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NWMO BACKGROUND PAPERS
6. TECHNICAL METHODS

6-12 LONG-TERM USED NUCLEAR FUEL WASTE MANAGEMENT - GEOSCIENTIFIC REVIEW OF THE SEDIMENTARY SEQUENCE IN SOUTHERN ONTARIO

EXECUTIVE SUMMARY

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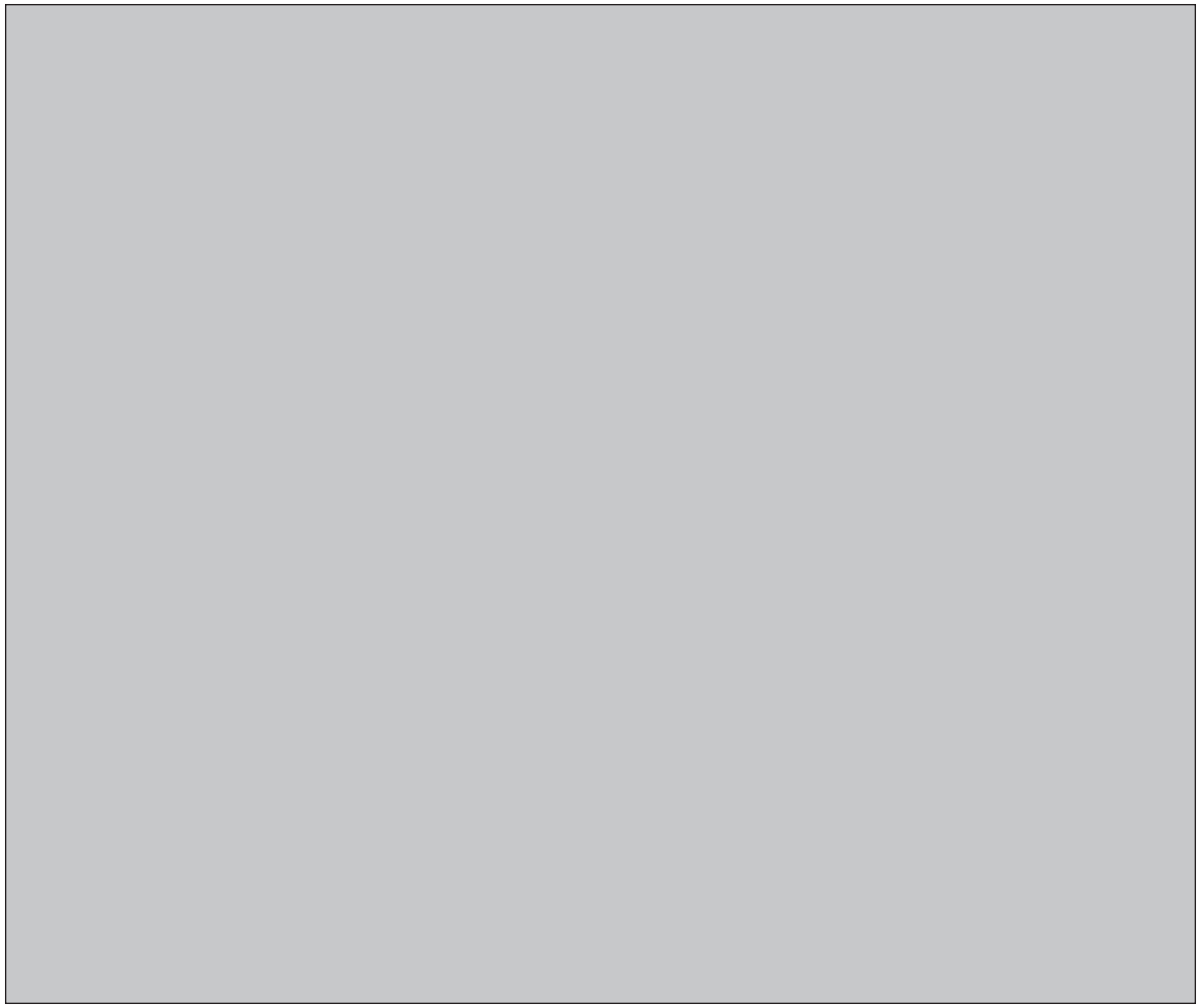

EXECUTIVE SUMMARY

A geoscientific assessment examining the suitability of the Paleozoic sedimentary rock occurring beneath southern Ontario to host a Deep Geologic Repository (DGR) for used nuclear fuel is described. The assessment involved a review of international radioactive waste management programmes in sedimentary media and a compilation of existing and publicly available geoscientific information for southern Ontario. A geosynthesis of this latter information was used to evaluate the suitability of the bedrock formations within this sedimentary sequence in the light of international experience. A structured approach consistent with international practice was undertaken to assess multiple and independent lines of reasoning regarding isolation properties, long-term stability of the flow system and geotechnical aspects. Middle to Upper Ordovician shales and limestones in southern Ontario were identified as potential host units.

Internationally, considerable experience with understanding the suitability of sedimentary media for radioactive waste management purposes has been gained over the last decade. Radioactive waste management programmes in Switzerland (Nagra), France (Andra), Belgium (Ondraf/Niras), Spain (Enresa) and Japan (JNC) have focussed on argillaceous media, which collectively refers to clay-rich sedimentary rock in various stages of induration (clays, shales). Safety Cases or comparable milestones targeted at deep geological 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:

- the horizontally bedded and weakly deformed units in sedimentary sequences are geometrically simple and straight-forward to conceptualise;
- the target formations are sufficiently homogeneous, which enhances predictability;
- the 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
- the formations provide sufficient geomechanical stability for safe repository construction and operation.

Salt formations also have favourable characteristics for long-term radioactive waste management as demonstrated at the Waste Isolation Pilot Plant in New Mexico, United States (licensed in 1999) and the German programmes at Gorleben and Morsleben. It is evident that sedimentary formations possess significant advantages for long-term waste management and Safety Case development and have become the preferred media where geologic settings permit.

Southern Ontario is underlain by a sedimentary ‘layer cake’ comprised of Paleozoic formations of Cambrian to Devonian (543 - 354 Ma) age. The near horizontally bedded and only weakly deformed sequence consists of shales, limestones, dolomites, sandstones and evaporites (salt, gypsum/anhydrite). These sedimentary rocks occur geologically within the Michigan and

Appalachian sedimentary basins and attain a maximum thickness of ca. 1500 m. Background geoscientific information with which to establish the geologic setting for the purpose of the assessment was assembled primarily through scientific literature and other public domain sources. A synthesis of this information permitted characterisation of the bedrock lithology, stratigraphy, structure, diagenesis/basin evolution, physical and chemical hydrogeology, stress regime, seismology, resource potential and geomechanical attributes.

Based on this synthesis, an initial assessment of formation suitability was completed using four simple criteria: i) existence of low hydraulic conductivity rock mass; ii) sufficient formation depth below ground surface (=200 m); iii) sufficient formation thickness (=100 m); iv) simple geometry (*i.e.* internal homogeneity, lateral continuity). In applying these criteria, suitable bedrock formations were identified as the Middle/Upper Ordovician age (ca. 470 - 443 Ma) shales (Blue Mountain, Georgian Bay and Queenston Formations) and underlying limestones (Simcoe Group, *i.e.* the Gull River, Bobcaygeon, Verulam and Lindsay Formations). These formations are laterally continuous throughout large regions of southern Ontario. A further more detailed assessment of these Ordovician sedimentary rocks was undertaken using an internationally accepted framework developed through the NEA Features, Events and Processes Catalogue for Argillaceous Rocks (FEPCAT). This assessment further supported the initial results.

Specific lines of geoscientific reasoning supporting the conclusions drawn in the report include:

- 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;
- Hydrochemical evidence indicates very long underground residence times of formation waters and no resolvable cross-formational flow at depth over geological periods of time;
- A surficial fresh-water flow system is underlain by a stagnant hydrogeological regime. Given the absence of exfiltration areas for deep ground waters, 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 low-permeability formations, such as shales or evaporites, that confine the more permeable units; and
- Tunnelling in deeply buried shales and limestones appears to be feasible in spite of high horizontal stresses.

Based on current knowledge, there are a multitude of independent arguments suggesting that Ordovician shales and limestones occurring beneath southern Ontario provide a highly suitable environment to host a deep geological repository for spent fuel. There is no evidence that would *a priori* seriously question the feasibility and long-term safety functionality. From a geoscientific perspective, the chance of success to complete a convincing safety case is substantial. One very positive aspect is the potential for using multiple lines of evidence (*e.g.* predictive flow/transport modelling *vs*. hydrochemical evidence *vs*. understanding of the hydrogeological system) to strengthen the safety case.