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# Greenstone Belts and Associated Granitoids: A CCDP Workshop Report

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The fourth of a series of thematic workshops sponsored by the Canadian Continental Drilling Program (CCDP) was held at the Geological Survey of Canada, Observatory Crescent, Ottawa, 23-24 November 1988. The workshop was attended by 40 participants, drawn from universities, government and industry in Canada and by a representative of KTB (Kontinentales Tiefbohrprogramm), the deep drilling program of the Federal Republic of Germany. The principal aim of the workshop was to encourage open discussion of proposals submitted to CCDP for the examination and sampling of greenstone belts and associated granitoids by drilling. Other presentations described current ideas of the nature and formation of greenstone belts and estimates of their depth extent from a number of geophysical techniques.

Robin Riddihough (Chief Scientist, Geological Survey of Canada (GSC), Ottawa) opened the workshop and welcomed the participants. He noted that the Geological Survey of Canada was glad to be involved with the Canadian Continental Drilling Program. CCDP represented an important initiative in Canadian geology and he wished participants in the workshop success in their deliberations.

James Hall (Chairman, Steering Committee, CCDP, Dalhousie U, Halifax) described the status of the review of proposals and the links CCDP has made within the geological community in Canada. The Steering Committee is a standing committee of the Canadian Geoscience Council. Industry is being most supportive, with 15 major companies have joined the project to date as Associate Members. Three-quarters of the proposals received so far ask for relatively low cost, shallow (<2 km) holes using conventional technology. In this sense, the initial stage of CCDP operations is more likely to resemble the highly successful French program than the programs of the Federal Republic of Germany and the Soviet Union, which are dedicated to the drilling of deep (>10 km) holes. More challenging tasks, such as drilling to ~7 km depth in the Sudbury Basin are, however, also under active discussion.

Phil Thurston (Ontario Geological Survey (OGS), Toronto, Ontario) reviewed current ideas on the nature and history of greenstone belts. He noted the important part being played by government agencies, including his own, in research on greenstone belts. This follows from a pressing need to understand their economic mineralization, currently realizing several billion dollars annually, in terms of their constructional, tectonic, and alteration history. With much new geochronologic and structural information available and models for greenstone belts beginning to evolve rapidly from those of the recent past, this was a very opportune time for increased involvement by university-based researchers, particularly in the areas of geochronology, stable isotopes and structure.

Archean areas typically consist of three major components, greenstone-granite terranes ("greenstone belts"), on which the discussion is concentrated, plutonic terranes, which range in age and metamorphism from nearly synchronous to much older than adjacent greenstone belts, and sedimentary megabelts, such as the Quetico, which consist largely of clastics that have experienced high temperature metamorphism and probably represent deformed accretionary prisms.

The task at hand is to define the original extent, develop a three-dimensional model, establish the continuity with depth, the alteration, the structure and the relationships with surrounding terranes of greenstone belts. In terms of drilling objectives, it would be practical to locate early sites in the Abitibi belt, where seismic data are available to constrain three-dimensional models, a geochronologic and stratigraphic framework work is available, and the mineral potential is high.

The most notable feature of current work in greenstone belts is the recent trend toward large, rapid change in the basic model for the nature and history of belts. Until this decade, it was thought that belts represented the products of a single formational environment, alternatively amalgamated island arcs, collapsed continental rifts, or back arc basins, later deformed into steep open folds. Several more recently developed models see greenstone belts as consisting of the products of four distinct lithostratigraphic associations; platform, mafic plain, rift-cyclic (continental magmatic arc) and pull-apart basins, represented by associations of the "Timiskaming" type. This latter association consists of fault-bounded packages of fluviatile sediments and calc-alkaline to alkaline volcanics, showing large, rapid lateral and vertical thickness changes. The age of these associations are later than the first but before the last phases of deformation, and clearly represent a phase of dilatant tectonics perhaps comparable to modern pull-apart basins. While in the Abitibi belt this association is known as the Temiskaming, similar associations also occur in other belts and thus appear to be a typical feature of granite-greenstone subprovinces.

Until about ten years ago, the structures of greenstone belts were thought to comprise synclinoria characterised by upright folds and late vertical faults. Granite diapirism was thought to be the dominant driving force for the structural pattern. During the last decade a very different structural model, with belts seen as tectonic collages, has been recognized. As an example of this, the Abitibi belt is now known not to be a simple synclinorium since the ages of volcanism on the northern side, at 2701 to 2730 Ma, differ from the ages on the southern side at 2701 to 2747 Ma. The type Timiskaming sequence, located for example near the southern "limb" of the syncline, at about 2685 Ma, is younger rather than older than the "axial" units as predicted by a synclinal model: the important late deformation event, involving the formation of the pull-apart basins, is now seen to represent a period of "transpression" or "oblique compression". The greenstone sequences as a whole are seen as a series of fault bounded panels in an accretionary prism setting. Within the Superior Province as a whole, deformation appears to young irregularly southward. Platform sequences, the oldest Superior Province greenstones, with ages >2850 Ma, are concentrated in Sachigo subprovince suggesting this area represents a sialic nucleus in northern Superior Province. The later penetrative deformation, concentrated along subprovince boundaries, resulted in the successive southward accretion of the granite-greenstone and the sedimentary subprovinces.

A drilling program in granite-greenstone subprovinces belts should address a number of objectives over a period of time. These should include: investigation of problems in evolution of the early crust, testing of large-scale Archean tectonic models, confirmation of medium-scale models of assembly and geometry of greenstone belts, and characterization of uniquely Archean mid-crustal lode-gold hydrothermal systems. One objective should be the resolution of contradictory values for the apparent thickness of belts

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obtained by different approaches: several tens of kilometres by stratigraphy *versus* only 5 to 10 km from geophysics. The limited vertical extent of greenstone belts mandated by geophysical data suggests that the observed substantial crustal shortening produced a basal décollement, raising the possibility that thin-skinned tectonics have occurred. The presence of regionally extensive subhorizontal reflectors observed in the Abitibi-Grenville LITHOPROBE reflection seismics, suggest the presence of previously unrecognized horizontal structures — problems amenable to drilling.

The state of knowledge of the structural situation is sufficiently advanced that a drill site designed to test a well-defined model in part of the Abitibi belt could be located in within 6 months to a year. Candidate problems and areas might include the structural relationship of the Blake River Group to the Kinojévis Group and, perhaps later, since the situation is more complex, the nature and depth extension of the regional scale, gold-bearing shears.

In general, drill site requirements are most or all of the following: seismic data, comparatively simple structure, reasonable outcrop density and distribution, economic importance, a geochronological framework and the involvement of a multidisciplinary research team. It will be important to obtain mining company interest and, if possible, to use 1-1.25 km mining holes to constrain deeper research holes.

In response to a question from John Percival (GSC, Ottawa), Thurston suggested that a thin-skinned tectonic event would be late in the Abitibi belt (~2680 Ma) structural history and the footwall might consist of the mid-crustal units seen in the crustal section exposed in the Kapuskasing structural zone to the west: both domal terranes and basic gneisses. The rationale for drilling, while it is possible to "walk off" the end of a greenstone belt through down-plunge section reconstruction, was to help obtain a three-dimensional view of typical mid-belt structures. Even a single initial hole would be valuable if it were located on a seismic line. In response to a question from Ed Spooner (U Toronto), Thurston pointed out that the geophysical data obtained from a hole would help greatly to improve the accuracy of geophysical models. Robin Riddihough (GSC) pointed out that drilling in a Canadian greenstone belt would not only help solve local problems, but would have worldwide significance. In particular, the results should aid the understanding of mineralized greenstone belt areas in the Third World, for example, in Zimbabwe.

Mike Thomas (GSC, Ottawa) reviewed current knowledge of Canadian greenstone belts, as viewed from the interpretation of geophysical measurements, and commented on what to needed to be done in terms of drill site evaluation. The largest set of greenstone belt thickness estimates are derived from gravity measurements which are favoured as a result of the marked contrast in the physical property involved, density. Values for the depth extent of individual belts are generally similar, *e.g.*, Yellowknife, 1-3 km typical, 7-8 km maximum; Wabigoon, 6-8 km; 6-12 km; Abitibi, <5 or <7. These values are similar to values for the Barberton of 3-7 km (15 km by stratigraphy) and other belts. It seems that greenstone belts nowhere extend to more than about 15 km and are therefore an upper crustal feature.

Modelling of the shape of greenstone belts at depth suggests a variety of forms including saucer, funnel and sheet form, sometimes with keels extending to depth, and with constant or variable dip on the lower surfaces of forms. However, on a crustal thickness scale, all models are essentially near surface sheets. Granites associated with greenstone belts yield gravity based thickness estimates similar to greenstone values. For example, the Aulneau batholith of the Wabigoon belt has a typical thickness of 7 km with feeders to 11 km. Some granitoids have a depth extent of only 2-3 km.

Magnetic modelling is also aided by strong magnetization contrasts. Greenstones generally show negative and granites positive anomalies. Remanence is probably not important in either lithology. An interesting feature of the granites is their apparent increase in magnetization with depth. Granites have been modelled by Don Hall (U Manitoba) as having thicknesses in the 16-19 km range and the Abitibi greenstone belt as ranging from 6 km in the centre to 14 km at the edges.

Seismic refraction may have a drawback since velocity inversions are possible. Combined gravity and refraction along the same line across the Yellowknife belt yielded conflicting depth estimates of 2-4 km (gravity) and ~10 km (seismic). Some mistaken picking of early seismic arrivals may have taken place.

Seismic reflection work, for example, in the GLIMPCE and Aulneau studies is yielding some interesting results. While greenstone-granite velocity contrasts are negligible, density differences lead to significant differences in acoustic impedance. The bottom of batholiths do not image. Lower crustal reflectors at depths of 16 to 21 km continue unbroken beneath both granites and greenstones, suggesting, as also indicated by potential field measurements, that mid-crustal lithologies are divorced from the granites and greenstones of the upper crust.

The speaker also commented on the potential value of the magnetotelluric (MT) method (greenstones are much less resistive than granites), and of the heat flow method. Malcolm Drury (GSC) has shown that heat flow is, on average, 10% lower in greenstones than in adjacent granites and that 7 km is a typical vertical extent for greenstones as derived from the heat flow – heat generation relationship; below the greenstones normal crust appears to occur. In answer to a question about the geophysical signature of interbelt contacts, the speaker noted that paired anomalies marked several known belt contacts, such as between the Uchi-English River contact and might mark the location of a suture in a collision belt.

Louis Mayrand (GSC, Ottawa) presented a proposal, co-authored by B. Milkereit and A.G. Green of the GSC and C. Hubert and J.N. Ludden of the Université de Montréal, to study the Cadillac fault and associated structures by drilling. The justification for the proposal is the tectonic and mineralization controlling significance of major breaks within and at the margins of greenstone belts, together with the availability of recent LITHOPROBE regional and high-resolution seismics in the Rouyn area of the Abitibi belt. The seismics appear to image Pontiac metasediments dipping steeply beneath Abitibi belt lithologies as the Cadillac break is approached. Two holes are proposed; the first through the Pontiac to sample a prominent group of coherent shallow reflections at about 3 km depth and the second to penetrate the Cadillac fault at depth. Objectives include both the ground-truthing of the seismic interpretations and study of hydrothermal fluid migration through the fault system. Diamond drilling is recommended for both holes. Necessary preliminary work includes the reprocessing of the seismic data to obtain better depth estimates. The presentation engendered active discussion on possible methods for the seismic imaging of steeply dipping features, such as many major faults in granite-greenstone terranes, and the balance between tackling individual problems as they become apparent against waiting on the development of larger scale structural models.

Michael Hocq (Ministère de l'Énergie et des Ressources, Québec) described the results of the last two years work in remapping the Abitibi and Pontiac subprovinces in Québec. The principal results are firstly the recognition that many of the units defined in earlier work are now seen to be slices within major shear belts and, secondly, almost all major structural breaks are now seen to be listric features showing uniform southward vergence with a surface of décollement at 10-15 km depth. This new structural view is consistent with the implications of the gravity measurements that greenstone belts are thin, upper crustal sheets.

In answer to a question on the evidence for the rather abrupt down-dip shallowing of major faults the speaker pointed out that the section he had shown should be seen as working models for future testing.

Howard Williams (OGS) presented results of his field work and modelling of the Wabigoon-Quetico-Wawa subprovinces, and pointed out that an understanding of the intervening Quetico metasedimentary belt was essential to understanding the evolution of the adjacent granite-greenstone subprovinces. In the area studied, the south margin of the Wabigoon consists of three northward-younging, homoclinal panels of sedimentary and volcanic units, forming a southward prograding clastic wedge. Each panel is separated by a shear zone with steep lineations and south side-down kinematics in which deformed ironstones can be used as a strain gauge. The Quetico consists of tectonically thickened wacke-pelite units with minor conglomerates intruded by S-type granites and rarer I-type calcalkaline bodies. The sediments show a history of rapid deposition from a volcanic source and dewatering. The sediments are either contemporary with or later than the Wabigoon and are more altered — migmatized — in the centre of the belt than in the margins. The boundary to the south with the Wawa is a major shear with evidence of dip slip motion — the Wawa being thrust northward beneath the Quetico.

The current model for the formation of the crustal section involves an active forearc, now the Wabigoon, at about 2750 Ma, with the Quetico accumulating and becoming imbricated in a forearc basin directly to the south of the Wabigoon. At about 2670 Ma, an arc on the subducting oceanic material to the south, now the Wawa, approached the Wabigoon and finally trapped the accretionary wedge, now the Quetico.

John Spray (U New Brunswick, Fredericton) described contacts between greenstones and granitoids in the Norseman-Wiluna greenstone belt area of the Yilgarn Block, Australia, as an example of the type of granite-greenstone relationships which should be examined in the drill program in Canada. He described areas of the Yilgarn block where volcanic constructional ages are ~2700 Ma, metamorphism ~2600 Ma and later granitoids 2550 to 2600 Ma. Basement to the north of the belt is ~3300 Ma and an undeformed early Proterozoic dyke cutting the belt is 2400 Ma. The apparent stratigraphic thickness of the Norseman sequence is 24 km, but there is plenty of evidence of folding and thrusting leading to possible repetitions.

The greenstone constituents as a whole show only sea-floor type low-grade alteration. However, within the 0.5 km wide contact zone of interleaved volcanics and granites and pegmatites, the grade of the volcanics increases to amphibolite. Shallow drilling in Canadaian greenstone belts through the several kinds of contacts would serve to elucidate the tectonic relationships between blocks where metamorphic and stratigraphic relationships suggest tectonic thickening in a possible collision zone.

Marc St-Onge (GSC, Ottawa) described the Cape Smith thrust belt of the Trans-Hudson Orogen as the best understood Canadian example of thin-skinned tectonics in a possible Proterozoic analogue of Archean greenstone belts In this area, a 1920-2000 Ma thrusted and folded former accretionary prism, containing both ophiolitic and sedimentary sequences, is preserved. Thirty kilometres of down-plunge structural relief allows close examination of the change of structural style with depth. A basal shear zone is underlain by basement, seen in outcrop to the north as an older hinterland. The imbricated thrust-fold sequence lies above the basal shear zone and shows vergences to the south. Within the thrust-fold sequence two kinds of thrust sequences occur, a regular sequence with individual thrusts rooting on the basal shear and out-of-sequence intervals representing reimbrication of the earlier, regular thrust stack.

Ralph Kretz (Ottawa-Carleton Geoscience Centre, Ottawa) described the Archean terrane immediately north-east of Yellowknife. Here a thick succession of greywacke-mudstone, the Yellowknife supergroup, is intruded by several muscovite-bearing granite plutons and both granites and surrounding cordierite zone metasediments contain abundant pegmatites, some carrying spodumene, beryl and tourmaline. Drilling could address three important problems regarding the regional geology. Firstly, the terrane forms part of a larger basin rimmed by inward-facing volcanics which appear to thin toward the centre of the basin. A ~3 km hole in the centre of the basin would determine whether volcanics are present at depth and also identify the nature of basement beneath the volcanic-sedimentary succession. A second objective would be to determine the shape of the granites at depth. Several carefully placed holes of about 1 km depth should provide critical tests of different models. Finally, the depth extent of pegmatites, and the pathways for pegmatite forming fluids could be determined by several shallow 100-300 m holes in areas of good surface exposure. An additional, social value of research drilling in the area would be the opportunity to train members of the Dene Nation in various aspects of the science and technology involved in the work.

Ed Spooner (U Toronto) described a test, involving research drilling, of the magmatic hypothesis for the origin of Archean gold systems. Other objectives would be to test the deep structures of two Archean gold systems and to test depth zoning of the hydrothermal system, including the $H_2O$-$CO_2$ phase separation process, as the mechanism for the precipitation of gold. Drilling would take advantage of the present 1500-2000 m depth of the Sigma mine. The drill would be sited at the deepest level of the mine and could penetrate a further several kilometers to intersect at depth the down-plunge extensions of the Lamaque mineralized plugs and/or the associated alteration aureole. Strong interest is being shown by the mining company and extensive background information is already available.

Peter Kehrer (KTB, Hannover, West Germany) described operations to date and plans for the German deep drilling program (KTB). The lead-up to the selection of the deep drill site at Oberpfalz had involved extensive site survey work; geophysical, surface geology, shallow drilling and geothermal studies, followed by a national colloquium, held at Seeheim in 1986. At present, the 5 km test hole has reached 3.5 km depth and is planned to be completed in April-May 1989. It is salutary that crustal breaks predicted on the basis of reflection seismics to be at about 3 km depth have not so far been identified in drill core. Again, while the site was selected in part for its apparent low thermal gradient of 22 mK/m, in contrast with 28 mK/m for the alternative Schwarzwald Site, the actual gradient in the test hole is similar to the Schwarzwald figure. The deep hole, which will be located 200 m from the shallow hole, is due to be started in 1990. The speaker gave a detailed description of the most impressive organization of KTB, involving nationwide management and scientific structure, very careful and extensive design and engineering preparations, and construction of a major laboratory, core storage and conference facility at the Oberpfalz site.

The second day of the workshop began with a discussion by Steve Jackson (OGS) of the problems of relating surface geology to LITHOPROBE seismic results, particularly in the Ontario part of the Abitibi greenstone belt. The speaker pointed out that while relatively simple shallow dipping reflectors at ~1 s TWT were present in both the Québec and Ontario profiles, the surface geology was complex and, in addition was significantly different in the two areas. Thus, the steep dips of major breaks in the Québec area contrasted with the apparent shallow dip of the Kinojévis group to take it beneath the Blake River Group in the vicinity of the Ontario seismic line. It was suggested that the results might be reconciled if major structural breaks were generally listric in form, an arrangement that would also aid in explaining the apparent thickness paradox. It was suggested that one of the initial tasks of drilling should be to test three-dimensional models based on both seismics and surface geology. The presentation raised a number of important questions. Firstly, surely it was too coincidental that, at the present erosional level, so many structures were steep at the surface and shallow at depth. This might be expected at the surface in an active area of listric faulting, such as Western Turkey, but not for a random erosional surface through an area of ancient faulting. Two responses were made to this question: shallow dipping surface structural breaks are now being recognized in increasing numbers, specifically in the Timmins camp, and that the reflections may not mark the extension to depth of the surface breaks. A plea was made for seismologists to design experiments to image potentially listric features at depth and to design the data processing which will allow projection of these features to the surface. Secondly, Ian Gibson (U Waterloo) wondered how a structural model involving such extensive Cordillera-like imbrication could be reconciled with the rather uniform, low grade hydrothermal metamorphism of greenstone belt lithologies as demonstrated by Jolly. It was suggested that more detailed studies of the distribution and degree of greenstone belt metamorphism were timely. John Percival wondered if the reflectors were, in fact, within the greenstone package. If they did mark the base, what lay beneath the package? Only the Pontiac metasediments at 2900 Ma were a known candidate.

Berndt Milkereit (GSC, Ottawa) discussed the possibility that the second phase of the processing of the LITHOPROBE seismic data might provide some of the information required to link deeper reflectors with surface structures. The Noranda high-resolution line would be suitable material. The processing would be slow and should have very specific objectives. An active discussion covering: the possibility of using mines to generate three-dimensional seismic coverage, the usefulness of vertical seismic profiling (VSP) to obtain more precise reflector location, the measuring of packages of reflectors separated by transparent intervals, and the relative claims of the following features: simple lithological boundaries *versus* package of cataclastics, mylonites or volcanics as the sources of reflections.

Greg Stott (OGS), in a brief commentary, suggested that either or both the Uchi greenstone belt and the Proterozoic Cape Smith belt, with their out-of-sequence stacking of volcanic slices and sequences, might prove to be good analogues for the Abitibi belt, and therefore of value in understanding the latter belt. Phil Thurston felt that structures such as this are known in the Uchi belt would also be found in the Abitibi belt now that renewed structural research in the Abitibi belt was being conducted at a more vigourous level.

The final session consisted of a comprehensive summary of the results of the workshop, with recommendations given by Phil Thurston followed by shorter general comments by two other speakers. Thurston's presentation consisted of three parts, a summary of the state of knowledge of belts, a list of problems that should be addressed by drilling, and organizational and other work necessary to prepare for drilling.

It now seems clear that at the scale of inter-subprovince relationships, evidence for accretionary tectonics is clear. The future challenge lies at the next scale downward — in discerning the processes involved in assembly of subprovinces prior to inter-subprovince collision events. We are at the stage now of recognition of the weaknesses of former models and the realization that greenstone belts consist of series of tectonic collages. A leap of faith had been made in the recognition of the products of the platform, oceanic, arc and pull apart basin environments in these collages. The analysis of complex terranes, such as the Abitibi, required the recognition of a number of fault bounded packages, each package differing from adjacent packages in terms of age and lithology.

It was suggested that effort should be concentrated on the Abitibi belt in view of its great mineral potential, the level of exploration activity, the good geochronologic database, and the excellent seismic reflection data obtained through LITHOPROBE. What was required now was to raise the state of knowledge of the Abitibi to the level of, the best understood aspects of for example, the geochronology and structural geology in the Uchi belt. It was largely a problem of scale. Howard Williams had demonstrated the importance of large scale interaction between subprovinces. Now it was necessary to delineate intermediate scale interaction within subprovinces, *i.e.*, to recognize the results of smaller scale accretionary events. When this is done, a convincing large-scale accretionary story can be set up for the belt, based on a high density of mapping, sampling geochemical and geochronological data, and thus will provide the basis for tests by drilling.

At least four problems are likely to require drilling to address them properly. These are:
– the validity of three-dimensional structural models;
– the solution of the paradox of very different stratigraphic and geophysical belt thickness estimates;
– the question of the horizontal and vertical form of the granitoids: are they "pancakes" or diapirs?;
– what is the origin and significance of the shallow dipping reflector packages beneath the belt?

A number of important steps must be taken before drill sites can be firmly identified to address these problems. The first is the need for better seismic processing. The Abitibi lines, costing $500,000, will not be duplicated for some time at least, so all possible information should be extracted from them. Increased academic involvement in this and other preliminaries is highly desirable.

Secondly, the understanding of other belts, such as the Uchi and Wabigoon/Quetico/Wawa, should be applied to the Abitibi. This will probably lead to targets in addition to those already proposed by Mayrand and Jackson.

A working group should be established with an interest in subprovince study, three-dimensional structural-stratigraphic models and granitoids and their relationships to other belt components. This group should aim to put together a global drilling proposal.

Sandy Colvine (Chief Geologist, OGS, Toronto) emphasized that CCDP targets should not only be directed at testing the accretionary prism hypotheses but also at looking at alternatives. Targets should also be of real interest to the mining industry and there should be a high priority for workshop groups to be formed that could interact with CCDP.

James Hall answered questions about the kinds of proposals CCDP might prefer, and possible sources of funding for drilling operations. No restriction has been placed on the kind or scale of proposals. However, it is clear that the community as a whole favours, at least in the earlier stages of CCDP, a substantial number of relatively inexpensive, high information return, operations using conventional technology. In this way the Canadian program is evolving toward a style similar to the French program, and in contrast to the programs for drilling single or few deep holes in Germany and the Soviet Union, for example.

A full report of the workshop (CCDP Report 89-1), incorporating abstracts, is available at no charge (while stocks remain) from the CCDP Planning Office. Other reports arising from the initial series of workshops are also available; 88-1 (The Kapuskasing Structure), 88-2 (The Sudbury Structure), 88-3 (Major faults), 89-2 (The Algonquin Arch, Southern Ontario) and 89-3 (Sedimentary basins).

A national discussion meeting, at which the proposals that have been developed following the workshops will be presented, has been scheduled for August 28th and 29th, 1989, at the Earth Sciences Centre, University of Toronto. Further information is available from the Planning Office in Ottawa.

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The 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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