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MORPHOSTRUCTURAL BASIS FOR PREDICTING MINERAL RESOURCES IN THE GOSMALIAN INTERMONTANE DEPRESSION

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Abstract. This study examines the morphostructural basis for predicting mineral resources in the Gosmalian intermontane depression within the Talysh mountain system of Azerbaijan. The objective is to identify geological and geomorphological features that may guide the localization of prospective mineralization zones. The investigation integrates comparative and paleogeomorphological methods, morphostructural analysis, satellite imagery, and published geological information. Particular attention is paid to dome-shaped uplands, intrusive bodies, dikes, ring structures, and the relationships between volcanic centers and fault systems. The oval configuration of the depression, the distribution of Eocene volcanic formations, and the centripetal drainage pattern support its interpretation as a caldera-type morphostructure. Local uplifts and volcanic centers are associated with intersections of longitudinal and transverse faults, while extensional deformation facilitated fracture development and magma emplacement. These structural relationships provide criteria for delineating areas potentially favorable for mineral accumulation. The analysis identifies the Gosmalian depression as a promising target for further investigation of metallic and non-metallic mineral resources. Potential occurrences of precious metals and other valuable minerals remain exploration hypotheses requiring geological, geochemical, and mineralogical verification. The findings provide a morphostructural framework for prioritizing detailed prospecting within the depression and its surrounding volcanic and intrusive complexes.

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1. Introduction

The identification of geological structures favorable for mineral accumulation is an important task in geomorphological and geological research. Dome-shaped, central, and ring structures are of particular interest because their formation is associated with interactions between magmatic activity, fault tectonics, and subsequent relief development. Their expression in the present-day landscape can provide useful indicators for identifying areas that warrant further mineral exploration.

The Gosmalian intermontane depression, situated within the Talysh mountain system of Azerbaijan, provides an opportunity to examine these relationships. Its volcanic origin, intrusive bodies, and intersecting fault systems form a complex geological and geomorphological setting. This study considers the mineral prospectivity of these structures and the morphostructures associated with them, with particular attention to their spatial configuration, origin, and structural relationships.

1.1. Objective

The aim of the study is to assess how the identification and more detailed characterization of prospective morphostructures can support the localization of potential mineral deposits within the Gosmalian depression. Particular attention is given to dome-shaped uplands, ring structures, intrusive bodies, and zones where longitudinal and transverse faults intersect. The study seeks to establish morphostructural criteria for prioritizing areas for subsequent geological exploration.

2. Materials and methods

The study combines comparative and paleogeomorphological methods with morphostructural analysis, published geological information, and satellite imagery. These sources are used to examine the relationships between landforms, geological structures, and features potentially associated with mineralization. The comparative approach supports the examination of similarities and differences among individual morphostructures, while

paleogeomorphological interpretation helps clarify their development in relation to earlier volcanic and tectonic processes.

Mineral prospectivity is examined within the Gosmalian intermontane depression, a volcanic depression forming part of the Talysh mountain system and representing a geologically and geomorphologically complex region of Azerbaijan (Figs. 1 and 2). The analysis focuses on the configuration of the depression, the distribution of volcanic centers and intrusive bodies, the expression of dikes in the relief, and the arrangement of the drainage network. These features are considered together to identify structural relationships that may guide further prospecting. The resulting interpretations provide a basis for exploration planning and require verification through detailed geological investigations.



Fig. 1. Satellite image of the Talysh mountain system (Source: Google Earth)



Fig. 2. Morphostructural map of the Talysh mountain system (Source: compiled by T.R. Gurbanov)

The distribution of mineral resources and the prospectivity of morphostructures for their identification, as presented in this article, have predictive significance and may serve as a basis for exploration and prospecting activities. At the same time, geological exploration work can confirm the prospectivity of morphostructures for mineral resources.

3. Relevance of the problem

To assess the mineral potential of the territory, following Khalilov (2019), emphasis was placed on identifying exploration criteria favorable for mineralization through morphogenetic analysis of morphostructures. These include magmatic (intrusive and volcanic), tectono-magmatic, and volcano-tectonic geological structures, as well as the morphostructures formed by them.

Considering the heterogeneity of dome-shaped, central, and ring (arc) structures and the morphostructures organized by them—i.e., the formation of the latter through the combined manifestation of magmatism and fault tectonics—such morphostructures are regarded by the author as ore-hosting bodies. Furthermore, taking into account that these morphostructures are located within supra-intrusive zones, their ore-hosting significance becomes evident.

The author further notes that, given the ore-controlling role of dome-shaped, central, and ring (arc) structures, it can be assumed that the morphostructures formed by them will have high exploration significance (Khalilov, 2019).

Palienko (1978) notes that since the most mobile blocks are subject to the most intense mineralization, it is clear that the most perspectives will be those morphostructures corresponding to the most mobile blocks of the Earth's crust and characterized as ore-controlling bodies (Palienko, 1978).

Considering that ring morphostructures are predominantly represented by volcano-tectonic formations and, being characterized by a ring-shaped arrangement of eruption centers, in most cases outline caldera depressions, such caldera basins are of considerable interest. This is because within these morphostructures, occurrences of various types of ores have been identified.

A more comprehensive definition of a "caldera" is provided by Leahy (1966). According to the author, during volcanic eruptions under conditions of an undissected relief, funnels are formed, while on the summits of volcanic uplifts, bowl-shaped depressions appear. The bottoms of the funnels have the same outlines as the vents through which eruptions occurred. Depressions of similar origin, but significantly larger than the vents, are called calderas (Leahy, 1966).

According to Valiyev (1984), the Gosmalian structure also belongs to the caldera type; it is located within depressions and basins or along their periphery. The authors note that, within the Talysh mountain system, the formation of a number of ore occurrences of copper, molybdenum, lead, zinc, and rare metals is genetically associated with Paleogene volcanism and intrusive magmatism. This fact makes it possible to outline a general pattern of their localization within ring structures.

Thus, ore occurrences are often situated in the central parts of ring structures, at the nodes where their arcuate elements intersect with linear faults, or at the junctions of two or more ring structures. These include the Byulyudul molybdenum occurrence, the Gamarat copper and copper–molybdenum occurrences, the Bilyar copper occurrence, the Rozanov copper occurrence, and a number of other ore occurrences and mineralization points (Veliyev et al., 1984).

According to Zeynalov and Mustafayev (1994), the presence of both ore and non-ore deposits is predicted within the Talysh mountain system. Ore formations are represented by layers, veins, and stocks, and their occurrence is associated with volcano-plutonic formations. The geological structure of ore occurrences includes Eocene volcanic and volcanogenic-sedimentary rocks intruded by plutonic formations. These are affected by hydrothermal processes, and their composition includes pyrite, chalcopyrite, malachite, azurite, gold, and silver. The formation of Iceland spar is localized within the Gosmalian depression (Zeynalov & Mustafayev, 1994).

The authors, based on a new concept, have identified within the Talysh mountain system the presence of plutonic volcanic edifices corresponding to kimberlite-type formations. These are associated with volcano-plutonic complexes.

Clarification of the mechanism of formation and distribution of plutonic rocks, their localization within any tectonic structure in the form of plutonic pyroclasts, as well as the detection of olivine, pyrope, chalcopyrite, ilmenite, and other minerals, makes it possible to predict diamond potential in all such structures.

Moreover, this supports the view that plutonic rocks are products of the upper mantle. The latter, together with carbon dioxide, methane, and other volatile substances, act as catalysts in diamond formation. In addition, the presence of platinum and platinum-group metals (traces of which have been identified in plutonic rocks), as well as organic formations with ilmenite, cobalt, and other elements within the host rocks, confirms the mechanism of possible diamond formation and allows for predicting the presence of diamonds, along with platinum-group elements.

4. Results of the research

The Gosmalian volcano-tectonic depression is located on the northwestern plunge of the Astara ridge. Overall, the depression is characterized by a gently sloping, weakly dissected hilly relief inclined to the northeast, with broad floodplains and terraced valleys. It is composed of Lower and Middle Eocene volcanogenic rocks.

Within the depression and along its periphery, a number of volcanic centers and subvolcanic bodies of Eocene age are present. Eocene volcanism (magmatism) played a major and active role in the formation of the morphostructure.

The characteristic oval configuration of the Gosmalian depression, the widespread development of volcanic centers (extrusive domes), geological evidence (such as the increase in thickness of volcanogenic formations toward the center of the depression and their decrease toward the periphery, faulting, curvature of longitudinal and transverse faults, etc.), as well as the centripetal pattern of the river network, allow us to confidently interpret it as a caldera-type morphostructure (Fig. 3).

It is complicated by several morphostructures of a lower order with varying characteristics. Within its relief, dome-shaped intrusive and subvolcanic uplands — Goveri, Kyalahán, and Rozanova—are clearly distinguished, located near the settlements of the same names. The largest among them are the Geldarin and Nimikesh dome-shaped, intensely dissected uplands.

In the central part, the morphostructure is complicated by lava flows superimposed from the aforementioned centers. In the present-day relief, these lavas form weakly dissected, gently inclined plateaus. It is noteworthy that with the transition into lava sequences, folding diminishes, which is apparently associated with the subsidence of volcanic apparatuses, forming a bowl-shaped volcanic relief with minor anticlines and synclines.



Fig. 3. The Gosmalian caldera (Source: Google Earth)

From a morphostructural analysis perspective, the pattern of the drainage network within the basin is particularly noteworthy. Two main tributaries of the Kondzhavuchay River — Ilederechay and Digovderechay—flow almost in straight lines along the sections between the villages of Gilyara–Lelyakaran and Digov–Tatoni, respectively, and join the main river at a single point (the village of Gosmalian). Apparently, both river valleys correspond to a fault zone that diagonally crosses the basin in a northwest–southeast direction (Gurbanov, 1999).

Below is a geological and geomorphological description of the main large magmatic bodies—volcanic dome-shaped uplands, intrusions, and dikes of the Gosmalian basin, based on literature data (Azizbekov et al., 1979; Hajiyev, 2004; Gurbanov, 1999).

It should be noted that the intrusive bodies within the Gosmalian basin are collectively referred to as plutonic formations. The presence of precious metals is predicted within rocks of plutonic origin. Dikes are also present here, which typically show traces of endocontact alteration.

Thus, the Gelda volcanic dome-shaped upland is located in the vicinity of the village of Gelda (in the upper reaches of the Iledzhachay River, a left tributary of the Kondzhavuchay). In the present-day relief, it forms a dome-shaped elevation with an absolute height of 1970 m and a relative height of 130–250 m. In plan view, the morphostructure has a pear-shaped outline, elongated in a northwest direction for about 5 km, with a width of 1–3 km and an area of approximately 10 km². The upland has steep slopes that descend to an eroded surface of Lower Eocene volcanic rocks. At an elevation of about 1860 m, the dome transitions into a lava flow with volcanic bombs on its surface.

The Goveri volcanic dome-shaped upland is confined to the central part of the basin and is located on the left bank of the Kondzhavuchay River, 4–5 km southwest of the settlement of the same name. In the present-day relief, it forms a dome-like elevation with an absolute elevation of 1676 m. In plan view, it has a pear-shaped form elongated in a northwest direction, with longitudinal and transverse axes of 1750 m and 850 m, respectively, and an area of about 1.5 km². Its slopes are steep, intensely dissected, and deeply incised by the Kondzhavuchay River.

The Goveri ring structure is located southwest of Lerik and occupies the Kondzhavuchay basin as well as the area of its left tributaries. It has a circular shape with a diameter of 6 km. Its southeastern outline closely coincides with the arcuate segment of the Kondzhavuchay River between the villages of Nesli and Divagach. The relief is mid-mountainous, dissected, with a peneplainized summit surface. Geologically, the area of the Goveri ring structure corresponds to a volcanic edifice of central type bearing the same name. This structure is intersected by longitudinal and transverse faults (Aliyev et al., 2009).

The Razgov volcanic dome-shaped upland is located southeast of the village of Razgov and, in the present-day relief, forms a cone-shaped elevation with an absolute height of 1980 m and a relative height of 30–35 m above its base. In plan view, it has an ellipsoidal shape. Around this main dome, there is a series of smaller volcanic centers within a radius of 600–700 m, rising 4–5 m above the surrounding relief and characterized by dome-shaped, and more rarely mushroom-shaped, forms.

The Arvana–Diman volcanic dome-shaped uplands are developed in the northwestern part of the basin (in the area of the villages Arvana, Diman, and Sarybulag) and are controlled by a northwest-trending fault zone. In the present-day relief, they form dome-shaped, cone-shaped, and mushroom-shaped landforms. In plan view, they have an oval shape oriented in a northwest direction, measuring 500–700 m in length and 200–300 m in width.

The Kyalahan intrusive body is located on the right bank of the Kondzhavuchay River. In the relief, it forms a cone-shaped elevation with an absolute altitude of about 1750 m. Here, volcanic breccias are convex and dip away from the intrusion at steep angles; with increasing distance from it, the dip angles gradually become gentler.

The intrusion has a weakly elongated ellipsoidal shape oriented in a northeast direction. Southwest of the intrusion, there are two small oval-shaped domes elongated in a northeast direction. The intrusive bodies associated with Kyalahan are characterized by a semicircular form.

The ore body located southeast of the Kyalahan intrusion has an arcuate shape at a distance of 500–600 m, with a maximum thickness of up to 20 m, and is confined to breccias. The feeder channel of the deposit is located laterally, and the host rocks are iron-stained.

The Rozanov intrusive body is located 3 km southeast of the Geldar dome-shaped upland. In the relief, it forms a ridge elongated from southwest to northeast, with absolute elevations of 1600–1800 m and a relative height of up to 100 m. In plan view, the intrusion has an ellipsoidal shape concave toward the northwest, elongated in a northeast direction, perpendicular to the orientation of the Kyalahan intrusive body. Its long axis is 1 km, while the short axis is 0.5 km.

Dikes of Early Eocene volcanism are mainly developed within the Gosmalian basin. In the relief, they are expressed as low ridges.

The dikes of the Rozanov intrusive body are predominantly confined to northwest-trending fractures dipping to the northeast and southwest. Their thickness varies from 2–4 m up to 30 m. In the relief, they can be traced along their strike for 3.5–4 km. These dikes are expressed in the landscape as narrow ridges and barriers and have a close genetic relationship with lava effusions.

According to Azizbekov et al. (1979), the dikes of the Rozanov intrusive body occupy a special position among the other intrusions. Among these dikes, one particularly prominent and most powerful body is distinguished, located east of Mount Kyalyvaz at a distance of up to 4 km. In the relief, it is expressed as a barrier rising 1–3 km above the surrounding surface.

South of the village of Ashaga Amburdere, its thickness is about 20 m; further south (toward the village of Kyalyvaz), it expands to a maximum of 30 m, and then narrows again in the same direction to 10–15 m.

During the formation of Early Eocene volcanism, the central part of the Gosmalian basin experienced maximum subsidence, within which the aforementioned dome-shaped uplands, intrusions, and dikes were formed. Extension processes contributed to the development of parallel north- and northeast-trending fractures.

According to Aliyev et al. (2009), in the subsequent stage of evolution of the Gosmalian graben, these fractures were filled with a weakly differentiated portion of a subalkaline olivine-basaltic melt. The homogeneity and weak differentiation of the dike rocks, as well as the presence of titanomagnetite in their composition, indicate that transverse deep-seated faults intersected deeper levels of intermediate magma chambers. In this context, portions of melt were transported to the Earth's surface.

However, after passing through a deep intermediate chamber at a depth of 20–25 km, these melt portions were only briefly retained in shallow intermediate reservoirs. As a result, accumulative inclusions did not have time to dissolve. From a petrological perspective, the loss of volatile components led to the crystallization of high-temperature leucite. Under graben conditions, the melt crystallized during intense extensional deformation, during which all magma-feeding fractures were opened (Aliyev et al., 2009).

5. Conclusions and recommendations

Within the Gosmalian basin, local uplifts (domes) are confined to the zones of intersection of longitudinal and transverse faults and are represented by volcanic centers.

After analyzing all available scientific-exploration studies and our own desk-based investigations, we conclude that the Gosmalian intermontane depression is a promising area where the above-mentioned detailed exploratory works are justified and advisable.

The geological and geomorphological analysis carried out by us may enhance the reliability of the proposed hypotheses for the prospecting and exploration of mineral deposits.

Since a mineral deposit is defined as a concentration of one or several minerals formed during sedimentation, metamorphism, or the crystallization of igneous rocks (Leahy, 1966), it is suggested that within the Gosmalian caldera, prospecting in highly metamorphosed rocks may be promising. In particular, based on morphogenetic analysis of morphostructures, the occurrence of diamonds, precious metals, and other mineral resources is predicted.

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QOSMALİAN DAĞARASI ÇÖKƏKLİYİNİN FAYDALI QAZINTI EHTİYATLARININ PROQNOZLAŞDIRILMASININ MORFOSTRUKTUR ƏSASLARI

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Xülasə. Tədqiqatda Azərbaycanın Talış dağ sistemində yerləşən Qosmalian dağarası çökəkliyində faydalı qazıntıların proqnozlaşdırılmasının morfostruktur əsasları araşdırılır. Məqsəd perspektivli minerallaşma zonalarının müəyyənləşdirilməsinə istiqamət verə biləcək geoloji və geomorfoloji xüsusiyyətləri aşkara çıxarmaqdır. Tədqiqatda müqayisəli və paleogeomorfoloji üsullar, morfostruktur təhlil, peyk təsvirləri və nəşr olunmuş geoloji məlumatlar birgə istifadə edilmişdir. Günbəzvari yüksəkliklərə, intruziv cisimlərə, daykalara, halqavari strukturlara, həmçinin vulkanik mərkəzlərlə qırılma sistemləri arasındakı əlaqələrə xüsusi diqqət yetirilmişdir. Çökəkliyin oval konfiqurasiyası, Eosen yaşlı vulkanik formasiyaların yayılması və çay şəbəkəsinin mərkəzə yönəlmiş quruluşu onun kaldera tipli morfostruktur kimi şərhini əsaslandırır. Lokal qalxmaların və vulkanik mərkəzlərin uzununa və eninə qırılmaların kəsişmə zonaları ilə əlaqəli olduğu, dartılma deformasiyalarının isə çatların inkişafına və maqmanın yerləşməsinə şərait yaratdığı göstərilir. Bu struktur əlaqələri faydalı qazıntıların toplanması üçün potensial əlverişli sahələrin ayrılmasına imkan verən meyarlar kimi qiymətləndirilir. Təhlil Qosmalian çökəkliyinin filiz və qeyri-filiz faydalı qazıntıların sonrakı tədqiqi üçün perspektivli ərazi olduğunu göstərir. Nəcib metalların və digər qiymətli faydalı qazıntıların mümkün təzahürləri geoloji, geokimyəvi və mineraloji yoxlama tələb edən axtarış fərziyyələri olaraq qalır. Əldə olunan nəticələr çökəklikdə və onu əhatə edən vulkanik və intruziv komplekslərdə ətraflı axtarış işlərinin prioritet istiqamətlərinin müəyyənləşdirilməsi üçün morfostruktur əsas yaradır.

Açar sözlər: *morfostruktur, hövzə, çökəklik, qraben, kaldera, metamorfizm, günbəzlər, daykalar, halqavari strukturlar, maqmatizm, vulkanizm*

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