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IP-Rs Geophysical 3D Modelling of Cu-Fe Skarns; A Case Study Ghalandar Skarn Deposit

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ABSTRACT

An efficient method in exploration of sulfide minerals (i.e. Cu Skarn and Porphyry deposits) is the application of geoelectrical techniques including the induced polarization (IP) and the electrical resistivity (Rs). As 2D electrical modelling presents an image of anomalies in depth, but for detail imaging of anomalies it is not as efficient as 3D modelling. 3D modelling of IP-Rs surveys results accurate view of anomalies which borehole suggestion for detail exploration would be easier. In this paper, three-dimensional modeling of Ghalandar Cu-Fe deposit has been prepared. According to skarn type of Ghalandar deposit and paragenesis of copper and iron, after different exploration studies such as, geochemistry, geology, and magnetometery, 10 IP-Rs profiles have been survived in north – south direction, then their 3D modelling result have been compared with 3D grade estimation modelling from16 boreholes results.

Keywords: 3D Modelling, IP-Rs, Geophysical Exploration, Cu-Fe Skarn, Ghalndar Deposit

INTRODUCTION

Three-dimensional modeling of IP-Rs data is one of the most important challenges in geophysical analysis. The most important factor in this challenge is the accuracy of modeling which could be different in each method [1]. In this paper, it was tried to apply a simple method for modeling of IP-RS data. This modelling method was performed for Ghalandar Cu-Fe Skarn, therefore 10 IP-Rs profiles were surveyed and after topography correlation and 2D modelling with finite difference method, the results were export and have been modeled in three dimensions.

GEGRAPHICAL LOCATION AND THE GEOLOGY OF THE AREA

The exact location of Ghlanadar Area is in 23rd km, north of Ahar and 124th km of Tabriz, NW of Iran. Study area contains lithology units of Eocene and Oligocene (65 to 24 million years ago) which have been created according to the influence of massive volcanic (Shivardagh batholith) in carbonated rocks which forms Fe-Cu skarns [2]. Different exploration studies such as geochemistry, geology, and magnetometery have been done in this area. According to studies, this area includes high potential of Copper and Iron, therefore detail exploration methods such as IP-Rs geophysical studies must be done in this area to optimize borehole location. The main mineralogy type of deposit is skarn in the west and the porphyry type in the south east. Qalandar Area is located in north west of Iran, East Azerbaijan province and north of Ahar. In **Figure (1)** [3], access roads and the location of Ghlandar area have been shown in geology map of Ahar.

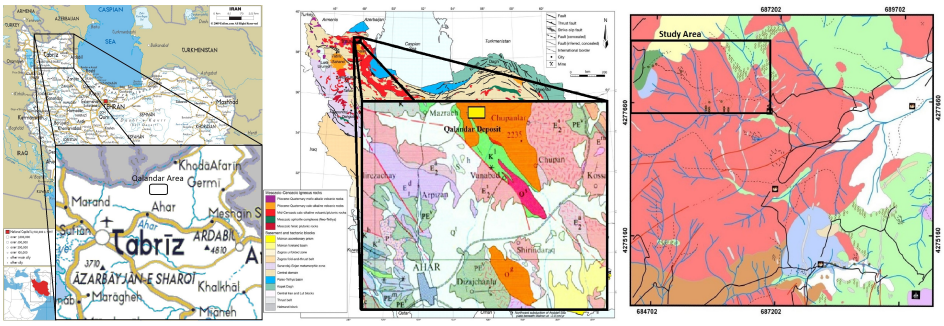

Figure 1. Location and Geology Map of Ghalndar Area [3]

METHODOLOGY

Results of geological and geochemical studies in Ghalandar Skarn occurrence, shows the efficient mineralization potential to form copper-iron deposits in this area. According to the characteristics of such ore mineralization, prevalent geophysical method in detection of sulfide minerals is the induced polarization (IP) and electrical resistivity (Rs). Since this Skarn deposit simultaneously consisting of Cu-Fe, to detect the iron mineralization, first magnetometery survey is used and then 2D electrical profiling involving IP and Rs were survived jointly for detail depth information of sulfides.

To detect the approximate trend of mineralization, the study area covered by a IP-Rs surveys over a region (X=1100 m & Y=1500 m). The distances of stations were chosen 100 m from west to east. All electrode spaces

(currents and potentials) were chosen 30 m and are surveyed from south to north. In **Figure** (2) [2] the location of IP-Rs Profiles has been shown on total magnetic intensity map of the area.

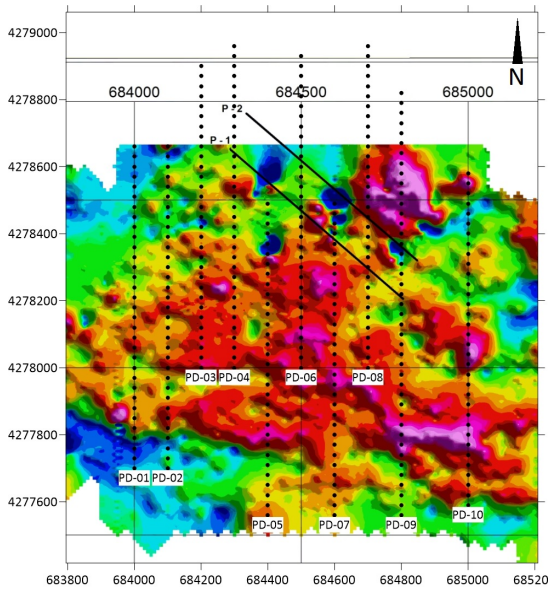

Figure 2. Location of IP-Rs Profiles on TMI Map of the Ara

ANALYSIS OF IP-RS DATA

After detection of the main trend of mineralization, 10 IP-Rs profiles designed and surveyed in this area. According to main trend of mineralization which is in E-W direction, the IP-Rs profiles are conducted in E-W direction, in pole-dipole array, the dipole distance is 30 m, while profiles distance is 100 m, and maximum penetration depth is 150 m [4]. At the first step, 2D modelling of surveyed profiles have been performed. In recent years, there has been much progress in rigorous inversion of induced polarization (IP) and electrical resistivity (Rs) data assuming a 2D earth structure. Published works on 2-D inversions has demonstrated that inversion can help extract information that is otherwise unavailable from direct interpretation of the pseudosections [5]. In this paper all surveyed data have been 2D inversed. The algorithm of 2D inversion is based on finite difference method and also using topography correlation. the 2D modelling result then exported to spatial data with UTM coordinates in x, y and z directions to be modelled in 3D.

The three-dimensional inversions show exceptional closeness to the revised geology, and are able to provide an understanding of the lateral variations in the physical characteristics of the conductive and chargeable units [6].

After correction of the output data from the 2D models, each spatial data is assigned for its coordinate and then 3D modelling created by using the kriging interpolation method, for both IP and Rs data. In **Figure** (3) all IP-Rs profiles and 3D models for both IP and Rs data is shown. According to the mineralization characteristics of Ghalndar Cu-Fe skarn, high IP data are the effect of sulphide minerals such as chalcopyrite, pyrite and etc. while high resistive zones are the effects of carbonate masses.

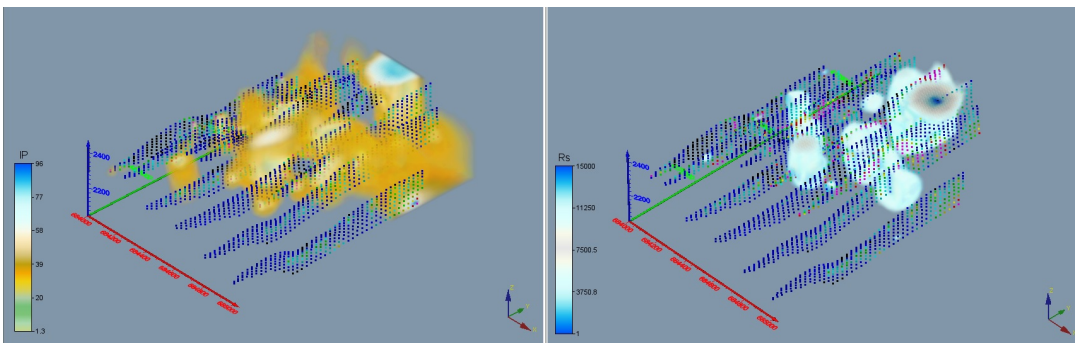

Figure 3. 3D Models for IP Data (left) and Rs Data (Right), View to NW.

CORELLATION OF 3D MODELLING WITH BOREHOLE RESULTS

In order to carry out further studies in this area and to provide a grade estimation model, according to the results of the 3D IP-Rs model, 23 exploratory boreholes have been suggested, out of which 16 boreholes at various

depths from 80 to 200 meters were drilled and graded. In **Figure (4)** location of 16 drilled boreholes is shown with IP-Rs profiles in red color. To construct a 3D grade estimation model and compare it with a 3D geophysical model, core grading was performed for each meters of cores. As the IP-Rs anomalies are affected different copper and iron mineralization, therefore grades of both Cu and Fe grades for each cores were summed and the final 3D grade estimation model was crated. In **Figure (5)** the 3D grade estimation of boreholes is shown. It should be noted that for a better display of the reserve, only the aggregate grades of 2 to 10 % were presented in model. As can be seen, there is a very good consistency with the geophysical and grade estimation of 3D models.

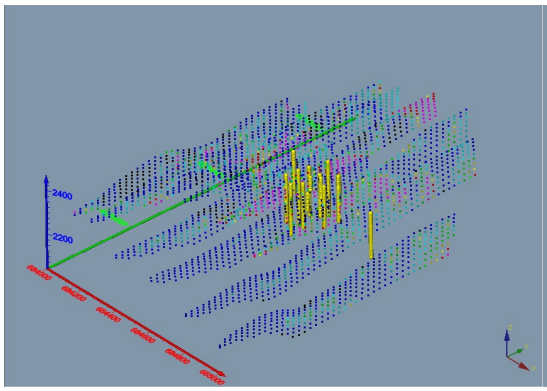

Figure 4. Location of drilled boreholes.

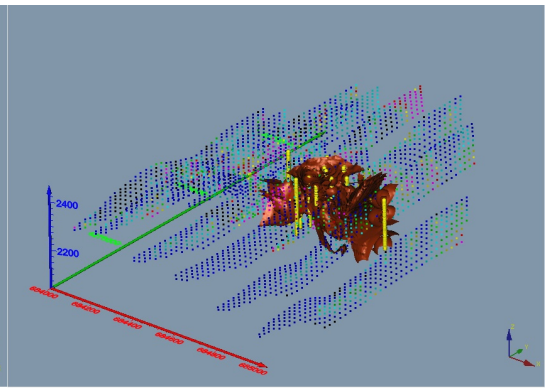

Figure 5. 3D grade estimation of Cu and Fe

CONCLUSIONS

The IP-Rs geophysical surveys have been performed to investigate the subsurface mineralization in the Ghalandar Cu-Fe deposit. Due to the wide extent and paragenesis of copper and iron mineralization in this area, and the conditions of rock mass such as carbonates, of a geophysical model in this area is required. A 3D geophysical model provides a better understanding of subsurface anomalies and detection of mineralization zones. For this area, the 3D geophysical model is derived from the output of 2D models for both IP and Rs Data. For the validation of 3D geophysical model, the results of 16 exploratory wells are used. Cumulative grades of copper and iron have been used to create a 3D grade estimation model and have been compared with a 3D geophysical model. It could be said that the creation of a 3D geophysical model in skarn deposits gives a better understanding of sub-surface anomalies to detect mineralization and optimization of the suggested boreholes locations.

AKNOWLDEGMENT

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