Secondary Minerals from Evolved Mine Waters: A Detailed Survey in Almadén Historic Mercury Mine Gallery

Ana Barroso[1], José Ignacio Barquero[2,3], Efrén García-Ordialesa[4], Judith L. Jaeger[2,3], Pablo Higueras[2,3], Teresa Maria Valente[1]

[1]*Universidade do Minho, Campus de Gualtar, Institute of Earth Sciences, 710-057 Braga, Portugal*

[2]*Instituto de Geología Aplicada, Universidad de Castilla-La Mancha, Pl. Manuel Meca 1, 13400 Almadén, Ciudad Real, Spain*

[3]*Escuela de Ingeniería Minera E Industrial de Almadén, 13400 Almadén, Ciudad Real, Spain*

[4]*ISYMAResearch Group, Mining, Energy and Materials Engineering School, University of Oviedo, C/ Independencia 13, 33011 Oviedo, Spain*

Abstract

Mercury (Hg) is a significant global pollutant, primarily associated with mining and industrial activities. The accumulation of waste containing elevated concentrations of Hg has resulted in the contamination of numerous sites, which presents a risk to human health and the integrity of ecosystems. In response to identifying Hg as one of the most harmful toxic metals, regulatory measures have been introduced that restrict the disposal of Hg without prior treatment. Despite a decline in mining activity due to economic and environmental concerns, it remains paramount to understand the environmental liabilities associated with historical mining districts. Investigating the formation of secondary minerals in these areas may assist in mitigating the risks associated with Hg pollution and its toxic legacy.

The primary objective of this study was to compile a comprehensive inventory of secondary minerals resulting from mine water precipitation within a Hg mine gallery in the Almadén mining region, Spain. This region has a mining history dating back to Roman times; however, it gained prominence during the 16th and 17th centuries. Open-pit and underground mining operations targeted cinnabar deposits, and the region's intensive exploitation established Almadén as a benchmark in Hg production until its gradual decline in recent decades.

Sampling was conducted in June 2024, with temperatures between 17 and 19 °C within the gallery at a depth of 50 m. To avoid mineralogical changes, samples were preserved in closed containers and analyzed promptly upon arrival at the laboratory. Temperature and relative humidity (RH) were recorded at each sampling point. The samples were initially examined using a binocular lens for morphological assessment, and subsequently separated for X-ray diffraction and energy-dispersive X-ray fluorescence analysis. The mine gallery exhibited a range of efflorescence, particularly in areas with elevated RH, highly faulty, and with water percolation. Secondary minerals of diverse colors and morphologies were documented, such as white minerals with saccharoidal or dendritic habits, yellow minerals exhibiting pulverous to globular habits, and globular pink minerals. The paragenesis included gypsum, jarosite, melanterite, bieberite, cinnabar, diadochite, and carbonates. Chemistry indicates Hg concentrations ranging from 17 to 470 mg/kg.

This study successfully establishes an inventory of secondary minerals on the gallery's walls, now classified as a mining park. It details the characteristics of the minerals, including habits and colors, with particular emphasis on those present in small stalactites. Furthermore, analyzing the mineralogy and chemistry of the efflorescent salts has provided valuable insights into the processes underlying their formation.

Keywords: Mercury, efflorescence, paragenesis, geochemical analysis