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Tracing toxic metal and semi-metal migration: supergene mineral dynamics in abandoned mines of Băiuț, North Romania

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Nestled in Romania's Oaş-Gutâi Mountains, the Baia Mare region boasts a rich history of mining focused on polymetallic deposits. Băiuț village (35 km east of Baia Mare) is renowned for extracting Au-Ag-Pb-Cu-Zn ores. The abandoned mines in the Băiuț area are having a strong impact on the local environment due to intense acid mine drainage (AMD). Our study investigates the geochemistry of secondary minerals (SM) and mine waters to track the migration pathways of toxic compounds within the weathering zone. Our findings highlight the ability of SM to accumulate significant quantities of toxic elements. For instance, melanterite, a common mineral within examined mines, can retain over 1 wt% of Zn and up to 3000 ppm of Cu. Halotrichite group minerals were observed to capture over 1 wt% of Zn, over 1000 ppm of REE, and to some extent U, Th (Σ > 40 ppm). Zinc-sulphate goslarite is enriched in Ni (>1300 ppm) and Co (1000 ppm), while Cu-sulphate chalcanthite may contain some amounts of Cd (~300 ppm). Lead tends to concentrate primarily in epsomite (>3000 ppm) and scorodite (>2500 ppm), while As is mainly concentrated in ferric sulphates and scorodite (>1 wt%). Significant anomalies of Hg have been identified in römerite (38 ppm) and halotrichite (15 ppm). Gold and silver, being mobile in AMD, can be captured by römerite (Ag 16 ppm; Au 1.4 ppm), scorodite (Ag 6.1 ppm; Au 23 ppm), and minerals of voltaite group (Ag 3.7 ppm; Au 2.5 ppm). Based on the chemical analyses of water samples they can be classified as high-metal and extreme-metal. Increased acidity correlates with high levels of dissolved metals (Σ >100 mg/L), especially in mine sectors with limited infiltration of meteoric water. Under these conditions As content exceeds 1500 mg/L, alongside other metals such as Zn (12000 mg/L), Cd (45 mg/L), Ni (30 mg/L), Co (18 ppm), and Sn (7 mg/L). Research indicates dangerously high levels of toxic elements, emphasizing the urgent need for close monitoring of these areas. Melanterite and halotrichite are considered highly risky due to their solubility and widespread occurrence within the mines.