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DEPOSITS DISCOVERED IN AZERBAIJAN IN RECENT YEARS (ON THE EXAMPLE OF GADABAY MINERALISATION DISTRICT)

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This article presents the results of recent exploration works carried out over the Gadabay NW project, Gadabay Mineralisation District, Azerbaijan which were undertaken between 2012 and 2023, over the last 11 years. The study was conducted by Gadabay Exploration Geologists (GEG) of Azerbaijan International Mining Company (AIMC). The results of the exploration activities within the Gedabek Mine and around the Gedabek mineral deposit have been provided in stages between 2008 and 2023. As a result of the exploration activities several new local epithermal mineralization areas have been discovered, one of which has underground mining, named Gadir deposit (low sulfidation type) (by GEG, 2012) and the other has open pit mining - Ugur gold deposit (by GEG, 2016). Other mineralisation perspective areas are in advanced stages of exploration, such as Gilar (by GEG, 2020) and Zafar (by GEG, 2020), which are expected to begin production in 2024 year.

The Gadabay ore district forms part of the Middle-Upper Jurassic Age Lök-Qarabag volcanic island arc structure-formation zone and is associated with the NW-trending fault system. Increasingly felsic intrusive magmatism is associated with 2 orogenic cycles ranging in age from the Bathonian to the Upper Jurassic. Mineralization is mainly hosted by Middle to Upper Jurassic volcanic and partly volcanic-sedimentary rocks of mostly acidic and intermediate composition with subvolcanic facies, interbedded lavas, tuffs and terrigenous clastic rocks.

The Gedabek, Gadir, Ugur, Zafar and Gilar mineral deposits were formed as a result of the island arc-type intrusive magmatism and are directly or indirectly related to the multiphase Gadabay granitoid intrusive complex.

Keywords: Gadabay mineralization district, Gadir, Ugur, Gilar, Zafar.

Introduction

Azerbaijan is located in the South Caucasus region of Eurasia, straddling Western Asia and Eastern Europe (Fig.1). It lies between latitudes 38° and 42° N, and longitudes 44° and 51°E. Three physical features dominate Azerbaijan: the Caspian Sea, whose shoreline forms a natural border in the east; the Greater Caucasus Mountain range in the north; and the vast plains in the country's center. Three mountain ranges, the Greater and Lesser Caucasus, and the Talysh Mountains, together cover about 40% of the country.

The Lesser Caucasus mountain-folded system covers the southern part of the Caucasus and is characterized by a heterogeneous internal structure, caused by the convergence within it of two branches of the Alpine-Himalayan mobile belt: Iberian-Elburs in the North and Dinara-Zond in the South (Fig.2). There are 4 structural-formation zones in Azerbaijan part of Lesser Caucasus metallogenic zone: Lök-Qarabag zone, Goycha-Hakari zone, Miskhana-Zangazur zone and Araz zone. This paper discusses mainly the Lök-Qarabag zone due the several mine operating deposits in the example of Gadabay ore region.

Mining activity at Gadabay (or Gedabek) is reported to have begun as long ago as 2,000 years ago. More recent activity began around 1849 when the Mekhor Brothers, followed by the German Siemens Bros Company, developed and operated a copper mine at Gadabay. At least five large (>100,000 tonnes) and numerous smaller sulphide lenses were mined during the period between 1849 and 1917. With the beginning of the Russian Revolution in 1917, the mining activity ceased.

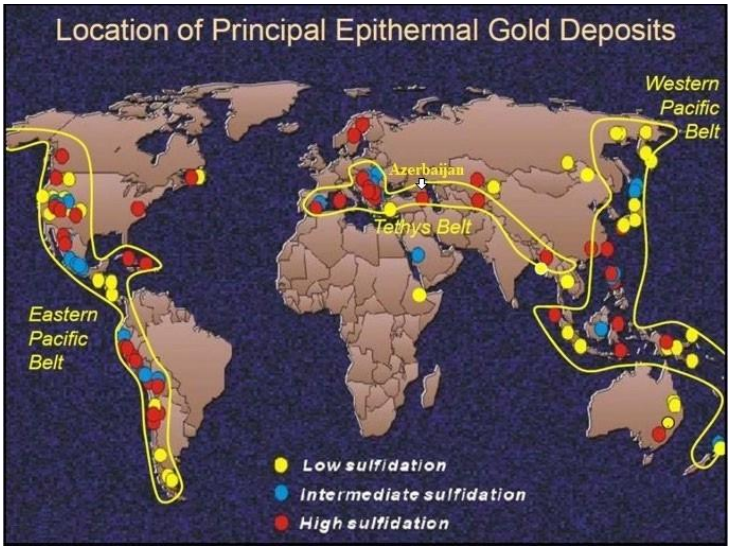

Fig. 1. Location map of the Azerbaijan Republic, Tethys metallogenic belt.

Mining activity resumed when AIMC (a subsidiary of Anglo Asian Mining company) began construction of an open pit mine and a conventional heap leach and processing facility for the recovery of gold, copper and silver in 2008. The Company poured its first gold in May 2009, making it the first gold/copper producer in Azerbaijan in modern times. Since then, gold production has been steady as the mine's efficiency continues to improve. In addition, in 2015 the Group commenced production from Gadir, an underground mine co-located in Gadabay and in 2017 the Group commenced production from the Ugur open mine. The Zafar and Gilar deposits were discovered in 2020 and are close to the Gadabay processing facilities.

Fig. 2. Tectonic map of the Anatolian-Lesser Caucasus-Iran segment of the Central Tethyan Belt.

Regional Geological setting of the mining district

The Gadabay ore region is located in Azerbaijan at its border with Armenia, in the central part of the Lök-Qarabag island arc, north of Goycha (Sevan) Lake. This region is considered to be the largest porphyry district in the country. Cu-porphyry deposits (Xarxar, Qaradag, Djaygir) associated with Kimmeridgian volcanism are characteristic of this area. Several epithermal deposits are exploited or in prospect (Bittibulag, Gadabay, etc.). Modern studies of copper mineralization have revealed the Qaradag-Xarxar copper-porphyry field [1]. This field is composed of the rocks of the Atabay-Slavyanka plagiogranite intrusive which is intruded by small dike-like and stock-like bodies of intermediate-basic composition. These small intrusions (quartz-diorite-porphyrites) correlate with sub-meridian fault zones and control the quartz-pyrite-molybdenite and quartz-pyrite-chalcopyrite vein-

disseminated ores. Gold mineralization in the Azerbaijan part of the Lök-Qarabag Zone aroused great interest when information became available about significant gold extraction (about 5–7 t) from the copper-sulphide ores of the Gedabek deposit by the German company Siemens, which owned copper concessions until the 1920s. However, no commercial gold-bearing mineralization was actually found.

The main features of the geological structure of the Gadabay deposit and ore specifics have been predetermined by its position within the large Gadabay-Qaradag volcanic-plutonic structure of central type, characterized by a rather complex internal structure, due to repeatedly tectonic movements, multicyclic magmatic activity and related mineralization processes. The comparatively large tectonic-magmatic structure enveloping a considerable part of the Shamkir uplift of the Lök-Qarabag structural-magmatic zone (Lesser Caucasus Mega-anticlinorium) has been significantly complicated (affected) by zone systems of different age and trend and divided into a series of blocks (Fig.3). The latter (blocks) enclose relatively small volcanic-plutonic structures of central type: Gadabay, Slavyanka-Qaradag, Almalitala, Ashagy Chaykend-Yukhary Chaykend and etc. The structures are composed of complex granite intrusions mostly of Mid-Upper Jurassic age.

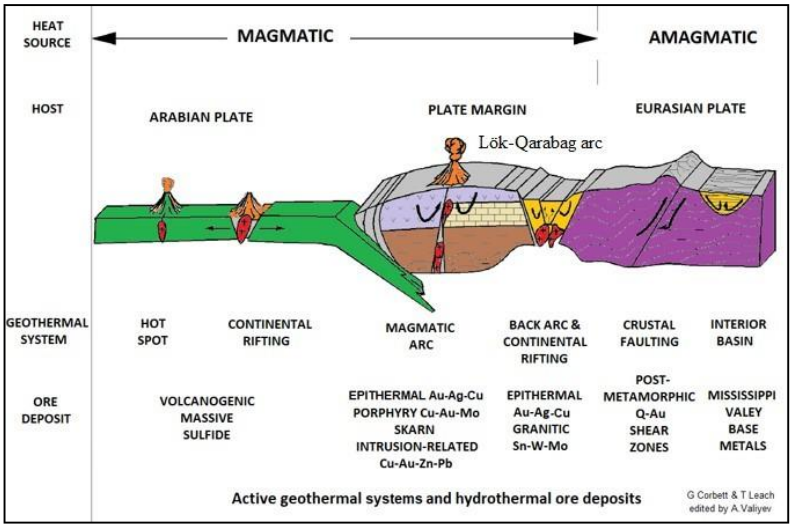

Fig. 3. Active geothermal systems and hydrothermal ore deposits model of Arabian-Eurasian plates with Lök-Qarabag magmatic arc (Corbett and Leach, 1998; Anar Valiyev, 2020) [5].

The latter and the Gadabay-Qaradag tectonic-magmatic structure enclose a series of deposits and mineralization areas (and a number of zones and mineralization spots) of gold-porphyry-copper, porphyry-copper, gold-copper-

pyrite, copper-pyrite, copper-polymetallic and other ore formations [2]: Gadabay, Qaradag, Xarxar, Ertepe, Bittibulag, Maarif deposits; Cholpan, Parakendsu-Maskhit, Goyyer, Djair, Shekerbey, Zehmet, Gyzyldjadag, Almalitala and other mineralization areas (Fig.4). These deposits and mineralization areas have been studied insufficiently and characterized by a large scale disseminated-streaky (vein) sulphide ores of mainly gold-porphyry-copper type (Gadabay, Qaradag, Xarxar, Maarif), associated at some spots with lenses, lens-stocks, and stocks of pyrite ores (Gadabay, Bittibulag, Ertepe). Infrequently the latter occur as veins of gold-sulphide-quartz type (Zehmet, Maskhit-Parakendsu). Remnants and traces of old and ancient mine works (shafts, pits, adits, furnaces for smelting, slags sinders and etc.) are preserved at some of the deposits and mineralization areas (Gadabay, Xarxar, Qaradag, Maarif, Böyük Qalaça, Zehmet and etc.).

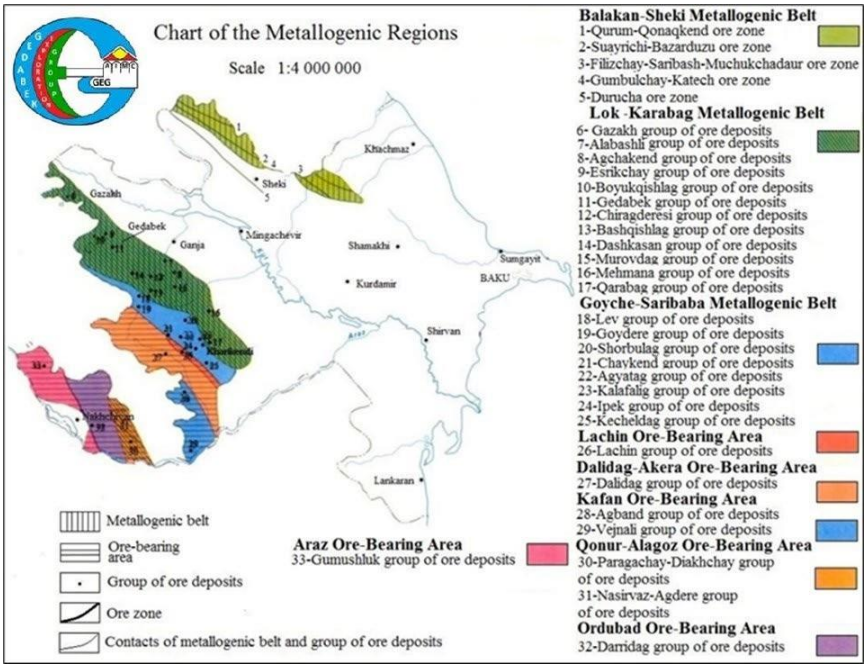

Fig. 4. Location map of the Gadabay ore district in Chart of the Metallogenic Regions, Azerbaijan Republic (created by Gedabek Exploration Geologists based on archive data).

The Gadabay ore district is located in the area of the Shamkir uplift of the Lök-Qarabag structural-formation zone in the Lesser Caucasus Mega-anticlinorium. The ore region has a complex geological structure, and it has become complex with the intrusive masses and breaking structures of different ages and different composition. Lower Bajocian is essentially

composed of an uneven succession of diabase and andesite covers, agglomerate tuffs, tuff-gravelites and siltstones. Tuff of the Lower Bajocian was exposed to strongly metamorphism (skarn alteration and hornfelsing) as a result of the impact of Upper Bajocian volcanism and intrusions of Upper Jurassic age. Only subvolcanic rocks of the Upper Bajocian in the Gadabay mine have been studied (rhyolite and rhyodacite, quartz-porphyry) [3]. Rocks related to the Bathonian stage have developed mainly in the northern and southern edges of Shamkir uplift.

This article describes 4 newly discovered deposits that may be of interest in the future from a commercial point of view (Fig.5): 1. Gadir low sulfidation deposit; 2. Ugur exploration area (Ugur gold deposit) 3. Zafar copper-polymetallic deposit and 4. Gilar gold-copper-polymetallic deposit.

Gadir deposit. Gadir low sulfidation deposit is located in 400 meters from the current Gadabay pit (Fig. 6). The area was first time discovered during the structural-geological mapping of the NW Flank of Gadabay mineral deposit [7]. Here the outcrop of quartz porphyry (rhyolite porphyry) subvolcanic formation on the surface was considered to be the main factor. The ore body is located at the contact between volcanic rocks and the quartz porphyry. There are some disseminations, breccia and vein-like hydrothermal structures in the quartz porphyry.

The Gadir low sulfidation adularia-sericite alteration is formed when the large volumes of groundwater fluids interact as the rising from the hot magma (Gadabay intrusion). The prolonged boiling of the fluids in low sulfidation systems produces high grade gold and silver deposits. The fluids interact with the surrounding rock for a much longer period of time than the rapidly channeled high sulfidation fluids. As a result, the fluids become diluted and neutralized; the silica dissolves. The silica is later precipitated in the veins as quartz, often sealing the fissure closed. When this occurs, the pressure of the gases beneath the sealed fault builds until the seal is ruptured, which provokes catastrophic boiling and the precipitation of gold. After this, passive conditions return, and quartz precipitates once again. This cyclical process results to the well-known banded texture of the quartz-adularia lenses typical of Gadir low sulfidation systems [4]. Maiden JORC Ore Resources estimate: Measured+Indicated Ore Resources of 2,347,000 tonnes at a grade of 2.29 grammes per tonne gold containing 172,400 ounces of gold, 11.14 grams per tonne silver containing over 840,400 ounces of silver and 0.19 percent copper containing nearly 3,866 tonnes of copper.

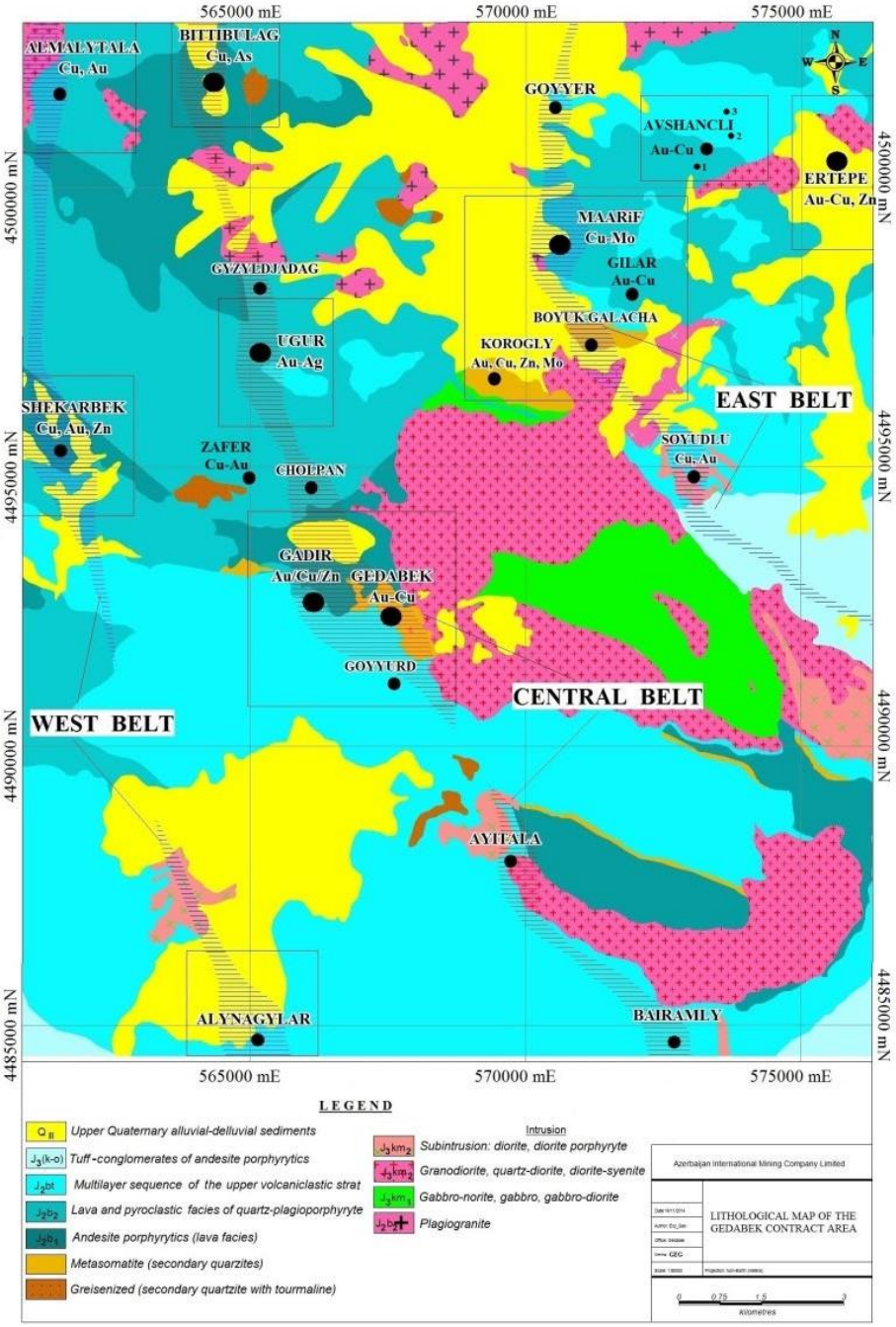

Fig. 5. Lithological map of the Gadabay ore district.

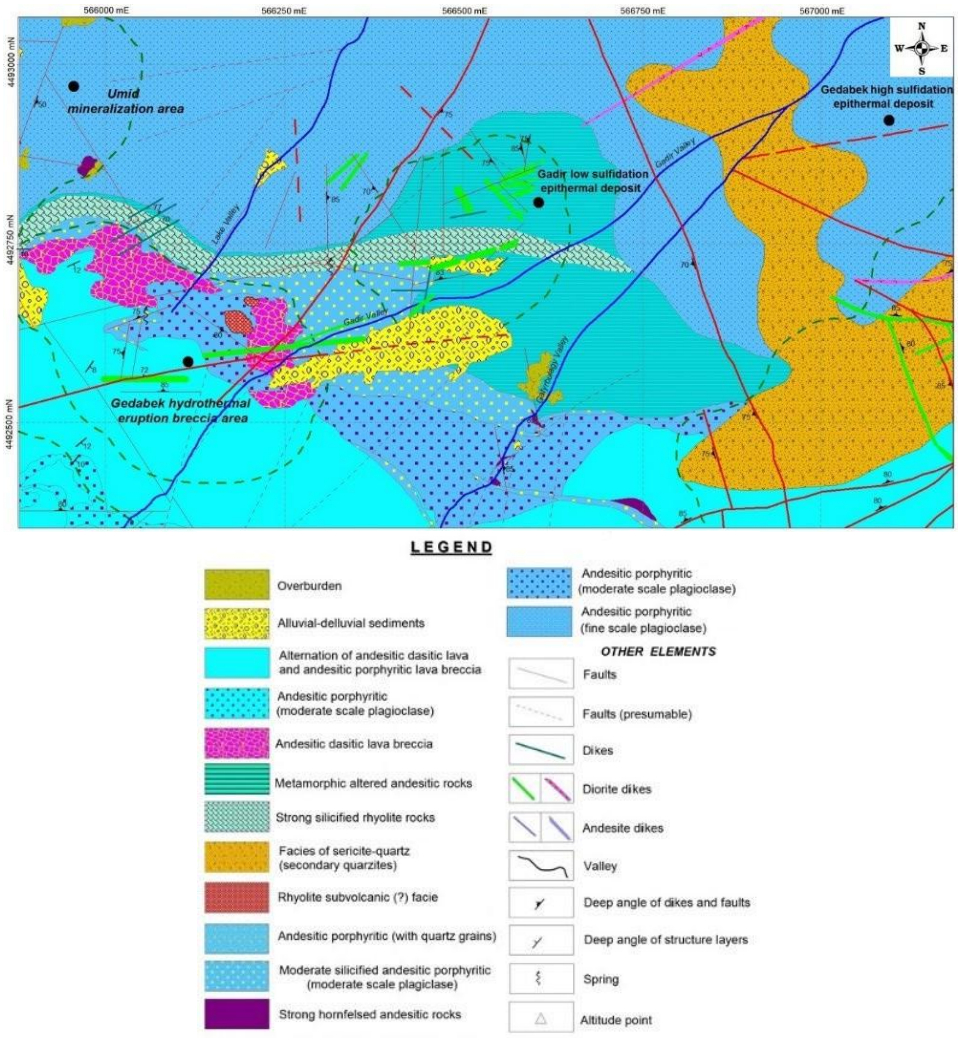

Fig. 6. Lithological-structural map of the Gadir deposit.

Ugur deposit. Ugur ore perspective exploration area is located in the Gadabay ore district of the Shamkir uplift of the Lök-Qarabag island arc volcanic structural-formation zone in the Lesser Caucasus Megaanticlinorium, Azerbaijan, Western Asia. The Ugur gold deposit, SHAH Yatag, Gyzydjadag, Dashbulag and Yukhari Narzan mineralisation areas are all located within the Gadabay-Bittibulag regional deep fault system of the Ugur exploration area. The Ugur high sulfidation epithermal gold deposit was discovered during geological exploration work of the northwest flank of the Gadabay gold-copper mine in 2016.

The gold mineralisation at the Ugur deposit developed mainly during the Upper Bajocian tectonic-magmatic cycle. During the Upper Bajocian, the

central tectonic zone formed a right-lateral strike-slip fault represented by a series of sub-parallel-trending faults (055º-085º) with a combined length of 1.0 to 1.5 kilometers. The Ugur gold deposit was emplaced at the intersection of NW-, NE-, NS- and EW-trending structural systems regionally controlled by a first order NW transcurrent structure that dips between 70º to 80° to the north-west. The faults of the central zone control the hydrothermal metasomatic alteration, gold mineralization, Upper Bajocian Atabek-Slavyanka plagiogranite massive intrusion, and in some cases are the boundaries of the elevated tectonic blocks formed by Lower Bajocian volcanic rocks. In cross-section, the geological sequence is dominated by secondary quartzites (strongly altered rhyolite) which were formed under the influence of the Atabek-Slavyanka plagiogranite intrusions with some exposures observed to the north of the gold mineralisation area. The mineralisation zone thickness in the area varies between 80 to 120 meters. Gold mineralisation at the deposit is interpreted as being of shallow high sulfidation epithermal system. The mineralisation occurs in two different styles; 1) well-confined hydrothermal breccias and 2) underlying pyrite stock-stockworks. Rocks in the alteration zone area strongly brecciated, and exhibit argillic alteration, with strong limonite and hematite alteration. Hematite is also observed in gossan zones. Near surface intense barite and barite-hematite vein and veinlets are present. Main mineralisation in the Ugur gold deposit consists of hematite-barite-quartz-kaolin veins-veinlets and breccia, pyrite stock-stockworks and quartz-sulfide veins (Fig.7).

The central surface expression of the mineralization shows accumulations of hydrous iron oxides cementing breccias of quartz and secondary quartzites overlaying secondary quartzites with vein-veinlets barite-hematite mineralization. In areas of erosion, gossans are represented by “reddish mass” of oxidation products of stockwork limonite-hematite ores is observed. Within trenching and shallow pits, mineralised zones vary in thickness from about 5-10 meters and contain gold with a grade of 0.3-3.5 g/t and silver with a grade of 1.0-45.0 g/t. Subsequent drilling has defined the depth of oxide zone mineralisation up to 100 meters, with an average depth of 60 meters. One gold-bearing body was delineated in the oxidized zone. Oxide zone resources were estimated to a depth of 50-110 m from the surface using a system of geological blocks. At a cut-off grade of 0.3 g/t Au the following resources were estimated: Category Measured+Indicated – 6,960 000 tons of ore, with in 199,000 Oz of gold, 1,049 000 Oz of silver.

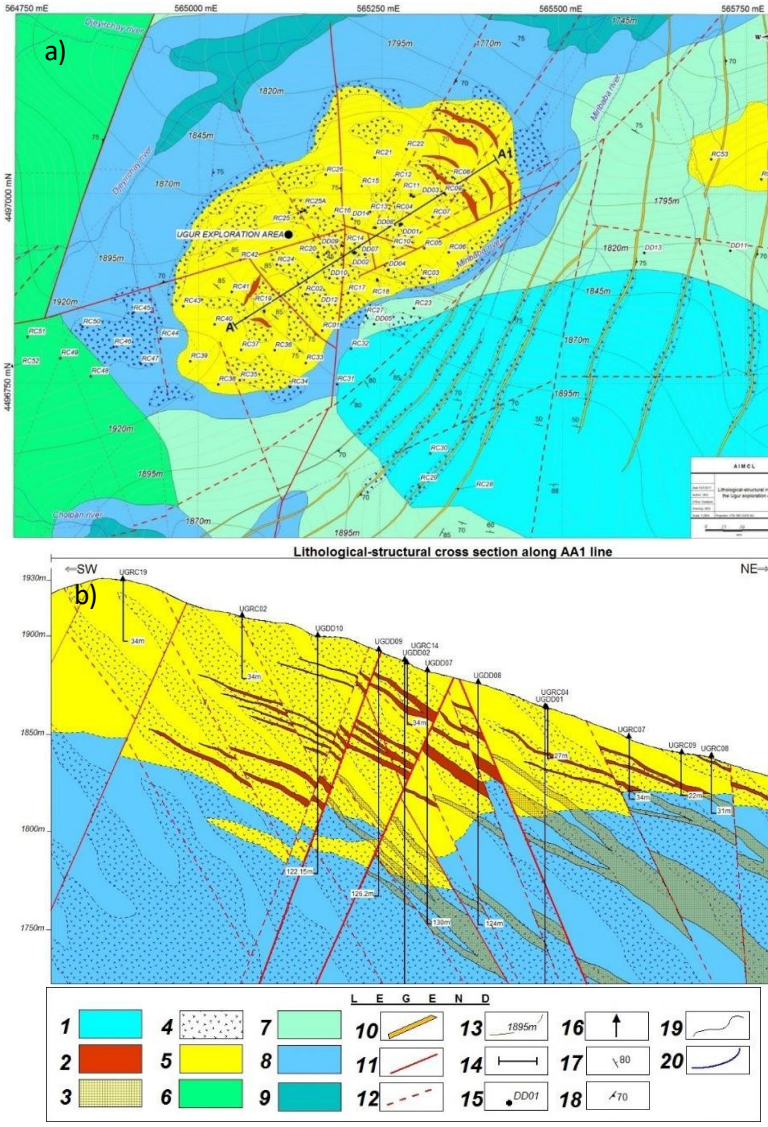

Fig. 7. Lithological-structural map of the Ugur deposit (a), Lithological-structural cross-section along AA1 line, Ugur gold deposit (b).

Legend for the lithological-structural map: 1) Andesite tuff agglomerates facie; 2) Gossan; 3) Pyrite stock and stockwork; 6) Breccia zone of silicified andesite porphyritic rocks; 5) Secondary quartzite; 6) Pyroclastic (from small clastic to lapilli) facie of rhyolite-dacite porphyry; 7) Lava facie of rhyolite-dacite porphyry; 8) Silicified andesite porphyritic rocks; 9) Andesite porphyritic rocks; 10) Quartz porphyry zone (weak hematitized, limonite-zation); 11) Faults; 12) Probably faults; 13) Topographic contour line; 14) Cross section lines; 15) Bore holes points; 16) Bore holes; 17) Deep angle of faults and dikes; 18) Struc-tural elements of rocks; 19) Lithological contact; 20) Rivers.

Zafar deposit. The deposit is located in the in AIMC's mineral-rich Gadabay contract area in Azerbaijan. Geologically, it is associated with the Gadabay-Bittibulag local deep fault in the Lök-Qarabag volcanic arc of the Lesser Caucasus. The study of the regional geology of Zafar by AIMC geologists since 2018 using a complex geological data interpretation, defined the mineralization potential and led to the discovery of the Zafar deposit in 2020 [7]. Spatially, the Zafar deposit is situated between two main epithermal systems hosting the Gadabay-Gadir and the Ugur deposits. The igneous rocks are extrusive and are mostly felsic to intermediate in composition, being rhyolites, dacites, andesites and their tuffs are distributed from the surface to depth (Fig.8). The host rock of main ore mineralisation is locally termed a metasomatic quartz-porphyry (rhyolite-porphyry), which starts from at depths of 250-300 metres from the surface to more than 500 metres. Mineral content is visual, however, further petrographic studies by polished-thin section were carried out on samples taken from outcrop and drill core. Resulting of these studies, pyrite is the main mineral observed in all drill core and outcrop samples in crystal structures in the form of massive, disseminated, euhedral, anhedral etc. Other primary sulphides include chalcopyrite, covellite, digenite, galena, and sphalerite. The genesis of covellite and digenite is open for discussion. Other copper sulfosalt minerals of tetrahedrite and tennantite have been identified by ore microscopy. Associated non-sulphide minerals including jasper, magnetite, barite, haematite and limonite have also been defined. Quartz is the major gangue mineral in the matrix of the host rocks. The mineral composition, textures and relationships, and chemical composition suggest an intermediate sulphidation type epithermal genesis for the Zafar deposit [5]. The Zafar mine has JORC Mineral Resources of 28,000 tonnes of copper, 73,000 ounces of gold and 36,000 tonnes of zinc. The mining design is based on ore production of 700,000 tonnes per annum and a 0.5 percent copper equivalent cut-off grade [6].

Gilar deposit. The deposit belongs to the Gadabay ore district of the Shamkir uplift which is part of the Lök-Qarabag volcanic arc that is one of the main structural formations of the Lesser Caucasus. The deposit is located over the East flank of the Böyük Qalaça local deep fault. Gilar was discovered during geological exploration work of the northeast flank of the Gadabay gold-copper mine [7]. Deposit is located between two systems: the Maarif porphyry and the Ertepe mineral occurrences. The rocks are Upper Bathonian extrusive represented by mostly felsic and intermediate composition rhyolite-dacites, andesite-porphyry, andesites and their tuffs distributed from the surface to depth (Fig.9). Ore minerals are hosted in the metasomatic rhyolite-porphyry of the Upper Bajocian age, at depths ranging from about 130 meters to more than 400 m from the surface. Preliminary

field mapping and outcrop sampling identified a continuous epithermal quartz vein, hosted in a rhyolite volcanic in the northern Gilar area. To the south of the vein system, significant massive mineralisation has been discovered. Mineral content is visual, however, further petrographic studies by polished and thin section were carried out on samples taken from outcrop and drill core. The majority of core samples from Gilar, samples contain high-grade gold, copper, and zinc. According to these observations and studies, pyrite is the dominant mineral which is observed in all drill core and nearby outcrop samples exhibit crystal structures: massive, disseminated, euhedral, anhedral, etc. with associated chalcopyrite, sphalerite, and other sulfide minerals. Jasper, magnetite, barite, and limonite are non-sulfide minerals present. The mineral composition, textures, relationships, the chemical composition suggest a high sulphidation or skarn type of epithermal system for the Gilar deposit. In-situ non-JORC mineral resource of over 249,083 ounces of gold, 46,466 tonnes of copper, and 48,786 tonnes of zinc.

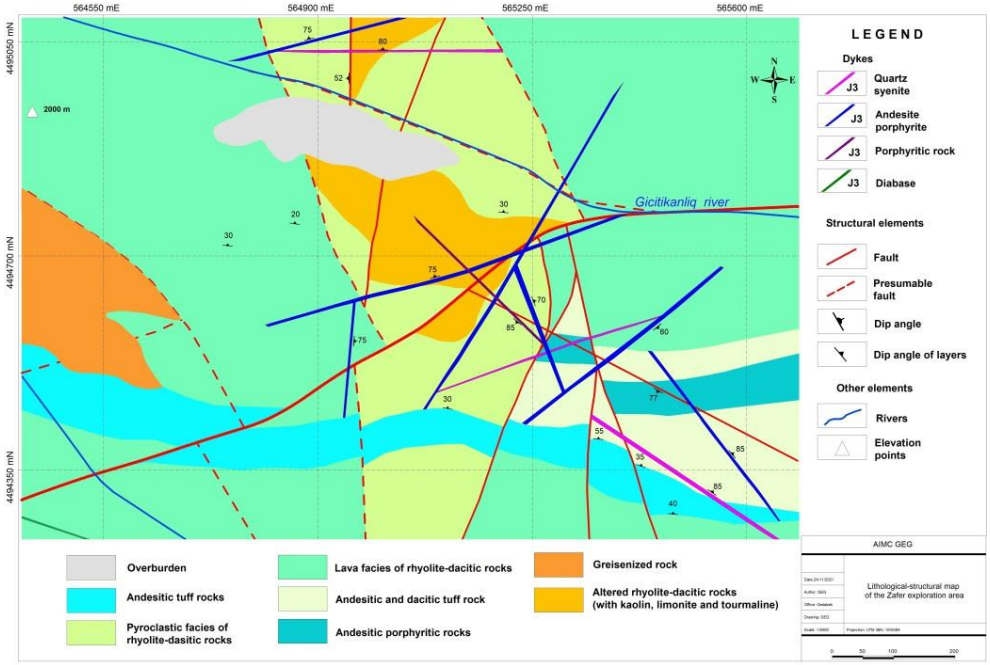

Fig. 8. Lithological-structural map of the Zafar deposit.

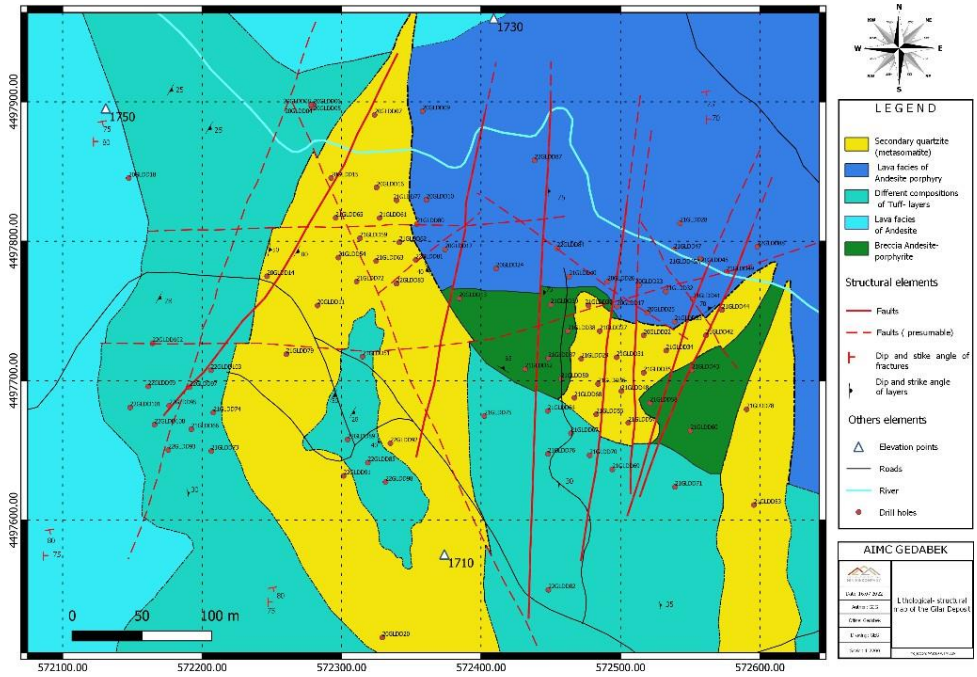

Fig. 9. Lithological-structural map of the Gilar deposit.

Conclusion

Despite nearly two hundred years of geological exploration in the Gadabay mineralisation district of Azerbaijan by the "Mekhor Brothers", "Siemens Bros" companies, and the Soviets, the identification of four new ore deposits shows that the area has great potential for making discoveries through the application of new exploration methods and complex geological interpretations.

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XÜLASƏ

Bu məqalə 2012-ci ildən 2023-cü ilə qədər olan zamanda, yəni son 11 il ərzində Azərbaycanın Gədəbəy filiz rayonunun Şimal-Qərb sahəsində aparılmış geoloji-kəşfiyyat işlərinin nəticələrindən bəhs edir. Tədqiqat işləri Azərbaycan İnterneyşnl Mayninq Kompani Limited şirkətinin (AIMC Ltd.) "Gədəbəy Kəşfiyyat Geoloqları" (GEG) adlanan qrupu tərəfindən aparılmışdır. Məqalədə 2008-2023-cü illərdə Gədəbəy filiz yatağı və onun cinahlarında aparılan mərhələli geoloji-kəşfiyyat işlərinin nəticələri təqdim olunur. Geoloji-kəşfiyyat işləri nəticəsində bir neçə yeni epitermal minerallaşma sahələri aşkar edilmişdir ki, artıq onlardan birində yeraltı, (Qədir yatağı, 2012-ci ildə GEG tərəfindən kəşf edilmiş "aşağı sulfidləşmə" tipli epitermal sistemlərə aiddir) digərində isə (Uğur yatağı, 2016-cı ildə GEG aşkar edilmişdir) açıq mədən istismar işləri aparılır. Digər perspektivli minerallaşma sahələrinə aid olan Gilar və Zəfər (hər iki yataq 2020-ci ildə GEG tərəfindən kəşf edilmişdir) geoloji-kəşfiyyat işlərinin tamamlanma mərhələsində olaraq 2024-cü ildə hasilata verilməsi planlaşdırılır. Gədəbəy filiz rayonu Orta-Gec Yura yaşlı Lök-Qarabağ ada-qövs struktur-formasiya zonasına və şimal-qərb istiqamətli qırışıqlıq qurşağına daxildir. Zona boyunca getdikcə daha çox turş tərkibli maqmatizm Batdan Gec Yurayadək olan yaş intervalını əhatə edən iki orogenik dövrlə əlaqələndirilir. Filiz minerallaşması, əsasən, Orta-Üst Yuranın vulkanik və qismən vulkanogen-çökmə süxurları, əsasən turş və orta tərkibli subvulkanik fasiyalı, növbələşən lavalar, tuflar və terrigen qırıntılı süxurlarda yerləşir. Gədəbəy, Qədir, Uğur, Zəfər və Gilar filiz yataqları mənşəcə ada-qövs tipli intruziv maqmatizmlə, bilavasitə və ya dolayısı ilə çoxfazalı Gədəbəy qranitoid intruziv kompleksi ilə bağlıdır.

Açar sözlər: Gədəbəy filiz rayonu, Qədir, Uğur, Gilar, Zəfər

ОТКРЫТЫЕ РУДНЫЕ МЕСТОРОЖДЕНИЯ В ПОСЛЕДНИЕ ГОДЫ В АЗЕРБАЙДЖАНЕ (НА ПРИМЕРЕ КЕДАБЕКСКОГО РУДНОГО РАЙОНА)

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РЕЗЮМЕ

Данная статья посвящена результатам недавних геологоразведочных работ, проведенных в пределах северо-западного участка (Gadabay NW project) Гядабейского рудного района, Азербайджан, осуществленных за последние 11 лет в период с 2012 по 2023 гг. Данное геологическое изучение участка недр было выполнено командой «Гядабейскими Геологоразведочные Геологами» ГГГ (Gadabay Exploration Geologists, GEG) Азербайджанской международной горнодобывающей компании (Azerbaijan International Mining Company, AIMC). В статье представлены результаты поэтапных геологоразведочных работ, выполненные за период с 2008 по 2023 год на Гядабейском руднике и в пределах месторождения Гядебей. В результате проведенных работ были обнаружены несколько новых участков эпитермальной минерализации, на одном из которых (месторождение Гадир, относится к эпитермальным системам типа «лоу сульфидейшн», открыто GEG в 2012 г.) ведутся подземные добычные работы, а на другом (месторождение Угур, открыто GEG в 2016) – добыча открытым способом. На других перспективных рудоносных площадях, к которым относятся Гилар (открыто GEG в 2020 г.) и Зафар (открыто GEG в 2020 г.), геологическое изучение недр отвечает поздней стадии геологоразведочные работ, а горно-эксплуатационных мероприятия планируется начать в 2024 году. Гядабейский рудный район является частью средне-позднеюрской Лок-Карабахский островодужной структурно-формационной зоны и приурочен к системе разломов северо-западного простирания. Магматизм, имеющий тенденцию становиться более и более кислым вверх по разрезу, приурочен к двум орогеническим циклам, охватывающим возрастной интервал от бата до поздней юры. Рудная минерализация в основном располагается в средне-верхнеюрских вулканических и частично вулканогенно-осадочных породах по большей части кислого и среднего состава, представленных субвулканическими фациями, переслаиваниями лав, туфов и терригенных пород.

Месторождения Гядабей, Гадир, Угур, Зафар и Гилар ассоциируют с интрузивным магматизмом островодужного типа, а также прямо или косвенно связаны с многофазным Кедабекским гранитоидным интрузивным комплексом.

Ключевые слова: Гядабейский рудный район, Гадир, Угур, Гилар, Зафар.

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