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Canadian Cordilleran Mississippi Valley-Type Deposits: A Case for Devonian-Mississippian Back-Arc Hydrothermal Origin

JoAnne Nelson,†

British Columbia Geological Survey Branch, Box 9320 Stn. Prov. Govt., Victoria, British Columbia V8W 9N3, Canada

Suzanne Paradis,

Geological Survey of Canada, Box 6000, 9860 West Saanich Road, Sidney, British Columbia V8L 4B2, Canada

John Christensen,

Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, California 94720

and Janet Gabites

Geochronological Laboratory, University of British Columbia, Vancouver, British Columbia V6T 1Z4, Canada

Abstract

A linear series of Mississippi Valley-type Zn-Pb deposits occurs within deformed and thrust-faulted Silurian-Devonian carbonates adjacent to the shelf front in the northern Canadian Rocky Mountains, east of a belt of Late Devonian shale-hosted, sedimentary exhalative (SEDEX) deposits. Farther east, minor sulfide minerals accompanies secondary coarse dolomite in petroleum reservoirs of the Western Canada Sedimentary Basin. The age and tectonic setting of the Cordilleran Mississippi Valley-type deposits are poorly known; two competing models ascribe them alternatively to Devonian-Mississippian or to Cretaceous Laramide orogenic processes.

This paper addresses the regional metallogeny of the Mississippi Valley-type deposits of the northern Canadian Rocky Mountains in terms of three issues: timing of mineralization, isotopic characterization, and tectonic setting. Rb-Sr data on sphalerite from the most significant deposit in the northern Rocky Mountains Mississippi Valley-type belt, the Robb Lake Zn-Pb deposit, although showing considerable scatter owing to heterogeneous $^{87}Sr/^{86}Sr$ values in primary fluids, suggest that it is Paleozoic. These data are consistent with the published Pine Point Rb-Sr isochron, which indicates a Late Devonian age (362 ± 9 Ma) for Zn-Pb mineralization, and they favor Devonian-Mississippian rather than Cretaceous orogenic models.

Isotopic data were collected to fill gaps in the data set from occurrences of Zn-Pb sulfides throughout the Western Canada Sedimentary Basin. New analyses of stable (C, O) and radiogenic (Sr) isotopes in carbonates from the Robb Lake deposit are compared with the extensive existing data set from the subsurface Western Canada Sedimentary Basin. New galena and sphalerite lead-isotope data from drill cored intervals of subsurface Devonian carbonates of the Western Canada Sedimentary Basin are compared with published data on outcrops of Mississippi Valley-type deposits. Values of $\delta^{18}O$ for Robb Lake hydrothermal dolomite range from –13.8 to –15.6 per mil Pee Dee belemnite (PDB), and $\delta^{13}C$ ranges from –1.7 to –0.8 per mil (PDB), similar to the lowest values for secondary dolomites in the Presqu'ile barrier and Manetoe facies of the Western Canada Sedimentary Basin to the northeast. $^{87}Sr/^{86}Sr$ values in Robb Lake hydrothermal dolomite range from 0.7118 to 0.7178, higher than the values of the host limestone and dolostone (0.7092 to 0.7097), but similar to the range of values (0.7108–0.7173) of the sphalerite-hosted fluid inclusions. All the $^{87}Sr/^{86}Sr$ values are radiogenic relative to average secondary dolomites within the Western Canada Sedimentary Basin. The radiogenic strontium, along with low $\delta^{18}O$ and $\delta^{13}C$ values, can be ascribed to relatively high temperature fluids, and also to the influence of siliciclastic sources. Although such fluids are commonly linked to deep burial during Cordilleran deformation, they could also have originated as hydrothermal solutions channeled along intrabasinal faults.

The characteristic linear, highly radiogenic lead isotope signature of the exposed northern Rocky Mountains Mississippi Valley-type belt is also found in galena from Devonian carbonates in the Western Canada Sedimentary Basin, along the Presqu'ile barrier and as far east as western Alberta. By contrast, several subsurface samples, including one from directly above the McDonald-Hay River fault, gave uniform, unradiogenic values, identical to the Pine Point cluster. These two strongly contrasting lead populations suggest that two separate fluid sources or pathways existed in the Western Canada Sedimentary Basin.

Rb-Sr geochronologic data suggest that the carbonate-hosted Mississippi Valley-type Zn-Pb deposits were coeval with Late Devonian SEDEX Zn-Pb sulfides, while the other isotopic data sets support continuity among the northern Rocky Mountains Mississippi Valley-type ore, SEDEX ore to the west, and hydrothermal dolomite in Western Canada Sedimentary Basin. Devonian-Mississippian tectonics on the western margin of North America were dominated by long-lived regional extension caused by slab rollback, which generated back-arc and intra-arc spreading and exhalative activity. Given this tectonic framework, we propose that carbonate-hosted Zn-Pb deposits and hydrothermal dolomite in the Canadian Cordillera and the Western Canada Sedimentary Basin were far-field effects of subduction, and that fluids were driven along both reactivated back-arc structures and permeable stratified units.