БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ • BULGARIAN ACADEMY OF SCIENCES
GEOCHEMISTRY, MINERALOGY AND PETROLOGY • 43 • SOFIA • 2005

Au-Ag-Te-Se deposits
IGCP Project 486, 2005 Field Workshop, Kiten, Bulgaria, 14-19 September 2005

Mineralogical features and ore-forming conditions of gold-bearing deposits of Uzbekistan

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Abstract The territory of Uzbekistan is a world-class gold-bearing province in Central Asia. Hundreds of large and small deposits of Hercynian age, including the giant Muruntau deposit, are located within Ordovician-Silurian sedimentary-terrigenous, Mid-Carboniferous intrusive, and Late Carboniferous-Permian volcanic rocks. The gold ores are either hydrothermal or polygenetic; the latter relate to metamorphic, magmatic and hydrothermal processes. The mineralogical composition of these deposits has been studied with the use of electron microprobe analyses; fluid inclusion studies were carried out to determine ore-forming conditions. Auriferous ores belong to the following types: gold-scheelite-quartz (Muruntau), gold-quartz (Karakutan), gold-sulphide- arsenical (Kokpatas, Daugyz) in metamorphosed sedimentary-terrigenous rocks; gold-telluride-quartz (Kochbulak, Kayragach), gold-silver-quartz (Revashte, Pirmirab) in volcanogenic rocks or intrusive rocks (Kyzylalma). Gold is both visible (up to some mm) and fine and invisible (<0.2 µm) in sulphides (pyrite and arsenopyrite).

Key words: Uzbekistan, Kochbulak, Kayragach, Daugyz, Muruntau, Kayragach, gold ore deposit

Introduction

The geological structure of Uzbekistan can be divided into two parts.

In the western part of the country, the Kyzylkum Desert with low mountains (Tamdytau, Bucantau etc.) is surrounded by mountain ranges (Nuratau and others).

Gold-bearing deposits such as Muruntau, Myutenbay, Vysokovoltnoe and Daugyz, are located in metamorphosed sedimentary-terrigenous and black shale series of Mid-Ordovician to Lower Silurian age or in sandstone-aleurolite and carbonate rocks of Mid-Carboniferous age (Kokpatas), with weak occurrence of magmatic activity represented by dike swarms and small intrusions). Gold and gold-bearing deposits of Western Uzbekistan are mainly mesothermal and formed at medium depth.

The territory of Eastern Uzbekistan is characterized by the extensive presence of Hercynian volcano-plutonic complexes. Hydrothermal volcanic deposits in the Au-rich auriferous Kurama Mountains (Kochbulak, Kayragach and others) relate to andesite-dacite formations.

Mineralogical investigations of the Au-bearing deposits have been conducted by numerous investigators.

Gold-scheelite-quartz type

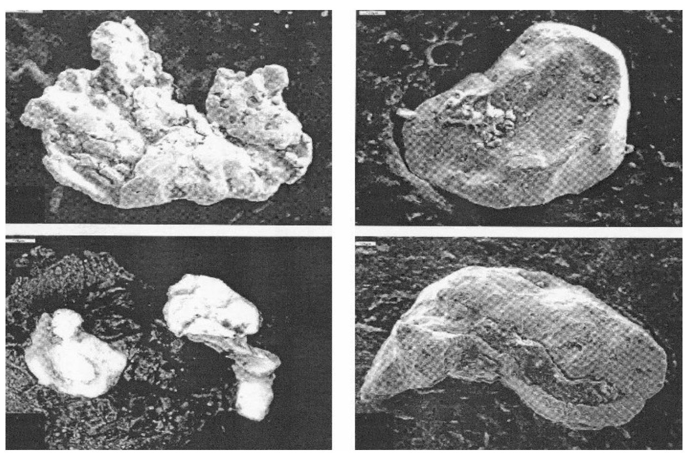
The giant Muruntau deposit is representative of this type. It is hosted by Carbonaceous aleurolites, sandstones, Late Ordovician-Lower

Silurian shales intruded by porphyritic diorite dikes and granite-porphyries of Late Carboniferous-Lower Permian age. The ores consist of sulphide disseminations and associated steeply-dipping quartz veins. The main mineral assemblages are: gold-scheelite-quartz (the main economic ore), gold-pyrite-arsenopyrite-quartz, and gold-polymetallic sulphide-quartz. The composition of native gold is typically 88-96% Au, 4-12% Ag (Fig. 1). A small part of the gold is present in pyrite and arsenopyrite in "invisible" form (Aripov et al., 2005). There exist a number of viewpoints concerning the genesis of the Muruntau deposit. These include sedimentary-metamorphogenic, hydrothermal-magmatic, polygenetic and other models. The age of the deposit, according to Rb-Sr geochronology, is 286-219 Ma (i.e., Permian-Lower Triassic). The economic mineralization was formed between 274-255 Ma (Lower Permian).

The ores are accompanied by alteration of the host rock, with quartz-chlorite-K feldspar assemblages prevailing. About 150 minerals are known from the deposit. Among these, quartz, gold and scheelite are the main minerals; pyrite and arsenopyrite are minor and sphalerite, tellurides, arsenides and others are rare.

Information received by the authors about the composition and character of fluid inclusions in a granitic intrusive rock (at a depth of 4,167 m) and the alteration of a granite dike, point to the importance of pneumatolytic and hydrothermal processes at deep levels. The gas phase in fluid inclusions from granites and auriferous quartz veins have similar composition and consists of CO_2 (90%), CO and CH_4. Moreover, the gas phase from the granite also contains N_2. The homogenization temperature of secondary inclusions from granitic quartz are in the range 320-340°C; primary inclusions in vein quartz give 280-300°C. This indicates that both metamorphogenic and pneumatolytic-hydrothermal processes took place during formation of the Muruntau deposit formation, and that the deposit can be considered to be polygenetic (Dunin-Barkovskaya et al., 1996).

Fig. 1. Gold grains from the Muruntau deposit



Au %	Ag %
80.07	19.03
85.25	14.75

Au %	Ag %
83.7	16.3
86.4	13.6

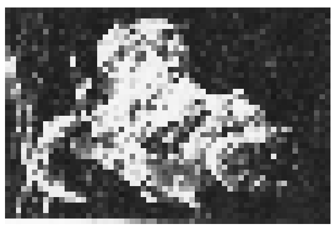
Gold-sulphide-arsenical type

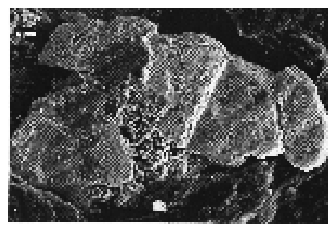
These deposits are positioned within sedimentary-terrigenous rocks. Representative examples include the Kokpatas and Daugyz deposits, in which the primary ores are refractory in character.

The Kokpatas deposit is hosted in within mid-Carboniferous sandstones, aleurolites, shales, tuff-aleurolites. Sulphide impregnated orebodies are layer- and lens-shaped and have gentle, or more seldom, steep dips. Sulphides (arsenopyrite, pyrite) account for up to 10% of the ore. Gold is finely dispersed with grain size up to 0.2 µm (Fig. 2); part of gold is 'invisible'. The maximum concentration of invisible gold in pyrite and arsenopyrite reaches 0.11 and 1.3%, respectively. Three mineral assemblages have been distinguished: gold-pyrite-arsenopyrite (the main economic assemblage), quartz-ankerite-gold-fahlore, quartz-silver-stibnite. In the first association, gold is present in pyrite and arsenopyrite and is either very fine (0.2-5 µm) or 'invisible' (<0.2 µm). In the second association, gold with size up to tens of µm is associated with tetrahedrite. Primary ores are difficult to concentrate. An oxidized zone is widely developed. Gold is native (83-91% Au, 9-17% Ag) and is associated with Fe-hydroxides.

The Daugyz deposit is situated in weakly metamorphosed carbonaceous sedimentary-terrigenous rocks of Mid-Cambrian age and Mid-Ordovician-Lower Silurian metasandstones, aleurolites and shales). The disseminated sulphide ores are controlled by a series of shear zones. The main mineral associations are: chlorite-quartz, gold-arsenopyrite-pyrite (main ore), sphalerite-fahlore-antimony.

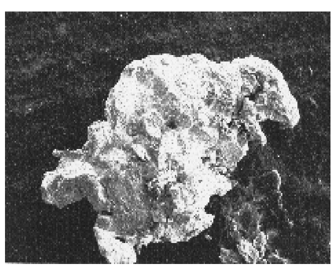
Fig. 2. Gold grains from the Kokpatas deposit

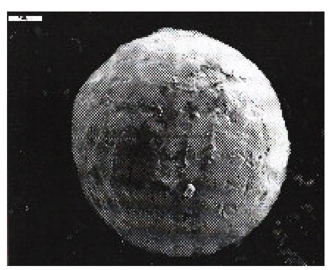




Au %	Ag %
89.52	10.48
87.28	12.72
89.23	10.77
91.28	11.31

Au %	Ag %
90.07	10.62
90.08	9.84
89.02	10.76





Au %	Ag %
54.68	45.32
61.95	38.56
69.45	34.55

Au %	Ag %
80.90	19.10
82.40	17.60

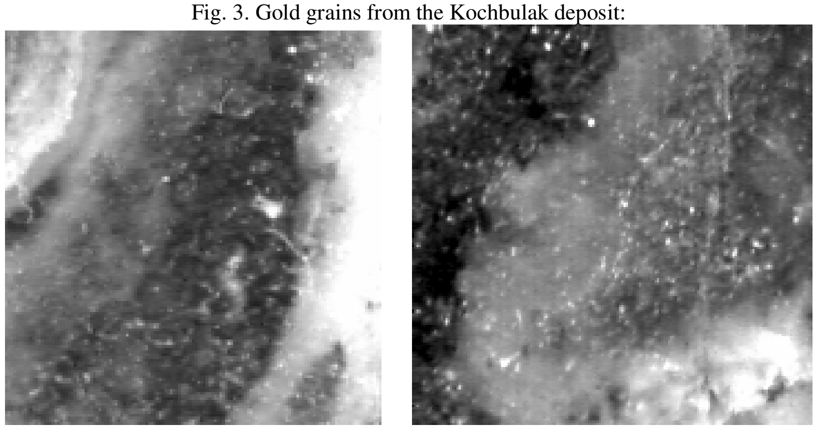
Pyrite, arsenopyrite, stibnite prevail; marcasite, sphalerite, tetrahedrite, chalcopyrite, gold and others are less widespread. In the primary ores, gold is associated with pyrite and arsenopyrite in the early assemblages (up to 90% of all gold in the deposit). The average Au content in pyrite impregnations is 37 g/t; in pyrite from veinlets, 90 g/t, and in arsenopyrite, 251 g/t. Microprobe analysis shows that gold is mainly present in an invisible form and it has been measured at local elevated concentrations of up to 910 g/t in pyrite and 890 g/t in arsenopyrite. Larger gold grains, up to 50 µm in size, are associated with minerals of sphalerite-fahlore association; these are rather rare. The temperature of deposit formation is within the range 180-300°C.

Gold-telluride-quartz type

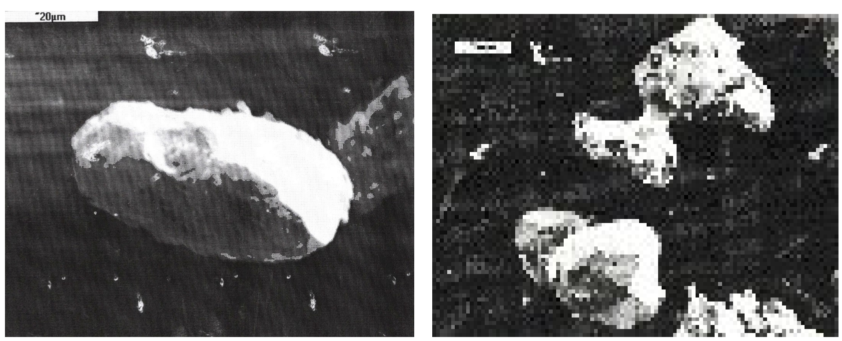
This type is represented by the Kochbulak, Kairagach and Samarchuk deposits.

The Kochbulak deposit is situated in Mid-Carboniferous porphyritic trachyandesite and dacite. The orebodies are either tubular and steeply dipping, or are mineralization zones within faults and shears along lithological boundaries. There is associated alteration of the alteration of the sericitic-quartz host rocks.

Fig. 3. Gold grains from the Kochbulak deposit:



a and b: quartz vein with gold; magnification 5x;



c. Crystal of native gold extracted from quartz by chemical dissolution. The photograph was taken using a Jeol microprobe; d. Rounded, dumbbell-shaped grain of native gold extracted from quartz by dissolution in HF. The photograph was taken using a Jeol microprobe

Detailed ore mineralogy has been reported by Kovalenker et al. (1997). Over 150 minerals are known from the deposit. Gold, Au-, Ag- and Bi-tellurides, fahlore and pyrite prevail. Minor minerals include Bi sulphides, sulphostannites and others. The main mineral associations are: quartz-gold-pyrite; quartz-gold-telluride-fahlore; quartz-polymetallic sulphides. In the first association, gold is finely dispersed and is present in pyrite. In the second association, gold forms two paragenesises: with fine-grained pyrite and inter-grown with Au-, Ag-, Bi- and Pb-tellurides and fahlore. Two morphological types of gold have been distinguished: spongy and as euhedral crystals. The spongy gold has been formed in the boundaries between pyrite grains and is typically no more than 7 µm in size. The gold crystals have size from 100 × 80 to 50 × 50 µm and contain impurities of Cu, Fe and Te (Table 1). This gold is associated with fahlore and calaverite. The crystallisation temperature of the quartz from the second association is estimated at 100-230°C.

Table 1. Composition of native gold in the Kochbulak deposit (wt.%)

Au	Ag	Cu	Fe	Te	Total
98.72	2.76		0.51	0.52	102.50
97.28	2.50	0.74	0.46	0.79	101.77
95.58	2.69	0.48	0.62	1.47	100.83
93.51	2.94	0.62		2.62	99.68
91.58	2.79	0.55	0.39	0.92	96.23
80.65	2.73	0.53	0.24	1.20	94.35

Gold-silver-quartz type

The Revashte, Kyzylalma and Pirmirab deposits are representative of this type. The Revashte deposit is situated among volcanic rocks of Upper Carboniferous-Permian age. Gold and silver occur in steeply dipping quartz veins which are accompanied by hydrothermal alteration of the host rocks. Two productive mineral associations are noted: quartz-gold-silver-acanthite and quartz-silver-polymetallic sulphides. The main ore minerals include electrum, native silver, kustelite, polybysite, stephanite and others.

Homogenisation temperatures of fluid inclusions from the ore-bearing quartz are mainly in the range 180-245°C; the gas phase accounts for 10-15 vol.%. Ore-bearing quartz from a vein in contact with a diabase porphyry dike is higher temperature (292-340°C) and gas phase contents of 20-25%. The rise of fluid temperature is probably related to the local influence of the dike.

Conclusions

The gold deposits of Uzbekistan are characterized by a great mineralogical diversity (Table 2). Gold forms at least 20 different minerals (native, compounds, alloys, tellurides, sulphotellurides and others). Among these, alloy compounds with silver prevail. Part of the gold is present as sub-microscopic inclusions and in ‘invisible’ form within the common sulphides (pyrite, arsenopyrite). In some cases, this refractory gold presents processing problems.

The main productive gold-bearing mineral assemblages are: gold-scheelite-quartz, gold-pyrite-quartz, gold-pyrite-arsenopyrite, gold-telluride-fahlore and gold-silver (electrum)-fahlore.

Formation temperatures of the deposits are in the range 100-400°C, mostly between 200-300°C.

Table 2. Gold minerals known from gold deposits in Uzbekistan

Mineral	Chemical formula	Gold-scheelite-quartz type	Gold-sulphide-arsenical type		Gold-telluride-sulphide-quartz type		Gold-silver-quartz type	
		Muruntau	Kokpatas	Daugys	Kochbulak	Kayragach	Kyzylalma	Pirmirab
Native metals and alloys								
Gold	Au	***	***	***	***	***	*	*
Electrum	(Au,Ag)	**	**	**	**	**	***	**
Kustelite	(Ag,Au)	*	*	*	*	*	**	***
Maldonite	Au_2Bi	Peschanoe deposit						
Yuanjiangite	AuSn				*			
Tellurides								
Calaverite	$AuTe_2$				**	**	*	
Krennerite	$AuTe_2$				**	**		
Montbrayite	$(Au,Sb)_2Te_3$				*	*		
Sylvanite	$(Au,Ag)_2Te_4$				**	**	**	
Kostovite	$CuAuTe_4$				*	*		
Petzite	Ag_3AuTe_2				***	***	**	
Sulphotellurides and sulphides								
Nagyagite	$AuPb(Sb,Bi) Te_{2-3}S_6$				*	*		
Uytenbogaardtite	Ag_3AuS_2				*	*		
Prevalence of minerals: main ***, minor **, rare *.								

Note: Many researchers have been involved in prepariation of this table: used: R.P. Badalova, M.I. Moiseeva, V.A. Kovalenker, G.M. Tchebotaryov, R.I. Koneeva, E.A. Dunin-Barkovskaya, etc.

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