

Formation and fate of gold thiosulfate under the leaching of sulfide rocks (experimental study)

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The mining of low-sulfide and sulfide ores of noble metals deposits is followed by the drainage of overburden and waste rocks with atmospheric precipitations. As a result of the contact of rocks with water and oxygen, the consistent oxidation of sulfide minerals takes place, and a number of sulfur species in various oxidation states is formed (fig.1). The interaction of some of these ligands with metal ions leads to the formation of stable complex compounds which specify migration behavior of elements. In part, neutral and basic media were shown to be favorable for the formation and existence of stable thiosulfate complexes of Au(I) ($\lg K = 26.5\text{--}28.0$) [Aylmore, Muir, 2001].

In a present paper, the formation of thiosulfate-ion and Au(I) thiosulfate complex has been studied in a dynamic experiment with pyrrhotite and pyrite-containing rocks with noble metal inclusions (rock composition is given in table 1). In addition, sorption ability of gold thiosulfate specie has been investigated in model sorption experiments with main constituents of natural geochemical barriers (goethite, humic acids (HA), as well as goethite in a presence of fulvic acid (FA) and compared with a behavior of hydroxochloride forms of gold in these systems.

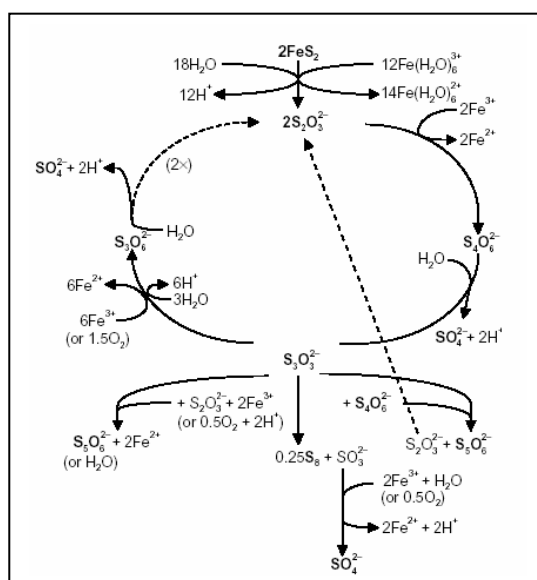


Fig. 1. A scheme of pyrite oxydation [Schippers, Rohwerder, 1999]

Table 1. Composition of ore used in the experiment

Element	Content
Al ₂ O ₃ , %	16,74
CaO, %	6,65
Fe ₂ O ₃ %	12,74
K ₂ O, %	0,08
MgO, %	8,68
MnO, %	0,13
Na ₂ O %	1,08
P ₂ O ₅ , %	<0.01
SiO ₂ , %	52,66
TiO ₂ , %	0,33
Ni, %	0,47
S, %	0,054
Cr, %	0,10
Cu, %	0,25
Co, ppm	89
Au, ppb	75

In preliminary batch experiments on the samples with the coarseness 200 mesh, the thiosulfate-anion was detected by ion chromatography (fig.2) after first hours of interaction of system components (fig.3). A possibility to register the appearance of gold-thiosulfate complex by combination ETAAS and HPLC was also shown (fig.4).

Leaching kinetics was studied in a dynamic experiment which was realized in a special unit with 300 g of rock (<5 mm) and alternate inflow of water (2 h) and air (22 h). In the 8th day of the experiment, the appearance of gold in the solution was detected in a presence of high concentrations of thiosulfate-anion (fig. 5). This allows to suppose the formation of gold-thiosulfate complex under the contact of rock with water and air oxygen.

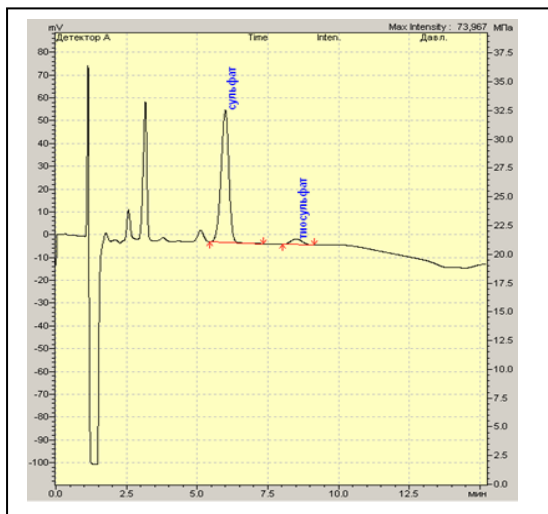


Fig. 2. Ion-chromatographic detection of sulfate and thiosulfate anions

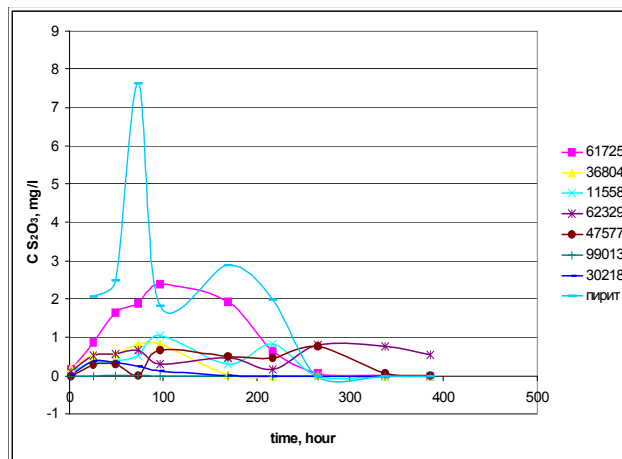


Fig. 3. Concentration of thiosulfate anion vs time in “water-rock” system (batch conditions)

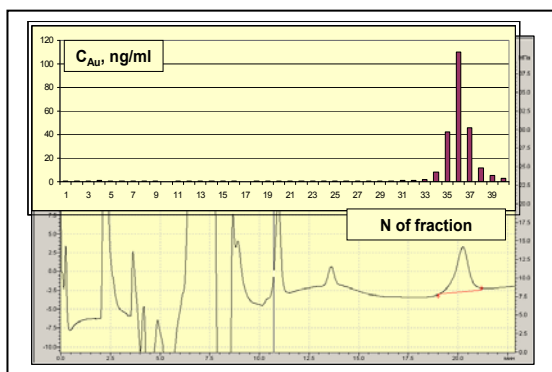


Fig. 4. The peak of gold thiosulfate on the chromatogram (bottom); gold content in chromatographic fractions measured by ETAAS (top)

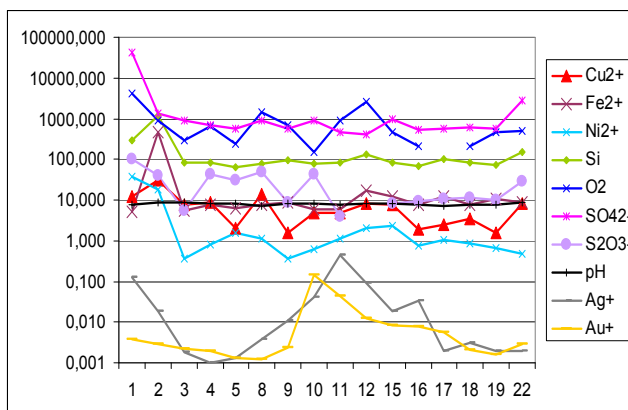


Fig. 5. The change of content of solution components with time (dynamic leaching)

Sorption of gold-thiosulfate complex on goethite, HA, and goethite in a presence of FA has been studied in experiments with the use of preliminary synthesized precipitates. Goethite was prepared from Fe(III) nitrate; low-ash HA were isolated from the peat (region of Tver’); fulvic acids (FA) for the modifying of goethite were isolated from the highly-colored water of Moskva river head. The experiment was carried out on the single algorithm. Twenty mg of HA, 50 mg of goethite or 50 mg of modified goethite were adjusted in a contact with gold(I) thiosulfate solutions with concentrations $n \cdot 10^{-5}$ M, preliminary aged to attain constant pH values (from 5.0 to 9.0). Via 1, 3, 7, 14, 21 days in 3 series of experiments gold concentrations for each pH value were measured, and dependences of gold sorption on time were graphed (fig. 6). Sorption values in equilibrium states of system were used to reveal a dependence of gold thiosulfate content on pH of solutions.

A high affinity of gold thiosulfate to goethite at pH 5.0 and 6.0 has been established: extraction of gold was 97% and 87%, correspondingly. With the increase of pH up to 9.0 a sorption decreased up to 55%.

Sorption on HA almost in the all pH range studied was even lower (around 40%); this sharply discriminates the behavior of gold thiosulfate and chloride complexes on these sorbents (fig.7, 8).

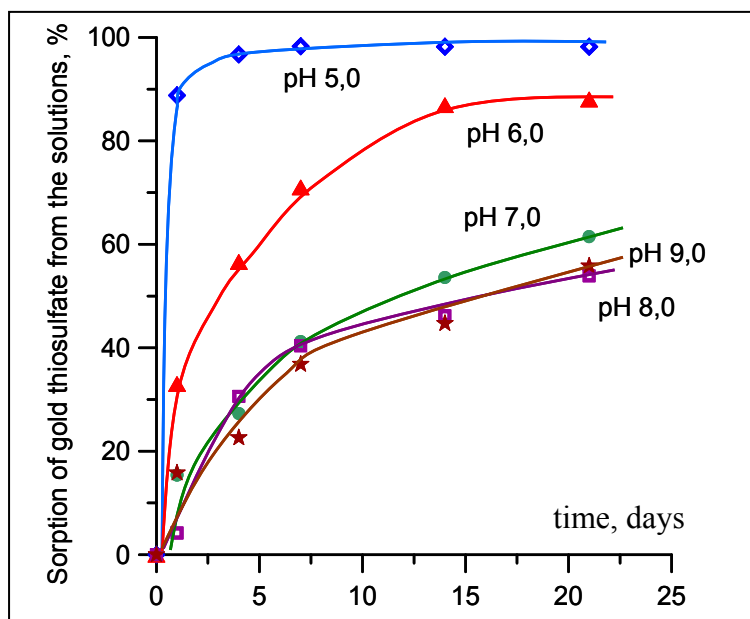


Fig.6. Sorption of thiosulfate Au(I) complexes on goethite vs time for various pH

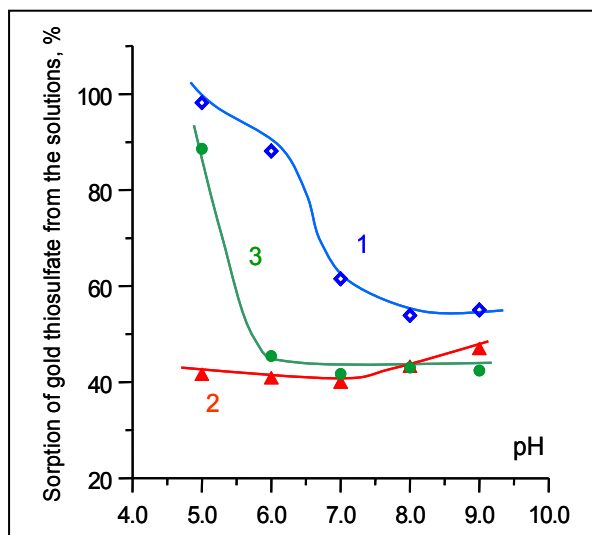


Fig.7. Sorption of thiosulfate Au(I) complexes on goethite (1); humic acids (2); on goethite modified with fulvic acids (3)

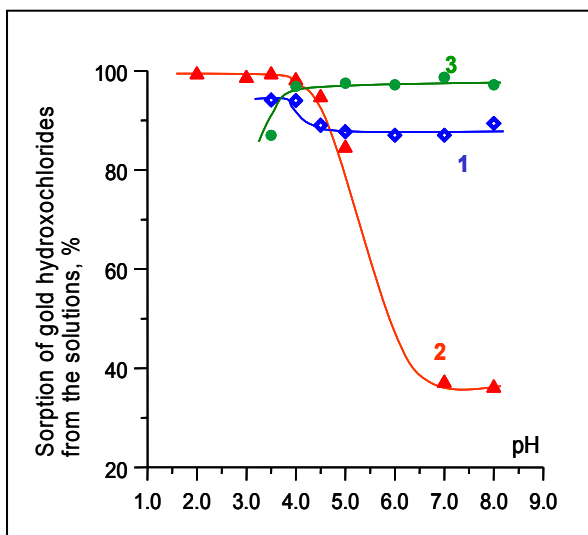


Fig.8. Sorption of hydroxochloride Au(III) complexes on goethite (1); humic acids (2); on goethite modified with fulvic acids (3)

As a result, under the investigation of water-rock interaction it was found, that even at the content of sulfides lower than 1%, thiosulfate concentration in drainage solutions can reach 0.35 mg/l. Generated solutions contain up to 1 mg/l of dissolved gold (under it's content in rock ~ 75 ppb).

In low-acid media (pH 5–6) dissolved thiosulfate Au(I) complexes are completely sorbed by iron oxyhydroxides and slightly – by organic precipitates. In neutral and low-basic media, in contrast to chloride complexes (fig.8), no less than half of dissolved thiosulfate gold species are able to migrate with natural waters.

References

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