Horn River Basin Aquifer Characterization Project, Northeastern British Columbia (NTS 094I, J, O, P): Progress Report

B.J.R. Hayes, Petrel Robertson Consulting Ltd., Calgary, AB, bhayes@petrelrob.com

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Introduction

Devonian shale units of the Horn River Basin (HRB) in northeastern British Columbia are the focus of one of the leading shale gas plays in North America. Economic gas production from these shale units requires drilling of up to 16 multileg horizontal wells from a single drilling pad, and conducting up to 16 staged hydraulic fracture stimulation (frac) jobs in each horizontal leg. Each frac injects up to 4000 m^3 of water into the reservoir, along with chemicals and proppants (generally high-grade silica sands) 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 (fracing) and safe disposal must be ensured for equally huge volumes of produced water. Deep subsurface aquifers, carrying nonpotable water and lying far below the water table and domestic water wells, represent ideal sources and sinks for the water volumes required. 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 water may serve as isolated, short-term water sources, but surface disposal of frac fluids will not be contemplated.

The petroleum industry is in its infancy in the HRB, and so suffers from lack of well control and other information to support characterization of subsurface aquifers. While numerous wells 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 shale units, and most new geological studies have focused on their reservoir characteristics. Within the past year, however, many industry operators have begun to drill water-source and disposal wells on their properties, and are working toward understanding subsurface aquifers as potential water sources and sinks.

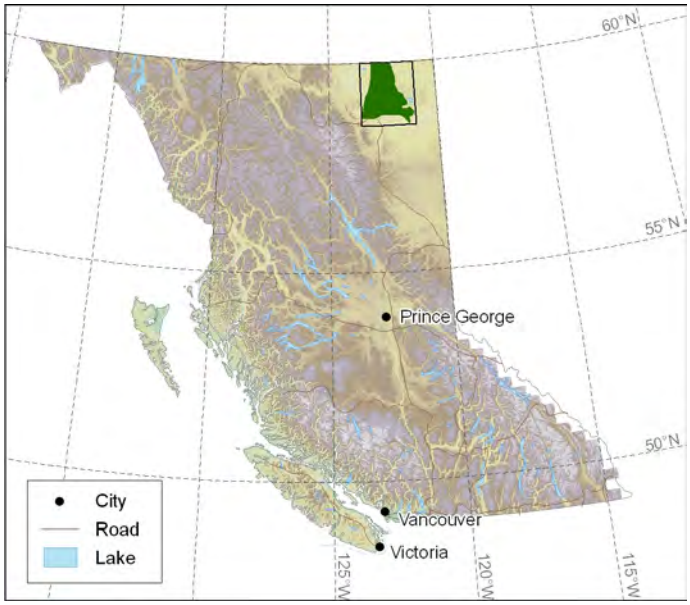

Figure 1. Location map showing the Horn River Basin (in green) and study area (outlined in black), northeastern British Columbia.

To determine whether subsurface aquifers have sufficient water volumes and flow capacity to support long-term development in the HRB, comprehensive regional mapping and reservoir characterization is required. The Horn River Basin Producers Group (HRBPG), a consortium of industry operators, recognized this issue in 2008, and asked Geoscience BC to undertake such a study. Geoscience BC commissioned Petrel Robertson Consulting Ltd. (PRCL) to develop a project workplan, manage the collection of test data from new HRBPG wells, undertake the required technical work, and to produce a report summarizing the findings.

Regional Setting

The HRB lies in northeastern BC, and is bounded to the east and south by Devonian carbonate platforms (Figure 1). The

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Bovie fault zone (BFZ), a major structural feature, separates the HRB from the Liard Basin to the west. The HRB continues northward into the Northwest Territories, but land, infrastructure and regulatory issues confine oil and gas activity to the BC portion (Moore, 1993).

Shale gas targets of the HRB occur in the 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 Devonian–Mississippian shale section (Figure 2; Moore, 1993). Stacked carbonate ramps and/or platforms of the Mississippian Rundle Group and Debolt Formation prograde across the Horn River Basin, passing basinward into the Prophet and Besa River formations to the west and north (Richards et al., 1993). Cretaceous Buckinghorse Formation shale units lie unconformably on the Mississippian carbonate rocks, except on the southern and eastern margins of the basin, where basal Cretaceous sandstone units are assigned to the Bluesky and Gething formations, respectively. Quaternary glacial deposits up to 100–150 m in thickness cap the Buckinghorse Formation shale units and Upper Cretaceous Dunvegan Formation sandstone and conglomerate units, which are preserved locally (Figure 2; Stott, 1982).

Westward across the BFZ, the top of the Mississippian carbonate ramp drops approximately 1000 m, and the overlying section thickens correspondingly (Figure 2; Monahan, 1999). The uppermost Mississippian Mattson Formation, a sand-dominated deltaic succession, lies on the carbonate platform above transgressive Golata Formation shale units, and thickens rapidly westward from the BFZ to a maximum thickness of several hundred metres. Chert and sandstone units of the Permian Fantasque Formation cap an unconformity overlying the Mattson Formation. The Triassic Toad and Grayling formations are primarily siltstone and shale equivalents to the Montney Formation of the Peace River area (Monahan, 1999). Overlying the pre-Cretaceous unconformity is the basal Chinkeh Formation sandstone, succeeded by Cretaceous shale units, themselves punctuated by widespread, generally low-quality sandstone units of the Scatter and Sikanni formations (Leckie et al., 1991; Leckie and Potocki, 1998).

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 available wells penetrating the pre-Cretaceous unconformity in the study area, 556 wells in total.

To establish a stratigraphic framework, 16 regional cross-sections were constructed (Figure 3), 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. All cores that appeared to provide significant reservoir or stratigraphic information were

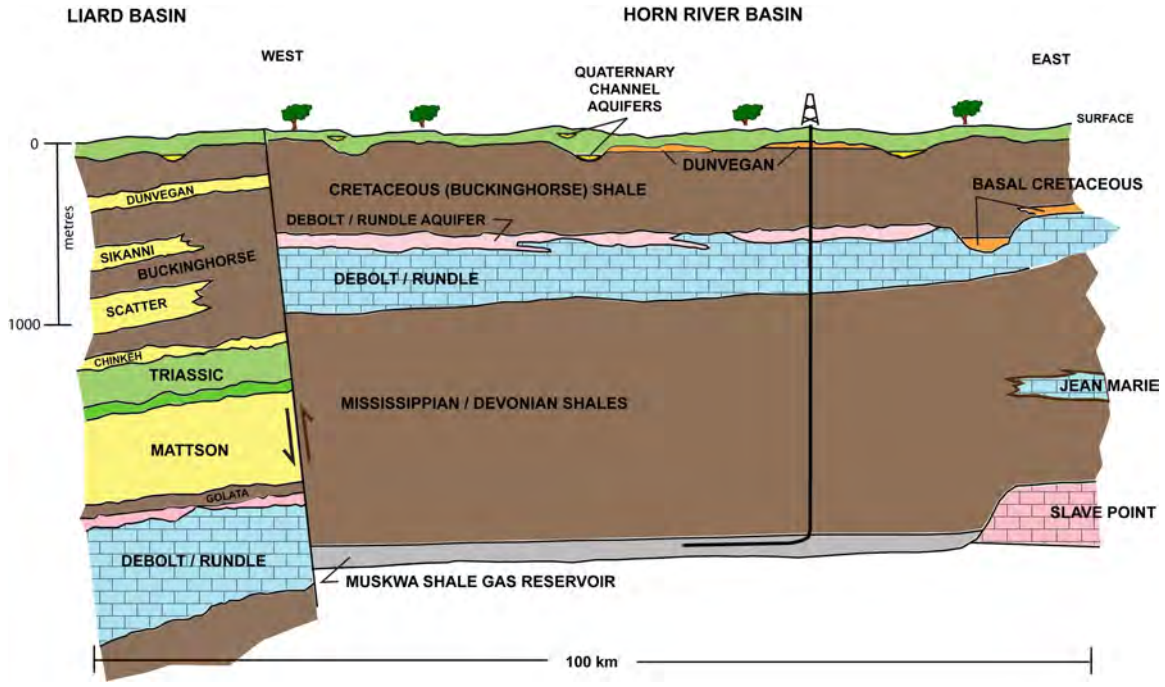

Figure 2. Schematic stratigraphic cross-section, Horn River Basin and adjacent Liard Basin, northeastern British Columbia.

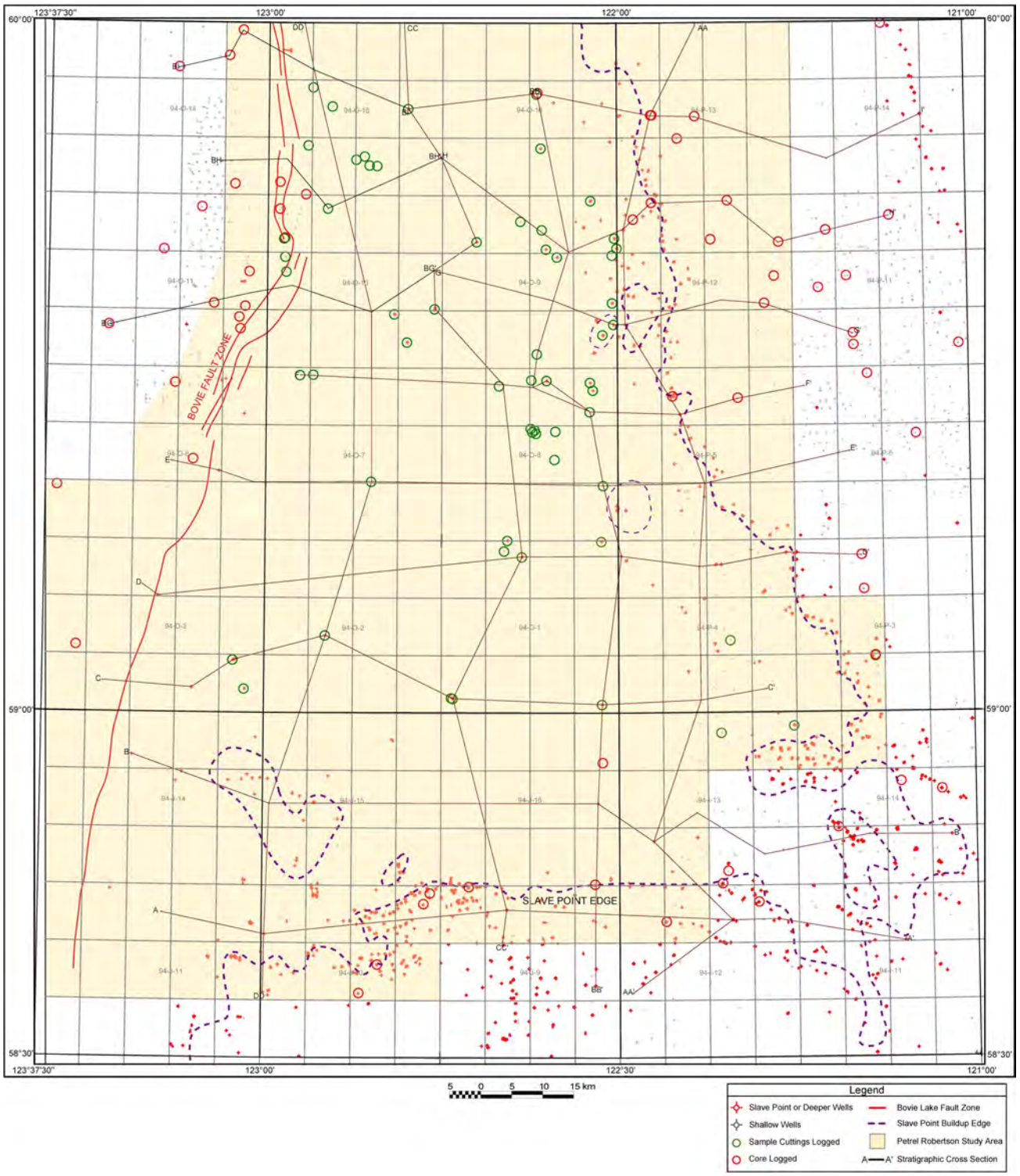

Figure 3. Locations of cross-sections, core logs and sample cuttings logs, Horn River Basin, northeastern British Columbia.

examined; however, very few cores were cut in Mississippian carbonate rocks within the HRB proper, and there is essentially no representation of the uppermost carbonate sections. Core coverage of Mattson Formation reservoirs to the west is similarly scanty.

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

spective section in relevant wells, and performed semiquantitative estimates of reservoir porosity and permeability. JMS Geological Consulting prepared samples for standard petrography, scanning electron microscope (SEM) imaging and X-ray diffraction (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 of each key unit.

Preliminary Results

Project results are scheduled for release to HRBPG members in late 2009, and will be held confidential for a period of time to protect the confidentiality of data supplied to the project. However, a few general observations can be made at this point:

Mississippian platform carbonate rocks (Debolt Formation/Rundle Group) show good 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 is most consistently developed. There are clear stratigraphic controls on the distribution of these aquifer rocks.

Uppermost Mississippian clastic rocks 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 Formation) and shoreface (Bluesky Formation) sandstone units exhibit lower grade aquifer potential along the eastern and southeastern flanks of the basin. Similarly, basal Cretaceous Chinkeh Formation sandstone units on the western side of the Bovie fault zone offer lower grade aquifer potential.

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