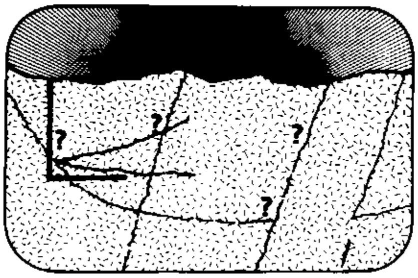

Developing the Data for Nuclear Waste Disposal - Investigations of the Lac du Bonnet Batholith

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Summary
Atomic Energy of Canada Limited (AECL) in conjunction with other federal agencies, universities and commercial firms has undertaken a program to demonstrate that the burial of nuclear wastes deep into carefully selected geological formations is a viable and safe method of disposal. During the next three years, approximimately eight formations in the Canadian Shield, representing various classes of plutons, will be investigated in detail. This paper describes a case history of the investigation of one of these, the Lac du Bonnet batholith, Manitoba.

Introduction

In modern industrialized countries, many people are concerned about the release of toxic wastes into the environment. Canada is no exception and the methods being proposed for the disposal of one of these wastes, that is, nuclear waste from CANDU (Canada Deuterium Uranium) electrical generating stations have been a matter of interest for some time. These disposal methods are being developed as part of a comprehensive program for management of Canadian radioactive wastes, the objective of which is to ensure that there will be no significant effects on man or his environment at any time. The overall programs and schedules for the research and development necessary to achieve this objective have been described elsewhere (Boulton, 1978; Hatcher *et al.*, 1979). This article will deal with one geotechnical research activity, namely, research area evaluation, and will specifically describe how the Lac du Bonnet (LDB) batholith, in south-east Manitoba, has been investigated. The geology of the batholith, the various geotechnical methods which were utilized, and the preliminary interpretations of the accumulated data are discussed. These data, and other information being developed by a wide variety of research activities, will be utilized to assess the safety of the nuclear waste disposal concept.

Active research on the batholith commenced in the spring of 1978 and Table I summarizes the research which has been performed since that date. In brief, 21 activities have been completed involving 18 organizations and over 90 people. Although some studies were carried out across the body, most activities were restricted to AECL's Whiteshell Nuclear Research Establishment (WNRE) property, which occupies about 44 km^2 near the southern boundary of the batholith. The location of WNRE was one of the main reasons for selecting the LDB batholith for investigation. The activities which are described form only the current phase of the evaluation of the batholith and geotechnical research will continue for several years.

Geology of the Batholith

The regional setting of the LDB batholith is illustrated in Figure 1. It is located near the Manitoba-Ontario border in the western part of the Superior Province which consists of a series of east-west trending belts. The LDB batholith is located in the English River Gneiss Belt. This belt has been subdivided into two portions and the LDB batholith is located in the southern one, the Winnipeg River Batholithic Belt.

Very few published data are available for the batholith and indeed the area of eastern Manitoba south of the Winnipeg River still does not have a published geological map. Over the past two years a reconnaissance geological survey of the LDB batholith has been performed. The survey has shown that the LDB batholith is predominantly a pink, medium- to coarse-grained, slightly porphyritic granite to grandiorite (IUGS classification). The rock consists almost wholly of K-feldspar (25%), plagioclase (40%) and quartz (30%) with minor biotite (5%). Microline phenocrysts (1 to 3 cm) form about 5% of the granite. The emplacement of the granite was the last event in the area and postdates the last major orogeny. Foliation along the margins indicates vertical emplacement. From the field mapping, it appears very uniform and essentially a single phase. At one site (out of over 140 visited), however, a different phase, a light grey tonalite (plagioclase about 60 to 80%, quartz 20 to 30%, biotite 2 to 5%, K-feldspar 0 to 5%) was observed. Outcrop is limited to east of the Winnipeg River. The WNRE site is covered with about 10 to 15 m of glacial overburden. Emphasis during field mapping was placed on the structural aspects, that is, recording of data on jointing.

Table I
Geotechnical Investigations on the Lac Du Bonnet Batholith

Formation-Wide Investigations
Geology
Gravity survey
Aeromagnetic gradiometer survey
Airborne electromagnetic survey

W.N.R.E. SITE Investigations

(a) *Surface Surveys*
Magnetotelluric survey
Seismic refraction survey
Electro-magnetic soundings
Electrical resistivity soundings

(b) *Borehole Studies*
Drilling and core logging
T.V. logging
Borehole geophysical logging
Seismic downhole survey
Seismic lateral survey
Radar surveys

(c) *Hydrogeology*
"Dry" borehole
Geochemical probe and sampler
Permeability and pressure tests

(d) *Other*
Seismometer station
Laboratory studies of drill core and water samples.

Research Activities to Evaluate the Batholith

Gravity Survey. The impression of apparent uniformity of the batholith was dispelled by the results of a N-S gravity profile performed by the University of Manitoba (W.C. Brisbin, in press). Measurements were made at 189 stations and over 300 samples were analyzed for specific gravity. A major mass excess, with no surface expression, lies below the northern part of the batholith. A number of interpretations of the data are possible, and one of these, which postulates that a slab of volcanic rock lies at a depth of about 8 km, is shown in Figure 2.

Aeromagnetic Gradiometer Survey. Most of the eastern part of the batholith was surveyed by the Geological Survey of Canada's aeromagnetic gradiometer. The pluton was found to contain many anomalies with different characteristics. The larger of these are currently interpreted as zenoliths in varying states of assimilation. The smaller anomalies probably represent several late-stage intrusions of more magnetic material. Thus, the LDB batholith is not a simple homogeneous mass.

Drilling. Four boreholes have been drilled on the northern part of the WNRE property ranging in total length from 110 to 930 m. Three of the holes were diamond-drilled, NQ size (7.5 cm) using triple-tube, split-inner barrel and wireline techniques to maximize the qulaity of core recovery. Core orientators were used and more detailed core logging than usual was applied under the supervision of the GSC.

Figure 3 shows an example of the data recorded. The lithology log verifies some of the complexities predicted by the gravity and aeromagnetic surveys. At a depth of 50 to 100 m there is a zone of quartz diorite, tonalite and granodiorite, parts of which are mixed with pegmatites and the normal LDB granite.

Of primary interest are the fractures (joints) intersected in the borehole. A histogram of the number of fractures encountered in 5 m intervals is also shown in Figure 3. As can be seen, the rock quality is very high except for a fracture zone encountered at 400 m. The strikes and dips of all joints are calculated utilizing the orientation line placed on the core.

Borehole Logging. The first log which was run, and one of the most useful ones, was the TV camera log. This tool permits videotaping of any interesting sections, measures the orientations of joints, as well as their apertures, and allows detailed inspection of any zones which are to receive further testing.

During the field season of 1978 Dr. Scott Keys (United States Geological Survey) ran a comprehensive suite of 13 different logs in each of the boreholes based on seismic, electrical, mechanical, thermal, and nuclear principles. His tools detected the lithology change and most of the cracks shown in Figure 3. In 1979, work is continuing in correlating the geophysical logs with the hydrogeological results, with the objective of determining which geophysical logs are best suited for detecting hydraulic properties of fractures.

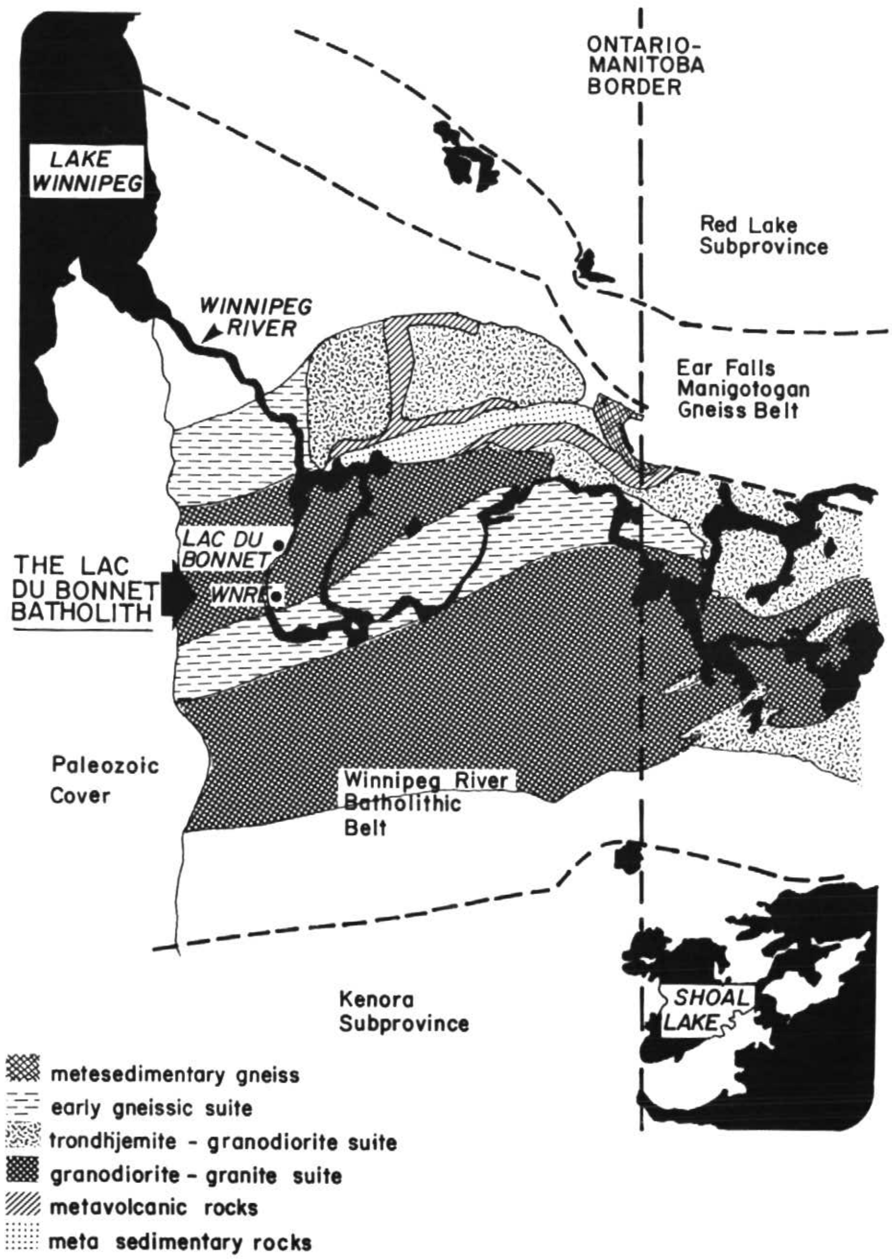

Figure 1

Regional geology in the vicinity of the Lac du Bonnet batholith.

Hydrogeology. The hydrogeology experiments conducted by Environment Canada consisted of two groups. The first, (using steady-state and transient injection of water into isolated borehole zones) assessed the physical hydraulic properties such as formation pressures and permeabilities. (Grisak, in prep.). The second determined groundwater chemistry both by down-hole sensors as well as by obtaining samples for subsequent laboratory analysis, age dating and so on (Bottomley and Graham, in prep.). Analysis of groundwater samples from the boreholes indicated that there was a dilute calcium-bicarbonate type water in the upper portions, as would be expected. A surprising result, however, was that a saline calcium-sodium-chloride rich water occurred in the bottom zone.

The hydrogeological program, whose objective is to define the groundwater flow system in rocks which intrinsically do not contain much water, is one which still requires considerable innovative and technological advance.

Other Activities. A number of surface geophysical surveys which were carried out have not been described. Because of the overburden and its clay content, these surveys were largely unsuccessful in providing useful information about the bedrock.

To begin assessing long-term crustal stability, a seisometer has been installed at WNRE by the Earth Physics Branch to supplement the Canada-wide network which is particularly sparse in the western part of the Canadian Shield. No earthquakes have yet been detected in this area.

Relevance to Nuclear Waste Disposal

The question now is: How can all these data be used in a fashion to assist in the verification of the viability and safety of nuclear waste disposal?

The answer lies in synthesizing results obtained by a number of disciplines, of which hydrogeology is the most important. Figure 4 illustrates the concept. The objective is to develop a knowledge of groundwater chemistry and flow at depth. That information, in combination with other data such as waste container corrosion rates and nuclide adsorption coefficients, can then be used by safety analysts to predict whether any toxic elements will be released to the environment from nuclear wastes emplaced in deep underground vaults. As indicated, a number of geological and geophysical studies will be used to construct a statistical description (orientations, spacings, connectivity, length, etc.) of those structural features which can form conduits for groundwater. These features can be grouped into major lineament and joint sets. Hydrogeologicl field-testing results will yield permeabilities for these classes of features. Initially, constant permeability values will be used, but as more field data become available, further degrees of complexity can be introduced, such as variations of permeability with depth, orientation, or fracture in-filling materials. Mathematical formulations will be devised to convert the permeability and structural data into porous media equivalent permeabilities and porosites. Regional geography and topography, as well as pressure data from boreholes, will yield the potential fields, i.e., the driving forces for the system. Finally, existing regional groundwater computer codes will use these input data to calculate the flow systems and to derive the required flow rates, fluxes, etc.

It must be stressed that at the moment this work is in only its initial phases. It will probably be 6 to 12 months before the first models are available and, of course, refinement and up-dating will need to continue for several years.

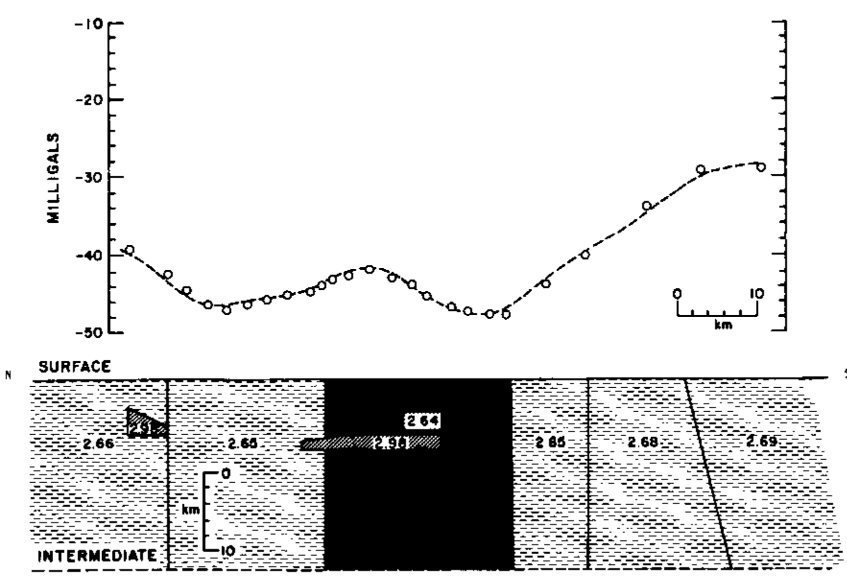

Figure 2
Bouguer gravity anomaly observed in a north-south traverse across the LDB batholith and a cross-section of one postulated mass distribution which satisfies the observed data (from Brisbin, 1979). The LDB batholith is represented by the darker shading.

Conclusion

An unprecedented amount of geoscience research is being focussed on plutons, rock units which have traditionally taken second place to the economically more interesting volcanic rocks of the greenstone belts. This research will not only assist in developing methods for disposing Canada's nuclear wastes safely, but will undoubtedly contribute significantly to the basic understanding of the early history of the Canadian Shield.

Acknowledgements

The research described in this presentation has involved many scientists and organizations. Major responsibility for drilling, logging and geophysics has resided with the Geological Survey of Canada and the Earth Physics Branch of Energy, Mines and Resources. The Hydrology Research Division of Environment Canada conducted the hydrogeology research. A large number of universities and contractors made

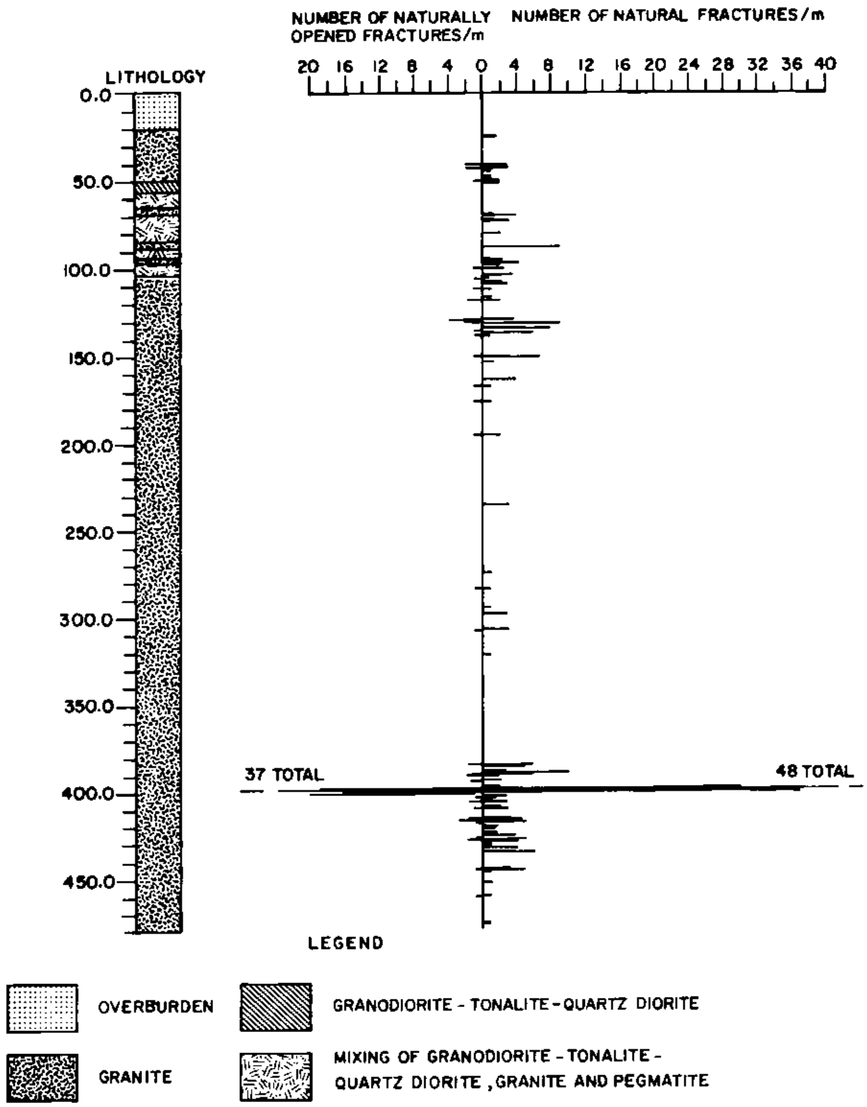

Figure 3
Lithology and fracture histogram as a function of depth for borehole WN-1 (from J. B Dugal, Geological Survey of Canada pers. commun.).

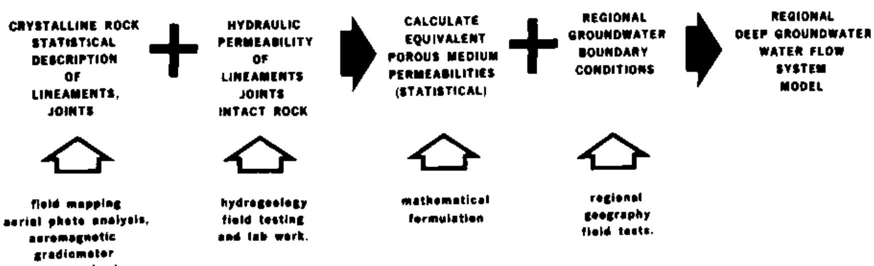

Figure 4
Block diagram indicating how the geotechnical data will be synthesized.

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