The potential sources of bauxite in Pir Mishi Tash, Semnan province, northern Iran

Alireza Ashofteh [a, *], Dariush Esmaeily [b], Golnaz Jozanikohan [c]

[a] *Department of Geology, Faculty of Sciences, Urmia University, Urmia, Iran.*
[b] *School of Geology, College of Science, University of Tehran, Tehran.*
[c] *School of Mining Engineering, College of Engineering, University of Tehran, Tehran.*

ABSTRACT

The Tash bauxite mine is located approximately 6 km northeast of Tash village and 40 km northwest of Shahroud city in Semnan Province with coordinates of 36° 32′ N to 36° 37′ N and 54° 41′ E to 54° 48′ E. The actions of the orogenic phase of the former Cimmerian as well as the chemical and physical factors have caused the erosion of the basalts in the Shemshak sedimentary basin, which has resulted in the simultaneous deposition of the Shemshak molasses and bauxite in the Tash area. According to some geological evidence and the location of Elias rule, bauxites in the vicinity of Shemshak Formation shales, it is concluded that the clay minerals have played an important role in forming the bauxite deposits in this area. The results showed that the basalts were formed from the alkaline magma and then altered to clay minerals. The remaining immobile elements such as aluminum and residual iron formed the Tash bauxite deposit. The investigation of thin sections designates that the studied ore contains ooidal, plitomorphic, allogeneic pizolite, coloform, and compressive dissolution texture, which indicates the autochthonous origin. Pyrite, chalcopyrite, goethite, and hematite were also recognized. The mineralogical study, performed by the X-Ray diffraction method, led to the identification of minerals of anatase, boehmite, diaspore, chamosite, kaolinite, quartz, and hematite. Analysis of ore samples by the X-Ray fluorescence method and calculation of aggregation coefficient of trace elements and geochemical indicators along with geological evidence revealed the source rock could be from the mafic type.

Keywords: *Mineralization, Bauxite genesis, Geochemical cross plots, X-Ray analysis.*

1. Introduction

Currently, in Iran, about 70% of the raw material used in aluminum production is imported from other countries. The lack of raw materials for producing this strategic metal is one of the main challenges in this industry, which can lead to importing more than 500 thousand tons of alumina powder in 2017 [1]. The objective of the vision document for the country up to the horizon of 2025 is to produce 1.5 million tons of aluminum. In this regard, significant reserves have been found in the PirMishi Tash, Semnan Province, Northern Iran (Figure 1). From the Permian period to the late Cretaceous period, along with the Tethys-Eurasian metallogenic belt, one of the richest bauxite belts, of which Iran is part of it has been formed. The most pivotal Iranian karstic bauxite reserves based on the time of formation are mainly situated on three Permo–Triassic, Lias base, and Cretaceous bauxite axes. Iranian bauxite deposits are mostly karstic, spatially distributed in three structural- sedimentary zones of Alborz, Central Iran, and Zagros [2]. One study on bauxite in Semnan province was conducted in the Touyeh-Darvar region of Damghan, which Zarei (2013) [3] introduced as one of the bauxite reserves of the Iranian Lias region, considering diabase rocks of the Shemshak base as a possible parent rock of this deposit. Another study in Semnan province was performed by Saberi (2000) in Shahmirzad region, who introduced the laterite-bauxite deposit and identified the basaltic andesite as the source rock for this

deposit; however, the studies conducted in Tash area as follows: Fardoust et al., (2001) [4] prepared a geological 1:1000 map of Tash and Mojen regions to investigate the geological situation and other mineral potentials of the region such as Zn and Pb mines. Setouhian (2004) [5] investigated the Elika Formation in Tash deposit. Because the host rock of the bauxite deposit is located in the Elika Formation, good data are available in this regard. Jafarzadeh (2012) [6] examined the excavation as well as exploitation measures at the Tash deposit; however, as these measures tended to be organizationally oriented and led by the Ministry of Industries and Mines, not all scientific data were provided. Sorkhdarrei (2013) elaborated on the bauxite horizons of the Permo-Triassic age at the Tash deposit, including the Tash bauxite deposit in the Permo-Triassic area. He also investigated the physical features of the deposit, finally determining the residual and non-residual sources from the physical and geological data. Up until now, no inclusive study has ever examined the geology, geochemistry, and mineralogy of the Tash deposit as the largest supplier of the Iranian bauxite following the Jajram bauxite, which this article aims to study.

2. Geology of the region

The age of the geological units of this region is between Late Ordovician to Middle Eocene. The predominant folds are in the east-west region, which is similar to the general direction of the folds in the

---

Eastern Alborz. The predominant lithology is related to the Lower to Middle Jurassic Carboniferous deposits, and its most important lithological divisions are Elika, Shemshak, and Mubarak. The existing rocks are located in the Permian range with Dorood Formation at the bottom and the Ruteh Formation at the top, which are covered by Triassic limestone units which are equivalent to Elika Formation in Alborz and Shemshak coal units which represent Jurassic deposits below Alborz. The upper boundary of the bauxite is covered in the form of steep to slightly angular discontinuities by the Shemshak Formation while the lower boundary is covered in the form of erosive discontinuities on the Elika karsts. Secondary changes in this deposit are due to epigenetic processes such as iron leaching and re-silicification [7]. The outcrops of Elika Formation indicate sediments of Triassic age. The outcrop of thick calcareous units and sand units of Dorood and Ruteh Formations represents Tash Permian deposits. The significant thickness of thick dolomitic limestones of Lar Formation and shale and sandstone units of Shemshak Formation are some other outcrops of the region. The Plunging anticline on the northern slope of Shahvar Mountain and in the eastern part of Tash village is one of the main structures with a northeast-southwest trend in this area (Figure 2). The core of this anticline is formed in Mubarak Formation and its ridges are formed from top to bottom by Elika and Ruteh Formations. The erosion destroyed the central part of the anticline and gave it a synovial shape. The slopes of the layers of the northern and southern ridges are to the southwest and northeast, respectively. The northern ridge of this anticline was deformed by a strike-slip fault. The anticline axis has a plunge in the valley of Jaban N75 NE and to the west, and a fault at the end of Fold has displaced some parts of it. Both ridges of the Fold have the potential to produce bauxite, where Tash bauxite mine is located on its northern ridge [8].

3. Geomorphology of the region

The stratigraphic column of the area from old to new includes Abrasaj Formation, Sultan Maidan Basalts, Padha Formation, KhoshYilagh Formation, Mubarak Formation, Dorood Formation, Ruteh Limestone Formation, Elika Formation, Shemshak Formation, Lar Formation, Cretaceous Limestone Rows, Fajan Formation, Ziarat Formation, and Karaj Formation. The formations along with the mineralization horizon are located in a Plunganticline building. A bauxite horizon outcrop is visible in the upper and lower part of Elika Formation, which indicates the occurrence of discontinuities in the permotria and the upper Triassic. The first discontinuity is layered while the second one is in the form of discontinuous lenses deposited on the Elika Formation (Figure 3). Tash bauxite deposit is located between Shahvar heights in the south, Pirmishi mountain in the west, Shotorpa mountain in the east, and Yazdaki mountain in the north. The height of the highest point of Shahvar peak is 3945 meters, and the height of Tash village is 2220 meters. The most common rocks in Tash bauxite deposit are limestone and dolomites of Elika Formation as well as shales and sandstones of Shemshak Formation, which have high physical erosion due to their location at high altitudes. Young valleys are generally V-shaped and follow faults. The permanent Tash River and the seasonal rivers move large amounts of soil, rocks, and materials out of the area in the spring as the snow melts. The routes of the rivers are located in the fault zones or in the direction of faults in the area [9].

4. Materials and procedures

Field studies were performed to determine the mineralization area and regional stratigraphy. Considering lateral and vertical changes of the bauxite deposit, two profiles, one perpendicular to the lenticular bauxite* and the other parallel to the lenticular bauxite†, were selected. Field studies helped introduce stratigraphy, and investigate textural and structural changes and the way they were related to the bauxite horizon of bedrock and caprock. Following the survey, samples of various bauxite horizons were taken as more than 65 samples were collected, of which 13 samples (N1-N11) were used to study thin and polished sections in order to identify texture and construct the mineral structure, as well as to identify iron and APEC ores minerals. Also, eleven samples were selected for geochemical analysis and identification of unknown minerals. Data analysis from field evidence, petrography, mineralogy, and geochemical surveys were interpreted using various shapes, tables, and diagrams, which are described as follows.
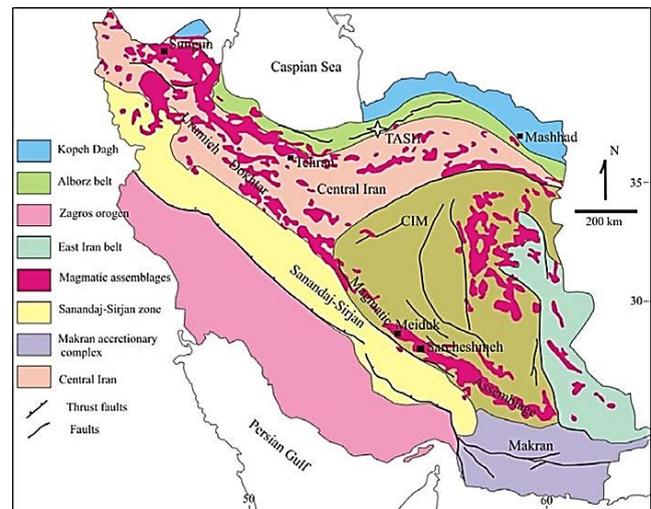

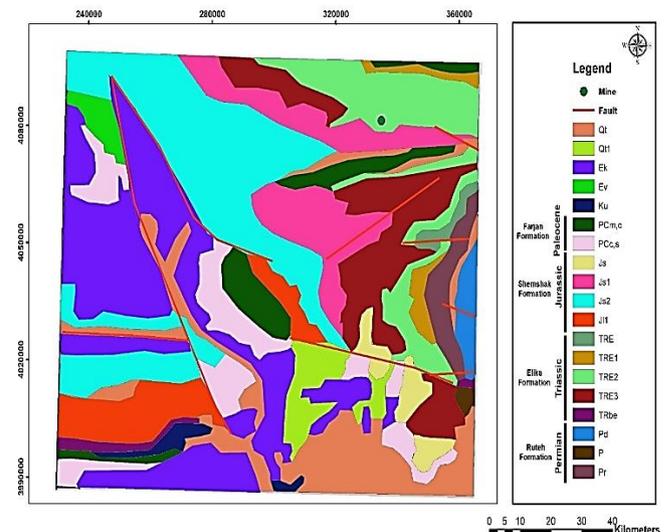**Figure 1.** The Geographical location map of the area.

Figure 2. Geological map of the area (The Iranian Geological Surveying Organization, 2010).

---

* The profile was cut by the road and had the highest changes in terms of apparent features including texture and color, leading to the identification of different bauxite horizons.

† Which captured lateral changes to the deposit.
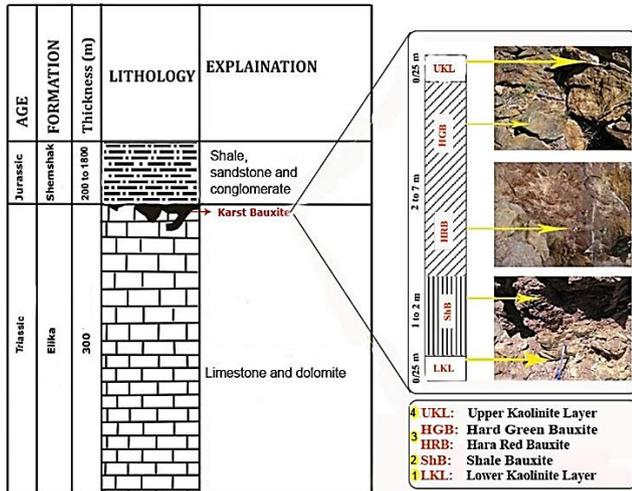
Figure 3. Lithostratigraphic column, Vertical facies and depositional distribution of the Tash.

4.1. Mineralogy of the region

Tash bauxite mine in the form of lenses and layers is located on the northern ridge of a Plunging anticline along the east-west direction in the bed of the Elika carbonate formation. The upper boundary of bauxite is Shemshak Formation. This formation is destroyed by erosion and the deposit is uncovered. The bauxite deposit consists of several bauxite horizons. The dimensions of the deposit vary between 3 and 10 meters thick and one kilometer long with several bauxite horizons. The strike-slip faults have caused bauxite horizons to be placed next to each other. Additionally, they have resulted in upgrading parts of the deposit, especially the middle parts.

Tash ore bauxite is divided into two types of hard and shale bauxite. The most important Tash bauxite ore is hard bauxite, and its main part is composed of diaspora. Shale types have a soapy and soft surface and produce layering effects along with very small hematite nodules. Tash bauxite comes in a variety of colors such as liver, gray, green, and red, which could be due to the presence of elements and minerals in gross form during settling. For example, gray indicates the presence of organic matter, yellow is related to limonite impurities, green is due to chamosite minerals in the regenerative environment, white shows the presence of abundant clay minerals, and red could be attributed to the presence of iron in the oxidant formation medium. Histological and mineralogical changes along the bauxite profile are normal but different in different deposits. In Tash mine, structural activities result in the repetition or elimination of bauxite horizons.

The best example of this phenomenon is the repetition of bauxite units on the ground. Bauxite lenses are internally zoned based on textural and mineralogical elements, which from bottom to top include four categories of bottom clay layer, shale bauxite unit, hard bauxite unit, and top clay layer. The minerals which constitute bauxite are anatase, diaspora, chamosite, kaolinite, quartz, and hematite. The diaspora is the major aluminum-bearing mineral found in most karst bauxites, which is most prevalent in Paleozoic deposits. This mineral is often formed in areas affected by moderate to severe tectonics. Gibcite mineral becomes boehmite in the process of bauxite after compaction and dehydration. Then, it is converted to diaspora during low-grade metamorphic processes and tectonic stresses while changing the crystal structure (Figure 4).

Most diaspora is found in hard bauxite units. Considering the latent presence of boehmite in crystal and the absence of corundum and other evidence of metamorphism in the mineralogical results, it can be concluded that tectonic factors play a major role in converting amorphous aluminum-containing gels to boehmites, diasporas, and gibbsite. Boehmite is mostly present in the hard bauxite unit. Chamosite is often found in diaspora bauxites, which is mostly associated with kaolinite and represents a regenerative condition. This mineral is found

in syngenetic conditions in the form of diagenetic and matrix in layers that make up the ooid and piezoid. Chamoisites in Alborz bauxite are oxidized on the surface and converted to kaolinite, goethite, and hematite. A similar phenomenon is observed in Tash. Goethite is the most abundant iron ore in bauxites after hematite, which is co-structured with diaspore minerals. Hematite, as one of the most abundant minerals in karst bauxites, is mostly observed in hard red bauxite unit and bauxite unit. Aluminum is called "alum goethite" when it replaces some of the iron in the goethite network. If the goethite crystals are smaller, it is easier to replace aluminum with iron. The formation of kaolinite in karst bauxites is mostly attributed to the diagenetic replacement of aluminum ores with silica or the dehydration of hydrated aluminum ores [10].

4.2. Host rock petrography

Mineral ores are composed of dolomites of the Elika Formation. Examination of thin sections showed that dolomite crystals in the form of xenotopic texture were present in mineral ores (Figure 5). This texture is the result of the crystallization of dolomites that have already formed or formed from the replacement of calcite at high temperatures *(Zenger, 1983)*. Xenotopic texture could indicate dolomite formation under epigenetic or deep burial conditions [11]. The mineral bedrock has many fractures which can be identified in thin sections. Another texture shown is the alternation of dark and light layers in the thin section, which could result in stromatolitic texture. This texture is formed in the upper environment of the tidal zone. Stylolithic fissures which indicate tectonic pressures are observed in some sections.

The minerals which constitute bauxite are so fine that they do not show specific light properties under a microscope. Therefore, it is not possible to identify them in this way. Thus, X-ray diffraction should be used to detect them (Figure 6). The texture-forming elements in bauxites are divided into two general categories based on their genetic and morphological characteristics.

Background textile units. The textural elements of the background include fine aggregates of more or less the same size which, like cement, surround the distinct textural elements. These components, which are composed of fine, uniform particles rich in Al_2O_3 and silica, have a diagenetic to twin indicates in situ of bauxite. Some types of panidiomorphic, plitomorphic, and microcrystalline matrices of cement were identified [12]. Plytomorphic texture occur when tectonic and environmental conditions remain unchanged during diagenesis and re-deposition does not occur [13]. In this case, they are formed from an amorphous colloid, which could be due to the absence of separate particles and other texture-forming elements. The presence of these textures is an indication of in situ bauxite. The association of these textures with the transported parts of detrital particles, eroded ova, and intraclast indicates their semi-in situ.
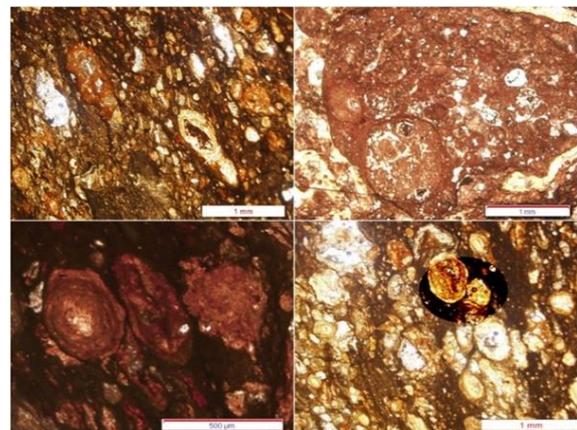

Figure 4. (a) Ooids and piezoids with flowing texture, (b) Allogeneic pizoid, (c) Dumbbell piezoid due to tectonic pressures, and (d) Compressive dissolution texture.
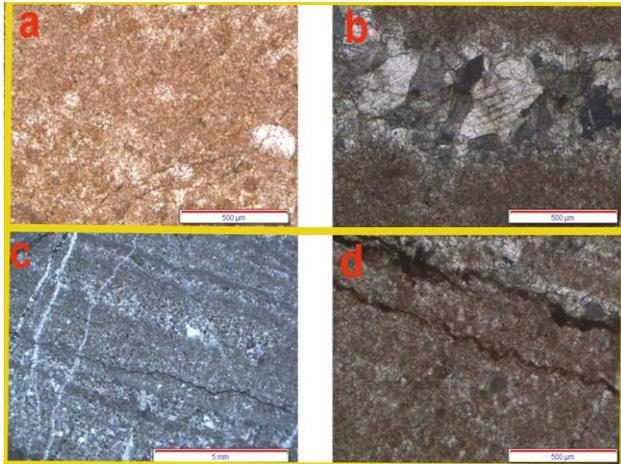
Figure 5. Thin sections of host rock (a) Xenotopic texture in bedrock dolomite (b) Joints and secondary fractures filled with calcite (c) Stromatolytic texture, and(d) Stylolytic texture.
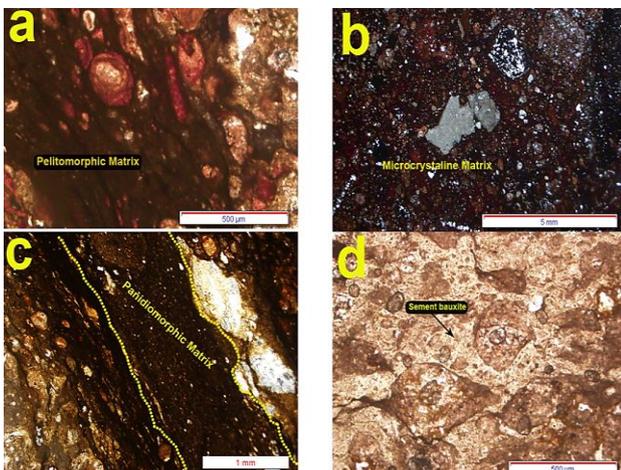
Figure 6. (a) Plytomorphic texture (b) Microcrystalline texture (c) Panidiomorphic texture (d) Cement.
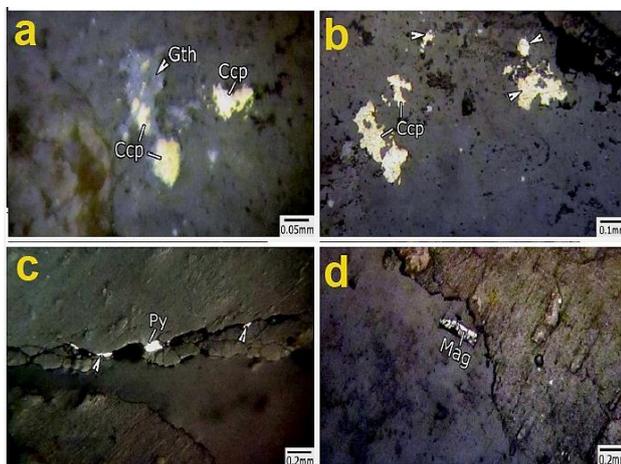
Figure 7. Hard bauxite polished sections (a) Replacement of chalcopyrite crystals by goethite (b) Occurrence of amorphous chalcopyrite crystals (c) Semi-formed pyrite crystals along with fractures (d) Semi-formed crystals of goethite.

Distinctive texture-forming units. These units can be distinguished from the matrix by their size and morphology as well as distinct textural elements including three categories of concentric textural elements,

detrital fragments, and minerals. Coated granules are one of the most important texture elements in bauxites. Ooids and piezoids have the same structure, except that the piezoids are larger and have more layers. Pisoids are usually less likely to break. Ooids and piezoids have an unsaturated or diagenetic soil origin. In diagenesis, ooids and piezoids are formed when changes in the chemical and physical conditions of the aluminosilicate gel occur. Simple ovaids are formed in a short time whereas complex ovaids and piezoids are formed over a long period of time and represent different transport processes. Piezoids are composed of concentric layers and nuclei due to climate changes in several stages. Pisoids whose nuclei are composed of small spherical communities are called allogeneic pizoids. The presence of this type of piezoid indicates the transfer of bauxite material. Dumbbell and elongated piezoids indicate deformation during tectonic activity and compaction. Piezo rounding indicates that the parts were transported in a soft matrix before deposition. Dissolved textures are evidence of pressures from the epigenetic process and tectonic conditions. Another texture in the samples is the flow texture formed due to the displacement of the primary colloid caused by weathering of the mother stone during the supergene process. The presence of detrital fragments in ooid and piezo indicates transmission. Another available texture is cloform, which is formed by separating aluminosilicate gel from iron.

The most important mineral in bauxite stone, which can be identified in thin section, is hematite. Hard bauxite polished sections were examined to identify primary minerals such as pyrite and chalcopyrite and secondary minerals such as goethite. Fine to medium-sized pyrite crystals are seen in semi-shaped form while medium-sized mannite crystals in the amorphous form are present in the cross-section. Primary metal minerals in the form of semicircular to amorphous crystals such as chalcopyrite have been replaced by goethite to varying degrees (Figure 7). To control the useful thickness, the quartz mineral cross-section is measured since it can be easily detected under a microscope [14-15].

4.3. Mineral crystallography

The X-ray diffraction analysis is a rapid analysis technique used to determine the type of material as well as its phase and crystalline properties [16-17]. Since mineral-forming rocks have fine crystals and their constituent minerals in these conditions do not have specific optical properties, not much information can be expected from polished section studies. The XRD analysis is used to find more accurate mineralogical information about mineralogical processing and interpretation of bauxite components. This method measures the distances of the atomic plates to identify the structure of the material, which can help determine the name of the mineral or minerals which make up the sample [18]. The results showed that the minerals forming bauxite were in five groups including iron and titanium oxides (anatase and hematite), tectosilicates (quartz), phyllosilicates (indialite, kaolinite, and halloysite), carbonates (aragonite, siderite, and calcite), chlorites (chamosite and clinochlorine), and aluminum and iron hydroxides (boehmite, diaspora, and goethite) (Figures 8-11).
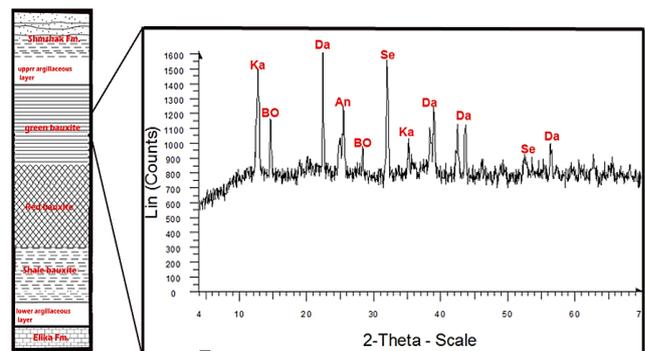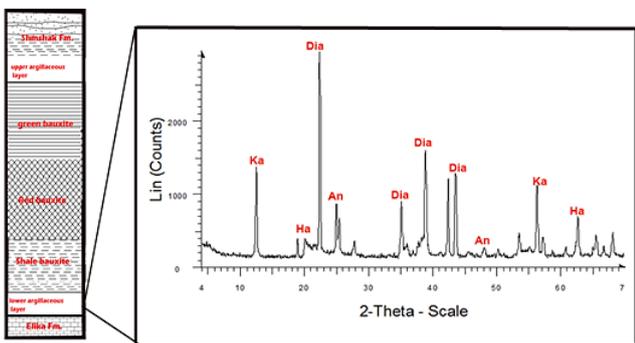

Figure 8. The XRD graph of a hard-green bauxite layer (Ka: Kaolinite, BO: Boehmite, Da: Diaspore, An: Anatase, Se: Siderite).
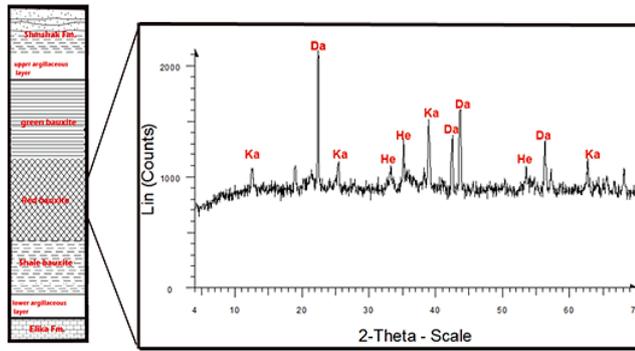
Figure 9. The XRD graph of a hard-red bauxite layer (Ka: Kaolinite, Da: Diaspore, He: Anatase).
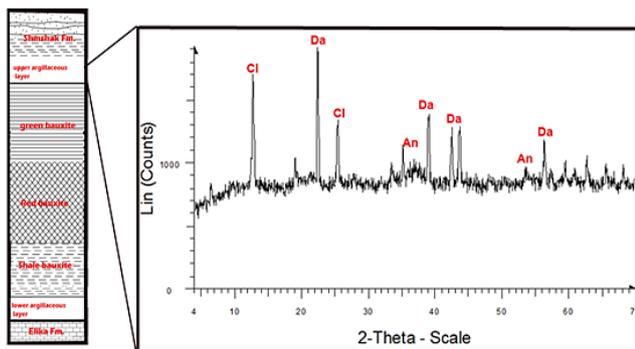
Figure 10. The XRD graph of an upper clay layer (Cl: Clinochlore, Da: Diaspore, An: Anatase).

Figure 11. The XRD graph of a bottom clay layer (Ka: Kaolinite, Ha: Halloysite, Dia: Diaspore, An: Anatase).

4.4. Genetic systems of the minerals constituting bauxite

The components of bauxite are mainly complex gels that contain aluminum, iron, titanium, silica, and clay materials including kaolinite and halloysite in situ forms. During the deposit formation, genetic changes occur in the minerals in epigenetic, diagenetic, and syngenetic processes. A small percentage of minerals are separated from the solution in the form of sediment. Finally, minerals are formed under the physical and chemical conditions of the environment. In the diagenesis or hardening stage, various processes, such as diasporicization of reserves that have boehmite, are formed. Another important process at this stage is the formation of ovaids and piezoids, which happens in gel-like materials saturated with water. This separation starts from the central core and continues outside. As a result, several layers are formed around the nucleus. In Tash ore, ovaids and piezides have a high concentration of this mineral due to the abundance of iron ores in the

shell matrix (Table 1). In the epigenetic stage, two factors are involved in tectonic changes and the infiltration of groundwater and surface water in the deposit. Epigenetic processes which begin after drying and crystallizing the initial gel of the bauxite formation develop further under the pressure of burial or tectonic forces, which is in the form of the expansion of dissolution and compressive effects and the conversion of open-structure minerals to compact-structured minerals. Such as changing anatase to rutile or goethite to hematite due to pressures. Re-silicification is an important epigenetic process in this deposit. In this process, water penetration into the silica-rich deposit causes the silica to combine with the aluminum ores, which leads to forming the kaolinite horizon. The kaolinization process sometimes increases so much that part of the deposit is completely converted to kaolinite. Although epigenetic kaolinite is known as a vein and filling gap in many bauxite deposits, silica is easily replaced by aluminum due to its similar geochemical properties and forms secondary kaolinite and other minerals [19].

### 4.5. Classification of Tash bauxite ore units

Depending on the range of changes of the main oxides in the selected profile, different diagrams can be used to understand the type of bauxite mass. Investigating semi-small amounts of aluminum and titanium ores, iron ores, and clay ores in the studied samples on a triple diagram and implementation of their results indicated the facies of iron-rich bauxite and clay bauxite. The ore position of the area can be found by drawing the main oxides in the triple diagrams of aluminum, iron, and silica as well as iron, silica, and L.O.I. Drawing of bauxite ores in the three-variable diagram of $Al_2O_3 + TiO_2$, Fe_2O_3, and SiO_2 showed that these deposits have a composition similar to lateritic bauxite (Fig12-18). The three-variable diagram of aluminum, iron, and silica shows that the bauxite horizon has undergone intense to moderate lateritic processes during the formation of Tash ore [20].

### 4.6. The determination of the origin of the bauxite source rock

In bauxite deposits, the source rock is not exposed and the complexity of bauxite events makes determining the source rock ambiguous. It is difficult to detect bauxites in situ and transported in karstic bauxite deposits since there is no intermediate layer between the bauxite and the mother rock and the surface of the mother rock becomes weathered. In addition, it is not possible to determine how much bauxite is formed by the alteration of the host rock due to the low amounts of aluminum in the host rock [21].

**Table 1.** Results of XRF analysis of Tash bauxite.

(%-Sample)	N1	N2	N3	N4	N5	N6	N7	N8	N9	N10	N11
SiO_2	40.01	7.26	5.70	17.77	7.08	7.93	7.52	16.86	11. 39	6.02	10.20
Al_2O_3	32.15	46.90	38.35	58.93	45.55	42.38	46.69	42.00	48.74	11.44	48.34
Fe_2O_3	05.31	25.02	41.70	2.38	29.35	24.17	26.93	20.43	22.97	68.89	23.03
MnO	0.02	0.13	0.18	-	0.08	0.04	0.05	0.05	-	0.11	0.01
MgO	0.57	0.25	-	-	-	0.64	-	0.47	0.67	0.24	1.00
CaO	2.41	1.12	0.16	0.06	0.14	0.45	0.19	0.66	0.19	0.15	0.61
K_2O	0.02	-	-	0.05	-	0.35	-	0.26	-	0.20	0.07
P_2O_5	0.06	0.06	-	0.04	0.04	-	-	0.07	-	-	0.05
TiO_2	2.15	3.71	2.13	5.35	3.77	3.24	4.05	3.42	3.35	0.67	03.86
CaO	-	0.04	0.06	-	0.04	0.03	0.04	0.03	0.03	0.09	0.03
SO_3	0.06	0.06	-	0.05	0.03	-	-	0.04	-	0.05	0.04
ZrO_2	0.05	0.12	0.07	0.44	0.13	0.09	0.13	0.10	0.11	0.02	0.12
V_2O_5	0.05	0.09	0.08	0.10	0.10	0.10	0.08	0.06	0.13	0.06	0.11
Cr_2O_3	0.03	0.06	0.04	0.06	0.05	0.03	0.05	0.04	0.05	-	0.04
Nb_2O_5	0.01	0.02	-	0.08	0.02	0.01	0.02	0.02	0.02	-	0.02
Cl	0.04	0.12	0.05	0.04	0.05	0.06	0.04	0.05	0.05	0.04	0.05
SrO	0.04	0.03	0.02	0.02	0.02	0.01	0.01	0.03	-	-	0.01
L.O.I	14.99	14.99	11.47	14.58	13.46	20.39	13.19	15.35	11.99	12.00	12.34
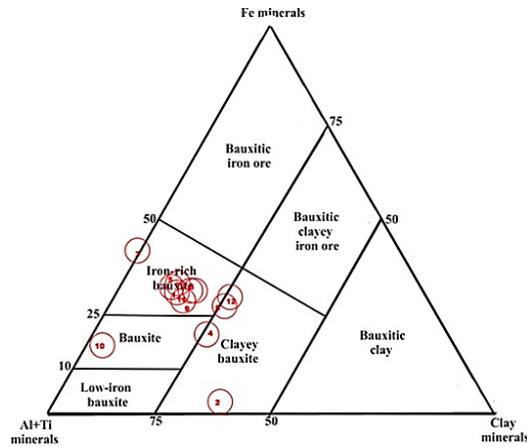
Figure 12. Position of Tash samples based on three-dimensional diagrams of titanium-bearing aluminum ores, iron-bearing ores, and clay ores.
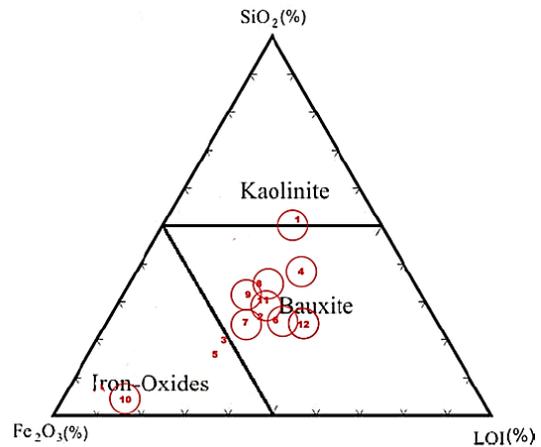
Figure 14. Position of Tash samples based on three-dimensional diagrams of Al_2O_3, Fe_2O_3, L.O.I, and Al_2O_3, Fe_2O_3, SiO_2.
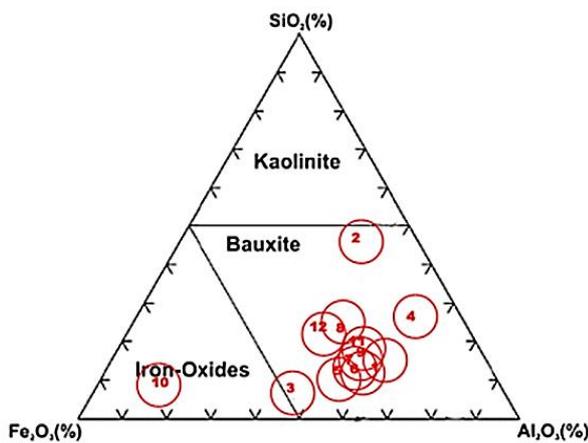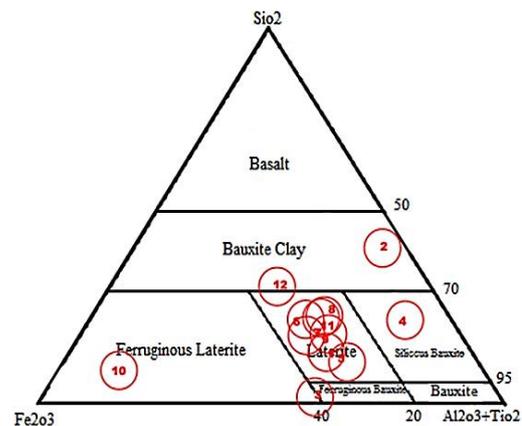

Figure 13. Position of Tash samples based on three-dimensional diagrams of Al_2O_3, Fe_2O_3, SiO_2.

Figure 15. Position of rock units by drawing Al + Ti, Fe, and Si oxides of ores in the three-variable diagram $Al_2O_3 + TiO_2$, Fe_2O_3, and SiO_2.

The source rock of the deposit could be identified by using geochemical data and different geochemical diagrams and combining their results with mineralogy and field findings (Figure 19). The reason for using the ratio of trace elements to each other is that the concentration of these elements does not change due to diagenesis and metamorphic processes [22].

These elements are transported in the detrital part of sediments and indicate their origin. The Cr-Ni binary diagram could be used to distinguish karst bauxites from lateritic bauxites. Accordingly, the logarithmic ratio of nickel to chromium in karstic type bauxites is higher than in the laterite type [23]. The results indicate that Tash samples are located in the realm of karst bauxites with basaltic source stone. Implementing geochemical data on the Cr, Ga, and Zr triangular diagram shows the range of the basalt source rock for this deposit (Figure 20).

In Figure 20, the highest accumulation is related to 50 to 55% of aluminum oxide and the range of 10% of silica. The more stable the chemical environment of bauxite formation near pH between 5 and 9, the more silica dissolves in this environment and becomes inaccessible. So, the bauxite grade will increase significantly. Figure 20 shows no relationship between aluminum oxide and iron oxide. The mobility and deposition of iron in different geochemical environments and the considerable thickness of Chilean bauxites in the mine have increased the rate of change in a wide range of geochemical ranges [24].

X-ray diffraction analysis is a technique used in materials science to determine the crystallographic structure of a material. XRD works by
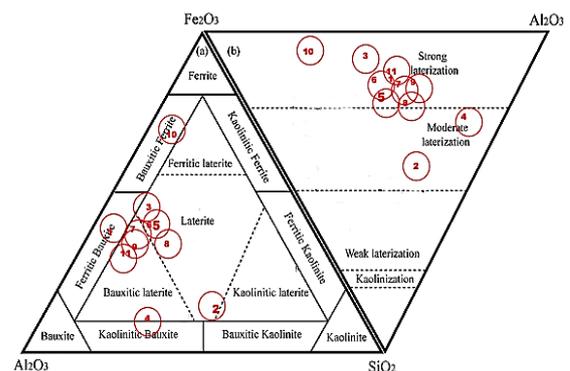
Figure 16. Determining the type of facies and placement of rock units in the range of laterite to laterite bauxite.

irradiating a material with incident X-rays and then measuring the intensities and scattering angles of the X-rays that leave the material [25].

The present article conducted precise exploratory research in the boundary between two formations to explore similar ore deposits due to the considerable expansion of Elika formation as the mineral host and Shemshak formation as bauxite cap rock [26]. The studies were merely organizational and not academic in order to reduce the costs of exploration and extraction in the mining operations of Iran Alumina Company [27-28]. The achievements of this study can be used in future exploratory and extractive studies and decisions. Geochemical studies
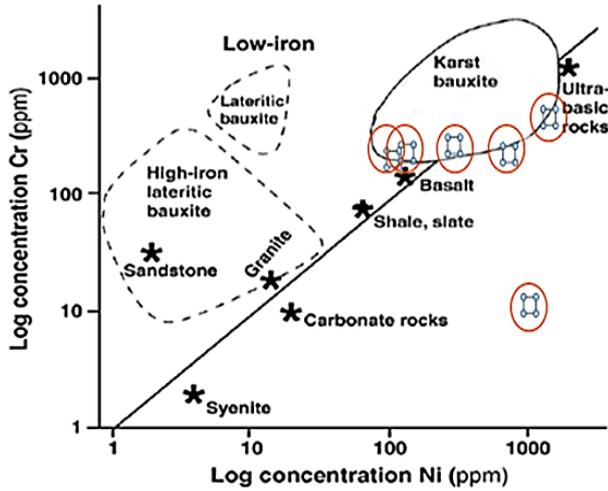
Figure 17. Logarithmic changes of Ni concentration against Cr of stone ores (red circle) in the range of karst bauxites with basaltic rocks.
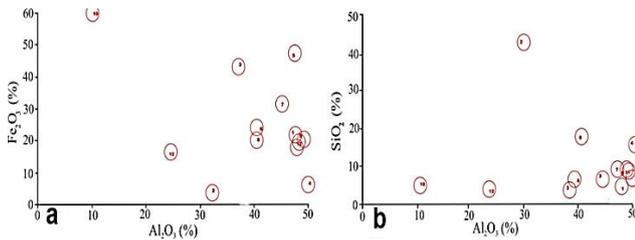

Figure 20. The Al_2O_3 and SiO_2 box plot indicates drastic changes, and the sudden difference between minimum and maximum and indicates insufficient knowledge of bauxite detection.

Figure 18. Correlations between Al_2O_3, Fe_2O_3, and SiO_2.

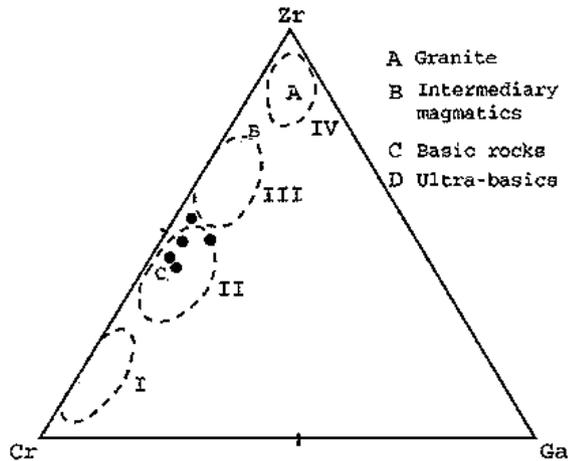**Figure 21.** XRD Data Visualization, Processing and Analysis.

Figure 19. Determining the source rock of Tash ores, which represent areas with the effect of ultramafic, mafic, intermediate, and acidic mother rocks, respectively, where A, B, C, D are related to the amounts of zircon, chromium, and gallium elements in acidic, intermediate, mafic, and ultramafic magmatic rocks, respectively.

were carried out through the ICP-Mass method in order to examine the rare light and heavy earth elements. No studies have ever been conducted in this regard. The important point regarding Tash bauxite is the rather insignificant amount of argillaceous or soft bauxite in this ore deposit [29-30].

Argillaceous bauxite contains a high amount of SiO_2 and a low amount of Al_2O_3. On account of its low quality, this type of bauxite is not used in manufacturing Alumina.
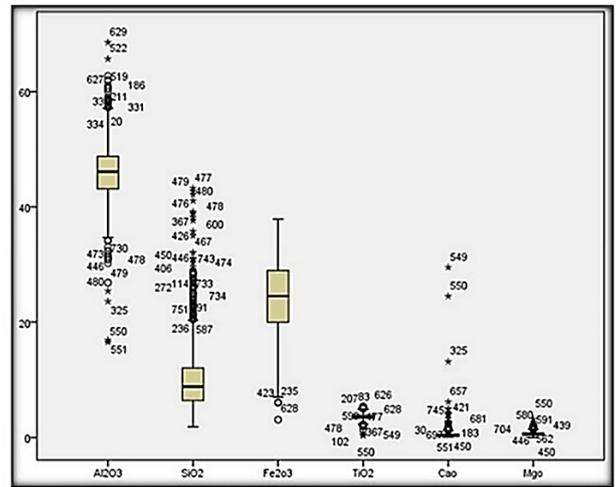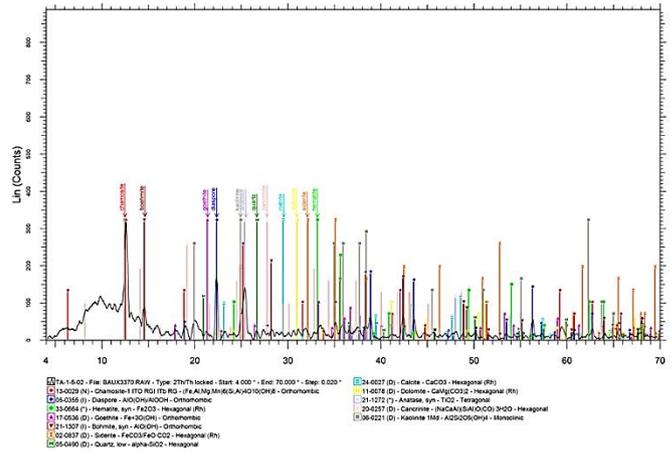
The cost of extracting hard bauxite is expected to be decreased considerably considering the insignificant amount of argillaceous bauxite, which is a reason that the Tash bauxite mine is regarded as cost-effective.

5. Results

In the current paper, geology, mineralogy, and deposition have been studied and the geochemical characteristics, ore genesis, and main and secondary minerals have been designated using laboratory results:

- Tash Bauxite is located in the eastern Alborz structural and geological zone. Geomorphological evidence and placement of minerals in carbonate karst bed showed that Tash bauxite was Mediterranean karst. The boundary between the bauxite horizon and the Shemshak Formation was irregularly eroded. Shemshak group in North Alborz started from an iron-bauxite section. The relationship between shale, clay minerals, and marls containing abundant organic matter could be observed in the areas of Tash deposit which Shemshak Formation has covered bauxites.

- The presence of compressive dissolution texture resulted in stresses caused by epigenetic and tectonic processes. The most important structures were mass, lens, concretion, layered, and nodular. Thin-section studies showed that the Tash deposit contained oide,

plitomorphic, piezoidal, coloform, and compression dissolution textures, which indicated in situ origin.

- Mineral analysis by XRD method helped identify anatase minerals, boehmite, diaspora, chamosite, kaolinite, quartz, and hematite. Additionally, pyrite, chalcopyrite, goethite, and hematite minerals were identified by polishing sections. The analysis of the samples along with the geological evidence indicated the source rock with medium to mafic properties.

- Facies of iron-rich bauxite and clay bauxite were found by examining the semi-quantitative values of samples of Tash ores on the Bardossy triplet diagram. Drawing of Tash ores in a three-variable diagram of $Al_2O_3+TiO_2$, Fe_2O_3, and SiO_2 indicated that most deposits had a composition similar to laterite bauxite. Drawing the values of Al_2O_3, Fe_2O_3, and SiO_2 of Tash ores on the three-variable diagram of Al_2O_3, Fe_2O_3, and SiO_2 indicates the range of laterite and laterite bauxite. The three-variable diagram of aluminum, iron, and silica indicated that the bauxite horizon had undergone intense to moderate lateritic processes during the formation of Tash ores. Additionally, Tash bauxite samples were located in the territory of karst bauxites with basaltic source stone. Calculating the accumulation coefficient of rare elements in the bauxite horizon demonstrated that the samples were located in the range of intermediate rocks.

- Binary diagrams of aluminum, iron and silica oxides were examined to investigate how they changed. There was a strong negative correlation between Fe_2O_3 and Al_2O_3, which indicated a good separation between aluminum and iron during bauxite processes. Furthermore, like most bauxite deposits, there is a strong negative correlation between SiO_2 and Al_2O_3.

- A large part of the samples included 15% SiO_2, which indicates that the Tash ore deposit consists of a high amount of silica that causes the reduction of the quality of the minerals. The samples with a high amount of silica are not regarded as the argillaceous and kaolinite bauxite zone, and they were taken from the waste section. Only the amounts with silica of less than 15% can be included in the hard bauxite zone. Therefore, in case the samples taken from the waste are excluded, the quality of ore will be increased considerably in this ore deposit.

- A great part of ore is not appropriate for the raw materials of the Alumina factory of Jajarm, and merely the parts with higher grades should be selected for extraction. However, it should be noted that the aforesaid analysis was carried out on the basis of all samples taken from ore deposits and in case the samples with the lower module are eliminated, the average module in the ore will be increased. Consequently, the required raw materials will be supplied for the Alumina factory in Jajarm.

- The bauxite zone is extended from northwest to southeast on the karst surface of dolomites of Elika formation and covered by the shale and sandstone sediments of Shemshak formation. The keratinization of the dolomite bed of Tash bauxite was low to average and the bauxite horizon filled the erosive and karst surface of Elika in a layer-lens-like shape. Bauxite lenses can be seen in the area with more extreme karsted beds. Due to the low or average keratinization of the bed, it can be indicated that after the erosion of dolomites of Elika, which were deposited in an epicontinental area, a shallow sea surrounded the area. Given that, bauxite was deposited in a marine environment.

- The analysis of deep samples revealed that the minerals in greater depth had higher quality. Bauxite bed outcrops on geological maps are marked as bauxite and laterite units in the Triassic base (TRe1). Studies suggested that Tash bauxite constituents anatase, boehmite, diaspore, chamosite, kaolinite, quartz, and hematite minerals. The majority of aggregation pertains to 10% silica and 50-55% aluminum oxide. If the pH of the chemical environment of ore formation is closer to 5 to 9, it has higher stability and it contains the same amount of silica solution in this environment and it will not be accessible. Consequently, the grade of bauxite will increase considerably.

Acknowledgment

REFERENCES

[1] Pahlevan, S.M., Hosseini, S.M.S. & Goli, A. Sustainable supply chain network design using products' life cycle in the aluminum industry. Environ Sci Pollut Res (2021). https://doi.org/10.1007/s11356-020-12150-8

[2] Ghorbani M. (2007) List of Mineral Deposits and Indications of Iran. In: The Economic Geology of Iran. Springer Geology. Springer, Dordrecht. https://doi.org/10.1007/978-94-007-5625-0_9

[3] Zarei, Habibeh and Hassannejad, Ali Akbar and Zahiri, Reza and Mossadegh, Hossein, 2013, Geochemical study of bauxite-laterite deposit in Toyeh Darvar, The first conference on applied geochemistry in Iran, Damghan

[4] khoramtash, Y., fardoost, F. (2020). Petrogenesis, geochemistry and mineralogical in the Saghari copper deposit, South of shahrood.. Scientific Quarterly Journal of Geosciences, 29(114), 209-220. doi: 10.22071/gsj.2018.112299.1358

[5] Setouhian F, (2008) "Sequential stratigraphy of Elika Formation in Tash section, Eastern Alborz" Journal of Science, University of Tehran, No. 34, pp. 69-61.

[6] Jafarzadeh R., (2012) "Final report of bauxite deposit" of the country's alumina company.

[7] Abedini, A., Khosravi., M, Harald G.Dill. (2020) "Rare earth element geochemical characteristics of the late Permian Badamlu karst bauxite deposit, NW Iran", Journal of African Earth Sciences, Volume 172, December 2020, 103974

[8] Bastami, Hassan and Ferdows, Farajollah, 2014, The relationship between bauxite formation and coal formation environment in Tash region, northwest of Shahroud, 2nd National Iranian Coal Congress, Kerman

[9] Jalili, B., Calagari, A.A., Abedini, A., Simonz, V., 2013., "Study of geology and mineralogy of the Ghardeh-Ghol Fe skarn, north of Oshnavieh, West-Azarbaidjan Province, NW Iran ", Proceeding of the 5td Symposium on Iranian Society of Economic Geology, University of Mahhad

[10] Ashofteh, A., Abedini, A., Esmaeily, D., SEPTEMBER – OCTOBER 2020, "Environmental impacts assessment of Tash bauxite mine in Semnan Province, Northern Iran, News of National Academy of Sciences of the Republic of Kazakhstan, Series of Geology and Technical Sciences.

[11] Lee, Y.I., Friedman, G.M., 1987. Deep-burial dolomitization in the Lower Ordovician Ellen Burger Group carbonates in west Texas and south-eastern New Mexico. Journal of Sedimentary Research 57, 544-557

[12] Abedini, A., Mongelli., G, Khosravi., M (2021) "Geochemical constraints on the middle Triassic Kani Zarrineh karst bauxite deposit, Irano–Himalayan belt, NW Iran: Implications for elemental fractionation and parental affinity", Ore Geology Reviews, Volume 133, June 2021, 104099

[13] Shujuan Yang, Qingfei Wang, Qizuan Zhang, Jiahao Chen, Yuanxiao Huang, Terrestrial deposition processes of Quaternary gibbsite nodules in the Yongjiang Basin, southeastern margin of Tibet, and implication for the genesis of ancient karst bauxite, Sedimentary Geology, Volume 373, 201 , Pages 292-306,

[14] Rahul Ram, Megan Becker, Joël Brugger, Barbara Etschmann, Cody Burcher-Jones, Daryl Howard, Patricia J. Kooyman, Jochen Petersen ,Characterisation of a rare earth element- and zirconium-bearing ion-adsorption clay deposit in Madagascar,Chemical Geology,Volume 522,2019,Pages 93-107,

[15] Maryam Kiaeshkevarian, Ali Asghar Calagari, Ali Abedini, Gholamhossein Shamanian, Geochemical and mineralogical features of karst bauxite deposits from the Alborz zone (Northern Iran): Implications for conditions of formation, behavior of trace and rare earth elements and parental affinity,Ore Geology Reviews,Volume 125,2020,103691,

[16] Aghazadeh, S., Abedini, A., 2013., "Mass changes geochemistry of rare earth elements of argillic alteration zone in in the Khankandi area, northeast of Ahar, East-Azarbaidjan Province, NW Iran. ", Proceeding of the 1th Symposium on Applied Geochemistrys, Damghan University.

[17] Aghazadeh, S., Abedini, A., 2013., "The controlling factors of the distribution and mobilization of major, minor, and trace elements of alteration system in the Khankandi area, northeast of Ahar, East-Azarbaidjan Province, NW Iran ", Proceeding of the 1th Symposium on Applied Geochemistrys, Damghan University.

[18] Jozanikohan, G., Sahabi, F., Norouzi, G. H., Memarian, H., & Moshiri, B. (2016). Quantitative analysis of the clay minerals in the Shurijeh Reservoir Formation using combined X-ray analytical techniques. Russian Geology and Geophysics, 57(7), 1048-1063.

[19] Alipour, V., Abedini, A., Alipour, S., 2010., "Role of hypogene and supergene processes in geochemical evaluation of Zonoz kaolin deposit, NE Marand, East-Azarbaidjan Province, NW Iran", Proceeding of the 28th Symposium on Geoscience, Geological Survey of Iran, Tehran and 14 th Symposium Geological Society of Iran, Urmia University.

[20] Alipour, S., Abedini, A., Hosseini, E., 2013., "Geochemistry of semi-west sediments of the Urmia Lake with an emphasis on silver anomaly.", Proceeding of the 32 th Symposium on Geological Survey of Iran, Tehran.

[21] Arefnia, M.H., Abedini, A., Kazempour, E., 2015., "Controlling factors of mobilization and distribution of REEs in altered zones of the Kerver area, east of Jiroft, Kerman Province, Iran.", Proceeding of the 7 th Symposium on Iranian Society of Economic Geology, University of Damghan.

[22] Arefnia, M.H., Abedini, A., Kazempour, E., 2015., "Geochemical characteristics of major, minor, and trace elements of the Kerver alteration system, east of Jiroft, Kerman Province, Iran.", Proceeding of the 7th Symposium on Iranian Society of Economic Geology, University of Damghan.

[23] Barati Lak, A., Alipour, S., Abedini, A., 2013., "Geochemistry of major, minor, and trace elements of the Balestan iron deposit, southeast of Urmia, West-Azarbaidjan Province, NW Iran ", Proceeding of the 1th Symposium on Applied Geochemistrys, Damghan University.

[24] Dadehzadeh, S., Abedini, A., 2013., " Geochemical features of rare earth elements in the kaolinized zones of the Anbagh area, northeast of Ahar, East-Azarbaidjan Province, NW Iran. ", Proceeding of the 1th Symposium on Applied Geochemistrys, Damghan University.

[25] Dadehzadeh, S., Abedini, A., 2013., "Geochemistry of rare earth elements of prophylitic and silicic alteration zones in the Anbagh area, northeast of Ahar, East-Azarbaidjan Province, NW Iran ", Proceeding of the 1th Symposium on Applied Geochemistrys, Damghan University.

[26] Hosseinpour, H., Calagari, A.A., Abedini, A., Simonz, V., 2013., "Mineralogy and geochemistry of kaolin deposit in the Ghalandar area, north of Ahar, East-Azarbaidjan Province, NW Iran ", Proceeding of the 5th Symposium on Iranian Society of Economic Geology, University of Mahhad.

[27] Kangrani Farahani, F., Calagari, A.A., Abedini, A., 2013. , "Investigation of REEs geochemistry of the Kombelu laterite deposit, Semnan Province, Iran ", Proceeding of the 17th Symposium Geological Society of Iran, Shahid Beheshti University.

[28] Kangrani Farahani, F., Calagari, A.A., Abedini, A., 2013., "Geochemistry of major, trace, and rare earth elements of the Zan laterite deposit, Tehran Province, Iran. ", Proceeding of the 1th Symposium on Applied Geochemistrys, Damghan University.

[29] MohammadiArjmand , S., Abedini, A., 2015., "Investigation of behaviour of major and trace elements during development of the Hangaran alteration system, southeast of Birjand, South Khorasan Province, Iran.", Proceeding of the 7 th Symposium on Iranian Society of Economic Geology, University of Damghan.

[30] Pahlevan, S. M., Hosseini, S. M. S., & Goli, A. (2021). Sustainable supply chain network design using products' life cycle in the aluminum industry. Environmental Science and Pollution Research, 1-25.

[31] SavariKordlar, A., Abedini, A., Kazempour, E., 2016., "Rare earth elements geochemistry of alteration zones of the Ghabagh-Tappeh area, west of Mianeh, NW Iran.", Proceeding of the 34 th Symposium on Geoscience, Geological Survey of Iran, Tehran.

[32] Siahcheshm, K., Abedini, A., 2011. , "Alteration mineralogy, geochemistry and elemental mass balance through the hydrothermal alteration zones of Maher Abad Cu–Au porphyry deposit, Khusf, Iran ", 34th Annual Winter Meeting of the Geological Society's Mineral Deposit Studies Group and the Applied Mineralology Group of the Mineralogical Society and the 14th CERCAMS Workshop on Ore Giants of Asia was held on 5th–7th January 2011 at the Natural History Museum, London.

[33] Siahcheshm, K., Calagari, A.A., Abedini, A., 2013., "Quantative evaluation of mass balance of hypogene alteration zones in the Maher-Abad porphyry copper-gold deposit, southern Khorosan ", Proceeding of the 1th Symposium on Applied Geochemistrys, Damghan University.

[34] Soleimani Matin, A., Abedini, A., Alipour, S., 2013., "Geochemistry of major, minor, and trace elements in the VarzaghanehTorkamanchay bentonite deposit, northwest of Mianeh, East-Azarbaidjan Province, NW Iran ", Proceeding of the 1th Symposium on Applied Geochemistrys, Damghan University.

[35] Tarighi, F., Abedini, A., 2013. , "Geochemistry of major, minor, and trace elements of the Arabshah kaolin deposit, southeast of Takab, West-Azarbaidjan Province, NW Iran. ", Proceeding of the 1th Symposium on Applied Geochemistrys, Damghan University.

[36] Tarighi, F., Abedini, A., Oruji, A., 2013., "Geochemistry of rare earth elements of kaolinized zones in the Arabshah area, southeast of Takab, West-Azarbaidjan Province, NW Iran ", Proceeding of the 5th Symposium on Iranian Society of Economic Geology, University of Mahhad.