Sulfidation of native gold

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ABSTRACT

We use microscopic and electron microprobe techniques to study samples of ores containing native gold with dark rims of Au-Ag sulfides from six deposits and ore occurrences of Russia: Khopto (Au-Cu-skarn), Ulakhan, Yunoe (Au-Ag epithermal), Dorozhnoe, Konouchoe, and Yakutskoe (Au-quartz). Dark rims around native gold are uytenbogaardtite (Ag,Au$_2$S) or petrovskaite (AgAuS), or a mixture of acanthite (Ag$_2$S) with uytenbogaardtite or uytenbogaardtite with petrovskaite. In the ore samples from the Khopto and Ulakhan deposits, we have found microrims of higher fineness gold at the contact of native gold and Au-Ag sulfide. The reactions of native gold sulfidation occurring in natural processes are proposed based on the compositions of Au-Ag sulfides, their mutual textural relationships. The composition of Au-Ag sulfides rims was found to depend on the primary fineness of native Au: uytenbogaardtite forms after gold of fineness above 380%, whereas petrovskaite, above 650%. We propose that the fineness of gold and silver may be used for forecasting presence of uytenbogaardtite or petrovskaite, or a mixture of acanthite with uytenbogaardtite or uytenbogaardtite with petrovskaite in sulfide ores at Au-Ag epithermal, Au-skarn, Au-Cu volcanic-hosted massive sulfide, Au-quartz-sulfide, and other deposits.

Keywords: Uytenbogaardtite, petrovskaite, native gold, fineness, reactions of sulfidation

INTRODUCTION

Gold and silver in nature occur in a native state, forming a continuous Ag-Au solid solution (White et al. 1957; Yushko-Zakhara et al. 1986; Morrison et al. 1991; Gammons and Williams-Jones 1995; Palyanova 2008; Spiridonov and Yanakieva 2009). The fineness (N$_{m}$) equal to 1000·Au/(Au+Ag) (by weight) is used for the characterization of the composition of Au-Ag alloys or native gold and silver. Depending on the fineness (in %), the following native gold and silver are distinguished: “Au-rich electrum” or “highfineness gold” (1000–700), “electrum” (700÷250), “Ag-rich electrum” or old term as “kustelite” (250÷100) and native silver (100÷0) (Boyle 1979; Petrovskaia 1993). Silver nuggets are commonly covered with black crusts of silver sulfide: acanthite (Ag$_2$S), The study of the chemical composition of dark rims on native gold has led to the discovery of the Au-Ag sulfides: uytenbogaardtite (Ag,Au$_2$S) (Barton et al. 1978) and petrovskaite (AgAuS) (Nesterenko et al. 1985). Mineral assemblages with these Au-Ag sulfides were found in Au-Ag epithermal, Au-skarn, Au-Cu volcanicogenic massive sulfide, and Au-quartz-sulfide deposits (Zhen-jie et al. 1979; Castor and Sjoberg 1993; Marcoux et al. 1993; Sheets et al. 1995; Dill 1998; Al’shevskii 2001; Greffie et al. 2002; Warnada et al. 2003; Chauvet et al. 2006; Koneev 2006; Majzan 2009; Palyanova and Savva 2008, 2009; Anisimova et al. 2008; Proskurnin et al. 2011; Savva et al. 2012; Cocker et al. 2013). Au-Ag sulfides coexisting with native gold were also stricken in the gold-placer mines of northeastern Russia (Al’shevskii 2001).

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Au-Ag sulfides form veinlets, isolated micro-inclusions and 10–100 µm rims occurring in native gold, rarely as single crystals and their aggregates 3–4 mm in size. Reaction rims are formed when two phases or assemblies that cannot coexist stably are in contact and react to produce a new phase or an assemblage along their interface (Fisher 1973). The specific chemical mechanisms of reaction rim formation are not well understood for these systems. Numerous disembodied data can be found in literature cited above on the fineness of native gold and compositions of associated Au-Ag sulfides. The concentration of gold and silver in Au-Ag sulfides, as well as in native gold, varies in a wide range (Savva and Palyanova 2007; Palyanova 2008; Palyanova et al. 2011). The objectives of the present study are to summarize the available data on the sulfidation of native gold, to reveal compositional variations and regularities and to explain the mechanism of Au-Ag sulfides formation. Uytenbogaardtite and petrovskaite are related to rare minerals that are not so widespread. However, the formation mechanism of Au-Ag sulfides in natural conditions is important for understanding the geochemistry, transport, and deposition of noble metals. Au-Ag sulfides were found in sulfide ores of some deposits in amounts comparable to native gold, for example, Yunoe (Palyanova and Savva 2009), Nazareno, Pongkor (Greffie et al. 2002), and Broken Hills (Cocker et al. 2013), and, therefore, their presence should be taken into account in the development of technological schemes of Au and Ag concentration and recovery.

MATERIALS AND METHODS

We have thoroughly studied some polished sections of ore samples or mounts containing grains of native gold with dark rims of Au-Ag sulfides from six deposits and ore occurrences of Russia: Khopto (Au-Cu-skarn), Ulakhan, Yunoe (Au-Ag