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Ground Magnetic Survey for Exploration of Massive Sulfide in Northeast Iran

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Abstract: The aim of this research was to use ground magnetic survey for exploration of new deposit in Taknar polymetal massive sulfide which is located in Northeast Iran in a tectonic corridor between two active faults. It is a syngenetic type mineralization formed at specific horizon within Taknar formation (Paleozoic?). Four mineralized zones named Tak 1, 2, 3 and 4 have been identified. Three style of mineralization such as layered, massive and stockwork have been recognized. Magnetite increases toward the massive part (up to 80 %), which is situated in the upper section. Magnetic susceptibility of the country rocks is 6×10^{-5} to 27×10^{-5}SI, the stockwork mineralization is 4600×10^{-4}SI, the layered is 7054×10^{-4} SI and massive is 1730×10^{-3}SI. Due to this sharp magnetic contrast magnetic method found ideal and used for the identification of new deposit in Tak 1, 4 and outside of Tak 1 (to the east). Magnetic maps and images revealed distinctive anomalies on Tak 1, 4 and outside of Tak 1. The amplitude of the anomaly on Tak 1, 4 and outside of Tak 1 was 1500, 2227 and 1231 gamma respectively. The anomaly outside of Tak 1 is similar in magnitude to Tak 1 and does not have surface exposure. By analogy the source of all magnetic anomalies in Tak 1, 4 and outside of Tak 1 is magnetite present along with mineralization. Therefore the location of the anomaly outside of Tak 1 on the reduction to the pole map was proposed as drilling target.

Key words: Taknar, polymetal massive sulfide, magnetic survey

INTRODUCTION

Taknar polymetal massive sulfide (Cu, Zn, Au, Ag and Pb) is located 28 km to the Northwest of Bardaskan in Khorasan Razavi province (Northeast Iran). It is structurally part of the Taknar zone which is situated between Doroune fault (great Kavir fault) to the south and taknar (Rivash) fault to the north (Fig. 1).

Taknar deposit is a syngenetic type mineralization formed at specific horizon within Taknar formation (Paleozoic?). Both volcanic and sub-volcanic rocks were formed during the sedimentation and they have wide

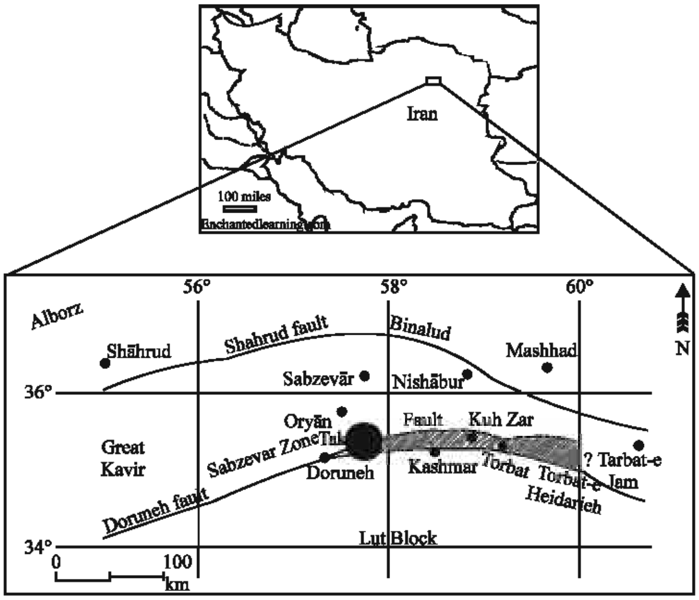

Fig. 1: Location map of the study area

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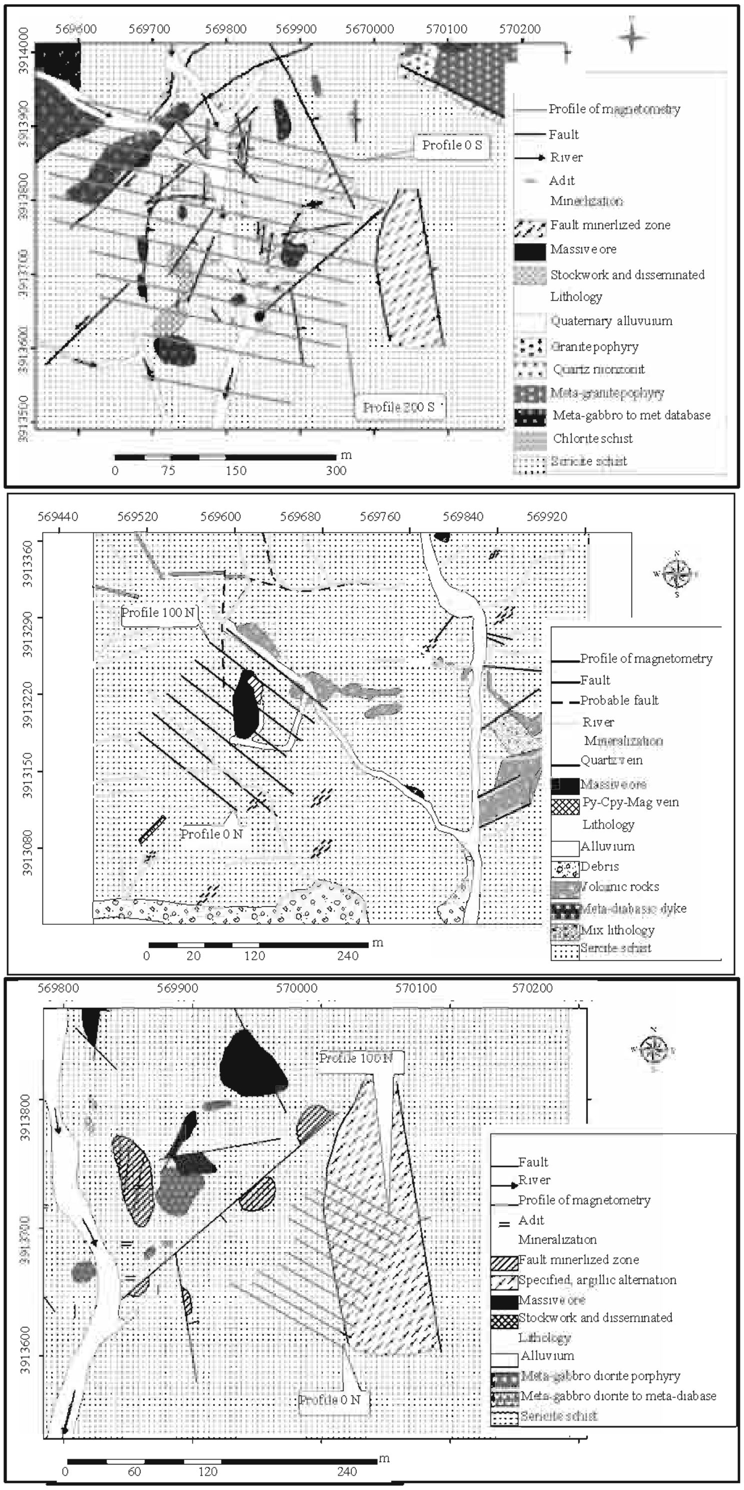

Fig. 2: (a) Geological and Mineralization map of Tak 1 with ground magnetic profiles, (b) Geological and Mineralization map of Tak 4 with ground magnetic profiles and (c) Geological and Mineralization map of the outside of Tak 1 with ground magnetic profiles

range of composition covering from acid to mafic (Karimpour and Malekzadeh Shafaroodi, 2005). Low grade regional metamorphism (Green Schist facies) was effected Taknar zone late in Paleozoic (Karimpour *et al*., 2004). Geology and the magnetic survey profiles are shown in Fig. 2a-c.

Three style of mineralization such as layered, massive and stockwork have been recognized. Major minerals are: pyrite±magnetite±chalcopyrite±sphalerite±galena, chlorite ±quartz±sericite±calcite. Magnetite increases toward the massive part (up to 80%) which is situated in the upper section. Sphalerite and galena are found mainly within the upper layered and massive section.

Situated within a window of active tectonic setting, the original position and dimension of the deposit had been changed and the present deposits which are called Tak-1, 2, 3 and 4, originally were part of a big deposit and due to faulting, they have been cut and moved at least 3 km from each other (Karimpour and Malekzadeh Shafaroodi, 2005).

All Known volcanogenic massive sulfide are associated with phyrrhotite or phyrrhotite and magnetite. Taknar deposit is a new type having only magnetite (Karimpour and Malekzadeh Shafaroodi, 2005). VMS massive lenses normally have high conductivity, density and susceptibility (Ford *et al*., 2006). EM and gravity have not been applied at taknar mineral deposit. However IP results had no success for the discovery of new deposit (Sarafzadeh, 2001). Due to the presence of high amount of magnetite in Taknar deposit and lack of magnetic minerals in the country rocks magnetic method is ideal for identification of new covered deposits (Haidarian Shahri *et al*., 2004). The aim of this work was to use ground magnetic survey for exploration of new deposit.

MATERIALS AND METHODS

- Geological mapping at scale of 1:1000 in Tak 1, 4 and outside of Tak 1
- Collecting 57 rock chip samples from surface and tunnel of Tak 1 and analyzed for Cu, Zn, Pb, Au, Ag, Bi and Mo in both Ferdowsi University of Mashhad and Sarcheshmeh copper mine laboratories by Atomic Absorption (A.A) method:
- Measurement of Total Magnetic Intensity (TMI) on 716 points over Tak 1, 4 and to the east of Tak 1 on 36 lines. Line spacing was 25, 20 and 10 m, respectively. Station spacing was 10 meter and reduced to 5 m where the gradient of TMI was high. The magnetometer was proton ENVI model of Sintrex having accuracy of 0.1 gamma
- Measurement of magnetic susceptibility over 536 rock outcrops along survey profiles. Magnetic susceptibility meter was GMS2 Sintrex having accuracy of 1×10^{-5} SI
- Plotting all magnetic and susceptibility profiles
- Applying diurnal variation correction to magnetic data
- Producing contour maps and images of TMI
- Producing images of RTP, first vertical gradient and continued maps using ER Mapper
- Interpreting the magnetic anomalies using known geology, mineralogy and magnetic susceptibility

RESULTS AND DISCUSSION

The position of the survey lines are shown in Fig. 2a-c. TMI varied from 48149 to 49580 gamma on Tak 1, 47988 to 50227 on Tak 4 and 48724 to 49231 on the outside of Tak 1. Main magnetic field of the earth in the survey area was 48000 gamma. Diurnal variation was corrected using Tie Line collecting data due to steep topography and lack of recording base station magnetometer. Atmospheric variation of the magnetic field was reported to be quite during the survey (inquired from Iranian Geophysical Observatory).

Susceptibility varies from 1×10^{-5} to 5068×10^{-5} SI on Tak 1, 1×10^{-5} to 950×10^{-5} SI on Tak 4 and 2×10^{-5} to 1428×10^{-5} SI on the outside of Tak 1. All TMI profiles were investigated in terms of magnitude and width and compared with their corresponding susceptibility profiles. Profiles 200 S on Tak 1, 100 N on Tak 4 and 40 N on the outside of Tak 1 are shown here for comparison (Fig. 3-5).

This comparison provides an estimation of the relative depth of the magnetic anomalies (i.e., where, both

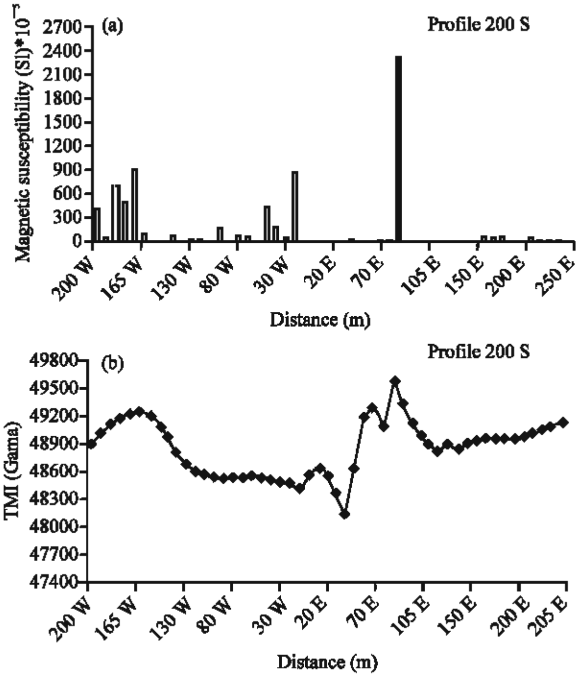

Fig. 3: (a) Susceptibility and (b) TMI in Tak 1

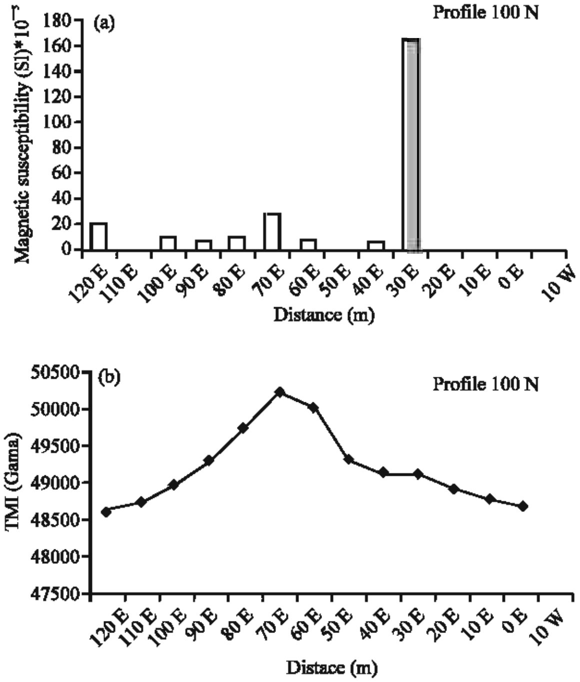

Fig. 4: (a) Susceptibility and (b) TMI in Tak 4

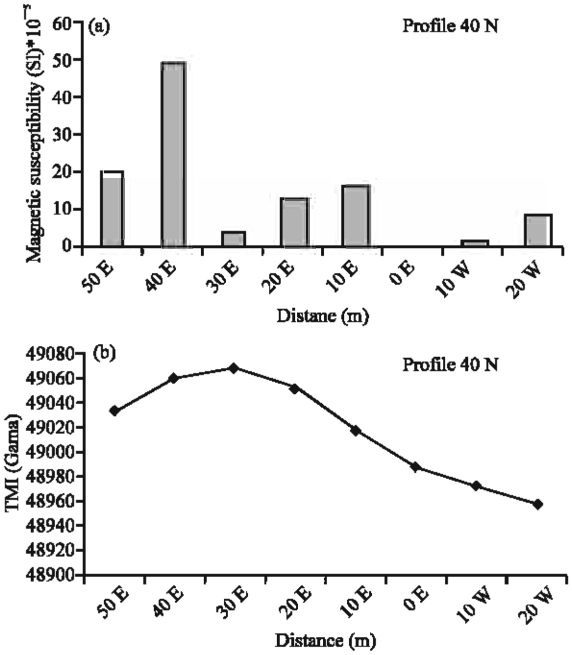

Fig. 5: (a) Susceptibility and (b) TMI in outside of Tak 1

susceptibilities and TMI are high the source of the magnetic anomaly is near surface and where susceptibility is low and magnetic anomaly is high the source of the magnetic anomaly is deep).

Canadian VMS deposits often associated with pyrrhotite resulting in ideal magnetic anomaly (Ford *et al*., 2006). The magnetic responses of an idealized volcanogenic massive sulfide model associated with various mineral assemblages are given by Gunn and Dentith (1997). Magnetic responses of Taknar VMS deposit neither comparable with the Canadian VMS deposit nor with the idealized models of Gunn and Dentith (1997) due to having high amount of magnetite and displaced tectonically from its original location (Karimpour and Malekzadeh Shafaroodi, 2005). Having no magnetic minerals in the country rocks of Taknar deposit magnetic anomaly should be related to magnetite along with mineralization provided that the magnetic data collected accurately and interpreted properly. The information available in magnetic data is generally underutilized and this is in part due to poor display of the data. Magnetic data either airborne or ground measurements cannot be interpreted until is displayed. To maximize the amount of information extracted from the data set and overcome the limitation imposed by using only one kind of display format, several display should be used to provide different perspectives. A wide range of presentation and enhancements are possible for magnetic data. Many Examples can be found in the literature particularity in ASEG, SEG and CSEG publications. Broom (1990), Isles *et al*. (1991), Teskey and Hood (1993), Milligan and Gunn (1997) and Liu and Mackay (1998) have all discussed the presentation and interpretation of magnetic data.

Data display along profiles and also using contour maps are both needed to have a preliminary idea about the amplitude of the anomalies and the magnetic trend. Images show the general pattern of the anomalies but not the gradient and it should be used together with more conventional presentations, such as contour map. Unenhanced color image of TMI with profiles path superimposed on the contour map are presented here for Tak 1, 4 and outside of Tak 1 (Fig. 6a-c).

Two separate anomalies on the western side of Tak 1 (Fig. 6a) strike N, NE-S, SW and correspond to the trend of the western abandoned tunnel. The length and width of the northern anomaly are 120 and 100 m and the southern one are 60 and 70 m, respectively. Several separate anomalies are present on the eastern side of Tak 1 (Fig. 6a) which overly the eastern old tunnel. The largest of these anomalies has 100 m length and 60 m width and strikes N-S. The source of all the anomalies on Tak 1 is magnetite along with mineralization which is remained between the surface and the roof of the tunnels and not mined.

A NW-SE anomaly with the surface dimension of 150×100 m is present on Tak 4 (Fig. 6b), which has surface mineralization on the trenches. The source of this anomaly is also magnetite associated with mineralization. A triangle shape anomaly which its apex is directed towards the Southwest and its base trends

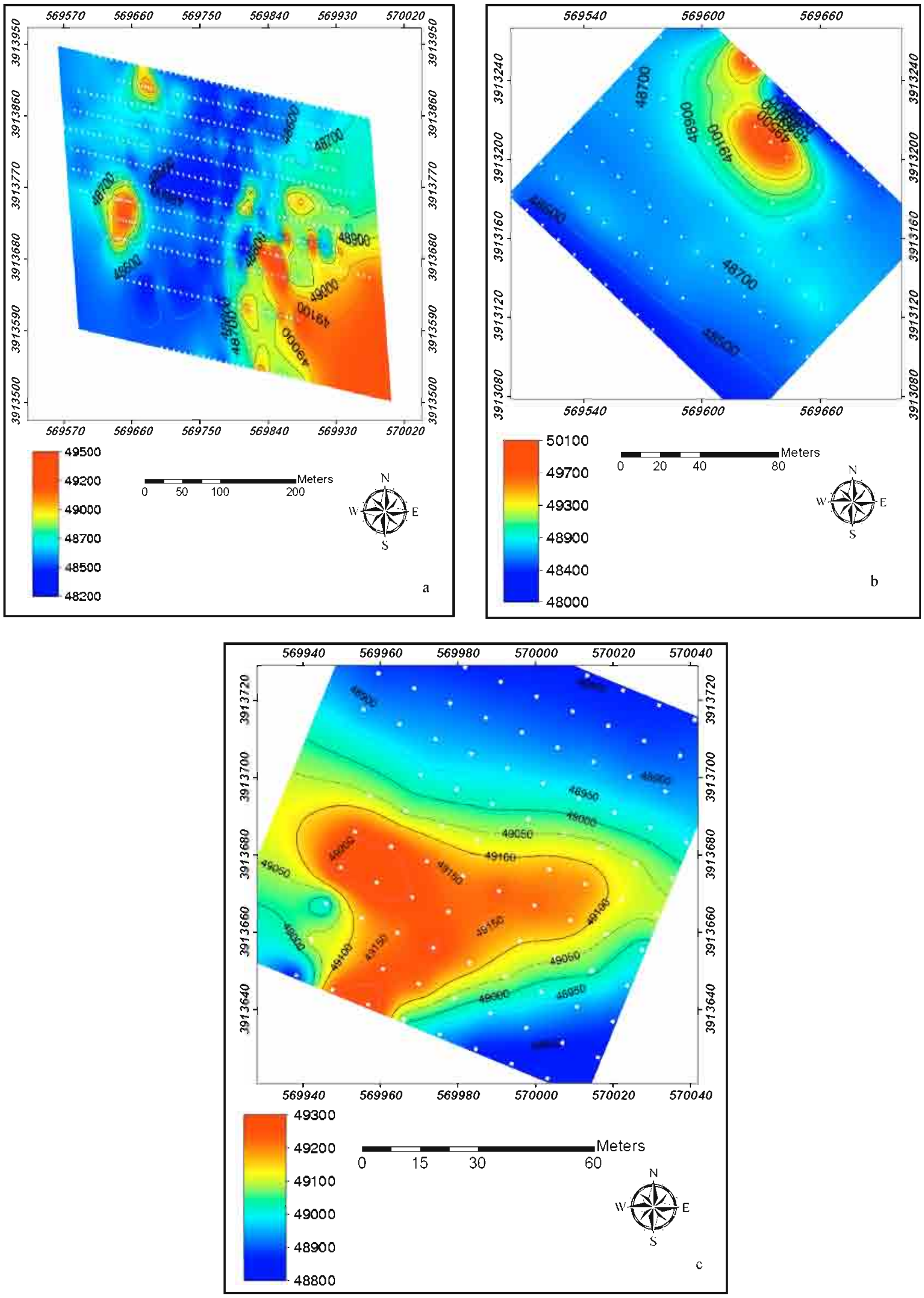

Fig. 6: TMI color image and profile path superimposed on the contour map. (a) Tak 1, (b) Tak 4 and (c) outside of Tak 1

towards the Northeast is identified outside of Tak 1 (Fig. 6c). Neither surface mineralization nor mining old tunnel coincides with this newly found anomaly. In terms of amplitude and width this anomaly is similar to the

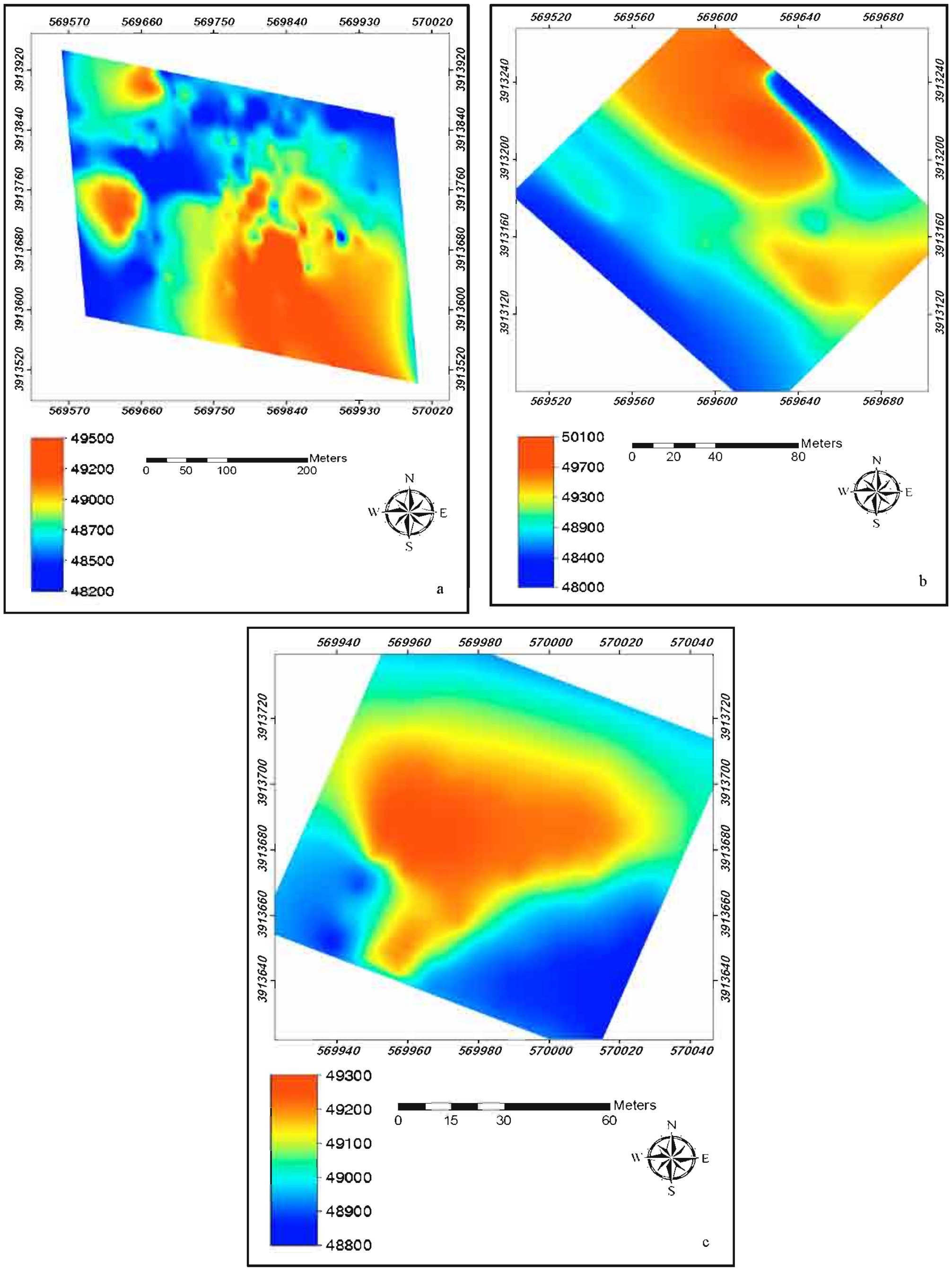

Fig. 7: TMI-RTP Images of (a) Tak 1, (b) Tak 4 and (c) outside of Tak 1

anomalies on Tak 1 which overlie the old mining tunnel. By analogy the source of the new anomaly outside of Tak 1 (Fig. 6c) is interpreted as magnetite along with mineralization which has been displaced from Tak 1 by active normal fault. The proper position of this new anomaly is presented on the Reduction to the Pole (RTP) map.

Magnetic anomalies should be reduced to the pole to remove the asymmetry due to the inclination of the magnetic field. This function puts the anomaly above it source (Clark, 1997). The RTP maps for Tak 1, 4 and outside of Tak 1 (Fig. 7a-c) were produced. They indicate a small displacement of the anomalies towards the Northwest relative to the TMI maps but the shape and general pattern remained unchanged.

Potential field data commonly presented as vertical gradient which enhances high frequency shallow features at the expense of the deep ones and sharpening the edges (Gunn, 1996).

First vertical derivative maps were produced from the RTP maps for Tak 1, 4 and outside of Tak 1 (Fig. 8a-c).

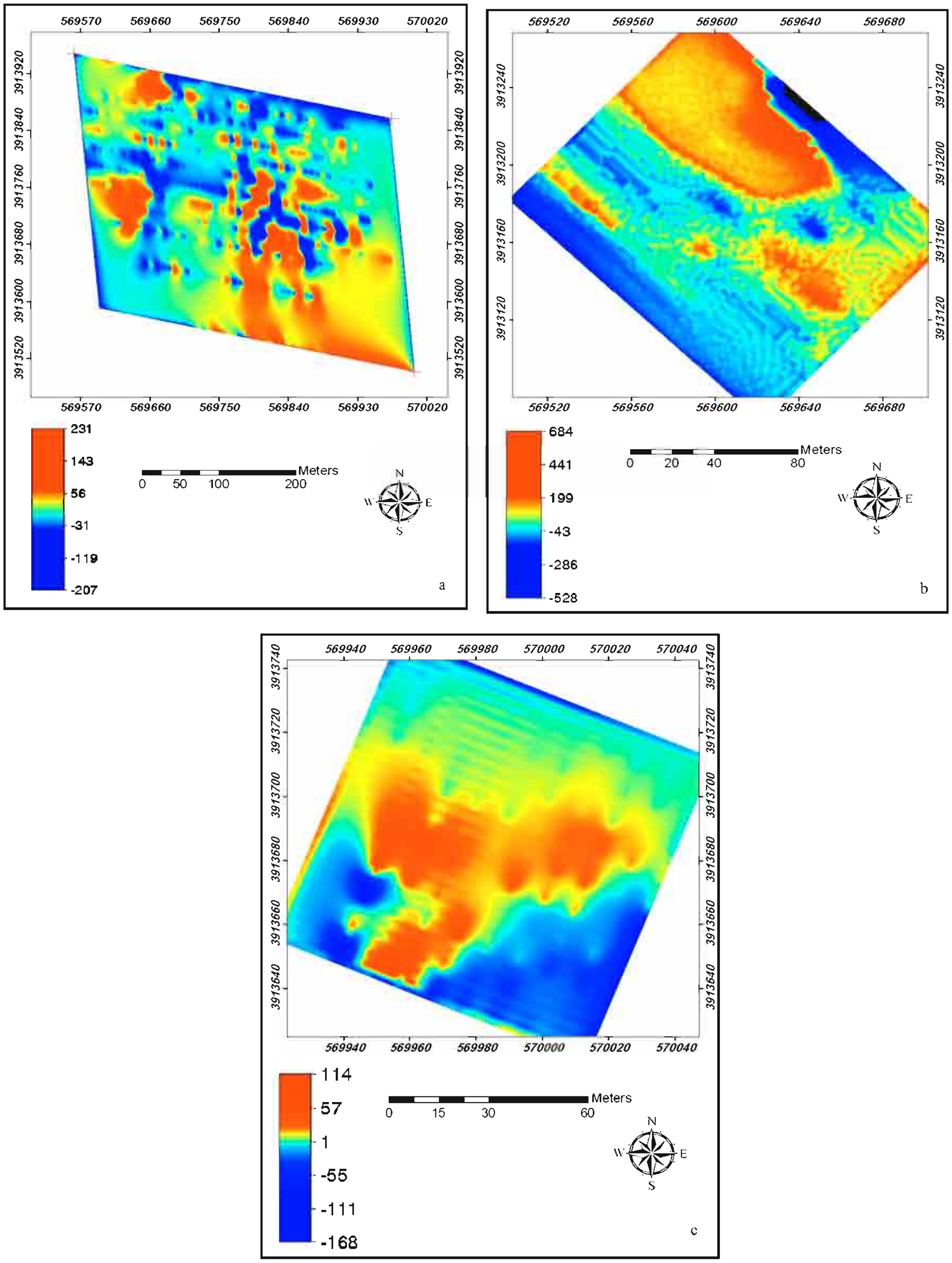

Fig. 8: First vertical derivative maps of (a) Tak 1, (b) Tak 4 and (c) outside of Tak 1

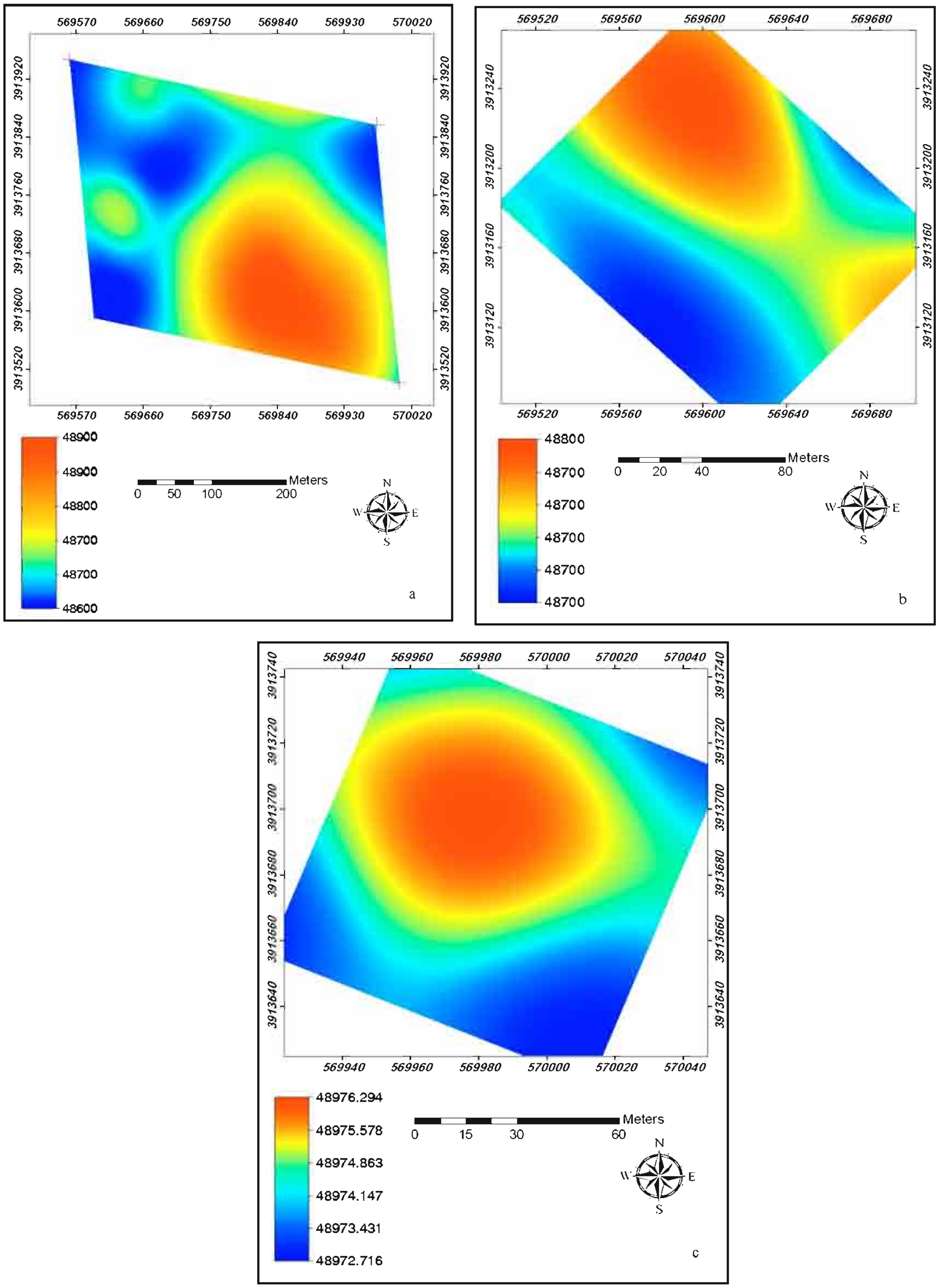

Fig. 9: Upward continued maps of: (a) Tak 1, (b) Tak 4 and (c) outside of Tak 1

The shallow expressions of the anomalies on Tak 1 and 4 (Fig. 8a, b) are consistent with surface mineralization. The new anomaly outside of Tak 1 (Fig. 8c) shows also shallow sources indicating that the anomaly source is not deep. First vertical derivative map of the outside of Tak 1 (Fig. 8c) gives an indication of the relative depth of the anomaly. This is important because this anomaly is not associated with surface mineralization.

Another common presentation of potential field data is the upward continued map. This function enhances deep and low frequency sources while diminishing the shallow features (Gunn, 1996). RTP maps of Tak 1 and 4 continued up to 50 m (Fig. 9a, b). The shallow features disappeared on these maps and a deep source is evident. The RTP map of outside of Tak 1 continued up to 90 m. A deep feature is apparent on this map. The continued map of Tak 1, 4 and outside of Tak 1 indicates that all anomalies are shallow.

CONCLUSION

The RTP map of Tak 1 revealed two anomalies on the western part of Tak 1 trending N, NE-S, SW. These anomalies coincide with the trend of the surface mineralization and the western old tunnel on Tak 1. Therefore magnetite along with mineralization confirms the source of these anomalies. Several anomalies were identified on the RTP map on the eastern part of Tak 1. The major one trend N-S and occurs over the eastern old tunnel of Tak 1. Consequently the source of all the anomalies on the eastern side of Tak 1 are also magnetite associated with mineralization. A single NW-SE anomaly is identified on the RTP map of Tak 4 which coincides with the surface mineralization on the trenches. The source of this anomaly is also magnetite along with mineralization. A triangle shape anomaly outside of Tak 1 was found on the RTP map. It is similar in magnitude to the anomalies on Tak 1 and 4 but associated with neither surface mineralization nor old tunnel. By analogy, the source of this anomaly is also magnetite along with mineralization. Since there is evidence of active fault on the eastern side of Tak 1 we believe that the source of this anomaly is also magnetite and it is part of the mineralization on Tak 1 which has been displaced from it by faulting.

Vertical gradient maps of Tak 1 and 4 reveal shallow features which correlate with surface mineralization. Vertical gradient map of the outside of Tak 1 also shows shallow sources but there is no surface mineralization. This means that the source of the anomaly is shallow.

Upward continued map of Tak 1 indicated that the shallow sources of the western anomalies disappeared at 50 m while the eastern ones persist to 90 m. The upward continued map of Tak 4 indicates the expression of the anomaly up to 100 m. Both vertical gradient and continued maps of the outside of Tak 1 reveal that the source of the anomaly extends from near surface to 100 m. The position of the anomaly of the outside of Tak 1 on the RTP map has priority order and proposed for drilling.

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