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Statistical Analysis and Study of Heavy Minerals in the Bampour River in Iranshahr (Southeast of Iran)

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ABSTRACT

The study area located in the general geological division of Iran in the Nehbandan Khash zone. In the study area, there are no older rocks than the Cretaceous, so the oldest and youngest rock units in the region are related to Upper Cretaceous and Quaternary periods, respectively. In the study area, after identifying the rock units according to the region's geomagnetic status and factors such as river topography, tectonics, and alteration, 12 samples of the river bed were taken for heavy mineral studies. After data processing, numerous graphs and maps for minerals [magnetite, rutile, barite, zircon, amphibole, hematite and pyroxene, pyrite oxide, garnet, alumina minerals, Calcite] were drawn using GIS and SPSS software. The iron group has the highest correlation coefficient with the group of altered minerals and the basic rock group. The group of ore-bearing minerals has the highest correlation coefficient with Titanium and Carbonate groups. The group of altered minerals shows the highest positive correlation coefficient with the group of basic minerals. Titanic minerals have the highest positive correlation coefficient with the carbonate group and acidic minerals group. The carbonate mineral group shows the most positive correlation with acidic mineral groups. The only mineral of the magnetic element is magnetite, which covers more than 90 percent of the volume. In this phase, garnet is also known as semi-precious gemstone. In non-magnetic minerals, in sample No. 12, there were large amounts of Zircon minerals, and in sample No. 9, there were large amounts of Saphir minerals.

1 .Introduction

Rivers are ideal sedimentary environments for the study of heavy minerals. Using stream sediment sampling, it can be seen the type of heavy minerals [19]. The study of heavy minerals is one of the oldest methods of analysis in sedimentology. Heavy minerals are used to determine the origin of sediments, the development of networks and branches of rivers, and the adaptation of layers and stratigraphic linkages [4].

Industrial and mining activities release heavy and toxic metals into the environment and endanger the life of ecosystems and human health. Natural phenomena such as alteration, weathering, and erosion in mineral potential areas can also have destructive effects on the environment and pollute water and soil

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resources [5]. Heavy minerals are significant constituents of clay, Fe and Al oxides and are critical combinations of entire sorts of soils [18]. The distribution of heavy minerals in the soil is derived from the raw materials that are continuously moving in the rock-soil cycle. Important factors play a role in the mobility of minerals and heavy metals. These include soil texture, clay content, pH, iron and aluminum oxides, and other factors [9]. Increased concentration of heavy minerals may occur through lithological interactions or mining activities [6].

In this research, placer minerals and sediments of the Bampur River were identified at the eastern dam of Bampur, Iranshahr, and the areas where the minerals of the placers (magnetite, pyroxene, hematite, etc.) were gathered. In addition, the type of placers minerals, and the extent to which they can do can be found in the case of introducing anomalies areas for additional detailed studies.

Placer deposits are deposits that are concentrated in heavy cemented minerals during the deposition of sediments. Most Placer deposits belong to the present day and maybe eroded due to being on the ground. In fact, Placer deposits form a mechanical accumulation of minerals due to the weathering of free-source rocks and their distribution in a semi-economic state [11, 12, 13, 14]. The formation of heavy minerals in a high rock and chemical weathering depends on the source region during transport [3, 8,16]. Rivers are ideal sedimentary environments for the study of heavy minerals. Using the sampling of stream sediments, one can observe the type of heavy minerals [19].

The larger the size of the grains, the greater the accumulation of heavy minerals. Heavy minerals at the river posts (convex section along the waterways) at the confluence of the sub lunches with the main river route and in the places where the dikes are seen in the riverbed, behind the dikes, and at the bottom of the cascades, there are numerous places for gathering Heavy minerals [7]. In the study area, 12 heavy mineral samples were taken to study the sediment and sediment minerals in the river sediments. Finally, the important areas for additional detailed exploration were introduced.

2.Geographic location and access routes to the study area

The study area is located in the central part of the Sistan and Baluchestan province (Fig.1). In terms of geological divisions of Iran, the study area is part of the southeastern zone of Iran and under the Jazmoryan zone, which is located in the east of Hamon Jazmoryan. According to the potential areas of Iran, the study area is considered the Iranshahr-Sarbaz zone.

2.1. General geology of the region

The Iranian plateau consists of several geological zones. Each zone has its own geological and tectonic history, separated by faults from other areas [15]. Exploration of the geological features of the eastern part of Iran shows that its events and events have their characteristics and its geological development is different from the surrounding areas, in the east and west of which continental pellets have come together and due to the closure of the Neotez Sea in this zone is therefore geologically different from the other parts of Iran [17]. The study area is located in the general geological division of Iran in the Nehbandan Khash zone [1, 2]. In the studied area, there are no older rocks than the Cretaceous. Thus, the oldest and youngest rock units in the region are, respectively the Upper Cretaceous and Quaternary periods [15].

Regarding stratigraphy, this area in the Nehbandan- Khash zone has Oligocene age to Pliocene. Formations in the region include granite and granodiorite, ophiolitic. Quaternary rock and alluviums spread out through the terraces of the riverbed. The rocks include granite, granodiorite, andesite, limestone, ophiolite, andesite-basalt and trachybasalt rocks (Fig.1). The main minerals that make up the rocks of this group include plagioclase, pyroxene, hornblende and sanidine, and these rocks mostly have a porphyry texture. It is a related member of this group of pyroclastic deposits, which are located in their lower part and are mostly tuff [10]. The rocks are alkaline in nature with mantle origin and were formed in the continental volcanic arc environment. Iranshahr Volcanic Complex is a part of a arc islands that extends from North Pakistan to Iran. It separated from its origin during a younger tectonic event [10]. The exposed rock units in the range, Upper Cretaceous volcanic-sedimentary rocks include ophiolitic mélange sets, sequences of shale, quartzarnite, limestone, meta diabase, as well as diorite to monzodiorite pyroxene mass, which is inside the sedimentary-volcanic unit (meta diabase and quartz Ernite) has penetrated. Pyroxene diorite contains abundant quartz veins with highly altered appearance. Mineralization in this area is mainly seen with siliceous and argillic alteration along with the wide Gosan zone [10].

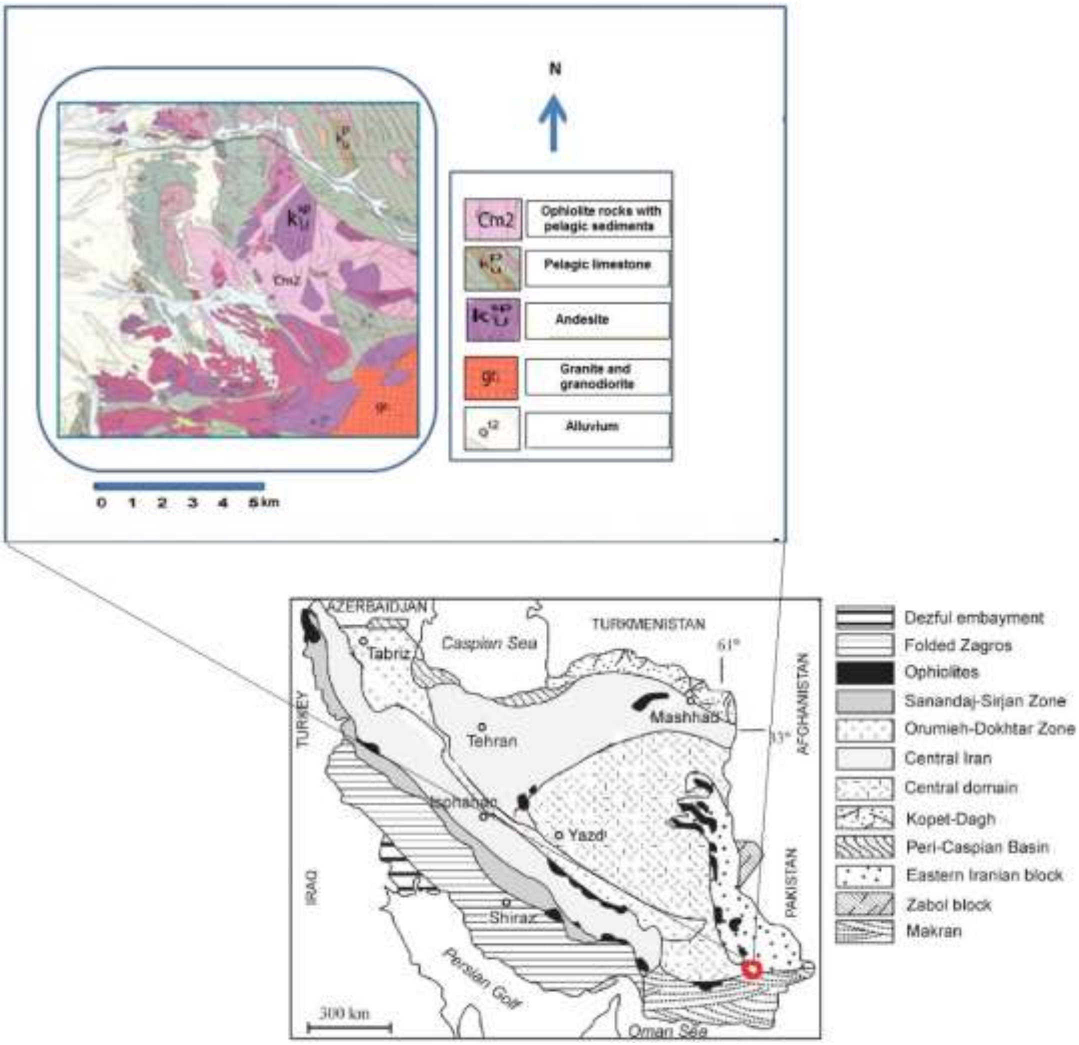

Fig 1. Geology map of study area [Napta Consulting Engineers, 1997] and location of the studied area in structural map of Iran [2].

2.2. Field studies

The following points were considered in field studies to identify heavy minerals in the river. At the beginning of the gathering of information, which relied on surveys of topography, geology, aerial and satellite images, and its adaptation to field observations. After identifying different formations and determining the boundaries of rock units according to geological status, topographic effects, river twists and arrivals of submarines, morphology, and rock or sediment containing heavy minerals as well as the particle size of degraded sediments, field operations for sampling are based on the following points.

1. The sampling of the active part of the river bed.

2. Residuous sediments covered with moss and mildew were not affected by the river flow regime and were not sampled.
3. In places where the river's width is more than 50 meters, along with an environment of a hypothetical circle, two samples of the margins next to a sample of the center and two samples of the upper and lower parts are taken.

After that, the five samples were mixed and some of them were selected as the representative of these five points to finalize the study. In this study, heavy mineral samples were taken from this method. Twelve specimens were taken manually from the conical volume to a depth of 20 to 30 cm and placed in plastic bags on the stick, including sample number, river channel coordinates, etc.

3. Laboratory studies

Samples were sent to the Zarazma Laboratory of Kerman to study sedimentology and mineralogy. Heavy mineral study stages included sample preparation, sample washing, bromoformation, and then volumetric testing was performed again. After separating heavy minerals by magnetism separation and dividing them into three groups of ferromagnetic minerals, paramagnetic minerals, and dye-magnetic minerals, their study was carried out with Bina Kollar microscope to identify the various minerals in each group.

4. Statistical studies on data

GIS SPSS, and Excel were used to process the data. Table 1 shows the geographic coordinates of the samples.

Table 1. Geographical coordinates samples.

Sample	x	y
1	261481	3008479
2	261418	3008495
3	261380	3008491
4	261351	3008512
5	261323	3008534
6	261288	3008559
7	261211	3008636
8	261144	3008728
9	261026	3008850
10	260920	3008998
11	260920	3009006
12	260913	3009027

Using the SPSS software, a graph of the frequency of the representation of the samples was drawn. As shown in Fig. 2, the histogram distribution of minerals in the pyrite group in the region follows an abnormal distribution and has negative skewness. The frequency distribution of altered minerals is of abnormal distribution and has positive skewness. The frequency distribution of iron minerals in the region is a normal distribution and the distribution of the abundance of titanium minerals is an abnormal distribution with positive skewness. Table 2 shows the descriptive statistics parameters of heavy mineral compounds in the region.

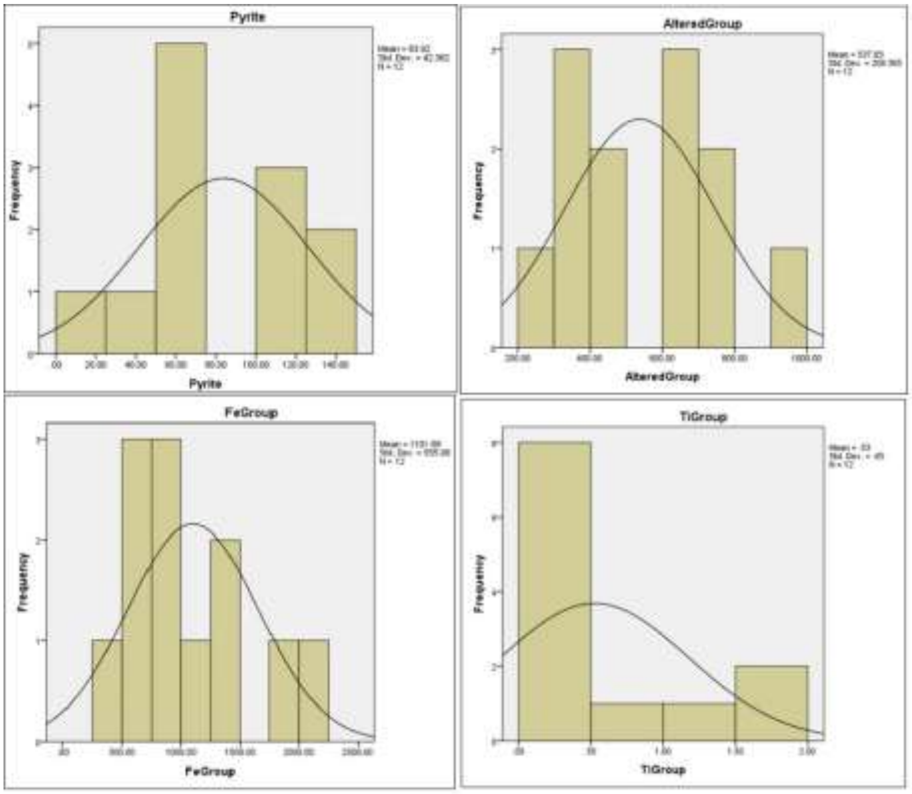

Fig 2. Histogram of the frequency of heavy minerals in samples.

Table 2. Descriptive statistics parameters of heavy minerals grouping.

	Mean	Median	Std. Deviation	Skewness	Minimum	Maximum
FeGroup	1101.6	988.0	555.1	0.9	478.0	2204.0
OreGroup	13.0	3.4	15.3	1.0	1.2	42.0
AlteredGroup	537.8	538.0	208.4	0.2	262.0	904.0
MetaGroup	40.3	39.5	31.0	0.1	0.0	90.0
TiGroup	0.5	0.2	0.6	1.4	0.1	1.9
BasicRock	350.8	339.0	140.5	0.1	164.0	560.0
AcidicRock	25.1	7.5	33.7	1.6	2.8	100.1
Pyrite	83.9	69.5	42.4	0.2	15.0	149.0
Carbonate	3.3	1.0	4.3	1.4	0.3	12.6

5. Correlation Coefficient study

Using heavy minerals, the correlation coefficients were calculated. Table 3 shows the Pearson correlation coefficients between grouped minerals. As can be seen, despite the grouping of minerals, the dominant correlation between groups is moderate to strong. However, the iron group has the highest correlation coefficient with the group of altered minerals and the basic rock group. The group of ore-bearing minerals has the highest correlation coefficient with Titanium and Carbonate groups. The group of altered minerals shows the highest positive correlation coefficient with the group of basic minerals. Titanic minerals have the highest positive correlation coefficient with the carbonate group and acidic minerals group. The carbonate mineral group shows the most positive correlation with acidic mineral groups.

Table 3. Pearson Correlation Coefficient Matrix.

Correlations									
	FeGroup	OreGroup	AlteredGroup	MetaGroup	TiGroup	BasicRock	AsidicRock	Pyrite	Carbonate
FeGroup	1								
OreGroup	.394	1							
AlteredGroup	.924**	.411	1						
MetaGroup	.617*	.593*	.573	1					
TiGroup	.506	.945**	.523	.630*	1				
BasicRock	.880**	.307	.966**	.417	.417	1			
AsidicRock	.556	.897**	.578*	.635*	.990**	.473	1		
Pyrite	.434	.421	.635*	.117	.492	.718**	.543	1	
Carbonate	.509	.951**	.535	.635*	.999**	.427	.988**	.509	1

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

6. Cluster analysis

One method for interpreting heavy mineral data by multivariate statistical methods is dendrogram drawing using cluster analysis. In this method, which is based on correlation coefficients, one can simultaneously examine the relationship between all variables. This method can be useful in understanding the relationship between various variables of heavy minerals. The reason is that the paragenesis of the relationship between heavy mineral variables is shown by this method. To determine the paragenesis between different variables and select the most suitable variables for drawing a heavy mineral map, multivariate analysis has been done by the cluster analysis method. The intersection of the lines to the left represents the high similarity, in other words, the high correlation. Therefore, using these diagrams, one can determine the number of mineral deposits in the area. In Figure 3, a dendrogram derived from cluster analysis of grouped heavy minerals data is presented. It can be seen that there are four groups that the first group is mainly related to carbonate, pyrite, titanium, ore deposits, metamorphic, and acid rocky minerals. The second group belongs to the group of ore deposits and the group of altered minerals, which has a direct relationship between the two groups in the region. The third group belongs to the group of altered minerals and the basic rocky group. The fourth group is related to the iron group with the previous three groups.

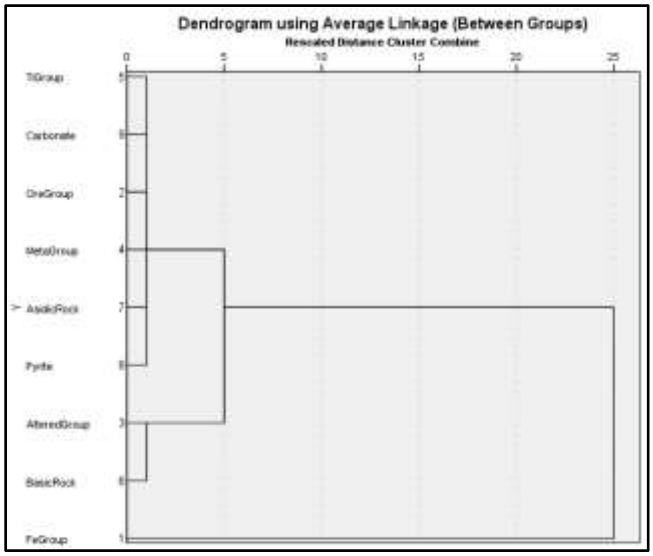

Fig 3. Dendrogram of Grouped Heavy Minerals Data.

7. Description of heavy mineral anomaly

Using the GIS software, the dispersion map of heavy compounds was drawn. The inverse Distance Weighting (IDW) method was used to interpolate the data. The result is shown in Figure 4. Alteration minerals contain mostly epidote, and chlorite. If minerals of pyrite oxide and pyrite of limonite are also added to this group of minerals, their dispersal is to some extent a reflection of the altered zones in the region. In Figure 4, the dispersion of these minerals is shown. The relatively rich enriched zones of these minerals in the northwestern part of the study area are shown in sample No. 12, indicating that the region is altered and the altered zone is more advanced in the region. Samples 8 and 9 show the slightest alteration in the center of the study area. The basins containing iron minerals include hematite, magnetite, goethite, limonite, martite, etc. whose dispersion is shown in Figure 4. The highest concentrations of these minerals are observed in samples 3 and 12, and the lowest values in samples No. 8 and No.9 are found in the central part of the area.

In general, the minerals in the region can be divided into three parts:

1. Minerals in the non-magnetic sector (NM): The minerals in this section that do not have magnetic absorption: minerals such as apatite, zircon, rutile, anatase, barite, calcium carbonate, quartz with a particle size distribution of part per million have been identified. In the NM sector, the presence of the mineral Saphir in Sample No. 9 was noted as a particle. Also, the colored zircon was present in sample No. 12 (Fig. 5).

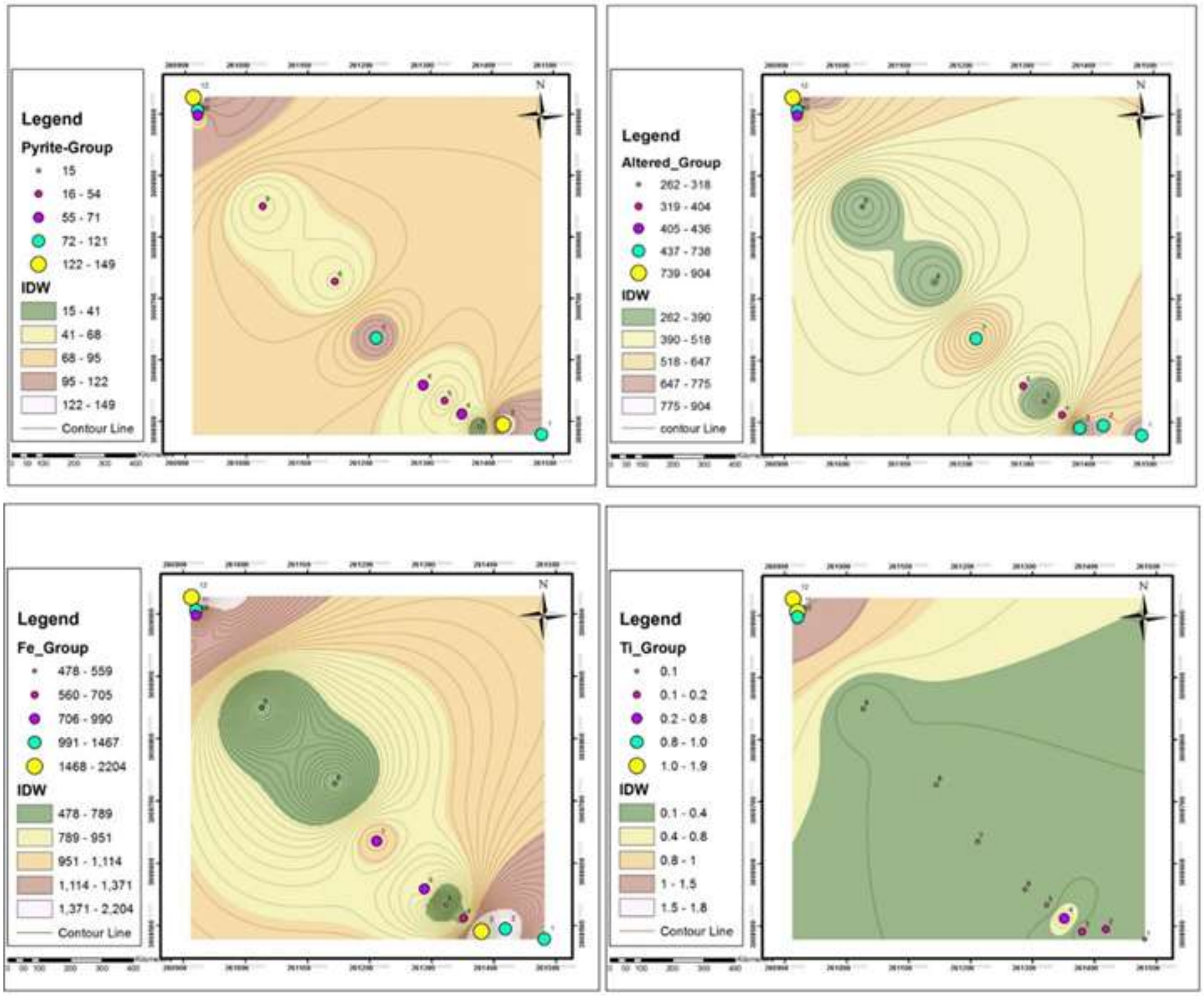

Fig 4. Dispersion map of heavy compounds in the Bampur area.

2- Moderate magnetic minerals: The minerals in this section include: hematite, pyrite oxide, pyroxene, amphibole, epidote, limonite, garnet, martite, and ilmenite. In this section, mineral garnet is also known as semi-precious and precious gemstone minerals, which is presented in most of the samples from small amounts to very small amounts (ppm).

3- Magnesium section minerals: The only mineral in this section is magnetite (Fe_3O_4), which covers more than 90% of the section.

Fig 5. A View of Zircon Mineral in Example No. 12.

8. Conclusion

This area is located in the Nehbandan Khash zone in terms of the general geological classification of Iran. In terms of stratigraphy and lithology, in the studied area there are no older rocks than the Cretaceous. The oldest and youngest rock units in the region are Upper Cretaceous and Quaternary, respectively. The constituents in the region include conglomerate and sandstone, condensed conglomerate, sandstone and marl, and finally siltstone and semicircular stones. Quaternary landscapes are located in the form of terraces on the margin of the river and separated deposits in the beds of the beds. No significant faults have been identified within the studied area. The probable cause of this is the folding of the formations at the end of the third period of geology. Small and small faults and scattered lines are identified in the study area. The processes of these faults are North-South, Northwest-Southeast, and East-West. The density index of the stream in this area is high and this can be due to the expansion of sedimentary rocks in the area. Dendrogram derived from cluster analysis grouped heavy minerals data. As we can see, there are four groups that the first group is mainly related to carbonates, pyrite, titanium, ore deposits, metamorphic minerals, and Acid stones. The second group belongs to the group of ore deposits and the group of altered minerals, which has a direct relationship between the two groups in the region. The third group refers to the group of altered minerals and also the basic rock group. The fourth group is related to the iron group with the previous three groups. The carbonate mineral group shows the most positive correlation with acidic mineral groups. The only mineral that formed the magnetism section in the area is magnetism that covers more than 90 percent of the volume. In this phase, mineral garnet is also known as semi-precious and precious gemstone minerals, which is reported in PPM [part per million] in most samples. In non-magnetic minerals, the color of the zirconium in sample number 12 and the presence of mineral Saphir in sample number 9 must be considered as very important.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Conflicts of interest/Competing interests

No potential conflict of interest was reported by the authors.

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