

Geological and geochemical characteristics of the Qosha gold deposit and the role of rare elements in ore genesis

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Abstract. Systematic geological investigations in the Qosha ore area began in 1966, when reconnaissance surveys at a scale of 1:50,000 were conducted between the Aghstafachay and Zayamchay river valleys. These initial studies led to the discovery of the Qosha gold deposit. Subsequent detailed exploration campaigns refined the geological framework of the deposit and resulted in the identification of 19 gold-bearing zones.

From 2005 onward, Azerbaijan International Mining Company Limited carried out phased and comprehensive geological exploration, culminating in the commencement of commercial extraction in 2014. Scientific evaluations conducted by the company confirmed that the deposit belongs to the high-sulfidation epithermal genetic type. The geological characteristics of the system were investigated through an integrated analysis of hydrothermal alteration patterns, ore paragenesis, and the litho-geochemical properties of magmatic rocks that reflect the nature and origin of the hydrothermal fluids responsible for ore formation.

Keywords: Qosha deposit, gold, ore minerals, hydrothermal alterations, Tovuz, Azerbaijan.

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Introduction. The geological framework of the Qosha deposit, located within the Qosha contract area, has been comprehensively characterized through investigations conducted by Azerbaijan International Mining Company Limited. The deposit is dominated by a Lower Bajocian volcanic–pyroclastic assemblage composed of a differentiated basalt–andesite–dacite–rhyolite sequence.

The Lower Bajocian subunit (basalt–andesite subformation) is distinguished by several lithological and mineralogical horizons, including:

1. A horizon of zeolitized andesite porphyry.
2. A fine- to medium-grained zeolitic andesite horizon.
3. An andesite-porphyry horizon containing almond-shaped vesicles filled with quartz–carbonate material.
4. A lens-shaped unit comprising magnetite-bearing sandstones associated with fine-grained andesite and andesite–basalt rocks.
5. A medium-grained andesite-porphyry horizon.
6. A clastic horizon composed of andesite and andesite–basalt lithologies.
7. An andesite porphyry horizon containing lenses of lava breccia and agglomerate tuff.

This classification demonstrates that the Lower Bajocian succession is predominantly composed of intermediate volcanic rocks. The presence of extensive hydrothermal alteration, however, significantly obscures their original petrological characteristics. Within the boundaries of the Qosha deposit, the Lower Bajocian strata attain a thickness of approximately 390–400 meters.

The Upper Bajocian unit (dacite–rhyolite subformation) is broadly developed within the Qosha gold deposit and is predominantly concentrated along the western flank of the ore field. These rocks constitute the Qosha–Itqırilan subvolcanic bodies, whose eastern contact extends through the area where adits No. 2, 5, and 6 are located, while the western boundary trends toward the northeastern outskirts of Qosha village.

In the western sector of the deposit, the rhyolite–dacite assemblage rests unconformably upon the Lower Bajocian sedimentary–volcanic sequence. Along the external contacts of these intrusions, zones of kaolinization, pervasive sulfide alteration (primarily pyrite), and locally weak hornfelsing are observed. In contrast, the internal contact zones are characterized by the development of

monquartzite bodies formed through the thermal and metasomatic influence of rhyolite and rhyolite–dacite magmatism.

The purpose of study. Tectonically, the Qosha deposit is situated within the western segment of the Shamkir uplift, belonging to the Lok–Karabakh structural–formational zone. The core of the Shamkir anticlinorium is composed of Paleozoic metamorphosed schists, whereas its flanks consist of Lower and Middle Jurassic sedimentary–volcanic successions. Within this structural framework, two major northwest-trending anticlines—the Boyuk-Gishlag and Ahmadabad–Qosha structures—are distinguished. The architecture of these anticlines incorporates complex volcanic–pyroclastic assemblages of intermediate to acidic composition belonging to both the Lower and Upper Bajocian stages.

A bending of the hinge zone of the Ahmadabad–Qosha fold near the Qosha deposit has resulted in the formation of subsidiary brachyfolds. The Qosha–Itqırılan anticline extends through the localities of the same name along a 35–40° northeast-oriented axial trend. Faulting is extensively developed in the area, and several faults possess deep-seated characteristics. At the surface, these structures are expressed as fragmented, fissured, and hydrothermally altered zones commonly associated with magmatic bodies and their vein-type derivatives.

Magmatism of Middle Jurassic age plays a dominant role in defining the geological and metallogenic features of the Qosha deposit. Volcanic activity commenced in the Early Bajocian and persisted intermittently until the close of the Bathonian. This magmatic evolution is characterized by differentiated basalt–andesite, dacite–rhyolite, and quartz diorite–granodiorite subformations. The most intense eruptive activity occurred during the Bajocian, when the principal volcanic apparatus was emplaced along the westward-trending Ahmadabad–Qosha deep fault, forming a laterally continuous volcanic mass.

Volcanic eruptions during this interval were predominantly explosive, marked by substantial emission of pyroclastic material and volcanic gases, resulting in the dominance of pyroclasts within the lava sequences. The Bajocian volcanic assemblage also includes numerous small intrusive bodies—dykes, sills, and stocks—of varying dimensions and morphologies. These intrusions indicate that, during certain stages, effusive lava outflow occurred under relatively calm conditions.

Within the Qosha deposit, metasomatic alterations can be classified into two fundamental genetic types: contact-related metasomatites and fracture-controlled hydrothermal metasomatites. These rock assemblages are exposed at the surface, within adits No. 4, 7, and 8 across the upper and middle reaches of the Asrikchay and Axıncachay valleys. Comparable alteration zones also occur at the Böyük-Shamlıq, Böyük-Qışlaq, and Qosha–Itqırılan pyrite-bearing prospects.

The hydrothermally altered rocks in these areas are localized along major deep-seated faults and in the zones where such faults intersect with subsidiary tectonic disruptions. Gold-bearing metasomatite halos develop preferentially within these structurally weakened domains and are typically situated close to the surface.

The Qosha deposit belongs to the gold–sulfide–quartz formation and is characterized by submeridional ore zones that occur as branching veins and mineralized bands. These zones are sharply bounded from their host rocks. The wall rocks consist mainly of greyish-black andesite and andesite–porphyry, which exhibit fine-grained pyritization, silicification, and weak kaolinization. In certain intervals, infiltration of groundwater generates a viscous kaolin–pyrite mass that partially fills the underground workings.

The submeridional ore zones are structurally aligned with fault systems and commonly form well-defined contacts with adjacent rocks. With dips ranging from 80° to 90°, these bodies possess a distinctly vein-like morphology. Subparallel veins occur across all meridional structural corridors, and clusters of narrow veinlets may coalesce to form a single ore body. These veinlets commonly pinch and swell both along strike and down-dip, reappearing intermittently (Figure 1).

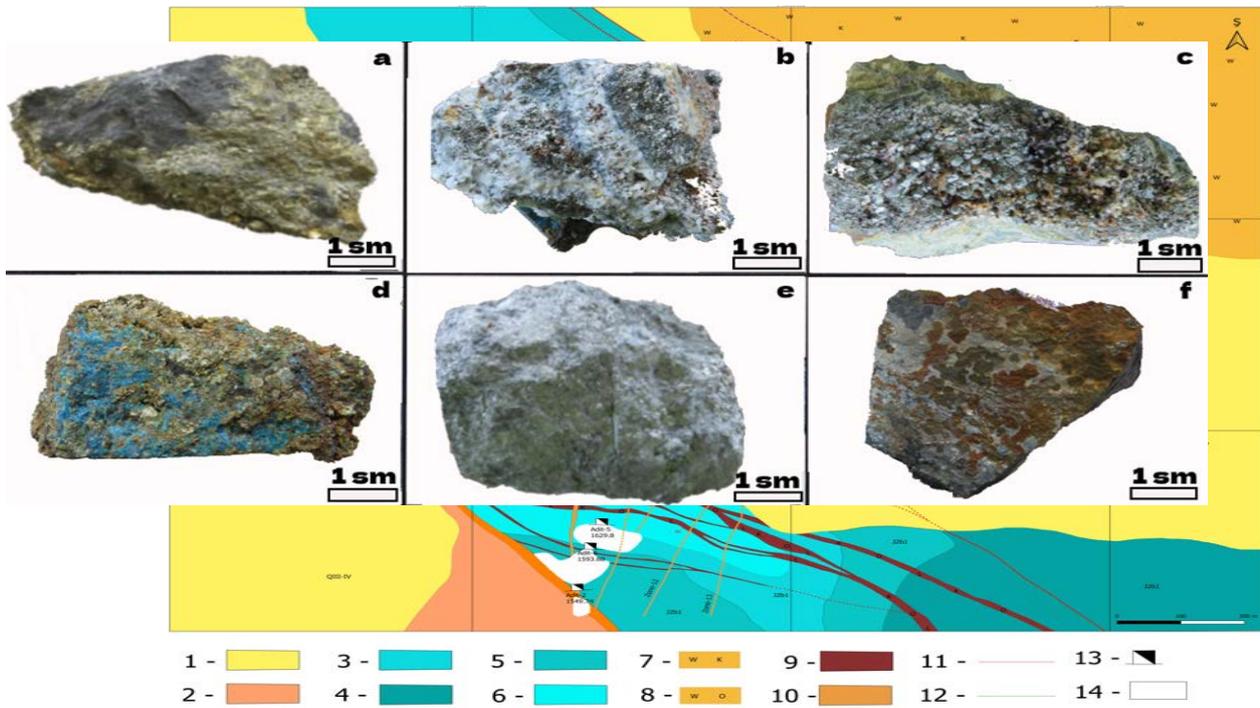


Figure 1. Geological map of the Qoşa gold deposit.

Explanation of Symbols: 1. Quaternary sediments; 2. Upper Bajocian light-grey, fine-grained rhyolites and rhyodacites; 3. Lower Bajocian fine- to medium-grained andesite tuffs; 4. Lower Bajocian interbeds of fine-grained andesite–magnetite sandstones and andesite basalts; 5. Lower Bajocian andesite porphyrites; 6. Lower Bajocian interlayers of andesite porphyrite and agglomerate lava; 7. Kaolinized secondary quartzites; 8. Secondary quartzites; 9. East–West-trending alteration zones characterized by silicification, kaolinization and limonitization (zones 1, 2, 3, 5); 10. North–South-oriented zones marked by pyritization and kaolinization (zones 4, 10, 11, 12, 13); 11. Faults; 12. Dykes; 13. Portal of the adit ; 14. Adit waste deposits.

Discussion. Mineralization within the ore bodies is expressed through three principal morphological styles: stratiform, veinlet-stratiform, and vein-type. Stratiform ores typically contain relatively low concentrations of gold. Veinlet-stratiform mineralization is associated with fracture systems and zones of brecciation or cataclasis, where ore thickness may range from a few centimeters (1–5 cm) up to several meters (1–2 m). The dominant minerals include pyrite, with subordinate chalcopyrite, and minor sphalerite and galena (Figure 2). Vein-type mineralization is widespread across all structural zones, and gold occurrence is predominantly linked to this style of ore formation.

All of these ore veins occur within hydrothermally altered zones characterized by kaolinization, silicification, and pyritization. Zone No. 13 hosts well-developed quartz–pyrite veins, which are also encountered sporadically within several other mineralized zones.

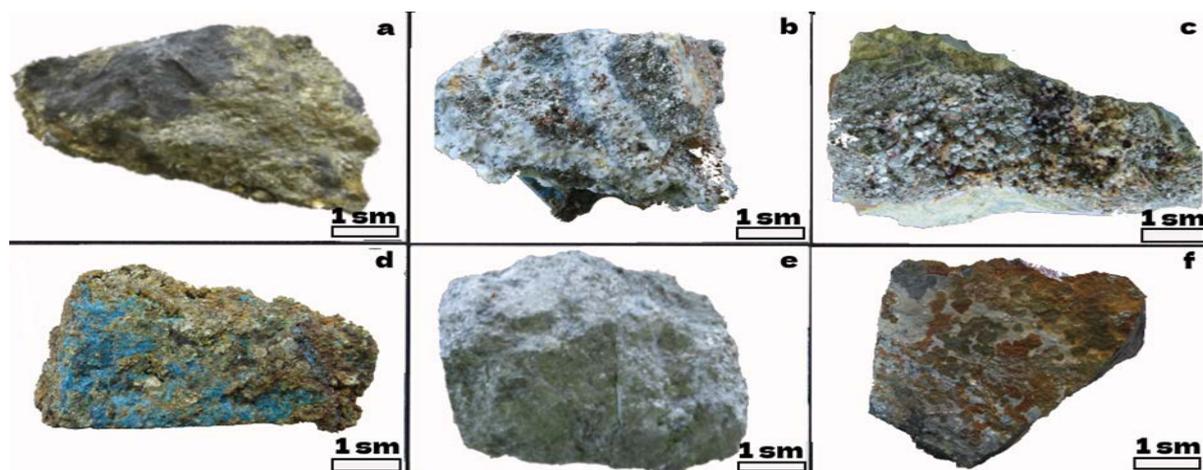


Figure 2. Widely distributed types of mineralization in zones, veins, and fractures of the Qoşa deposit: (a) Semi-massive pyrite filling fractures; (b) Semi-massive quartz-pyrite; (c) Quartz druse and quartz-pyrite; (d) Semi-massive chalcopyrite, azurite, pyrite; (e) Massive pyrite; (f) Vein-filling massive pyrite.

Experimental Methodology. Within the framework of the “Geology and Exploration of Mineral Deposits” laboratory, systematic sampling was carried out in the Qoşad area, which serves as the designated research site. The collected samples were subsequently analyzed using X-ray diffraction (XRD) techniques at the Institute of Geology and Geophysics.

An X-ray diffractometric (XRD) analysis was conducted on Sample No. 50 collected from the deposit area. Based on the diffraction pattern, it can be stated that kaolinite, quartz, and dolomite are the dominant mineral phases in the sample. The presence of these minerals provides valuable information regarding the temperature conditions under which the sample was formed. The occurrence of these mineral assemblages indicates that the formation environment Result. The deposit’s ores exhibit a relatively simple composition, comprising over ten ore minerals of the free-element class, including sulfides, intermetallics, sulfosalts, and others. Alongside carbonate minerals, quartz, and kaolinite, minor amounts of muscovite, chlorite, and plagioclase are also present. Pyrite is the most prevalent ore mineral, primarily occurring in disseminated and veinlet forms. Although the degree of oxidation varies across the deposit, the oxidation zone is distinctly defined. In certain areas, oxidation extends to depths of 200–250 m.

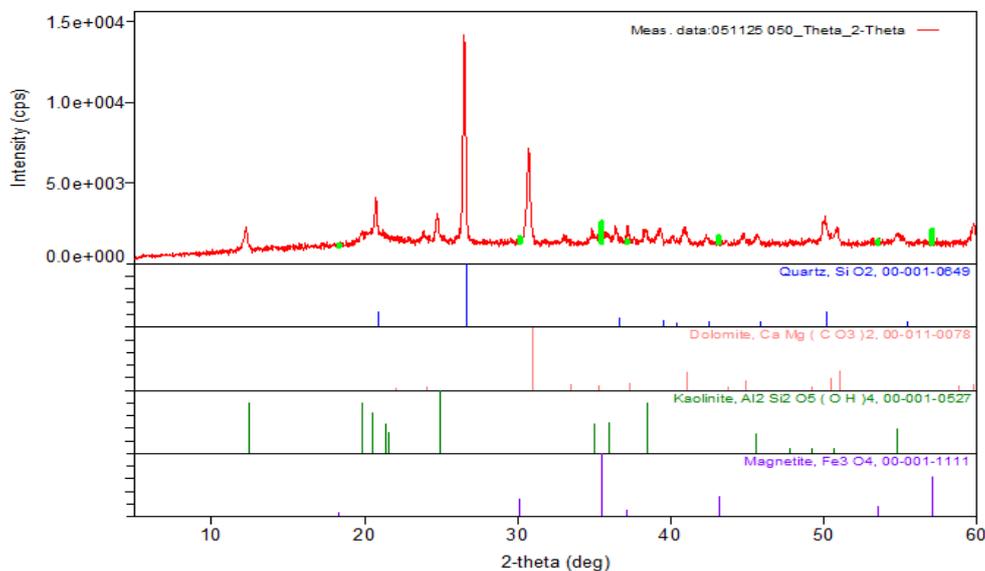


Figure 3. Sample taken from the ore (Sample No. 50)

The boundary of this zone is visually discernible and reaches approximately the 1555 m horizon, having developed along fractures formed post-ore genesis.

As shown in Table 1, kaolinite predominates in the mineralogical composition of the sample. This observation further confirms that the sample was formed under low-temperature conditions.

Table 1. Mineralogical analysis, -%.

Sample No.	SiO ₂	Kaolinite	Magnetite	Dolomite	Other impurities
50	26	38	10	24	2

The presence of major oxides in the chemical composition (Table 2) serves as important geochemical indicators. The SiO₂ content is associated with kaolinite and quartz, Al₂O₃ corresponds to kaolinite, CaO is related to dolomite, while Fe₂O₃ is indicative of magnetite.

Table 2. Chemical analysis, -%.

Sample No.	Al ₂ O ₃	CaO	Fe ₂ O ₃	SiO ₂	TiO ₂	ZnO	SO ₃	CO ₂	Na ₂ O	K ₂ O	MnO	MgO	LOI	TOI
50	.01	.15	7.81	3.75	.10	.04	.14	1.35	.75	0.56	.26	.01	.01	2.04

An evaluation of the rare element analysis results for Sample No. 50 indicates that the concentrations of rare elements are relatively low. This is interpreted as a reflection of the comparatively low quality characteristics of the sample.

Table 3. Trace and rare element concentrations, -ppm.

Sample No.	As	Zn	Sb	Co	Pb	Sr	Ba	Zr	Rb
0	41	156	3	4	3	61	2	39	2

The visual examination of the sample also reveals a high abundance of kaolinite within the rock matrix.

Result. The deposit's ores exhibit a relatively simple composition, comprising over ten ore minerals of the free-element class, including sulfides, intermetallics, sulfosalts, and others. Alongside carbonate minerals, quartz, and kaolinite, minor amounts of muscovite, chlorite, and plagioclase are also present. Pyrite is the most prevalent ore mineral, primarily occurring in disseminated and veinlet forms. Although the degree of oxidation varies across the deposit, the oxidation zone is distinctly defined. In certain areas, oxidation extends to depths of 200–250 m. The boundary of this zone is visually discernible and reaches approximately the 1555 m horizon, having developed along fractures formed post-ore genesis.

Conflict of interest.

The authors declare that they have no conflict of interest in relation to this research.

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