

## **Sedimentology and Reservoir Characterization of the Mississippian (Tournaisian) Pekisko Formation, Hawk Hills Area, Northern Alberta**

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### **Summary**

The Mississippian (Tournaisian) Pekisko Formation in the Hawk Hills area of northern Alberta is a 25-40 m thick carbonate succession interpreted to have been deposited on a south-facing ramp along the northern margin of the Peace River Embayment. Investigation of the facies architecture suggests that the ramp orientation, semi-enclosed basin configuration and overall transgressive conditions strongly influenced Pekisko deposition. The best reservoir facies are found in the middle to inner ramp lithofacies association (LA 3), typically composed of argillaceous to clean skeletal-peloidal packstones which have microporosity ranging from 15 to 20%. The thickest reservoir packages, up to 13 m thick, are present in the upper carbonate unit in the southernmost part of the study area.

### **Introduction**

The Pekisko Formation is a Lower Mississippian (Tournaisian) carbonate ramp succession that extends from southern Alberta to the District of Mackenzie (Richards et al., 1994). The formation hosts prolific oil and gas reserves and recently has been targeted by a number of companies interested in developing low permeability reservoirs using horizontal drilling technology (Canadian Discovery Ltd., 2010). In northern Alberta, the Pekisko Formation is relatively understudied and little published work is available. This project was initiated as a result of the discovery of a large oil resource in the Pekisko Formation in the Hawk Hills area of northern Alberta and the interest by ARC Resources Ltd. in evaluating the resource potential in the area. ARC's Hawk Hills property has an estimated 30 million barrels per section of original oil in place. However, low permeability, low reservoir pressure and medium to heavy-gravity oil present technological challenges.

The Hawk Hills study area extends from Township 95 to 105 and Range 25W5 to 8W6, with the eastern margin of the study area defined by the Pekisko subcrop edge. The Pekisko Formation in this area is 25 to 40 m thick and commonly composed of massive skeletal-peloidal limestones with local shale beds. The formation is interpreted to have been deposited on a south-facing carbonate ramp along the northern flank of the east-west oriented Peace River Embayment (O'Connell, 1990). Carbonate-shale cycles have been tentatively attributed to basin formation and regeneration due to tectonism in the region of the Peace River Embayment (O'Connell, 1990; Richards et al. 1994). The Pekisko Formation gradationally overlies and laterally grades into the Banff Formation and is, in turn, gradationally overlain by the Shunda Formation (O'Connell, 1990). The Pekisko and Shunda formations together compose a third-order transgressive-regressive cycle (O'Connell, 1990; Brandley & Krause, 1997).

### **Objectives and Methodology**

The primary objectives and methodology of the Hawk Hills Pekisko project include the following:

1) Determination of Pekisko Formation stratigraphy via correlation and mapping of the formation in the Hawk Hills area using wire-line log analysis and correlation to available cores. In the study area, 508 wells

intersect the Pekisko Formation; 43 of these wells also have cores in the Pekisko Formation. Of the cored wells, 24 were selected for detailed core analysis.

- 2) Characterization and interpretation of lithofacies using lithologies, sedimentary structures, textural characteristics, fossil content, grain composition, and porosity determined from cores, thin-sections, and wire-line log analysis.
- 3) Description of diagenetic fabrics and crosscutting relationships, using standard petrographic techniques, and interpretation of paragenesis and relative timing of porosity development.
- 4) Evaluation of the influence of biological processes, paleotemperature, and rock-water interactions on diagenesis via elemental and isotopic (stable C and O; Sr) analyses.
- 5) Evaluation of reservoir characteristics and the controlling factors, based on the integration of lithofacies analysis and diagenetic interpretations.

## Results

Based on detailed core and thin section examination, the Pekisko Formation in the Hawk Hills area has been divided into three lithostratigraphic units, informally named the lower carbonate, middle shaly, and upper carbonate units. An argillaceous marker bed is present within the upper carbonate unit, just below the upper contact of the Pekisko Formation, and is very useful for regional stratigraphic correlation.

Three lithofacies associations, composed of 11 lithofacies, are recognized in the formation. The basal lithofacies association (LA 1) includes: lithofacies A – massive to laminated, argillaceous lime mudstone; lithofacies B – mottled, argillaceous crinoid wackestone; lithofacies C – massive, crinoid lime mudstone; and lithofacies D – laminated lime mudstone. The outer ramp lithofacies association (LA 2) includes: lithofacies E – argillaceous crinoid-brachiopod packstone; lithofacies F – mottled to nodular, crinoid-brachiopod wackestone; lithofacies G – laminated to bioturbated, crinoid wackestone; and lithofacies H – interbedded bituminous skeletal packstone and crinoid wackestone. The middle to inner ramp lithofacies association (LA 3) includes: lithofacies I – burrowed, argillaceous skeletal packstone; lithofacies J – bituminous skeletal packstone; and lithofacies K – skeletal-peloid packstone to grainstone. The three lithofacies associations are typically stacked into meter to decameter-scale cycles, which are either asymmetrical deepening-upward cycles or symmetrical, deepening and shallowing-upward cycles. Several depositional trends were observed from south to north in the study area, including overall thinning, decreasing argillaceous content, and decreasing lithofacies variation in the basin and outer ramp associations.

The cyclicity and lateral trends are tentatively interpreted to reflect both the orientation of the south-facing ramp, flanking the Peace River Embayment, as well as relative sea-level fluctuations. Both cool- and warm-water features have been observed within LA 3, suggesting that temperature-stratified water conditions may have existed during deposition (cf. Brandley & Krause, 1997; Martindale and Boreen, 1997).

Reservoir packages, up to 13 m thick, were identified in the Pekisko Formation in the Hawk Hills area, with the best quality reservoir rocks occurring in the upper carbonate unit. The best reservoir lithofacies are I (burrowed, argillaceous skeletal packstone), J (bituminous skeletal packstone), and K (skeletal-peloidal packstone) of the middle to inner ramp association (LA 3), which have 15-20% microporosity. Up-ramp, towards the north, porosity and overall reservoir thickness decrease within these lithofacies.

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