Geologic investigation of the Bruce nuclear site for development of a Deep Geologic Repository

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Introduction

Ontario Power Generation is proposing to develop a Deep Geologic Repository (DGR) for the long-term management of its Low and Intermediate Level Radioactive Waste (L&ILW) at the Bruce nuclear site located near Tiverton, Ontario (Figure 1). The objective of an on-going geoscientific site characterization program is to contribute to understanding the evolution of the site and the integrity of the geological barriers as they apply to assessing safety. Specifically, this geological investigation tests the hypothesis that, i) lithostratigraphy across the site is predictable, and ii) the site exhibits a simple structural setting with no evidence of major sub-vertical faulting.

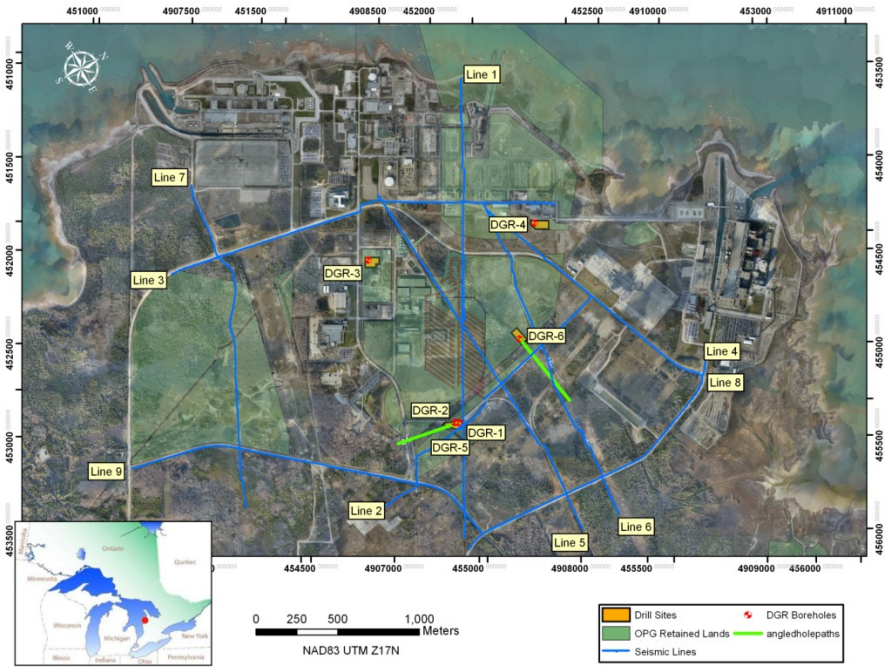

Figure 1: Bruce nuclear site showing 2-D seismic reflection survey lines, vertical (DGR-1, DGR-2, DGR-3, DGR-4) and angled (DGR-5, DGR-6) boreholes surrounding the proposed repository footprint.

Continuous core retrieved from 4 vertical and 2 angled boreholes spaced approximately 1 km apart (Figure 1) confirms that the Bruce nuclear site is underlain by an approximately 840 m thick Paleozoic sedimentary sequence comprised of carbonates, shales, evaporites and sandstones, ranging from Cambrian (543 Ma) to Devonian (360 Ma) in age overlying crystalline basement rocks of the Grenville tectonic province (Figure 2). The L&ILW will be emplaced at a depth of 680 m within Middle Ordovician

argillaceous limestone of the host Cobourg Formation, bound below by more than 150 m of lower Middle Ordovician limestone, and above by more than 200 m thickness of Upper Ordovician shale.

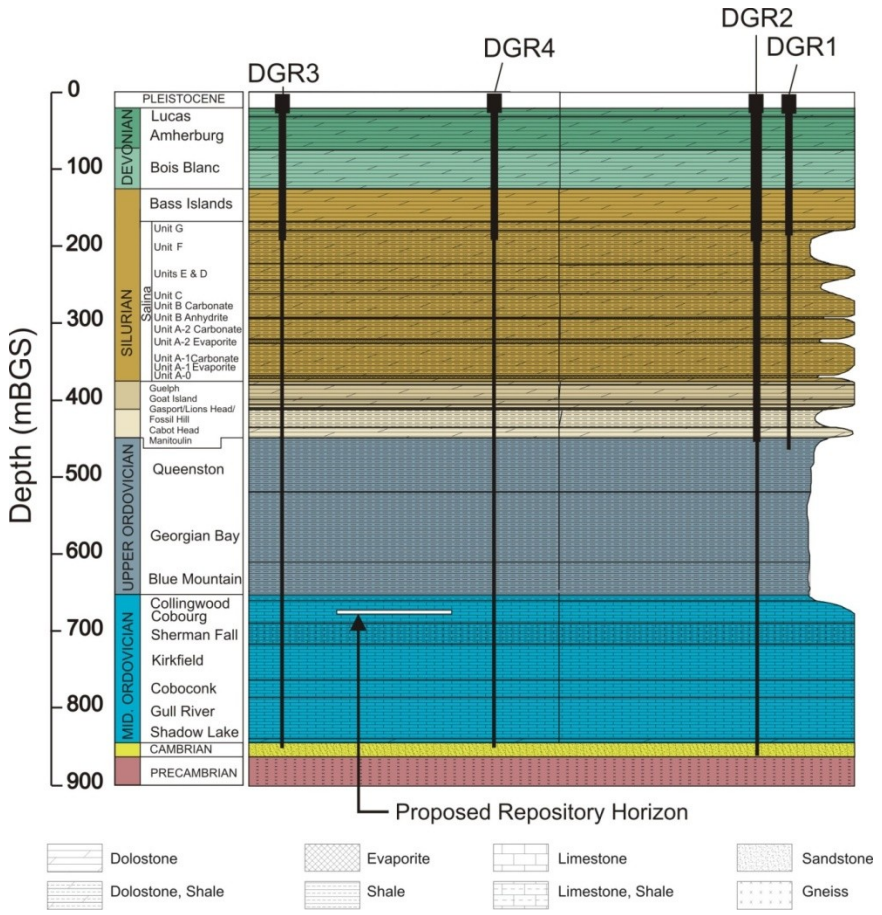

Figure 2: Stratigraphic cross-section at the Bruce nuclear site with projected vertical boreholes indicating depth of subsurface penetration.

Lithostratigraphy

The borehole investigation identified 34 distinct stratigraphic formations, members or units in correspondence with the accepted regional stratigraphic framework. Core workshops were convened to seek expert consensus on the identification and naming of these geological units. Formation thicknesses of the Ordovician host and bounding rocks are consistent with variations less than 5 % across the DGR site. A detailed analysis was undertaken to assess lateral and vertical lithofacies distribution between the boreholes. A comparison of downhole geophysical logs and core logging from the three vertical holes indicates lateral consistency throughout the Ordovician section and that lithofacies are predictable at m-scales or greater. Lithofacies changes occur primarily as small-scale variations in quantities of shale, siltstone or limestone. These results confirm regional predictions that Middle Ordovician paleodepositional environments and corresponding lithofacies vary at a scale larger than the DGR footprint. The predictable lithostratigraphy also suggests that no major syn- to post-depositional structural modification by tectonic faulting has significantly influenced the site. A lack of pervasive hydrothermal dolomite in the Ordovician rocks further supports this interpretation.

There are clear mineralogical associations or trends which can be summarized based on laboratory analyses of core samples. The Upper Ordovician shales are dominated by clays with increasing amounts of quartz with depth and moderate amounts of calcite and dolomite. The Middle Ordovician limestone formations consist of typically greater than 80% calcite, with the remainder being variously composed of clays, dolomite and orthoclase. In all cases the major clay mineral is illite with minor chlorite. The major iron mineral changes with increasing depth in the Upper Ordovician shales from hematite to pyrite indicating a trend towards reducing conditions.

Structural Setting

The site is located in a stable tectonic regime with low seismicity, as confirmed by micro-seismic monitoring. In addition, there are no known active faults in the Regional Study area around the DGR. Distinct Ordovician-aged marker beds are observed within the same stratigraphic interval in all vertical boreholes and exhibit uniformly planar attitudes dipping shallowly-southwest at approximately 0.6 degrees, consistent with those of the bounding formation tops. The regular and consistently low dip magnitude of all layers through the Ordovician section reduces the probability that basement-rooted normal faults with any significant offset exist within this enclosed area.

Interpretation of 19.7 km of 2-D seismic reflection survey data (Figure 1) is consistent with marker bed and lithofacies studies which predict lateral continuity of the stratigraphy across the site. The seismic survey did identify several potential features interpreted as basement-seated faults with minor displacements of 10 m or less. The seismic study concluded, however, that a fault offset in the overlying stratigraphy was not supported by the triangulated borehole structural analysis. The orientations of the two inclined boreholes (Figure 1) were selected in order to intersect and verify the apparent fault zones. The inclined drilling and coring showed no indication of the presence of a fault (e.g., vertical jointing, shear zone, slickensides, mylonitic texture) or fault-related offset in the stratigraphy.

Fracture data from site and regional mapping, and regional fault orientations are consistent in orientation with two major roughly orthogonal joint sets trending ENE and NNW. These data are comparable with preliminary fracture sets measured at depth within the vertical and inclined boreholes. In general, Ordovician shales and argillaceous limestones are very sparsely fractured to unfractured with excellent RQD. The consistency of the fracture dataset at all scales suggests limited post-Paleozoic tectonic activity at the DGR site. In support of the interpreted absence of major post Paleozoic faulting, a neotectonic field investigation found no evidence of seismically-induced sedimentary features within an approximately 50 km radius of the DGR site.

Conclusions

The results of the geological site investigations including an examination of lithofacies demonstrate that the geology is predictable across the DGR site and between boreholes within the DGR footprint. The combined data from marker bed investigations, inclined borehole drilling, 2-D seismic survey, and fracture mapping supports the hypothesis that the DGR site is structurally simple with no evidence of major sub-vertical faulting.