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PETROGRAPHY OF MAIN ROCK UNITS AND PETROGRAPHIC ALTERATION OF THE HUGO NORTH DEPOSIT, OYU-TOLGOI, SOUTHERN MONGOLIA

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Introduction

The Hugo deposits extend NNE over a strike length of 2.6kms, and are divided into two ore-bodies, Hugo South and Hugo North. At the northern end, a N70E trending high-angle reverse fault may truncate the Hugo deposit, whilst at the southern end grade gradually diminishes. The Hugo deposits are classified as Cu-Au porphyry and high sulphidation-related styles. Mineralization is hosted by quartz monzodiorite (qmd) and adjacent host rocks. The mineralized sequence comprises basaltic volcanics overlain by 80 to 600m of dacitic ash flow. These volcanics in turn are overlain by the Lower sedimentary-volcanic sequence. The volcanic and sedimentary cover rocks have been folded into a NNE-trending monocline which has been intruded by several stages of qmd along the steeply-dipping easterly limb and with final intrusions along the monoclinal axis. The final intrusion is bell-shaped in cross section and may be an elongate body, about 0.6 x 2km in plan at a depth 1km below the surface. The western boundary of the monocline is cut by a steeply dipping fault referred to as the West BAT Fault, and the eastern limb is faulted by a similar trending fault, referred to as the East BAT Fault.

Since 2002 year we have worked in cooperation with Ivanhoe Mines company at Oyu-Tolgoi project and have performed several ordered works as petrography, mineragraphy and XRD from Oyu-Tolgoi Au-Cu porphyry deposit. During this period we have analyzed over 500 samples and selected photomicrographs to emphasize perhaps the most critical aspects of rock type, alteration mineralogy and mineralization. But from Hugo deposit were logged several drill holes and from these OTD 514I drill hole was logged and sampled in detail. From these samples were prepared polished thin sections, thin sections and polished sections for petrography (514I-section figure). First module of my study is petrography of main rock units, i.e., intrusives, volcanic wall rocks, etc. These samples have been studied using petrographic and mineragraphic methods, supplemented by confirmation of the principal mineralogy by X-ray diffraction methods. During this study (petrography, mineragraphy and XRD analyses) have tried to identify all rock types, mineral component and origin of advanced argillic alteration relating to the copper-gold mineralization of the deposit.

Petrography

Rock types of the north Hugo deposit (OTD 514I drill hole)

Shallow part (901m and 996.2 mm) of this drill hole is composed of quartz, dolomite veined intense altered basaltic flow breccia (breccia of basalt) altered andesite-dacite and sediment rocks as altered sandstone.

In depth from 996.8m-to1136 mm all rocks are relatively strongly advanced argically altered and consisted of altered dacitic ash flow tuff (ignimbrite) converting to kaolinite- alunite-topaz-muscovite-pyrophyllite-quartz altered rock with sulphides.Rocks, in depth 1137m-1193m are also intensively altered and represented as altered augite basalt (quartz veined muscovite-chlorite-illite altered rock with sulphides)

Rocks in depth 1193m-1304.6m are represented by altered early quartz monzodiorite (Eqmd) and composed of strongly altered and intensively mineralized quartz monzodiorite or otherwise intence quartz and sulfide veined muscovite-sericite altered rock by Eqmd.

Rocks in depth 1304.6m-1672 m are consisted of carbonate, quartz and sulphide veined muscovite-sericite altered rock, carbonatizated chlorite-quartz-muscovite- -sericite altered rock, quartz veined topaz-sericite- altered rock with sulphideds by gold rich quartz monzodiorite (Au Qmd). Have to note that this altered Au rich quartz monzodiorite is intensively cut by veinlets of altered granodiorite with thickness from 2.0m to 65 m.Basaltic breccia is dark green and comprises of fine-grained basaltic clasts (0.1-2.0mm) usually in contact. Often it is cut by thin veins of carbonate and quartz.

Andesite-dacite is grey green and composes of phenocrysts (20-25%) of plagioclase and muscovite in ground mass of plagioclase microlits and quartz forming microlitic and poikilitic texture.

Altered fine-grained arcose sandstone is greenish grey and constitutes of weakly oriented quartz, plagioclase clasts (with few clasts of rocks as microdiorite and miroquartzite) in chlorite-sericite matrix.

Biotite granodiorite post intrusions at Hugo-Dummett range from meters to over 600 m wide. It is pinkish-grey colour and consists of plagioclase phenocrystals in fine-grained ground mass of plagioclase and altered biotite and hornblende.

Altered dacite ash flow tuff composes of lithic fragments (plagioclase-phyric andesitic lava, jasperoid, high-intensity phyllic altered rocks, and possible ?pumiceous lava) and crystal fragments (plagioclase, K-feldspar, quartz, ferromagnesians, apatite, biotite) in a fine matrix of sericite with clay minerals (pyrophyllite, kaolinite) and chlorite which forming after alteration.

They are altered to intense advanced argillic alteration and resulting from the alteration completely obliterated primary composition and texture of the rock. Usually under the microscope they consist of advanced alteration assemblage as quartz, kaolinite, pyrophyllite, topaz, diaspore, alunite, muscovite with sulfides.

Altered augite basalt composes of altered phenocrysts and altered ground mass in which almost no preserved its relic texture and mineral composition. Relic phenocrysts like accumulations are filled with flakes of chlorite by biotite, quartz with sulfides and they have six and eight grained relic shapes. (Fig4) Reflecting on relic shape it could be presented by augite? The ground mass consists of very tiny aggregate of sericite (illite) and chlorite. Also there are some fine grained crystals of topaz. The rock is cut by veinlets of chlorite, quartz and carbonate with width 0.1-2.0mm. Often augite basalt is intense altered to an assemblage of quartz, muscovite ±chlorite (with relic biotite) and also advanced argillic assemblage as muscovite, pyrophyllite, topaz and kaolinite.

Quartz monzodiorite rocks display a range of rock types including quartz monzodiorite and quartz monzodiorite porphyry. Generally there are three different quartz monzodiorite in Oyu-Tolgoi: Early Qmd, Au rich Qmd and Late Qmd. There are Early Qmd and Au rich Qmd in our section (OTD514I). The earliest Qmd dykes are small (meters-to10 meterswide) and discontinuous in drill sections, highly altered and strongly Cu-Au mineralized and occur in the core of mineralization. Due to intense alteration and quartz veining, obscured primary mineral composition and texture. Usually under the microscope it composes of quartz, muscovite, sericite with sulfides and microscopically we have named it as quartz and sulfide veined muscovite-sericite altered rock by Qmd. Often it includes some chlorite, topaz and veined by late carbonate.

Gold rich quartz monzodiorite is represented by altered quartz monzodiorite porphyry and quartz, carbonate and sulphide veined, altered fine and medium grained leucocratic quartz monzodiorite. The altered quartz monzodiorite porphyry is phenocryst-crowded and composes of 40-60 % phenocrysts (0.4-3.0mm) of altered plagioclase and ground mass with relic hypidiomorphic and aplitic texture.

The altered fine and medium grained quartz monzodiorite composes of altered plagioclase, quartz, kfeldspar, muscovite forming hypidiomorphic texture. Quartz monzodiorite is suffered to alteration and resulting from this alteration the rock-forming minerals shifted to sericite, carbonate, albite, muscovite and hematite. Due to fine-dispersed hematite the rock has acquired reddish brown colour.

Also they veined by later veins of carbonate, quartz and Cu-Au mineralized. Kfeldspar is confirmed by XRD analyses.

Petrographic alteration

Second module of the study is to help characterize early K-silicate alteration and the advanced argillic alteration utilizing principally polished thin sections and XRD analyses. Supporting on this study to clarify origin of the advanced argillic alteration (AA) due to vapor condensate above the porphyry system and telescoping back over the porphyry system, or due to ascending low salinity porphyry fluids that cool to generate an acidic fluid, capable of forming advanced argillic alteration, or perhaps a combination of both. Alteration studies focused on defining alteration assemblage and their paragenesis. The alteration depends on rock type and has multiple overprinting stages which are difficult to distinguish and identify with almost no remnant of original host rock.

K-silicate alteration

By detailed investigation of quartz monzodiorite under the microscope couldn't reveal obvious second kfeldspar even though some specimen (514I-1498.7, 514I-1529, 514I-1539 and 514! -1672) contain >5-10% kfeldspar. Presence of kfeldspar is also confirmed by XRD analysis. In quartz monzodiorite plagioclase intensively altered to sericite and often sericite surrounds by thin rims of albitizated kfeldspar. Sometimes albitizated kfeldspar developed as spots and thin veins in sericitizated plagioclase.. From this texture can consider that plagioclase may have been replaced by kfeldspar and kfeldspar overprinted by albite alteration. It will not be denied that kfeldspar entirely shifted to albite. Often this part (albitizated kfeldspar in sericitizated plagioclase) of the rock is slightly dusted with hematite and due to it the quartz monzodiorite has acquired brownish-pink colour.

Therefore k-silicate alteration is characterized by secondary biotite replacing original mafic minerals in augite-basalt and in early quartz monzodiorite. Biotite alteration is not abundant and muscovite (sericite) overprint usually turns the biotite into chlorite-muscovite-rutile or muscovite-rutile combinations. These combinations we can see either in quartz monzodiorite and in altered augite basalt. (Fig3) Usually in quartz monzodiorite mafic minerals are represented by muscovite with rutile and chlorite and it could be formed after biotite. Before biotite it could be represented as hornblende? or pyroxene? The muscovite-sericite alteration is closely associated with sulphide precipitation in quartz monzodiorite and overprinted by main stage of advanced argillic alteration. The porphyry late sulphides (mostly chalcopyrite, bornite and pyrite) appear to be earlier than the high sulphidation sulphides (mostly pyrite, enargite, chalcocite) This alteration type is best preserved in the basalt screen between the early porphyry dyke and quartz monzodiorite. Retention of this early alteration type in the basaltic volcanic rocks is attributed to their relatively low permeability compared with the dacitic ignimbrite and various quartz-veined intrusions.

The chalcopyrite mineralization was introducec as part of the potassic event, although perhaps during the onset of chloritisation (Sillitoe)

Whereas hydrothermal biotite occurrences were observed in augite basalt brown biotite replaced by chlorite, muscovite and illite. Sometimes in augite basalt phenocrysts of altered augite are entirely shifted to chlorite after biotite with quartz and sulphide. (Fig4)

Advanced argillic alteration

The advanced argillic alteration is particularly concentrated within the dacitic pyroclastic rocks and also confirmed that it overprints the sections of the augite basalt (Va) and quartz monzodiorite (Qmd)

Visually it occurs as zones of granular, pink-creamy, white creamy, yellowish and greenish alteration which has destroyed the original rock texture. By our observation the advanced argillic alteration zone has five different colour depending on its characteristic mineral composition and original rock. They are gradually transferred from one to another (from upper to deeper) First layer (upper part of dacite pyroclasts) is pink-creamy and white-creamy colour with pyrophyllite-kaolinite +-alunite, zunyite, disapore, topaz mineral composition. Next to this layer (upper of basalt zone) is yellowish and has muscovite-hematite-pyrophyllite-kaolinit e-topaz composition. Third layer (bottom of basalt and contact with Qmd) is green and composes of clinochlore-illite-hematite. Last two layers are (upper and bottom of Qmd) pale green and brown and mean constituent is muscovite-sericite. Otherwise muscovite has different (in upper has pale green and in lower part has brown color) colour for these zones. Advanced argillic alteration is commonly associated with hard white patches (topaz) and vague veins of quartz. Paragenetic relationship within advanced argillic systems is always extremely difficult to establish, due to their fine grain size and similar range of colours under the microscopy and visually. Generally major products such as alunite, pyrophyllite, illite, etc. are commonly indistinguishable. Detailed mineralogical study of the advanced argillic assemblage is performed utilizing X-ray diffractometer (XRD analysis). This provides qualitative mineralogical data for minerals such as alunite, pyrophyllite, muscovite, diaspore, topaz, illite, zynuite, crandallite and kaolinite.

Fig1. Muscovite replaced by

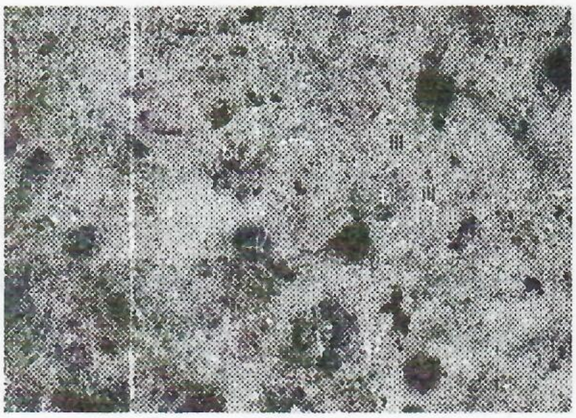

Fig 2. Biotite overprinted by illite

Fig3. Chlorite-muscovite- pyrophyllite

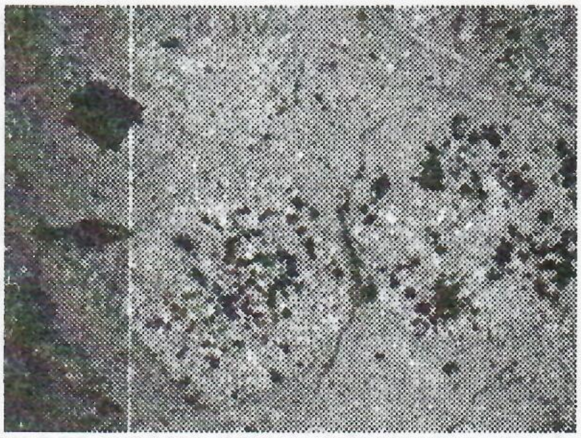

Fig 4. Altered phenocrysts of

This mineralogical composition is also confirmed by petrography and under the microscopy has identified paragenetic sequence of AA minerals as following (from early to later): muscovite-pyrophyllite-alunite, diaspore, zunyite-kaolinite-topaz-dickite. In the all rock types (dacitic pyroclastic rocks, basalt and quartz monzodiorite) muscovite flakes are strongly overprinted by pyrophyllite aggregate. (Fig1) This relationship between muscovite and pyrophyllite suggests that advanced argillic alteration formed due to ascending low salinity porphyry fluids that cool and generated an acidic fluid. So our conclusion is that early biotite alteration of host rock is converted to chlorite and muscovite and finally to pyrophyllite, where there is strong overprinting advanced argillic alteration.

Subsequent to the k-silicate alteration muscovite-stable fluid that cools during ascent became pyrophyllite stable, and other advanced argillic minerals may form as well, such as diaspore and zunyite. Such upward transitions are common in porphyry deposits (e.g.,Butte, Resolution, El Salvador, Far Southeast) By our investigation we consider that this upward transition also developed in Hugo Dummet deposit.

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ЭХ ОРНЫ ЭРДСИЙН ТҮҮХИЙ ЭДЭД ИНДУКЦИЙН ХОЛБООТОЙ ПЛАЗМЫН СПЕКТРОМЕТРИЙН АРГААР ГАЗРЫН ХОВОР ЭЛЕМЕНТИЙН НЭГ БҮРЧЛЭН ТОДОРХОЙЛСОН ДҮНГЭЭС

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Индукцийн холбоотой плазмын спектрометрийн арга (ICP-AES) нь гэрлийн үүсгэврээр индукцийн холбоотой плазмыг ашигласан нэгэн төрлийн эмиссийн спектрийн шинжилгээний арга юм [1]. Саад бологч элементийг урьдчилан салгалгүйгээр геологийн дээжинд газрын ховор элементийг (ГХЭ)-ийг нэг бүрчилэн зөвхөн индукцийн холбоотой плазмын масс-спектрометрийн