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CONFERENCE REPORT

The Second Canadian Symposium on Aquitard Hydrogeology June 21–23, 2011, University of Ottawa

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The Second Canadian Symposium on Aquitard Hydrogeology was held this past June at the University of Ottawa, Ontario, and brought together over 120 geoscientists from Hong Kong to Bern and from Mississippi to Saskatoon. Delegates constituted a unique group of academic and industry leaders in the fields of contaminant hydrogeology, hydrogeological modelling and nuclear waste management.

The First Canadian Symposium on Aquitard Hydrogeology was held in June 2009 in Saskatoon and was hosted by the University of Saskatchewan's College of Engineering. It honoured John Cherry's contributions to aquitard research over his career, which began at the University of Saskatchewan as an undergraduate student of geological engineering. This second meeting was hosted at the University of Ottawa from June 21–23, 2011, with the purpose of presenting not only the latest cutting edge research on aquitards of many origins, but also to examine their use for hazardous and nuclear waste management.

The Second Symposium was organized by members from the Ottawa Geotechnical Group, the Canadian National Chapter of the International Association of Hydrogeologists and the University of Ottawa, and was supported by seven corporate and government sponsors. The event kicked off with a scenic boat cruise along the Ottawa River, welcoming delegates to the city and gearing them up for the week's events.

The technical program followed a novel approach elaborated by John Cherry. It featured an impressive list of invited speakers only, with preassigned presentation topics, offering a refreshing approach to conventional symposia proceedings. Presenters included a number of home-grown heroes in the field of hydrogeology, and also included an impressive showing from international leaders in the field from across the border and abroad.

Coffee breaks were complemented by student research posters pertaining to the characterization of aquitard systems, and disposal of hazardous and radioactive waste within these hydrologic units. The poster session was judged by John Cherry, who felt recharged by the growing interest in aquitard studies among young scientists. Matt Herod (University of Ottawa) and Laura Smith (University of Saskatchewan) were co-awarded the prize for best student poster.

The first day was devoted to aquitard characterization and highlighting methods and case studies in the context of aquifer protection formations. John Cherry provided an introductory presentation on aquitards, going through the history and evolution of aquitard science, highlighting some of the key discoveries such as the role of fractures in clays in solute transport and the retardation effect of matrix diffusion. He noted that aquitard hydrogeology is of particular importance to Canadians, as aquitards cover most of the North American continent. They play many important roles because of their unique properties: protecting aquifers, containing contaminants and controlling groundwater geochemistry. Their properties also make them suitable candidates for long term hazardous and radioactive waste disposal. However, the science requires continuing attention and research.

Jim Hendry (University of Saskatchewan) presented several case studies of near-surface clay aquitards in the Canadian prairies, and innovations in the analysis and interpretation of isotope profiles to assess pore water diffusion and groundwater age. He discussed the effects of oxidation on the clay, and vertical solute transport at two different sites in Saskatchewan.

Jimmy Jiao (University of Hong Kong) discussed the hydrogeology of coastal Chinese aquitards with a case study in the Pearl River Delta. Jiao highlighted the source of 'fertile water' from the Pearl River Delta aquifer arising from degradation of organics in confining aquitards. These are among the most concentrated naturally-occurring ammonium groundwaters in the world. Jiao made the point that important aquifers such as these could not be studied without studying their adjacent aquitards. On average, the ammonium in porewater from the surrounding aquitard is 3.5 times greater than that in the aquifer, where much of the organic nitrogen has not yet converted to ammonium, indicating a slow continuous supply of ammonium to the aquifer.

Beth Parker (University of Guelph) discussed the use of forward

and back diffusion in clay aquitards to assess aquitard integrity, providing several case studies. Features that provide an indication of strong aquitard 'integrity' (an aquitard's ability to strongly impede the movement of contaminants within a groundwater system) include: lack of fractures, high natural solid organic content, contaminant degradation or immobilization reactions. Parker also highlighted conditions that produce aquitards with the highest integrity (either depositional or postdepositional processes), including thick lacustrine deposits, and deposits having high plasticity or that have not been exposed to the atmosphere or overridden by glaciers, etc. Beth observed that not all clayey aquitard sites are ideal, and they must be evaluated on a case-by-case basis.

Rick Gerber (Central Lake Ontario Conservation Authority) presented the aquitard characteristics of southern Ontario. Gerber introduced the delegates to spatial and hydrogeological characteristics of shallow clay aquitards that occur throughout much of Ontario and drew connections to aquifer protection, landfill siting and water supplies. Gerber also highlighted the need for future geochemical and physical studies of Ontario's aquitards.

François Duhaime (École Polytechnique de Montréal) presented his research with Robert Chapuis on the porewater chemistry of the Lachenaie marine clays in Quebec. Their findings suggest that porewater was initially Champlain seawater that has evolved through methanogenesis, bacterial sulphate reduction and reactions with carbonates.

Paul Martin (AquaResource Inc.) gave a presentation on building aquitard numerical flow models in 3-D. He described many important steps and considerations when building a model, and illustrated them with a site study.

Ken Bradbury (University of Wisconsin) discussed recent aquitard studies in Wisconsin, including instrumentation, observations and analysis. A large part of his talk focused on enteric virus transport through bedrock aquitards in deep municipal wells, likely originating from municipal sewage, suggesting that fractures, breaches, and/or cross-connecting wells are degrading the inherent aquitard integrity.

Knud Erik Klint (Geological Survey of Denmark and Greenland) discussed the hydrogeologic implications of clayey till aquitards in fracture mapping and structural analysis. In his talk, Klint characterized various fracture forms, and introduced a polymorphological concept, which is an integrated methodology for multi-scale characterization and classification of fractures in diamictons for the evaluation of geological and hydraulic variability at a regional scale.

Chris Neuzil (USGS) wrapped up Day 1 with an enlightening discussion on our current understanding of flow and solute transport in aquitards. Neuzil pointed out that the best environments for waste isolation may also be the hardest to characterize. His talk highlighted the historical use of indirect characterizations in aquitard studies, the incompleteness and ambiguity of modern characterizations due to technological challenges and limitations, as well as the potential for unexpected behaviour.

The first day concluded with a conference banquet held at the National Arts Center, and featured a keynote speech by John Gale (Fracflow Consultants Inc.), a pioneer of international research to characterize rock masses for radioactive waste disposal. Gale gave an enlightening synopsis of the history of Canada's approach to radioactive waste management, which served to introduce the second day of talks.

The second day focused on hazardous and radioactive waste storage in aquitard systems, with emphasis on the Ontario Power Generation's proposed Deep Geologic Repository for low and intermediate level waste (L&ILW) later in the day. Martin Mazurek (University of Bern), Jim Hendry (University of Saskatchewan), Robert Holt (University of Mississippi) and Gunther Funk (RWDI AIR Inc.) opened the morning session by presenting several case studies of clayey-aquitard characterization in the context of hazardous and radioactive waste disposal. They highlighted various key methodologies to examine the hydrogeology, and discussed both the challenges and successes that arose from these projects.

Mark Jensen, Director of NWMO Geoscience Research, began the afternoon session by introducing the proposed Bruce Deep Geologic Repository site, discussing the history of the DGR project, site characterization and geoscience planning activities, synthesis of the geological research and aquitard characterization, and the next steps to be taken towards repository permitting and construction at the Bruce DGR site.

Ken Raven (Geofirma Engineering Ltd.) followed by presenting the geology and hydrogeology of the proposed Bruce DGR. Geofirma (formerly Intera Engineering Ltd.) undertook the geoscientific site characterization at the Bruce nuclear site, with the purpose of assessing the suitability of the site to implement a Deep Geologic Repository (DGR). Raven's presentation provided a summary of the results obtained from the numerous detailed studies performed towards the DGR investigation. Raven emphasized that the results thus far indicate that the highly indurated shales and argillaceous limestones through the proposed repository horizon have limited spatial variability, high Rock Quality Designation (RQD), are uniform and predictable and lack any offsetting vertical faults. Hydraulic testing has identified a 450 m thick aquiclude having remarkable underpressuring, possibly due to Cenozoic erosion and glaciation, and ultra-low permeability with horizontal K measurements on the order of 10-14 m/s (i.e. a displacement of approximately 1 m over 1Ma), compared to 10-1 m/s in exceptional aquifers/reservoirs. Chris Neuzil put these ultra-low permeabilities into perspective by using a 'if permeability was money' analogy, which would be like comparing the price of a small bottle of pop to the US national debt.

Ian Clark (University of Ottawa) followed Raven with a presentation of his group's research on the porewater chemistry of the proposed Bruce DGR. Clark presented new methods for porewater extraction from rock core as well as results of ^{18}O, deuterium, methane, major ion geochemistry and radiogenic isotopes (e.g. ^{129}I, ^{4}He) to characterize the origin, age and movement of porewaters at the Bruce

site. Clark's results show that the Bruce DGR is an extremely low permeability environment and that the pore fluids in the thick aquiclude at the site are essentially Paleozoic in age, and have experienced little to no movement since their emplacement.

Tom Al (University of New Brunswick) gave a presentation on the research of his group to develop methodologies for determining the iodine-accessible and tritium porosities that were measured along with their diffusion coefficients in the Bruce DGR cores. His presentation discussed the results from different methods, and the presence and significance of anisotropy at the formation scale, particularly layers of hard-beds within the Georgian Bay formation.

Kent Novakowski (Queen's University) presented the results of his modelling of the geochemical data of the Bruce DGR site in order to evaluate its suitability for waste storage. His model incorporated fractures, over- and under-pressuring, density and glaciations. The findings suggest that molecular diffusion controls transport in the middle layers of the Bruce DGR, while advection dominates in the top and bottom layers, where glacial waters are present in some of the near-surface layers.

The second day closed with a panel discussion (Fig. 1) reviewing the state of aquitard science and implications for the use of deep Canadian aquitards for radioactive waste isolation. The panel discussed what constitutes a 'demonstration' of the ability of the geosphere to safely contain and isolate the waste for a long period of time (i.e. >100 000 yrs). Discussions centered on addressing the issue of presenting clear, unambiguous and accurate information, especially in the case of sensitive issues such as nuclear waste disposal. Dialogue shifted to the case of the Ontario Power Generation's proposed L&ILW DGR at the Bruce Nuclear site, and what aspects of the geologic/hydrogeologic setting provides the strongest positive evidence for long-term geosphere barrier performance. Members of the panel and audience agreed that this can be found in the ultra-low permeabilities, limited spatial variability and lack of continuous fractures observed thus far.

Figure 1. John Cherry (left) leading a panel discussion on 'The State of Aquitard Science and Implications for Use of Deep Canadian Aquitards for Radioactive Waste Isolation'.

Also discussed was how to proceed with science-based decision making and its importance as the project moves forward, given the advanced science for site selection.

The third day featured concurrent workshops for teaching skills required for aquitard characterization, and also highlighted new laboratory and field work methods and future prospects. The morning sessions included a workshop given by Chris Neville (S.S. Papadapulos & Associates) and Garth van der Kamp (Environment Canada) on measurement of the hydraulic properties of aquitards, as well as a session lead by John Cherry, Jessica Meyer and Thomas Coleman (University of Guelph) on multi-level monitoring in aquitards. The afternoon workshops were led by Ian Clark (University of Ottawa), Len Wassenaar (University of Saskatchewan) and Martin Mazurek (University of Bern) who discussed the measurement of the hydrogeochemical properties of aquitards, and Beth Parker (University of Guelph), characterizing organic contaminants in aquitard sequences and the importance of mass storage in aquitards controlling site remediation.

Aquitards are critical components of hydrogeological systems that are vital to the protection of groundwater resources, and yet remain largely underexploited, underappreciated and understudied. This symposium brought to our attention new insights to their hydrogeological characteristics and how they can serve societal needs, particularly in the case of aquifer protection and waste disposal, both in the Canadian and international arena. Meetings such as these are an excellent forum to present the merits of the DGR to the geoscientific and professional communities. In addition, as these studies on aquitard hydrogeology move from preliminary to more advanced stages, there is a desire to publish material with comprehensive evaluations and new insights, reaching broader audiences.

The Third Canadian Symposium on Aquitard Hydrogeology will be hosted at the University of Guelph in 2013. We also wish to draw attention to the 39th Congress of the International Association of Hydrogeologists to be held in Niagara Falls, Ontario, September 16–21, 2012 [www.iah2012.org], which will feature several sessions on the role of aquitards in aquifer protection.