

# LIMITS OF GOLD INCORPORATION INTO MAGNETITE AND PYRRHOTITE

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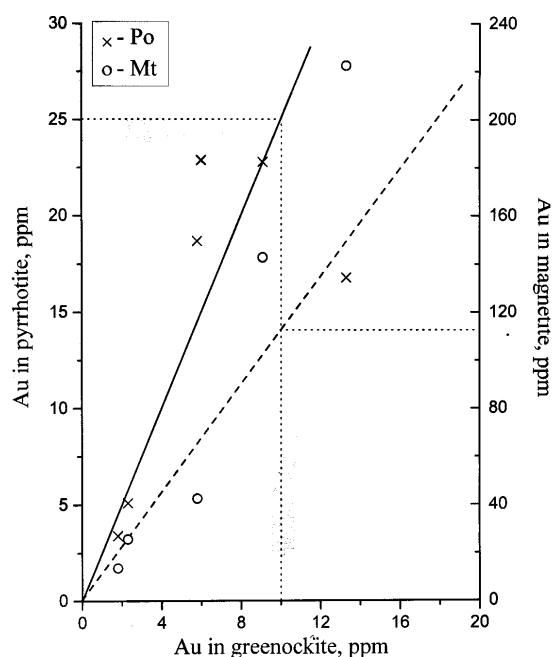
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Advance in geochemistry of gold is impossible without accurate understanding of mechanisms and limits of its incorporation to mineral phases. In this respect, the data available at the present time for pyrrhotite and magnetite are questionable. The problem of potential ability of these minerals as gold concentrators is not only of fundamental geochemical interest but of practical value too. The present article gets an insight into this question using new approaches in experimental geochemistry of trace elements proposed by one of the authors [1].

The co-crystallization of pyrrhotite (Po), magnetite (Mt) and greenockite (Gr) is performed using a conventional hydrothermal gradient technique [2]. The growth medium was a 10% aqueous ammonium chloride solution. Temperature of the growth zone was 450°C, and pressure in the autoclave – 1 kbar (100 MPa). The experiments were carried out for 12 days, for the first 3 days, isothermal regime was maintained. A finely dispersed Fe, S and CdS were used as starting materials. Au was added as a thin foil. As and Se were used as the components that provide highest Au contents in the fluid (“saturation-favoring components” [1] or “gold-assisting” elements [2]). Au concentration in individual crystals (monocrystals) of Po, Mt and Gr was determined by graphite furnace atomic absorption spectrometry using an AAS Perkin-Elmer M503 spectrometer with a deuterium background corrector and a HGA-74 graphite atomizer. The structurally bound Au was discriminated by the method of statistic samples of analytical data for monocrystals (SSADM) [3,4]. This statistical method can indirectly show a proportion of the element concentration distributed in the same manner as the lattice form of trace element. The lattice character of a part of Au concentration can be substantiated more rigorously by study of the element distribution in the system “studied mineral – reference mineral” [1,2]. The “noise signal” from other forms can be filtered out at the first (statistical) stage by SSADM method. Then the proportion of element concentration of interest (the “utile signal”) is proved by its obedience to common physical-chemical regularities of isomorphous admixture partitioning: phase composition correlation and Henry’s law. Actually, this problem is solved for the system “Po-Mt-Gr” by the present work. Preliminary, in a special set of experiments in the system CdS-Fe-S-As (Se)-Au-NH<sub>4</sub>Cl-H<sub>2</sub>O, the incorporation limit (IL) of Au to ferrous Gr (reference mineral) was estimated under 450°C and 1 kbar. For this purpose Gr was synthesized in presence of Fe and As and Se dopants (1 and 2 wt. %). Despite the high total gold contents (20-60 ppm), supporting As and Se action as “gold-assisting” elements, the concentration of uniformly distributed (structurally bound) form of the element remains nearly the same ( $10 \pm 2$  ppm) independently of iron content in Gr. The data on the system “stoichiometric Po – Mt – Gr” are shown in Figure. Despite of some dispersion of data, though not transcending the error bars of distribution coefficients data, it can be seen that the phase composition correlation principle is obeyed. Lattice Au concentrations in Gr, Po and Mt are grown correspondingly with elevation of both, As and Se contents. The distribution coefficient of Au between Po and Gr is 2.5 on the average, and the incorporation limit of Au to Po is estimated as  $25 \pm 9$  ppm. Because Po is stoichiometric, the isomorphous capacity (IC) of FeS in Au is the same [1]. For non-stoichiometric Po, the phase composition correlation was not observed; the reason for this is not clear yet. Magnetite represents a more effective Au concentrator than Po: the distribution coefficient of Au between Mt and Gr is 11.7 on the average, giving IL value  $117 \pm 55$  ppm. Recall that these data are related to specific conditions of low sulfur fugacity and existence of metallic Fe (in the batch) and stoichiometric Po in the system. Thus, in relation of IC in Au, the studied mineral substances can be disposed in a series (in parenthesis – IL in ppm): Fe<sub>3</sub>O<sub>4</sub> (117) > FeS (25) > CdS (10) > FeS<sub>2</sub> (3). A noticeable feature of this series is the fact that it absolutely contradicts the geochemical concepts on mineral concentrators of gold, traditionally allocated the first place to pyrite [5]. In every respect, pyrite is the best geochemical barrier mineral for gold, but merely a sorption barrier [4]. From a crystal chemical point of view, pyrite is not a most favorable matrix to including gold and even very low concentrations that could be considered as lattice gold, are due to endocrypty and structure defects of pyrite [1, 2].



**Fig.** Structurally bound gold distribution between coexisting phases: stoichiometric pyrrhotite, magnetite and greenockite under 450°C and 1 kbar. Estimates of gold incorporation limits in Mt and Po are shown.

Magnetite represents another case. Its wide isomorphous possibilities in respect of a number of elements of different chemical nature are well known. The reason can be found in mixed-valence state of iron and incorporation of admixtures facilitating by the defects – cation vacancies appearing due to the formation of solid solution with defected gamma-spinel. An “ambiguity” of the chemical state of Fe provides the favorable conditions for incorporation of elements chemically indifferent to some extent for which not so important to form polar bond with anions (oxygen) as a possibility to have common electron system in the sublattice of atoms exchanged. Actually high abilities of Mt in gold uptake support this suggestion. However, the abilities mentioned as well as the gold concentrating phase association “Mt+Po” are realized in specific conditions. In the majority of natural environments the gold concentrations in Mt are very low because Au is partitioning in favor of sulfides [6]. This is the reason of discrepancy of the series of isomorphous capacity of minerals in respect of Au and geochemical speculations about its mineral concentrators.

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#### References

1. Tauson V.L. // Russian Geology and Geophysics. 1999. V.40. N10. P.1468-1474.
2. Tauson V.L. // Eur. J. Miner. 1999. V.11. N6. P.937-947.
3. Tauson V.L., Salikhov A., Matschullat J. et al. // Geochem. Internat. 2001. V.39. N9. P.864-872.
4. Tauson V.L., Bessarabova O.I., Kravtsova R.G. et al. // Russian Geology and Geophysics. 2001. V.43. N1. P.56-64.
5. Springer J. // Ontario Geological Survey Miscellaneous Paper. 1983. V.110. P.240-250.
6. Wilson G.C., Rucklidge J.C., Kilius L.R. // Econ. Geol. 1990. V.85. N6. P.1252-1259.

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