Economic Geology, v. 100, pp. 1511–1527

Geochemistry of Jasper Beds from the Ordovician Løkken Ophiolite, Norway: Origin of Proximal and Distal Siliceous Exhalites

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Abstract

Stratiform beds of jasper (hematitic chert), composed essentially of SiO_2 (69–95 wt %) and Fe_2O_3 (3–25 wt %), can be traced several kilometers along strike in the Ordovician Løkken ophiolite, Norway. These siliceous beds are closely associated with volcanogenic massive sulfide (VMS) deposits and are interpreted as sea-floor gels that were deposited by fallout from hydrothermal plumes in silica-rich seawater, in which plume-derived Fe oxyhydroxide particles promoted flocculation and rapid settling of large (~200 μm) colloidal particles of silica-iron oxyhydroxide.

Concentrations of chalcophile elements in the jasper beds are at the parts per million level implying that sulfide particle fallout was insignificant and that the Si-Fe gel-forming plumes were mainly derived from intermediate- (100°–250°C) to high-temperature (>250°C) white smoker-type vents with high Fe/S ratios. The interpreted setting is similar to that of the Lau basin, where high-temperature (280°–334°C) white smoker venting alternates or overlaps with sulfide mound-forming black smoker venting. Ratios of Al, Sc, Th, Hf, and REE to iron are very low and show that the detrital input was <0.1 percent of the bulk jasper. Most jasper beds are enriched in U, V, P, and Mo relative to the North American Shale Composite, reflecting a predominantly seawater source, whereas REE distribution patterns (positive Eu and negative Ce anomalies) reflect variable mixing of hydrothermal solutions with oxic seawater at dilution ratios of ~10^2 to 10^4.

Trace element variations in the gel precursor to the jasper are thought to have been controlled by coprecipitation and/or adsorption by Fe oxyhydroxide particles that formed by the oxidation of hydrothermal Fe^{2+} within the variably seawater-diluted hydrothermal plume(s). Thick jasper layers near the Høydal VMS orebody show distinct positive As/Fe and Sb/Fe anomalies that are attributed to near-vent rapid settling of Si-Fe particles derived from As- and Sb-rich hydrothermal fluids prior to extensive mixing with seawater in the buoyant plume. Particles that formed later in the highly diluted nonbuoyant plume formed relatively As and Sb poor distal jasper. The large particle sizes and accordingly high settling rates of the particles, together with mass-balance calculations based on modern vent field data, suggest that individual meter-thick jasper beds formed within a plume lifetime of 200 years or less. The lack of thick jasper beds near the Løkken VMS orebody, which is larger than the Høydal orebody by more than two orders of magnitude, probably reflects a shift to anoxic conditions during Løkken mineralization. This environment limited oxidation of iron in the hydrothermal plume and formation of the ferric oxyhydroxides necessary for the flocculation of silica and sea-floor deposition of the gel precursor of the jasper beds.

Distal pyritic and iron-poor cherts are more common than jasper in ancient VMS-hosting sequences. The origin of these other types of siliceous exhalite is enigmatic but at least in some cases involved sulfidation, reduction to magnetite, or dissolution of the original ferric iron in precursor Si-rich gels, either by hydrothermal or diagenetic processes.

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0361-0128/05/3555/1511-17 $6.00