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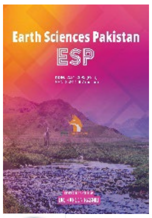

RESEARCH ARTICLE

THE INTEGRATED GEOPHYSICAL STUDY FOR DELINEATING CU-AU SULFIDE DEPOSITS IN RUWAN GORA ANKA AREA, NORTHWESTERN, NIGERIA

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ABSTRACT

The Copper-Gold (Cu-Au) ore-bearing veins in Ruwan Gora, Anka, were studied using ground magnetic, resistivity, and induced polarisation (IP) geophysics methods. The study indicated that shallow/deep tectonic structures in the Precambrian Basement Complex may retain sulphide ores, while shallow granitic intrusive/volcanic rocks have high magnetic susceptibility values. Basement rock ore-bearing veins have susceptibilities of ≤ 50 nT because of the removal of IGRF, resistivity of ≥ 100 Ωm, and IP of > 203 ms. The ores' electrical data demonstrates mineral zoning. High and low magnetic anomalies which amplitudes of 50nT and -50nT reside in the examined area. This is commendable given the slight magnetic anomaly. The residual magnetic field intensity map, down to the Interpreted Structural Map with an identification number, indicated considerable anomalies with trends in the NE-SW and N-S and few in E-W ones, which matched various structural trends in the region. IP and resistivity models identified shallow veins and bodies with considerable resistivity and chargeability. Large charged bodies were detected at a depth of ≥ 60m. Most magnetic anomalies examined by the IP survey are charged, and their chargeability increases with depth.

KEYWORDS

Cu-Au ore, Ground magnetic, Electrical Resistivity Tomography/Induced Polarization, Anka

1. INTRODUCTION

The integration of geophysical data, including ground magnetic, radiometric, electromagnetic, and gravity data, along with satellite imagery, is increasingly employed in mineral exploration efforts as a primary tool for assessing mineral potential in various regions of Nigeria, due to the cost-effectiveness of such data availability. Mineral exploration in any region worldwide encourages sustainable development and economic progress within a nation. The Nigerian economy is currently depending primarily on crude oil output (Obaje, 2009). The unpredictability and unsustainability of global crude oil prices have dramatically harmed the nation's economy. Nigeria includes economically important mineral deposits across numerous regions; however, the bulk of these resources are underutilised, and in certain situations, their occurrence, composition, and reserves have not been adequately examined (Ogungbemi et al., 2018).

The peculiarities of the deposits usually affect the research of solid minerals and the selection of techniques. The study applied the ground magnetic technique, electrical resistivity tomography, and induced polarization to identify Pb–Zn sulphide deposits in the Asu River Group shales of Nkpuma-Ekwoku, Abakaliki area, southern Nigeria (Adejuwon et al., 2021). Their findings suggested that low magnetic susceptibility levels correlate with shallow tectonic structures within the sedimentary basin that may contain sulphide ores, whereas high susceptibility values signal the existence of shallow intrusive or volcanic rocks. Recent studies undertaken indicate structural lineaments suggestive of possible mineralised zones employing aeromagnetic data by (Ejepu et al., 2020; Oguche et al., 2021; Arifin et al., 2019; Andrew et al., 2018; Adewumi and Salako, 2018; Wemegah et al., 2015; Priscilla et al., 2021). Aeromagnetic surveys are essential for identifying metal deposits since they proficiently identify igneous intrusions and subsurface geological formations (Eldosouky et al., 2017). Researchers include have effectively combined aeromagnetic data with pertinent field data to identify porphyry intrusions (Holden et al., 2011; Eldosouky et al., 2017; Elkhateeb and Abdellatif, 2018; Ogungbemi et al., 2018).

Textural analysis has demonstrated its utility in elucidating and delineating geologic lineaments, including lithologic boundaries, faults, folds, joints, and contacts, especially given the association of several mineral deposits with igneous intrusions (Eldosouky et al., 2017). Porphyry deposits, distinguished by their near-circular characteristics, are important igneous intrusions that include a variety of minerals, such as molybdenum, copper, gold, silver, and other rich by-product metals (Eldosouky et al., 2017).

2. SITE LOCATION AND GEOLOGY

The study area is enveloped within longitude 5^{0} 50’ 59’’ E to 5^{0} 53’ 11’’E and latitude 12^{0} 19’ 45’’N to 12^{0} 21’ 29. The geology of the study area of the north of the core portion is schist and copious quartz fragments, poorly sorted and extensively broken. It’s vital to observe that some of these quartz shards trend in a certain orientation that suggests they may represent veins that have been fully fractured. Moving south of the core part are quartz veins associated with highly broken granites. These quartz veins are often glassy, with medium fracture density and considerable alteration (Omatola et al., 2024). Nevertheless, most of the outcrops around are many quartz fragments and quartz veins. These quartz veins are coupled with significantly to entirely worn schist, they are very fractured and relatively modest (not more than 0.5m broad and 20m long). The quartz veins appear to be highly fractured and relatively small in length and width (not more than 1m wide and 20m long), also observed

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within the schist are abundant quartz fragments, these quartz fragments at some locations are observed to be closing packed together and trending in a particular orientation that suggests they may be veins that have been completed fractured. Quartz rarely appears in great proportions within schist except for the spot where the two (schist and Quartz) occur as a moderately elevated ridge, schist detected at these locations is extremely silicified Within the granite, the quartz vein looks gigantic and vast (often more than 200m long and 30m broad), with mild to moderate fracture density (Omatola et al, 2024).

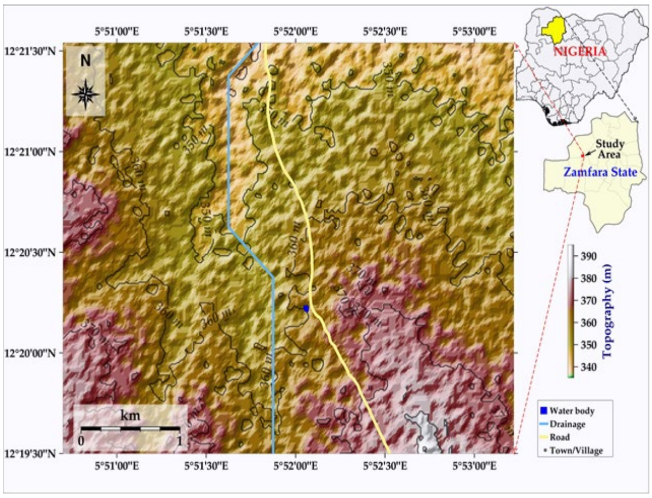

Figure 1: Location and Topography map of the study area

Figure 2a: Quartz vein

Figure 2b: Schist and Quartz) occur as a moderate elevated ridge

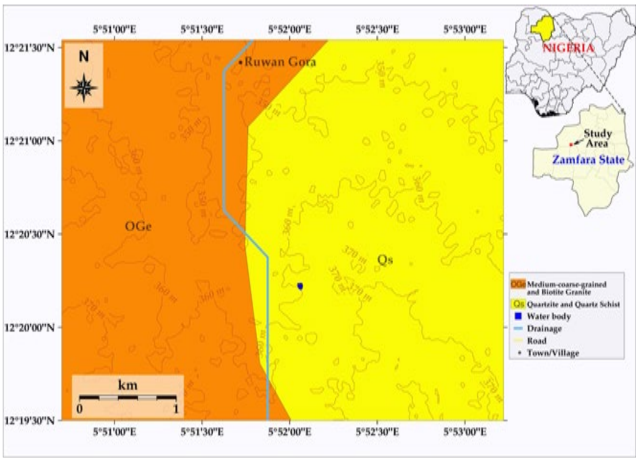

Figure 3: Geological map of Ruwan Gora.

3. MATERIALS AND METHODS

The ground magnetic data were acquired with two GEM GSM-19 magnetometers, one used in base configuration, and the other used as a rover.

The geomagnetic field orientation in Nigeria usually displays an inclination close to zero, while most of the geology in the field areas surveyed strikes approximately north-north-east.

As such, the traverse line orientation was specified to be 120 degrees for all survey areas. This was done as a trade-off between minimizing the aliasing of anomalies between lines which can happen in low magnetic latitudes if east-west lines are surveyed, and to try and capture as much detail across the strike of the formations.

ERT/IP data acquisition was conducted using the Geomative GD-10, an advanced resistivity imaging system developed by a Chinese company for diverse geophysical applications. This instrument combines centralized and distributed cabling systems, offering flexibility, efficiency, and dependability. Using a dipole-dipole electrode array of 10m electrode spacing, a total of 6 profiles were acquired along a profile of 290 to 300m length.

4. PROCESSING OF GROUND MAGNETIC DATA.

4.1 Diurnal Correction

The first stage of processing was the diurnal correction which was carried out by physically linking the GEM GSM-19 base station magnetometer to the GEM GSM-19 rover magnetometer with a data transfer cable. The base station magnetic data were then transferred to the rover unit. Upon reviewing or dumping the data from the rover unit, the diurnal correction is applied via the instrument using this simple equation:

Corrected magnetic field = rover magnetic field – base station magnetic field + datum

For the surveys in Nigeria, a datum value of 34,000 nT was used. Both the uncorrected and corrected magnetic data are provided in the data file (see also pages 66-69 in the GEM GSM-a9 v7.0 Instruction manual).

4.2 Second difference Filter

The magnetic surveys were often acquired in areas near villages or man-made infrastructure. As such, there were many large spikes of up to several thousand nT in the data. To remove spikes from the data a second difference filter was used. This filter uses column maths in Geosoft Oasis Montaj to first calculate the difference between each successive corrected reading, and the difference between each of the first differences, which is the second difference. Readings that display second differences greater than 40nT are nulled.

4.3 Dynamic Range Filter

The dynamic range filter simply nulls all data that falls outside of a specified range (less than 29000 and greater than 39000 nT).

4.4 Decorrugation filter

The data were then gridded and checked. If striping effects were noticed in the data, Decorrugation techniques were applied using grid-based FFT filtering

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5. RESULTS AND DISCUSSIONS

After the removal of the International Georeferenced Field (IGRF) using GMT and Geosoft software from the TMI data grid, the residual map (Figure 4) was produced whose amplitude depicts a zonation and hydrothermal alteration zone that ranges from 50nT - (-50nT). The analytical signal map was used to centre the peak of the anomaly, which ranged from 0.5 – 0.9nT and was mostly observed in the southwestern area. The vertical derivative and the tilt derivative show the structural trend is mostly dominated in NE-SW and N-S direction with few in E-W which aligned with quartz schist vein and the medium-coarse-grained with biotite granite observed from the geological map (figure 3) and Figure 2a and 2b which are possible potential host rock for gold and copper mineralization within the study area. The source parameter imaging and 3D SPI map in Figures 8 and 9 indicate some of the anomalies are shallow bodies while some are a little bit deep-seated as was also observed in the first vertical derivative map. The structural interpreted map obtained from the first vertical derivation, tilt derivative, the potassium map and thorium potassium and potassium thorium ratio Map helps to identify the structural trend, the magnetic unit boundary, magnetic lineaments and alteration zone also shows how these structures aligned well with the geology of the study area as shown in the structural interpreted map with an identification number (Figure 10)

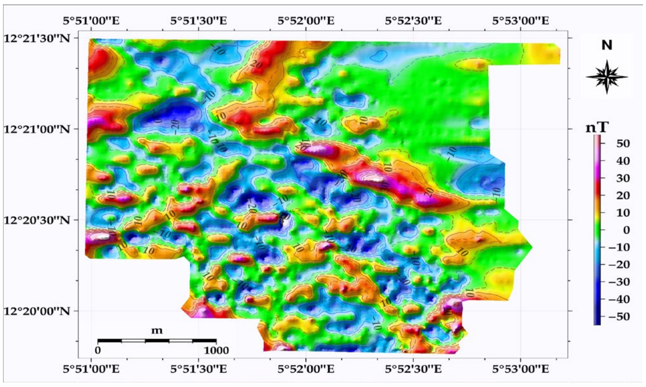

Figure 4: Residual map

The inversion result from ERT/IP data shows profile (PR3) revealed two disseminated sulphide lodes along the profile with resistivity values of 183Ωm and 100Ωm and chargeability values of 130ms. The findings of the 2D electrical resistivity and IP tomography for the second profile (Fig. 11) cut across three mineralized zones and one dispersed deposit at roughly 50m, 130m and 170m distances along the profile. They have resistivity values of ≥100Ωm, while their chargeabilities are ≥100ms. Profile (PR5) displayed six disseminated deposits and mineralized zone with resistivities ≥1129Ωm, and their chargeabilities ≥ 101ms. Its resistivity tomography demonstrates a continuous vertical and horizontal increase in the resistivity of the quartz, schist, medium coarse-grained with biotite granite host rock in a circular pattern. Because of high numbers in the resistivity value, the presence of an igneous body at a depth near the ore vein may indicate a possible relationship between magmatism and mineralization in the area IP model. The profile (PR6) met two sulphide deposits at roughly 100m and 160m respectively with a resistivity value of 89.4Ωm and chargeabilities exceeding 203ms. Depth to the top layer of the sulphide deposits varies from profile to profile looks like it was spatially distributed. The depth to the top of the shallower ore bodies ranges from 13 to 50 m, while the deep-seated deposits are deeper than 60 m. Disseminated Sulphide mineralization is characterized by higher-than-average chargeability which can be assessed with Induced polarization. Primary gold and copper deposits in this region of the Anka schist belt are associated with quartz and schist. A high chargeability becomes a pivotal indication of possible mineral prospects in the region. Quartz veins are often characterized by high resistivity. Most primary gold mineralization in the schist belt commonly occurs in quartz veins within several lithologies, therefore geophysical properties of the quartz veins become an important factor in the delineation of the potential minerals. Since the projected primary gold deposits in these places occur within quartz-vein linked with sulphide mineralization, such a zone will be marked by higher-than-average chargeability and high resistivity (low conductivity). For copper sulphide in this area, the principal host rocks are connected with Quartz Schist and medium-coarse-grained with biotite which are granite-like rocks with copper-bearing sulphide minerals (e.g. chalcopyrite ($CuFeS_2$), bornite (Cu_5FeS_4) and covellite (CuS)

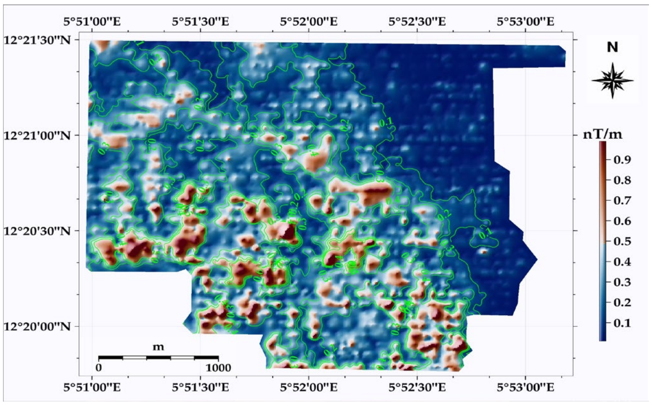

Figure 5: Analytical signal map

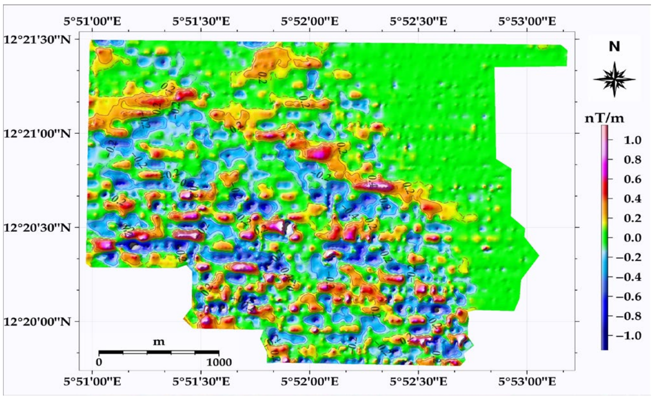

Figure 6: First vertical derivative map

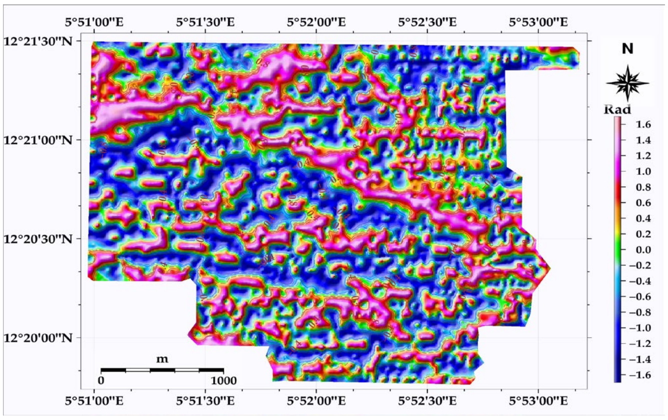

Figure 7: Tilt derivative map

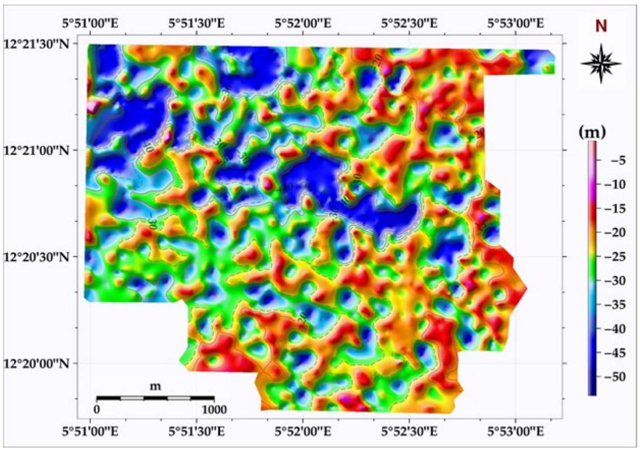

Figure 8: Source parameter imaging map

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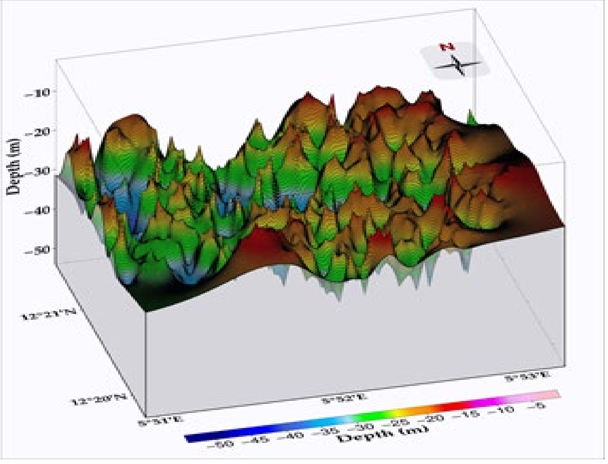


Figure 9: 3D SPI map

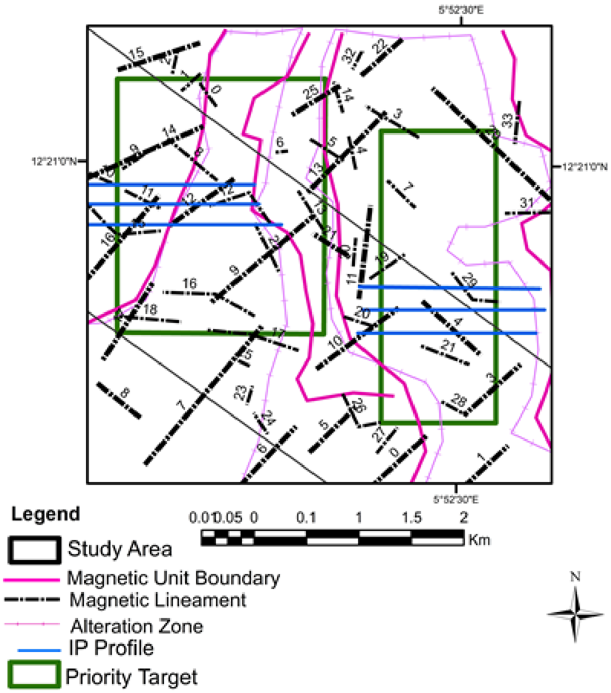
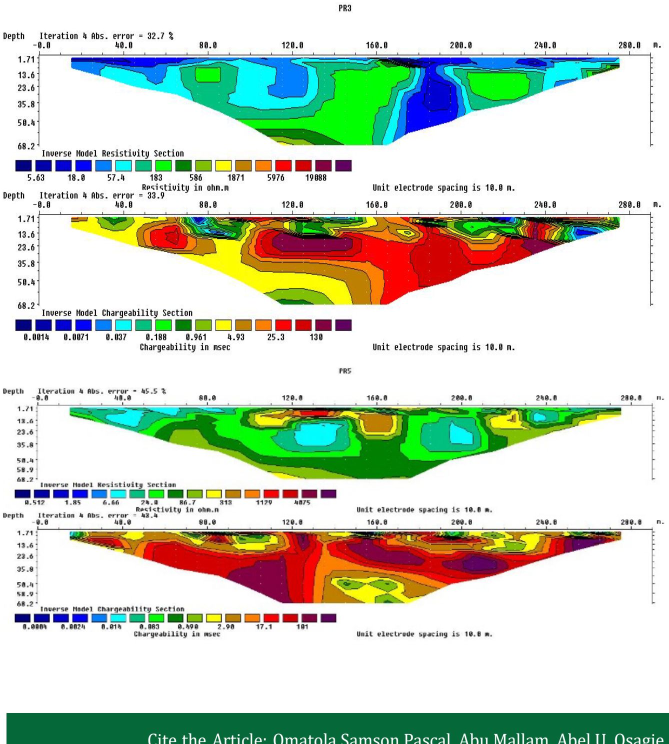


Figure 10: Interpreted Structural Map with identification number Ruwan Gora Anka study area



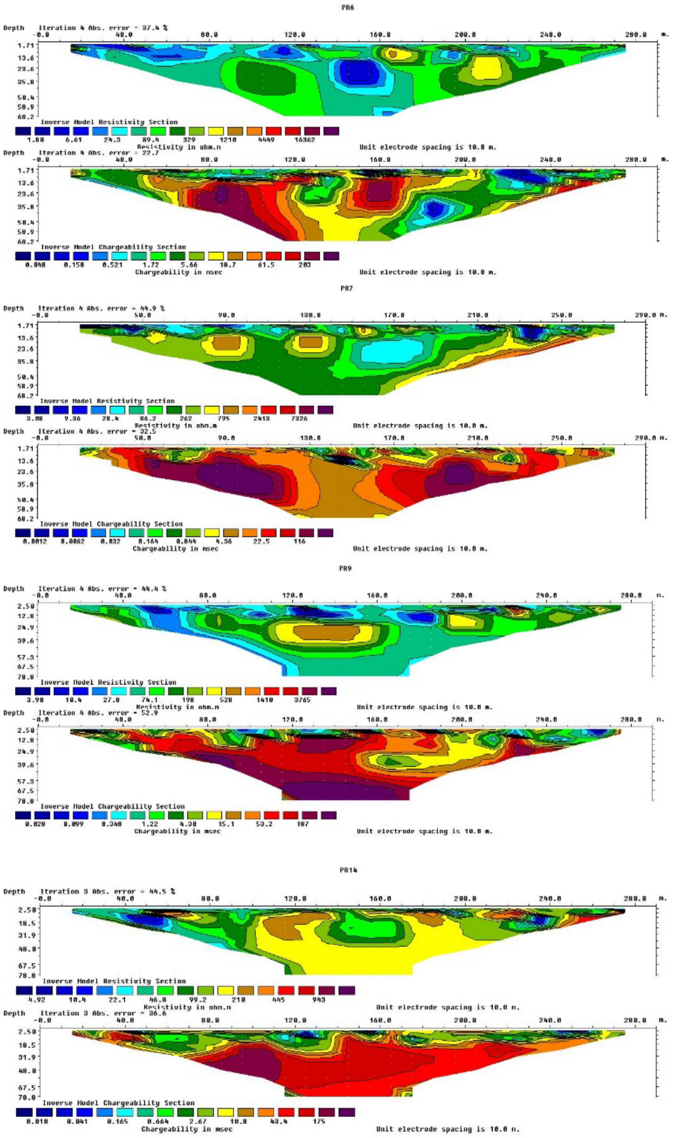


Figure 11: ERT/IP Inversion results of some selected profiles Ruwan Gora Anka Zamfara State.

6. CONCLUSION

The ground magnetic and 2D ERT/IP methods were employed to delineate Cu-Au sulphide deposits in Ruwan Gora, revealing that the spatial distribution of anomalies within the study area is instrumental in locating Cu-Au ore deposits hosted by quartz, schist, and medium-coarse-grained biotite granite. The significance of the ground magnetic approach has been underscored as an indirect and effective reconnaissance tool for structural mapping in environments where Cu-Au is not magnetically responsive. It further corroborated the perspective of a magnetic hydrothermal origin for the ores in the region, with the alteration zone also being significant in delineating a possible location for ore deposits.

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