CNSC Regulatory Research on Geological Disposal

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• Two current initiatives for geological disposal in Canada
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The Canadian Nuclear Safety Commission (CNSC):
- regulates the use of nuclear energy and materials to protect health, safety, security and the environment
- implements Canada's international commitments on the peaceful use of nuclear energy
- disseminates objective scientific, technical and regulatory information to the public

The CNSC regulates all nuclear facilities and activities in Canada throughout the nuclear fuel cycle
Two Current Geological Disposal Initiatives

Both crystalline and sedimentary rock types are being considered.
Rationale and Overview of CNSC Research

- Geological disposal projects typically last decades from conceptualization to implementation
- Early involvement of regulator: an international best practice to keep abreast of technological, social and regulatory best practices
- Independent regulatory research: important component of this involvement
- Leveraging through national and international collaborations, while retaining in-house expertise
- Objective of regulatory research: build the CNSC’s in-house knowledge in order to make well-informed licensing recommendations
- Summary of research findings is available on the CNSC website
Chronology of CNSC Research (1)

- The chronology of CNSC research is summarized in a chart that shows:
  - the relationship between independent research from the CNSC and geological initiatives developed by the proponents
  - the way the CNSC’s research results were used in the review of the proponents’ submissions and in providing recommendations to the relevant authorities

- The Atomic Energy Control Board’s (AECB – the CNSC’s predecessor) research started in the late 1970s to prepare for the review of AECL’s concept of geological disposal of used nuclear fuel in crystalline rocks
Chronology of CNSC research (2)

• The AECB concluded in 1996 that the AECL concept is acceptable and recommended that Canada proceed to site selection

• The AECB/CNSC has conducted research from 1996 to present. The results have and will continue to enable the CNSC to provide science-based recommendations on:
  - OPG’s proposal for a DGR for LILW in sedimentary rock; it was found that based on multiple lines of evidence, the proposed DGR would provide for the long-term protection of people and the environment
  - The NWMO’s site selection process for Canada’s used nuclear fuel and future application for a construction licence on a selected site
CNSC Coordinated Assessment and Research Program

**Perturbations**
- Excavation
- Heat generation
- Gas generation
- Geological events
- Climate change

**Barrier performance**

**CNSC research**
- THMC processes
- Natural analogues
- Paleohydrogeology
- Safety assessment

**Goal**
- Protection of people and the environment at all times

CNSC research focuses on safety of geological disposal
Current Research Projects

Integration of experimentation and modelling to verify the safety case

- THMC modelling
  - DGR scoping model
  - URL in situ experiments
  - Rock model
  - Seal model
  - DGR updated model
  - Glaciation modelling

- Natural analogues (University of Manitoba)
  - Safety assessment and safety case
  - Dating of fracture infill (University of Ottawa)

- URL experimental data obtained through international collaboration
- Laboratory experiments through Canadian and international collaboration
Geomechanics

- Developed constitutive models for Opalinus clay, Tournemire shale and Cobourg limestone
- The models were used and validated in the simulation of laboratory and field tests consisting of excavation, water and gas injection
The hydraulic-mechanical response is well simulated by the model. The model is a reliable tool for assessing the excavation damage zone.
The Behaviour of Bentonite Seals

- Simulation of heater experiment (HE), Mont-Terri URL
- Simulation of SEALEX experiment, Tournemire URL
- Experimental program on effects of brine on bentonite seals
Swelling Pressure of Bentonite

- Very high salinity is found in porewaters of Canadian sedimentary rocks
- Swelling pressure tests at Queen’s University shows a substantial reduction of the swelling potential of bentonite infiltrated with brine

Effects of brine on the performance of bentonite seals must be taken into account in the Canadian Program
The CNSC has been involved since 1992 – a very fruitful collaboration with fellow researchers in THMC coupled processes.

The CNSC’s current involvement in D-2019:
- gas flow in low-permeability materials
- induced slip of a fault
Glaciation Modelling

- During the last million years, Canada has been subjected to nine glacial cycles.

- For each cycle, the ice sheet imposes a surface load of 30–40 MPa, leading to:
  - substantial increase in hydraulic gradients
  - redistribution of natural tracers by advection, dispersion and diffusion

- The CNSC developed and validated a mathematical model for the THMC response to the past nine glacial cycles of the sedimentary rock at a DGR for LILW proposed by OPG.
Conclusions from Glaciation Modelling

• Mathematical modelling and field data at a proposed LILW DGR site provide multiple lines of evidence that:
  - the host and cap formations at the site of the proposed DGR for LILW and their groundwater have been unaffected by nine cycles of glaciation over the last million years
  - the deep groundwater system in the host and cap rock formations at the site is hundreds of million of years old and virtually stagnant – transport of solutes is diffusion dominated
  - the Great Lakes are features resulting from Quaternary glaciation cycles – surface water bodies such as the Great Lakes have remained isolated from the deep groundwater
Natural and Anthropogenic Analogues Review (1)

- Bridging the gap between laboratory experiments and modelled safety assessment time frames that are usually in excess of 10000 years
  - analogue studies increase confidence in DGR safety providing data on geological and spatial scales that can’t be replicated in experiments (for example, next slide)
Image of core samples from the End Uranium Deposit, Kiggavik, Nunavut, Canada. Area 1 shows uranium minerals along a fracture, and areas 2 and 3 show secondary uranium mineralization within a clay-rich matrix.
Natural and Anthropogenic Analogues Review (3)

- Review conclusion and implications:
  - analogues provide input into the long-term safety case and increase public confidence in deep geological disposal concepts at all project stages
  - national analogues may build more public support for a DGR because of geographical and cultural familiarity
  - analogues which are site-specific are even more powerful; for example, natural tracers and past glaciation
  - integrating analogue information with other studies (e.g., hydrogeological and geomechanical studies), including laboratory experiments, can account for the range of temporal and spatial time scales
Fracture Research in Southern Ontario

- Investigating potential for fault reactivation in southern Ontario by studying fracturing and fracture-filling minerals:
  - field-based study on the stability of the geosphere
  - absolute age dating of fracture-fill minerals
  - support seismic hazard assessment
Fracture Infill-Analytical Approach and Conclusions

• Analytical approach:
  - field mapping and structural analysis: 35 calcite veins sampled from 15 outcrops; trace element geochemistry on 33 samples
  - stable isotope analysis of δ13C and δ18O on 37 samples
  - radiometric dating

• Scientific conclusions:
  - Fluids are likely derived from distal sources and mobilized at ~100 Ma, via inherited joint sets from basement-seated structures in the Grenvillian basement
  - Hypothesized plate reorganization at 100 Ma

The fractures are millions of years old and have not been reactivated
Concluding Remarks

- CNSC research on the safety of geological disposal dates from the late 1970s
- The CNSC collaborates with national and international institutions
- Regulatory research:
  - builds independent expertise
  - adds to the CNSC’s credibility
  - provides a solid scientific basis to the CNSC’s licensing decisions and recommendations
Recent Publications

- T.S. Nguyen and D.A. Le, 2014, Development of a constitutive model for a bedded argillaceous rock from triaxial and true triaxial tests, Canadian Geotechnical Journal, d.o.i. 10.1139/cgj-2013-0323
- D.A. Le and T.S. Nguyen, 2014, Hydromechanical response of a bedded argillaceous rock formation to excavation and water injection, Canadian Geotechnical Journal, d.o.i. 10.1139/cgj-2013-0324
Acronyms

- AECL: Atomic of Energy of Canada Limited
- APM: Adaptive Phased Management
- DGR: Deep Geological Repository
- OPG: Ontario Power Generation
- NWMO: Nuclear Waste Management Organization
- THMC: Thermal-Hydrological-Mechanical-Chemical
- URL: Underground Research Laboratory
- LILW: Low- and Intermediate-Level Waste
Questions?

Thank You!