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Gold Sequestration in Pyrite and Sphalerite temperature from the Boumadine Polymetallic Deposit (Anti-Atlas, Morocco): A LA-ICP-MS Study

IKRAM ARSALAN[1,2], DAMIEN GABOURY[3], DAVID LALONDE[1], KARAOUI BRAHIM[2], EL MAHJOUBI MAHJOUB[4] AND ALEXANDRE MUNGER[1]

[1]Aya Gold & Silver, Boumadine Global Mining.

[2]Faculty of Sciences and Techniques (Errachidia), Moulay Ismail University of Meknes, Morocco

[3]University of Quebec at Chicoutimi, Canada

[4]Moulay Ismail University of Meknes, Faculty of Science, Morocco

The Boumadine deposit (Eastern Anti-Atlas, Morocco) is a major Neoproterozoic polymetallic system (Au–Ag–Pb–Zn) with significant economic potential, estimated at **29.2 Mt grading 82 g/t Ag, 2.63 g/t Au, 2.11% Zn, and 0.82% Pb** [1].

The mineralization consists of subvertical sulfide lodes dominated by pyrite, with lesser arsenopyrite, sphalerite, galena, chalcopyrite, and silver-bearing phases, cutting across flat volcanoclastic rocks. Three texturally distinct pyrite generations coexist: massive, vein-hosted, and disseminated.

LA-ICP-MS analyses (n = 155) reveal a heterogeneous gold distribution across all pyrite types. The complete dataset shows a weak Au–As correlation ($R^2 \approx 0.2$), with median concentrations of **0.7 ppm Au**, **5000 ppm As**, and a median Au/Ag ratio of **0.02**. Gold concentrations range from **0.002–25 ppm**, indicating strong variation in concentration.

However, when isolating the massive and fractured pyrite generation (n = 48), a robust correlation emerges between log Au and log As ($R^2 \approx 0.7$). In this subset, median values reach **2.2 ppm Au** and **5634 ppm As**, with Au locally exceeding **20 ppm**. Despite this enrichment, the Au/Ag ratio remains consistently low (median = 0.09), and no significant correlation exists between log Au and log Ag, suggesting that silver is preferentially hosted in discrete Ag-rich phases rather than structurally incorporated in pyrite.

Calculated Au/As molar ratios, combined with the lack of Au–Ag coupling, suggest that gold sequestration in this generation was controlled by a specific process. Arsenian domains likely enhanced gold incorporation in pyrite. Electrochemical precipitation, where semiconductor behavior in pyrite induces Au^+ incorporation under fluctuating redox conditions, is a potential mechanism.

The **GGIMFis** sphalerite geothermometry (n = 52) constrains mineralization temperatures between 260°C and 350°C, providing a thermal framework for this gold-bearing stage. These data support a model in which gold enrichment represents a discrete hydrothermal pulse, distinct from broader silver-rich mineralizing events recorded in other sulfide generations.

This study is part of an ongoing PhD thesis aimed at refining the metallogenic model for the atypical Boumadine deposit.

[1] (PEA, Aya Gold and Silver, February 24, 2025)

Keywords: Boumadine, Anti-Atlas, Morocco, Neoproterozoic, LA-ICP-MS, Au–As correlation, Electrochemical precipitation, Sphalerite geothermometry, hydrothermal pulse.