

# New orogenic type gold occurrences in the Uyanga ore knot (Central Mongolia)

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**Abstract.** The Khangay-Khentey belt is located in central Mongolia (Central Asian Orogenic Belt). The Uyanga ore knot district of the Khangay metallogenic zone are hosted by the lower-middle Devonian volcanogenic-sedimentary *Erdenetsogt* formation. The new Burgetei, Ult and Senjit gold occurrences were studied. The rocks of the *Erdenetsogt* formation have an irregular gold content: 0.96 g/t Au is determined in quartz vein (BG-7/16), Au content is highest up to 3.5 g/t in the quartzite-jasper (Ult-7/16 and Ult-9/16) cut by quartz veins in the Ult occurrence. The Senjit occurrence represents Au-Hg-Sb epizonal level of orogenic gold deposits structure with highest Hg- and Sb content up to 8.5 ppm and 39 ppm respectively. The Au content of arsenic pyrite of the Burgetei and Ult is below the detection limit by electron microprobe analysis. The Au content of arsenopyrite of the Ult occurrence is highest (up to 238 ppm). The ore-mineral assemblages in the new gold occurrences reflect the differences between three explored sites, formed in the course of fluid evolution during the water-rock interaction. Variable concentrations of indicative elements (As, Te, Sb, Hg) and their ratios confirm this fact.

## 1 Page layout

The classical theory implies that orogenic Au deposits are formed during the late stage of orogeny and are typically hosted by the rocks of greenschist to amphibolite metamorphic grade that may be spatially related to granitoid intrusions [1-3]. Arsenopyrite and pyrite represent the most abundant sulphide minerals that occur in association with the Au mineralization, which formed from low salinity, CO<sub>2</sub>-bearing, reduced and near-neutral pH fluids that show a wide range in fluid temperatures from about 200 to 500°C.

The vast territory of Mongolia occupies a large part of the Central Asian Orogenic Belt (CAOB). The Khangay-Khentey belt is located in central Mongolia [4]. The primary ore occurrences of the Uyanga gold ore knot district of the Khangay gold zone are hosted in volcanogenic-sedimentary rocks of the lower-middle Devonian *Erdenetsogt* formation. The volcanogenic rocks are metamorphosed under greenschist facies. The Uyanga group of

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primary gold occurrences are associated with the gold quartz-sulfide mineralization in the hydrothermal metasomatism of shear zones [5]. In this paper, new information concerning the Burgetei, Ult, and Senjit gold occurrences of the Uyanga gold ore knot is presented. An assumption is made about their belonging to the orogenic type deposits.

## 2 Methods

This work used the field data sampled from the exploration trenches in the Burgetei, Ult and Senjit gold occurrences of the Uyanga ore knot district in 2016. About 40 rock samples were collected from the host rocks, veins and quartz veins. Minerals were separated into heavy and light fractions for mineralogical analysis. Microprobe analysis was carried out by electron scan microscope with Energy Dispersive X-ray Spectroscopy method (SEM-EDX) at the laboratory of substance analysis of the School of Geology and Mining Engineering, Mongolian University of Science and Technology. Samples were analyzed by electron scan microscope LEO 01430VP, by electron probe microanalyzer Camebax-Micro, JEOL JXA-8100 and atom-absorption methods at the Sobolev Institute of Geology and Mineralogy, SB RAS (Novosibirsk). Gold was determined by electron-probe microanalyzer JEOL JXA-8100 at 20kV and 200 nA with the extended diameter of up to 10-15  $\mu\text{m}$  electron beam. Gold analysis were carried out by atomic absorption spectrometer (AAS) with 55 AA Agilent instrument in the SGS-IMME Co Ltd., Mongolia, rare element analysis was carried out by ICP OES method with Optima 7300DV Perkin Elmer-pair inductive plasma spectrometer. Sulfur isotope analyses were carried out at the Analytical Centre for multielement and isotope analyses (Novosibirsk).

## 3 Results

### 3.1 Occurrences type and ore mineralization

Gold occurrence Burgetei (46°34'30.00"N /102°15'5.00"E) is located in the valley of Burgetei and Ovor Burgetei slope junction, at the top of 2300 m watershed hill on the center of the NE-NW arched anticlinal fold of the volcanogenic-terrigenous Erdenetsogt formation. Host sediments, basalt, microdiorite dyke (composed of plagioclase 65%, amphibole 25% and quartz 10%) near the gold-bearing quartz veins of the Burgetei occurrence are all changed by the hydrothermal-metasomatic alteration. The sericitized quartz metasomatites with pyrite (BG-4/16, Au 0.02 ppm) are spread like veins and lens. Pyrite cube crystal aggregates of larger size are spread along the veins and fractures. These crystals are sampled for the microprobe study. The SEM-EDS analysis identified ore minerals such as pyrite, antimonite, gold, barite and nickel arsenide.

Gold mineralization of the Ult occurrence (46°34'55" /102°17'20") is represented by the argillic altered dark siltstone observed in the fractured iron hat (gossan) formed from the sulfide oxidation on the exploration trench at the 2300 m altitude. It might be interpreted as a pipe to the deep. Small size quartz-sulfide veins are observed also in the jasper-quartzite-basalt formation. Predominantly sericite, chlorite, carbonates, pyrite and arsenopyrite were observed; rarely monazite and ilmenite were formed.

Gold occurrence Senjit (46°33'50"/102°18'20") is represented by the clayey schist, brecciation, and argillic alteration that are intensely developed along the NE directed transform fault inside the fine grain, green grey sandstone-siliceous siltstone layers of the *Erdenetsogt* formation. These conditions suggest their formation in a shallow ocean environment and at a certain Au-Hg-Sb epizonal level [6].

### 3.2 Geochemical study

The volcanogenic-terrigenous layers of the Uyanga group occurrences altered by metamorphic and metasomatic processes contain visible content of Au. For instance, 0.96 g/t Au is determined in quartz vein taken from trench of the Burgetei occurrence (BG-7/16). Au content is highest up to 3.42 g/t in the quartzite-jasper (Ult-7/16) cut by quartz veins in the Ult occurrence, and 0.05-0.12 g/t Au content is defined at the Senjit occurrence. Relatively high content of As, Sb, Hg, S, Sc, Cr, Ni, Co, V, Mn, Mg, Fe that are accumulated in association with the gold mineralization in comparison with the Clarke content of the metamorphic and magmatic rocks were defined in the volcanogenic-terrigenous layers of the *Erdenetsogt formation*. The high content of As is in the Burgetei occurrence (532 ppm in BG-2/16) and Sb (20 ppm in BG-7/16 and 8/16) simultaneously with Co, Ni and Fe (50 ppm, 152 ppm and 10% respectively) and W (BG-1/16). The Burgetei could be attributed to the Au-As±Sb mesozonal type. The highest contents of Mn, As and Au are characteristic of the Ult tectonic structures with intensive metasomatic transformations, namely siltstone with sericitization, beresitization and limonitization. Because the increased content of mercury (up to 86 ppb) was determined in the two samples (Ult-6/16, Ult-7/16), the type of this ore occurrence could be attributed to the Au-As±Hg one. The Senjit occurrence represents Au-Hg-Sb epizonal level of orogenic gold deposits structure with highest Hg content up to 8.5 ppm (Sn-5/16, aleurolite with argillization). Sulfide minerals were not found during 2016-sampling year.

Pyrite and arsenopyrite dominate in sulfide minerals composition of the Uyanga gold primary occurrence. Pyrite is stable under various physicochemical conditions and its refractory behavior to post-depositional metamorphism and its near-ubiquity makes it suitable for micro-analytical studies to reconstruct ore-forming processes through space and time [3]. Chemical composition of pyrites of the Burgetei and Ult ore occurrences is shown in Table 1. Chemical composition of arsenopyrites of the Ult occurrence is shown in Table 2.

**Table 1.** Pyrite chemical composition of the Burgetei and Ult occurrences.

Element / Occurrence		Fe, wt. %	S, wt. %	Ni, ppm	As, wt. %	Sb, ppm	Se, ppm	Te, ppm	Bi, ppm	Cu, ppm
Burgetei (n=60)	Min	43.76	51.4	n.d.	n.d.	n.d.	n.d.	45	n.d.	n.d.
	Max	46.91	53.01	5735	1.29	357	348	589	1171	297
	Mean	46.39	52.67	445.2	0.44	81.61	81.6	325	166	53
Ult (n=30)	Min	45.61	51.19	n.d.	0.15	n.d.	n.d.	59	n.d.	n.d.
	Max	46.69	52.85	1207	2.34	130	409	597	1212	292
	Mean	46.43	52.40	114.7	0.66	6.27	78.4	343	312	96.2

**Table 2.** Arsenopyrite chemical composition of the Ult occurrence.

Element / Occurrence		Fe, wt. %	S, wt. %	As, wt. %	Ni, ppm	Se, ppm	Te, ppm	Bi, ppm	Sb, ppm	Au, ppm
Detection limit, ppm		129	45	163	82	110	85	393	39	78
Ult (n=13)	Min	33.65	18.98	45.41	n.d.	n.d.	264	268	n.d.	n.d.
	Max	34.13	19.86	47.10	3043	513	1124	3146	293	238
	Mean	33.85	19.54	45.97	293.9	216	661.5	1911	59.54	108

As shown in Table 1, the S content in pyrites varies from 51.4 to 53.0 wt.%, with a mean of 52.67 wt.% (Burgetei) and from 51.19 to 52.85 wt.%, with a mean of 52.40 wt.% (Ult). The S contents of the samples are lower than the theoretical values (53.45 wt%). From all the analyzed trace-elements the highest As impurity (2.34 wt.%) was observed in the tabular pyrites of the Ult occurrence (as in its host rocks). The mean As content is in the Burgetei occurrence (up to 1.29 wt.%) simultaneously with highest Ni (5735 ppm) and Sb (377 ppm) contents. It is noteworthy that the admixture of arsenic in pyrites from quartz veins is higher than in pyrites from host hydrothermally altered rocks. The concentration of gold in the studied pyrites is below the detection limit (78 ppm). Arsenic pyrite is of great environmental interest because its oxidative dissolution can release significant amounts of As and trace metals into the environment. The average gold content in re-crystallized, coarse-prismatic arsenopyrite is 108 ppm with a maximum of 238 ppm. Tellurium content reaches of 0.11 wt.%. The high concentration of Bi (up to 0.3 wt.%) and Se (up to 0.05 wt.%) is characteristic of the Ult arsenopyrite, but silver is detected only in two samples (103 and 97 ppm). We have analyzed the concentrations of Te and Se vs. As in some interesting pyrites and arsenopyrites of the studied occurrences. Significant amount of pyrites contains Te in the range of 45 - 600 ppm much more tellurium is found in arsenopyrite, the range is 0.03-1.1 wt.%. Tellurium concentrations above the Reich solubility line indicate telluride inclusions in pyrite, e.g. at 10,000 ppm of As, Te should be low than 200 ppm. Selenium most likely occurs in the pyrite solid solutions due to the isovalent S substitution [3]. No systematic correlation exists between As and Se in pyrite; a weak negative correlation is observed between As and Te-Se in arsenopyrites.

## 4 Discussion

Sulfide minerals are important indicators of hydrothermal mineralization, and the stable isotopes of sulfur offer a useful tool to constrain the origin of sulfides. Different forms of sulfur-bearing materials such as basic sills, primary igneous rocks and volcanic gases show distinctly narrower ranges of  $^{34}\text{S}$  values, which tend to be disposed symmetrically about zero [7]. The isotopic content analysis of sulfur in pyrites from Ult-5/16 sample (siltstone with pyrite) and Ult-9/16 sample (quartzite-jasper, Au content is 3.5 g/t) shows the mantle origin of Uyanga mineralization:  $\delta^{34}\text{S}$  is -6.94 ‰ and -0.91 ‰ respectively. Assume that the changes in pH or temperature are minimal, all changes in sulfur isotope and trace element concentrations can be attributed to changes in oxygen fugacity. The increasing in  $\delta^{34}\text{S}$  is most likely due to a reduction in oxygen fugacity.

The chemical composition of pyrites in the Uyanga group occurrences includes a considerable amount of arsenic admixture. We could distinguish between two varieties of pyrites: with a lower As content in the altered host rocks of the *Erdenetsogt formation* and with a higher one in the ore-bearing quartz veins. The volcanogenic-terrigenic layers altered by metamorphic and metasomatic processes contain Au: up to 0.96 g/t Au in quartz vein of the Burgetei occurrence, 3.5 g/t in the quartzite-jasper of the Ult and 0.12 g/t in the Senjit occurrence (aleurolites). The main accompanying elements in these three cases are: Sb, Fe, Co, Ca; Mn, Hg, Zr and Sb,Hg respectively. The varying content of this ore elements indicates the different erosion level of ore formation: Au-As±Sb Burgetei-, Au-As±Hg Ult- and Au-Hg±Sb Senjit occurrences. It is interesting that The contents of Cu, Pb, Zn and Sn are lower than average content of earth crust. This is the distinct geochemical characteristic of the orogenic gold type deposit [8].

## 5 Conclusions

The primary ore occurrences of the Uyanga gold ore knot district of the Khangay gold zone are hosted in volcanogenic-sedimentary rocks of the lower-middle Devonian *Erdenetsogt* formation. New information on the Burgetei, Ult, and Senjit gold occurrences of the Uyanga gold ore knot is presented.

The ore mineralization of these occurrences is accumulated mainly in zones of tectonic breccia and quartz veins, pyrite and arsenopyrite are the most abundant sulfides in comparison with chalcopyrite, antimonite, galena and sphalerite. Intensively oxidized and non-oxidized pyrites of different stages were distinguished confirming the variation in oxidation conditions.

The content of metalloids (As, Sb, Te) and transition metals (Hg and iron group elements Mn, Co, Ni) increases in the ore minerals of the Uyanga gold occurrences in comparison with the host rocks. Highest gold content was determined (up to 3.5 g/t) in the quartzite-jasper with limonitization of the Ult occurrence cut by numerous small quartz veins and in arsenopyrites of this occurrence (238 ppm). New orogenic gold occurrences can form over a variety of depths and could be referred to the Au-As±Sb Burgetei-, Au-As±Hg Ult- and Au-Hg±Sb Senjit types.

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