Devonian karst aquifer induced vertical fluidization structures in lower McMurray Formation (Aptian) deposits of the northern Athabasca oil sands

Paul L. Broughton
Chevron Canada, Calgary, Alberta T2P 0L7
pbroughton@chevron.com

Abstract

Episodic salt dissolution collapse structuring of the central Bitumont trough during and prior to accumulation of lower McMurray Formation (Aptian) strata induced ascent of the Middle Devonian karst aquifer into overlying Upper Devonian strata. These flows fingered upward along the collapse-fracture network that cross-cut the Upper Devonian strata underlying the central Bitumont trough. The aquifer flows breached many areas of the central-east trough floor.

Hydroplastic mud flows formed and were mobilized upwards along dikes that expanded vertical fractures to accommodate the aquifer-induced flows. These multi-meter long slurry filled dikes cross-cut tens of meters thick Firebag Member strata of the Waterways Formation (Upper Devonian). Dike wall rocks of thinly bedded limestone and friable calcareous shale mechanically and chemically disintegrated to source the upward transported viscous slurries. Prominent upward fluidization flow lines developed with increasing slurry viscosity (Figure 1).

Many of the Upper Devonian dikes opened onto the central Bitumont trough floor. These conduit injected karst waters with lesser amounts of mud into overlying lower McMurray sands and other heterolithic beds as aquifer pressures dissipated. Larger and more voluminous aquifer flows into the overlying sand beds resulted in sand dikes composed of multiple sand fluidization and transport conduits that variously intertwined and coalesced into larger columns (Figure 2). Smaller aquifer flows that breached the trough floors with less pressure and velocity remobilized the lower McMurray deposits into vertical, decimeter to multi-meter long, sand-dominated pillar and elongated mud-dominated ribbon fluidization structures (Figure 3). Grain size sorting resulted in fabrics with unusual vertically oriented color bands. These new types of sand dike and pillar-ribbon structures have been observed only within lower McMurray strata accumulated across structurally low areas of the northeastern Athabasca oil sands deposit.

The east-central Bitumont trough area, such as the JackPine mine, overlies extensive salt dissolution collapse-subsidence that resulted in the lower McMurray strata positioned beneath the oil/water contact. In contrast, the western trough area, such as the Muskeg River and

Aurora North mines, extends over the partial dissolution dissected Middle Devonian salt scarp and remained structurally higher. Oil migrations into the lower McMurray sands accumulated within the western Bitumont trough were sufficiently elevated and removed from the aquifer flows that breached the trough floor eastward. Genesis of sand dike and pillar-ribbon structures was mostly limited to lower McMurray strata that filled the east-central trough areas. The lower structural position precluded trapping oil migrations and therefore subsequent biodegradation into bitumen, but also resulted in these injection structures being more readily visible beneath the oil/water contact.

Figure 1. Hydroplastic mud flow along a dike that cross-cut Firebag Member strata of the Waterways Formation (Upper Devonian). Ascending karst aquifer flows disintegrated wall rocks and sourced the upwardly mobilized hydroplastic slurries along the expanded dike conduits. Prominent upward fluidization flow lines developed as the slurry viscosity increased. Each core box slat is 75 cm long.

Figure 2. Sand dikes developed as numerous intertwined conduits that mobilized fluidized sand upward, often mixed with wall rock. Mud laminar mud ribbons were usually suspended in the flow. Each core box slat is 75 cm long.

Figure 3. Vertical fluidized mud-dominated ribbons (frame) have sinuous to contorted color banded fabrics. The central mud streak passes outward to parallel layers of silt and very fine sand. Each core box slat is 75 cm long.