Economic Geology, v. 103, pp. 387–404

Genesis and Evolution of Bitumen in Lower Cretaceous Lavas and Implications for Strata-bound Copper Deposits, North Chile

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Abstract

Small, strata-bound copper sulfide deposits are found associated with bitumen in Lower Cretaceous basaltic andesite flows of the Pabellón Formation near Copiapó, north Chile. The physical characteristics of the bitumen and hydrocarbon biomarkers provide clues to the genesis, evolution, and possible role during copper mineralization. Biomarker analysis reveals a predominantly bacterial origin, with minor contributions from phytoplankton and higher plants, which were deposited in a shallow marine environment. An expulsion temperature between 64° and 87°C was determined, typical for low maturity petroleum. This petroleum was altered during migration by mixing with brines, increasing its viscosity by aromatization and sulfurization. At the moment of the accumulation, the temperature of the brine was under 150°C. The viscous oil filled the primary and secondary porosity of the basaltic andesite, which acted as an oil trap. After the oil accumulation, a hotter, hydrothermal influx resulted in thermal alteration of the petroleum and a further decrease of light alkane concentrations. High sulfur concentrations in the hydrothermal fluids led to further aromatization of the organic compounds, generating highly alkylated benzonaptho- and dinaphthothiophenes. Copper in the sulfur-rich solutions was reduced, triggering the precipitation of bornite, chalcopyrite, digenite, chalcocite, and covellite through thermochemical sulfate reduction. The bitumen interacted with metals by virtue of its inherent reducing characteristics (activated carbon) and was itself oxidized to form a pyrobitumen residue.

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0361-0128/08/3731/387-18