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Fracturing and carbonate mineralization in Paleozoic carbonates in Southwestern Ontario, Canada: origin and evolution of basinal fluids

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Integrated petrography, stable carbon and oxygen isotopes, strontium isotopes and rare earth elements (REE) geochemistry as well as fluid inclusion microthermometry of diagenetic minerals from the Paleozoic carbonates of southwestern Ontario, Canada provide new insights into the nature of fluids affecting these rocks and their spatial and temporal relationships. Fractures in the Paleozoic succession had an important role in reservoir enhancement, channelling of diagenetic fluids and migration of hydrocarbons.

The spatial patterns, extent of dolomitization and dolomite petrography indicate that different hydrologic systems were responsible for dolomitization in each of the stratigraphic intervals considered. Fine-crystalline Devonian and Silurian dolomite formed in early stages of diagenesis, whereas coarse-crystalline, fracture-related Ordovician dolomite formed at later stages of diagenesis in burial environment and in the presence of hydrothermal fluids.

The distinct δ18Ofluid, δ13C, ΣREE values, and REESN patterns of dolomite from each age interval suggest compartmentalization of diagenetic fluids. The δ18Ofluid and 87Sr/86Sr ratios indicate diagenetic fluids in each strata originated from coeval seawater and evolved through water/rock interaction. The more positive δ18Ofluid calculated from dolomite δ18O values and the high salinity of Ordovician and Silurian brines and less radiogenic 87Sr/86Sr ratios of Ordovician dolomite relative to those of coeval seawater indicate mixing of Ordovician and Silurian connate waters with 18O-enriched fluids influenced by dissolution of Silurian evaporites.

The significantly higher dolomite Th values (75 to 120°C) from Devonian to Ordovician units relative to inferred maximum burial temperature (60 to 90°C) of these strata suggest involvement of hydrothermal fluids in the precipitation and/or recrystallization of dolomite. The presence of hydrocarbon-bearing fluid inclusions with high Th values (>80°C) in late-stage calcite cements from Devonian to Ordovician and their negative δ13C values (approaching –32‰ VPDB) implies that hydrothermal diagenetic fluids carried hydrocarbons.

A thermal anomaly along the mid-continent rift during Devonian to Mississippian (Alleghanian orogeny) time likely was the source of excess heat in the Michigan Basin. The potential thermal buoyancy of hot brines was the driving force for migration of hydrothermal fluids from the center of the basin towards its margin through regional aquifers and network of fractures.