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Genesis of the hydrothermal Pb-Cu ± (Zn) mineralized veins of the Bou-Oudadene deposit (Jbel Addana district, western Anti-Atlas, Morocco): Insights from Mineragoly, Geochemistry and Strucrutal evidence

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Located about 35 km southeast of the Tagragra d'Akka Precambrian inlier, Jbel Addana is a NE-SW trending anticline belonging to the Paleozoic cover of Moroccan western Anti-Atlas. It is dominated by Upper Ordovician terrain, represented by alternating beds of sandstones, quartzites, and schists. These terrains were folded during the Hercynian orogeny and are characterized by a high density of fractures, mainly developed at the anticline hinge (1). The Bou-Oudadène deposit located in the north-eastern extremity of the anticline, it is characterized by a predominately lead-copper mineralization, macroscopically represented by galena, traces of malachite and azurite, with a quartz-iron gangue composed by siderite and quartz. These mineralizations correspond to veins oriented N10 to N30°E with vertical dips. The mineralized veins are hosted by sandstone and quartzite units, whereas they are less developed in schistose units (2), characterized by cleavage planes where mineralizing fluids become dispersed. Metallographic and SEM investigations suggest a paragenetic sequence linked to two hydrothermal stages and a supergene stage (3). The early stage begins with silicification involving the crystallization of quartz I, followed by galena I and minor traces of pyrite and chalcopyrite in the intergranular spaces of the sandstone host rock. A late stage with quartz II, calcite, galena II, and siderite. The supergene stage is represented by a secondary replacement paragenesis with smithsonite, cerussite, anglesite, azurite, malachite, and limonite. Chemical analyses using electron microprobe showed that galena I may contain traces of bismuth ($Pb_{0.98}Bi_{0.01}S_{1.01}$), while galena II may contain traces of both bismuth and gold ($Pb_{0.98}Bi_{0.01}Au_{0.01}S_1$). Structural interpretations demonstrate a correlation between the uplift of Precambrian basement blocks beneath Paleozoic strata and the emplacement of Bou-Oudadène mineralization. This uplift was controlled by the inversion of normal paleofaults related to the Late Proterozoic-Lower Cambrian extension into reverse faults during the Hercynian compression caused by the Variscan collision between Laurussia and Gondwana. This structural context gave rise to the structuring of the Jbel Addana anticline with the opening of fractures in the fold hinge, which have been sites of circulation and precipitation of mineralizing fluids.