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Investigation of Iron Mineralization in Sourk Mineral Area Based on Geophysical Magnetic and Radiometric Data

Investigação de Mineralização de Ferro na Área Mineral de Sourk com Base em Dados Geofísicos Magnéticos e Radiométricos

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Abstract

The study area is located in the west of Yazd province, a part of the structural zone of Central Iran, adjacent to the Urumieh-Dokhtar magmatic arc and in the Dehshir fault zone. The rocks of this area include sandstone, limestone, ophiolite rocks, Eocene volcanic units and granodiorite and granitoid intrusions. The minerals that make up Sourk iron ore are magnetite and hematite, which are associated with minor minerals such as pyrite and epidote. In this study, airborne geophysical survey including magnetic and radiometric data and surface geophysical survey have been used to identify the exact anomaly location and approximate estimation of mineralization depth by Euler method and residual magnetic map. According to the airborne geophysical survey, an anomaly corresponding to the intrusion mass in the area was identified and based on the analysis of data with airborne and surface geophysical methods and its adaptation to the results of exploratory drillings, while identifying anomalous blocks, it was determined that these anomalies are separate lenses with different dimensions at depth of about 180 meters in form of several separate layers, and are covered by interlayers of skarn units.

Keywords: Geophysics; Sourk; Iron Skarn; Magnetometry; Radiometry.

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Resumo

A área de estudo está localizada a oeste da província de Yazd, parte da zona estrutural do Irã Central, adjacente ao arco magmático Urumieh-Dokhtar e na zona de falha Dehshir. As rochas desta área incluem arenito, calcário, rochas ofiolíticas, unidades vulcânicas do Eoceno e intrusões de granodiorito e granitóides. Os minerais que compõem o minério de ferro Sourk são magnetita e hematita, que estão associados a minerais menores, como pirita e epídoto. Neste estudo, levantamento geofísico aéreo incluindo dados magnéticos e radiométricos e levantamento geofísico de superfície foram usados para identificar a localização exata da anomalia e estimativa aproximada da profundidade de mineralização pelo método de Euler e mapa magnético residual. De acordo com o levantamento geofísico aerotransportado, foi identificada uma anomalia correspondente à massa de intrusão na área e com base na análise de dados com métodos geofísicos aerotransportados e de superfície e sua adaptação aos resultados das perfurações exploratórias, identificando blocos anômalos, determinou-se que essas anomalias são lentes separadas com diferentes dimensões em profundidade de cerca de 180 metros na forma de várias camadas separadas, e são cobertas por camadas intermediárias de unidades skarn.

Palavras-chave: Geofísica; Sourk; Skarn de Ferro; Magnetometria; Radiometria.

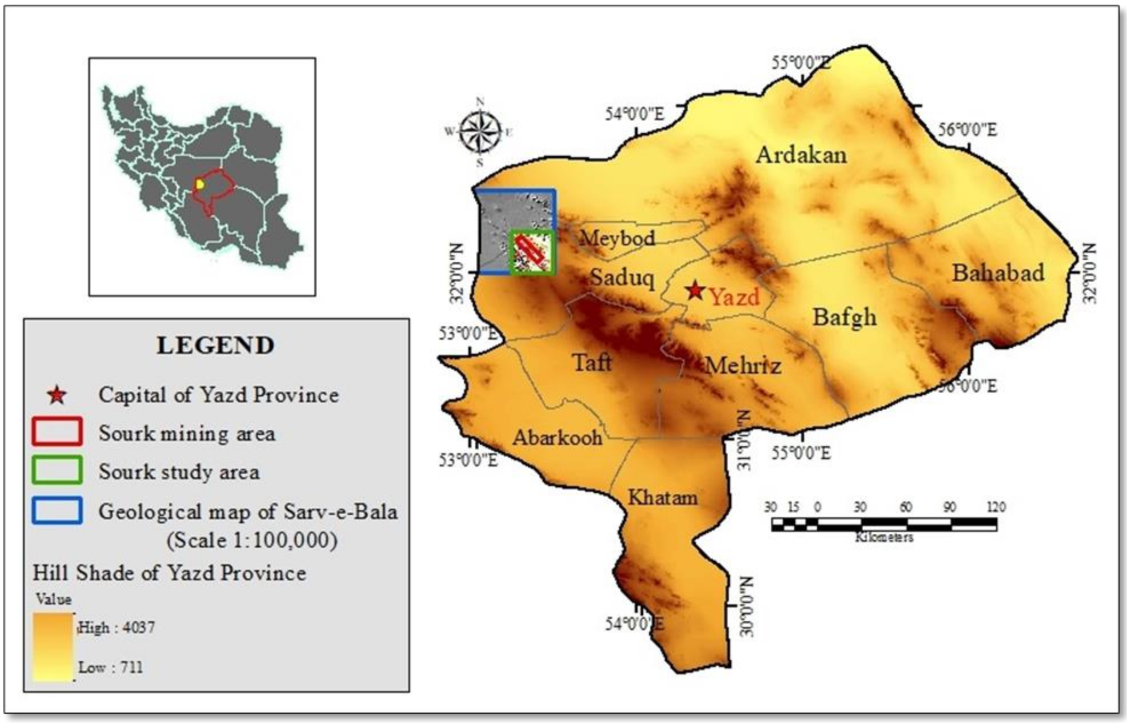
Introduction

Important applications of airborne geophysical surveys include the extraction of surface information and In-depth information. Surface information includes preparation of surface geological maps and revealing alteration zones (potassic). In-depth information includes revealing of deep and hidden structures as sites for mineralization and up rise of mineralization fluids, studies of bedrock and ultimately the exploration of minerals that are deep (especially hidden massive sulfide deposits) (Bolouki et al., 2007; Baratian et al. 2018; Bina et al. 2020; Yazdi et al. 2022).

Geophysical explorations by magnetic method are also one of the methods of geophysical studies that have long been used for exploration activities in various fields, especially the exploration of iron deposits (Hafez Darbani et al., 2020; Yazdi and sharifi teshnizi 2021). Principled logging and correct interpretation of surface magnetometry data along with other exploratory data can provide researchers with valuable information about the location, depth, and expansion of hidden sections of iron deposits while reducing costs (Robinson and Coruh, 1988; Gharib-Gorgani et al. 2017).

The study area is located in geographic coordinates longitude of 53° 16’ 26″ E to 53° 18’ 36″ E, and latitude of 32° 03’ 48″ N to 32° 12’ 03″ N, with an approximate area of 90 square kilometers in Yazd province and is located in the Central Iran zone. This area is part of geological quadrangle map of Nain (Scale 1:250,000) and geological map of Sarv-e-Bala (Scale 1:100,000). The exploration area is located in the west of the sedimentary structural zone of Central Iran based on the divisions of tectonic zones of Iran (Aghanabati, A., 2004; Alavi, M., 1991; Aghanabati, A., 1998; Angiolini et al., 2007; Nogolsadat, M. A. A., 1993; Nabavi, 1976; Stocklin, 1968; Eftekharnejad, J., 1980; Ramezani and Tucker, 2003; Hajalilou and Vusuq, 2009) Which is part of the Alpine-Himalayan orogenic belt and is located next to the Urumieh -Dokhtar magmatic arc (UDMA) in Dehshir fault zone (Figure 1).

Figure 1 - Geographical location of Sourk iron ore in the geography of Iran



Source: Authors (2021).

Geology of The Area

Sourk area is located in the structural zone of Central Iran and adjacent to the Urumieh - Dokhtar magmatic arc (UDMA), which causes various metallization including the occurrence of iron mineralization in this area, which is along the Dehshir fault zone on the border between the colored ophiolite complexes on the mentioned fault zone and volcanic and pyroclastic rocks of Eocene (Shafaii Moghadam et al, 2013).

The Rocks of this area can be divided into three categories (Figure 2):

1) Pre-Eocene sedimentary and igneous rocks with more severe folding and tectonics.

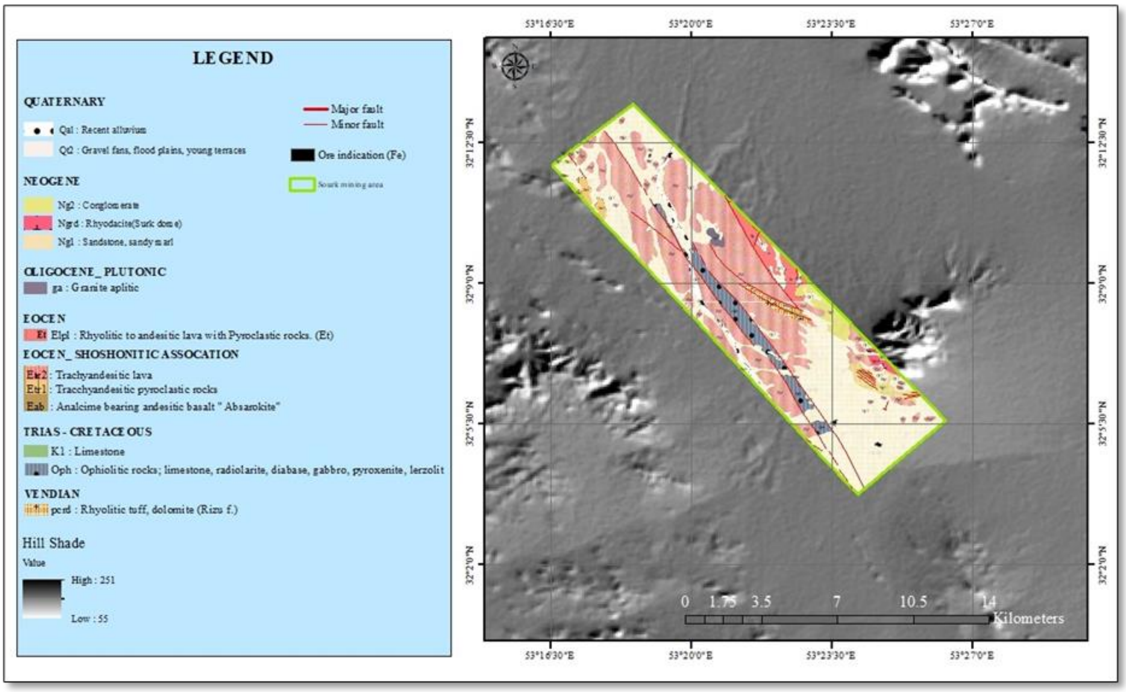
2) Sediment-volcanic rocks of Triassic with a gentle fold.

3) Ophiolite complex that is stretched as a narrow and overall strip.

Granitoid intrusions in Sourk which is part of the Cenozoic magmatism band of central Iran in northwestern Yazd, have caused skarns to occur with iron mineralization. Observation of texture relationships of minerals has shown that the formation of skarns has occurred in three different stages and therefore Sourk skarns can be considered as a polygenic skarn (Makizadeh, 2008). Sourk skarns have outcrops in the vicinity of the ophiolitic complex of Sourk (along the Dehshir zone) and granodiorite intrusive masses in volcanic rocks and pyroclastic sediments of Eocene period (host rock) have caused skarnization with iron ore (Makizadeh et al., 2007; Yazdi et al. 2019-a).

There are three main types of lithology in the Sourk study area, which include iron ore, iron skarns, and tuffs. The main ores of sourk mine are minerals such as magnetite, hematite and pyrite. The most important ore is magnetite with a maximum abundance of 70%. The presence of zonation in Sourk iron skarn is similar to contact metamorphism skarn deposits with magma emplacement, and the presence of garnet, pyroxene, epidote and magnetite is evidence to prove it (Reyhani et al., 2010; Yazdi et al. 2019-b; Jehangir Khan et al. 2021). Alteration of the region includes phyllic, propylitic, argillic, and the most common type is siliceous alteration (Yazd Steel Company Exploration Report, 2013).

Figure 2 - Geological map of Sourk study area based on geological map of Sarv-e-Bala (Scale 1:100000)



Source: Amidi and Nabavi (1989)

Methodology

In this study airborne geophysical survey including magnetic and radiometric data, and also surface geophysical studies are used; for airborne geophysical studies the data is logged by flight at altitude of 40 to 60 meters (mostly 40m of altitude) above surface and flight spacing of 250 meters. Tie lines spacing and direction is orthogonal to flight line direction with spacing ratio of 1:12 spacing relative to the flight lines. Control lines are logged at 10 to 1 ratio, which in this case makes the spacing of tie lines 3000 meters. The azimuth of flight lines is 45°.

After data logging and final processing, the obtained information is presented in the form of magnetic field and radiometric field intensity maps.

The resulting maps are interpreted separately and finally the information obtained from different methods is combined with each other and a combined map of the two methods, which includes the revealed anomalies, is plotted. Oasis Montaj software is used in the qualitative interpretation of airborne geophysical data. Based on the data obtained from initial and preliminary explorations, including the results obtained from the interpretation of magnetic and radiometric data, evidences of subsurface mineralization are revealed. Then, in order to further investigate and identify the subsurface anomalies revealed by airborne geophysics in the exploration area, additional magnetic studies were carried out by surface geophysical investigations.

For surface geophysical study the first step was picking the right distance between logging stations and this is primarily related to changes in surface geology and mineral outcrops and of course the results of already conducted airborne geophysical survey. In the early stages of exploration (general exploration), the distances of the profiles are considered to be large and approximately 50 to 100 meters, and the distances of the stations are half of this distance, ie varying between 25 and 50 meters. With the completion of the explorations and in proportion to the high accuracy required, the magnetometer sensor network also becomes more compact and usually a 10 × 20 network is used.

In the magnetic surveys of Sourk iron ore, according to the detailed exploration stage and also the use of airborne geophysics results, a 10 × 20 network was used to plan a regular network. However, in some areas due to the low magnetic intensities and the lack of significant signals, which was proven both by geological changes and in preliminary surveys, the network plan was expanded to the size of 20 × 40. The alluvium coverage over mineral is another factor that justifies the use planning to use a 10 × 20 network for logging. The extension of the profiles in this area is planned north-south.

The position of magnetometer stations was determined by GPS in the UTM coordinate system according to the European 1950 standard. The total magnetic intensity was measured by a proton magnetometer with an accuracy of 0.01 nanotesla.

A total of 32000 magnetic points were surveyed in this area. Processing and interpreting the data includes examining the magnitude of the total magnetic intensity of the region and examining the residual magnetic map. Mineral depth was estimated by using Euler Deconvolution methods.

For this purpose two specialized softwares, Geosoft (Oasis Montaj. V8) and Model Vision Pro (Encom), have been used. Finally network of exploration drilling points for boreholes were proposed for this area based on the geophysical study results to confirm the anomalies found by geophysical studies quantitatively and qualitatively.

Discussion and Results

Interpretation of Airborne Magnetic Surveyed Data

The principles of geophysics in magnetic method are based on the changes of magnetic susceptibility of rocks and minerals, which is used to determine the dispersion of magnetic minerals and consequent changes in lithology (Armstrong and Rodegheiro, 2006). Magnetometry is the most ideal geophysical method for direct exploration of magnetite and hematite iron deposits (Heidarian Shahri, 2005; Zomorodian and Hajeb Hosseinieh, 1989; Dobrin and Savit, 1998; and Donohue and Brewster, 2012). Because the metasomatism of dolomitic rocks causes formation of abundant magnetite, in magnesium skarns strong magnetic signs will cause detection of the deposit presence. (Chermeninov, 1988).

Rocks have a residual magnetic property, which is related to the place where they formed in the past. Magnetic residual properties of magnetic minerals, such as magnetite, record the direction of the magnetic field and the size of the field at the time of rock formation. By measuring the angles of deviation (relative to the north of the geographical field) and inclination (relative to the horizon) of the residual magnetic field of rocks, one can identify the latitude and orientation relative to the north of the place where a rock was formed.

The use of geophysical methods such as magnetic method, gamma ray spectrometry and gravimetry provide important information for identifying and tracing minerals in depth and selecting suitable sites for exploration (Richardson et al, 2002).

Magnetic method is the oldest and most widely used method in geophysical exploration (Nabighian et al., 2005) used to locate hidden deposits. Magnetometric method examines changes in the Earth's magnetic field based on changes in the magnetic properties of rocks and minerals, and is able to detect hidden geological structures, altered areas and lithological changes. These data can also be used to identify intrusive masses that have no outcrops in aerial photographs and satellite images (Afzal et al., 2012).

Investigation of Total Magnetic Intensity Map

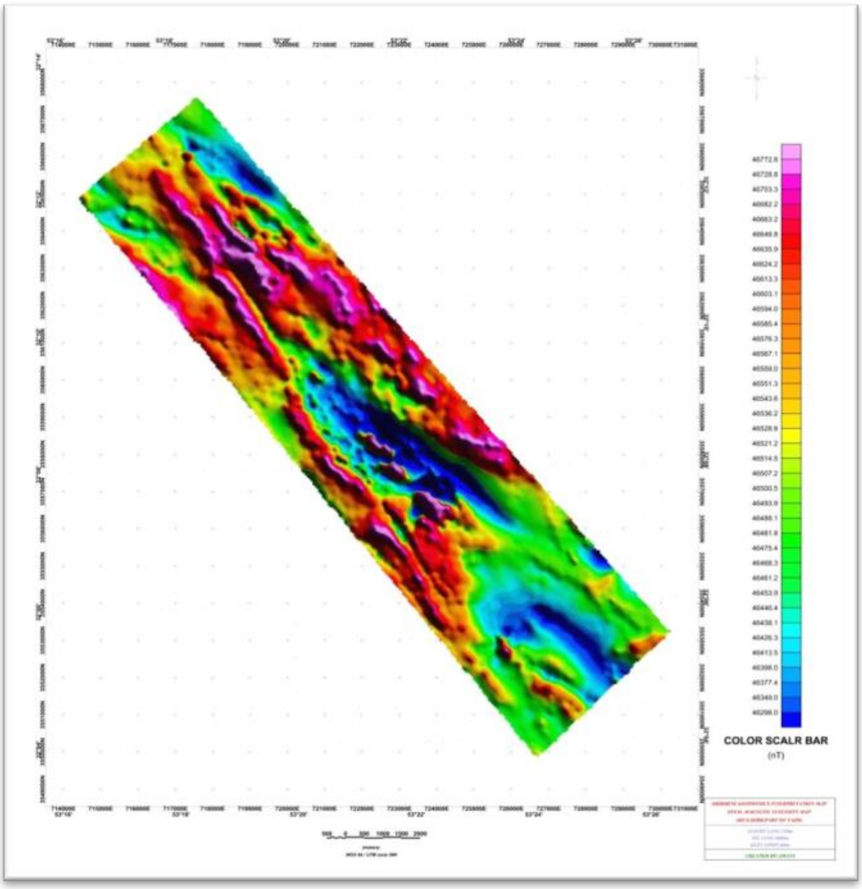
The colored total magnetic intensity map (Figure 3) provides an overview of the magnetic data and is used in the general interpretation (Heydarian Shahri, 2005).

This map is the magnetic data base map that shows the magnitude of the magnetic field of earth at the measuring points. The total magnetic intensity at any point is affected by the magnetic materials and structures present at that point. The previously measured IGRF value of the land has been removed from the recorded data values and the remaining value is only for anomalies in the area. Considering the angle of inclination and magnetic deflection of the earth, it is obvious that the source of these anomalies is not exactly below the measuring points and their shape may also change slightly (Yazdi, 2013).

The total magnetic intensity map provides an overview of magnetic data and is used for general interpretations (Liu and Mackey, 1998). In order to show the shape and anomalies' locations, colored total magnetic intensity map is used (Heydarian Shahri, 2005). In these maps, the shape of the anomaly depends on the color shown and can be used to compare the extent of the anomalies. In a color map, each intensity is indicated by a color, and usually low intensities are shown in blue and high intensities in red (Jaques et al., 1997).

Although color maps of magnetic intensity are visually desirable, they are merely a tool for quality control and they do not provide a realistic interpretation due to the earth's magnetic field inclination in accordance to the geographical location of the measuring points (Nabighian et al., 2005).

Figure 3 - Total Magnetic Intensity (TMI) map of the Sourk study area based on airborne geophysical survey.

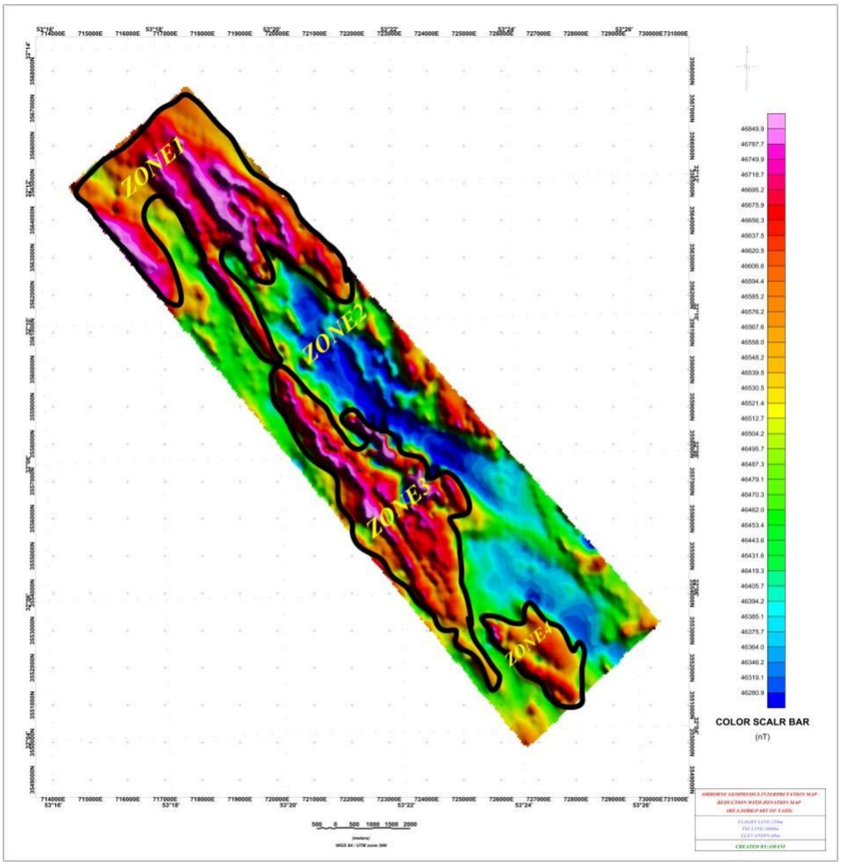


Source: Authors (2021).

According to the total magnetic intensity map (Figure 3) from the airborne geophysical survey for the study area, the highest recorded magnetic intensity is 522690 Nanotsela and the lowest magnetic intensity is 44533 Nanotsela and the average magnetic intensity is 46533 Nanotsela. The area is divided into four zones (Figure 4) according to magnetic intensities. In this research, the third zone that has the highest potential has been studied. A high magnetic intensity is recorded in this zone.

The reason for this is the existence of ophiolite units with more expansion than what is shown in the geological maps and these ophiolites are covered by volcanic flows and only parts of them are affected by two large and major bedrock faults and have appeared on surface in the form of Horst. The presence of extensive alterations here and the type of rock units and various structures in this zone make it one of the desirable zones in terms of mineralization and most of the identified anomalies are located in this area.

Figure 4 - Zoning map of the study area.



Source: Authors (2021).

Investigation of Upward Continuation Map

The upward continuation method is a type of filtering in which long wavelengths are detected and the effect of shallow masses and noise on the mapped data can be minimized without damaging the data. In this filter, the data can be fitted to any hypothetical horizontal level, in other words, it transfers the potential measured magnetic intensity at one level to another level, farther away from the source of the magnetic intensity.

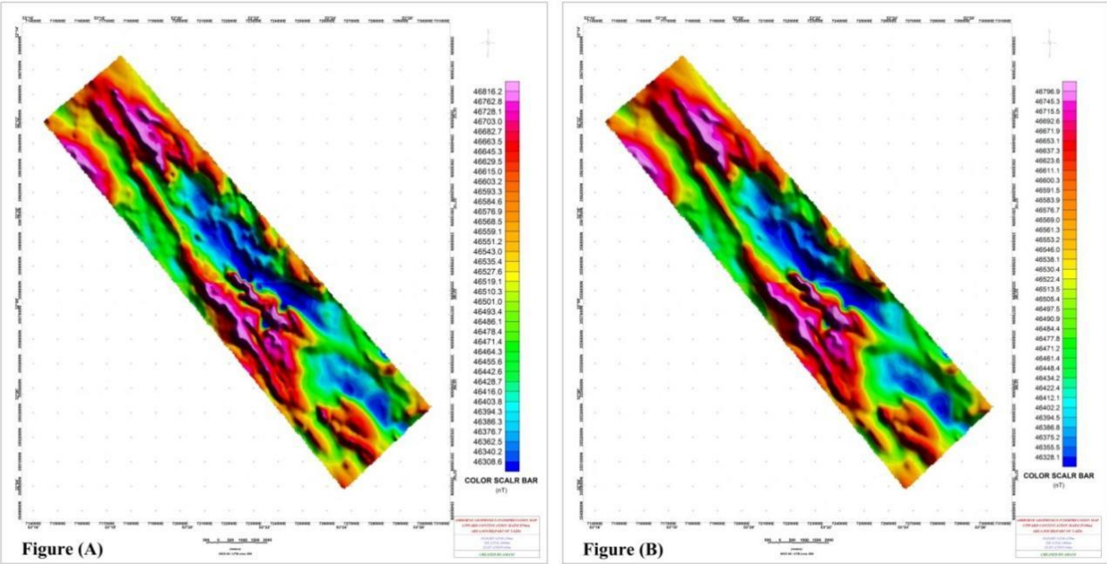
The upward continuation filter eliminates the effect of high-frequency surface anomalies, thereby better revealing the effect of deeper anomalies (Guun et al., 1997). By applying this filter, which is a low-pass filter, deep and long-wavelength anomalies remain and shallow and high-frequency anomalies are weakened or eliminated (Jacobsen, 1987). The upward continuation filter eliminates the effect of short-wavelength anomalies, weakens the domain of the anomaly, and reduces existing disturbances. Thus, this filter acts as a low-pass method (Tarlowski et al., 1997).

The upward continuation filter, in contrast to the vertical derivative filter, is designed to amplify deep-source anomalies and weaken surface anomalies (Blakely, 1996). The upward continuation method eliminates the effect of high-frequency surface anomalies and thus better reveals the effect of deeper anomalies (Ganiyu et al., 2012). This transition reduces the anomalies with respect to the wavelength, in other words, the shorter the wavelength, the greater the reduction (the smaller anomalies become weaker).

First, as can be seen in the upward continuation maps (Figure 5 and Figure 6), the effects of ophiolite massifs can be seen even up to a depth of 1000 meters, which indicates that these massifs originated from great depths, which are located under the alluvium and surface lava flows.

Secondly, the effects of the main faults in the region can be seen throughout the upward continuation map, which shows these faults are very deep and it can be said that these faults are bedrock faults that have caused vertical lithospheric fractures.

Figure 5 - (A) upward continuation filter (50 meters) in the study area, (B) upward continuation filter (100 meters) in the study area.



Source: Authors (2021).

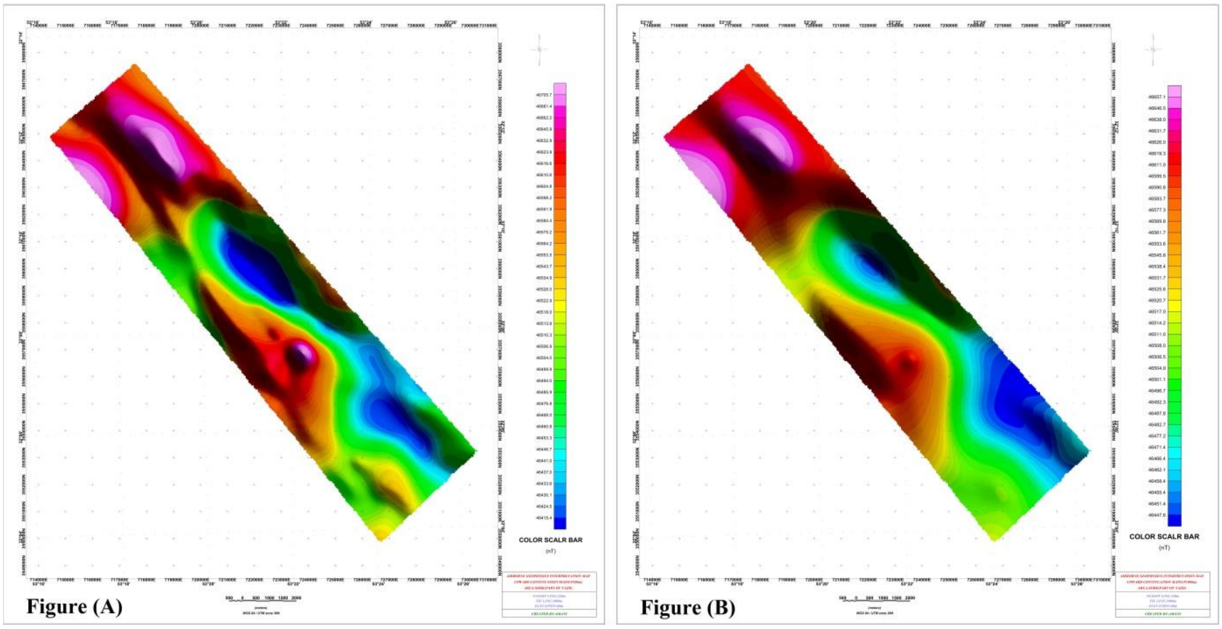
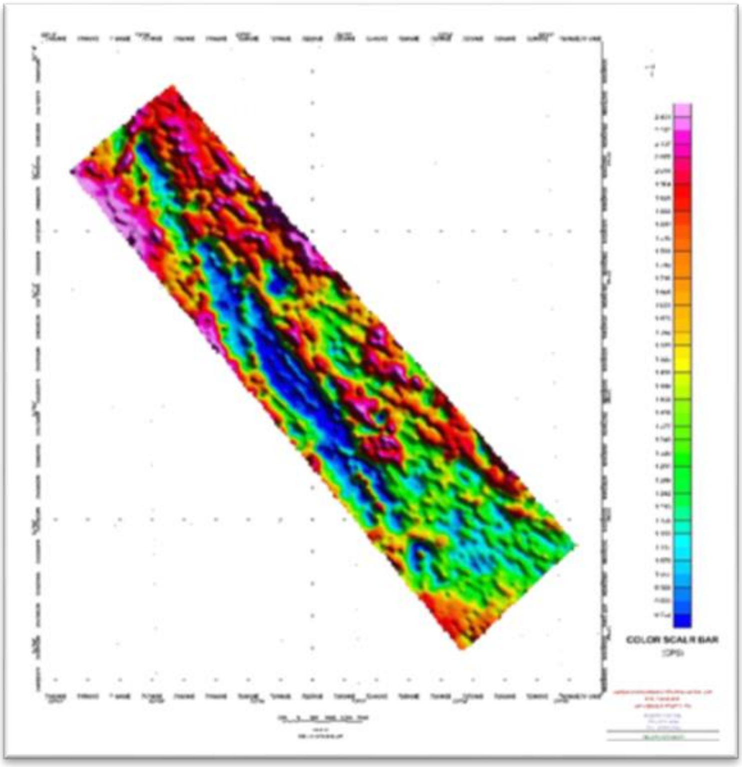


Figure 6. (A) upward continuation filter (500 meters) in the study area, (B) upward continuation filter (1000 meters) in the study área.
Source: Authors (2021).

Interpretation of Airborne Radiometric Surveyed Data

One of the geophysical methods surveyed by the system in use is radiometric or spectrometric method which includes potassium (K) data. The values of this data are in terms of the number of signals recorded per second by the spectrometer. Airborne gamma ray spectroscopy has been used for many years to directly determine mineral ores and as a tool for lithology mapping (Rezaei Azad et al., 2010). Based on this, geological units and altered areas can be distinguished from each other due to their special radioactive properties (Figure 7).

Figure 7 - Map of potassium dispersion in the study área.



Source: Authors (2021).

Interpretation Results Of Airborne Geophysical Survey

Achieving a proper interpretation is related to many factors, the most important of which are geology and scale of the survey. To quantitatively and qualitatively calculate anomalies, it is necessary to make simple hypotheses about their source, because little is known about their geology, mineral status, and structural phenomena (Billings et al., 2006). For this purpose, filters are applied to the collected data in order to achieve the desired results with the least possible error. Of course, none of these filtering operations completely separate desirable anomalies from undesirable ones.

In order to study the geophysical maps more precisely and to interpret the results, various filters must be applied to the data and the resulting maps to be created for the study area (Guo et al., 2012).

According to the maps of shallow magnetic units, three magnetic anomaly zones were observed in the center of Zone Three, and one of these anomalies is very much in line with the map of intrusive masses in this section.

By reviewing the map of high potassium ranges which can be strongly related to high alteration sections, it can be seen that the magnetic anomaly sections are exactly associated with these alterations.

This zone shows the high magnetic intensity, and this is because the ophiolite units are probably much more extended than what is shown in the geological map and these ophiolites are covered by the volcanic flows mentioned, and only the parts of them that are affected by the two large and major bedrock faults have appeared as a Horst on the surface.

The presence of extensive alterations here and the type of rock units and numerous structures in the Zone 3, introduces this zone as one of the good zones compared to other zones in terms of mineralization, and the most anomalous areas identified are located in this area.

Interpretation of Surface Geophysical Study Data For Verification of Airborne Results

Investigation of Total Magnetic Intensity Map

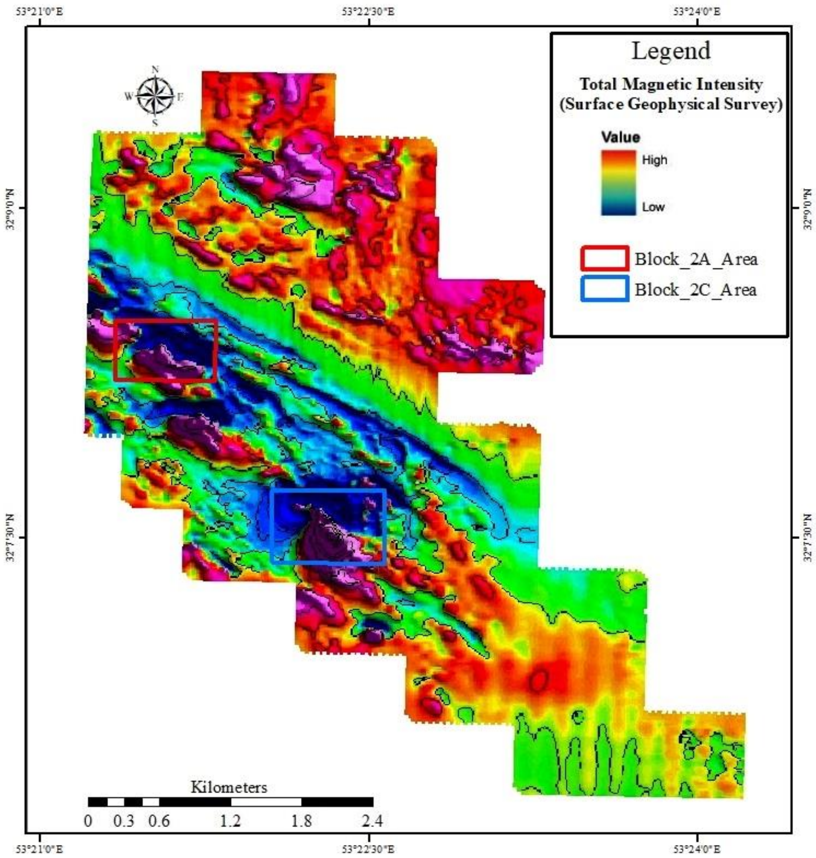
Figure 8 shows total magnetic intensity map of the Sourk area obtained from the collected data of surface geophysical survey. The purpose of the map is to furthermore study the status and trends of magnetic intensity in the area.

From south to north in the total magnetic intensity map, the followings are significant:

A) Southern Zone: In the south of the surveyed area and from the longitudinal coordinates of 724000, total magnetic intensities are approximately higher than the amount of the Earth's magnetic intensity. In this part, we see a high-intensity magnetic zone, which is shown in the map with the northwest-southeast trend.

B) Middle Zone: After the mentioned Southern Zone and in the middle parts of the region, we see a decrease in magnetic intensity values. In other words, there is a low-intensity magnetic zone in this part. If we look closely at the total magnetic intensity map, these two zones can be considered as two zones that form a throughout dipole. The lines around this zone to the east and west also show the same amount of magnetic irregularities. This zone is marked in blue on the map. The prevailing trend in this zone is northwest-southeast. In general, in this map a bipolar magnetic zone is visible from the northwest corner to the southeast corner of the surveyed area. As expected, the negative pole of this dipole is located at the top of the positive pole.

Figure 8 - Total Magnetic Intensity (TMI) map of the Sourk study area based on surface geophysical data.



Source: Authors (2021).

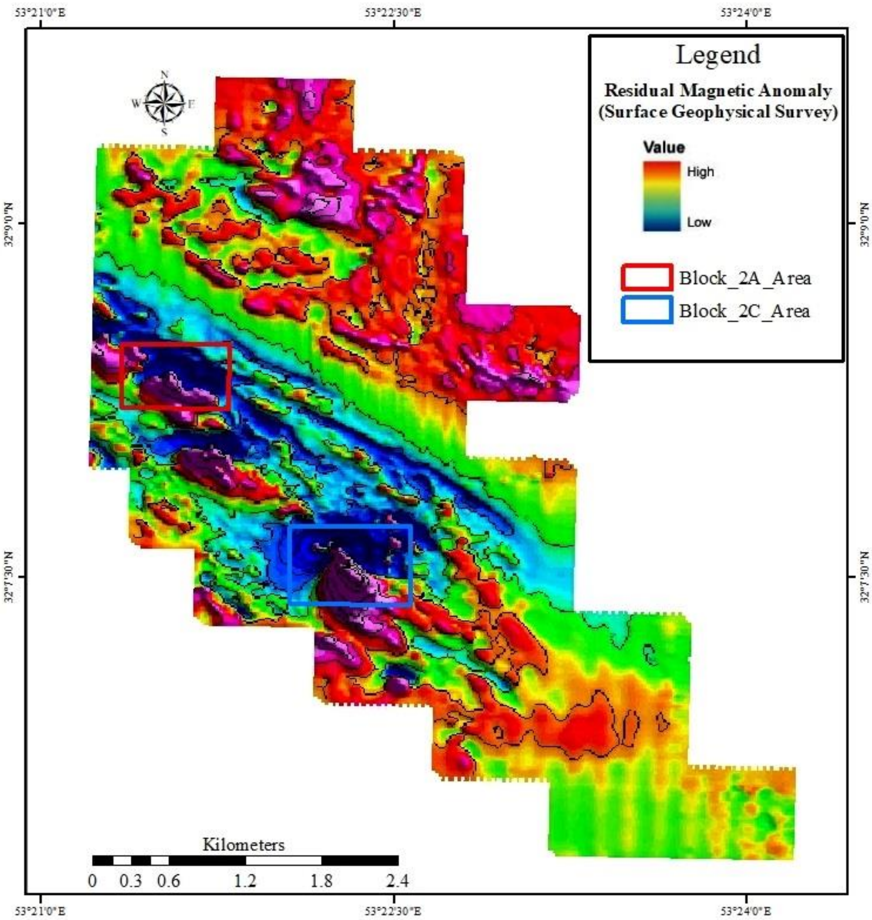
Investigation of Residual Magnetic Map

Magnetic anomalies can be interpreted as structural anomalies or mineral deposit anomalies (Enjil Ela, 2013). Detected anomalies can be divided into regional anomalies (large-scale and deep structures) and residual anomalies (related to near-surface and small structures). A residual anomaly is the result of subtracting a regional anomaly from the whole detected anomaly (Pitcher, 1994). The residual magnetic map of the study area is shown in Figure 9. There is a lot of artificial noise in this area due to the existence of active extraction workshops as well as mining machines. In addition, the presence of placer layers of iron in the study area has disarranged the results. The following items can be identified in this map:

A) South Bipolar: This dipole has a northwest- southeast trend. The mentioned zone corresponds to the 2C extraction block marked on the maps. The positive and negative poles of this dipole are shown in red and blue, respectively. In the eastern part of the dipole, the amount of residual magnetic intensity decreases. It can be said that this dipole is the largest magnetic dipole in this map. In the southern part of this dipole, a smaller local dipole is also seen, which seems to be due to the outcrop of the mineral.

B) Central dipole: Central dipole is in the longitude coordinates 723060 to 722360. The dipole is in line with the southern dipole. In the southern part of this dipole, a positive magnetic zone with a circular pattern can be seen.

Figure 9 - Residual magnetic anomaly map.



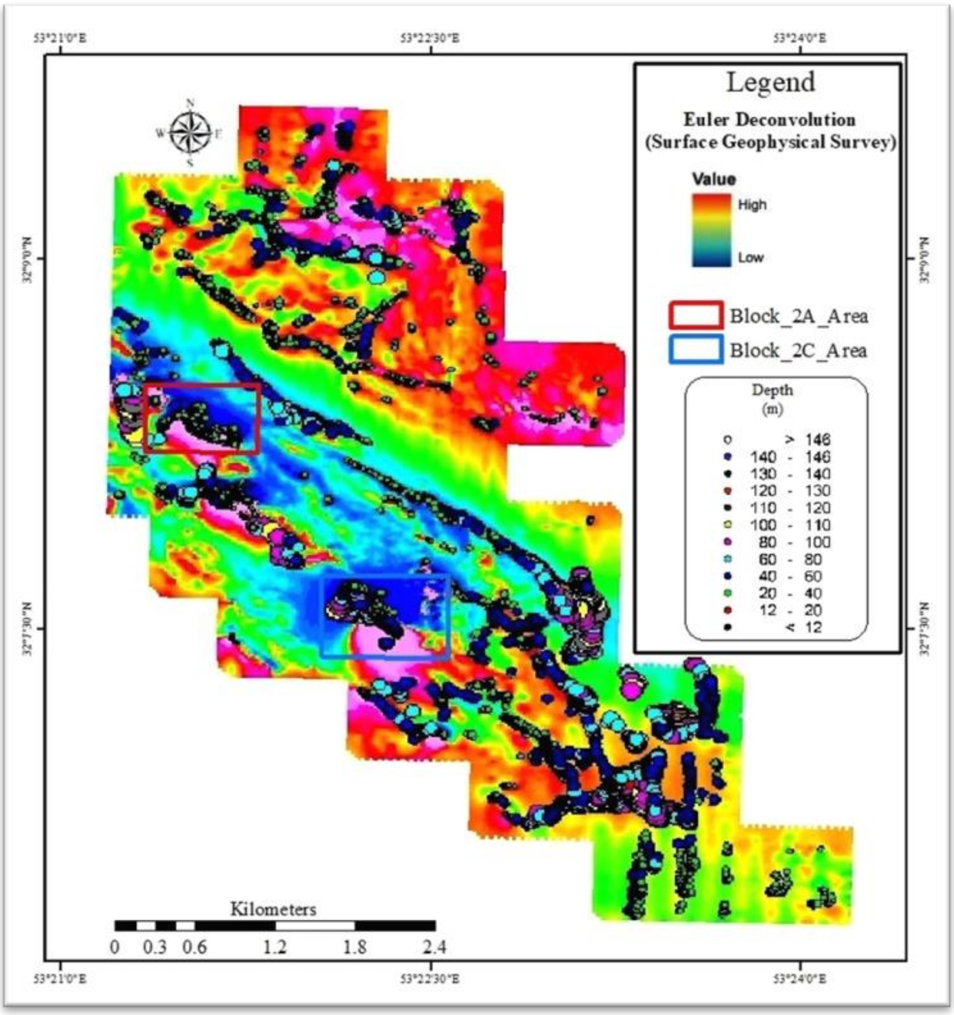
Source: Authors (2021).

Depth Estimation by Euler Deconvolution

The Euler deconvolution method is used to estimate the depth of mineralization at any point (Thompson, 1982). Euler method is one of the methods that can be used to determine the approximate depth of magnetic anomalies (Masoumi et al., 2017).

The result of Euler method is shown in Figure 10. The point to be noted is that this method determines the depth of all anomalies in the map, not a specific anomaly; On the other hand, each anomaly itself is shown with several points that these points confirm each other according to the type of structural index so that the depth of the anomaly is reliable. That's why the map is covered with so many points on it. In Figure 10, the depths obtained from the Euler method are plotted on the residual magnetic map, and according to the results of this method, in the anomalous zone of block 2C of Sourk iron mine, the average depth of the mass is estimated between 10 to 250 meters.

Figure 10 - Results of depth estimation by Euler method with structural index.



Source: Authors (2021).

Exploratory Boreholes Drilling

The planning of Sourk iron ore mine exploratory boreholes network (Figure 11 and Figure 12) has been done based on geophysical studies and geological features of the deposit. According to geological and geophysical studies, the dimensions of the initial drilling network for blocks 2A and 2C were considered 50×50 meters. With the start of drilling and analysis of the results of each borehole, in some cases, the dimensions of the drilling network were changed and its dimensions reached about 25×25 meters. Obviously, due to the changing conditions of the mineral, the

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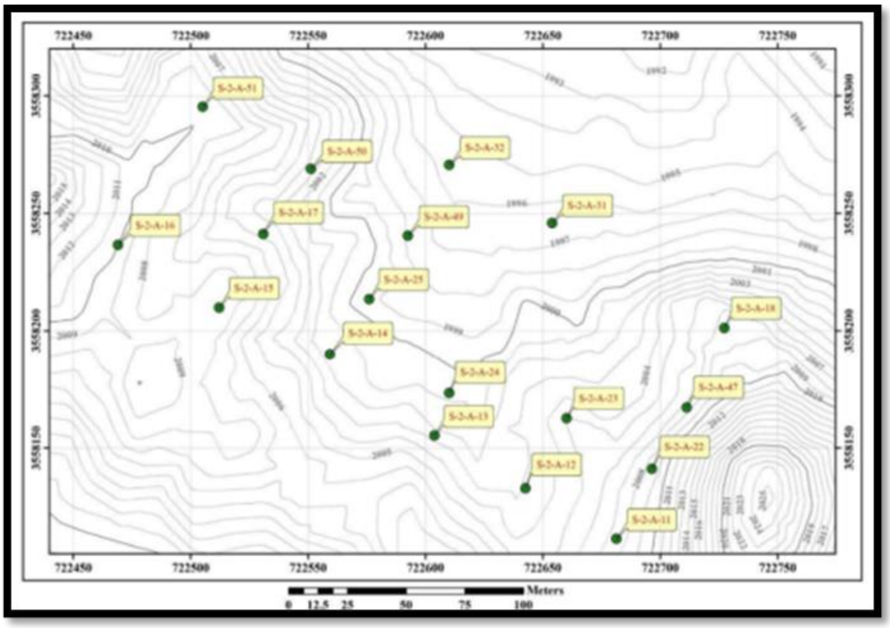
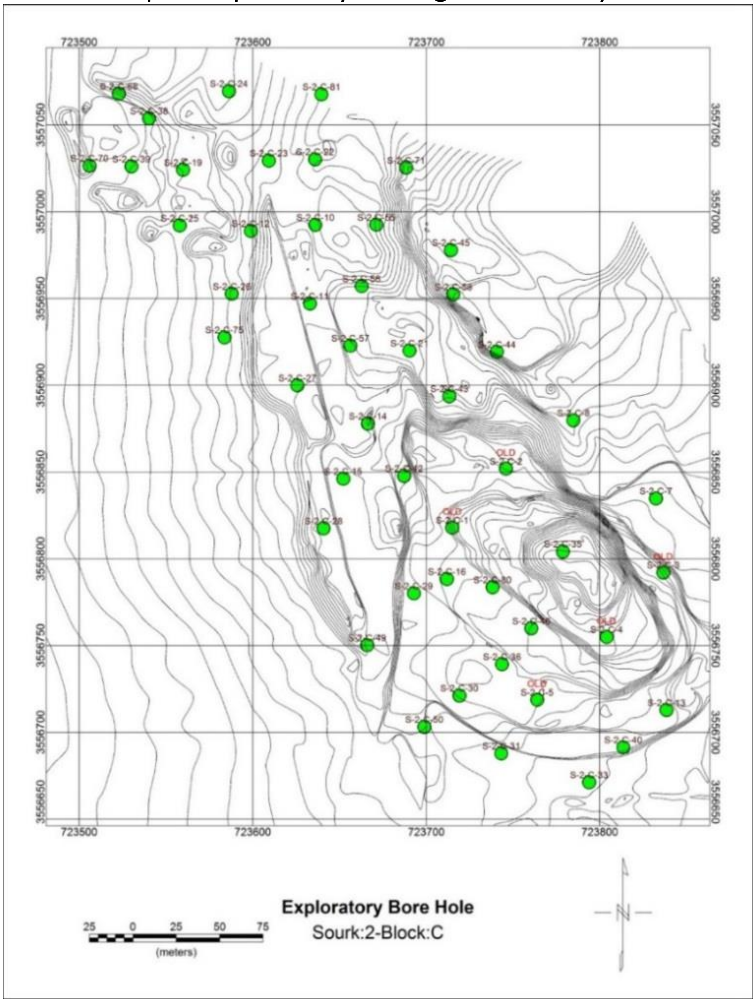
designed drilling network was out of order in some situations and it should be noted that in areas where the mineral has outcrop, the distance of the boreholes is more than 50 meters.

Figure 11 - Distribution map of exploratory drillings in anomaly 2A of Sourk iron ore mine.



Source: Authors (2021).

Figure 12 - Distribution map of exploratory drillings in anomaly 2C of Sourk iron ore mine.



Source: Authors (2021).

<u>Subsurface Geological Studies by Borehole Logplots</u>

Table 1 and Table 2 show the logged information of blocks 2A and 2C boreholes on average, which includes lithological information, depth, thickness of mineral-containing layers, and grade of iron samples. After standardization operations, sampling operations were performed on these parts in order to assay grade and determine the specific gravity of the ore-bearing sections. The logic of sampling is overshadowed by two theoretical foundations of geochemistry, namely accuracy and validity. Accordingly, accuracy means the ability to repeat the experiment with similar results and validity means that the test result is close to the actual value.

Anomaly	**2A**	**Low grade iron ore (magnetite)**	**ASSAY (Average)**
Total Thickness(M) (Average)	DEPTH(M) (Average)	DESCRIPTION	Fe TOTAL
3.78	80	-with low sulfide (pyrite) in skarnified host rock - with low sulfide (pyrite) in skarn bear host rock -with low sulfide (pyrite) in skarn bear host rock in crushed zone - with low sulfide (pyrite) in a epidote - garnet rich skarnified host rock	23.66
Anomaly	**2A**	**Medium grade iron ore (magnetite)**	**ASSAY (Average)**
Total Thickness(M) (Average)	DEPTH(M) (Average)	DESCRIPTION	Fe TOTAL
4.83	73.65	-with high sulfide (pyrite) -with low sulfide (pyrite) in skarn bear host rock -with high sulfide (pyrite) in crushed zone	33.19
Anomaly	**2A**	**High grade iron ore (magnetite)**	**ASSAY (Average)**
Total Thickness(M) (Average)	DEPTH(M) (Average)	DESCRIPTION	Fe TOTAL
5	70.85	-with high sulfide (pyrite) -with low sulfide (pyrite) -with high sulfide (pyrite) in crushed zone	47.87 (Top average: 60.76)

Table 1 - Average information obtained from borehole LogPlots of block 2A in Sourk iron ore mine. Source: Authors (2021).

Anomaly	**2C**	**Low grade iron ore (magnetite)**	**ASSAY (Average)**
Total(Thickness)(Average)	DEPTH(M) (Average)	DESCRIPTION	Fe TOTAL

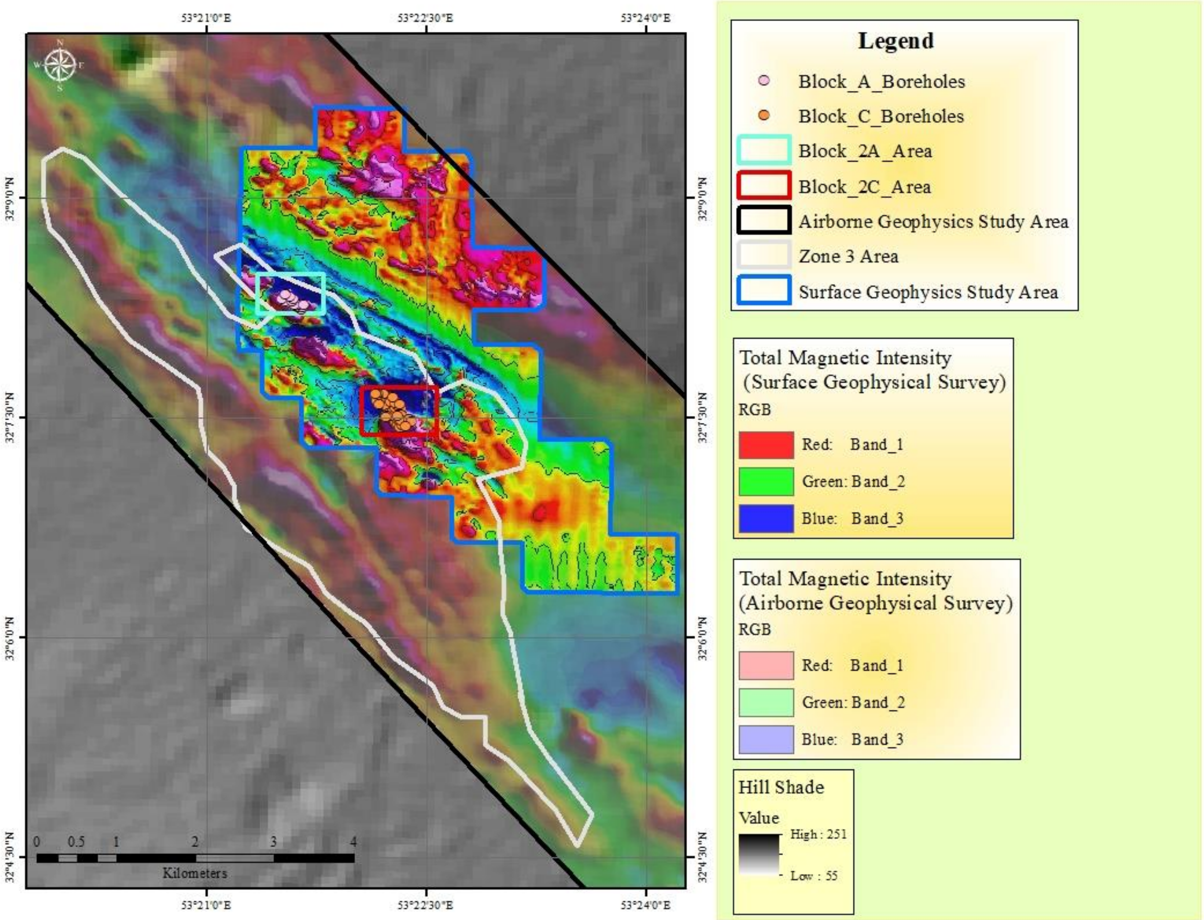
Anomaly	2C	Low grade iron ore (magnetite)	ASSAY (Average)
3.62	99.45	- with low sulfide (pyrite) in a skarn bear host rock - with high sulfide (pyrite) in a skarn bear host rock - with low sulfide (pyrite) in skarn bear host rock in crushed zone	22.35
Anomaly	**2C**	**Medium grade iron ore (magnetite)**	**ASSAY (Average)**
Total(Thickness)(Average)	DEPTH(M) (Average)	DESCRIPTION	Fe TOTAL
4.36	91.10	- with low sulfide (pyrite) in a skarn bear host rock - with low sulfide (pyrite) in a skarn bear host rock in crushed zone - with high sulfide (pyrite) in a skarn bear host rock	39.50
Anomaly	**2C**	**High grade iron ore (magnetite)**	**ASSAY (Average)**
Total(Thickness)(Average)	DEPTH(M) (Average)	DESCRIPTION	Fe TOTAL
8.43	99.34	- with low sulfide (pyrite) , fine grained crystals -with low sulfide (pyrite) -with low sulfide (pyrite) , fine grained crystals in crushed zone	53.75 (Top average: 71.29)

Table 2 - Average information obtained from borehole LogPlots of block 2C in Sourk iron ore mine. Source: Authors (2021).

Conclusions

A noteworthy point in this study is that airborne geophysical survey with suitable survey and data quality like what was used in this study (flight lines at altitude of 40 to 60 meters above surface with flight line spacing of 250 meters) is a very reliable method, especially for exploration in large areas since it is faster and a lot more cost effective method compared to surface geophysical survey and exploratory drillings to cover a large area. As shown in Figure 13, by overlaying the results of airborne geophysical survey and surface geophysical survey and exploratory drillings it can be noted that the accuracy of airborne geophysical survey results is evident and the results of surface geophysics and exploratory drillings confirmed it very well in this study.

Figure 13 - Map of overlayed results from the three studied methods of Airborne Geophysical Survey, Surface Geophysical Survey and Boreholes Log Plotting.



Source: Authors (2021).

According to the results obtained from geophysical surveys in the region, especially blocks 2A and 2C in Sourk mining area, it seems that most anomalies have depths of about 40 to 60 meters and extend separately in the direction of northwest-southeast fault of this area. In the upward continuation method estimations, the anomalies observed in the area have continued to depth of 180 meters, which has been proven in most of the boreholes drilled in these areas.

Furthermore, according to the studies and by the adaptation of the drilled borehole results of blocks 2A and 2C, these anomalies are seen as separate lenses with different dimensions and an approximate depth of 180 meters as separate layers from the surface, covered with interlayers of skarn units.

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