Characterizing Subsurface Aquifers to Support Development of Horn River Basin Shale Gas, Northeastern British Columbia

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Introduction

Devonian shales of the Horn River Basin (HRB) in northeastern British Columbia host one of the leading shale gas plays in North America. Development plan includes drilling of up to 16 multileg horizontal wells from a single drilling pad, and conducting up to 16 staged frac (hydraulic fracture stimulation) jobs in each horizontal leg. Each frac injects up to 4000 m^3 of water into the reservoir, along with chemicals and proppants to ensure that the rock is effectively fractured, and that fractures remain open. Upon completion, the well flows back some of this water, contaminated by the injected chemicals.

Thousands of wells will be drilled to fully develop the HRB shale gas play. Enormous volumes of water will be required for reservoir stimulation, and safe disposal must be ensured for large volumes of produced water. Deep subsurface aquifers, carrying non-potable water and lying far below the water table, represent ideal water sources and sinks. Shallower aquifers, such as buried valley fills associated with Quaternary glaciation and drainage, are less desirable targets, as there is less separation from surface and well waters. Surface waters may serve as isolated, short-term water sources, but surface disposal of frac fluids cannot be contemplated.

To determine whether subsurface aquifers have sufficient water volumes and flow capacity to support long-term shale gas development, comprehensive regional mapping and reservoir characterization was undertaken by Petrel Robertson Consulting Ltd., under the direction of Geoscience BC and the Horn River Basin Producers Group (HRBPG).

Regional Setting

The Horn River Basin lies in northeastern British Columbia, and is bounded to the east and south by Devonian carbonate platforms (Fig. 1). To the west, a major structural feature – the Bovie Fault Zone – separates the HRB from the Liard Basin to the west. The HRB continues northward into the Northwest Territories, but land, infrastructure, and regulatory issues currently confine oil and gas activity to the B.C. portion.

Shale gas targets occur in siliceous, organic-rich Evie and Muskwa shale members of the Middle to Upper Devonian Horn River Formation. Westward and northward of the Devonian carbonate platform margins, the Horn River Formation forms the basal part of a thick Mississippian – Devonian shale section (Fig. 2). Stacked carbonate ramps/platforms of the Mississippian Rundle Group and Debolt Formation can be mapped across the Horn River Basin. Cretaceous Buckinghorse shales lie unconformably on the Mississippian carbonates, except on the southern and eastern margins of the Basin, where basal Cretaceous sandstones are assigned to the Bluesky and Gething formations, respectively. Quaternary glacial deposits up to 100-150 metres thick cap the Buckinghorse and Upper Cretaceous Dunvegan sandstones and conglomerates, which are preserved locally (Fig. 2).

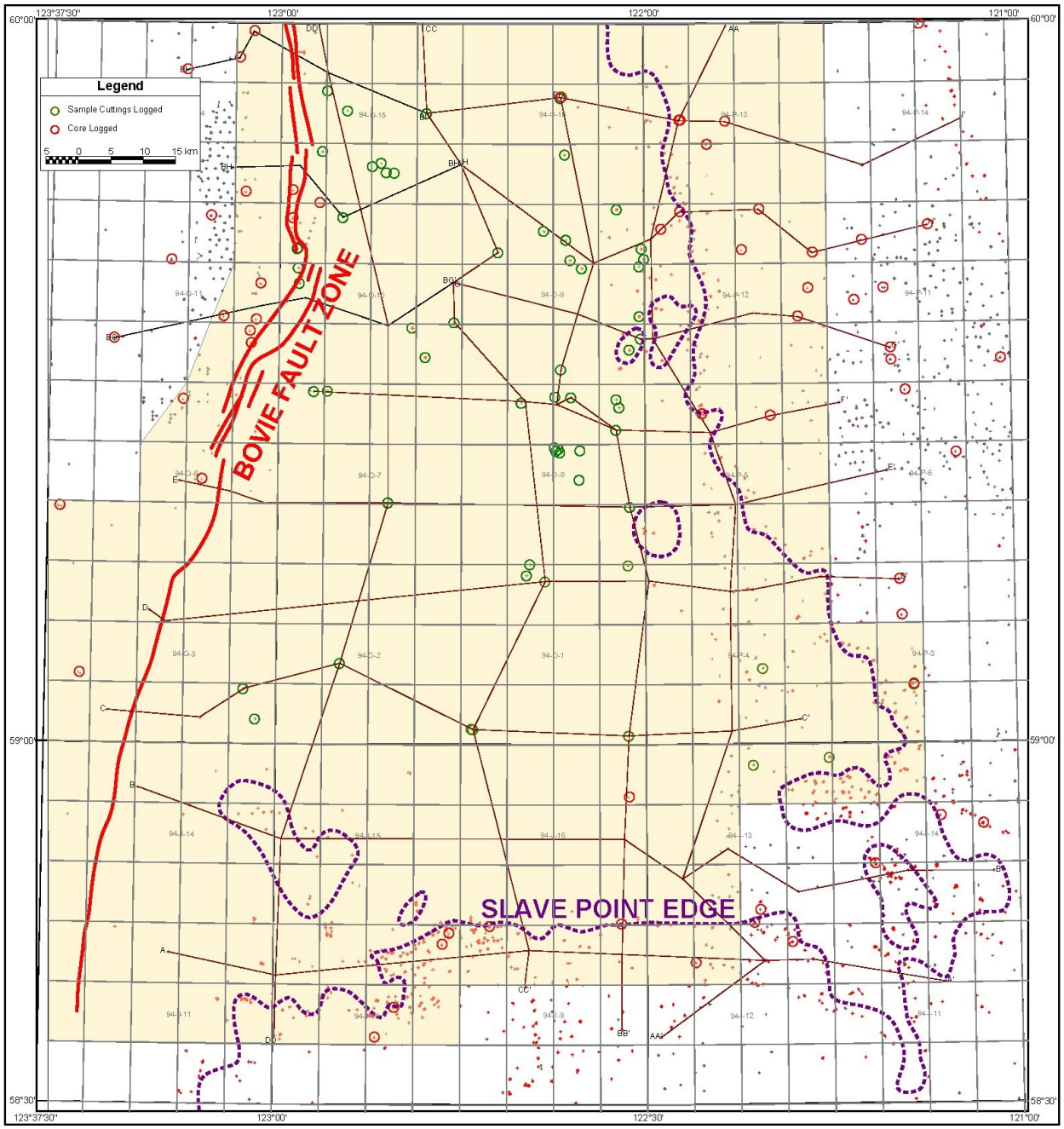

Figure 1. Horn River Basin study area, N.E.B.C. All wells in the yellow map area were included in the study, as were logs and selected data from wells in adjacent areas.

Westward across the Bovie Fault Zone, the top of the Mississippian carbonate ramp drops approximately 1000 metres, and the overlying section thickens correspondingly (Fig. 2). The uppermost Mississippian Mattson Formation, a sand-dominated deltaic succession, lies on the carbonate platform above transgressive Golata shales, and thickens rapidly westward from the BFZ to several hundred metres. Cherts and sandstones of the Permian Fantasque Formation cap an unconformity overlying the Mattson. The Triassic Toad and Grayling formations are primarily siltstone and shale equivalents to the Montney of the Peace River area. Overlying the

pre-Cretaceous unconformity is the basal Chinkeh sandstone, succeeded by Cretaceous shales, and widespread, generally low-quality sandstones of the Scatter and Sikanni formations.

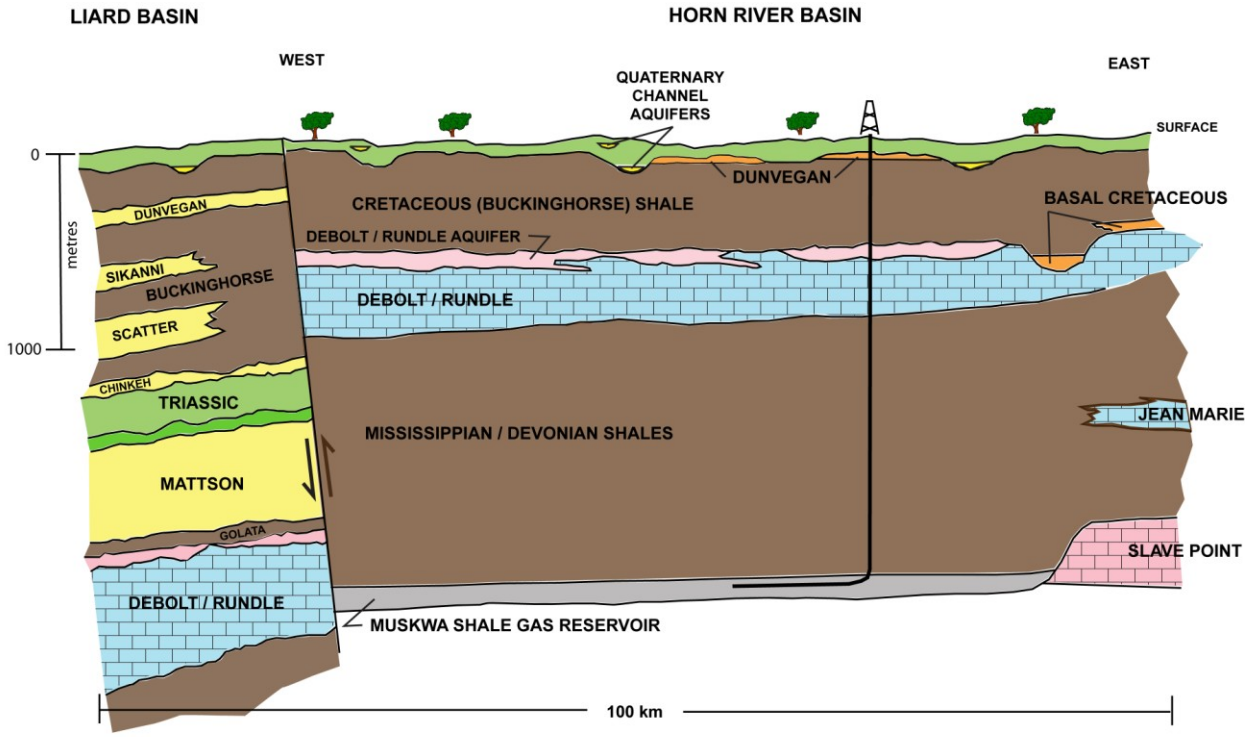

Figure 2. Schematic west-east cross-section across Horn River Basin.

Methodology

Stratigraphic mapping and reservoir characterization were supported by interpretation of well logs, cores, sample cuttings, and well test data. The HRB well database comprises all 556 available wells penetrating the pre-Cretaceous unconformity in the study area. Most of these have been drilled on the basin margins for conventional gas reservoirs – there are relatively few wells in the basin proper, and large areas remain virtually undrilled. New wells target the Devonian gas shales, and most recent geological study has focused on their reservoir characteristics. Within the past year, however, operators have drilled water source and disposal wells, and are working toward understanding subsurface aquifers.

To establish a stratigraphic framework, we built 16 regional cross-sections (Fig. 1), establishing correlations from the literature and previous studies, and calibrating them with observations from cores and sample cuttings. Logs from each well were tied to the cross-section grid to interpret stratigraphic tops. We examined all cores that appeared to provide significant reservoir or stratigraphic information; however, very few cores were cut in Mississippian carbonates within the HRB proper, and there is essentially no representation of the uppermost carbonate sections. Core coverage of Mattson reservoirs to the west is similarly scanty.

A project was therefore commissioned, to systematically examine and document drill cuttings from Mississippian carbonates throughout the HRB, and from Mattson sandstone sections near HRBPG lands in the west. JC Consulting Inc. examined cuttings across the prospective section

in relevant wells, and performed semi-quantitative estimates of reservoir porosity and permeability. JMS Geological Consulting prepared samples for standard petrography, SEM imaging, and XRD analysis, to provide additional reservoir characterization information.

Regional hydrostratigraphy and flow characteristics were examined by Canadian Discovery Ltd., which compiled available well test data, including flow and injectivity test data supplied by HRBPG members on their new water source wells within the basin.

Incorporating all these data and interpretations, PRCL produced regional maps of key stratigraphic surfaces and intervals throughout the aquifer section. Core and sample data were tied to logs to estimate reservoir quality, which was also systematically mapped. Finally, reservoir maps were combined with hydrogeological interpretations to generate a basin-scale aquifer characterization.

Preliminary Results

Final results were released to HRBPG members in early 2010, and will be held confidential for a period of time to protect the confidentiality of data supplied to the project. However, the following observations can be made:

- Mississippian platform carbonates (Debolt / Rundle) show excellent aquifer potential in many areas of the Horn River Basin. The best and most continuous reservoir quality is found immediately beneath the pre-Cretaceous unconformity, where solution and dolomitization are most consistently developed. There are clear stratigraphic controls on the distribution of these aquifer rocks.
    - Enormous volumes of water – billions of cubic metres – are hosted by Mississippian carbonates with enhanced reservoir quality
    - Water salinities range from about 15,000 to 40,000 ppm – definitely not potable, but suitable for frac operations
    - DST and production / injectivity tests indicate excellent permeabilities associated with the leached / dolomitized carbonates

- Uppermost Mississippian clastics of the Mattson Formation thicken rapidly west of the Bovie Fault Zone on the western flank of the Horn River Basin, and provide locally good aquifer potential in that area

- Cretaceous valley fill (Gething) and shoreface (Bluesky) sandstones exhibit lower-grade aquifer potential along the eastern and southeastern flanks of the Basin. Similarly, basal Cretaceous Chinkeh sandstones on the western side of the Bovie Fault Zone offer lower-grade aquifer potential.

Acknowledgements

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