OVERVIEW OF ONTARIO POWER GENERATION'S PROPOSED L&ILW DEEP GEOLOGIC REPOSITORY BRUCE SITE, TIVERTON, ONTARIO

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ABSTRACT

The Nuclear Waste Management Organization on behalf of Ontario Power Generation (OPG) in 2006 initiated a multi-year program of geoscientific studies to confirm the suitability of the Paleozoic sequence beneath the Bruce site, near Tiverton, Ontario, for development of a proposed Deep Geologic Repository (DGR) for its Low and Intermediate Level nuclear Waste (L&ILW). This paper provides an overview of the DGR project and on-going regional and site-specific geoscience investigations.

1 INTRODUCTION

The Nuclear Waste Management Organization (NWMO) on behalf of Ontario Power Generation (OPG) is conducting multi-disciplinary geoscientific studies at the Bruce site to confirm the suitability of the underlying Paleozoic sequence for development of a proposed Deep Geologic Repository (DGR) for Low and Intermediate Level Radioactive Waste (L&ILW) from OPG owned nuclear generating facilities (Figure 1). An Environmental Assessment for the proposed DGR is currently underway in accordance with the Canadian Environmental Assessment Act. Bruce site, situated 225 km northwest of Toronto on the eastern shore of Lake Huron, is underlain by an 850 m thick sedimentary sequence of Cambrian to Devonian age near horizontally bedded, weakly deformed shales, carbonates and evaporites of the Michigan Basin. Within this sedimentary pile, the proposed DGR would be excavated within the low permeability argillaceous limestone Cobourg Formation at depth of 680 m, which is overlain by 200 m of upper Ordovician shale formations.

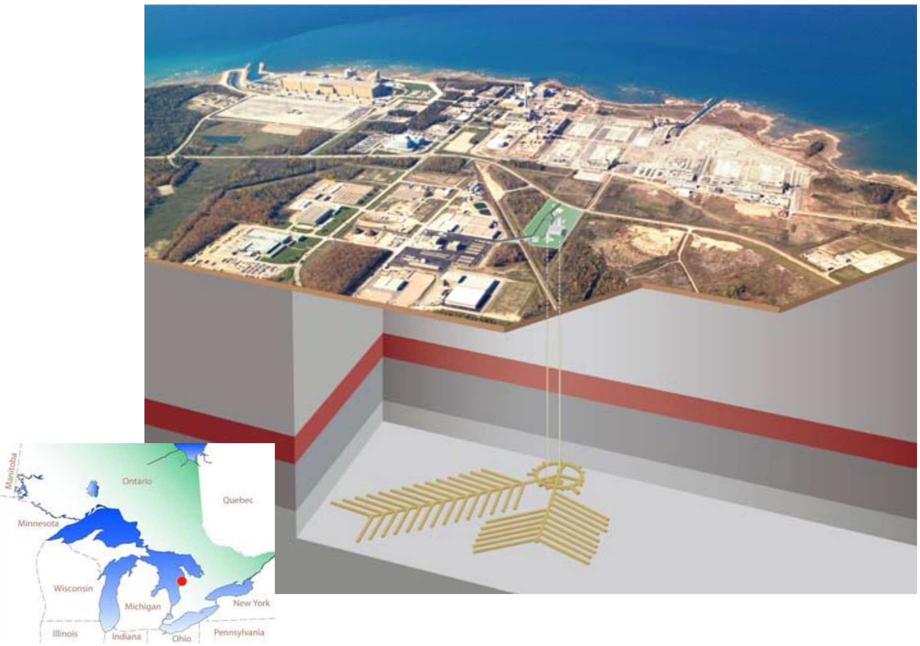

Figure 1: Artist Rendering of Proposed Ontario Power Generation Deep Geologic Repository at the Bruce site, Tiverton, Ontario.

A key aspect of the DGR Safety Case is the integrity and long-term stability of the sedimentary sequence to contain and isolate L&ILW at timeframes on the order of 1Ma. Early in the project, geoscientific studies that considered regional and site-specific public domain data sets indicated favourable geologic conditions for implementation of the DGR concept (Golder, 2003; Mazurek, 2004). In 2006, site-specific investigations were initiated following the development of a Geoscientific Site Characterisation Plan (GSCP) (Intera 2006; 2008). The GSCP represents a stepwise 4-year, multi-phase program of geoscientific investigations that describes site-specific field and laboratory investigations to further develop and test the existing geoscientific knowledge of sub-surface conditions as they relate to understanding geosphere stability and evolution, engineered repository systems design, and long-term DGR safety.

This paper provides an overview of the DGR project and the on-going implementation of the GSCP.

2 BACKGROUND – DGR PROJECT

Ontario Power Generation's Western Waste Management Facility (WWMF) at the Bruce site has received L&ILW from the Pickering, Bruce and Darlington nuclear stations for over 30 years. The waste is stored in engineered above and below ground storage structures depending on the physical and radiological characteristics of the waste. At present there is approximately 70,000 m^3 of L&ILW stored at the WWMF with annual waste arisings of between 2,000 m^3 to 3,000 m^3 following volume reduction (5,000 m^3 to 7,000 m^3 before volume reduction).

The WWMF storage structures have a minimum design life of 50 years and are suitable for the interim storage of L&ILW. Although current storage practices are safe, these wastes will eventually need to be transferred to a long-term management facility as some of the wastes remain hazardous for thousands of years.

Since the mid-1980s, OPG has reviewed a wide range of options for the long-term management of L&ILW, including above- and below-ground repository concepts considered by the Municipality of Kincardine and OPG through an Independent Assessment Study completed in March 2004. The outcome of this Independent Assessment Study was that all L&ILW repository concepts were considered technically feasible. Due to margins of safety, the municipality in spring 2004 selected the DGR concept, which then became the preferred option for long-term L&ILW management.

In October 2004, the Municipality of Kincardine and OPG signed a Hosting Agreement to site a DGR on the Bruce site. This agreement explicitly excludes used nuclear fuel from the DGR. The agreement required a formal survey of community support, which was completed in January 2005. Results of the survey indicated a clear majority supporting the DGR project and a Kincardine Municipal council decision to continue with the DGR Hosting Agreement was affirmed on February 16, 2005.

As envisioned, the DGR would involve the excavation of waste emplacement rooms within the Ordovician age argillaceous limestone Cobourg Formation at a depth of 680-m beneath Bruce site (Figure 1). The repository, accessed via two vertical shafts, would require the excavation of nearly 890,000 m^3 of rock to accommodate an emplaced L&ILW volume of 200,000 m^3 within an approximate 28 Ha repository footprint. Support buildings would be located on ground surface above the underground workings. The current repository concept would consist of a series of emplacement rooms arranged in parallel rows on either side of central access tunnels. A concrete floor will be poured to provide a stable base for stacking of the L&ILW packages.

In July 2005, OPG initiated a process that culminated in the preparation of a Phase I GSCP for the proposed DGR (Intera, 2006). The GSCP provides a comprehensive and internationally peer-reviewed basis for DGR-related geoscientific studies. In this capacity, the GSCP describes surface and sub-surface site characterisation activities necessary to:

- assess and reaffirm the technical suitability of the proposed DGR concept;
- provide evidence on the geoscientific basis for repository safety at timeframes of 1Ma (i.e. stable rock formations; diffusion dominant transport regime);
- yield information to support development of a site-specific engineered repository design;
- provide a geoscientific basis for the post-closure safety assessment; and
- contribute to the development of an integrated DGR Safety Case describing the expected long-term safety and potential impacts of the DGR.

The activities described in the GSCP are intended to support two key deliverables:

- a **Descriptive Geosphere Site Model**, which is an integrated, multi-disciplinary, geoscientific description and explanation of the undisturbed subsurface environ as it relates to site-specific geologic, hydrogeologic and geomechanical characteristics and attributes; and
- a **Geosynthesis**, which is a geoscientific explanation of the overall understanding of site characteristics, attributes and evolution (past and future) as they relate to demonstrating long-term DGR performance and safety.

Upon completion of Phase I investigations in Fall 2008, acquired site knowledge was used to test and revise, as necessary, the GSCP to ensure adequacy for Phase IIab activities (Intera, 2008). Completion of Phase IIab activities is scheduled for early 2010 and pending EA approval, a provisory schedule would seek regulatory approval for DGR construction in 2012 and operation in 2017.

3 GEOSCIENTIFIC BASIS: DGR CONCEPT

The geoscientific basis for the DGR concept is drawn from: i) a site-specific Descriptive Geosphere Model; and ii) international advances in geoscience research related to long-term radioactive waste management in sedimentary environs.

The main elements of the Bruce site Descriptive Geosphere Model are illustrated in Figure 2. This conceptual model understanding is founded principally on studies by Golder (2003), and Mazurek (2004). The Golder (2003) feasibility study assembled public domain geoscientific and precedent underground construction information within the bedrock formations occurring at Bruce site. As shown in Figure 2, a thin layer of glacial and glacio-fluvial sediment is underlain by a near flat lying sequence of laterally continuous Paleozoic carbonates, shales, evaporites and minor sandstones. From a hydrogeologic perspective, the bedrock sequence is divided into 3 distinct horizontally stratified bedrock regimes; i) an upper permeable fresh water carbonate aquifer (0-100 mbgs); ii) an intermediate brackish, moderately permeable stratified aquifer-aquitard system (≈100-400 mbgs); and iii) a deep, saline (TDS 300 g L^{-1}), extremely low permeable sequence of shales and carbonates (≈400-800 mbgs). Within the deep groundwater regime, extremely low formation permeabilities ($<10^{-19}$ m^2), typical Na-Ca-Cl dominant fluids, distinct isotopic ^{18}O – ^{2}H signatures, $^{87}Sr/^{86}Sr$ signatures consistent with a marine origin and long residence times, groundwater viscosities, and environmental heads strongly support the existence of a stagnant, diffusion dominant transport regime.

Mazurek (2004) documents a second assessment that included an international radioactive waste management perspective. The assessment involved a review of international radioactive waste management programmes and repository concepts in sedimentary media, and a compilation of existing and publicly available geoscientific information for southern Ontario. A synthesis of this latter information served as a basis to evaluate the bedrock formation attributes in the light of international experience. This approach adopted the structured NEA FEPCAT framework, which examines multiple and independent lines of reasoning focused on assessing the isolation and containment properties and, long-term geologic, hydrogeologic and geomechanical stability of the setting for radioactive waste management purposes (Mazurek et al, 2003).

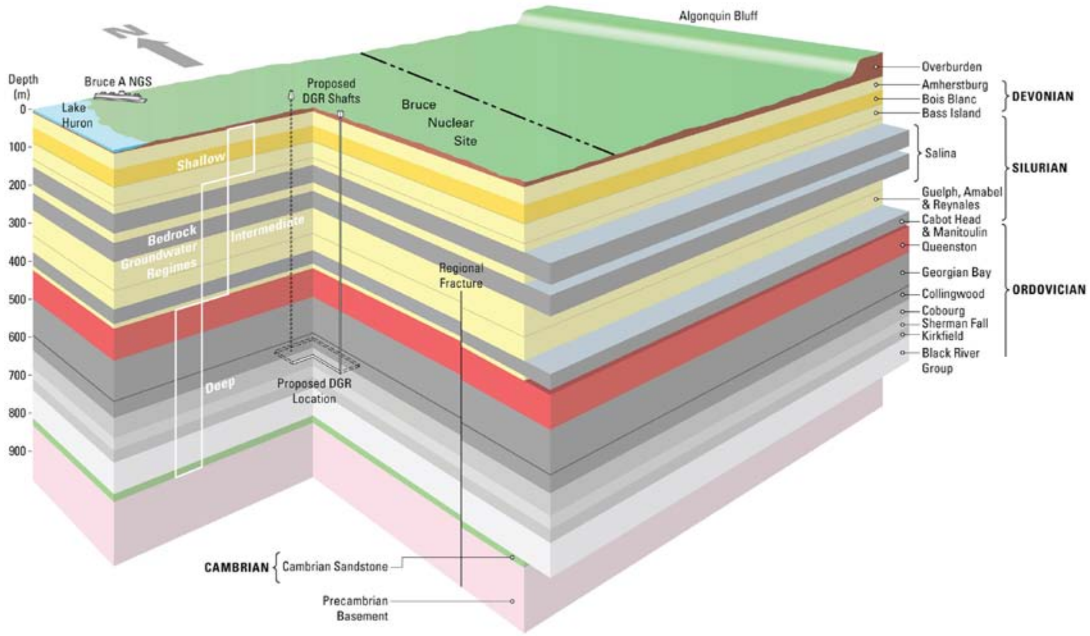

Figure 2: Illustration of Bruce site Descriptive Geosphere Model

Internationally, the understanding of the geoscientific basis for long-term radioactive waste management in sedimentary media has advanced significantly during the last decade (Mazurek, 2004). Radioactive waste management programmes in Switzerland (Nagra), France (Andra), Belgium (Ondraf/Niras), Spain (Enresa) and Japan (JNC) have focused on argillaceous media. Safety Cases or comparable milestones targeted at deep geologic disposal have recently been completed by Nagra, Andra and Ondraf/Niras. The development of these Safety Cases was supported by well established collaborative research programmes at the Mont Terri (Switzerland), Mol/Dessel (Belgium) and Bure (France) Underground Research Laboratories. The key safety related attributes of argillaceous media include:

- horizontally bedded and weakly deformed units in sedimentary sequences, which are geometrically simple and straight-forward to conceptualise;
- target formations are sufficiently homogeneous, which enhances predictability;
- formations possess very low permeabilities, thus mass transport is likely diffusion-dominated;
- transport through the pore space is very slow and sorption on clay minerals retards the migration of many dissolved species;
- the formations possess an ability to self-seal fractures and faults;
- multiple lines of geoscientific evidence indicate the geosphere is robust to long-term perturbations on geologic time scales (*i.e.* erosion, glaciation, permafrost); and

- formations provide sufficient geomechanical stability for safe repository construction and operation.

Among other factors, the application of the FEPCAT methodology to the Paleozoic sediments of southern Ontario considered bedrock lithology, stratigraphy, geologic structure, basin evolution, diagenesis, physical and chemical hydrogeology, regional stress regime magnitude and orientation, seismology, resource potential and geomechanical attributes. Results of the assessment identified the Middle to Upper Ordovician limestones and shales as potential host formations. Specific lines of reasoning that supported this conclusion included:

- The thickness of the Ordovician shales and limestones well exceeds 100 m, a value internationally regarded as a siting preference;
- The degree of vertical and horizontal heterogeneity of geological and hydrogeological attributes in the potential host formations is limited and reasonably well known;
- Hydrogeochemical evidence indicates very long underground residence times for formation pore fluids and no resolvable cross-formational flow or mixing over geological periods of time;
- A surficial fresh-water flow system is underlain by a stagnant hydrogeologic regime. Given the absence of exfiltration areas for deep groundwaters, flow does not occur or is very limited. Solute transport is probably dominated by diffusion;
- Deep infiltration of surficial waters is unlikely due to the high density of brines occurring in the deep underground and due to the presence of several horizontally layered low-permeability formations that confine the more permeable units; and
- Tunnelling in deeply buried shales and limestones appears to be feasible in spite of apparent high horizontal stresses.

Based on the results of Golder (2003) and Mazurek (2004), the principal elements or attributes of the Descriptive Geosphere Model for Bruce site favourable for DGR implementation and to be tested as part of on-going investigations are:

- **Predictable**: horizontally layered, undeformed sedimentary shale and limestone formations of large lateral extent.
- **Multiple Natural Barriers**: multiple low permeability bedrock formations enclose and overlie the DGR.
- **Contaminant Transport Diffusion Dominated**: deep groundwater regime is ancient showing no evidence of glacial perturbation or cross-formational flow.
- **Seismically Quiet**: comparable to stable Canadian Shield setting.
- **Natural Resource Potential Low**: commercially viable oil and gas reserves not present.
- **Shallow Groundwater Resources Isolated**: near surface groundwater aquifers isolated.

4 SITE CHARACTERISATION STUDIES

The Bruce site Geoscientific Site Characterisation Plans are described in detail by Intera (2006; 2008) and are available from www.nwmo.ca. Key elements and activities associated with the on-going work program are described below.

4.1 Site-Specific Investigations

Site-specific investigations at the Bruce site involve a coordinated sequence of field and laboratory studies. Key amongst these has been completion of a 2-D seismic reflection survey and a deep borehole drilling program. In the fall of 2006, a 20 line km 2-D seismic reflection survey was shot along 9 transects. This survey was designed to focus on the imaging of the Ordovician sediments and in so doing provide a basis to assess the lateral continuity of the underlying bedrock formations and the presence of regional or local scale sub-vertical structural discontinuities beneath the 10 km^2 Bruce site.

The seismic reflection survey is complemented by a deep drilling program that includes the eventual drilling, coring and testing of 6 deep boreholes at 4 drill sites as shown in Figure 3. The first of these deep boreholes (DGR-1 and DGR-2) were completed in the Fall of 2007. These initial boreholes (152 mm dia.) intersected the entire 850 m thick sedimentary sequence and were purposely designed to provide isolated access to the Silurian and Ordovician sediments as shown in Figure 4. In 2008, an additional two deep boreholes DGR-3 and DGR-4 (143 mm dia.) were drilled to establish a triangular pattern enclosing the DGR footprint. The bedrock stratigraphy as determined from rock core logging from these boreholes is depicted in Figure 4. Additional inclined boreholes, DGR-5 and DGR-6, will be completed in 2009.

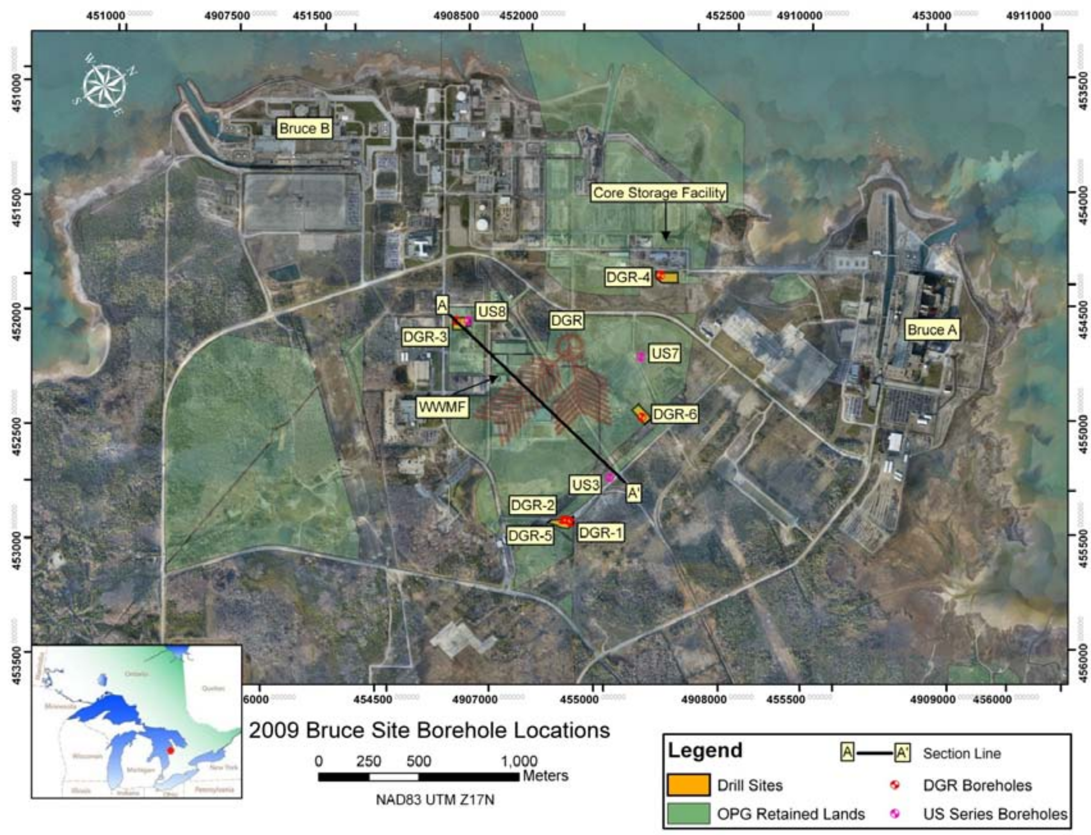

Figure 3: Bruce site base plan showing location of WWMF, proposed DGR layout, DGR Drill sites; DGR(deep)- and US(shallow)-series boreholes and Core Storage Facility.

The drilling program and borehole design were devised to minimize risk of borehole failure during in-situ testing and to provide assurance that intra-borehole flow and head re-distribution did not compromise data integrity. Under the DGR Project Quality Plan specific procedures have been prescribed for the logging, sampling and storage of the rock core. This includes the preservation of core samples necessary for pore fluid/noble gas characterisation (University of Ottawa; University of Bern), estimation of effective diffusion coefficients (University of New Brunswick) and geomechanical testing (University of Western Ontario; CANMET). All core (76 mm Φ) is stored at the Bruce site core storage facility that is designed to accept core from the entire work program (≈ 4.5 km).

Upon completion of coring, a program of geophysical logging and hydraulic testing is performed within the open bores. A suite of geophysical logs were completed to assist with formational contact interpretation and initial identification of permeable horizons within the sedimentary sequence. The geophysical logs included conventional and nuclear logs, acoustic televiewer log, borehole video and Fluid Electrical Conductivity logging. Borehole hydraulic testing involved straddle packer drill stem, pulse and slug testing dependent of the formation permeability. This latter hydraulic testing program applied in-situ borehole techniques and analysis methods developed at the Waste Isolation Pilot Plant in New Mexico (Sandia National Laboratories). Once in-situ testing is complete retrievable Westbay MP-55 multi-level casing systems will be installed into the vertical boreholes to allow long-term pressure head monitoring and groundwater sampling. These monitoring data will, in part, allow background hydrogeologic and hydrogeochemical conditions to be established.

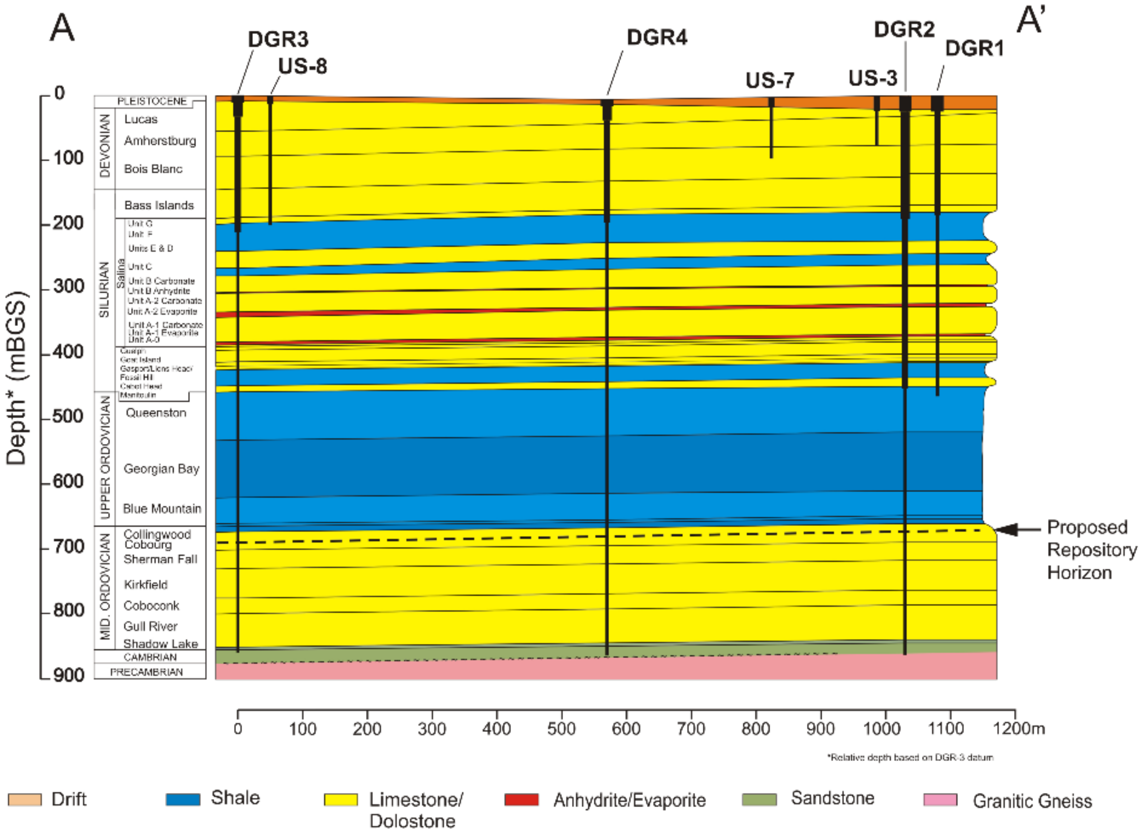

Figure 4: Bruce site Bedrock Stratigraphy as Determined Through Core Logging of Deep Boreholes DGR1, DGR-2, DGR-3 and DGR-4 (crossection shown on Figure 3).

In addition to site-specific activities, efforts have been taken to improve the ability to monitor low-level seismic activity in the vicinity of Bruce site. While located in an area of low seismic hazard, an improved understanding of micro-seismicity as it relates to the regional earthquake distributions and interpretation of regional scale faulting is important in assessing DGR performance. To this end, a new borehole seismograph network has been installed (Figure 5; University of Western Ontario). The seismographs (3) are positioned in cased bedrock wells 27 to 55 m deep, within 50 km of Bruce site. The detection threshold magnitude is $M \geq 1$. The monitoring of the seismograph network, including the processing of data streams from Polaris and Geologic Survey of Canada (GSC) hubs, will be performed by the Canadian Hazard Information Service (GSC).

4.2 Geosynthesis

The Geosynthesis task of the SCP provides the overall integration of all project data and the development of a Descriptive Geosphere Model(s) consistent with all the acquired data and information necessary for preparation of the DGR Environmental Assessment and regulatory site preparation/construction license application. The Geosynthesis for the GSCP is intended to develop and present the overall geoscientific understanding of the site, the host rock and the geological barrier system, its present state and future evolution, as well as the geoscientific data base for Safety Assessment and Repository Engineering. Geosynthesis is an essential component in the development of a basis to understand the long-term performance of the DGR concept. It is an activity that is conducted throughout the entire site characterization work program and involves the coordinated and collaborative efforts of specialists from all relevant disciplines.

Figure 5: Micro-seismic Borehole Seismometer Network (BASO; BMRO; BWLO) within 50 km of Bruce site and Micro-seismic Monitoring Data Reported for 2007.

As part of Phase I Geosynthesis (Gartner Lee, 2008a) activities, a series of technical reference documents have been being prepared, in part, to establish a regional context for the DGR program. These technical reports include: i) Regional Geology (Gartner Lee, 2008b); ii) Regional Geomechanics (Gartner Lee, 2008c); iii) Regional Hydrogeochemistry (Hobbs et al., 2008); iv) Long-term Climate Change – Glaciation (Peltier, 2008); v) Regional Hydrogeology (Sykes, et al,. 2008 and iv) Long-term Cavern Stability (Damjanac, 2008). These reports are publically available at www.nwmo.ca.

Regional Geology

Developing a regional scale geologic and structural geologic understanding of the deep sedimentary formations surrounding the Bruce site is an essential element of the DGR geosynthesis (Gartner Lee, 2008b). It includes establishing existing geologic knowledge as it relates to bedrock stratigraphy, facies changes, basin history, sedimentology, mineral diagenesis, pinnacle and barrier reef complexes, dolomitization, thermochronology and depth of burial, tectonics and structural fracture framework model(s) for the sedimentary sequence.

As part of this study, scientific visualization (Gocad) has been applied to aid with the interpretation of the regional stratigraphy from 300+ historic oil and gas well log records (Itasca). This approach allows for improved spatial data quality inspection and traceability in extrapolation of spatial formation contacts and discontinuities beyond Bruce site. Visualization is further simplifying the process of communicating complex stratigraphic and hydrostratigraphy geometries and relationships within the GSCP site characterisation group and to project stakeholders. This work and the completion of the geologic studies above have provided meaningful context for the DGR project through, for example, improving the basis to understand regional predictability and homogeneity of DGR host and overlying bedrock formations.

Regional Hydrogeology

A key aspect of the DGR concept is the role of multiple geosphere barriers in providing long-term isolation and containment of the L&ILW. To illustrate the behavior of the groundwater system within the Paleozoic sediments including the Precambrian basement, a 3-dimensional numerical simulation of a ≈20,000km^2 regional domain (Figure 6) has been performed (Sykes, et al., 2008). These simulations were performed with the code FRAC3DVS.

Regional modeling of groundwater flow within the Paleozoic sedimentary sequence underlying southwestern Ontario (e.g., Niagara Escarpment to Lake Huron) has yielded a reasoned basis to explain aspects of groundwater flow patterns, rates and quality relevant to conveying an understanding of DGR safety. This regional scale groundwater flow modeling was founded on a geologically constrained understanding of basin hydrostratigraphy and structural fracture network geometry as determined through interpretation of oil and gas and other deep drilling records, water well resource studies and structural/fault mapping. Given knowledge of formation specific brine hydrogeochemistry, it also explored the influence of variable density groundwater distributions on groundwater movement. This work has also served as a basis for "what-if" or illustrative simulations to examine the resilience of the deep groundwater regime to perturbations created by long-term climate change.

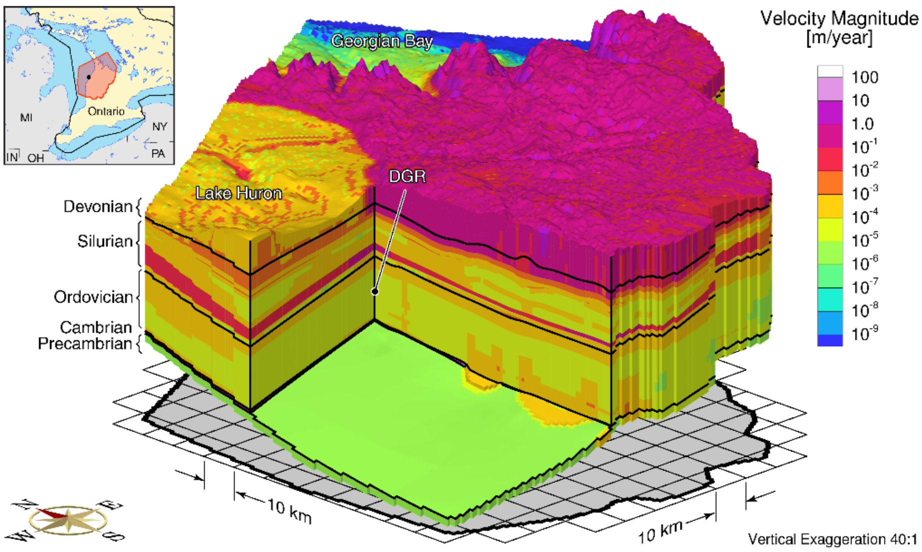

Figure 6: FRAC3DVS Regional Variably Saline Dense Freshwater Simulation – Predicted Groundwater Velocities.

Regional Hydrogeochemistry

Hydrogeochemical evidence from the Paleozoic sediments of southern Ontario provides evidence that deep groundwaters have remained undisturbed despite multiple perturbations on geologic time scales (Hobbs et al., 2008). Multiple lines of evidence include formation distinct chemical compositions (Figure 7), extremely high salinities (TDS 200 – 350 g L^{-1}) and isotopic signatures consistent with long-residence – rock/water interaction times. As part of this work program a comprehensive geochemical database of elemental and isotopic analyses on groundwater within the Paleozoic sediments of south-western Ontario was assembled (University of Waterloo). These data have been assessed with respect to: i) depth of penetration of glacial waters; ii) cross formational solute migration with specific emphasize on the role of regional scale structural discontinuities; iii) inter-formational groundwater mixing within the sedimentary sequence; and iv) the spatial variability in formational groundwater composition throughout south western Ontario.

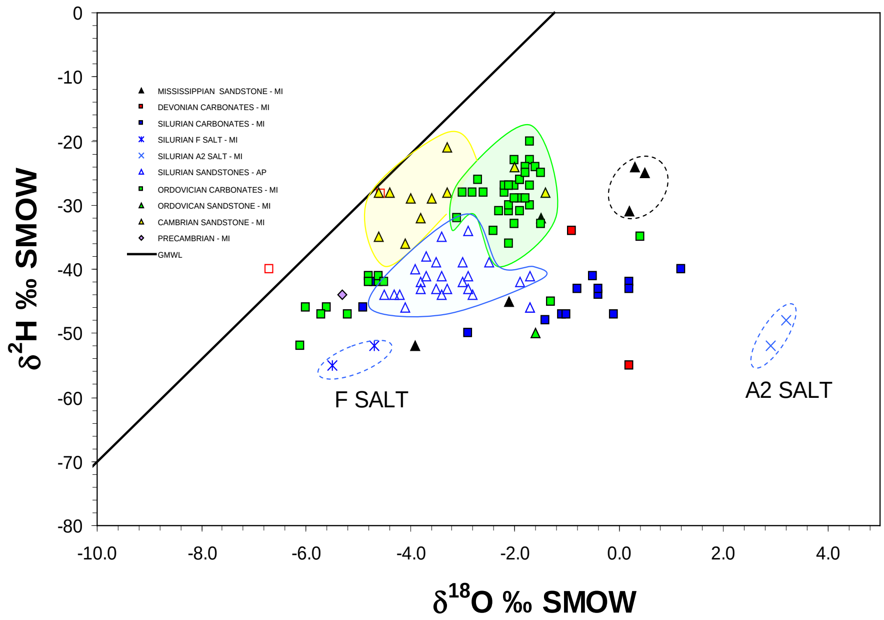

Figure 7: Southwestern Ontario Isotopic Signatures ^{2}H – ^{18}O for groundwaters with salinities > 100 g L^{-1}.

Long-term Climate Change

Within the northern latitudes climate change and, in particular, glaciation events are likely to influence the long-term performance of the DGR. Prolonged and cyclic periods of glacial and peri-glacial conditions have existed in these regions on numerous occasions in recent geologic history. During the latter half of the Pleistocene, long-term climate change has resulted in 9 glacial events with a typical 115 ka cycle. Ice-sheet thickness at glacial maximum would have exceeded ≈2.5 km over southern Ontario (Figure 8). Transient temperature, hydraulic and mechanical boundary conditions resulting from glacial conditions may, on a site-specific basis, materially affect groundwater flow system dynamics, fracture network interconnectivity, fracture rejuvenation/propagation, post-glacial lake formation, groundwater redox front migration and geomechanical stability of repository access tunnels and emplacement rooms. Demonstrating a knowledge and awareness of the time history and magnitude of these effects is an important aspect in the development of a repository safety case.

In order to explore the range of surface boundary conditions that could develop at Bruce site, the University of Toronto Glacial Systems Model was subject to a Bayesian calibration and employed to construct a suite of equally plausible models of the glaciation-deglaciation process (Peltier, 2008). These boundary conditions, on normal stress, surface temperature, permafrost depth and meltwater production, are highly time dependent and vary substantially across the suite of models that are able to satisfy the observational constraints. These constraints are taken to be those appropriate to the most recent cycle of shield glaciation that began following the Eemian interglacial that was initiated 116,000 years before present and that ended approximately 10,000 years ago.

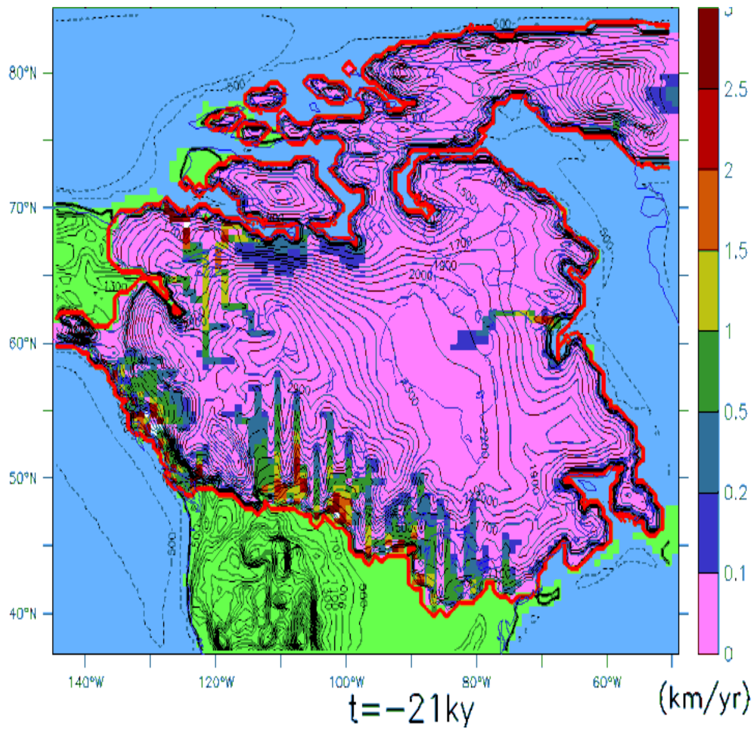

Figure 8: Laurentide Ice-sheet Geometry, Thickness and Ice Sheet Velocities at Last Glacial Maximum 21 ka BP (Glacial Systems Model - University of Toronto)

Geoscience Review Group

As part of the overall site characterisation work program an independent Geoscience Review Group (GRG) has been assembled by the NWMO to provide an advisory and oversight role on geoscientific site characterization activities at Bruce site. In Phase I GRG activities have focused on guidance and expertise related to the following: i) implementation of field and laboratory measurement techniques/methods; ii) interpretation and synthesis of field and laboratory data given measurement/geosphere uncertainty; iii) international practice for geoscientific investigations in sedimentary sequences for radioactive waste management purposes; iv) review and direction of strategies for Descriptive Geosphere Model development; and v) review and direction of strategies for Geosynthesis development. In this role the GRG is positioned to independently assess the adequacy of all aspects of the Bruce site investigations with findings reported directly to OPG Management. A key benefit of the GRG has been the direct involvement and access to international geoscience work programs, in particular, those of ANDRA (France) and NAGRA (Switzerland), which has been of significant advantage to the DGR program.

5 CONCLUSIONS

Ontario Power Generation is proposing the development of a Deep Geologic Repository (DGR) at Bruce site for the long-term management of low and intermediate level radioactive waste (L&ILW) generated at OPG owned nuclear generating stations. The DGR concept envisions a shaft accessed repository excavated at a depth of approximately 680 m within the argillaceous limestone Cobourg Formation that is overlain by 200 m of shale (Queenston, Georgian Bay and Blue Mountain/Collingwood Formations). Site-specific geoscientific studies to confirm the suitability of the site to host the DGR were initiated in Fall 2006, as part of a 4-year multi-phase investigation. In support of an Environmental Assessment, these studies are to explore the long-term stability and integrity of the geologic formations and respective hydrogeologic regimes to contain and isolate the L&ILW at timeframes relevant to repository safety. Interim results from the site investigations coupled with regionally based Geosynthesis studies are providing useful insight into the long-term integrity and effectiveness of the sedimentary formations to contain and isolate the L&ILW. This work conducted, in part, with support from Canadian Universities and international radioactive waste management programs (Nagra; Andra) are scheduled for completion in 2010.

ACKNOWLEDGEMENTS

Numerous individuals and organizations have contributed to the DGR project since initiated in 2002. Early work by Golder Associates Ltd. and Martin Mazurek (University of Bern) established the geoscientific basis and precedent to understand the suitability of the Paleozoic sequence for long-term radioactive waste management purposes. The Geoscience Review Group comprised of Dr. Andreas Gautschi (NAGRA), Jacques Delay (ANDRA), Dr. Joe Pearson and Dr. Derek Martin (UofA) has provided valuable access to international experience and expertise.

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