Mineralium Deposita (2005) 40: 115–122
DOI 10.1007/s00126-005-0471-2

LETTER

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First lead isotopic data for cinnabar in the Almadén district (Spain): implications for the genesis of the mercury deposits

Received: 15 July 2004 / Accepted: 13 March 2005 / Published online: 24 May 2005

Abstract The Almadén district constitutes the largest and probably the most intriguing mercury concentration in the world. Two types of mineralization are recognized: 1) stratabound, of Lower Silurian age, well represented by the large Almadén deposit; and 2) fully discordant mercury deposits of minor importance in terms of size, and exemplified by the deposit of Las Cuevas. The latter ones can be found at different positions along the Almadén stratigraphic column. Both types of deposits are always associated with the so-called *frailesca* rocks (diatremes of alkali basaltic composition). This paper reports the first lead isotope compositions of cinnabar in the district. Whole samples and stepwise leaching cinnabar aliquots display relatively homogeneous isotopic compositions ($^{206}Pb/^{204}Pb$ = 18.112–18.460; $^{207}Pb/^{204}Pb$ = 15.635–15.705; $^{208}Pb/^{204}Pb$ = 38.531–38.826). Taken together with Jébrak et al.'s (2002) pyrite lead isotope results, the new cinnabar isotopic data define a steep array trend on the $^{207}Pb/^{204}Pb$– $^{206}Pb/^{204}Pb$ diagram, indicating a mixed contribution of lead and probably mercury from different sedimentary sources in the Almadén basin. The Almadén Hg deposits are related to a contemporaneous mafic magmatism that might have provided part of the mercury. Hydrothermal leaching of organic matter from sedimentary rocks and formation of Hg organic complexes enhanced metal solubility, promoting transport from and within the volcanic units.

Keywords Mercury · Almadén · Lead isotopes · Upper continental crust · Mantle

Editorial handling: M. Chiaradia

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Introduction and geological setting

The Almadén mining district (Fig. 1) constitutes one of the largest mercury geochemical anomalies on the Earth crust. The different mines of the district produced almost one-third of the total historic production of Hg, which is more than any other production by any other mercury-mining district in the world. Mercury ore bodies are hosted by sedimentary and volcanic rocks belonging to a Lower Palaeozoic sequence that unconformably overlies the pre-Ordovician basement of the Central Zone of the Iberian Variscan Chain (Higueras1995; Hernández et al. 1999) (Fig. 1). The volcano–sedimentary rocks, ranging from Ordovician to Upper Devonian in age, comprise several packages of black shale and sandstone/quartzite units and include frequent intercalations of submarine mafic volcanics including the so-called *frailesca* rocks. The latter represent diatremes that locally cut the sedimentary and volcanic units (Saupé1990; Higueras1995). Mafic volcanism in Almadén was by far more important than elsewhere in the region. Magmatic activity was almost continuous and evolved from early basanitic/nephelinitic and alkali–olivine basaltic extrusions, mostly into the Silurian–Devonian part of the section, to late tholeiitic intrusive dolerites, which are scattered throughout the whole sequence (Higueras and Munhá1993; Higueras1995). Basalts and dolerites underwent long-lasting (427–365 Ma; Hall et al. 1997; Higueras et al. 2000a) regional hydrothermal alteration,