

THE THERMODYNAMIC MODELLING OF GOLD CONCENTRATION AT THE KAIRAGACH EPITHERMAL DEPOSIT (UZBEKISTAN)

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The Kairagach deposit belongs to a rare for the former USSR's territory high-sulfidation (acid sulfate) type of epithermal mineralization. It is situated within the Near-Angren area (northern slope of the Kurama Range). The deposit is located in a caldera composed of volcanic and sedimentary and subvolcanic andesite-dazit rocks of Middle-Late Carbonaceous age [1]. The gold-sulfide-telluride-selenide mineralization is confined to sub-vertical and flat silicification zones and quartz and quartz-barite veins and breccia zones. Four stages of the ore formation are distinguished: I - pre-ore quartz-sericite-carbonate alteration, II – gold- quartz-pyrite (early ore-bearing), III- gold-fahlore-sulfosalt-telluride (main ore-bearing), IV – galena-sphalerite (post-ore).

The fluid inclusion studies and isotope data evidence the mineral assemblages of the main ore-bearing stage to be formed by low-acidic fluids of mixed meteoric and magmatic source under temperature of 330-200°C. Fluids were characterized by broad salinity range (from 21.5 to 0.5, mainly 7,0-0,5 wt.% equiv.NaCl) and various ratios $\text{SO}_2/\text{H}_2\text{S}$ at shallow and deep levels [2].

For revealing the possible gold species and gold concentration evaluation in the ore-forming solution depending on physical and chemical parameters changes the thermodynamic modeling of equilibrium gold solubility in the system $\text{Au-NaCl-CO}_2\text{-H}_2\text{S-H}_2\text{O}$ was carried out. The GIBBS program version 3.6 with the UNITERM database version 3.6 was used [3]. The temperature and pressure ranges, as well as a system initial composition were chosen according to fluid inclusion and isotope data. It was established that gold species and their solubility strongly depend on temperature, pH, and Eh change of a model solution.

The dependence of gold solubility from temperature was calculated for interval of 350-25°C. According to calculation results gold in a model solution should be present mainly as AuHS^0 and $\text{Au}(\text{HS})_2^-$ complexes under insignificant role of other forms - Au^+ , Au^{3+} , AuOH , $\text{Au}(\text{OH})_2^-$, $\text{Au}_2(\text{HS})_2\text{S}^{2-}$, AuCl_2^- , AuCl_4^- . At the temperatures from 350° to 175°C AuHS^0 complex; under temperatures lower than 150°C $\text{Au}(\text{HS})_2^-$ complex dominates (Fig.1, a). With temperature decreasing (beginning from about 250°C), the total gold solubility drops resulting in gold precipitation.

The dependence of gold solubility from the solution acidity-alkalinity variation was calculated for pH from 3 to 8 under $T=250^\circ\text{C}$ (Fig.1, b). It was established that under $\text{pH} = 3-4$ AuHS^0 complex should prevail in solution; gold concentration should be about 1×10^{-5} M/kg H_2O and remain almost constant. During alkalinity increasing up to $\text{pH}=6.5$ (e.g., due to acid gas separation as a result of fluid boiling) gold solubility increases more than one order of magnitude and reaches up to 1.6×10^{-4} M/kg H_2O . Further increasing of solution alkalinity (up to $\text{pH}=8$) leads to decreasing of gold solubility up to initial value. At $\text{pH}>4.5$ $\text{Au}(\text{HS})_2^-$ complex dominates in solution. Since the early ore-bearing stage mineralization and early assemblages of main ore-bearing stage were formed in acidic environment ($\text{pH}=2-4$), and late assemblages of main ore-bearing stage - in near-neutral environment, the gold solubility increasing during pH growth explains gold enrichment mainly of early assemblages of main ore-bearing stage.

The influence of redox state (Eh) on gold solubility was evaluated for $\text{H}_2\text{S}/\text{SO}_2$ ratios from 0.1 to 10.0 at $T=250^\circ\text{C}$. The calculations showed (Fig. 1,c) that Eh change from 0.60 to -0.01 causes gold concentration fall on four order of magnitude- from 10^{-1} to 10^{-5} . Further Eh decreasing right up to -1.20 does not lead to any real solubility variation. At Eh up to 0.005 chloride (AuCl_2^- and AuCl_4^-) and hydroxide (AuOH) complexes prevail in a model solution; in other cases AuHS^0 complex dominates. According to mineralogical and geochemical zonality and isotope data, mineral-forming conditions changed from relatively reduced ($\text{H}_2\text{S}>\text{SO}_2$, $\text{Eh}<0$) at deep levels to highly oxidized ($\text{H}_2\text{S}<\text{SO}_2$, $\text{Eh}>0$) at shallow levels. The gold solubility growth in a model solution during Eh increasing is in a good agreement with gold content decreasing in ores formed under more oxidized conditions, i.e. in the direction of the deposit upper parts.

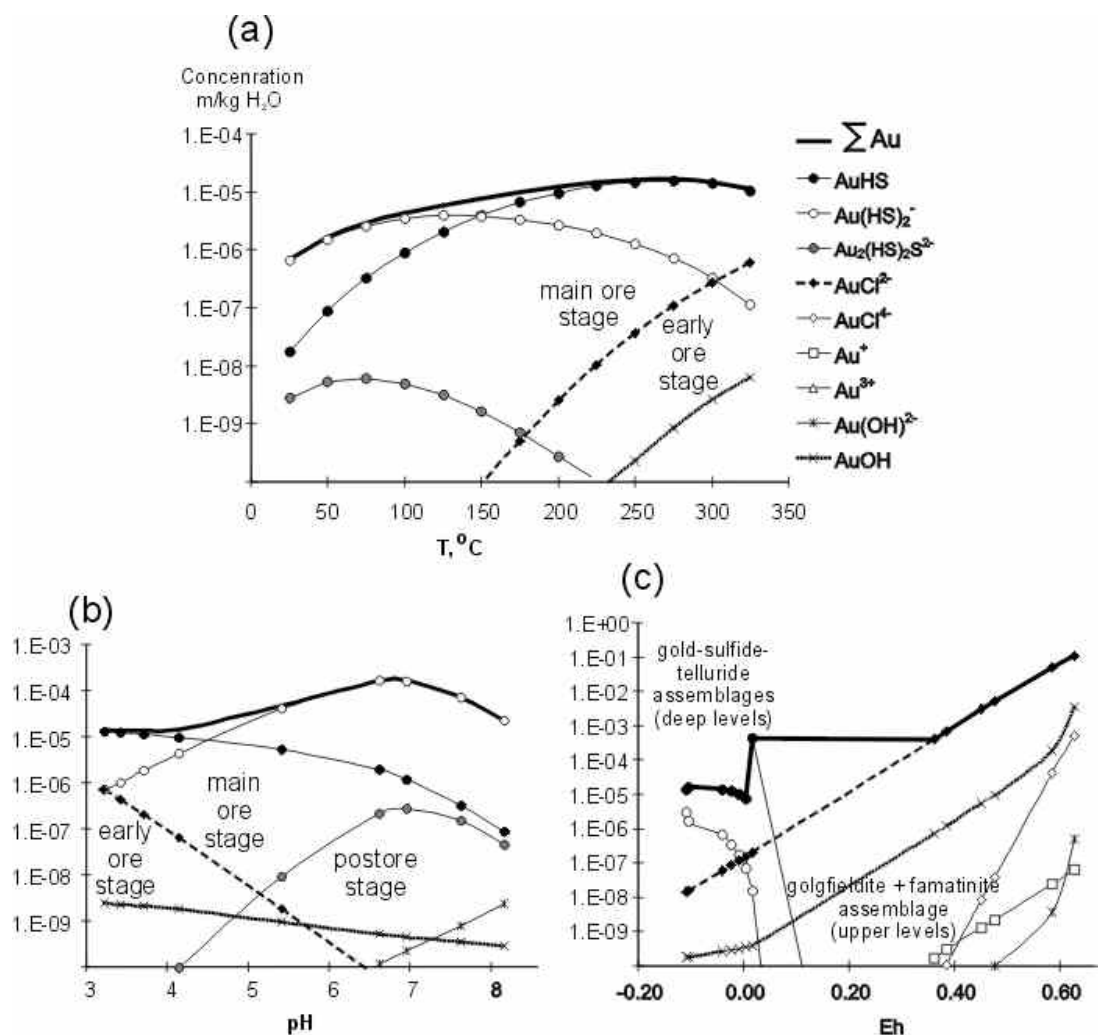


Fig.1. The dependence of gold complex solubility from physical and chemical conditions

The modeling results obtained allows us to conclude that native gold of an early ore-bearing stage mineralization was formed mainly due to destruction of $Au(HS)_2^-$ complex and partly - of $AuCl_2^-$ complex at relatively high temperatures (300-250°C). The main amount of native gold was deposited from an ore bearing solution due to destruction of $AuHS^0$ complex in acidic environment under temperatures 250-125°C during main ore-bearing stage. The data presented show that the temperature decreasing of mineral-forming solution caused by its cooling with transport away from heat source and mixing with meteoric waters is one of main factors of gold precipitation during gold-bearing ore formation.

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