothermal process. The mapped IP anomalies are best indicators of sulphide mineralization in the area. The IP/resistivity method directly and easily detects sulphide mineralization and is here-by recommended for incorporation in nearly all

investigations for gold, in conjunction with magnetics, geological mapping and geochemistry before drilling. Its incorporation certainly optimizes drill-hole targeting and avoids “blind drilling”. This study resolved magnetic signatures that are required to optimize drill-hole targeting. This gold exploration procedure should be applicable to any region where non-alluvial gold is to be mined.

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