

Anatomy of a Porous Diagenetic Stratigraphic Trap in Little Knife Field, North Dakota

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Abstract

Little Knife field is productive from porous, dolomitized, Mississippian Mission Canyon Formation strata, within Glenburn strata (lower reservoir porosity), Mohall strata (middle reservoir porosity), and Sherwood strata (upper reservoir porosity) subintervals. The reservoir is trapped within the Little Knife anticline, a low-lying anticlinal nose that plunges northward and provides structural closure to the north plunging nose ($0.25\text{-}0.5^\circ$), east flank (0.25°), and west flank (0.5°). South and up-dip a lateral stratigraphic trap holds oil-in-place, within: 1) a lateral stratigraphic trap with porous dolomitized strata terminating up-dip into non-porous dolomitized strata, forming a lower reservoir that holds a smaller volume of oil-in-place in Glenburn and Mohall strata; and 2) a porous diagenetic stratigraphic trap that holds a larger volume of oil-in-place in an upper reservoir composed of porous dolomitized Sherwood strata. The porous diagenetic stratigraphic trap consists of depositional and diagenetic components. Sherwood porosity forms a wedge ~ 40 ft (~ 12.2 m) thick to the north that thins to 3 ft (1 m) to the south. Top seal for Sherwood porosity is Bluell evaporite strata and bottom seal is provided by non-porous K-1 dolomitic siltstone Fryburg marker. Sherwood reservoir strata were deposited in an offshore, restricted, shallow marine ramp, composed of bioturbated, sparsely skeletal, peloid-pellet mud-dominated dolopackstone. Thick, porous dolomitized strata, to the north, transition southward into non-porous shoreline shoal complexes of limestone strata, with basal Sherwood porosity extending to the south end of the field and continuing on an additional 30 miles (48.3 km) farther south to Fryburg and Medora fields. At the south end of Little Knife, porous basal Sherwood strata form an effective porous diagenetic stratigraphic trap composed of net fabric that holds the complete Sherwood reservoir volume of oil-in-place. Net fabric looks like a chain link fence. Creation of net fabric was by two phases of dolomitization delivered by a large volume of highly saturated Mg^{2+} -rich brine that swept through porous Sherwood strata. Source of Mg^{2+} -rich brine was from up-dip evaporite strata. First phase of dolomitization precipitated dolomite crystals with nucleation sites closely-spaced around walls of burrow traces to form non-porous–non-permeable, slightly smaller-finely crystalline, anhedral-euhedral, non-planar–planar interlocking dolomite resembling a halo. Second phase of dolomitization was less saturated, with dolomite nucleation sites spread farther apart as burrow trace interiors dolomitized to form porous, sucrosic, slightly larger-finely crystalline, subhedral-euhedral, planar dolomite containing intercrystal and moldic pores within the halo. Resulting net fabric formed tightly interlocking, non-porous–non-permeable dolomite crystals, which created a barrier to fluid flow. While interiors of burrow traces contain porous-permeable, sucrosic dolomite with intercrystal and moldic pores isolated between net fabric. Net fabric extends half-way into the field, but only becomes an effective barrier (aquiclude) at the south edge of the field where it forms a porous diagenetic stratigraphic trap.