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The Magic School Bus Inside Devonian Dolomites – South Alberta Shelf and Williston Basin

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Broadly dissimilar textures exist among Devonian dolomites over the south Alberta Shelf and Williston Basin. Stratigraphic, facies, and areal distribution of dolomite textures and their relative reservoir characteristics are documented by careful study of more than 400 cores and

3300 thin sections of the Ashern, Winnipegosis, Dawson Bay, Duperow, and Birdbear formations of eastern and north-central Montana, western North Dakota, and southeastern Saskatchewan and the Nisku Formation of southern Alberta. This paper attempts a brief excursion inside Devonian dolomites in the manner of the indomitable, ever unruffled *Ms. Frizzle of The Magic School Bus**. Inferred origins of dolomite textures tentatively proposed herein are based largely on conditions presumed inherent to interpreted depositional and burial environments and on the voluminous literature on dolomite, but very little on critical geochemistry. Nevertheless, whatever the origins of distinct dolomite textures, knowledge of their distribution patterns ultimately proves useful for predicting reservoir seals and the loss, preservation or enhancement of Devonian reservoir porosity and permeability.

Predominantly anhedral-mosaic dolomicrite textures, comprised of interlocking rhombs measuring 10 μm and interpreted to have been deposited under highly saline conditions in salina to peritidal facies, characterize entire formations or members (i.e. Ashern, Grotto) and individual strata or sedimentary infill within other formations (i.e. Winnipegosis, Duperow, Birdbear, Nisku). Tight dolomicrite serves as vertical and updip reservoir seals. Suggested modes of formation are: 1) subaqueous precipitation of dolomite from sub-gypsum brines, 2) syndepositional dolomite replacement of aragonite and calcite existing subaqueously beneath sub-gypsum brines, 3) by repeated wetting and evaporation of sea water over broad tidal flats, or 4) by shallow-burial brine reflux.

Predominantly euhedral dolomicrospar and coarser dolospar textures consisting of rhombs measuring 10-63μm and >63 μm, respectively, having appreciable intercrystalline porosity and often accompanied by moldic, intraskeletal, and vuggy porosity, are developed in marine shelf, biostromal bank, *Amphipora* shoal, lagoon-fill, and peritidal facies. Wide variations in porosity are partly a function of original depositional textures and carbonate constituents. Intercrystalline pores typically measure 10-200 μm in dolomicrospar and 20-500 μm in dolospar, and chalky microporosity is notably rare. These textures, comprising the bulk of Devonian reservoirs, are believed to have resulted from seepage reflux dolomitization; that is, mole-by-mole replacement of aragonite and calcite by dolomite precipitated from sulfate brines substantially enriched in Mg ions and depleted in Ca ions, either in shallow-burial settings or in deep-burial settings where high lithostatic pressures facilitate gypsum-to-anhydrite transformation and expulsion of Mg-rich brines. Other deep-burial mechanisms, including massive invasion of dolomitizing fluids transmitted along major faults and fracture systems or, on a smaller scale, along stylolites and interconnected vugs, may be responsible for most dolomitization or for enhanced dolomitization of the Duperow and Birdbear formations in the Williston Basin.

Relatively uncommon leached or corroded dolomicrospar and dolospar textures may have originated by similar deep-burial processes, but involving vastly different pore-water chemistry. Corroded, porous dolomite textures in the Duperow Formation of the South arch and Sweetgrass arch region of Montana and southern Alberta are accompanied by microvugs, leaching-enlarged molds and vugs, leached and hydrated anhydrite cements, chalcedony and megaquartz replacement of anhydrite cements, and appreciable bitumen residue and pyrite lining voids. Drill stem tests in the Duperow of that region invariably recover quantities of black, sulfurous, fresh to brackish water. These circumstances were likely initiated by post-Laramide uplift and unroofing of the Belt and Little Belt Mountains of Montana and subsequent invasion of microbial-infested meteoric groundwater. Production of the altered Duperow textures and mineralogy and the enormous carbon dioxide and nitrogen-charged Duperow reservoirs beneath Kevin-Sunburst and Utopia domes may have resulted from northward-advancing fronts of organic and/or sulfuric acids generated by microbial degradation of pre-existing, *in situ* hydrocarbons.

Tight, anhedral-mosaic dolomicrospar and dolospar textures are likewise present in all of the above-named facies and in all Devonian carbonate formations. Although these textures may retain isolated molds and vugs, the virtual absence of intercrystalline porosity inhibits permeability, except where locally fractured. Perhaps some mechanisms suggested above had led to "over-dolomitization," but now supplemented by additional calcium, carbonate, and bicarbonate ions supplied from outside the sites of dolomitization, so that dolomitization goes well beyond replacement of pre-existing, *in situ* aragonite and calcite. For example, concurrent vadose-zone leaching of lime mud and clasts and concurrent brine phreatic dolomitization above impermeable hydroseals may account for brecciation, over-dolomitization, and porosity loss in Nisku barrier bank, lagoon fill, and tidal flat facies in southern Alberta. Regional incidence of anhedral-mosaic dolomicrospar and dolospar textures comprising much of the Winnipegosis and Dawson Bay formations within and beyond the Williston Basin, appears less readily explained.

Finally, it is not wholly out of context to consider why particular Devonian carbonate facies were not dolomitized. Winnipegosis platform margin reefs and Birdbear stromatoporoid boundstone and bafflestone facies are typically preserved as tight limestone, in places fortuitously creating reservoir seals in otherwise well dolomitized sequences. Biotic composition and textures of these facies are those most likely to have accumulated under prevailing currents and at least modest wave activity, conditions which would foster syndepositional cementation and micrite lithification. Early lithification and loss of permeability clearly would have either prohibited or inhibited subsequent invasion of dolomitizing fluids.

* The names *The Magic School Bus* and *Ms. Frizzle* are taken from the popular and similarly titled series of children's books written and illustrated by Joanna Cole and Bruce Degen, published 1986-1994 by Scholastic Inc., New York.