



1992 Friends of the Grenville Workshop

R.M. Easton

Ontario Geological Survey Advance Office
6th Floor, 200 Brady Street
Sudbury, Ontario P3A 5W2

The Friends of the Grenville (FOG) is an informal group that started meeting with H.R. Wynne-Edwards' Grenville Field Trip at the 1967 Geological Association of Canada—Mineralogical Association of Canada (GAC-MAC) Joint Annual Meeting in Kingston. Since then, the fellows of FOG have organized many informal field excursions (since 1970), workshops (1982, 1988), and symposia and field trips in conjunction with GAC-MAC and Geological Society of America (GSA) meetings (1984, 1988, 1989, 1990). These events have provided a forum for discussions and communication and a source of inspiration for many Grenvillian mappers, researchers and students. The latest workshop, held 3-5 April 1992, in Quebec, was no exception, and drew more than 70 FOGers from Newfoundland, Quebec and Ontario representing six government agencies and ten universities.

Major breakthroughs in our understanding of the Grenville Orogen have occurred since the publication in 1957 of *The Grenville Problem* by the Royal Society of Canada, which included contributions from Grenvillian pioneers such as F.F. Osborne, D.F. Hewitt, A.E. Engel and A.F. Buddington, and the regional synthesis of the Grenville Province by H.R. Wynne-Edwards in 1972 published in *Variations in Tectonic Styles in Canada* by the Geological Association of Canada. One theme of the 1992 meeting was to honour these pioneers, and both Fitz Osborne and Hugh Wynne-Edwards were able to attend and participate in the meeting. In addition, the meeting was dedicated to the memory of Dr. André F. Laurin, who passed away in 1991, and whose mapping studies contributed greatly to our understanding of the Grenville Orogen in Quebec.

The Workshop began on Friday evening with a series of three overview talks. Tony Davidson of the Geological Survey of Canada (GSC) spoke on "The Grenville Problem: Update", and reviewed some of the important

developments that have occurred during the last thirty years in our understanding of the Grenville Province. He also presented a 1:1,000,000 scale compilation map of the Grenville Province which will form the basis of the 1:5,000,000 scale map of Canada that will accompany the DNAG volume on the Canadian Shield. According to Tony, current "problems" in the Grenville include: identifying the source of the flat reflectors that appear so prominently on GLIMPCE and LITHOPROBE seismic reflection surveys of the Grenville Province; determining how much of the Province has re-equilibrated from high pressure metamorphic conditions (*i.e.*, from eclogite to amphibolite facies); and defining the nature of the uplift history of the Orogen.

Al Sangster, Michel Gauthier and Charlie Gower outlined progress on a metallogenic synthesis of the Grenville Province being prepared for DNAG. Naturally, emphasis focussed on the Central Metasedimentary Belt (CMB) in Ontario and western Quebec as this is the area that has received the most mineral exploration. The metallogenic synthesis is geographic- and commodity-based, and represents an update of published syntheses by Sangster and Bourne (1982) and Carter and Colvine (1985). It is similar to the metallogenic overview of the Grenville Province in Ontario prepared by J.A. Fyon and R.M. Easton for the Ontario Geological Survey's *Geology of Ontario* volume. Current "problems" in mineral deposit geology in the Grenville Province include: recognition of Na and K alteration associated with mineralization in rocks that have been subsequently metamorphosed; greater description and subdivision of carbonate rocks during regional mapping; understanding why many CMB deposits contain mercury (which presumably would be volatilized during regional metamorphism); and adapting geochemical and geophysical exploration methods to Grenvillian environments. It is also necessary to convince governments to devote more resources to the study and exploration of Grenville Province mineral deposits.

J.-L. Caty of the Ministère de l'Énergie et des Ressources du Québec (MERQ) remembered Grenville pioneers, namely Fitz Osborne, André Laurin and Hugh Wynne-Edwards. He noted that all had brilliant careers in public and private life after they left their Grenville studies, indicating that the Grenville Province is a great area for training and nurturing scientists. Fitz Osborne, now 89, pointed out that his interest in the Grenville was sparked by Adams' GSC Memoir 6, which was published in 1910, and which is still an invaluable source of detailed observations on the Grenville Province. Hugh Wynne-Edwards noted that rather than continue to discuss the Grenville "problem", perhaps after 30 years, we should start to talk about "solutions".

During the next day and a half, 30 oral and 26 poster presentations were made on all

aspects of Grenville Province geology. It is not possible to cover all of these presentations in this report, although it is possible to discuss some of the results as they pertain to specific topics or geographic areas. The meeting's program illustrated the wide range of studies needed to understand the evolution of any Precambrian orogenic belt. These include precise U-Pb zircon geochronology to determine depositional and emplacement ages of rock units, zircon and titanite U-Pb ages and Ar-Ar studies to determine cooling histories for various regions, dating of cross-cutting dikes in order to date deformation, detailed P-T studies to determine metamorphic conditions and P-T paths, stratigraphic, structural and mapping studies to outline distribution of rock units and major tectonic breaks, geophysical surveys (mainly seismic reflection studies) to determine crustal structure, and modelling studies to assist data interpretation. The success of this workshop lay in its ability to present this wide array of studies to a broad cross-section of researchers who could then absorb, discuss, and apply this information to their own studies.

In contrast to previous meetings, there was a heightened interest in mineral deposits. These included a talk by Brian Christie of Homestake Canada Ltd. on its gold property at Gilmour, Ontario; two talks on the Montauban base metal and gold deposits, which were originally studied by F.F. Osborne, by L.R. Bernier (McGill U.) and V. Jourdain (U. du Québec à Montréal (UQAM)); the aforementioned talk by Sangster *et al.*; and a talk by Michel Gauthier (UQAM) on how massive sulphide ores behave during prograde and retrograde metamorphism, using examples from the Morin Terrane in Quebec. Michel clearly indicated how both mineral paragenesis and textures change and the implications of these changes to the study of a specific deposit. Posters on CMB zinc deposits (Al Sangster, GSC), tourmalinites and tourmaline-rich rocks in the CMB in western Quebec (Nantel, MERQ and Gauthier) and U-Th-Mo deposits along the CMB boundary in Quebec (Giguere *et al.*, UQAM) rounded out the mineral deposit part of the program. It is hoped that these presentations will encourage more FOGers to direct their talents and energies to mineral deposit research in the Grenville.

Six talks were given by the Dalhousie University group on their research along the shoreline of Georgian Bay stretching from Killarney to Parry Sound. Becky Jamieson presented a talk on behalf of S.D. Willet, C. Beaumont and P. Fullsack on finite-element modelling of compressional orogens. Although the work is in a preliminary stage, the models produce a geometry similar to that observed on seismic profiles across the Grenville Province, and many of the formal and informal discussions during the workshop concerned these models and their im-

plications. Two talks, by Haggart *et al.* and Culshaw *et al.* concerning work in the Beaverstone domain of the Grenville Front Tectonic Zone (GFTZ), raised the possibility that the GFTZ migrated northwestward during the "Grenville Orogeny". Such a migration was consistent with the finite-element modelling presented earlier, and would explain certain aspects of GFTZ geology. Several talks dealt with the Britt and Parry Sound domains. Ketchum *et al.* presented U-Pb geochronology data indicating that the Central Britt shear zone was an extensional shear zone that developed at ca. 1000 Ma. Natashia Wodicka discussed the nature of the Britt-Parry Sound boundary near Parry Sound, while Rob Macfie and John Dixon (Queen's U.) described the Parry Sound-Rosseau-Seguín boundary farther to the east.

Several talks dealt with the Archean parautochthon of the Grenville Province in Quebec. Rejean Girard (MERQ) presented a multi-authored talk on the structures present in the parautochthon in the Val d'Or area, which was complemented by a talk by Tyson Birkett (CGQ) and others on the geochemistry of amphibolitic and granitic rocks in the same area. Despite metamorphism, the geochemistry shows notable differences between the parautochthon and the allochthonous Proterozoic terranes in the area. An accompanying poster allowed for informal discussion of the data presented in these two talks. Andre Ciesielski (GSC) compared the geology and structure of the Archean parautochthon in the Val d'Or and Chibougamau areas and presented a history of the tectonic evolution of the parautochthon.

Recent geologic mapping in the Portneuf-St. Maurice area, including the Montauban Group and La Bostannais Complex by Centre Géoscientifique du Québec (CGQ) and MERQ, was presented in oral and poster form by Leo Nadeau (CGQ), D. Corrigan (Carleton U.), P. Brouillette (MERQ) and C. Hébert (MERQ). A complementary geochemical study on the La Bostannais Complex was presented in poster form by E. Gauthier (U. Laval), and Leo Nadeau and Otto van Breeman (CGQ and GSC, respectively). Serge Perreault (MERQ) reported on the geochemistry of granitoid rocks in the Rivière-à-Pierre area, which includes one of the three lithotectonic domains described by Nadeau *et al.* A structural re-interpretation of the Morin anorthosite east of the St. Maurice region, by Jacques Martingole (UQAM), proved complementary to structural observations reported by Nadeau *et al.* in the St. Maurice region. All of these studies served to illustrate that the geology of the Grenville Province in central Quebec has no direct counterpart in Ontario.

Several studies dealt with the CMB in Ontario and western Quebec. No Grenville meeting would be complete without a discussion of the "Hastings series-Grenville

series" debate that has been ongoing since 1870, and Mike Easton (OGS) and Fred Ford (Carleton U.) reported on the results of new mapping in the Mazinaw area including additional preserved unconformity sites, and geochemical studies of the Flinton Group (*i.e.*, "Hastings series"). Hans Meyn (Ontario Ministry of Northern Development and Mines (MNDM), Bancroft) described his stratigraphic studies in the lowest grade part of the CMB near Madoc. A pair of talks by Simon Hanmer, Sally McEachern and Otto van Breeman (GSC) dealt with the nature of the boundary zone between the CMB and the Central Gneiss Belt, and the timing and causes of development of this boundary. They invoked a model of rifting of the Central Gneiss Belt at ca. 1300 Ma to form a marginal basin and arc terrane (now represented by the CMB), which closed between 1230 Ma and 1180 Ma to initiate formation of the boundary. This model has yet to be integrated with the wealth of detailed mapping, stratigraphic and geochemical information presently available for the CMB. A talk by Madore and Sawyer (UQAM) and a poster by Sharma and Lévesque (MERQ) described detailed studies along the boundary in western Quebec.

Several talks dealt with broader subject areas. Mike Higgins and Michel Hervet (UQAC) discussed magmatic events in the Grenville Province at ca. 1160 Ma. This time period appears to be a critical one, as it seems to represent a period of extension that followed continental closure that juxtaposed the Frontenac Terrane, the rest of the CMB and the Central Gneiss at ca. 1180 Ma. A time-space chart and cladogram of Grenville events in Ontario presented in poster form by Mike Easton proved useful in the informal discussions that followed from this presentation. Toby Rivers contrasted styles of crustal styles in the northern Grenville Province, noting that in western Labrador, a foreland fold-and-thrust belt style of shortening was preserved, whereas, in Ontario, a crustal ramp style of shortening was present. This presentation resulted in considerable discussion, particularly in light of the finite-element modelling study presented the previous day by Willet *et al.*

Alan Dickin (McMaster U.) reported on the use of Nd-model age mapping in delineating crustal extraction events throughout the Grenville Province, and the utility of these studies in the reconnaissance of large areas. Charlie Gower (Newfoundland Dept. of Mines) discussed Grenville (1050-950 Ma) magmatic and metamorphic events in southeastern Labrador and Quebec and in Baltica. The youngest, and some of the most precisely dated Grenville events (earthquakes), were discussed by Maurice Lamontagne (GSC).

Seismic images from LITHOPROBE lines 32 and 33 across the western CMB in Ontario (White *et al.*, GSC-OGS), a survey along

lakes Erie and Ontario (Forsyth *et al.*, GSC-Purdue), and a wide-angle survey in southeastern Ontario to northern New York (Celt and Forsyth, GSC), were presented in poster format and were a focal point of considerable discussion, particularly in light of a revised terrane subdivision of the CMB proposed in a poster by Mike Easton based on the Grenville synthesis in *Geology of Ontario*. The current, widely used subdivision had been presented by John Moore at the first FOG workshop in 1982, and the need for revision was based on the advances of the last decade. For the most part, there was general agreement between the seismic images and the terrane subdivision. The seismic data did, however, point out an additional lithotectonic domain that could be present, and various gaps in our geologic knowledge along the transect line. The latter will undoubtedly be the subject of future research.

The session closed with an address by Hugh Wynne-Edwards entitled "Grenville tectonics, fractals, chaos and 'bucky balls': models of creative innovation". One of his points was that most of the advances made in the study of the Grenville Orogen during the last three decades were the result of technological innovation, (*e.g.*, improved methods and accuracy in geochronology, geochemistry, mineral separation techniques, *etc.*). In addition, in looking back at "30 years of Grenvillainery", many topics that would have been considered heresy in 1957 (*e.g.*, basement-cover relationships, role of tectonics, importance of mylonites and shear zones) were now orthodoxy. In fact, he saw considerable orthodoxy at the meeting and too little heresy. He also cautioned us to bear in mind the following:

- sample *versus* analysis
- precision *versus* accuracy.

We are now in the position of collecting a sample that can then be the subject of years of worthwhile analysis and research, yet do we spend sufficient time in choosing and documenting the sample? Further, we must not confuse precision of results with accuracy. And, just because the results are precise and accurate does not mean that they have great significance. Finally, if what we are doing is no longer fun, then it is probably time to change careers.

Formal and informal discussion continued throughout the three-day workshop, fostered by the venue, and aided by communal meals and an on-site bar. A few themes kept cropping up again and again in discussion. One was the significance of late extensional shears in the Grenville Province. Do these shears represent a widespread event of some significance, or are they of local significance only? This discussion, interestingly enough, touched on all the points made by Hugh Wynne-Edwards in his closing remarks. Another was the mechanism of orogen formation, uplift and exhumation. Finally, although seismic reflection images

provide insight into the nature of the underlying crust, the interpretation of these results, in particular, what causes the reflectors, is still unclear.

Finally, I will conclude this report with a few general impressions I had of the meeting. I have already noted the increased emphasis on mineral deposit studies in the Grenville, as well as the breadth of subjects covered during the meeting. The venue in Quebec was particularly timely, because of the increased activity in the Grenville Province in recent years by CGQ and MERQ. The meeting helped disseminate these results to a wide audience, and will help increase our overall understanding of the evolution of the Grenville Province. The utility of geochronology in unravelling complex orogens was further emphasized. Mapping studies without geochronologic and geochemical backup yield inconclusive results. It is increasingly apparent that team efforts, either through co-operation of government agencies (e.g., CGQ and MERQ and universities), and teams of university researchers (e.g., Dalhousie U.) are becoming more the norm, and the only way of effectively applying the breadth of expertise needed to unravel geologically complex regions. Although many studies pointed out the difficulties in extrapolating the results of local studies to a regional or orogen scale, there still seemed to be an emphasis by many on making such regional

correlations. This may not be a bad thing, as such attempts at extrapolation commonly challenge orthodoxy, and heresy helps drive innovation.

Restriction of talks to 15 minutes rather than the standard 20 minutes helped to keep the audience attentive, and allowed for some formal discussion. Many of the talks had accompanying or related poster sessions which aided discussion. Ample space was provided for posters, and organizers of future FOG workshops should encourage this type of presentation. There were some notable absences from the workshop, particularly our colleagues from the United States, and Ontario was not well represented. The view was expressed that the next workshop should be held in the United States. As FOG field trips currently alternate among Ontario, Quebec and New York, it is only logical that the workshops follow a similar pattern, especially if we wish to ensure the vitality of FOG and Grenville research.

The organizing committee of Léo Nadeau, Louise Corriveau, Pierre Brouillette, André Gobeil, Claude Hébert and Karmal Sharma, representing both CGQ and MERQ, are to be congratulated for organizing a timely, stimulating and fun meeting. Their choice of venue beside Montmorency Falls was excellent, and the 1992 FOG workshop will long be remembered by the attendees.

REFERENCES

- Carter, T.R. and Colvine, A.C. 1985. Metallic mineral deposits of the Grenville Province, south-eastern Ontario: Canadian Institute of Mining and Metallurgy, Bulletin, March 1985, p. 95-106.
- Sangster, A.L. and Bourne, J.M. 1982. Geology of the Grenville Province and regional metallogenesis of the Grenville Supergroup, in Hutchinson, R.W., Spence, C.D. and Franklin, J.M., eds., Precambrian Sulphide Deposits: Geological Association of Canada, Special Paper 25, p. 91-125.

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ERRATA

"Net Smelter Return Models and Their Use in the Exploration, Evaluation and Exploitation of Polymetallic Deposits"
by R. Goldie and P. Tredger (*Geoscience Canada*, v. 18, p. 155-171)

Please note the following corrected versions of formulae appearing in Appendix 1 (v. 18, p. 169-170).
[Only the last column contains corrections (shown in bold), however, other columns are included here for clarity].

	Calculated figures	Labels
Payable Pb, lb/t of ore	10.15	BA = AZ × ((AW-AY)/AW) × D × F × 2204.6
Payable Cu, lb/t of ore	0.17	BD = AX × BB × BC × 2204.6
Payable Ag, %	83.9	BO = (BN × (BL - BM)/BL); zero if (BM > BL)
Payable Ag, oz/t of ore	0.101	BP = BO × BL × AX × 0.03215
Participation, /DMT of concentrate	\$1.79	BT = BR ((DV/BS) - 1) × BQ/DZ
Total treatment charges, /t of ore	\$2.79	CD = CC + CA + BV

Because the errors were typographical, the "calculated figures" appearing in Appendix 1 do not need to be changed.

A Quattro Pro or Lotus 1-2-3 version of the spreadsheet in Appendix 1 may be obtained by mailing a 5¼" or 3½" floppy disk to: R. Goldie, Richardson Greenshields of Canada Ltd., Suite 1400 - 130 Adelaide Street W., Toronto, Ontario M5H 1T8 or P. Tredger, Tredgco Mineral Services, Suite 1400 - 25 Adelaide Street E., Toronto, Ontario M5C 1Y2.

Our thanks to Dennis Waddington of Phelps Dodge Corp. of Canada Ltd. for having identified the above errors.