Carbonate and Sulphate Diagenesis of Upper Devonian Restricted-Shelf Sediments in the Eastern Part of the Western Canada Sedimentary Basin

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Diagenesis of Devonian carbonates has greatly influenced the present hydrogeologic framework and distribution of hydrocarbon reservoirs in the Western Canada Sedimentary basin. The style of diagenesis of these rocks is largely affected by the original rock types and depositional environments. In southeastern Alberta and southwestern Saskatchewan, Upper Devonian carbonates of the Leduc, Nisku and Wabamun formations (and equivalents) were formed in a shallow shelf that had higher salinities than normal seawater as indicated by the numerous interbedded evaporite deposits occurring in this region. The abundance of evaporites generally increases eastward, and anhydrites often form the capping units in numerous meter-scale shallowing upward cycles.

Dolomitization of limestones is pervasive in this region, and most finely crystalline and texture-preserving dolomites are interpreted to have formed during very early diagenesis. $^{87}\text{Sr}/^{86}\text{Sr}$ ratios ($\approx 0.7081$) of these dolomites indicate that seawater was the most probable dolomitizing fluid, and the association with evaporites indicates that the seawater was likely modified through evaporation. Bedded anhydrites also have $^{87}\text{Sr}/^{86}\text{Sr}$ ratios and $^{34}\text{S}$ values that indicate formation from Late Devonian seawater. In addition, many of these evaporites have undergone dissolution at very shallow burial and at greater depth in the subsurface, both of which affected patterns of sedimentation of subsequent deposits. Moreover, subsurface dissolution of these evaporites resulted in solution breccias and probably produced subsurface fluids having a high degree of diagenetic reactivity. The geochemical compositions of these fluids are probably reflected by later anhydrite cements which have similar compositions to the bedded anhydrites, but with some additional contribution from basinal waters indicated by variable and more radiogenic $^{87}\text{Sr}/^{86}\text{Sr}$ ratios ($\geq 0.7083$). Medium-crystalline, planar-replacement dolomites also have a similar range of $^{87}\text{Sr}/^{86}\text{Sr}$ ratios, and may have formed at times overlapping with anhydrite dissolution. Such dolomites are extensive in this region and are found both in close association with, and removed from, evaporitic deposits. The replacement dolomites are petrographically and geochemically very similar to dolomites of the hydrocarbon-bearing reef-trends of central Alberta that essentially obliterate former sedimentary textures, but form porous and permeable reservoirs.

Given the range of depositional environments that existed throughout the WCSB and variations in burial history, there is remarkably uniformity in the O, C, Sr isotopic compositions of the volumetrically major diagenetic phases formed in rocks of this basin. This similarity of geochemical compositions is observed in dolomites from north and south extensions of the central Alberta reef trends, underlying carbonate platforms, and the extensive shallow-shelves of the eastern portion of the WCSB. The generation of subsurface fluids associated with extensive evaporitic deposits in the eastern portion of the basin may have influenced basin-scale processes affecting regional diagenesis. The magnitude of subsurface flow associated with this process is uncertain, but is particularly crucial as regional conduit systems and diagenetic patterns may ultimately affect reservoir quality and the migration of hydrocarbons.