Geoelectrical Explorations in the Graphite Deposit :a Case History at Khenadareh-Bala (Arak)

Maryam Sadri[i]; H.R. Ramazi[ii]

ABSTRACT

Geoelectrical surveys were carried out in Khenadareh-bala area, Sarband district, Markazi province, Iran for exploration of the graphite veins. In Sarband region, there are some potential areas for graphite mineralization, but most of them are not economical. Geoelectrical surveys were designed in Khenadareh-bala area based on the geological evidences and physical properties of graphite. At first, self-potential (SP) method was carried out along 10 N-S profiles with 2 m distance between measuring points. Then, mise-a-la-masse measurements were implemented over there. The prepared self-potential and equipotential maps confirm each other and prove the presence of graphite mineralization with north-northeast trend. After that, resistivity measurements were performed over the same profiles using dipole-dipole array (AB=MN=4 m) for more investigation of graphite distribution in the depth. The apparent resistivity pseudo sections indicate that the graphite veins (ρ<20 Ωm) are approximately extended to depth of 25 m where SP profile shows the amplitude about -200 mV. Some excavation such as exploratory pits, well, and trench dug in this surveying area, demonstrate that these veins are discontinuous, thin, and impure.

KEYWORDS

Graphite, self-potential (SP), mise-a-la-masse, electrical resistivity, dipole-dipole array.

1. INTRODUCTION

The Khenadareh-bala area locates on the Hendudar, Sarband region in southwest of Markazi province (Fig.1). There are five anomalous zones in this area: Khenadareh-bala, Khenadare-paeen, Vesmestan, Emamzadeh, Khomestan (Fig.2). The major feature of the Sarband regional geology located on the Sanandaj-Sirjan zone is mainly composed of metamorphic rocks. Since many decades geological structures have been studied because of the presence of many deposits and mines in this zone. The mineral localization is along the fractures of the bearing rocks and faults. Thickness of graphite veins exposed on the surface is increased in the Khenadareh-bala area. Also, some ancient excavations are seen in this region. Geological surveys with some exploratory pits and one trench were carried out to locate graphite veins (Ardeshiria et al ., 2001). Regarding the results of the analyzed samples taken from these excavations, Khenadareh-bala was chosen to study more. Electrical properties of the graphite and its differences with the metamorphic bearing rocks are the main factors that could be used to clearly distinguish these veins. Therefore, self-potential (SP), mise-a-la masse and electrical resistivity measurements were planed to practice in an area about 100x100 m.

2. GEOLOGICAL SETTING

Graphite deposits of Sarband in southwest of Markazi province in Iran locates in 49°25′ east and 33°56′ north. In this area, graphite veins with the thickness up to 30 cm have outcrops. This area is located in metalogenic state of Sanandaj-Sirjan. The special property of this state is the presence of the metamorphic rocks like schist, gneiss and marble. Geological setting of area has especially affected by magmatic activities of upper cretaceous. Nezamabad Malmir and Astaneh are two major igneous bodies. Granodiorite body of Nezamabad Malmir that has

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exposure as chain stocks with length of 45 to 60 km in western part of area has been caused to create the metamorphic contacts, andalusite schist and mineralization related to the pegmatite. The Astaneh granodiorite body has been seen in the northeastern part. This body has changed the morphology of metamorphic Hamedan green schist. There are four different formation types as following: 1- Sedimentary and metamorphic formations of Permian: That's the oldest formation

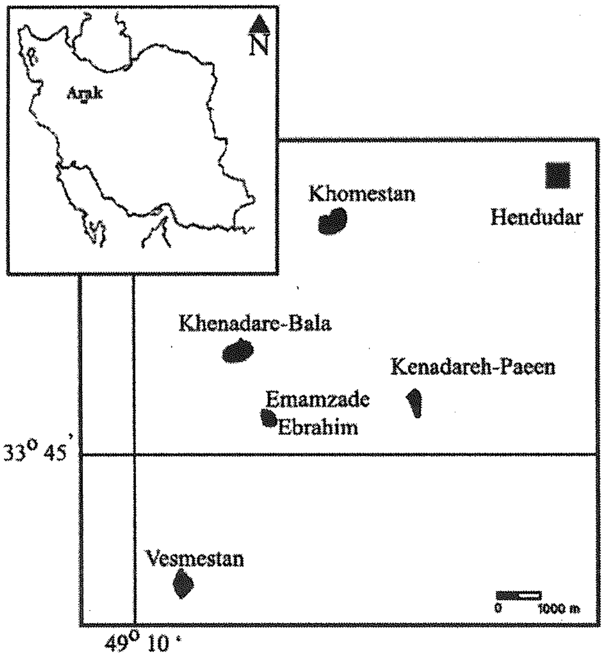


Figure 1: Location of graphite zones, Hendudar area, Arak district, Iran.

composed of metamorphic limestone, meta-quartzite and sandstone. The several quarry mines have been concentrated in metamorphic limestone zones. 2- Sedimentary and metamorphic formations of Jurassic: injection of two main metamorphic bodies caused to create metamorphic zones known as Hamedan green schist. The thermal gradient of region is suitable to generate slate and phyllite facies, but some quartzite veins have been injected inside them related to Cretaceous. These green phyllite and slates have covered the northwest, central and southwest parts as a broad band.

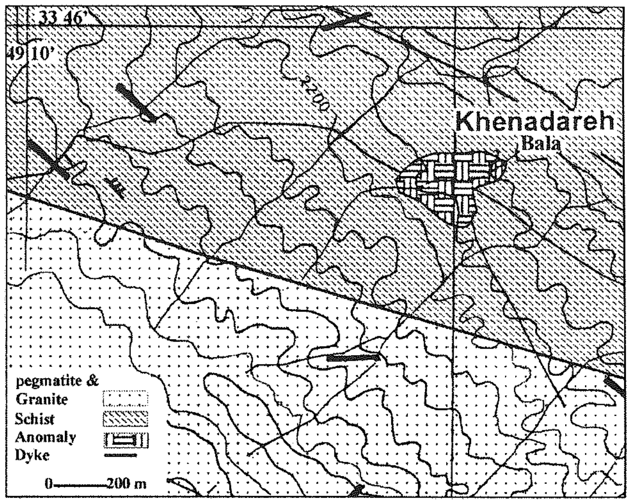


Figure 2: Geological location map for Khenadareh-bala area.

3- Rock units of Cretaceous: Cretaceous deposits have informed of limestone with northwest-southeast trends. This formation includes conglomerate and quartzite sandstone in lower and volcanic porphyry-andalusite in upper parts. It is overlaid by dolomite-sandstone and sandy limes. 4- Rock units of quaternary: These formations usually include river terrace deposits and river alluvial deposits. These deposits have been generally created by erosion of granite-arena or Jurassic schist [1].

During prospecting in Khenadareh-bala, sampling carried out from mineral outcrops. Some exploratory excavations such as five pits and one well with 7m depths were dug in vicinity of geophysical profiles. Two graphite veins co-oriented with schist layers were appeared in the well (Fig.3). In addition, one trench with length of 16m was dug in western part of the area, but no perceptible veins were observed. Therefore, geophysical techniques were used to explore graphite veins in the surveying area. Location of excavation points is shown in Fig.4.

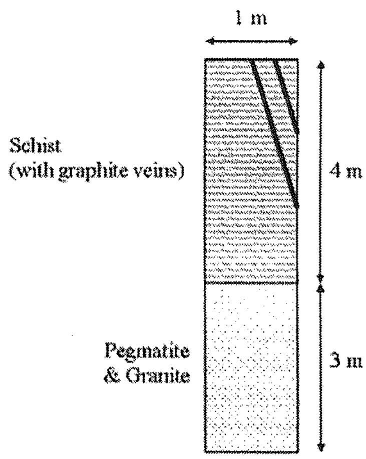
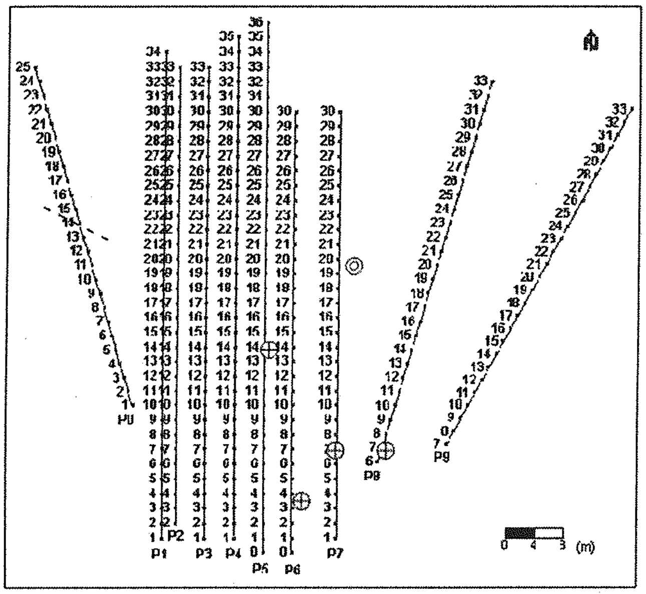


Figure 3: Stratigraphy derived from well. (after Ardeshirian et al., 2001.)

3. GEOPHYSICAL METHODS

High difference in electrical resistivity between graphite with its bearing rocks and self-potential anomaly produced over graphite are good discrimination factors to use geoelectrical methods for investigation of Khenadareh-bala deposit. Therefore, self-potential (SP), mise-a-la masse and electrical resistivity measurements were carried out along 10 N-S strike profiles. Position of geophysical survey lines in the Khenadareh-bala site is shown in Fig.4. According to veins exposure, distance between profiles was changed. Some profiles were crossed the graphite outcrops.



◎: well; ⊕: pit; `\`: trench; * : recording point

Figure 4: Geophysical profiles and measuring points of SP and potential.

First of all, SP and mise-a-la masse measurements were done to examine the veins distribution. Then, electrical resistivity surveying with dipole-dipole array was used along the same profiles to investigate more details.

A. SP measurement

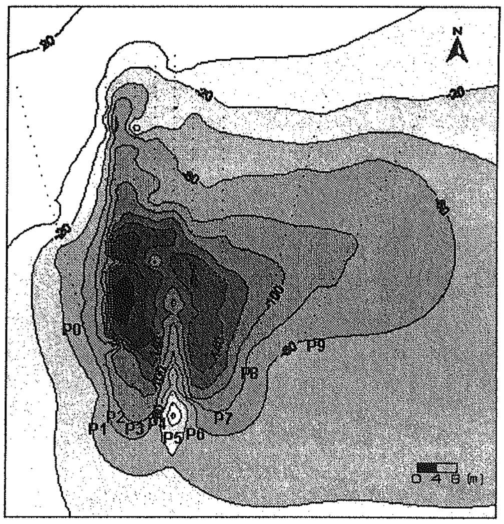
The SP method is based on measuring the natural potential differences which generally exist between two points on the ground. Robert Fox (1815) discovered that certain minerals exhibit spontaneous polarization. The most reasonable and complete theory of mineralization potentials is that proposed by Sato and Mooney in 1960. Graphite mineralization causes a significant spontaneous electrical polarization. Ground water flows generally help to oxidize graphite and produce self-potential around the graphite veins.

Self-potential measurements enable us to determine the extension of mineralization. So, it was arranged to survey SP measurements along 10 profiles (Fig.4). Distance between surveying points was 2 m. One potential electrode was placed at a distant point and the other one was moved along the surveying lines for measuring the SP value. The result was shown as a self-potential map (Fig.5a). According to the graphite outcrops, SP anomaly with magnitude of -220 mV extends over the low resistivity zone and SP values less than -120 mV show the region of graphite veins distribution. Self-potential contours are closed to the west. This proves that there is no mineralization in western part. It would be recognized that veins orientation is toward the north-northeast and it seems mineralization existence outside of SP anomaly is impossible.

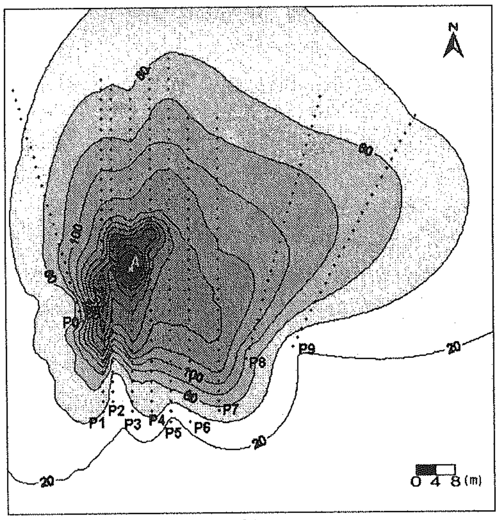
B. Mise-a-la masse measurements

As a consequence, surface indications of the presence and the geometrical extent of the ore body are generally weak. The mise-a-la masse method utilizes a current electrode placed in the mineralized zone with the second electrode placed a large distance away from the source on the surface. This method was first attempted by Schlumberger in 1920. Only very limited case histories are available for this method.

The mise-a-la masse measurements were carried out over the same SP profiles (Fig.4). In this surveying, one current electrode was connected to the graphite vein at an approximate depth of 2 m below the ground surface (point A in Fig.5b) and the other current electrode B was located at far distance from fixed electrode.



(a)



(b)

Figure 5: Geophysical profiles and measuring points of SP and potential. (~100: equipotential lines(mV); S4: station; xA: connected electrode; *: recording point.)

During the surveying, the reference potential electrode was kept on the opposite side of the fixed current electrode at a distant point from the surveying stations. Then, graphite vein was charged with electrode A by passing 168-172 mA (D.C) current. Finally, the potential values were measured by moving potential electrode. The equipotential map was prepared by acquired potential values (Fig.5b).

This map describes the extension of mineralization. Potential contours distort when they reach the electrical conductive inhomogeneous media. Density of contours on the western side shows that dip inclination of veins is toward the east-northeast. In Fig.5b, the areas with potential more than 140 mV are certainly related to the graphite veins. The results from equipotential map coincide with the self-potential map.

C. Resistivity measurements

It is well known that areas of low resistivity are usually produced by graphite. Therefore, electrical resistivity measurements were designed along each profile to investigate more details. These measurements were concentrated on the mineralization area.

The electrical resistivity surveying was done with dipole-dipole array (AB=MN=4 m), so that stations with 4 m distance were approximately located on the points where the SP and mise-a-la masse potential have been measured. The array coefficient (K) was calculated for each depth level, according to equation (1) following by:

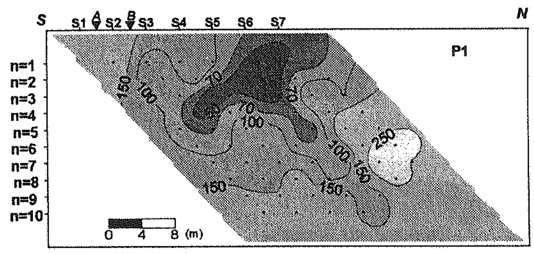
$$K = \pi . a . n . (n+1) . (n+2) \qquad n = 1,2,\ldots,15 \quad (AB = MN = a = 4m) \qquad (1).$$

Then, apparent resistivity (ρ) was determined in every point using following equation:

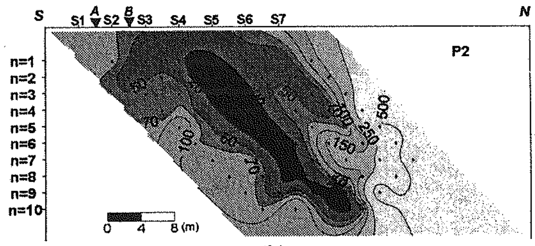
$$\rho = K \frac{\Delta V}{I} \qquad (2)$$

where, ΔV and I are the potential and current values, respectively.

Finally, the apparent resistivity values were shown as a resistivity pseudo sections along each profile. Fig.6a shows the resistivity pseudo section related to profile No. 1. Presence of water springs and clay mineral concentration in southern part of profile No.1 make deviate the contours on potential maps to the south. This also approved by reducing the electrical resistivity values over there. In Fig.6b, station No. S4 was placed on the graphite outcrop. This pseudo section indicates a zone that the resistivity value has been reduced to less than 20 ohm-m, whereas resistivity values in adjacent rocks such as schist have increased to 500-700 ohm-m. The graphite veins have caused this low resistivity zone and extended to the depth about 25 m. Also, low resistivity zones observed between S6 to S8 on the profile No.3 (Fig.6c) correlate with the anomalous parts in the SP and mise-a-la masse equipotential maps (Fig.5a,b). In Fig.6d, probability of mineralization in depths more that 30 m is impossible. The resistivity pseudo section in Fig.6e shows the earth model up to 35 m. The low resistivity zone between station No. S3 and S4 shown in Fig.6f are related to clay coverage in area. The well excavated in vicinity of profile No.6 approves this. Fig.6g indicates a sudden increase in resistivity values toward the north. The exploratory pits excavated in vicinity of this profile (Fig.4) approves that there is not any graphite zone. Also, the SP and equipotential maps show that graphite mineralization is mainly concentrated between profile No.1 and profile No.7. Resistivity pseudo section along profile No.8 shows that values more than 150 ohm-m belongs to the surrounding rocks (Fig.6h).



(a)



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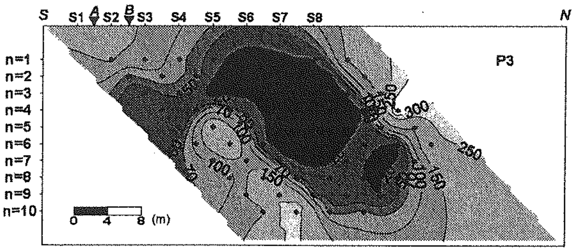

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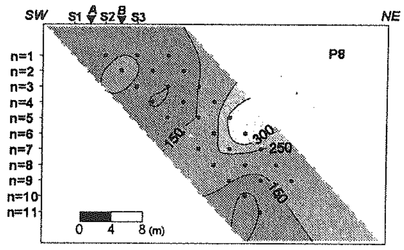

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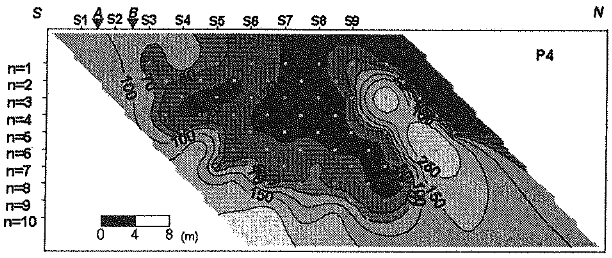

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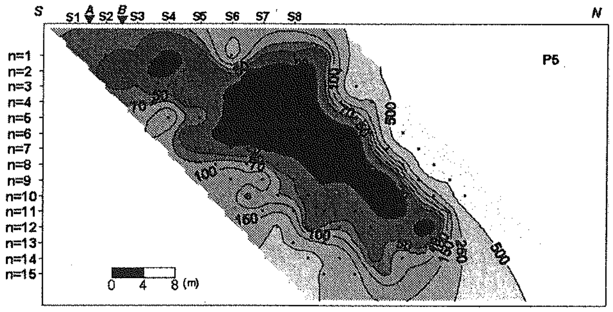

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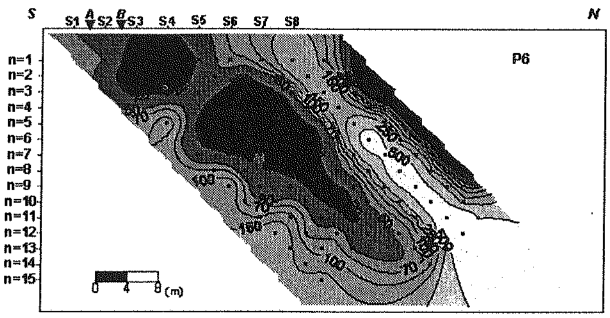

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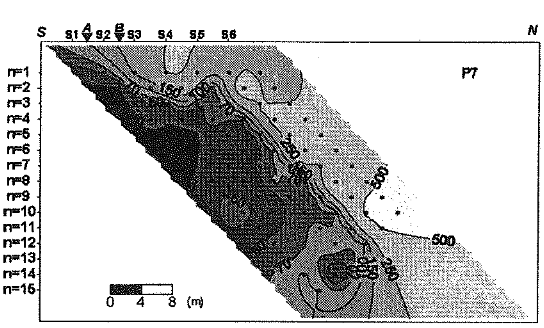

(g)

Figure 6: (a) Apparent resistivity pseudo section in Khenadareh-bala with an electrode spacing of 4 m, along profile No.1, (b) Profile No. 2, (c) profile No. 3, (d) profile No. 4, (e) profile No. 5, (f) profile No. 6, (g) profile No. 7 and (h) profile No. 8. (~50: apparent resistivity (ohm-m); S4: station; ▼: current electrode; *: recording point.)

As can be seen in Fig.7, the maximum value of the SP anomaly (~ -200 mV) is above the low resistivity zone (graphite outcrop). It appears that the dip of vein tends to the north. Perhaps, the presence of clay minerals has caused the variation on the SP profile.

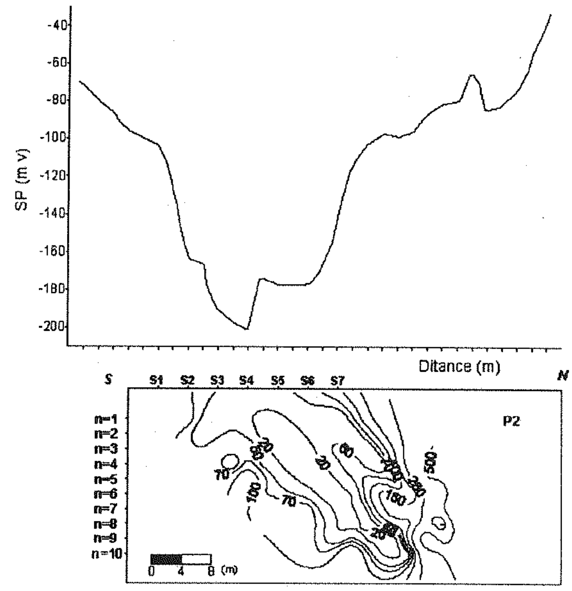

Figure 7: SP profile (a), and apparent resistivity pseudo section (b) along profile 2.

4. Conclusion

The Kenadareh-bala area where locates on the metalogenic state of Sanandaj-Sirjan includes metamorphic rocks, caused to create different deposits in this zone. Self-potential study indicates that the SP anomaly with magnitude of -220 mV over the graphite outcrops. It was considered that mineralization region has limited to maximum SP value of -120 mV. SP results oriented our study to the eastern parts and confirmed with mineralization margins specified by mise-a-la masse measurements. SP and mise-a-la masse maps indicate that main mineral concentration is between profile No.1 and No.7. Resistivity measurements carried out for detail investigation show that the presence of veins with electrical resistivity less than 20 ohm-m distributed up to 25 m depth.

In addition, presence of water springs and clay mineral-coverage near the surface cause artificial anomalies on the records. The same as geophysical results, some exploratory excavations such as pits, well, and trench dug in the surveying area demonstrate that these veins are discontinuous, thin, and impure.

5. ACKNOWLEDGMENT

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