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Research Article

RESULTS OF GROUND BASED MAGNETIC SURVEYS OF THE KULZHUKTAU MOUNTAINS

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ABSTRACT
This study presents the results of detailed magnetic exploration conducted in the western part of the Kuldzhuktau Mountains over an area of approximately 1,011.75 km². The investigation aimed to identify magnetic anomalies associated with intrusive bodies, skarnification zones, fault systems, and sulfide mineralization. Magnetic field analysis revealed a clear regional zonality and numerous positive and negative anomalies related to gabbroic intrusions, granitoid massifs, hydrothermal alteration zones, and pyrite-pyrrhotite mineralization. Several magnetic anomalies correlate spatially with known gold, mercury, zinc, yttrium, lithium, and rare-earth mineral occurrences. The study also refined the structural framework of the region by confirming known faults and identifying previously unrecognized tectonic features. The obtained results demonstrate the effectiveness of magnetic surveys for delineating concealed intrusive complexes and prospective ore-bearing zones in the western Kulzhuktau region.

Keywords: *Geophysics, Magnetic Survey, Magnetic Map, Skarn, Structure*

INTRODUCTION
The Kuldzhuktau Mountains represent one of the perspective geological regions of Uzbekistan characterized by complex Paleozoic tectonic structures, intrusive magmatism, and diverse mineralization.

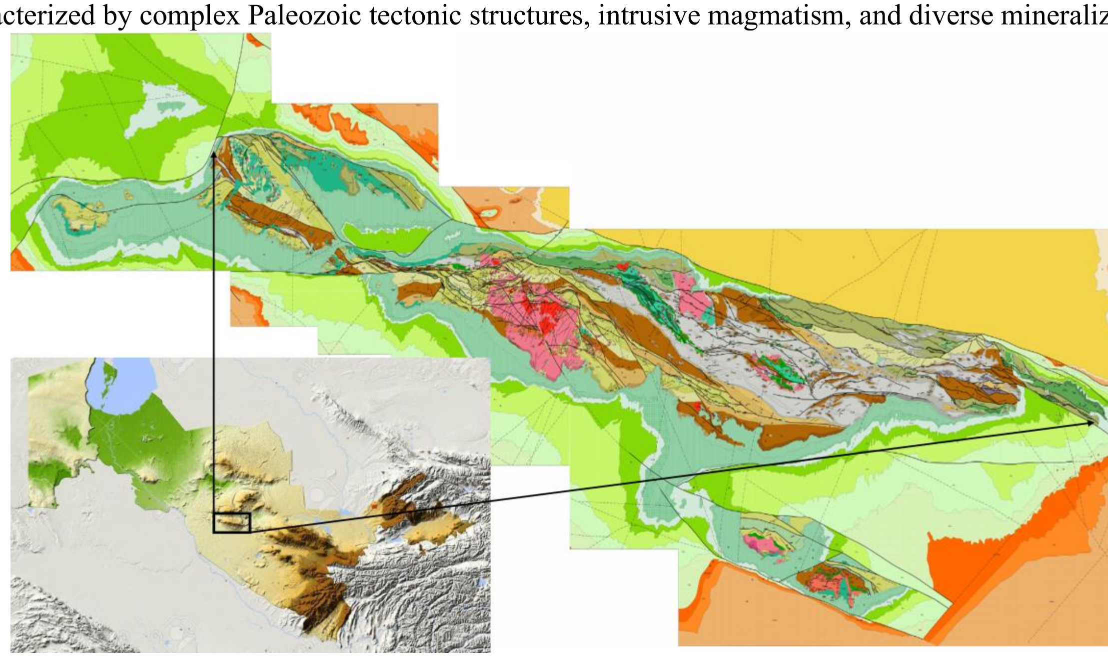

Figure 1. Location and schematic geological map of the Kulzhuktau mountains
(*modified from Aysanov, 1984*).

Geophysical investigations, particularly magnetic surveys, play an important role in mapping concealed geological structures and identifying ore-controlling zones beneath sedimentary cover. The western Kuldzhuktau area contains numerous intrusive complexes, skarn zones, and hydrothermal systems associated with gold and polymetallic mineralization. The purpose of this study was to analyze the magnetic field distribution of the region, determine its relationship with geological structures, and identify anomalies potentially associated with economically significant mineralization. (figure 1) (*Khamrabaev, 1975*).

MATERIALS AND METHODS

Magnetic exploration surveys were conducted at a scale of 1:25,000 across the western Kuldzhuktau area and adjacent territories. The study included the compilation and interpretation of magnetic field maps, transformed magnetic field maps, and regional magnetic anomaly maps derived from both recent investigations and previous geophysical datasets. Interpretation focused on identifying regional magnetic zonality, local anomalies, and their spatial relationships with intrusive bodies, fault systems, skarnification zones, and known ore occurrences. Quantitative interpretation methods were applied to estimate the depths and geometries of magnetically active bodies. Correlation with geological, gravimetric, and electrical prospecting data was also performed to improve the reliability of geological interpretations (*Kerimov et all, 2009*).

RESULTS AND DISCUSSION

The magnetic field of the region is characterized by a certain zonality and differentiation, highlighting certain features of the geological structure of the territory. Using the assumed zero survey level, magnetic

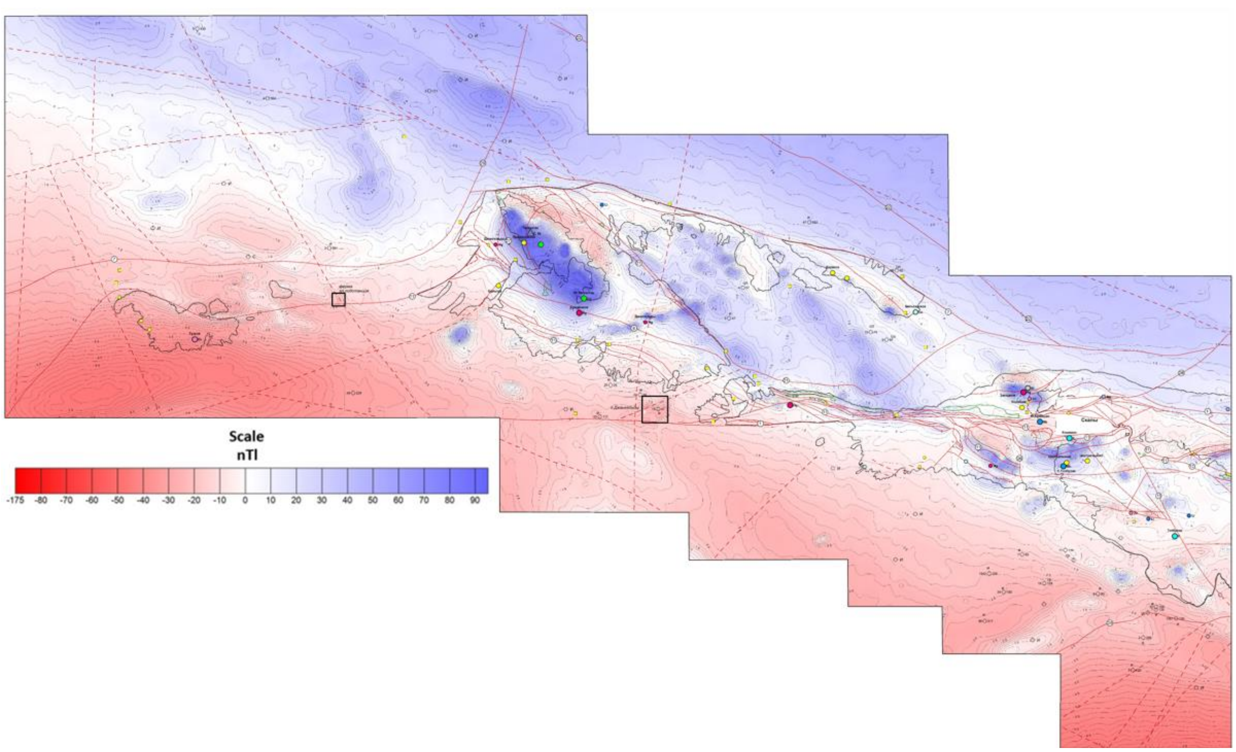

Figure 2. Magnetic map of Western part of Kulzhuktau mountains.

field values are negative in the southern part of the area, while they are positive in the rest of the region. The intensity of the positive component varies from 0 to +100 to +445 nT, while the negative component ranges from 0 to -75 to -175 nT. A smooth, or less frequently, stepwise, increase in intensity is observed from south to north, northeast toward the Kuldzhuktau Mountains, and further to the Auminzatau Mountains. The general orientation of the magnetic field isolines and anomaly axes coincides with the general sublatitudinal and northwesterly strike of the main structural elements of the area.

In terms of its general character and level, the magnetic field is clearly divided into three regional zones: southern, central and northern.In the southern plain of the area, the field is negative, calm, and smooth, characterized by large minima and relatively rare small anomalies of both signs and higher orders. The central part of the area, with the Paleozoic protrusions of Kuldzhuktau and Beltau, is characterized by a differentiated magnetic field, predominantly positive T_a values, a virtually zero background level, and numerous positive, and less commonly negative, anomalies of varying size and intensity. Finally, in the northern part of the area, in a closed area, the magnetic field again becomes calm and smooth, with T_a values increasing to the north and northeast, and occasional positive anomalies. Furthermore, the southeastern part differs sharply from the regional zones by the submeridional strike of the isolines, increasing T_a values to the east, and the virtual absence of local anomalies. The transitions between the different fields are generally smooth and characterized by minimal gradients. These regional features are clearly shown on the map of the regional component of the magnetic field (figure 2).

The Beltau gabbroic intrusion is clearly marked by a northwest-trending, oval-shaped positive magnetic anomaly. On the northeastern side, it is accompanied by a characteristic minimum caused by oblique magnetization at our latitudes (63°). The anomaly intensity is 55-60 nT, with negative values ranging from -15 to -20 nT. It is complicated by small local maxima with intensities of 63-113 nT, isometric and oval in shape, and meridional and subconformable northwestern orientation. The average dimensions of the oval local anomalies with a submeridional strike are 650 x 400 m, while the isometric ones are 300-350 m in diameter. Known ultramafic rock bodies (ultramafics) are located at the epicenters of local anomalies or frame them along their periphery. This also applies to known skarn zones. Local magnetic maxima clearly mark ultramafics and skarns containing significant amounts of pyrrhotite. It is noted that pyrrhotite, chalcopyrite, arsenopyrite, and pyrite have been identified among the ore minerals in the Beltau skarns. The total sulfide content reaches 1%. The boundaries of the intrusion are more clearly defined on the map of local magnetic anomalies.

A completely different magnetic field pattern is observed over the Shaidaraz and Taushan gabbroic intrusions. They are marked by a single positive magnetic anomaly of low intensity (5-15 nT). The anomaly extends northwestward, narrows to the northwest, and widens to the southeast. The anomaly extends up to 25 km and is up to 2 km wide (Shaidaraz intrusion) and up to 4.5 km wide (Tauhan intrusion). A similar pattern is observed in the gravity field. The elevated magnetic field generally follows the contours of the gravity anomaly over the Shaidaraz and Taushan intrusions. These data confirm the conclusions of G.I. Zhuravlev (1971) that the Taushan intrusion is the southeastern continuation of the Shaidaraz massif.

The Shaidaraz intrusion is accompanied, as noted above, by a linearly elongated magnetic anomaly with an intensity of 5-15 nT, which can be traced as a continuous band to the Taushan intrusion. The northern, northeastern boundary of the anomaly practically coincides with the intrusion contact, suggesting its steep dip; the southwestern boundary runs south of the contact, reflecting the overlain southwestern part of the intrusion. The multiphase nature and variegated petrographic composition are reflected in the magnetic field by localized positive anomalies, mostly isometric, less commonly oval-elongated, with intensities ranging from 20-40 to 75 nT. These anomalies clearly mark serpentinized peridotites, both known and suspected. It is also worth noting that a linear zone of local magnetic maxima with an intensity of 20-25 nT, 2800 m in length, is spatially confined to the skarnification zone in the southwestern contact of the intrusion, which most likely corresponds to this skarnification zone (*Kerimov et all, 2009*).

Taushansky intrusion It is marked by an isometric magnetic anomaly with an intensity of 10-20 to 30 nT, with the epicenter of the anomaly confined to the gabbroic outcrop, and the contour of the anomaly itself significantly exceeding the geological boundaries of the intrusion in the south, which indicates that the southern part is blocked.

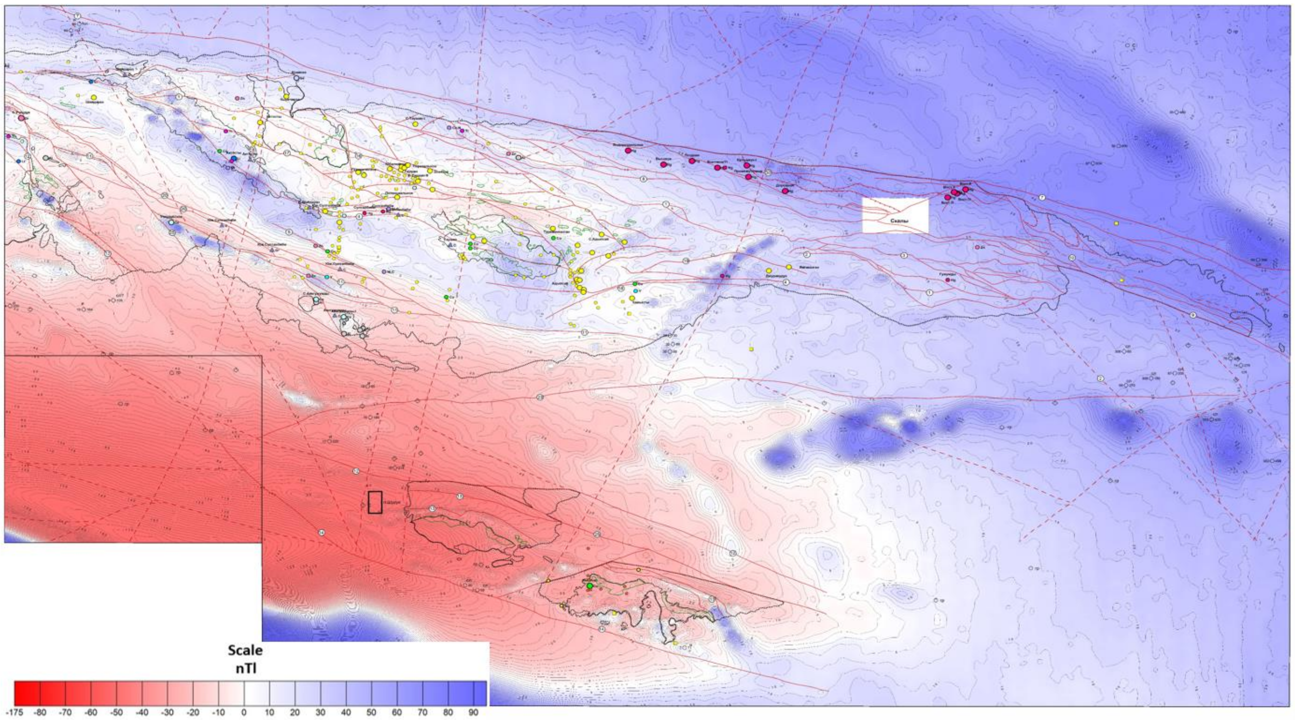

Figure 3. Magnetic map of Eastern part of Kulzhuktau mountains.

Tozbulak granitoid massif the massif is located within the Western Kuldzhuktau area, except for its easternmost part. The magnetic field is virtually undifferentiated. A quiet, near-zero magnetic field of a few nanoteslas is observed above the granitoid and the predominantly carbonate formations that host it. However, the field is slightly higher in the northern part of the massif and slightly lower in the southern part. A similar division of the granitoid into two parts, northern and southern, is also observed in the gravity field. A number of positive anomalies of varying intensity and size are observed in the endo- and exocontact parts of the intrusion.

The largest magnetic anomaly, with an intensity greater than 20 nT, was identified in the west of the Tozbulak intrusion. It is irregularly oval in shape and extends along a sublatitudinal fault for a distance of 3.5 km and a width of 1.2 km. The western half of the anomaly is observed above the Silurian terrigenous and carbonate sediments hosting the intrusion, while the eastern half is observed above granites with small xenoliths of host limestone. The magnetic anomaly is not manifested in the gravity field. The magnetic anomaly likely marks a halo of contact metamorphism (hornfelsing, skarnification). The Central I and II gold occurrences and the North Tozbulak niobium occurrence are confined to the southern flank of the anomaly, while the Koshshashak yttrium occurrence is confined to its northern flank. It is localized at the contact of granite with Lower Silurian limestone in the Central Tozbulak fault zone, which has a sublatitudinal strike here. A local narrow-linear higher-order anomaly has been identified in the epicentral part of this anomaly along the northern edge of the sublatitudinal fault. This local narrow-linear anomaly is represented by three maxima with intensities from west to east: 50, 40, and 20 nT. Skarnification zones are confined to the first two maxima. It is obvious that this narrow-linear high-frequency anomaly marks the skarnification zone.

A skarnification zone, established in the northeastern exocontact of the intrusion with Silurian carbonates and confined to the southern branch of the Central Kuldzhuktau fault, is also marked by an intense anomaly (25-40 nT), only of smaller dimensions. A skarnification zone is marked at the contact of granites with xenoliths of Lower Silurian limestones in the southeastern part of the intrusion, and a weak magnetic anomaly (5 nT). Another intense magnetic anomaly (50 nT), caused by skarnification and hornfelsing processes, is located at the eastern exocontact of the Tozbulak intrusion in the Uchkuduk fault zone. It is confined to small granite and syenite-diorite stocks and is accompanied by a local VP anomaly, with skarns noted on its northern flank.

Next, we will describe the magnetic field and its most important elements of the Darvaza Depression, filled with Cretaceous deposits up to 150 m thick. The outcrops of the Paleozoic complex framing the depression are represented by terrigenous-volcanic rocks of the Kazakasuyskaya suite of the Lower-Middle Ordovician, carbonate deposits of the Upper Ordovician, Silurian and Devonian. Numerous positive magnetic anomalies with intensities ranging from 10-15 nT to 30 nT have been identified within this area. The shape of the anomalies varies - linear, oval, isometric. The sizes of isometric anomalies are 300-500 m in diameter, linear-elongated ones - from 0.8-3 km to 6-9 km. The strike of the anomalies is mainly northwesterly. Carbonate rocks are generally characterized by reduced (to negative) magnetic fields.

Based on the saturation of magnetic anomalies, the Darvaza area is clearly divided into two blocks – western and eastern. The western block features an anomalous region with a higher concentration of local anomalies, giving the magnetic field a banded-mosaic character. The anomalies are traced in subparallel chains in a northwesterly direction. The longest magnetic anomaly (9 km) is observed in the North Beltau fault zone (21). Within the outcrops and shallow occurrence of the Paleozoic basement, magnetic anomalies are confined to anomalies of increased polarizability caused by carbon-bearing metaterrigenous formations of the Ordovician Kazakasuy suite, as well as zones of graphitization and sulphidic mineralization. In the gravitational field, most anomalies coincide with local gravity maxima. Magnetic anomalies can be mapped both in sulfidized gabbroids and in zones of pyrite-pyrrhotite mineralization in the metamorphic formations of the Kazakasu Formation. According to quantitative calculations, the depth of the upper edge of magnetic features ranges from 100 to 376 meters.

The eastern block exhibits a number of small anomalies and only one large linear anomaly, extending with bends and constrictions from northwest to southeast for a distance of 6.5 km. In the gravity field, it is associated with a local positive anomaly, almost exactly matching its configuration. The magnetic anomaly most likely maps a buried or cryptically buried gabbroic intrusion. The estimated depth of the upper edge of the magnetic body is 256 m in the north, 215 m in the center, and 250 m in the south.

Small isometric anomalies frame the meridional outcrop of Silurian limestones to the east. They are associated with local IP anomalies. Further east, along the contact of carbonaceous deposits of the Kazakasu Formation with Cretaceous sediments, small isometric (one of them bipolar) and oval-shaped anomalies are observed. Overall, this group of anomalies fits into a northwest-trending structure, which is consistent with the IP electrical prospecting and gravimetry data. Magnetic anomalies are associated with local IP anomalies and a locally elevated gravity field. Given their shape, the isometric anomalies most likely map stock-like bodies of gabbroic rocks; however, it is possible that they mark areas with elevated pyrrhotite content in zones of sulfide mineralization. The Darvaza gold occurrence (No. 24) is associated with one of these 24 nT anomalies. According to quantitative calculations, the depth of the upper edge of the magnetically disturbing feature is 56 m.

A number of positive and negative magnetic anomalies have been identified in the western rim of the Kuldzhuktau Mountains, a piedmont plain composed of Mesozoic-Cenozoic deposits. The largest positive anomalies were recorded in the northwest of the West Kuldzhuktau area. The anomalies are oval and linear in shape, with an intensity of 20-30 nT. They extend northwestward, highlighting the main geological structures of the buried Paleozoic basement. The geological origin of the positive magnetic anomalies is presumably linked to manifestations of regional thermal metamorphism—zones of pyrite-pyrrhotite mineralization in metaterrigenous rocks of the Kazakasu Formation. A local oval anomaly (30-50 nT), complicating the longest anomaly, possibly marks a gabbroic rock stock.

A gabbroic stock is also identified by a positive magnetic anomaly striking meridionally. The anomaly's intensity is 10-30 nT. It is narrowly linear in the north, gradually widening to an isometric shape southward. To the east of it, in the area of Mount Donguztau, a near-isometric anomaly likely maps a small gabbroic stock. In the central part of the study area, small magnetic anomalies with an intensity of 5-10 nT may also be associated with small gabbroic bodies.

At 2.9 km to the north-east of the Tuzkoy Upland, a supposed granitoid stock has been identified by a negative magnetic anomaly with an intensity of -15 nT, bordered on the south and east by a strip of low-intensity (2.5-5 nT) magnetic maxima, possibly caused by contact-metasomatic formations.

In the northern rim of the Tuzkoy Upland, positive magnetic anomalies associated with the Central Kuldzhuktau Fault zone are identified against a negative magnetic field. Within the shallow basement, magnetic anomalies correspond to VP anomalies, and an EP anomaly is also observed here. It is assumed that these magnetic anomalies map zones of pyrite-pyrrhotite mineralization.

An isometric, intense positive magnetic anomaly has been identified in the piedmont plain at the southwestern foot of the Beltau Mountains. It coincides perfectly with the isometric epicenter of the local gravity minimum. The anomaly's intensity is 40 nT and it measures 1.4x1.1 km. It is associated with the Taskazgan thrust-slip fault, its downthrown limb. It is believed that this magnetic anomaly maps a skarnification zone in the apical portion of a granitoid stock that does not outcrop at the basement surface. A similar, but less intense, gravity-magnetic anomaly marks the Ayaguzhumdinsky stocks of two-mica granites in the central part of the Kuldzhuktau Range.

The West Kyngyrtau (Shuruq) intrusion is composed primarily of biotite granites and granodiorites. Its outcrop in the West Kyngyrtau Mountains, against the surrounding negative magnetic field, is clearly marked by a local minimum of oval morphology with an intensity of -50 to -95 nT. The gabbro-diorites that make up the margins of the intrusion are either virtually unaffected by the magnetic field or are marked by localized, weakly intense minima, indicating that they are composed of non-magnetic varieties (without sulfides). Along the periphery, the minimum is accompanied by narrowly linear zones of localized increases in the magnetic field and isolated, isometric, relatively positive anomalies (maximum) of small size. The northern chain of localized positive anomalies with an intensity of up to 15 nT is confined to dolomites intruded by spessartite dikes. The magnetic anomaly is not evident in electric fields, but in gravity fields it is accompanied by a local gravity maximum caused by the dolomites. The anomaly most likely marks an overlying skarnification zone at the northern exocontact of the intrusion. The zone is up to 0.5 km wide and extends up to 7.5 km. According to quantitative calculations, the depth of the magnetic features is 117 m.

DISCUSSION

The magnetic field of the western Kuldzhuktau region exhibits strong regional differentiation associated with major tectonic and lithological units. Positive magnetic anomalies are mainly related to gabbroic intrusions, skarnification zones, and sulfide mineralization containing pyrrhotite and magnetite. In contrast, large negative anomalies correspond to granitoid intrusions such as the South Tozbulak and Kyngyrtau massifs. Numerous local anomalies coincide spatially with known gold, mercury, zinc, yttrium, lithium, niobium, and rare-earth occurrences, suggesting a close relationship between magnetic anomalies and ore-forming processes (*Yin et all, 2025*).

Particularly significant are the anomalies associated with the Beltau, Shaidaraz, Taushan, and Tozbulak intrusive complexes, where magnetic signatures reflect varying lithological compositions, hydrothermal alteration, and concealed intrusive bodies. The study also demonstrated that many magnetic anomalies align with deep fault zones, indicating tectonic control over magmatism and mineralization. The integration of magnetic, gravimetric, and electrical prospecting data improved the interpretation of concealed geological structures and allowed the identification of promising exploration targets beneath sedimentary cover.

CONCLUSION

The magnetic exploration conducted in the western part of the Kuldzhuktau Mountains successfully identified numerous regional and local magnetic anomalies associated with intrusive complexes, skarnification zones, sulfide mineralization, and tectonic structures. The results significantly refined the geological and structural understanding of the area and confirmed the high prospectivity of several zones for gold and polymetallic mineralization. Positive magnetic anomalies are interpreted to reflect concealed gabbroic bodies, hydrothermal alteration, and pyrite-pyrrhotite mineralization, while negative anomalies correspond to granitoid intrusions. The study confirms the high effectiveness of magnetic surveying as a tool for mineral exploration and structural mapping in complex geological environments of Western Uzbekistan.

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