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Dating and Fluid Geochemistry of the Sarkobu Gold Deposit in Altay, Xinjiang, China

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Abstract The dating of fluid inclusions of quartz yields an Ar-Ar isochrone age of 320.4±6 Ma. Three types of fluid inclusions have been identified with the homogenization temperature ranging from 157°C to 362°C. The homogenization temperature consists of two groups. The first group varies from 157°C to 166°C, and the second from 232°C to 362°C. Their chemical composition is dominated by Na^+–Ca^{2+}–Mg^{2+} and Cl^-. The relative concentration of ions is characteristic by $Na^+>Ca^{2+}>K^+>Mg^{2+}$ and $Cl^->SO_4^{2-}>F^-$. The δD and $\delta^{18}O$ values indicate that the ore-forming fluid originates from mixing of multi-source water. The Sarkobu gold deposit has experienced two mineralization stages: gold was enriched during the volcanic-exhalative-sedimentary process in the early stage, while the gold deposit was finally formed under compression-shearing during the orogenic period.

Key words: metallogenetic age, genesis, ore-forming fluid, Sarkobu gold deposit, Altay, Xinjiang

1 Introduction

The Sarkobu gold deposit is located in the Koktal gold and nonferrous ore belt on the south margin of the Altay orogenic belt, 9 km east of Altay, Xinjiang, where exploration and mining have been carried out since 1995. Accordingly, studies on its metallogenic age and fluid geochemistry can be conducive to the prospecting prognosis.

2 Geology and Geochemistry

2.1 Geological setting

The Keketal gold and nonferrous ore belt is located in the NW-SE-trending Late Paleozoic Kelang and Maizi inland rift basins on the Altay active continental margin in the Siberian plate. Basement strata include the Lower Paleozoic Kulumuti and Habahe groups consisting of terrigenous fragmental rocks, and the Proterozoic Fuyun and Kemuqi groups consisting of high-grade metamorphic rocks. Several deposits, such as the Mengku iron deposit, Keketal lead-zinc deposit, Tiemuerte lead-zinc deposit, Qiaxia copper deposit and Sarkobu gold deposit, have been found within the NW-trending Devonian volcanic-sedimentary basin (He et al., 1994, Wang et al., 2000).

The strata consist mainly of Devonian volcanic rocks and sedimentary rocks. The Sarkobu gold deposit is hosted in the Upper Kangbutiebao Formation of the Lower Devonian. Skarnoid, barite, manganous marble, silicalite and acidic pyroclastic rocks outcrop in the deposit.

The Sarkobu gold deposit is composed of 5 NW-trending orebodies characterized by branching and converging (Fig. 1). Gold occurs as native gold and minor electrum. The native gold occurs mainly as an individual free metal, secondly as intergrowths and occasionally inclusions. The ores are dominated by allotriomorphic-granular, veined, and idiomorphic-hypidiomorphic textures, and streaked, irregularly veined, schistose and massive structures.

The orebodies are hosted in meta-calcareous sandstone and phyllite. The wall-rock alteration mainly includes silicification, skarnoidization (assembly of amphibole, actinolite, andalusite, biotite and pyrope) and chloritization. The central part of the alteration zone is intensively silicified, grading into skarnoides and chlorites towards the outer sides. In the depth, the wall rocks become acid crystal tuff, and the two sides of the silicification zone are characterized by bioritization and garnitization. Pyritization is a common alteration in the deposit.

2.2 Geochemistry

The analyzed results of 7 ore samples indicate that skarnoid chlorite schist and actinolite garnetization skarn have high contents of Al_2O_3, CaO, Fe_2O_3 and FeO, and low contents of K_2O and Na_2O, and that the quartz veins are rich in Fe_2O_3+FeO and SiO_2, and depleted in K_2O and Na_2O (Ding et al., 2001).

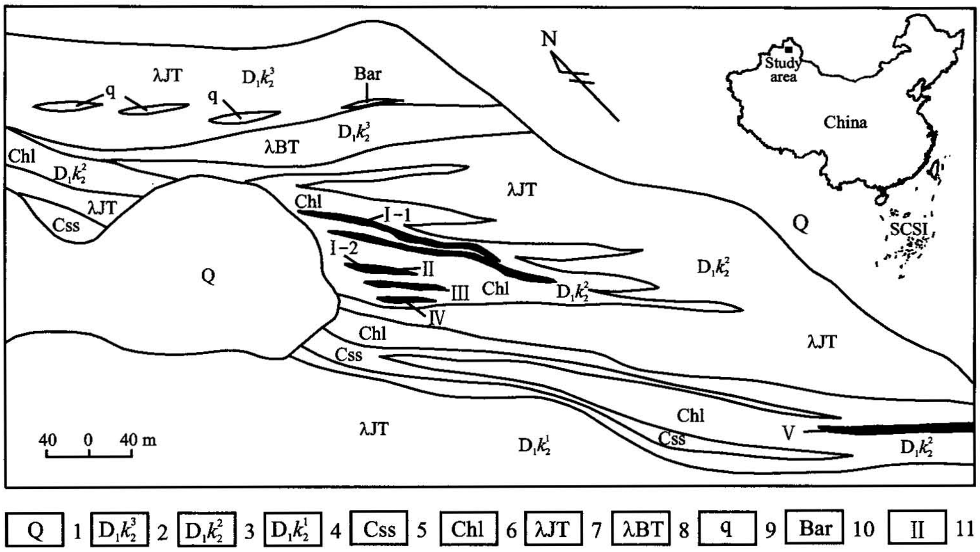

Fig. 1. Geological sketch map of the Sarkobu gold deposit, Xinjiang.
1. Quaternary; 2. upper part of the second member in the Lower Devonian; 3. middle part of the second member in the Lower Devonian; 4. lower part of the second member in the Lower Devonian; 5. calcareous sandstone; 6. chlorite schist; 7. acid lava; 8. volcanic breccia tuff; 9. quartz vein; 10. barite vein; 11. number of gold orebody.

The associated elements of the ores are Au, Ag, Cu, Pb, Zn, As, Cd, Bi, Mo, W, Bi and Mo. The contents of elements such as W, Bi and Mo in the ores are 80–100, 20 and 5 times of their Clarke values respectively. It suggests that gold mineralization is related to magamatism and volcanism.

The ores show a similar REE distribution pattern to that of the wall rocks, characterized by a LREE enrichment and Eu depletion.

3 Dating of Ores

Samples were collected from the auriferous biotite quartz veins. By using the ^{40}Ar-^{39}Ar quick neutron activation method, an isochrone age of 320.4±6 Ma and a plateau age of 320.4±5 Ma were obtained (Table 1, Fig. 2).

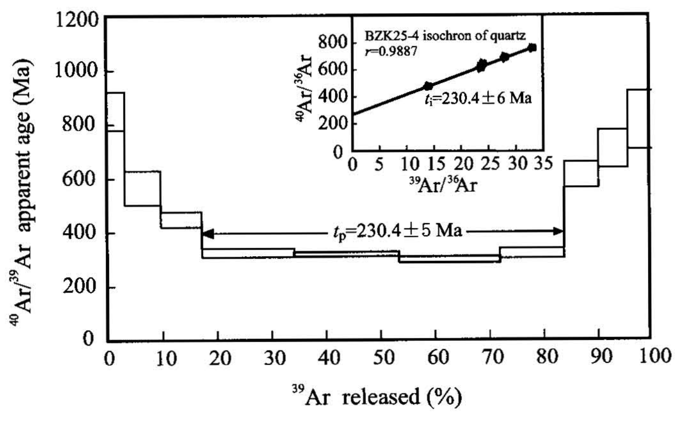

Fig. 2. ^{40}Ar-^{39}Ar isochron diagram of inclusions in quartz in the Sarkobu gold deposit.

The gold deposit is related not only to volcanic mineralization but also to secondary fractures. The metallogenic age of the gold deposit is similar to that of the Sarbulak (285 Ma, Li et al., 1998) and Sadu (294 Ma, Li et al., 1998) deposits in the Ertix metallogenetic belt and falls in the period of regional metamorphism. But its final mineralization is later than that of the Tiemuerte lead-zinc deposit (407 Ma, Li et al., 1998) related to volcanism (Ding et al., 1999).

4 Inclusion Geochemistry

4.1 Fluid inclusions

Inclusion samples were analyzed with the Leitz-1350 heating stage for homogenization temperature. The gas phase was measured with a gas chromatograph, and liquid measured with a liquid chromatograph (Table 2 and Fig. 3).

Three types of fluid inclusions have been identified. One is the aqueous inclusions that take the shape of an ellipse with diameters ranging 3–18 μm. The second one is the gas-aqueous inclusions with diameters of 5–20 μm and gas-liquid ratios 15%–30%. They usually occur as negative crystals and ellipses. The other type, in the form of an ellipse, consists of poly-phase inclusions containing carbon dioxide inclusions with diameters of 3–8 μm.

The homegenization temperature of all types of inclusions varies from 157°C to 362°C. It is divided into two groups: one is 157–166°C, the other 232–362°C. It may suggest that two kinds of fluids have been involved in the ore-forming process.

Table 1 Ar-Ar isotopic isochron of quartz in the Sarkobu gold deposit

Heating stage	Heating temprature (°C)	$(^{40}Ar/^{39}Ar)_m$	$(^{36}Ar/^{39}Ar)_m$	$(^{37}Ar/^{39}Ar)_m$	$(^{38}Ar/^{39}Ar)_m$	$^{39}Ar_k$ (10^{-12}mol)	$(^{40}Ar^*/^{39}Ar_k)$ $\pm 1\sigma$	$^{39}Ar_k$(%)	Apparent age $t \pm 1\sigma$ (Ma)
1	480	97.449	0.1786	1.0543	0.3061	0.04	44.9±0.33	3.4	850.8±72
2	640	90.203	0.2128	0.9781	0.3041	0.07	27.6±0.28	6.1	568.2±65
3	720	65.578	0.1508	1.1444	0.3015	0.09	21.3±0.21	7.8	452.7±30
4	850	27.143	0.0417	0.6413	0.1786	0.19	14.9±0.08	16.6	328.4±15
5	950	25.169	0.0356	0.5272	0.1441	0.28	14.7±0.07	24.3	324.4±8
6	1050	26.056	0.0423	0.8783	0.2254	0.16	13.7±0.08	13.9	303.3±12
7	1150	36.182	0.0727	0.9823	0.2909	0.13	14.8±0.10	11.4	327.0±18
8	1250	88.421	0.1974	1.2042	0.3947	0.08	30.4±0.27	6.9	616.8±50
9	1400	112.26	0.2581	1.3431	0.4194	0.06	36.4±0.35	5.2	716.9±70
10	1600	157.83	0.3913	1.2684	0.5217	0.05	42.8±0.48	4.3	817.5±113
plateau age t_p=320.4±5 Ma; isochron age t_p=320.4±6 Ma									

Note: Analyzed by Sang Haiqing, Institute of Geology, Chinese Academy of Sciences, 1998.

Table 2 Characteristics of ore-forming fluid inclusions in quartz

Sample No.	Features of Fluid inclusions				Homogenization temperature (°C)	Salinity (wt% NaCl)	Density (g/cm^3)	Pressure (×10^5 Pa)
	Type	Shape	Size (μm)	Gas-liquid ratio (%)				
SK4-2	L	Elliptical	3–8	5	157–166			
	L	Elliptical	6–12	10	243–253			
	V-L	Negative crystal	6–12	30	278–302	15.9–16.2	0.89	1500
SK4-4	L	Elliptical	3–6	5	245–260			
	V-L	Elliptical and negative crystal	10–20	15	278–291	14.4–15.2	0.88	1400
	V-L	Negative crystal	6–8	30	341–362			
ZK25-4	L	Elliptical and negative crystal	5–12	10	245–265	16.5–17.4	0.96	1600
SR275-4	L	Elliptical	4–18	5	158–165			
	C	Elliptical	3–8	15	233–278	12.6–11.20	0.82	1600
	V-L	Negative crystal	5–8	20	305–310			

Note: Analysed by Xie Yihan, Institute of Geology, Chinese Academy of Sciences, 1998. L – liquid inclusion; V-L – vapor-liquid inclusion; V – vapor inclusion; C – three-phase CO_2 inclusions at room temperature.

4.2 Composition of fluid inclusions

The chemical analysis suggests that the fluid inclusions are mainly composed of Na^+, Ca^{2+}, Mg^{2+} and Cl^-. The ions can be ranged according to their relative concentrations as: $Na^+>Ca^{2+}>K^+>Mg^{2+}$ and Cl^-–$SO_4^{2-}> F^-$.

4.3 Oxygen and hydrogen isotopes

The measurement of oxygen and hydrogen follows the following procedures. The first step is to heat and break the inclusions, and to release the volatile components. And then, water vapor is extracted to react with zinc at 410°C aiming at producing hydrogen. Finally, the hydrogen gas is measured with a mass spectrograph.

Based on the oxygen isotope of quartz, the value of oxygen isotope of the fluids is calculated according to the following formula.

$$\delta^{18}O_{H_2O}=\delta^{18}O_Q-10^3\ln a_{Q\text{-}H_2O}$$

where $10^3\ln a_{Q\text{-}H_2O}$ = 3.38 (10^6T^{-2}) – 3.40 (after Clayton, 1972).

Eleven samples were determined for oxygen and hydrogen isotopes in the Sarkobu gold deposit ($\delta^{18}O_{water}$= 2.04‰ to 3.54‰; δD = –132.9‰ to –102.4‰) and other deposits ($\delta^{18}O_{water}$ = 0.35‰ to 4.81‰; δD = –115.3‰

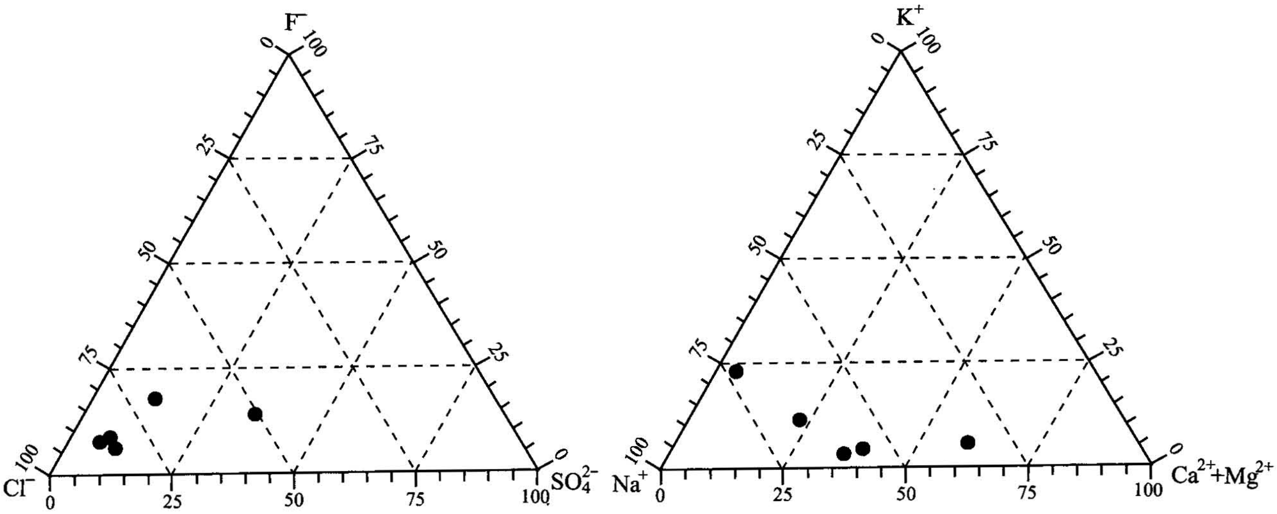

Fig. 3. F^-–Cl^-–SO_4^{2-} and K^+–Na^{2+}–Ca^{2+}+Mg^{2+} plots of the ore-forming fluids.

to −74.9‰) in the Keketal ore belt. The δD and $\delta^{18}O$ values were plotted within the left area outside the field of magmatic and metamorphic water. It suggests that the ore fluids come from multiple sources.

5 Conclusions

The Sarkobu gold deposit occurs at the pinch-out place of lead-zinc orebodies, at the same horizon of massive sulfide ores. The very early stage of gold mineralization was related to the volcanic-exhalative process, and the gold deposit was formed in the secondary fractures of the Abagong thrusting fault belt, yielding an ore-forming age of 320.4±6 Ma. It indicates that the final stage of gold mineralization was related to the compression-shearing process during the orogenisis. Multi-source ore-forming fluids were involved in the mineralization.

The altered minerals are coarse-grained tremolite, garnet and chlorite. In the depth the altered minerals are finer in size, and aphanitic quartz is common. Therefore, orebodies occur at the transitional place from compressional to extensional fracturing.

In conclusion, the Sarkobu gold deposit has two stages of mineralization. At the first stage, gold was preliminarily gathered during the volcanic-exhalation process, and VHMS-type Pb-Zn deposits were formed in the volcanic-sedimentary basin. At the final stage the gold deposit was formed in the compression-shearing process and situated in the transitional place from compressional to extensional fracturing.

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References

Clayton, R.N., O'neil, J.R., and Mayeda, T.K., 1972. Oxygen isotope exchange between quartz and water. *J. Geophys. Res.*, 77: 3057–3067.

Ding Rufu, Wang Jingbin, Ma Zhongmei, Zhang Jinhong and Fang Tonghui, 2001. Geochemical charateristics of the Sarkobu volcanic exhalative-sedimentary-Superimposed gold deposit in Xinjiang. *Geology and Exploration*, 37(3): 11–15 (in Chinese with English abstract).

Ding Rufu, Zhao Lunshan, Wang Jingbin and Zhang Jinhong, 1999. Metallogenetic evolution of gold and polymetallic ore deposits in Keketale, Xinjiang. *Geol. Rev.*, 45(sup.): 1132–1138 (in Chinese with English abstract).

He Guoqi, Li Maosong and Liu Dequan, 1994. *Paleozoic Crustal Evolution and Mineralization in Xinjiang of China.* Urümqi: Xinjiang People's Press, 246–329 (in Chinese with English abstract).

Li Huaqin, Xie Caifu and Chang Hailiang, 1998. *Study on Metallogenic Chronology of Nonferrous and Precious Metallic Ore Deposits in North Xinjiang, China.* Beijing: Geological Publishing House, 264 (in Chinese with English abstract).

Wang Jingbin, Qin Kezhang, Wu Zhiliang, Hu Jianghui and Deng Jiniu, 1998. *Volcanic-Exhalative-Sedimentary Lead-Zinc Deposits in the South Margin of Altay Mountains, Xinjiang.* Beijing: Geological Publishing House, 210 (in Chinese with English abstract).

Wang Jingbin, Zhang Jinhong, Ding Rufu and Fang Tonghui, 2000. Tectono-metallogenic system in the Altay orogenic belt, China. *Acta Geologica Sinica* (English edition), 74(3): 485–491.