Conference Reports

The Algonquin Arch, southern Ontario: A CCDP Workshop Report

R.W. Yole and M.J. Drury [1]
CCDP Planning Office
Department of Earth Sciences
Carleton University
Ottawa, Ontario K1S 5B6

In October 1987, a proposal for a scientific drilling program, involving three boreholes in southern Ontario, was submitted to the Canadian Continental Drilling Program (CCDP) by a group representing four Ontario universities, three provincial government agencies, two federal government agencies, and Ontario Hydro. A multidisciplinary study, focussing on detailed analyses of Paleozoic and Precambrian rocks on and flanking the Algonquin Arch, was envisaged. The principal aims were clarification of fundamental stratigraphic, sedimentological and tectonic relationships, accompanied by significant additions to hydrogeological, geochemical and geophysical data, designed to assist in resolution of regional problems in resource evaluation and environmental geology.

The proposal was presented for open discussion at the fifth of a series of workshops sponsored by CCDP, held on February 9-10, 1989, in Toronto, appropriately in the "Algonquin Room", MacDonald Building, 900 Bay Street. The attendance of 45 earth scientists representing governments, universities and industry, from both Canada and the USA, demonstrates the wide interest in this CCDP proposal.

[1] also Geological Survey of Canada, 601 Booth St., Ottawa, Ontario K1A 0E8

Owen L. White opened the workshop on behalf of the host agency, Ontario Geological Survey, and Mike Johnson (Ontario Geological Survey) briefly introduced the workshop topic and background. He was followed by James Hall (Dalhousie University; Chairman, CCDP Steering Committee), who outlined the history and present status of the CCDP.

S.K. Frape (University of Waterloo) outlined the Algonquin Arch Transect proposal. The original proposal has evolved to the stage of tentative site selections for at least five, and possibly six boreholes, which would form a transect from the Niagara Peninsula across the Algonquin Arch to the Bruce Peninsula. The deepest hole envisaged (2.5 km) is intended to penetrate the basement at or near a significant Precambrian geological boundary (Grenville Central Gneiss Belt - Central Metasedimentary Belt), as well as exploring in detail the Paleozoic rocks. Other proposed holes (<2.0 km) would test Paleozoic facies changes as well as other Precambrian geological/geophysical features. The possibility of addressing fundamental problems related to the transition between foreland basin (Appalachian) and Cratonic interior basin (Michigan) across the Arch makes this area particularly attractive for a scientific drilling program.

The rationale for additional deep holes in southern Ontario includes improvement and testing of stratigraphic and lithofacies models and evaluation of the tectonic history of this periodically active Precambrian Arch. The high quality lithologic and seismic data obtained from carefully sited cored holes will form the basis for new insights for resolution of major geological problems of this region. In addition, the scientific sampling and instrumentation of the holes should lead to major advances in understanding of shallow and deep hydrogeological systems, fundamental rock properties and stress regimes.

R.M. Easton (Ontario Geological Survey) described the several situations that might be tested by the deepest of the proposed holes (Niagara Peninsula) by extrapolating Grenvillian geology southward from the Minden-Fenelon Falls map area. The proposed 2.5 km hole could penetrate the shallowly dipping Central Metasedimentary Boundary Zone, or alternatively encounter rocks of the Central Gneiss Belt or Central Metasedimentary Belt.

M.D. Johnson (Ontario Geological Survey) presented an array of objectives for holes penetrating the Paleozoic section in the proposed site areas. Major facies changes from the Appalachian to the Michigan Basin side of the Arch and their relationships to tectonics need clarification and closer documentation based on completely cored sections from carefully sited holes. A better understanding of the four subsurface systems (Cambrian, Ordovician, Silurian and Devonian) is expected to yield scientific and economic-social benefits, particularly with respect to petroleum occurrence and exploration, sediment-hosted mineral deposits, and non-hazardous waste disposal systems.

M. Coniglio (University of Waterloo) described possible relationships of his current research in carbonate rocks to objectives of the drilling program proposed. In particular, the patterns of dolomitization in Paleozoic rocks may be related to regional stratigraphic and structural controls.

P. Karrow (University of Waterloo) pointed out opportunities for significant additions to our understanding of Quaternary stratigraphy and geological history that might be presented by cored holes, particularly if they were to penetrate early Wisconsin or older Pleistocene deposits. The acquisition of paleomagnetic data and *in situ* stress measurements, in addition to standard dating and paleoenviromental analysis, would greatly enhance the interpretation of results.

G. McFall (Ontario Geological Survey) reviewed the evidence for ancient and recent tectonic events in southern Ontario. Two major tectonic cycles (Late Precambrian to Late Paleozoic; Mesozoic-Tertiary) Recent investigations suggest that some tectonic activity may have continued, as some southern Ontario lineaments appear to show evidence of recent activity. Mapping of fracture systems by direct observations and by remote sensing show two blocks, differentiated by fracture patterns. (Bruce block - simple pattern; Niagara block - complex pattern). Aeromagnetic lineaments and seismicity are spatially related to some of the known major faults of southern Ontario. Subsurface information from proposed

scientific boreholes located on or close to such features may be critical for accurate interpretations of ancient tectonics as well as neotectonics.

A. Dickin (McMaster University) reviewed evidence for the complex history of the Grenville Province of the Canadian Shield, with particular reference to Nd model-ages. Geochronologic evidence for the presence of the Penokean suture belt (± 1900 Ma) within the Grenville Province (± 1100 Ma) indicating reworking may be tested by new data on basement rocks from the proposed bore holes in southern Ontario. At present, a significant gap in data between outcrop areas in Georgian Bay and Wisconsin limits interpretation of crustal accretion for the Grenville Province.

S.K. Frape summarized geochemical characteristics of formation waters of southwestern Ontario and Michigan. Although each formation in the Paleozoic section appears to have a distinctive geochemical and isotopic signature, there is evidence for mixing of waters from adjacent formations and for significant rock-water interactions. The implications of such mixing for hydrological interconnections and basin dynamics between the Michigan and Appalachian basins could be better evaluated by detailed sampling in cored holes of the proposed program.

D. Siegel (Syracuse University) described results from geochemical studies in western New York State. Early work on calcareous Paleozoic concretions later supported by subsurface studies yielded isotope data suggesting mixing of Pleistocene meltwater with pore waters. Hydrochemical facies for some subsurface units (*e.g.*, Medina Formation) demonstrate differences between Ontario and New York waters which suggest a possible "hinge-line" separating waters of Appalachian and Michigan Basin origin.

K. Novakowski (National Water Research Institute) discussed a theory to explain anomalous hydraulic heads discovered in deep boreholes in southern Ontario. Zones of pressures either exceeding or less than the expected hydrostatic pressures occur in all of the holes tested. Out of several possible mechanisms to generate such anomalies in the Paleozoic rocks, neotectonism is regarded as an attractive one to test by additional subsurface data. Boreholes drilled into the basement and appropriately instrumented for fluid-pressure monitoring should provide data, which with known or measurable rock properties and stress data, could enable numerical simulations of pressure distributions across the basin-arch complex.

R.H. McNutt (McMaster University) presented results and implications of studies of brines from Paleozoic and Precambrian rocks of the Canadian Shield and the Michigan Basin, based on radiogenic isotopes. The Michigan Basin brines have, with a few exceptions, Sr isotopic ratios higher than those postulated for seawaters of host-rock ages, suggesting water-rock interaction. Also, isotopic signatures using Sr, O, and H isotopes appear to be unique for individual oil and gas fields in southern Ontario. Such studies have demonstrated the potential for determining the scale and pattern of fluid migration in basins. With similar studies from cored sections in propose deep holes in southern Ontario and additional data on Nd and Pb isotopic values from both Paleozoic and Precambrian sections penetrated, significant advances in analysis of fluid migrations should result.

B. Sherwood Lollar (University of Waterloo) reviewed work on the origin of gases and brines in shield rocks. Chemical and isotopic analyses indicate an abiogenic origin for methane, hydrogen and helium in Shield rocks both in Canada and Fennoscandia. Inconclusive indications of basement contributions to southern Ontario natural gases (possibly high temperature methane and some helium) suggest the need for further study of gases and brines to clarify this situation. Significant contributions to understanding of the generating environment and geochemical history of both basinal and Shield gases should be expected from detailed profiles of geochemical and isotopic parameters developed from new borehole sampling techniques.

D. Tepper (United States Geological Survey) gave an overview of the USGS program of hydrogeological studies in the Niagara Falls area, New York, a co-operative study with the US Environmental Protection Agency. Major groundwater flow is through subhorizontal bedding planes, which are connected with vertical fractures. The area is crossed by regional structures which may locally intensify the fracturing and transmissivity. Formation pressure data from 17 deep boreholes with multi-level monitoring systems show shallow overpressured zones which impede vertical fluid migration.

C. Fordham (University of Waterloo) described how ISRM rock mechanics tests may be applied to rock cores. Potential results of research test programs include: change in properties with depth and time-dependent changes, particularly of shale units; analysis of halite behaviour under stress (*e.g.*, salt creep).

D. Nobes (University of Waterloo) listed the geophysical methods and applications for boreholes of the southern Ontario transect. Downhole geophysical logging and laboratory determinations of rock properties would facilitate stratigraphic correlation, identification of seismic reflectors, fracture analysis, and possibly other scientific investigations as the program develops.

R. J. Heystee (Ontario Hydro) discussed the "pros" and "cons" of disposal of fuel-waste in basement rocks beneath thick cover rocks. Preliminary investigations have demonstrated the apparent viability of this approach and data from some tunnels in southern Ontario below tight (unfractured) Paleozoic rocks tend to support the proposition. The additional data provided by CCDP Algonquin Arch transect drilling would be useful in further assessment of this option for waste disposal.

F. Patton (Westbay Instruments) described the Westbay MP system for groundwater monitoring, and its present limitations and approximate costs. The principal advantages of the system are the opportunity for multiple monitoring zones and relatively less cost than other methods for such extensive sampling and monitoring. The maximum depths instrumented to date are 1200 m, but modifications may permit even deeper holes to be monitored.

T. Carter (Ontario Ministry of Natural Resources) commented on the possible extension into southwest Ontario of the Midcontinent Rift System, and recent interpretations from GLIMPCE data that place the Grenville Front relatively close to the southern part of the southwest Ontario peninsula. The proposed locations for CCDP holes include some which may contribute to clarification of these relationships.

A full report on the workshop, including abstracts, is available at no charge, while stocks remain, from the CCDP planning office.

The workshop participants agreed to prepare a modified proposal for submission to the next CCDP Steering Committee meeting (April 7, 1989). By that time, it was expected that renewed consultation amongst participants and perhaps scientists from other groups would have brought the proposal to a more mature stage.

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The Industrial Associate Members of CCDP are currently: BP Canada, Bradley Bros. Ltd., Chevron Canada Resources, Esso Minerals Canada, Falconbridge Ltd., Heath and Sherwood Drilling (1986) Ltd., Inco Gold Co., JKS/Boyles Industries Inc., Longyear Canada Inc., Midwest Drilling, Newmont Exploration Ltd., Noranda Explorations Ltd., Petro-Canada Inc., Teck Explorations Ltd. and Tonto Drilling Company.

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