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James M. Hall

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See table of contents

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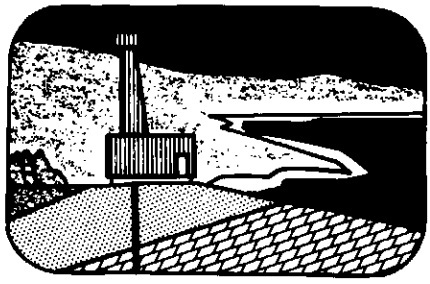

Continental Scientific Drilling in Canada

James M. Hall
Centre for Marine Geology
Dalhousie University
Halifax, Nova Scotia B3H 3J5

A discussion meeting on the subject of Continental Scientific Drilling in Canada was held at Camsell Hall, Energy, Mines and Resources, Ottawa, from 3 to 5 February, inclusive, 1986. The meeting was co-sponsored by CANDEL (Canadian Committee on the Dynamics and Evolution of the Lithosphere), LITHOPROBE, and Energy, Mines and Resources (EMR), Canada. The purpose of the meeting was to determine whether a number of geological problems of current international interest could be addressed most effectively in Canada using research drilling as a major tool, in conjunction with more conventional geological and geophysical techniques. About 180 participants attended the meeting, these being drawn from universities, governments and industry in Canada, the Natural Sciences and Engineering Research Council, and from the national continental research drilling programs of the Federal Republic of Germany and the USA. The meeting began with a review of its objectives by Ray Price (Geological Survey of Canada (GSC)), followed by reviews of other national programs (Frank Stehli, Chairman, Scientific Advisory Committee, DOSECC and Rolf Emmerman, Koördinatorenburo (KTB)) and of past and current activity in Canada. The main part of the program consisted of a consideration of the major themes of the geology of Canada, with a view to the identification of world-class problems that could be addressed through research drilling and other techniques. Each theme was addressed by a lead speaker, followed by a series of submitted presentations.

Paul Hoffman (GSC) introduced the tectonic phenomena theme. He suggested that extension of our knowledge of basement age would be a basic task for research drilling. Recent results for the mid-continent region of the USA suggest that Proterozoic additions to the continental nucleus might be much more important volumetrically than had previously been thought, that is, the Archean age of most of the exposed Shield may not be representative of the nucleus as a whole. Hoffman's presentation was followed by a proposal from Gordon Gross (GSC) that important relationships between the Superior, Ungava and Grenville Provinces of the Shield could be addressed by research drilling along the eastern margin of the Labrador-Quebec fold belt.

John Ludden (U de Montréal) reviewed current problems concerning large mafic extrusive and intrusive masses, including ophiolites, and concluded that Canada offered the best opportunities to study large mafic intrusions. Projects would study both plutonism and tectonism, the former including recovery of complete vertical sections to evaluate primary nature, metamorphism and alteration, and to locate deep sulphide reserves. Tectonic projects would include explanation of basement relationships, emplacement history and the different signs of the gravity signatures over different anorthosite bodies. Potential targets would include Archean layered complexes, such as Dore Lake, Bell River and Bad Vermillion, Grenville anorthosite-troctolite bodies, the Sudbury structure and alkaline complexes such as Coldwell. Burkhard Dressler (Ontario Geological Survey (OGS)) followed John Ludden's presentation with a specific discussion of problems relating to the Sudbury structure. He suggested that three questions could be addressed using research drilling: (i) a choice might be made between models for the gravity high associated with, but of significantly larger area than, the exposed part of the structure; (ii) recovery of a section through the lower part of the structure would determine its nature and that of the subjacent basement, of possible lower crustal origin; and (iii) recovery of a section through the Onaping Formation from within the basin, should lead to choice between a fall-back impact or volcanic origin for the breccia component of the formation.

David Strong (Memorial University of Newfoundland (MUN)) presented a review of problems associated with granite plutons, in which he concentrated on the Caledonian-Hercynian granites of Newfoundland and Maritime Canada, and of western Europe. Strong pointed out that recent work, in Brittany, had shown, at least in some instances, a strong spatial relationship of granites with large-scale shear belts and elsewhere granites occured in thrust environments. Similar associations had been noted in Newfoundland, where more leucocratic granites occured close to and more mafic at distance from major shear structures. These observations require explanation and relate to questions of the depth of formation, approach to the final location, mixing, convection within cooling bodies, and final or later stages of mineralization. The occurence of Sn-W greissen type mineralizaton in the Caledonian-Hercynian batholiths, and porphyry copper mineralization in other types of granite bodies also require explanation. Drilling could assist by recovering complete sections of mineralized zones. Submitted presentations by William Morris (Morris Magnetics) on borehole magnetic logging, and Glen Woodsworth (GSC, Vancouver) followed the thematic section. Woodsworth's presentation was of particular interest: he suggested that long vertical sections could be compiled for Cordilleran granites by combining drillhole date with the extensive vertical exposure of the area.

Malcolm Drury (Earth Physics Branch (EPB), GSC) described current questions regarding heat flow and geothermal systems. Basement research drillholes could provide key information on the generally assumed, but poorly known, depth variations in K, U and Th and also test the supposed existence of provinces with different depth signatures for these elements. The variation of apparent heat flow with depth is another important question, and bears on the presence and flow of fluids at depth in continental crust. The recent discovery of substantial amounts of fluids of unexpected compositions in the Kola Superdeep hole emphasizes the need for this kind of information. Drury concluded with a

plea for the long-term instrumentation of a number of drillholes. This would not only yield information on a number of thermal and fluid parameters, but also provide an opportunity to follow long-term changes in seismicity, *in situ* stress and the magnetic field.

Phil Thurston (OGS) reviewed current problems regarding greenstone belts. He began with an outline of our present knowledge of these belts, their relative importance as constituents of the Superior, Slave and Nutak Provinces of the Shield, the 2.7-3.0 Ga time interval for their formation, the typical volcanic to sedimentary sequence within belts, metamorphism, internal deformation and relationship to other Shield terranes. Research-drilling could aid materially in providing solutions to several important outstanding questions. In particular, resolution between the apparently contradictory indications of the thickness of belt sequences; tens of kilometres from stratigraphy and less than ten kilometres from geophysics, would be very valuable. Again, the question of the overall tectonic origin of belts, sagduction versus obduction, could be addressed by complete recovery in drillcore of sections of the contacts between belts and adjacent terranes. Three submitted presentations, by Rejean Herbert and Michel Rocheleau (U. Laval), Michel Chouteau (École Polytechnique/EPB) and David Smith (Dept. of Energy, Québec) followed, dealing with specific problems in the Abitibi and Cape Smith Belts.

Roger MacQueen (Institute of Sedimentary and Petroleum Geology (ISPG), GSC) introduced the sedimentary basins thematic area. An underlying question in the presentation was usefulness of research drilling in areas where industry had been very active for several decades. It was suggested that research drilling should both complement and take advantage of industrial drilling. Complementary work could be directed at areas of basic structural, stratigraphic, and thereby basin formational importance where there was no likelihood of industrial drilling being carried out. Research drillholes could be used for a wide range of in-hole geological and geophysical tests. A scientific drilling program could take advantage of planned industrial drilling by providing funds for, as examples, the coring of intervals of interest, or extension of holes to sample basement. A thematic area allied to sedimentary basins, stratigraphic standards, was discussed by Digby McLaren (Carleton U/GSC). Advantage could be taken of industry drilling in the Cordilleran, Western and Arctic basins to recover key sections for boundary, biostratigraphic, correlation, geochemical signatures and basin analysis purposes. Dedicated drillholes should be considered for specific targets where industry work is not presently planned. These include the Cretaceous-Tertiary boundary section at Turtle Mountain, Manitoba, the Quaternary and Paleozoic of the Great Lakes and Hudson Bay areas, and the offshore basins of the Gulf of St. Lawrence. This last basin was discussed in more detail by Godfrey Nowlan (GSC) who proposed a series of drillholes, one on Anticosti Island and two offshore, to define key stratigraphic elements likely to be present. Ray Yole (Carleton U) suggested that the drilling of basement uplifts or arches in the western basins would be worthwhile, while Donald Sangster (GSC) suggested that the deeper, unexposed part of the Middle Proterozoic Purcell Basin Sequence would be a worthwhile target for research drilling.

Blyth Robertson (EPB) reviewed current questions regarding impact structures. He identified complex structures, such as Manicougan as targets for investigation by drilling. In addition to basic information on the nature of these structures, drilling might also sample uplifted lower continental crust, and test for fluids of mantle or other origin that may be present in the fracture systems associated with major impact structures. In this connection, John Beswick (Kenting Drilling) described the evidence for hydrocarbons associated with the Siljan major impact structure in Sweden, and plans for testing for hydrocarbons at depth in the structure by drilling to 5000 m during 1986.

Ian Gough (U of Alberta) gave the thematic presentation on crustal geophysics, in which he concentrated on the recent recognition, through deep reflection seismics, of the laminated nature of lower continental crust in the USA, UK, West Germany and elsewhere. He noted the coincidence of the onset of lamination at several locations with the top of a layer of high electrical conductivity, and suggested that this correlation favoured explanations of the seismic laminae that involved fluids, rather than structural or lithological explanations. Gough suggested that identification of the causes of the contrast between the upper and lower continental crust was a question of major current international interest that could be addressed as well in Canada as elsewhere. A site should be selected where the onset of laminated reflectors was at about 10 km depth, and the hole drilled to at least 12 km so that a representative sample of the lower crust could be obtained. A submitted presentation by Trevor Lewis (GSC) addressed geothermal questions in western Canada, and the mapping of highly reflective features, such as the Leech River thrust fault, an important terrane boundary on Vancouver Island followed to depth during the 1984 LITHOPROBE reflection profiling experiment.

John Percival (GSC) reviewed present knowledge of the nature of continental crust at depth, based on geophysical studies augmented by examination of surface exposures of terranes transported upward from a former position in the lower crust. The objectives of a drilling program would be to test geophysical observations and check models. As lowest crustal depths are inaccessible, drilling into granulite terranes with lower crustal characteristics would be the next best thing. There are many localities in Canada where this could be accomplished. Specific questions to be addressed include the nature of the seismic reflectors, the bulk composition and mineralogy of high velocity, lower crustal material and the origin of the high conductivity zones. If these are due to the presence of saline fluids, do these reside in fractures or in intergranular pore spaces? Are they residual metamorphic fluids and how do they affect strength, heat flow and isotopic systems? Finally, what is their relationship to mineralizing fluids, for example, to the deposition of gold? The Kapuskasing zone, which is already a LITHOPROBE target, where the present level of exposure is 20 km deeper than the adjacent Michipicoten greenstone belt, is a potential location for addressing some of these questions by research drilling. Submitted presentations following this review were given by Jacques Martignole (U de Montréal) who has identified a high paleopressure zone in the Baskotatong Uplift of the Grenville Province, and Robert NcNutt (McMaster U) who, with his colleagues, is investigating Shield brines of demonstrable non-meteoric origin.

The final thematic area to be addressed, downhole logging and long-term instrumentation, was given by Patrick Killeen (GSC) and George Coates (Schlumberger of Canada). The presentation covered current downhole instrument calibration capability in Canada, and the range of downhole tools available, classified into rotary and slimhole groups, and by temperature capacity. Submitted presentations by Sebastian Bell (AtlanticGeoscience Centre (AGC), GSC) on in-hole stress-tensor measurements, Louis Meyrand (EPB) on vertical seismic profiling (VSP) and Leonard Collett (GSC) on the opportunity for the funding of technical developments followed the thematic presentation.

Following the thematic sessions, Barry Krause (INCO Limited) spoke as a representative of the mining industry on the desirability of a Canadian program of continental drilling. His analysis was based on the answers to three questions: is it scientifically worthwhile?; are there advantages to be gained from drilling in Canada?; and, if the answer to both of these questions is positive, what contribution could be expected from the mining industry? On the question of the worthwhile nature of scientific drilling, Krause suggested that the answer is very much in the affirmative. In a general sense, all new major scientific programs provide valuable spin-off of many kinds. In a more specific sense, scientific drilling in Canada is likely to lead to better ore deposition models, and information of value for future energy needs. It is also relevant that 12 other nations are already committed to the government funding of research drilling programs of some type, and have, presumably, gone through a similar

evaluation process as that currently underway in Canada, and have concluded that such programs are worthwhile.

On the question of whether Canadians should be observers of or collaborators in other programs or should we establish a Canadian program, the conclusion is that, while we may participate in some programs, and should monitor all programs, there should be a Canadian program. The reasons for this conclusion relate to the opportunities a national program will provide for technological development in the drilling and logging industries, which will benefit the mining industry in Canada, and the reputation of Canadian industry elsewhere. Again, scientific drilling in Canada will provide valuable background information for models of ore deposition, which can be used in the search for new mineral deposits in Canada. If industry can participate in the choice of targets, drilling in greenstone belts, Archean sedimentary basins and impact structures is likely to receive considerable support. The results of scientific drilling should be disseminated rapidly, so as to allow advantage to be taken of the work in the shortest possible time. At several points in the geological presentations, speakers had pointed out that the question of international interest could be addressed in Canada through shallower, less expensive and less technically demanding drilling operations than elsewhere. Other positive reasons for a Canadian program are in the employment opportunities a program will create, both in drilling operations and during the development of new drilling and geophysical instrumentation. Technical spin-off developed through the stimulus of a national drilling program will benefit the mining industry in Canada, Canadian expertise and the prestige acquired from a successful program in which all Canadians would share. Finally, there is the question of the industrial contribution to a Canadian program. While at present direct financial contributions will be difficult to provide, industry is likely to be willing to provide a wide range of assistance that will substantially reduce costs. This assistance could be in the form of the provision of geophysical surveys, analyses and site selection at cost. Access, both physical and legal, to sites could be provided and industry would probably be willing to share its considerable bank of knowledge in the areas of logistics, drilling, geology, geophysics and so on. In summary, it is believed that industry would look upon continental drilling as being worthwhile and, further, that the advantages to our industry and to Canada warrant early funding of drilling in Canada to depths which are currently feasible. These advantages also warrant funding research toward developing the skills and instrumentation needed to increase the depths of drilling. Ultimately, this would help practical exploration at shallower depths due to reduced costs and improved effectiveness. Also, Canada has always been a leader in geophysical instrumentation. This position should be maintained and new skills developed to fully exploit the deeper holes. It is hoped that enthusiasm for the concept will generate the maximum level of support from industry.

In order to give participants at the meeting an indication of the technical and other factors involved in the planning of research drilling operations, presentations were made by John Beswick (Kenting Drilling) and Frank Schuh (ARCO/DOSECC Drilling Advisory Panel). Beswick outlined the existing drilling technologies available and summarized the key questions that must be addressed in planning drilling operations. If coring is the main objective, and depth is to be less than 5 km, then the high speed wireline method is probably indicated. For depths in excess of 5 km, or if a large diameter hole is required, the oilfield method is indicated, although this is less suitable for coring and is significantly more expensive than the wireline method, particularly at modest depths. John Beswick's points were illustrated with recent examples of drilling projects, and the costs of various options were estimated. Frank Schuh, who is involved with the planning toward a deep hole in the USA to test the proposed thin-skinned tectonic nature of the southern Appalachians, outlined the requirements, and many unknowns, of drilling to 15 km depth.

The final session of the meeting consisted of two parts: brief reviews by thematic speakers of the major points raised during the meeting in their thematic areas, and consideration of recommendations in support of the establishment of a Canadian program of continental scientific drilling. Following the brief reviews, the Organizing Committee for the meeting presented a series of draft recommendations to the participants present. These were discussed briefly, and, as a result, modified in detail. The recommendations, which are given below, were then accepted unanimously by the 80 participants present, on a proposal by Ian Gough (U of Alberta)which was seconded by Jack Souther (GSC).

Participants in the Discussion Meeting, held in Ottawa 3-5 February 1986, to consider the desirability of a program of continental scientific drilling in Canada, noted that:

I. The diversity of geological settings found in Canada and the substantial knowledge of these settings, leads naturally to the identification of Canada as a preferred location to address, through a combination of research drilling and other geological and geophysical methods, a number of fundamental geological questions of current international focus. Among these questions are the ongoing construction of the geologically young Cordilleran orogenic belts of western Canada, the present tectonic setting and original construction mechanisms of the fragments of oceanic crust preserved in Precambrian greenstone belts, and the nature of constructional processes, and possible fluid content of continental crust and uppermost continental mantle.

II. World-class drilling and instrumentation technology exists in Canada, together with the skilled manpower to meet present and future technological needs. Canada also has an earth science community that contains all the skills necessary for proper description and interpretation of the products of a continental scientific drilling program. Both in technological development and in resource exploration, a continental scientific drilling program will provide a substantial return to Canada for the necessary investment.

Recognizing these opportunities, we recommend to CANDEL and the Canadian Geoscience Council that:

1. Measures be taken to introduce such a drilling program for Canada.

2. As a first step in this process, a steering/co-ordinating committee representing university, industry and government (Federal and Provincial) interests be established to investigate the structure, funding, organizational and operational aspects of such a program.

3. As an interim measure at least, that the co-ordinating committee should be convened under the auspices of the Canadian LITHOPROBE project.

4. That the committee should, by 1 June 1986, draw up a formal plan for the establishment of a Canadian continental scientific drilling program for consideration by the Canadian LITHOPROBE Committee, the Canadian Geoscience Council and other appropriate sponsoring and participating agencies.

Developments Subsequent to the Discussion Meeting (JMH, 30 May 1986)

The recommendations made at the Discussion Meeting received the support of CANDEL at its meeting of 6 February 1986 and of the Canadian Geoscience Council at its meeting on 13 March 1986. A "Planning for Continental Drilling" Subcommittee of the LITHOPROBE Steering Committee has been established, with the task of preparing a co-ordinated proposal for the first phase of a Canadian Program of Continental Drilling. It is anticipated that a small full-time group will be established to work with the LITHOPROBE subcommittee toward this end. The first task of the full-time group will be to seek proposals for specific drilling-based investigations, and to review, cost, and prioritize these proposals, in co-ordination with the LITHOPROBE subcommittee, toward their incorporation in the larger, co-ordinated, proposal. The second task of the full-time group will be to establish an inventory of past and current drilling activity in Canada, both to aid in proposal production and to advise scientists of opportunites arising from industry activities.

Accepted 10 June 1986.