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Characteristics of mineral alteration and weathering in Ereen gold ore in Mandal Soum, Selenge province, Mongolia

The Ereen deposit lies within the North Khentei gold belt, which is bounded to the north-west by the Bayangol fault system and to the south-east by the Yeroogol (or Sujigtei) fault system. Both fault systems have a similar south-west-north-east trend (generally NE45°) faults of east-west, north-south and north-western direction; regional scale north-easterly trending Sujigtei fault controls position of the large-scale Gatsuurt gold deposit. The gold mineralization in Ereen deposit is confined spatially with hydrothermal alteration of rhyolite, Ereen deposit area was affected by three tectonic and consecutively, three hydrothermal alteration cycles.The Ereen southern mineralized zone is characterized by extensive quartz veining and a series of ore bodies with similar east-north-easterly striking and south-east dip direction, but the northern zone is different.

Keywords: *Ereen deposit, alteration, weathering, gold.*

1. Introduction

The Ereen property is located in north-central Mongolia approximately 42 km to SW from the centre of Mandal Soum, Selenge Province and 140 km to NNW of Ulaanbaatar, capital of Mongolia. The Dzüünharaa, one of the largest stations on the Trans-Mongolian Railway is located 35km to the north. The main towns in the area are served by good infrastructure including power, water and communications. It is the detailed location in north-central Mongolia. There are two main access rates to the Ereen site; by paved road from Ulaanbaatar to Bornüür (110km) and then approximately 50km on dirt road to the site, or 136km to the north of Ulaanbaatar to Boroo gold mine's improved earth road, and then approximately 30km by unpaved road to the site.

Ereen deposit is located in North Western Khentii Mountain region, which is characterized by forest field belt and medium elevated rugged relief. Highest peaks are Noyon Mountain with elevation 1722.4 m ASL and Bumbug Uul Mountain with elevation 1575.5 m ASL; the lowest peak is 1040 m ASL located in the Bayangol valley.

River network is well developed and could provide good source for industrial and drinking water supply. River Zuun modnii occurs to the north, Bayangol river to the south and Gatsuurt river to the east. Small rivers include Boroo river in 12 km to the west and Kharaa river in 16 km to the east. Climate is relatively soft compared to the other regions and it is favourable for agriculture and livestock farming.

The area of the project has good soil and vegetation; it is fully covered with vegetation. To the west and north west of the project area is relatively abundant in tree and forest covers. There are plenty of bushes around the Boroo and Kharaa rivers. About wild animals forest and forest field animal inhabit in the area: bear, wolf, fox, deer, boar etc.

2. Geology of the region and deposit

Ereen deposit is located near to the principal gold deposit in the district, Gatsuurt mine, developed by Centerra Gold Corporation. The Sujigtei fault separates Devonian rhyolites (which host Ereen) in the west from Palaeozoic granites in the east. Therefore, certain Gatsuurt ore controlling features could be similar to Ereen ore-controlling factors. Stratigraphic section of the Ereen area is consecutively represented by Cambrian-Ordovician Kharaa group formation, Ordovician-Silurian Undur formation, Silurian Mandal group formation, Devonian Uaan Undur formation, Jurassic-Cretacious Ajnai white fracture formation, lower Cretacious Shariin Gol formation, Quaternary Holocene sedimentary formation. Plutonic rocks are spread moderately in the project area. From the previous research the following groups of plutonic rocks were identified on the basis of the geologic-structural location, stratigraphy deposition and border relation towards each other, petrography, and petrochemical characteristics.

1. Medium late Ordovician Boroo river formation
2. Late Ordovician Ikh Tashir formation
3. Medium Devonian rock formation
4. Permian Guadeloupian small Khentii formation
5. Early Triassic Tukhum formation

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Fig.1 Project location in North-Central Mongolia

3. Mine geology

Gold grades vary from trace to 409g/t along the strike and depth extension of the vein. Better grades (from 14g/t to 363.4g/t) of Au were distributed in the middle and deeper parts of the vein, with near-surface grades (down to 40m) considered uneconomic. The average gold grades were 18-23g/t in different blocks.

Ore minerals are pyrite, arsenopyrite, tetrahedrite, chalcopyrite, sphalerite, galena, scheelite, malachite, azurite, limonite and free gold. Free native gold is associated with quartz, galena and arsenopyrite. The average size of visible Au was reported to be of 1mm

Vein 2 is located in the north-east part of the deposit, strikes north-east and dips gently (12°) to the north-west. It has a strike length of 200m and an average thickness of 0.4m. Trenching was undertaken between 1959 and 1960 showed the average thickness of the vein to be of 1m on surface and is surrounded by a 7m wide silicified halo. Gold grade varies from 0.5g/t to 2.7g/t on the surface.

4. Mineral alteration and weathering

The gold mineralization in Ereen deposit is confined spatially with hydrothermal alteration of rhyolites therefore were a subject of special attention during drill core logging. Rhyolites cover a wide area within the Dzun-Modo ore region in the south part of Hentey ridge and are traced along east-west direction for 15-20 km and along north-north-western direction for 25-30km. The host rocks for rhyolites are represented by Ordovician chlorite, chlorite-actinolite, and calcian metamorphosed schists of Kharinsky suit and by Palaeozoic granites and granodiorites. Ereen gold deposit geological section is represented by rhyolites down the depth of at least 300-350 meters. Grayish-green homogenous porphyritic rhyolites Dzun-Modo vary by size (1-2 to 4-6 mm) and quantity of quartz and potassic feldspar porphyritic inclusions. Microscope study describes rhyolite as light-grayish fine grained, nearly completely recrystallized massive rock. 2-3 mm size biotite, chlorite, sericite aggregates and inclusions are also present (Figs.4-10).

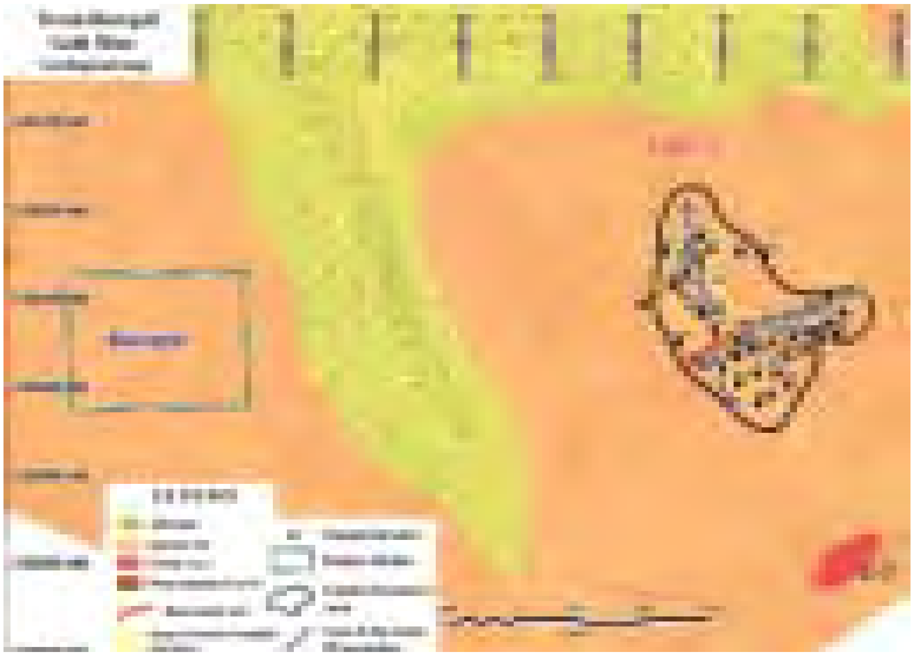

Fig.2 Geological map of Ereen-Baavgait area

During the logging the variety of textures and colours were observed and described. These varieties were generated by repeated stages of regional tectonic activity and associated processes of hydrothermal-metasomatic alteration (Fig.4). Hydrothermally altered, bleached volumetric blocks of rhyolites are spatially connected with intensive fractures and veinlets systems (Fig.5). The hydrothermal alteration is resulted in re-crystallization of fine grained matrix and release of silica during feldspar kaolinization and saussuritization. As a result, rhyolite acquires light colours that are typical for acid rocks.

Fig.3 Rhyolite – borehole ED-07, depth 230 m.

Ereen deposit area was affected by three tectonic and consecutively, three hydrothermal alteration cycles. The first, pre-ore stage quartz-albite-orthoclase stage is likely to be post-magmatic. It is presented by fractured zones with minor thickness (0,5-3.0 mm) quartz-feldspar veinlets that can be single or grouped into 20-40m zones. The pre-ore hydrothermal alteration of rhyolites is represented by 15-40% of drill core. A pre-ore age of the first stage hydrothermal rocks is proved by the practically complete absence of arsenopyrite and a poor pyritic impregnation. In addition, it is also proved by analytical data. Gold grades does not exceed 0,01-0,05 g/t.

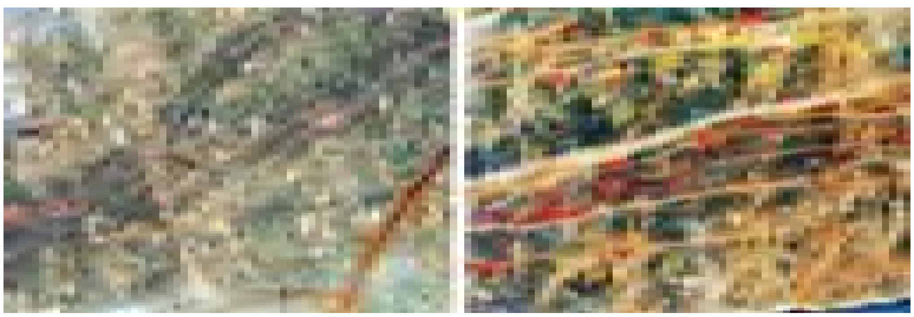

Fig.4 Multi-age vein systems in rhyolites

The second stage of hydrothermal-metasomatic alteration is associated with next cycle of tectonic magmatic activity. Fractured, crushed and brecciated structures were developed independently but in some cases can follow earlier tectonic directions (Figs.4-9). A quartz-carbonate-sericite hydrothermal alteration is connected with later stage and was accompanied by intensive sulphidization represented by pyrite, arsenopyrite and infrequent pyrrhotine. Carbonates are presented by siderite, ankerite and calcite. The veins are chaotically distributed, but someties are oriented along certain directions and generate 3-5 m thick zones.

Quartz-carbonate-sulphide breccias are widely developed. The veinlets are mainly sulphide with arsenopyrite domination over pyrite (Fig.7a). Quartz is mainly occurs in veinlets but is also frequently recorded as quartz crystals in interstice cavities (Fig.7b). Second tectonic stage was followed by intensive release of hydrothermal fluids. Assumingly, tectonic stress of the second stage had not only strike-slip but also hydrostatic nature and was resulted in intensive micro-fracturing and increased permeability of rhyolites. This explains considerable increase of pyrite and arsenopyrite contents in rhyolite matrix between veinlets and generation of sulphide impregnations that are associated with chlorite, carbonate and rarely-with quartz. Hydrothermal ores, typical for this stage are less developed in comparison with pre-ore alteration. They form the zones from 10-50 cm up to 2-5 and even up to 10 m. Insignificant, poor zones often cluster in the ore intervals up to 7-15 m. In a volumetric sense these rocks occupy 5-10 and even 15% in several drillholes. Gold grade in the carbonate and quartz-sulfide veining zones typically is 0.2-0,5 to 1-3 g/t. The third stage of hydrothermal-metasomatic transformations is directly connected with the second one and expressed by veining and partially volumetric rhyolite silification. Fig.8 shows a clear mutual intersection of sulfide (pyrite-arsenopyrite) and quartz veins which resulted in series of the different direction tectonic movements with consequence of

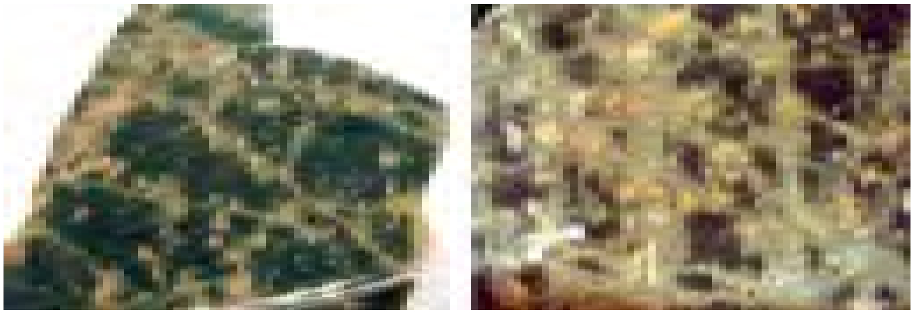

Fig.5 Successive increase of the veining and volumetric hydrothermal alteration in rhyolites

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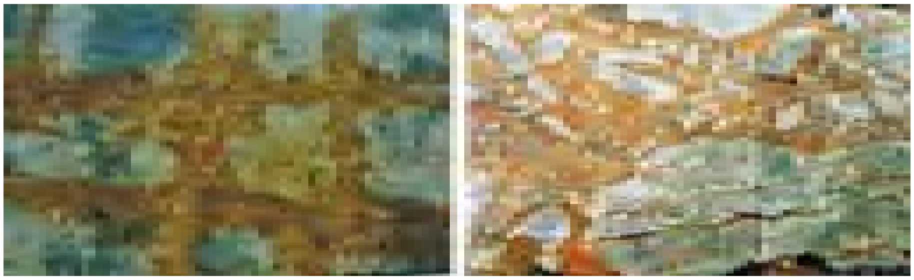

Fig.7 Examples of second alteration stage

Fig.8 Veinlets of sulphides (a) and quartz druse (b)

Fig.9 Quartz-sulphide alteration of third stage

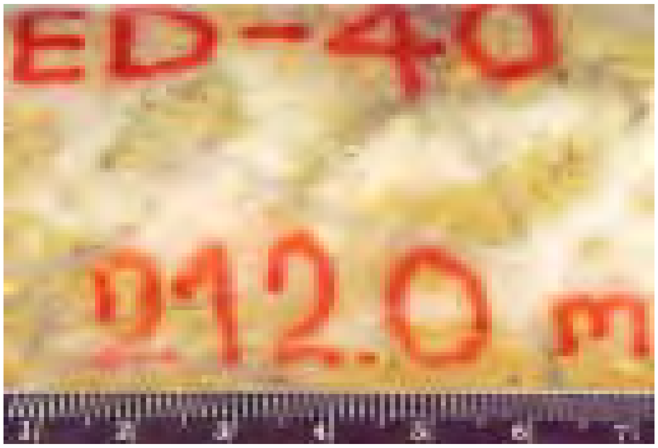

Fig.10 Ereen-Baavgait magnetic map

Fig.11 Mesothermal gold system of Zuun mod area

applied and released stress.

Quartz veins are barren of sulphides. Pyrite and arsenopyrite occur along veinlets margins and in their endo-contacts. Pyrite and arsenopyrite split out into bunches of the veins pinching out. Third stage alteration is easily distinguished from other types of alteration.

Average thickness of quartz veins vary from 0.5 to 2.0 cm but can reach 10 cm and more. Vein morphology types cover veinlets, lenses, boudines, irregular separation etc. Replacements of rhyolite by quartz are observed in the selvages. Chalcedonic quartz (as a low temperature indication) takes place in semi-transparent quartz and forms its own irregular shape bundles.Sericitization occurs on all stages of hydrothermal-metasomatic alteration of rocks, but particularly during the final stage. Sericite and hydromica occur along veins salvages, chlorite and biotite form isolated impregnations and pervasive distribution in rhyolites. Talks also are on next to sericite and chlorite in the quartz veins and along their selvages and can be considered as an indication of the process contrast variety.The recrystallization of rhyolite matrix, kaolinization of feldspars and the destruction of mafic minerals lead to the release of significant volume of silica and generation of secondary quartzites. Gold grades and its extend into secondary quartzites are still to be explored. Silicification associated with veins represents 3-7% of total rock volume. Gold grade of silicified veins is not less than 2-3g/t. in these intervals. Minor sulphide-quartz veins appear to be gold-bearing. Native gold was discovered in quartz breccia (DH ED-40B), which is considered as metasomatic quartz. Milky-white quartz replaces earlier quartz veins (Fig.9). The picture demonstrates how milky white quartz dissolves earlier quartz veins.

Thus, successful exploration of Ereen should be connected with special attention to areas of quartz veining that are also the areas of increased permeability. The study of these area is a subject for detailed geophysical survey and structural mapping.

Supergene alteration of pyrite and arsenopyrite: Depending on topography Ereen supergene zone is of 70-120 m thick. Pyrite and arsenopyrite are completely or partially oxidized and destroyed in deeper intervals of geologic section are also subjected to crushing, iron oxidation and destruction of sulphides and represent gold-bearing horizons. Supergene processes could stimulate a gold release but do not affect level of Ereen mineralization.

5. Ereen ore bodies structural setting

It is believed, that the extensional regime of the Sujigtei (Yarangol) fault, which was reconstructed in the Ereen-Gatsuurt section has direct impact on the structural environment of the Ereen-Baavgait mineralized area (Fig.10).

The Ereen southern mineralized zone is characterized by extensive quartz veining and a series of ore bodies with similar east-north-easterly striking and south-east dip direction. These orientation parameters inside the limits of the southern mineralized zone are consistent with the position in the western block (hanging-wall) of the major extensional Sujigtei (Yarangol) fault, which is characterized by generation of linear structural elements similar to the southern zone orientation, and of different scale resulting from down-throw movements of the Sujigtei (Yarangol) fault hanging wall. Multiple pre-mineralization tectonic movements along structural directions of the southern zone prepared and generated gold-bearing stock work and disseminated zones and finally quartz vein types of ore bodies that were both controlled by single structural planes. On the other hand, the Ereen northern mineralized zone is characterized by similar striking, but by different north-west dip directions of a much less extensive

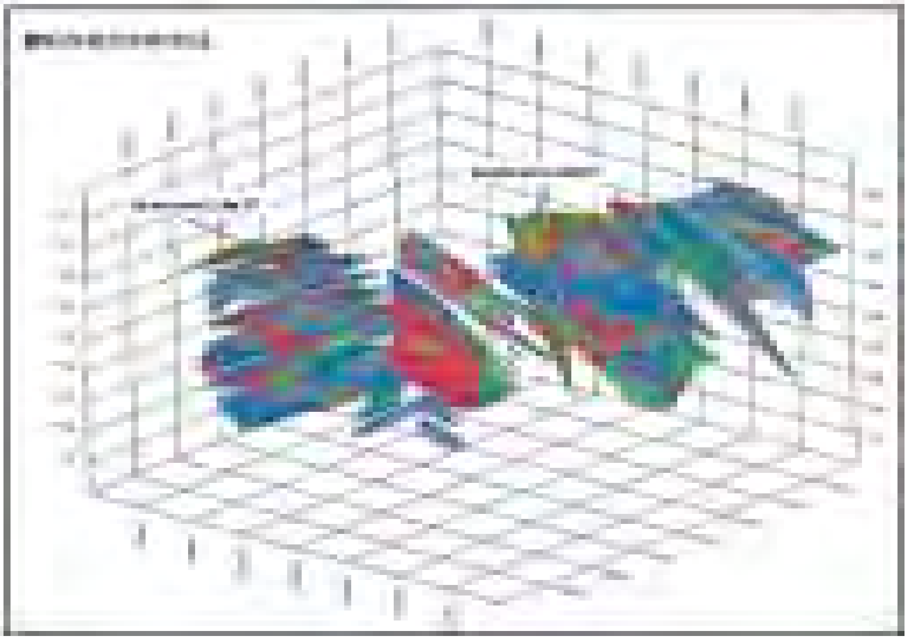

Fig.12 Ereen deposit block model

quartz vein, but intensely mineralized stock work-disseminated ore bodies (Fig.11).

The Northern zone is believed to represent another separate stage of tectonic movements along second order structural elements, within the Ereen license, but still under strong influence of Sujigtei (Yarangol) fault extension. Thus, though extensional linear elements have similar strike to the southern zone the dip directions change relative to the distance from the main fault (i.e. north-west). This may be intensified by the orientation of original jointing directions related to the emplacement of the rhyolite dome underlying most of the Ereen license.

6. Conclusion

The Ereen deposit lies within the North Khentei gold belt, which is bounded to the north-west by the Bayangol fault system and to the south-east by the Yeroogol (or Sujigtei) fault system. Both fault systems have a similar south-west-north-east trend (generally NE45°), faults of east-west, north-south and north-western direction; regional scale north-easterly trending Sujigtei fault controls position of the large-scale Gatsuurt gold deposit.

(1) The gold mineralization in Ereen deposit is confined spatially with hydrothermal alteration of rhyolites, microscope study describes rhyolite as light-grayish fine grained, nearly completely recrystallized massive rock. 2-3 mm size biotite, chlorite, sericite aggregates and inclusions are also present

(2) Ereen deposit area was affected by three tectonic and consecutively, three hydrothermal alteration cycles. The first, pre-ore stage quartz-albite-orthoclase stage is likely to be post-magmatic. The second stage of hydrothermal-metasomatic alteration is associated with next cycle of tectonic magmatic activity. The third stage of hydrothermal-metasomatic transformations is directly connected with the second one and expressed by veining and partially volumetric rhyolite silification.

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