



## **Petroleum Resource Assessment of the Alberta Basin Using 4-D Petroleum System Models**

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### **Summary**

The U.S. Geological Survey assessment of undiscovered resources for conventional and continuous (unconventional) oil and gas in the Western Canada Sedimentary Basin (WCSB) will be based on the geologic elements of each Total Petroleum System (TPS) defined within the province, including petroleum source rocks (source-rock maturation, oil and gas generation and migration), reservoir rocks (depositional setting and petrophysical properties), and hydrocarbon traps (trap formation and timing). 1-D and 4-D petroleum system models of the WCSB will also be incorporated in the assessment. Advantages and disadvantages of incorporating modeling for assessments are listed in Higley et al. (2006). Figure 1 shows the petroleum system model area within the WCSB. The WCSB includes the Alberta Basin, northwest extension of the Williston Basin, and the Rocky Mountain deformed belt (Figure 1). WCSB assessment area and results from the 2000 assessment are in USGS World Energy Assessment Team (2000). The WCSB reassessment will include oil and continuous accumulations, which were not assessed in 2000.

The WCSB in the model and for the upcoming assessment is subdivided vertically and laterally into petroleum systems. Included strata have been grouped by similar reservoir, source, or seal characteristics. Modeled strata were subdivided vertically and laterally with assigned lithofacies based on Mossop and Shetsen (1994) and other publications. Modeled formation layers have been published as grid files (Higley et al., 2005). The 4-D model uses pressure, temperature, and volume changes through time, combined with flow path (lateral) and Darcy flow to calculate and display oil and gas generation, expulsion, migration, accumulation, and loss for all included source and reservoir formations. Models must be calibrated to measured thermal maturation and geologic/geochemical data, which are documented in Higley et al. (2009).

Structural relief on the top of each reservoir layer is the primary control on migration pathways for oil and gas that (1) is not trapped in the reservoir layer, (2) does not breach bounding seals, or (3) escapes along open faults. Also critical are location of reservoir strata relative to vertical and lateral seals, and to thermally mature source rocks. One modeling limitation is that much of the oil and gas in the WCSB is stratigraphically

trapped, which is more difficult to model than structural accumulations, particularly at basin scales. The petroleum system software also cannot readily model biogenic gas traps or updip biodegradation seals, such as for oil sands.

The Alberta portion of the WCSB has three major petroleum systems based on model results. Upper boundaries of these systems are the Devonian Woodbend Group, the Lower Cretaceous Mannville Group, and the Upper Cretaceous Colorado Group. This grouping is somewhat generalized because of mixing of petroleum from numerous source rocks in some accumulations. One example of modeled contributions from Devonian-Mississippian through Lower Cretaceous source rocks is the oil sands of northern Alberta; termination of Devonian through Jurassic source rocks against the sub-Mannville Group angular unconformity resulted in contributions of oil from numerous source rocks (Higley et al., 2009). The Jurassic Fernie Group is the primary and initial source of oil for the oil sands, and the oil sands are located at focal points of modeled migration pathways. Early generation of oil from the Jurassic, prior to that from older and deeper source rocks, was due to the high organic-sulfur content of the kerogen. This resulted in onset of oil generation at vitrinite reflectance equivalents of ~ 0.4%.

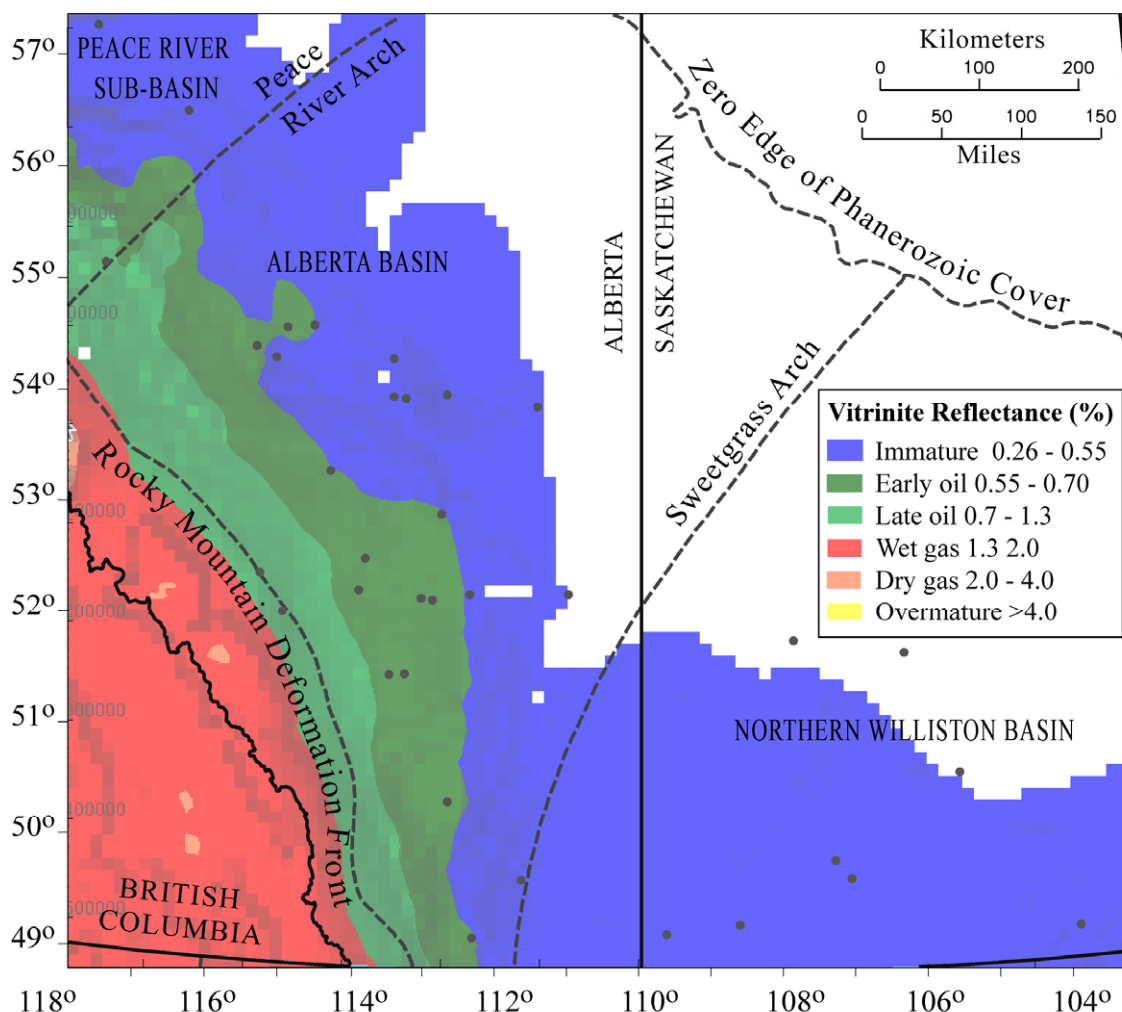


Figure 1. Study area for the 4-D petroleum system model within the WCSB. Modeled vitrinite reflectance ( $R_0$ ) contours on the Devonian-Mississippian Exshaw Formation are shown near maximum burial, at ~ 60 million years ago. Present calculated  $R_0$  is slightly more mature, including the area west of the deformation front being in the dry gas phase. Variable shading results from topography of the 3-D image.

## References

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