Mineralogical And Microthermometrical Studies On The Gonharan Lead-Zinc Deposit, Daran, Isfahan Province

Mahdieh Safizadeh *

Department of Geology, Payame Noor University, PO BOX 19395_3697, Tehran, Iran
Email: safizadeh@pnu.ac.ir

Abstract

The Gonahran lead-zinc deposit in Isfahan is located in the central part of the Sanandaj-Sirjan zone and is situated along northwest-southeast trending faults. The primary mineralization is hosted in Cretaceous limestones and occurs as silica-carbonate veins containing sulfides of lead, zinc, and copper. The style of mineralization varies across the deposit. In the western part, it appears as a network of lead veins within a dolomite and calcite gangue. In the eastern section, mineralization occurs as masses, lenses, and pockets parallel to the layering at the contact with metamorphic sandstone and shale. Mineralogical studies show that galena is the main ore mineral, with minor amounts of pyrite, sphalerite, and chalcopyrite. Analysis of fluid inclusions indicates formation temperatures between 160 and 180°C and a salinity range of 5 to 21%. This wide range of temperature and salinity suggests the mixing of hydrothermal and meteoric waters, a process considered crucial for concentrating the ore. Based on this data, the Gonahran deposit is classified as a Mississippi Valley-Type (MVT) deposit, with a minimum formation depth estimated at 80 meters.

Keywords: Deposit, Geochemistry, Geology, Gonharan, Metamorphism, Mineralogy, plumb, Zinc.

1- Introduction

Lead-zinc deposits are among the world's most vital metal resources, with wide-ranging applications in industries like automotive manufacturing, battery production, and construction. These deposits often form in sedimentary and carbonate environments, with Mississippi Valley-Type (MVT) deposits being one of the most significant. MVT deposits are typically hosted in limestone and dolomite and form from relatively low-temperature (around 50-200°C) brines rich in metals (Leach et al., 2005). Understanding the formation of these deposits is crucial for future exploration.

Due to its unique geological setting, Iran has several metallogenic belts, with the Sanandaj-Sirjan metallogenic belt in western and central Iran being one of the most prominent for lead and zinc. The Gonahran deposit, located within this belt, is a prime example of a sediment-hosted hydrothermal system where mineralization occurred in Cretaceous limestones. This deposit provides a unique opportunity to study the geochemical and petrogenetic processes associated with MVT deposits in a tectonically active region.

Modern economic geology and geochemical studies on these deposits, particularly using techniques like isotope geochemistry and fluid inclusion analysis, provide detailed insights into the origin of hydrothermal fluids, their migration pathways, and the physicochemical conditions of ore formation (Emsbo et al., 2003). For instance, fluid inclusion studies can reveal precise homogenization temperatures, salinity, and the chemical composition of the mineralizing solutions, helping to model the fluid mixing process (Goldfarb et al., 2011). This research, by focusing on the Gonahran deposit, aims to analyze the specifics of its mineralization, alteration, and formation conditions to provide a comprehensive genetic model and evaluate its exploration potential in the region.

2- Methodology

The outlined research methodology is designed for a comprehensive investigation of a mineral deposit. It consists of three primary stages, moving from initial sample preparation to detailed laboratory analyses.

1. Sampling and Preparation of Thin and Polished Sections

This stage is the first step in mineralogical and petrographic studies.

Thin Sections: Fifteen polished thin sections were prepared to examine the mineralogy, texture, and structure of the host rocks and vein-bearing rocks under a petrographic microscope. By passing polarized light through these sections, non-opaque minerals like quartz, calcite, and dolomite can be identified, and their relationships within the rock fabric can be studied. This method is crucial for understanding alteration processes, such as dolomitization.

Polished Sections: Twenty-five polished sections were prepared to examine the opaque ore minerals under a reflected light microscope. Since metallic minerals like galena, sphalerite, and pyrite do not transmit light, they must be studied using reflected light. These sections allow for a detailed examination of the paragenesis (the order of mineral formation), textures, and relationships between the ore minerals. For example, it's possible to observe the spatial relationship between galena and sphalerite within a vein to determine their formation sequence.

2. Analysis of Samples using the X-ray Diffraction (XRD) Method

This stage is performed for the precise identification of minerals at a crystalline scale.

Purpose: XRD analysis is a non-destructive technique that records the X-ray diffraction pattern of a powdered sample. Each mineral has a unique crystal structure, producing a distinct diffraction pattern that acts like a fingerprint.

Samples: Five samples were selected for this analysis: two from the mineral veins and three from the inclusive rocks. This selection allows for the accurate identification of minerals in both the main mineralization zones and the surrounding host rock.

Location: The analyses were conducted at the Iran Mineral Processing Research Center, which is equipped with advanced instruments.

Application: The XRD results confirm the minerals identified through microscopic studies and can also detect fine-grained or minor minerals that are not easily recognizable with traditional microscopes.

3. Sampling and Preparation of Double-Sided Polished Sections for Microthermometry Studies

This final stage is critical for understanding the physicochemical conditions under which the deposit formed.

Microthermometry: This technique involves the study of fluid inclusions—microscopic bubbles of ancient fluids trapped within crystals as they grew. These inclusions act as time capsules.

Samples: Ten double-sided polished sections were prepared from ore veins. These sections are carefully made to allow light to pass through them, enabling the observation of the fluid inclusions.

Application: Using a microthermometry stage, the sample can be gradually heated and cooled to measure key temperatures, such as the homogenization temperature and the freezing point.

Homogenization Temperature: Represents the temperature at which the mineral and the fluid inclusion formed.

Freezing Point: Allows for the estimation of the salinity of the mineralizing solution.

The results from these analyses provide valuable data on the formation temperature, pressure, and chemical composition of the hydrothermal solutions, which are essential for developing a genetic model for the deposit.

3- Geographical position

Ganhoran plumb and zinc deposit is located in longitude coordinates of 50 41’ 34’’, latitude of 32 59’ 4’’ and in the distance of 20 kilometers of east of Daran town (of Isfahan functions) (Figure 1).

4- Geology

From geological aspect, understudied region is located at the center of Sanandaj-Sirjan zone Schtoklin, 1968) (Figure 2), and also is located on North of 1:100000 geological map of Chadegan (Ghasemi et al., 1385). According to 1:10000 geological map of the area (Safizadeh and Rastad, 1391) (Figure 3), units which have outcrop in the area are Jurassic, Cretaceous units and Quaternary sediments.

Metamorphic units with age of Jurassic are seen in the uppermost part of north of area and in the form of green schist and slate along with less metamorphosed sedimentary rocks (Sandston and siltstone). Major stone units of the area are consist of Cretaceous units including Dolomitized and Orbitolina limestone, fossiliferous marly limestone, thin layers of clay- sand limestone, red sandston, thin layers of clay limestone and Conglomerate, and main host rocks are also these units. Extensive part of the area is covered by Quaternary sediments. These sediments generally includes old and young terraces and Alluvium, and form agricultural lands. The contact between Jurassic metamorphic rocks and Cretaceous sedimentary rocks are in the form of thrust fault (Darre-Bid Fault, 1:10000 geological map of Ganhoran, Safizadeh, Rastad, 1391) (Figure 3).

The tectonic phase in mineral region of Gonharan caused frequent faults with north west-south east trending and in some of these faults silica and carbonate veins are formed. Veins consist of sulfide mineralization mostly with Pb and low amount of Zn and Cu. Younger faults have crushed the silica veins.

5. Metamorphism and mineralization

As it was mentioned, in the area hydrothermal phase with the presence of silica veins and with a certain trend (North West – South East) is obvious. The solution has penetrated along the fault and done the mineralization of plumb and participant elements in a proper location (limeston) (Figures 3 and 4).

From stratigraphy position aspect, the mineralization in the Ganhoran mine is in two forms (1:10000 geological maps of Gonharan, SAfizadeh and Rastad, 1391) (Figure 3):

First section (West of Ganhoran): is located in the contact of mass Orbitolina limestone with marly calcic unit. The foot wall of this section is Orbitolina limestone with color of dark gray and abundant fault and fracture. The cream marly-calcic unit forms the hanging wall of the mentioned mineralized horizon. In this section some trenches have been drilled on the mineralization zone and silica veins containing minerals (Figure 6. a).

Second section (East of Darre-Bid): is located in the contact of Cretaceous limestone with Jurassic metamorphic shale-sandstone, and apparently this impermeable metamorphic shale-sandstone layer has acted as an impervious horizon or cap rock and make an stratigraphic trap in sedimentary sequences. In this section has drilled a tunnel in order to have access to minerals (Figure 6. b). Silica veins have also occurred in plain located at southeastern part of Darre-Bid and is without mineralization.

To extract mineral material, a tunnel was excavated in the west part of Gonharan, and some outdoor veins are located there by excavating trenches (Fig 3). In the West of Darre-Bid, the extraction is limited to a tunnel drilled in the mountains, and because of being mineral-free, Silica veins scattered in the lower plain of tunnel are intact. The next high-purity mineral was extracted from Sangjuri and low-grade depots are remained. Inside these depots the mineralization of Galena, Malachite, Pyrite and chalcopyrite with Calcite and dolomite can be seen (Figure 6.c).

Generally, the effect of wall rock metamorphism on Ganhoran deposit is simple and includes dolomitization, jasperiods, hematitization, recrystallization and pyritization (Figure 4). Silicification has occurred widely in host rock and it seems that the formation of silica veins along fractures has occurred simultaneous and after the mineralization. The mineralization is along with silica veins and jasperiod zone. Hematitization is observed around the ore veins and veinlets in contact with host rock and with slight thickness and limited extension (Figure 6. d). Hematite and other iron oxides are the result of Pyrite metamorphism (Figure 7.a). In the Far East of the village of Darre-Bid, intensively hematitization along with silicification has occurred at the contact of Jurassic metamorphic rocks and Cretaceous limestone, which is mineral-free (Figure 4).

Recrystallization in Ganhoran deposit has caused the generation of spar Calcite from Micro-crystalline Calcite and recrystallization of crystalline quartz from Micro-crystalline quartz (Figure 7. b). In the tunnel located at the East of Darre-Bid, there is Calcite abundantly as gangue along with Galena (Figure 8.a). Quartz is the second gangue (Figure 8. b).

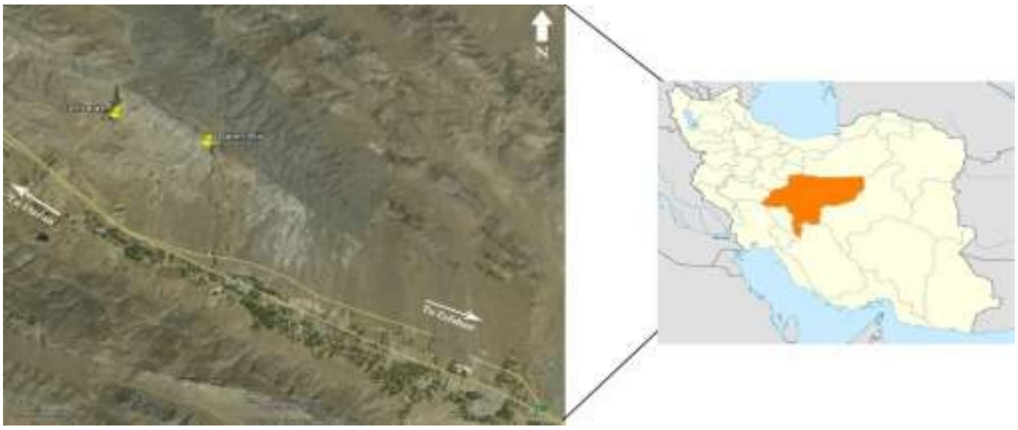

Figure 1- Reaching ways to understudied zone

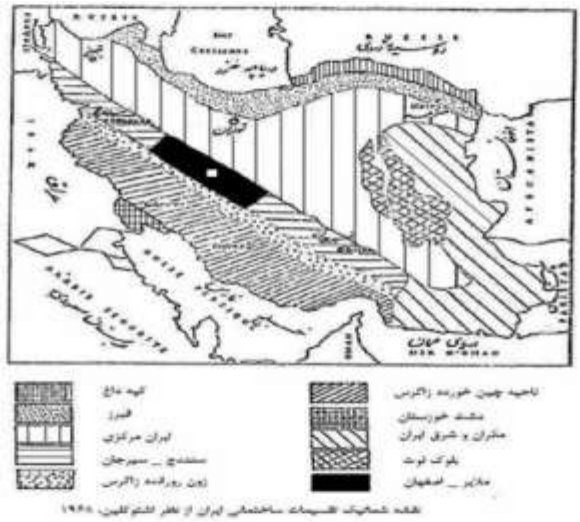

Figure 2- The geographical position of understudied zone in Gonharan on Iran structural earth map (Schtoklin, 1968)

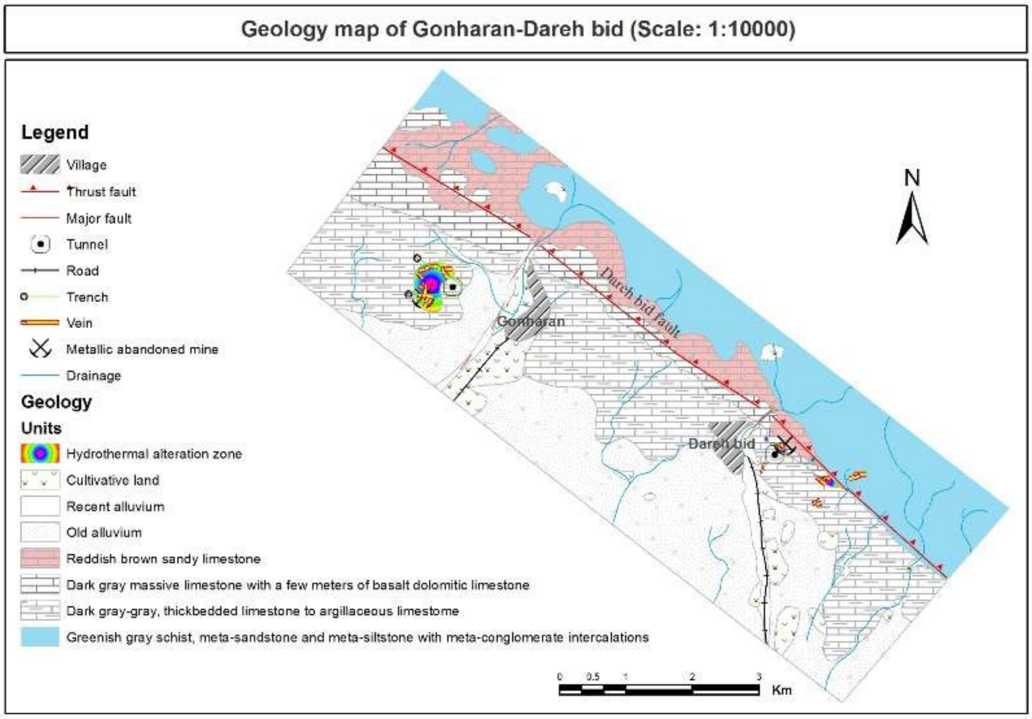

Figure 3- Geological map of Gonharan zone, 1:10000 scale (Safizadeh and Rastad, 2012)

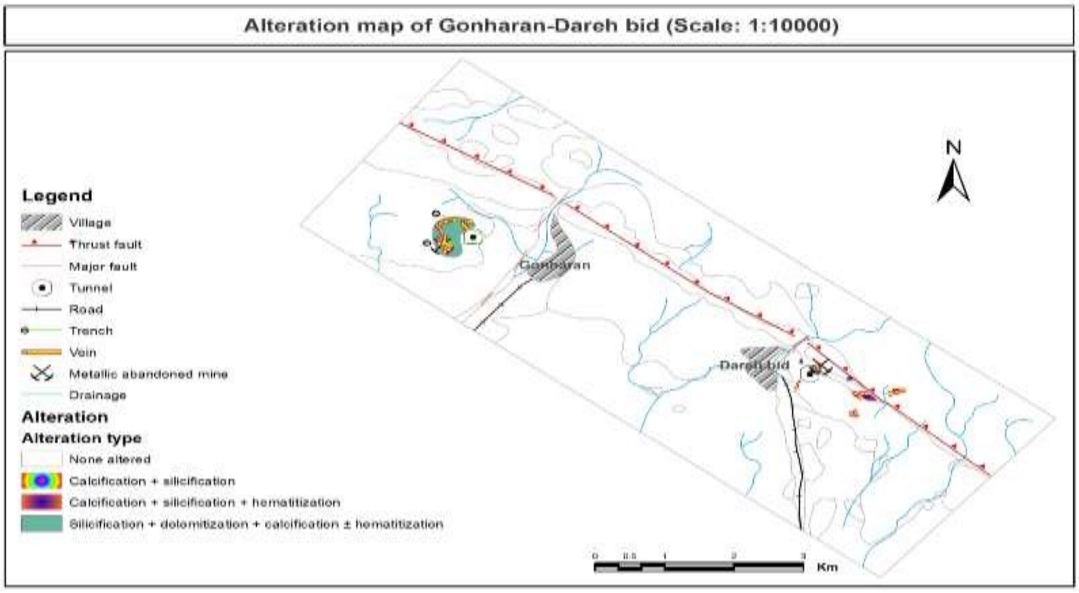

Figure 4- Metamorphism map of Gonharan zone, 1:10000 scale (Safizadeh and Rastad, 2012)

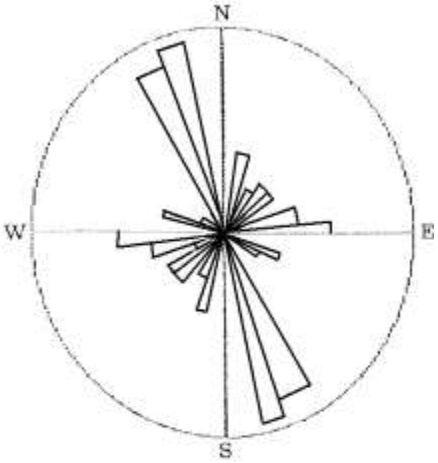

Figure 5- Rose diagram for existed faults and fractions in Gonharan, common trend is NW-SE (Safizadeh and Rastad, 2012)

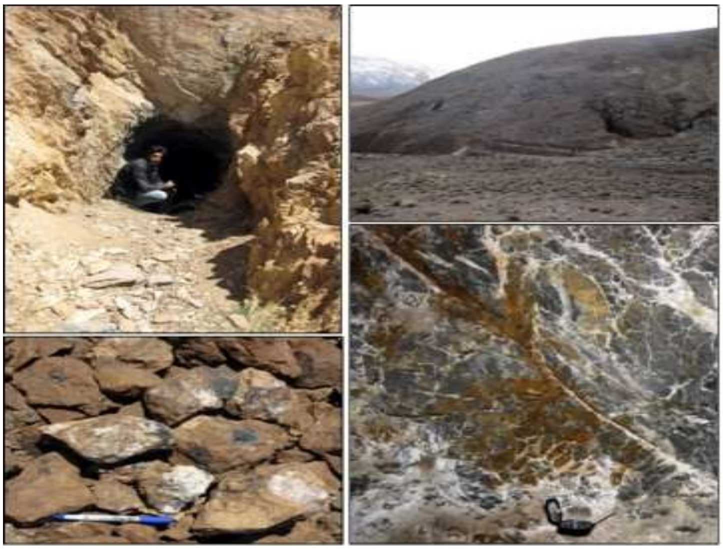

Figure 6- a) View of trenches on mineralization zone and veins that are included mineralization of west Gonharan, b) Drilled tunnel in mineralization zone in east of Daree-Bid, c) Depots contain the mineralization of Galena, Malachite, Pyrite and Chalcopyrite with Calcite and Dolomite, d) Hematitization in mineralization zone and inclusive rock.

Figure 7- a) Pyrite metamorphism to hematite and other iron oxides. b) Recrystallization of Calcite, 20 x magnitudes

Figure 8 a) Calcite abundantly as gangue along with Galena in tunnel located at the east of Darre-Bit. b) Quartz is the second gangue in Gonharan tunnel

6. Mineralogy

The mineralogy of Ganhoran plumb and zinc deposit has determined using microscopic studies and the analysis of 5 samples by XRD method. These analyses have been done in Iran mineral processing research center. Chalcopyrite, Malachite, Sphalerite, Bornite and Covellite are not observed in the results of XRD. This can be due to the low percent of these minerals in Ganhoran deposit, but in microscopic studies these minerals were observed slightly.

Pyrite (FeS_2):

In the Ganhoran deposit, Pyrite is observed inside the veins and fractures (with or without mineralization), inside the shale and limestone of upper horizons of mine.

In Ganhoran deposit, Pyrite is seen in the following forms:

1. Idiomorphic Pyrite: which seems has been formed in the syngenetic process and has a symmetric geometric shape. This kind of Pyrite is usually big in size (about 0.2 mm) and is observed inside shale and limestone (Figure 9. a).
2. Tiny and sprayed crystals in the rock matrix: in many cases, along with these tiny crystals, idiomorphic Pyrite is also observed which probably is the result of recrystallization and nutrition of one crystal of adjacent tiny crystals (Figure 9. b).
3. Pyrites located along the fractures: these fractures had been probably a channel for fluid transmission and Pyrite is the result of deposition from these fluids (Figure 9. c).
4. Oxidized Pyrite: Pyrite decomposes to iron oxides in the oxide zones (Figure 9. d).

5. Cataclastic Pyrites: Pyrite was crushed as a result of stresses and these fractures were filled by gangue minerals (Figure 9. e).
6.

a. Pyrite mineralization stages:

According to observations and evidence, in Ganhoran deposit 4 Pyrite mineralization stages are recognizable:

a. Syngenetic mineralization stage: the Pyrite has been formed primarily inside shale and limestone.
b. Diagenetic stage: due to stress and pressure, Pyrite has been crushed and deformed.
c. Epigenetic along with mineralization stage: in this stage, Pyrite is formed along with the formation of Galena and Sphalerite.
d. Epigenetic after mineralization stage: the presence of Pyrite in delayed veins without mineralization represents the formation of Pyrite after the stage of mineralization.

Galena (PbS):

Galena is the main deposit mineral in Ganhoran mine, and is in the form of coarse crystals (the size of some crystals reaches 1cm). In Galena the amount of argent is high and in some samples it reaches 625ppm.

a. In Ganhoran deposit, Galen is seen in the following shapes and forms:
1. Galena in syngenetic form: this form is observed in limestone available at upper horizons and Galena has sediment primarily while deposition. There is no relation between these crystals and fractures.
2. Galena with cataclastic texture: in some cases, under the stresses and forces, Galena crystals have been crushed.
3. Deformed Galena crystal by tectonic stresses (Figure 10.c). This phenomenon is called gneisses fold.

b. Galena mineralization stages:

In Ganhoran deposit, 3 Galena mineralization stages are recognizable:

1. First stage: syngenetic mineralization of galena in depositional environment. Because of the presence of high amount of plumb in the area, the content of plumb while deposition has been high and the Galena was formed. It is probable that these crystals have grown and become larger during diagenes stage. Due to the low percentage of zinc in this area rocks, Sphalerite has not been formed in this stage.
2. Second stage: mineralization of Galena with Sphalerite, however, it needs to be mentioned that the abundance of Sphalerite in comparison with Galena is negligible.
3. Third stage: mineralization of Galena without Sphalerite, the main part of Galena in Iran has been formed in this stage.

Chalcopyrite ($CuFeS_2$):

In Ganhoran deposit, Chalcopyrit is only observed in mineralized zone. The abundance of chalcopyrite in Ganhoran is low, and this mineral was observed in several samples which most of them has been converted to secondary copper-bearing minerals.

a. In Ganhoran deposit, Chalcopyrite is seen in the following shapes and forms:
1. In many cases, chalcopyrite in ore-bearing zone has been decomposed to Bornite, Covellite and Malachite (Figure 10. d).
2. In some cases, chalcopyrite has been decomposed to bornite and Pyrite (Figure 10.e), and Pyrite has been also decomposed to iron oxides.

Sphalerite (ZnS):

In Ganhoran deposit, the percent of Sphalerite is very small and only in some samples has been observed (Figure 10.b). The abundance of zinc is also very low and is lower than to form an independent mineral abundantly. The Sphalerite available at Ganhoran seems to be full of iron because of being dark.

Cerussite ($PbCO_3$):

This mineral is formed in oxidation zone and is the result of Galena oxidation in an alkaline environment.

Mimetite ($Pb_5(AsO_4)_3Cl$):

Accordin to X-ray diffractometery studies, secondary mineral of Mimetite was identified. This mineral is also formed in oxidation zone and of Galena oxidation.

Siderite ($FeCO_3$):

This mineral, similar to Cerussite and Mimetite, is observed in oxidation zone. Siderite can be the result of reaction between iron sulfate and calcium carbonate or substitution of iron in calcium carbonate.

Bornite (Cu_5FeS_4) and Covellite (CuS):

In ganhoran deposite, Bornite and Covellite is the product of decomposition of Chalcopyrite (Bornite is also formed as primary mineral). In most cases the remains of Chalcopyrite is observed with them (Figure 10. d). Sometimes, chalcopyrite is decomposed to Pyrite + Covellite. The following equation shows this decomposition:

$$\mathbf{FeS_2 + CuS \qquad CuFeS_2 + S} \quad \longrightarrow$$

Iron oxides:

Minerals Goethite, Jarosite, Hematite and Limonite are results of decomposition of Pyrite and the composition of it with water (Figure 10.f). Oxidation process along faults and fractures is widely extended.

As it was mentioned, in Darre-Bid in comparison with Ganhoran, main part of mineralization is in the border of Cretaceous limestone and Jurassic metamorphic sandstone and shale, and the variety of nonmetallic minerals is low. Silica veins are also outspread in this plain. Microscopic and instrumental (XRD) studies have also indicated the presence of following nonmetallic minerals: Quartz, Calcite and Muscovite.

3-5-1 Quartz (Q):

In Darre-Bid, Calcite and Quartz are the main gangue, and Quartz is known as the main gangue of Silica veins. This mineral is observed in 4 forms:

- Clastic Quartz which is spread in the form of tiny particles in the rock matrix and these particles are cemented together and shows a mosaic texture (Figure 11.a).
- Quartz available in jasperiod zone.
- Vein Quartz with Breccia texture (Figure 11.b).
- Quartz with chloroform or rubble texture which indicates the deposition of minerals from a solution, and is the typical of hydrothermal deposits (Figure 11.c).

Calcite ($CaCO_3$):

Calcite with Quartz is observed in veins and veinlets inside limestone, Shale and sandstone which is the confirmation of simultaneous deposition of Quartz and Calcite from the fluid, and is seen in 3 forms of microcrystalline, Spar Calcite and vein Calcite (Figure 11.d).

Muscovite:

This mineral is observed along with Quartz in veins and fractures without mineralization. In ore-bearing veins, Quartz and Calcite are present together, and Muscovite is not seen in these veins. Therefore, the presence of Muscovite in mineral veins is an indication of lack of mineralization.

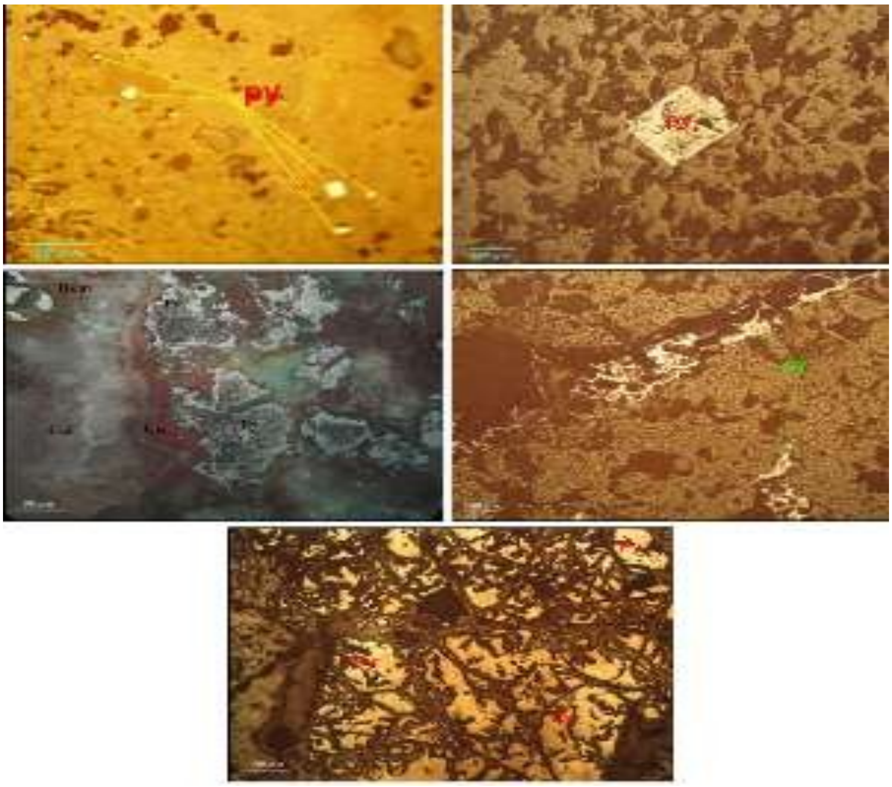

Figure 9- a) Pyrite (Py) syngenetic in lime matrix. b) Pyrite tiny and sprayed crystals which are observed as shaped, semi shaped and unshaped forms. c) Pyrite (Py) veins in host rock. d) Pyrite (Py) decomposed to Hematite (Hem) and Gutite (Gu), Pyrite is along with Calcite viens. e) Crushed Pyrite (Py) under tectonic pressures, the gap between crushed Pyrite particles was filled by iron oxides.

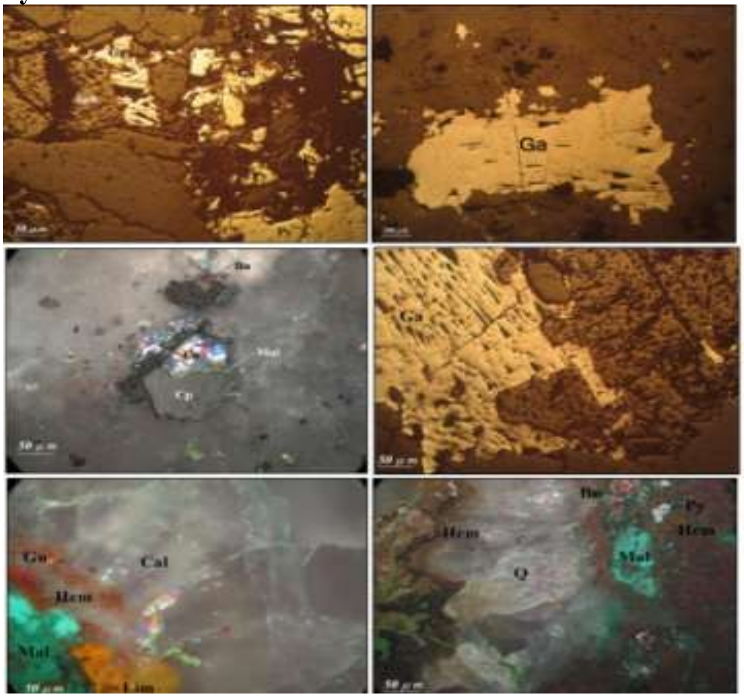

Figure 10- a) Syngenetic Galena crystals. b) Galena (Ga), Pyrite (Py), Sphalerite (Sph) crystals which are crushed under tectonic pressure, c) Spiral transformation in Galena (Ga) crystals under tectonic accidents, d) Chalcopyrite decomposed to Bornite, Covellite and Malachite. e) Chalcopyrite decomposed to Bornite, Pyrite and Malachite. f) Decomposition of primary metallic minerals to secondary minerals such as Hematite, Geothite and Himonite

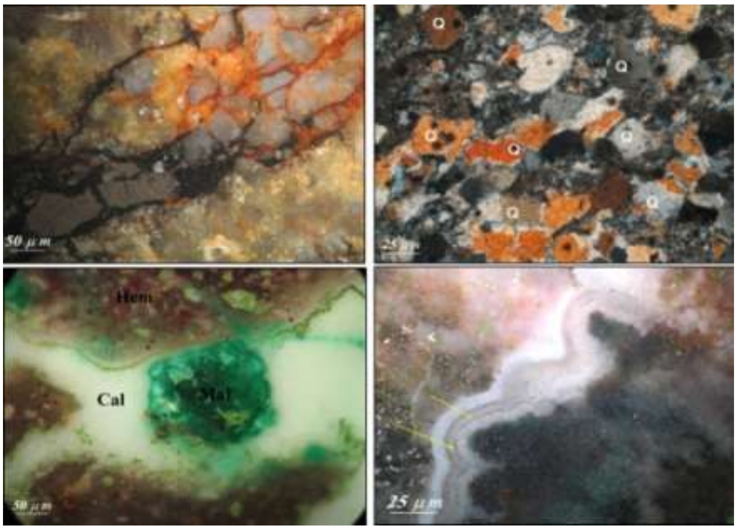

Figure 11- a) Clastic Quartz particles in a section of host rock. b) Vein Quartz with Breccia texture, around Quartz particles is treated by iron oxides, c) Quartz with Chloroform texture, d. Vein Calcite

Sequence of minerals in Ganhoran deposit:
In Ganhoran deposit, the sequence of minerals is as follow (Table 1):

- Formation of sandstone shale and limestone host rock, deposition of syngenetic Pyrite and Galena has been accomplished in this stage. It needs to be mentioned that Pyrite mineralization has been done during all these stages.
- The operation of tectonic processes which has caused faulting and generation of fractures in limestone and sandstone host rock.
- The penetration of ore-bearing fluids through fractures available in host rock and then the formation of Silica – Calcite veins, deposition of Galena, Sphalerite, Chalcopyrite and probably Bornite have been accomplished in this stage.
- Main stage of Galena mineralization without Sphalerite mineralization.
- Alteration and decomposition of Galena, Pyrite and Chalcopyrite as well as formation of Cerussite, Siderite, Covellite and Mimetite (the formation of Silica-Calcite veins has not been done in this stage).
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Table 1- Paragenetic sequence of minerals in Pb and Zn deposit of Gonharan

Minerals	Minerals stages			
	Sedimentation	Diagenesis	Mineralization	Processes after mineralization
Pyrite	—	—	━	⋯
Chalcopyrite		—	—	
Galena	—	—	━	
Sphalerite		⋯	—	
Quartz	—	—	━	—
Calcite		—	—	—
Bornite			⋯	—
Cerusite				—
Mimetite				—
Covellite				—
Malachite				—
Siderite				—
Iron oxides		⋯	⋯	—

7- Involved Fluids

Petrography of involved fluids

To do microthermometric study, 10 quartz samples (from mineral veins of Gonharan deposit) were used. Samples were cut and made thinner till 200 micron, and were polished in both sides. At first, the studies on involved fluids carried out in microthermometry laboratory on 40 involved fluids by Ziess microscope and Linkam device THM600 model.

The sizes of under studied involved fluids were different and varied between7-35 micron (Fig. 12). The shapes of most of the fluids in the samples were: circular, elliptical, spindle, semi shaped and none shaped (Fig. 13). The sources of understudied involved fluids were categorized in to 3 groups according Yermakov et al. (1965) classification: Primary inclusion, Secondary inclusion, and Pseudo secondary inclusion (Fig. 14).

Four types of involved fluids regarding the ratios of phases are listed below:

Type A- Two phased involved fluid (liquid- Gas) Liquid rich

In this type of fluids, liquid phase is along with the phase of gas bubbles. Most of the fluid's volume is liquid and the gas phase formed only 10-35% of fluid's volume. In such fluid, there isn't any solid phase of salt. Most of the studied fluids are categorized among this group of fluids. The salinity amount of this type varied between 5.5-20.7 % by weight of NaCl (Fig. 15).

Type B- Two phased involved fluid (liquid- Gas) Gas rich

In this type of fluids most of the volume is related to gas bubbles. Sometimes, more than 70% of fluid's volume is gas bubbles. Homogeneity temperature in this type is higher while the density is lower (Fig. 16).

Type C- One phased involved fluid (Liquid)

This type was observed in samples rarely. Although liquid one phased fluids were observed more than gas one phased fluids, they weren't used in thermo barometric measurements (Fig. 17).

Type D- One phased involved fluid (Gas)

In this type of fluids, gas bubbles form more than 95% of fluid's volume, and there is not possibility of observing liquid phase, therefore this type of fluids is not proper for thermo barometric measurements. Frequency of this type indicates extreme boiling condition; although the frequency of this type is really rare (Fig. 18).

Temperature measurements of involved fluids

Measuring temperatures carried out by heating and cooling stage model THM600 that was made by Linkam Company, which its temperature range varied between 190-600 ° C. This device is capable to be linked to computer simultaneously, and make it possible to provide film or slide.

In under studied samples the salinity amount (%Wt NaCl) and density calculated by Flincor and PNTX modeling software, then data was indicated through table and histogram graphs. Achieved data from fluids that were mostly liquid rich type are presented in next tables and graphs. In some samples with gas one phased fluids or gas rich fluids that their numbers were rare, measurement was impossible. In Table 2, measured temperature (Th, Tm), salinity, and density of involved fluids are presented.

Regarding achieved data from involved fluids, homogeneity temperature varied between 108-268 °C, and the most frequent temperature variation was 160-180 °C (Fig. 19). The salinity of involved fluids also varied between 5.5-21% by weight of NaCl, and the most frequent salinity amount was between 11-14% (Fig. 19).

By plotting salinity and homogeneity temperature data that was achieved from fluids and comparing them with Wilkitson's graph (2001) (Fig. 20), the main factor of mineralization, which leads to changes in conditions of ore-bearing fluids, can be determined. Regarding achieved procedure (Fig. 21), dilution of ore-bearing fluid by surfing water, was the main factor of mineralization in Gonharan's deposit. By the means of Wilkinson's graph (2001) and applying salinity and homogeneity temperature, Gonharan deposit classified in the range of deposits of Mississippi valley type (MTV) (Fig. 22).

To understand depth of mineralization, temperature and salinity information of involved fluids was applied in the Hus's graph (1971). As the least temperature for mineralizing was between 108-268°C, and salinity amount varied between 4-21% by weight of NaCl, if the mean temperature of homogeneity was supposed 180°C and the mean of salinity amount was supposed 14% by weight of NaCl, the least depth of mineralization is estimated about 80m regarding aforementioned graph (Figure 23).

8. Geological and Mineralogical Results

The mineralization in Ganhoran deposit is in the form of syngenetic and epigenetic. In syngenetic mineralization stage, Pyrite and Galena have been formed. The Ganhoran deposit has a low variety of mineralization and the abundance of galena is remarkable. Main minerals of Ganhoran deposites include: Galena, Pyrite, Chalcopyrite, Sphalerite, Cerussite, Siderite, Bornite, Covellite, Mimetite and iron oxides. Quartz and Calcite are main gangues. In petrographic studies, most of the involved fluids are patterned and biphasic which liquid phase is dominant. The most common sizes of involved fluids are 20-30 micron. Involved fluids are mostly circular, elliptical and spindle. The proper temperatures for forming entrances are between 160-180° C, with total temperature of 170°C. The salinity amount mostly varied between 5-21% by weight of salt and the salinity mean was 14% by weight of salt. The wide temperature domain of homogenization and salinity of involved fluids can indicate the mixture of atmospheric aqua with hydrothermal solvents; the mixture of salty mineralizing fluids with surface waters is the main factor of mineralization concentration. According achieved data from studies on involved fluids, Gonharan deposit is located in the region of MVT deposits, and the least depth of formation of such deposit is estimated about 80 meter.

Figure 12- Size differences of involved fluids which varies between 7-35 micron

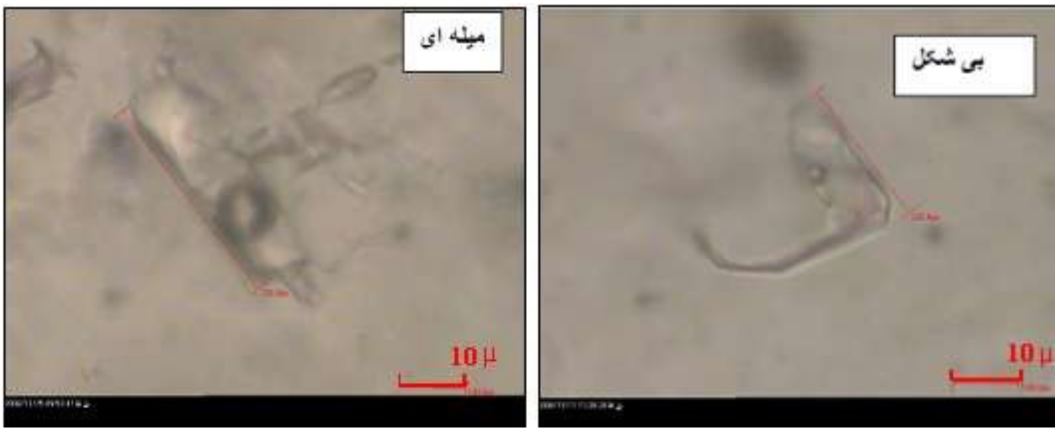

Figure 13- The most frequent shapes of involved fluids that were observed in samples

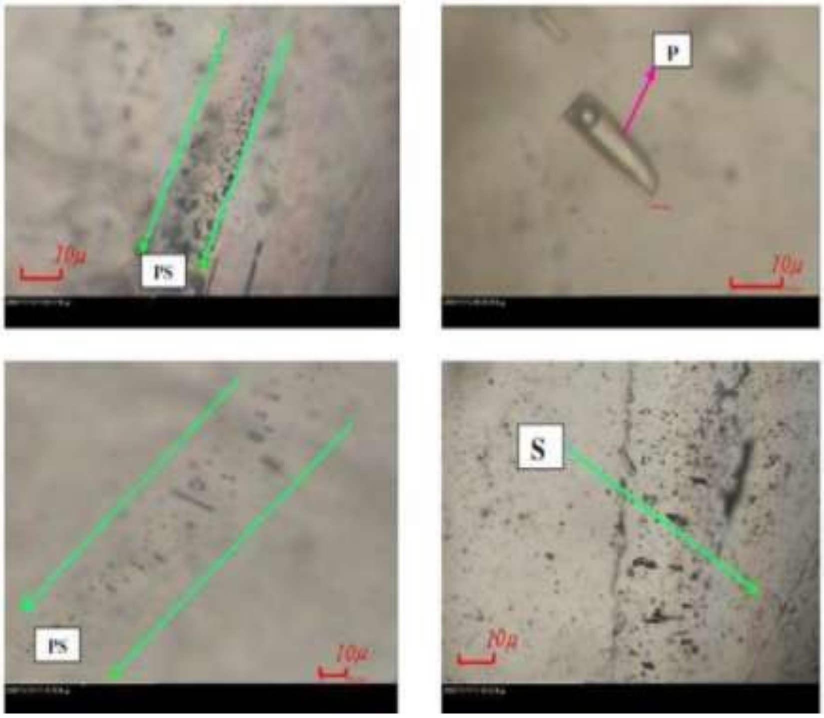

Figure 14- Different types of observed involved fluids

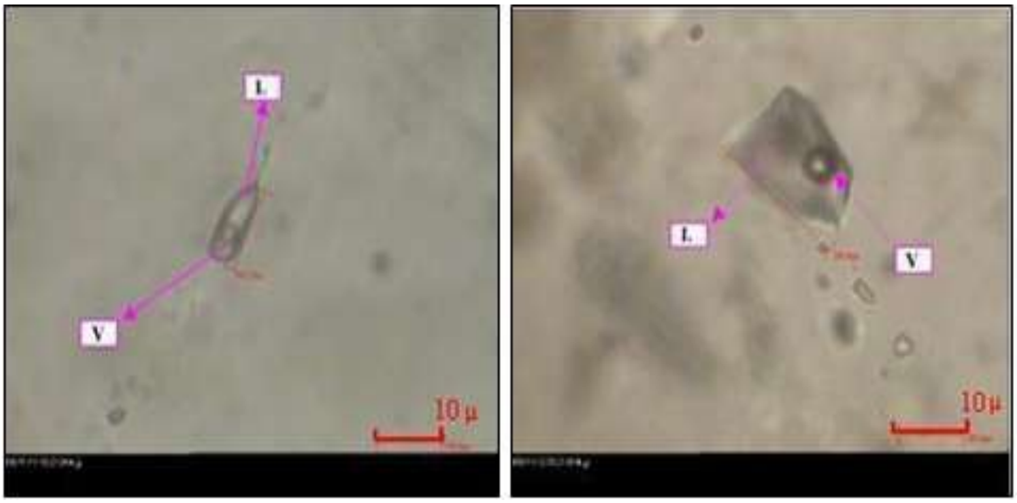

Figure 15- Two phased involved fluid (liquid- Gas) Liquid rich

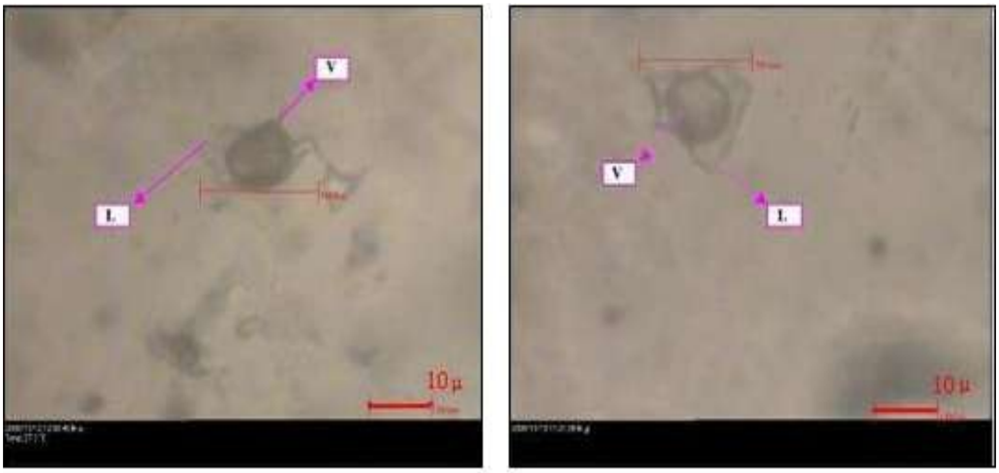

Figure 16- Two phased involved fluid (liquid- Gas) Gas rich

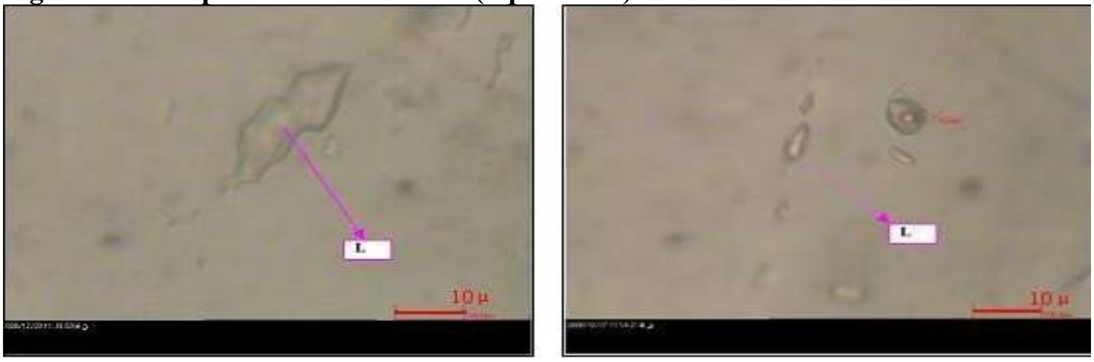

Figure 17- One phased involved fluid (Liquid)

Figure 18- One phased involved fluid (Gas)

Table 2- The homogeneity temperatures of some fluids are not calculated that are shown by hyphen

Inclusion Number	Inc. Type	Class	Tm-ice	Th	Salinity %	Dencity
1	L+V	Primary	-3.4	123	5.54	0.948
2	L+V	Primary	-5.6	135	8.68	0.96
3	L+V	Primary	-6	155	9.22	0.962
4	L+V	Primary	-6	171	9.22	0.962
5	L+V	Primary	-6.2	157	9.48	0.963
6	L+V	Primary	-6.3	-	9.61	0.964
7	L+V	Primary	-7	-	10.51	0.968
8	L+V	Primary	-7.1	108	10.6	0.968
9	L+V	Primary	-7.2	232	10.76	0.969
10	L+V	Primary	-7.2	-	10.76	0.969
11	V+L	Prim+Sec	-7.3	168	10.85	0.97
12	L+V	Primary	-7.4	-	10.93	0.971
13	L+V	Primary	-8	-	11.69	0.973
14	L+V	Primary	-8.1	185	11.85	0.974
15	L+V	Primary	-8.2	203	11.97	0.974
16	L+V	Primary	-8.2	-	11.97	0.974
17	L+V	Primary	-8.3	-	12.09	0.975
18	L+V	Primary	-8.3	173	12.09	0.975
19	L+V	Primary	-8.4	168	12.2	0.975
20	L+V	Primary	-8.5	176	12.32	0.976

21	L+V	Primary	-8.5	119	12.32	0.976
22	L+V	Primary	-8.6	193	12.45	0.976
23	L+V	Primary	-8.8	154	12.66	0.977
24	L+V	Primary	-8.8	166	12.66	0.977
25	L+V	Primary	-9	206	12.89	0.978
26	L+V	Prim+Sec	-9.1	165	12.96	0.978
27	L+V	Primary	-9.2	161	13.11	0.979
28	L+V	Primary	-9.2	-	13.11	0.979
29	V+L	Primary	-9.6	268	13.51	0.981
30	L+V	Primary	-9.7	-	13.66	0.982
31	L+V	Primary	-10	-	13.99	0.984
32	V+L	Primary	-10.2	250	14.15	0.985
33	L+V	Primary	-10.5	233	14.46	0.986
34	L+V	Primary	-10.6	-	14.61	0.987
35	L+V	Primary	-11	-	15.02	0.989
36	L+V	Primary	-12	236	16	0.994
37	L+V	Primary	-12.1	175	16.09	0.995
38	L+V	Primary	-12.3	159	16.32	0.996
39	L+V	Primary	-13	-	16.92	0.999
40	L+V	Primary	-13.7	-	17.54	1.002
41	L+V	Prim+Sec	-13.9	138	17.68	1.003
42	L+V	Primary	-14	-	17.8	1.004
43	L+V	Primary	-14.1	172	17.96	1.004
44	L+V	Primary	-14.3	201	18.12	1.005
45	L+V	Primary	-14.6	-	18.27	1.007
46	V+L	Prim+Sec	-15.1	126	18.7	1.009
47	V+L	Primary	-15.3	211	18.86	1.01
48	L+V	Primary	-15.9	151	19.34	1.013
49	L+V	Primary	-16	207	19.43	1.014
50	L+V	Prim+Sec	-16.1	182	19.5	1.014
51	L+V	Primary	-16.3	166	19.51	1.015
52	L+V	Prim+Sec	-16.4	124	19.74	1.015
53	V+L	Primary	-16.8	180	20.05	1.017
54	L+V	Primary	-17.6	227	20.65	1.021
55	L+V	Prim+Sec	-17.8	187	20.82	1.022

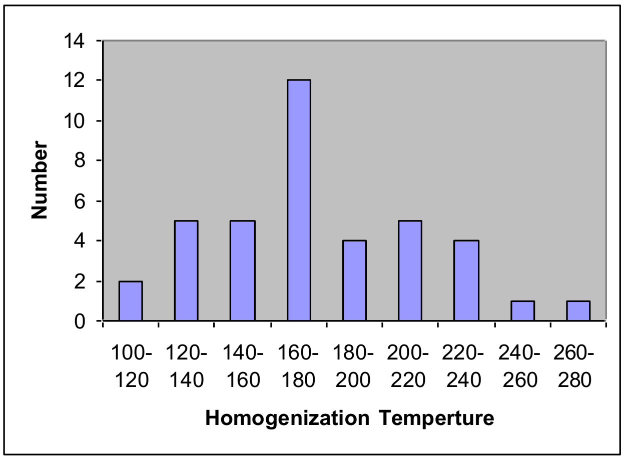

Figure 19- The frequency of homogeneity temperature among involved fluids

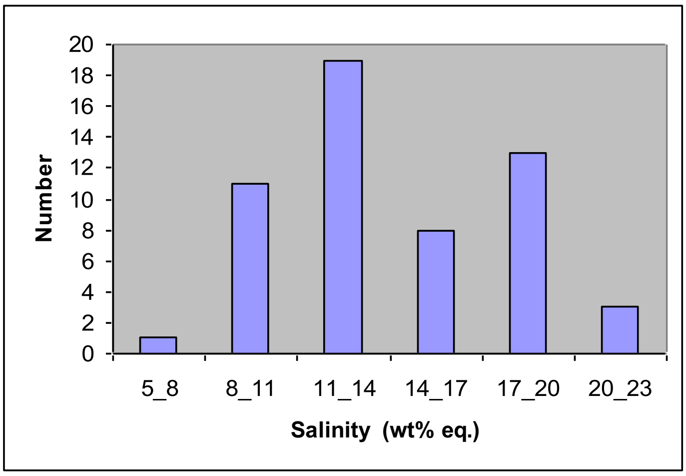

Figure 20- The frequency of salinity among involved fluids

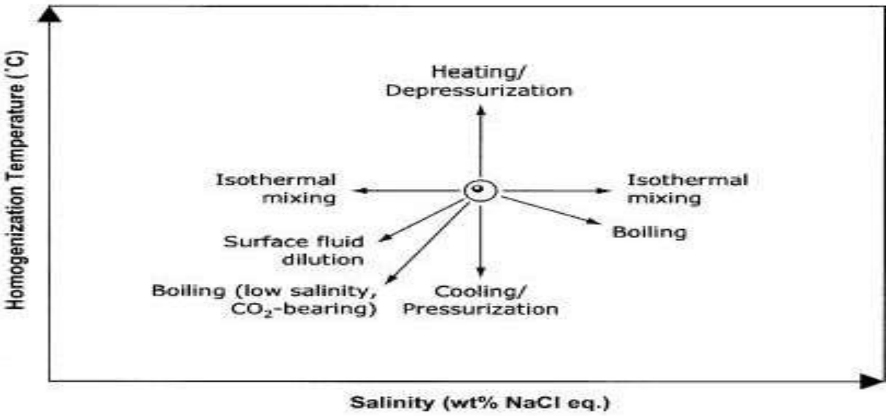

Figure 21- Schematic diagram about the effect of homogeneity temperature- salinity on next changes in fluids, adopted from Wilkinson (2001).

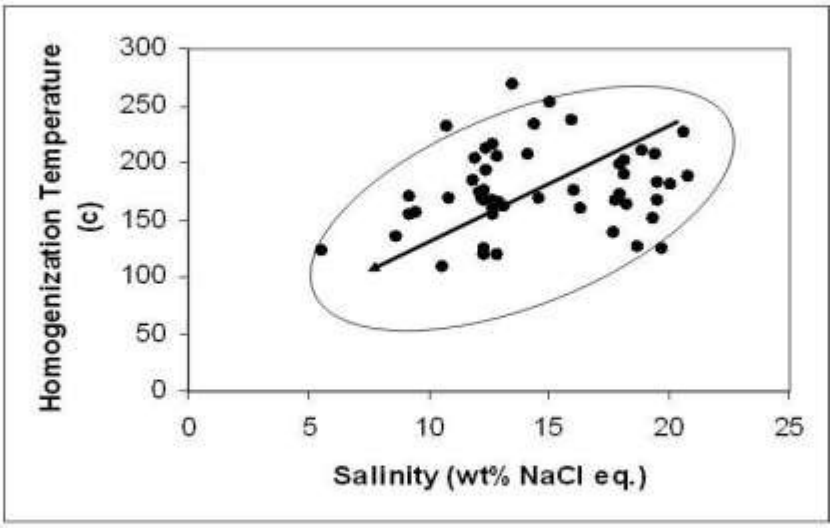

Figure 22-The graph of homogeneity temperature by salinity of involved fluid, which shows the dominancy of mixing by surfing water

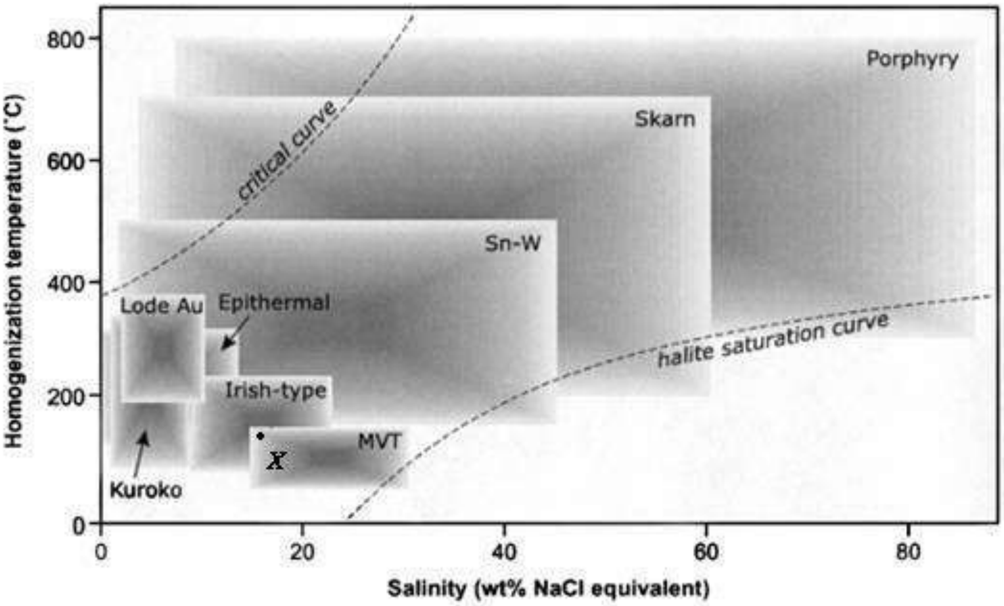

Figure 23- The graph of homogeneity temperature by salinity of involved fluid shows Gonharan deposit is categorized among MVT. Adopted from Wilkinson (2001)

9 -Conclusion

The research conducted on the Gonahran lead-zinc deposit, based on detailed mineralogical, petrographic, and fluid inclusion analyses, has led to a comprehensive understanding of its genetic processes. The findings clearly indicate that the mineralization in this deposit was not only influenced by the characteristics of its Cretaceous carbonate host rocks but was also strongly controlled by regional tectonic structures. The northwest-southeast trending faults acted as primary pathways for the migration of hydrothermal solutions, leading to the formation of veins and ore bodies.

The XRD and microscopic analyses of the minerals confirmed a simple mineralogical composition dominated by galena, with minor amounts of pyrite, sphalerite, and chalcopyrite. This mineral assemblage, lacking high-temperature minerals, provides the initial evidence for a low-to-moderate temperature hydrothermal system.

The most significant findings came from the fluid inclusion studies. Homogenization temperatures of these fluids were in the range of 160 to 180°C, and salinity varied between 5 to 21 wt% salt. This wide range, especially in salinity, strongly suggests that the mineralization resulted from the mixing of metal-rich brines with cooler meteoric or surface waters. This fluid mixing mechanism, which causes a drop in temperature and a change in the chemical composition of the solution, is a key factor in the precipitation and concentration of the ore minerals.

Ultimately, based on the collective evidence, including the carbonate host rock, low-to-moderate formation temperature, fluid type, and the fluid mixing mechanism, the Gonahran deposit is definitively classified as a Mississippi Valley-Type (MVT) deposit. This conclusion provides a consistent genetic model for the deposit and offers a valuable guide for future exploration activities within the Sanandaj-Sirjan zone and other similar regions both in Iran and globally.

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