Geoscience Canada

Terranes, Domains and Lithotectonic Assemblages Within the Grenville Province

R. M. Easton et A. Davidson

Volume 21, numéro 1, march 1994

URI : https://id.erudit.org/iderudit/geocan21_1con02

Aller au sommaire du numéro

Éditeur(s)

The Geological Association of Canada

ISSN

0315-0941 (imprimé)
1911-4850 (numérique)

Découvrir la revue

Late Triassic magmatic arc which subsequently enclosed the Cache Creek Terrane, or did these coeval magmatic arcs develop independently of one another?).

None of the models discussed claims to be comprehensive: there remain too little data, too many unconstrained variables, and too few quantitative constraints to allow the construction of a comprehensive model. It became clear, however, that advances in our understanding of the evolution of the Northern Cordillera are being hindered by two additional significant problems:

1. Rarely does a package of rocks, upon detailed mapping and study, fit nicely into the pre-existing terrane scheme. This has not, however, resulted in any significant change to the set of terranes laid out some 15 years ago. There needs to be less respect paid to, and a greater willingness to throw out, existing terrane definitions. Given the lack of data (and consensus), this overhaul of the existing terrane scheme should consist of a reduction in the number of terranes (the existing data cannot, in many instances, justify the current terrane boundaries); and
2. To gain a full appreciation of terrane evolution, it is necessary to evaluate the significance of a wide variety of observations and data, from sedimentology to gravity data, from initial Sr ratios to paleontology. However, few of us are capable of critically evaluating all these types of data. There is, therefore, a clear need for an integrated, multidisciplinary approach to the unresolved questions concerning the evolution of the NIS. The recently initiated ACCRETE and LITHOPROBE SNORCLE programs are a step in the right direction.

The success of the conference was in providing a forum for an open exchange of views freed from the formality that characterizes most conferences. The debates were lively (even acrimonious at times) and focussed. For many, it was the first opportunity to meet with many of the other researchers and industry explorationists working in the northern Cordillera. The result is that a number of new co-operative research projects, designed to test some of the problem areas identified at the conference, have been initiated. The conference served to identify the terranes and terrane relationships in need of the most attention and resulted in the development of testable models of the geologic evolution of the Northern Cordillera. Probably the single best indication that the conference was successful was that there was unanimous agreement to reconvene in three years' time.

ACKNOWLEDGEMENTS

Ian McIlreath, Steve Morison and Hugh Hendry of the GAC provided encouragement, advice and support. Dirk Tempelman-Kluit and Lori Walton were instrumental in making this conference a reality. Julie Hunt and Jay Timmerman assisted in organizing and defining the field trips and in preparation of the field guide. Assistance with running the field trips and the discussion sessions was provided by Daniel Heon, Julie Hunt, Jay Timmerman and Carol Wallace. Drafting assistance, including the development of the NUNA '93 logo, was provided by Will Van Randen. Administrative concerns were efficiently dealt with by Sheila Johnston and Diane Carruthers. Financial assistance was provided by: the Yukon Mineral Development Agreement (a joint Department of Indian and Northern Affairs Canada and Department of Economic Development, Yukon Territorial Government program), Capitol Helicopters and Food For Thought, Whitehorse.

REFERENCES

Hein, F.J. and Simony, P.S., 1991, GAC NUNA Research Conference: Late Proterozoic glaciation, rifting and eustasy: Windermere Supergroup: Geoscience Canada, v. 18, p. 86-88.

Monger, J.W.H., Price, R.A. and Tempelman-Kluit, D.J., 1982, Tectonic accretion and the origin of the two major metamorphic and plutonic welts in the Canadian Cordillera: Geology, v. 10, p. 70-75.

Posamentier, H.W. and Leckie, D.A., 1992, Key topics in high-resolution sequence stratigraphy: Episodes, v. 15, p. 214-215.

Robert, F., 1991, GAC NUNA Research Conference: Greenstone Gold and Crustal Evolution: Geoscience Canada, v. 18, p. 83-86.

Accepted 3 October, 1994.

Terranes, Domains and Lithotectonic Assemblages Within the Grenville Province

R.M. Easton
Ontario Geological Survey
Precambrian Geoscience Section
933 Ramsey Lake Road
Sudbury, Ontario P3E 6B5

A. Davidson[1]
Geological Survey of Canada
601 Booth Street
Ottawa, Ontario K1A 0E4

A special session on the Terranes, Domains and Lithotectonic Assemblages within the Grenville Province was held 16-17 May 1994 at the Geological Association of Canada–Mineralogical Association of Canada (GAC–MAC) annual meeting in Waterloo, Ontario. There were 35 contributions to the session, with researchers from across Canada and the United States participating. Most participants are actively involved in Grenville Province research. In this summary, we describe some of the reasons for convening the session, review the related field trip held during the meeting, and summarize areas of consensus and disagreement that arose out of discussions held during and after the session. The session provided an update on advances in the last decade in the application of the terrane concept within the Grenville orogen. The special session also addressed some of the same questions raised at a recent GAC NUNA Conference on the Northern Intermontane Superterrane in the northern Cordillera (see Johnston *et al.*, this volume). It also complemented a special session on Tectonic Settings of Archean Greenstone Belts that was organized by G.M. Stott and H.H. Helmstaedt for GAC–MAC Waterloo '94, highlighting the fact that lessons are to be learned through comparisons with both younger and older orogenic belts.

As originally conceived, the session was to have focussed on three themes or problem areas: terrane nomenclature and definition, relationships between terranes, and tectonic models. In practice, most contributions focussed on terrane relationships, with only a few presentations dealing with definitions and tectonic models. This, in part, reflects the fact that in many places within the Grenville Province, researchers are still in the process of defining terranes and understanding terrain relationships, thus the development of realistic models is still to come. In the end, a geographic order to the presentations proved to be the most practical arrangement for presentation, with the first day's focus on the Central Metasedimentary Belt in Ontario, and the second day focussing mainly on the Central Gneiss Belt from Ontario to Labrador.

Although the first day of the session dealt only with the Central Metasedimentary Belt, the presentations covered two of the three original themes of the session. The first three presentations dealt with terrane definition, broadly defined. Keynote speaker Jim Monger (Geological Survey of Canada, Vancouver) presented a summary on the development of terrane and tectonic assemblage concepts within the Canadian Cordillera. He pointed out that the Canadian Cordillera resulted from a lengthy process of arc accretion along the western edge of North America, in marked contrast to the Grenville, which has long been compared to collisional orogens such as the Himalayas. He concluded that the Canadian Cordillera might not be a good analogy in looking for solutions to some Grenville tectonic problems. That being said, several speakers on both days did make comparisons with the Canadian Cordillera, especially with respect to seismic line interpretations. Thus, the keynote address not only outlined the development of terminology and definitions (see Table 1 for a summary of terms and definitions, as used herein), but also provided a framework for subsequent comparisons with the Cordilleran orogen.

John Moore (Simon Fraser U.), the father of the terrane concept for the Central Metasedimentary Belt (Moore, 1982), gave his perspective as an outsider looking in on the evolution of the terrane concept within the Central Metasedimentary Belt. He provided a history of the concept ranging from Wynne-Edwards' 1972 subdivision to the present-day. John cautioned against the practice of defining new terranes where perhaps the term "domain" might be more applicable. There was, however, a general consensus that the two fundamental divisions of the Central Metasedimentary Belt in Ontario were the Bancroft-Elzevir and Frontenac subdivisions, no matter what terminology was used (Fig. 1). Further, although new subdivisions have been suggested since 1982 (see Fig. 1), the broad divisions Moore first proposed in 1982 are still viable. There was also general consensus that all the various subdivisions do exist, however, the significance of these divisions (*i.e.*, be they terranes or domains) is debatable. Unfortunately, time did not permit discussion as to which terms should be retained, and which terranes/superterranes should be redefined as domains/terranes.

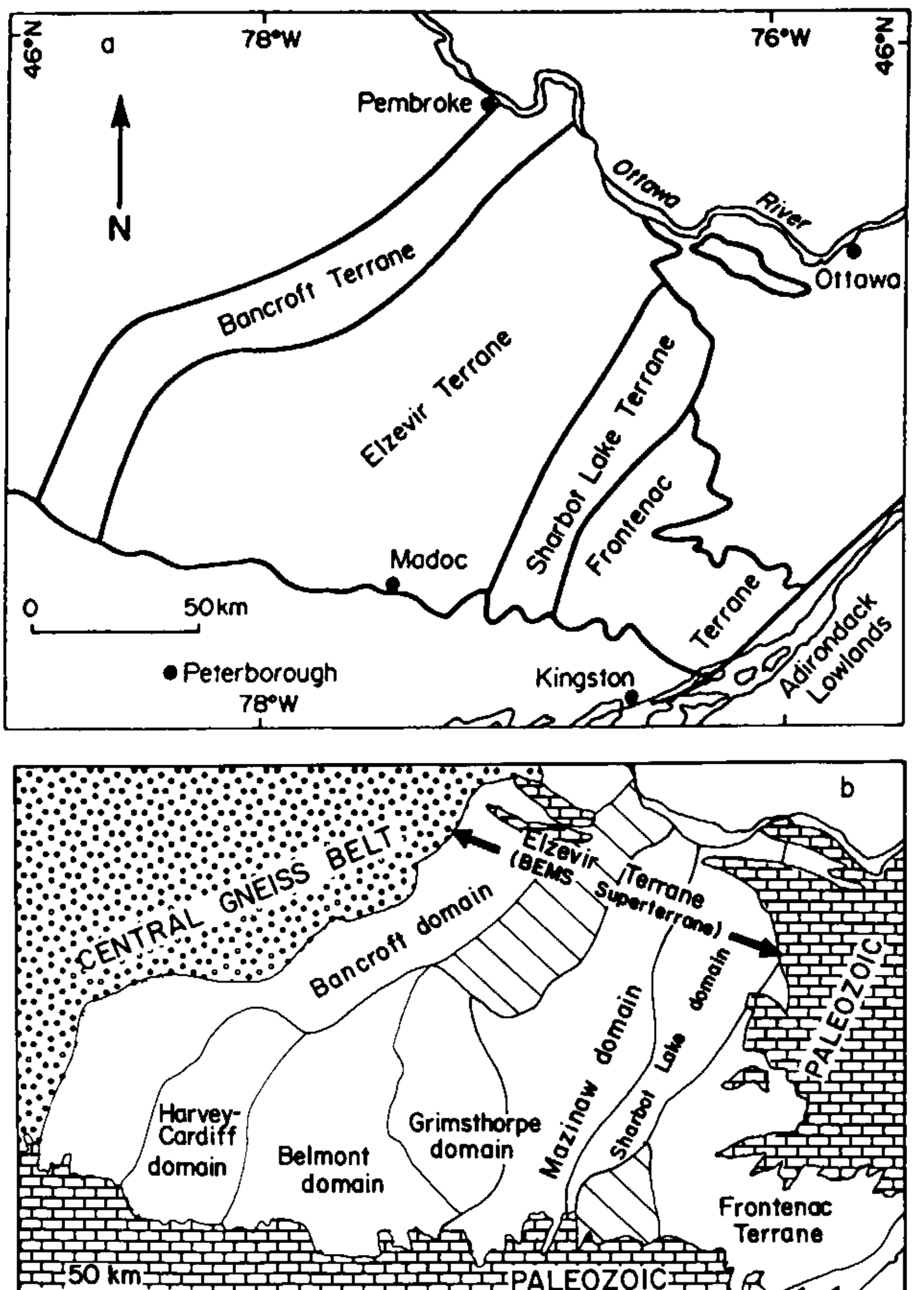

Figure 1 **(A)** *Terrane subdivision of the Central Metasedimentary Belt as proposed by Moore (1982).* **(B)** *Proposed terrane subdivision of the Central Metasedimentary Belt (after Easton 1992). Diagonally hatched areas are not easily assigned to any existing domain. (BEMS = Bancroft-Elzevir-Mazinaw-Sharbot Lake.)*

In the last overview presentation, Steve Jackson and Mike Easton (both Ontario Geological Survey) compared the early evolutionary history of Central Metasedimentary Belt and the Abitibi greenstone belt, noting similarities in scale, types of volcanic assemblages, and relationships between metavolcanic tectonic assemblages in both areas. They suggested the early history of both areas may have resulted from microplate interactions similar to those presently occurring in the southwest Pacific.

The remaining talks on the first day dealt primarily with terrane relationships. Louise Corriveau (Centre Geoscientifique du Québec – CGQ) posed the question as to whether some terrane boundaries are largely cryptic. Her answer was yes, in some instances, particularly boundaries that may have resulted from early terrane accretion (as opposed to boundaries due to later orogenic movements). A series of three excellent student presentations by Jim Cureton and Jay Busch (U. of Michigan) and Fred Ford (Carleton U.) dealt with the boundary relationships of the relatively recently recognized (since 1990) Mazinaw terrane/domain, in part through examination of P-T and U-Pb and Ar-Ar cooling histories across terrane boundaries. Such studies work best where such information is gathered along transects at a high angle to terrane boundaries (*e.g.*, paper by Busch), rather than using data scattered along the length of a boundary. Understanding terrane boundary relationships is partly hampered by the lack of detailed P-T histories within terranes/domains of the Central Metasedimentary Belt. A paper by Fernando Corfu (Royal Ontario Museum) on the second day described the geologic and metamorphic history of the Mazinaw terrane/domain and complemented these three presentations. Ben van der Pluijm and co-workers at the University of Michigan described the Bancroft shear zone (Central Metasedimentary Belt) as a structure originating due to orogenic collapse after most terranes were emplaced into their present positions.

Two oral presentations by Sharon Carr and Jon Burr (Carleton U.), as well as several poster presentations, successfully related the surface geology and structures in the Bancroft area to the seismic reflection profiles of LITHOPROBE lines 32 and 33. Although these lines have only been generally available for the last year, they are already having an enormous influence on geologic thought and research directions within Central Metasedimentary Belt studies.

Although the Central Gneiss Belt constitutes more than 75% of the exposed Grenville Orogen in Canada, it is still less studied compared to the Central Metasedimentary Belt, particularly outside Ontario, as noted by Tony Davidson (GSC, Ottawa) in his keynote presentation, which introduced the second day's series of talks on the Central Gneiss Belt. Tony, who pioneered the application of the concept of this tectonic unit in the early 1980s, provided a review of terrane analysis in the Central Gneiss Belt, noting both the benefits

TABLE 1 Terrane terminology.

Terrane: a fault-bounded package of strata that has a geologic history distinct from the adjoining geologic units.

As outlined by Howell (1989), terranes may be:

Stratigraphic a) representing fragments of continents
b) representing fragments of continental margins (*e.g.*, Frontenac Terrane)
c) fragments of volcanic arcs (*e.g.*, Elzevir or Mazinaw terrane)
d) fragments of ocean basins

Disrupted (*e.g.*, Bancroft Terrane)

Metamorphic (*e.g.*, Mazinaw Terrane?)

A combination of the above (*e.g.*, Mazinaw Terrane).

Other, more genetic terminology is also prevalant, and includes:

Exotic, suspect or accreted. This implies that the terrane has been transported some distance to its current position. For example, an island arc sliver accreted to a craton can be regarded as exotic to the craton.

Pericratonic. Contains cratonal detritus and formed on attenuated continental crust.

Terranes are sometimes described in terms of *tectonic assemblages*, which are rock-stratigraphic units formed in actualistic tectonic settings, such as island arcs or ocean floors. A terrane may consist of one or more tectonic assemblages.

Domain: a volume of rock, bounded by compositional or structural discontinuities, within which there is structural homogenity. In some instances, these may contain minor stratigraphic distinctions as well and can be viewed as subterranes.

Superterrane: a composite terrane, consisting of two or more component terranes, that were amalgamated prior to subsequent orogenesis.

and the pitfalls of the technique. In particular, criteria for defining terranes in deeper levels of orogens are less straightforward than in areas where stratigraphy is more easily defined, such as within the Elzevir terrane of the Central Metasedimentary Belt (CMB).

Rivers *et al.* (1989) originally proposed a three-fold subdivision of the Grenville orogen into a parautochthonous belt and two allochthonous belts, and defined a parautochthon-monocyclic allochthonous belt boundary. John Ketchum and co-workers (Dalhousie U.) explored the location of the allochthon-parautochthon boundary in Ontario. Ketchum and co-workers suggest that the parautochthon-monocyclic allochthonous belt boundary (Parry Sound shear zone in Ontario) is located further north than previously suggested, along the Central Britt shear zone, and that the parautochthon in Ontario is less extensive than originally defined (although its eastern extension between Ontario and Quebec is still not well defined). Natasha Wodicka (GSC, Ottawa) presented a wealth of U-Pb data from the Parry Sound area, all of which suggests that this area is similar in age to the Central Metasedimentary Belt (with age peaks at *ca.* 1300-1250 Ma, 1170-1150, 1120-1100 and 1070-1020 Ma), younger than previous work, which suggested an age range of 1350-1425 Ma for rocks in the area. This presentation evoked considerable discussion with respect to the interpretation of U-Pb ages from areas subjected to high-grade metamorphism and extensive deformation, and our ability to recognize igneous *versus* metamorphic zircons (see also discussion below). The final oral presentation on Ontario geology was by Nick Culshaw (Dalhousie U.) and co-workers, who raised the idea that the Central Gneiss Belt (and Central Metasedimentary Belt) were assembled elsewhere at 1190-1100 Ma, and were not attached to the parautochthon until 1080-1060 Ma. This concept has significant implications with respect to tectonic modelling of the orogen, as well as the interpretation of geochronology in the region, however time did not allow adequate discussion of the concept during the meeting.

Léo Nadeau (CGQ) and Dave Corrigan (Carleton U.) presented two related presentations covering three newly defined terranes in the St-Maurice region in Quebec. This region covers roughly the same area as the Central Metasedimentary Belt in Ontario, however, it is poorly known. In addition to describing terrane characteristics and terrane boundaries, new geochronologic and geochemical information was also presented. Of significance is a *ca.* 1450 Ma age of the Mountabaun Group, which had long been correlated with the younger (*ca.* 1300-1250 Ma) Grenville Supergroup. Also recognized was the *ca.* 1500 Ma arc terrane in the area. Nd-Sm work by Alan Dickin and co-workers (McMaster U.) presented in the poster session also points to an extensive region of 1500 Ma arc rocks in eastern Quebec, a package not yet documented in the better studied western Grenville orogen. The only other presentation on Quebec was by J. St. Jean and co-workers (McGill U.) who described the geology of the Hart–Jaune terrane in eastern Quebec near the Labrador border. These studies point to along-strike variations in geology within the orogen, as well as the value of working in areas hitherto long neglected.

The final presentation of the session was the only one dealing with the theme of "models." Toby Rivers (Memorial U.) presented a model for the development of the orogen in Labrador and eastern Quebec, in part based on the concepts for orogenic uplift and collapse presented by Willett *et al.* (1993). This model represents the result of more than a decade of research in the area by Toby and several students, and clearly indicates how much time it takes to accumulate the data for well-constrained tectonic models.

The oral presentations on the second day were followed by a poster session of 15 contributions. The posters consisted of maps and geochronologic data that complemented some of the oral presentations (similar authorship), geochronologic data best handled in poster format, data relevant to our understanding of the Grenville orogen, but not directly tied to the theme of the session, and work in progress. The posters provided the specifics of particular presentations, as well as an ideal focal point for discussing the results of the session.

A related four-day pre-meeting field trip led by Tony Davidson and Mike Easton examined a variety of structural boundaries across the Central Metasedimentary Belt, many of which have been suggested as terrane/domain boundaries. These included the Central Metasedimentary Belt boundary tectonic zone in the Barry's Bay area, the McArthurs Mills line, the Mooroton shear zone, the Robertson Lake mylonite zone, and the Maberly shear zone (*i.e.*, Frontenac-Sharbot Lake boundary, see Fig. 1). In addition, the trip highlighted some of the typical rock types characteristic of several suggested terranes and domains within the Central Metasedimentary Belt, including the Bancroft, Elzevir, Mazinaw, Sharbot Lake and Frontenac terranes (Fig. 1). The trip attracted a variety of participants, was graced with excellent weather, and served to foster discussion that continued during the session.

A few general problems were identified by the session:

1. The first problem is the same as that stated by Johnston *et al.* (this volume), namely that it is rare for a package of rocks to fit nicely into a pre-existing terrane scheme (*e.g.*, Mazinaw terrane/domain in the CMB). Despite this, in the case of the CMB, the identification of new terranes and domains has not significantly changed the terrane scheme established more than a decade ago by John Moore.
2. Although it is possible to identify distinct lithotectonic assemblages that can serve as the basis for defining new terranes or domains, boundaries between terranes remain difficult to identify in many cases. A prime example is the Mooroton shear zone, the focus of several presentations. Contrasts in metamorphic history and P-T conditions, as well as lithologic and geochronologic contrasts, exist across this boundary, yet examination of this boundary on the field trip, produced little consensus as to its presence and significance. Further, some terranes are bounded by a variety of geologic structures of differing ages. Other boundaries may be cryptic. Some insight can be provided by reading Johnston *et al.* (this volume), in their discussion of "hard" *versus* "soft" terrane linkages. Clearly more work needs to be done on terrane boundary relationships both in the Grenville and in other orogens.
3. Interpretation of high-precision U-Pb geochronology in many areas, especially when attempting to date metamorphic and deformational events, needs to be addressed. In some areas (*e.g.*, the Parry Sound area and the Mazinaw terrane), we are achieving a

density of geochronologic information greater than that found in many orogenic belts or individual greenstone belts in the Superior Province; not all these ages are geologically consistent. In the past, the tendency has been to reinterpret geologic relationships in terms of the geochronology. One unanswered question of the session is how much do we really know about the systematics of many isotopic systems during high-grade metamorphism, or repeated metamorphism? Can we always recognize igneous *versus* metamorphic zircons or partial resetting? Perhaps a little more skepticism and caution is needed. Then again, maybe our difficulty in interpreting the geochronological data reflects a lack of understanding of the geological relationships in the area.

4. Geophysical information is becoming more significant in interpretation and modelling, especially seismic reflection images. Geophysical data were very influential in many of the studies presented, even though this influence was not apparent in the titles of the scheduled talks. In future sessions, organizers should encourage greater involvement by geophysicists, perhaps by ensuring that a geophysicist serves as a session organizer.

5. Terrane definition and analysis in the Central Metasedimentary Belt has been based primarily on the classical methods or on recognizing distinctive stratigraphic packages bounded by faults or shear zones. Within the Central Gneiss Belt, however, more latitude has been used, including isotopic signatures (U-Pb, Nd-Sm, systems), timing and age of regional metamorphism, structural history, and potential field maps. In the case of the Central Gneiss Belt, this usage is similar to the broadening of terrane-defining characteristics being discussed in the Cordillera (see Johnston *et al.*, this volume).

The session was successful in bringing together much of the current research within the Grenville Province, and providing all concerned with a snapshot of a work that is still in progress. The only drawback is that the setting of the GAC–MAC Annual Meeting made discussion and debate difficult, compared to the atmosphere found at more focussed meetings, such as Friends of the Grenville workshops. This is in spite of the fact that many speakers, especially the students, gave properly timed talks that allowed for in-session questioning. True, many informal discussions occurred over meal times and during the field trip, but these were only accessible to a few. If GAC–MAC Annual Meetings are to continue to be relevant forums, methods of fostering in-session discussion (at least in some circumstances) need to be pursued. Then again, perhaps these types of issues can only be resolved in a different type of setting (*e.g.*, a NUNA conference).

Session abstracts are published in the Geological Association of Canada–Mineralogical Association of Canada, Program With Abstracts, v. 19, 168 p. A field trip guide for the meeting, titled Terrane Boundaries and Lithotectonic Assemblages within the Grenville Province, Eastern Ontario, 89 p., is available from the Department of Earth Sciences, University of Waterloo, Waterloo, Ontario N2L 3G1. Cost is $16. Cheques should be made payable to "Waterloo '94."

REFERENCES

Easton, R.M., 1992, Revised Terrane Subdivision and Observations on the Tectonic Assembly of the Central Metasedimentary Belt, Ontario: Geological Society of America, Program with Abstracts, v. 24, p. 94.

Howell, D.G., 1989, Tectonics of Suspect Terranes: Chapman and Hall, New York, 232 p.

Johnston, S.T., Hart, C.J.R. and Mihalynuk, M.G., 1993, NUNA conference report: the Northern Intermontane Superterrane: Geoscience Canada, v. 21, p. 27-30.

Moore, J.M., 1982, Stratigraphy and tectonics of the Grenville Orogen in eastern Ontario: 1982 Grenville Workshop, Rideau Ferry, Abstracts, p. 7.

Rivers, T., Martingole, J., Gower, C.F. and Davidson, A., 1989, New tectonic subdivisions of the Grenville Province, southeast Canadian Shield: Tectonics, v. 8., p. 63-84.

Willet, S., Beaumont, C. and Fullsack, P., 1993, Mechanical model for the tectonics of doubly vergent compressional orogens: Geology, v. 21, p. 371-374.

[1]GSC Contribution Number 51094

Accepted 3 October, 1994.

Hamilton Harbour Remediation: The Role of Environmental Geology

N.A. Rukavina and J.P. Coakley
National Water Research Institute
867 Lakeshore Road
Burlington, Ontario L7R 4A6

In the mid 1980s, the International Joint Commission identified Hamilton Harbour as one of 42 "Areas of Concern" in the Great Lakes with severely degraded water quality and toxic contamination. The harbour occupies a natural bay at the western end of Lake Ontario in the midst of an urban-industrial complex and is one of the busiest ports in the Great Lakes. For more than 150 years, it has served as the equivalent of a secondary-sewage treatment plant for industrial, municipal and agricultural waste. The task of clean-up and restoration of the harbour has now been assigned to a local stakeholders group charged with setting up and implementing a "Remedial Action Plan" (RAP). Clean-up is to be based on an ecosystem approach that takes into account the results of research on the processes and materials of the harbour.

Environmental research in the harbour is a fairly recent activity. Most of the studies have been done within the past 20 years by the Ontario Ministry of the Environment, the federal National Water Research Institute (NWRI) in Burlington, Ontario, and local universities. Work has been accelerated recently by the federally-sponsored Great Lakes University Research Fund (GLURF) and by a sizeable NSERC grant to McMaster University. At this stage, some perspective on what has been accomplished and its relevance to the RAP program was identified as useful in specifying and assessing future