Hydrothermal dolomites in Paleozoic rocks of eastern Canada: a story from identification to recent hydrocarbon production record

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In North America, world-class conventional hydrocarbon discoveries in the last decade were made in hydrothermal dolomites of Ordovician (Trenton-Black River play in the Appalachian basin in eastern USA), Devonian (Ladyfern and Tay River discoveries in the Western Canadian sedimentary basin) and, speculatively to Mesozoic (Deep Panuke in the Atlantic margin of Nova Scotia) age rock units.

Controversies exist on the exact definition and criteria for recognition of hydrothermally altered carbonates in the rock record. By definition, a hydrothermal fluid has temperatures over that of the ambient burial fluid. A difference of at least 15°C is required to designate such fluid as hydrothermal. Therefore, it is important to note that even if late burial allows the rock unit to be exposed to temperatures higher than those recorded by an early hydrothermal event, it is the difference of temperature at that specific event which is critical for the hydrothermal alteration process. Any later high temperature, sedimentary to tectonic burial events will only serve to mask and render difficult the recognition of hydrothermal alteration.

Whatever the age of the host rock, efficient (e.g., porosity/permeability generating) hydrothermal alteration of a carbonate precursor will follow a rather unique suite of tectono-diagenetic events that will be recorded in an almost ubiquitous mineral paragenetic succession. High temperature and saline fluids will move upwards along early extensional to transtensional faults and flow laterally into a porous precursor carbonate host. It can be demonstrated for most hydrothermal reservoirs that alteration occurred within the first 500–1000 m of burial. The initial faulting will enhance permeability through brecciation. However, an economic reservoir can only be formed if fluids are confined to specific intervals and do not breach any upper seal layer that preserve the integrity of the newly formed reservoir. The high temperature fluids will dissolve a significant volume of limestones and with increased carbonate ion saturation, eventually precipitate the peculiar high temperature saddle dolomite cement, the latter also occuring as a matrix-replacive phase. Following porosity generation and saddle dolomite precipitation, some late calcite and sulphate cements are commonly observed in most hydrocarbon fields. Diverse geoscience tools are used for the recognition of hydrothermal alteration: regional tectonic scenario, petrography and geochemistry of the diagenetic phases and the seismic expression of brecciation known as platform sag.

In 1995, the discovery of a hydrothermal dolomite reservoir in Lower Ordovician rocks in the Port au Port #1 well was a milestone for hydrocarbon exploration in the Appalachians of eastern Canada. Since that discovery, hydrothermal dolomites have been documented in Lower and Middle Ordovician, in Lower and Upper Silurian and in Lower Devonian carbonate rock units in eastern Canada. Small hydrothermal dolomite hydrocarbon fields have been put into production (both oil and gas fields in Lower Devonian Upper Gaspé limestones in eastern Gaspé peninsula) and major Canadian exploration companies have started to extensively explore the Paleozoic belts in eastern Canada looking for hydrothermal dolomite reservoirs.