Formation waters and brines from the NW part of the Western Canada Sedimentary Basin

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Formation waters from the southern and central parts of the Western Canada Sedimentary Basin (WCSB) have received much attention in the literature. Here we report new data from the largely unstudied petroleum-rich NW part of the basin. Formation waters there are divided into three principal groups: Cretaceous, Mississippian/Triassic, and Devonian. Group I waters (Cretaceous strata) comprise a mixture of sea water and Laramide meteoric waters. Group II (Mississippian to Triassic) exhibit both lateral and vertical variability. Mississippian and lower Triassic strata from the central and southern parts of the area contain predominantly Na-Cl brines that consist of ancient sea water and/or pre-Laramide meteoric water. These brines acquired solutes by dissolving evaporitic minerals. Limited incursion of low salinity fluids, likely from the overlying Cretaceous strata, occurred in the Montney, Doig, and Halfway formations. In contrast, upper Triassic strata are dominated by a mixture of Na-Cl brines and low salinity fluids. To the north selected Mississippian formations (e.g. Debolt) are flushed completely with low salinity waters. Group III fluids (Devonian) comprise a mixture of Ca-Cl evaporitic brines of apparent Devonian sea water origin and Na-Cl brines that acquired salts by halite dissolution. Remarkably, some Devonian formations (e.g., Jean Marie and Pine Point) have remained closed to Laramide water influx even in areas proximal to the N edge of the basin. This study provides interesting new insights into the origin and evolution of aqueous fluids within the Western Canada Sedimentary Basin.

The triplite-wagnerite group: A modulated series

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The space group for wagnerite $(Mg,Fe)_2PO_4(F,OH)$ was considered to be $P2_1/c$ with a=9, b=12.6, c=11.9 Å, β=108° until Ren *et al.* [1] reported a new polytype (space group *Ia*, a=9, b=31.5, c=11.9 Å, β=108°) named wagnerite-5*b* as it has a five-fold superstructure along **b** relative to triplite Mn_2PO_4F and zwieselite Fe_2PO_4F (space group *I*2/*a*, a=9, b =6.5, c=12 Å, β=106°).

Single-crystal X-ray diffraction patterns and chemical compositions were obtained on 38 wagnerite samples formed under conditions ranging from near surface in sediments to high temperatures (granulite facies) and ultrahigh-pressures. We found five commensurate modulated structures (polytypes) in decreasing abundance: 5*b* (21 examples), 2*b* (12), 7*b* (3) and 9*b* (2) and 3*b* (1). Although we tested at least three crystals per sample, we found only one type of superstructure per sample with one exception. Five additionally studied triplite-zwieselite samples from pegmatites showed the 1*b* type structure. The crystal structures of all 6 polytypes have been refined from single-crystal X-ray data and imaged by HRTEM.

The main structural difference among the various polytypes is modulation of the (F,OH) arrangement giving rise to different space groups and periodicity along b. F-dominant triplite-zwieselite (mean octahedral radius: > 0.79 Å) has the 1*b* polytype. The 5*b* polytype prevails in F-dominant, Fe, Mn-rich wagnerite (mean octahedral radius: 0.74-0.79 Å) and in Mg-rich samples (octahedral radius = 0.72 Å) with near F end-member composition. The single 3*b* wagnerite plots among the 5*b* samples but close to the triplite-zwieselite (1*b*) boundary in terms of X_F and mean octahedral radius. Mg-rich wagnerite (octahedral radius = 0.72-0.73 Å) is characterized by the 2*b* polytype, whatever the OH content. 7*b* and 9*b* polytypes are found for compositions stradling the boundary of the 5*b* and 2*b* fields with X_F between 0.84 and 0.98. These broad relationships suggest a major role for compositional control in determining modulation periodicity.

[1] Ren *et al.* (2003) *Can. Miner.* **41**, 393-411.