A genetic model for mineralization of Lower Windsor (Viséan) carbonate rocks of Nova Scotia, Canada[1]

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This paper summarizes and integrates some of the results of a three-year research project on the source, path, and timing of fluid movement within and between sub-basins in Nova Scotia, lower Carboniferous (Viséan) carbonates, and the relationship of these fluids to base metal mineralization. The Kennetcook, Shubenacadie, and Musquobodoits sub-basins in central mainland Nova Scotia and the River Denys sub-basin on Cape Breton Island are, excellent examples of platformal onlapping sedimentation of the larger Maritimes basin. Within each of these sub-basins, one base metal deposit was selected for detailed research. Prior to mineralization, potential host rocks in the four sub-basins contained substantial zones of porosity as a result of various processes. For example, at Walton, synsedimentary breccias provided abundant (open space in the otherwise fine-grained, tight Macumber Formation carbonates. The lower grade mineralization at Gays River was deposited in primary porosity within reefal facies of the Gays River Formation. Both overpressuring and gravity-driven flow have been proposed and tectonic conditions prevalent during the time of mineralization provide permissive support for either process, especially in the Walton and Gays River areas. Tectonic breccias, developed in Macumber Formation carbonates during movements associated with the Ainslie detachment, are the main host of the Jubilee deposit. In all three deposits, however, open-space filling was accompanied by widespread replacement of the host carbonate. With increasing burial, Windsor Group limestones were selectively sideritized at Walton, totally dolomitized at Gays River, and simply lithified at Jubilee. Preore burial temperatures reached 70°C at Walton, 135°C at Gays River, and 65°C at Jubilee.

Timing of mineralization has been determined by a variety of methods indicating that ore fluids entered the Gays River area at about 320 to 300 Ma, the Walton area at 333 to 307 Ma, and the Jubilee area at 330 to310 Ma. Given the uncertainty in the dating methods used, these data are interpreted to indicate overlapping mineralization among the three areas.

The distribution of-deposits and occurrences in the Kennetcook and Shubenacadie-Musquodoboit sub-basins suggest a northerly source of fluids for deposits in these sub-basins; the direction of fluid flow in the River Denys sub-basin remains speculative. Evaporated seawater was the most likely original source of ore fluids, but these were modified during burial by halite dissolution and by reaction with underlying siliciclastic aquifers.

Temperatures of ore-stage deposition decrease from Walton (median ~200°C, range 100-300°C), to Gays River (median ~140°C, range 80°-220°C),and to Jubilee (median ~140°C, range 80°-220°C). The high-temperature, high-salinity ore-forming fluid is interpreted to have entered the host rocks and mixed with, and was cooled by, an ambient low-temperature, high-salinity fluid. Several possible sources of the extraordinary heat in the primary fluid are proposed and include an underlying basalt plate, high. heat-production granites, an increase in geothermal gradient caused by coeval extension, or a combination of these.

Ore fluids appear to have been primarily complex NaCl-$CaCl_2$-KC1-$MgCl_2$-$FeCl_2$, aqueous solutions with lesser amounts of light gases such as CO_2 and CH_4. Hydrocarbons were present in ore-stage fluids at both Walton and Jubilee and more than 99.9 percent of the hydrocarbon occurs as liquid petroleum. Given the high temperatures of these deposits, the presence of liquid petroleum indicates a short-lived mineralizing system, probably on the order of a few hundred thousand years.

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A clear relationship with underlying basement lithologies is indicated by the sub-basin-specific character of Pb and Sr isotopes in ore-stage minerals, suggesting that ore fluids leached metals directly from basement rocks, or more likely, from sediments derived from it.

Isotopic data indicate that sulfur at Walton, Gays River, and Jubilee was derived from the same source, probably deeply circulating sulfate-rich brines. The data also suggest that sulfate reduction at Gays River must have taken place away from the deposit area whereas data from the Walton and Jubilee deposit suggest *in situ* thermochemical reduction of sulfate by hydrocarbons.

Compared with other Carboniferous, carbonate-hosted deposits in Newfoundland and Ireland, those in Nova Scotia are considerably younger, relative to their host rocks; are more inhomogeneous, in terms of $^{206}Pb/^{204}Pb$ ratio than those in Newfoundland but compare well with those in Ireland; posses Pb isotope compositions which plot above the Stacey-Kramer growth curve whereas those in both Newfoundland and Ireland plot below it; and exhibit fluid inclusion temperatures and salinities comparable with those of Newfoundland deposits but many are hotter and most are more saline than those of deposits in Ireland. Collectively, the following common parameters are suggested for deposits in all three localities: (1) formation of most, if not all, by replacement of lithified carbonate rocks; (2) derivation of metals from directly underlying basement rocks, resulting in the control of ore-lead isotope compositions according to age and composition of basement lithologies; and (3) ore-stage mineralization at temperatures higher than those typical of Mississippi Valley-type deposits but lower than those typical of sedimentary exhaltive deposits.