

Sulfur Isotope Characteristics of Gold Transport and Sulfidation Processes: a Study from Eastern Rhodopian Sedimentary-Rock Hosted Epithermal Gold Prospects, Bulgaria

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The Eastern Bulgarian epithermal gold mineralization with a low-sulfidation character at Ada-Tepe and surrounding prospects are dominantly hosted by syn-detachment sedimentary rocks of Maastrichtian-Paleocene age. A low angle normal fault between the metamorphic basement and the sedimentary rocks constitutes the major ore-controlling associated structure (Marchev *et al.* 2004).

Ore textures suggest several gold deposition processes, including: cooling and boiling of the ore fluid, dilution, oxidation and other chemical changes caused by mixing of two fluids, and wall rock reactions such as reduction of fluids by organic matter or sulfidation. Assuming that gold was transported in hydrothermal solutions as a gold bisulfide complex, a decrease in H₂S content may have caused gold precipitation. A decrease in H₂S content can be due to precipitation of sulfide minerals or mixing with an H₂S-poor solution (e.g., shallow ground water). The reduction of fluids is favoured by the presence of organic matter and ferrous-bearing minerals in the host rocks.

The importance of sulfidation and gold transport as a bisulfide complex in the case of the studied deposits are indicated by: 1) petrographic evidence which suggest that sulfidation of host rock iron was an important process; 2) mass transfer studies which show that sulfur was one of the most abundant elements introduced by hydrothermal fluids, whereas iron contents remained nearly constant; 3) the low fluid inclusion salinity and 4) high Au/Ag ratios in electrum. These observations are consistent with chemical reaction path modelling, which shows that sulfidation can result in ore grades (Shenberger and Barnes 1989; Gammons 1997) similar to the ones observed in the sedimentary-rock hosted gold deposits of the Eastern Rhodopes.

A better understanding of the source of sulfur and mechanism of H₂S generation may help to discriminate between the various models and fluid sources proposed for the deposits. Therefore, sulfur isotope studies were conducted on pyrite samples from the different prospects. The wide range of sulfur isotopic compositions (Fig. 1) suggests a variety of sulfur sources for the sedimentary-rock hosted gold deposits of the Eastern Rhodopes.

Interpretation of sulfur isotope data requires consideration of the isotopic composition of potential sulfur sources and mechanism of H₂S generation. Given that gold was transported as a bisulfide complex, knowledge of the sites of H₂S generation and migration pathways is important to gather information on the source of gold. High

H₂S concentrations could promote high gold solubility. The mechanisms that can generate high abundances of H₂S include: (1) influx of magmatic H₂S; (2) release of H₂S during metamorphism of sulfide-rich country rocks; (3) dissolution of sedimentary pyrite; and (4) bacterial (30-110 °C) and thermochemical sulfate reduction (150-200 °C).

Dissolution of sedimentary pyrite could explain the light sulfur isotopic fluid components (Ada Tepe, Skalak). The abundant framboidal pyrite, interpreted to be of diagenetic origin, at one of the prospects (Stremtsi) also underlines this. However, pyrite dissolution is not sufficient to explain the unusually high H₂S contents necessary for the formation of sedimentary rock-hosted gold prospects in the Eastern Rhodopes, and the large range of sulfur isotopic compositions shown in Figure 1. Deep sourced H₂S is suggested by oxygen isotope data (Márton et al. 2006). However, since no magmatic reservoir contemporaneous with the formation of the sedimentary rock-hosted epithermal deposits has been identified so far, and because of the low sulfide content of the metamorphic basement rocks, an alternative mechanism is required. Studies on other sedimentary rock-hosted gold deposits (e.g. Carlin-trend, Gammons 1997; Cline et al. 2005) highlight the importance of thermochemical sulfate reduction as a source of sulfur. This process could explain the high sulfur isotopic compositions of pyrite at Rosino and Surnak (Fig. 1). Thermochemical sulfate reduction is the process during which buried organic matter reduces sulfate to hydrogen sulfide. The occurrence of sedimentary rocks rich in organic matter and sulfates are evidence for the possibility of this process in the Eastern Rhodopes.

In conclusion, the sulfur isotope data are consistent with a magmatic/metamorphic fluid source, or a surficial fluid that has been extensively reequilibrated with magmatic and metamorphic rocks, and dissolution of sedimentary pyrite and thermochemical sulfate reduction were likely additional sulfur sources.

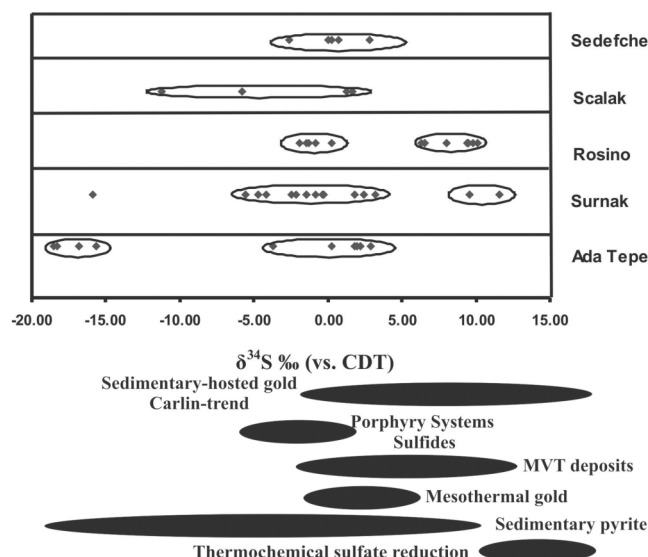


Figure 1. Sulfur isotope data from Eastern Rhodopian sedimentary-rock hosted epithermal gold prospects compared to the sulfur isotopic composition of other deposits and sulfur produced by thermochemical sulfate reduction (Ohmoto and Rye 1979; Cline et al. 2005).

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