Program and Abstracts
Programme et Résumés

Canadian Structural and Tectonic Group
1999

Annual Meeting
October 29th - 31st

Domaine FRASER
Bernierville (Quebec)

<u>Program/Programme</u>

Conferences/Conférences

<u>8:30 -: Introduction</u>

8:40 –1-: The Eastern Highlands shear zone in Cape Breton Island, Canadian Appalachians: kinematics, differential uplift and associated $^{40}Ar/^{39}Ar$ age pattern.
***Shoufa Lin**

9:00 –2-: Tectonometamorphic evolution of the southern Quebec Appalachians: $^{40}Ar/^{39}Ar$ evidence for middle Ordovician crustal thickening and Silurian/Early Devonian exhumation of the internal Humber zone.

***Sébastien Castonguay**

9:20 –3-: Tectonique néoprotérozoïque et paléozoïque le long de la rive nord du golfe du Saint-Laurent entre Baie-Comeau et Blanc Sablon.

***Serge Perreault**

9:40 –4-: Extension in the Omineca belt of southern Yukon Territory.

***Martin de Keijzer, Paul F. Williams and Charles F. Roots**

10:00: COFFEE

10:30 –5-: Structure and seismic modeling of the oil sands near FT. McMurray.

***Willem Langenberg**

10:50 –6-: Fold nappes revisited.

***Paul Williams**

11:10 –7-: Archean and Paleoproterozoic fault history of the Big lake shear zone, MacQuoid-Gibson lakes area, Kivalliq Region, Nunavut.

***Jim Ryan, Simon Hanmer, Hamish Sandeman, William Davis, Rob Berman, and Subhas Tella.**

11:30 –8-: Thrusting in the Northern part of the Labrador Trough: exemple from the Supracrustal sequence of lac Nagvaraaluk region.

***Normand Goulet, Nathalie Bouchard et Louis Madore**

12:00: LUNCH

13:30 –9-: Crystallographic preferred orientation (CPO) of experimentally sheared anorthite aggregates.

***Shaocheng Ji, Zhenting Jiang, R. Wirth.**

13:50 –10-: Plasticity of Fine-Grained Garnetite at High Temperature: Implications for the Strength of the Earth Lithosphere**.**

***Zichao Wang and Shaocheng Ji.**

14:10 – 11-: Is the Saint-Joseph fault the overturned Bennett Fault?

***Marc Bardoux.**

14:30 – 12-: Demonstration of Stereoplot program.
***Robert Stesky.**

Posters/Affiches

1- The La Grande, Opinaca and Ashuanipi sub-provinces, Eastern Superior Province : Common Tectonic features and Metamorphic evolution, North-central Quebec.
***Cadéron S., Goulet N., and Lamothe D.**

2- Appalachian foreland and platform architecture in Quebec, New Brunswick and Newfoundland: an up-to-date NATMAP contribution to the Geological Bridges of Eastern Canada.
Lavoie, D., Lebel, D., McCutcheon, S, Colman-Sadd, S., Tremblay, A., Hersi, O.S., *Castonguay, S., Rocher, M., Lauzière, K., Gagnon, J., Lemieux, Y.

3- Contribution to the Geological Bridges in Eastern Canada NATMAP project: a compilation geologic map of the Appalachian section of the Montréal-Mégantic transect (#1).
*** Castonguay, S.**

4- An Outrageous Proposal: Quesnellia Is Not A Terrane.
***P. Erdmer, R.I.Thompson, K.L.Daughtry, L.Heaman, R.A.Creaser**

5- Structural Analysis of the Quebec promontory nappe.
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6- Preliminary U-Pb geochronologic constraints on metamorphism and deformation within the northern Selkirk Mountains, southeastern Canadian Cordillera
***H.D. Gibson, S.D. Carr, and R.L. Brown.**

7- Central Foreland NATMAP Project: Domainal geometry controlled by pre-existing subsurface structure.
***L.Lane.**

8- Étude tridimensionnelle de la structure de Moose Mountain, Foothills sud-albertaines.
***J.S. Marcil et D. Kirkwood.**

9- Tectono-metamorphic relationships between the La Grande and the Goudalie sub-provinces,northern Quebec**.**
***E.N'Dah and N.Goulet.**

10- Shear zone kinematics investigation at Cross Lake.
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11- Petrography and geochemistry of cements in fractures: a tool for establishing the chronology of structural elements.
***S.Sejourne.**

12- Post-ore faulting at the Beaufor mine: tectonic implications for the Val d'Or mining camp, Abitibi Greenstone Belt, Canada.
***Tremblay, A.**

13- Structural analysis of shear zones and veins at the CANMET laboratory mine, Val-d'Or, Québec.
***K.Williamson.**

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15- Analyse structurale des veines polymétalliques et des failles tardives de la mine Velarde a, centre-nord du Mexique.
***E. Hoffmann.**

Abstracts/Résumés

The Eastern Highlands shear zone in Cape Breton Island, Canadian Appalachians: kinematics, differential uplift and associated $^{40}Ar/^{39}Ar$ age pattern

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The Eastern Highlands shear zone is a crustal scale thrust. It is characterized by an amphibolite-facies deformation zone ~5 km wide that formed deep in the crust overprinted by a greenschist-facies mylonite zone ~1 km wide that formed more shallowly. Hornblende $^{40}Ar/^{39}Ar$ plateau ages on the hanging wall decrease towards the centre of the shear zone. In the older zone (over 7.8 km from the centre), the ages are between ~565 and ~545 Ma; in the younger zone (within 4.5 km of the centre), they are between ~425 and ~415 Ma; and in the transitional zone in between, they decrease rapidly from ~545 to ~425 Ma. Pressures of crystallization of plutons in the hanging wall, based on Al-in-hornblende barometer and corresponding to depth of emplacement, increase towards the centre of the shear zone, indicating a differential uplift of up to ~28 km associated with movement along the shear zone. The age pattern is interpreted to have resulted from the differential uplift. The pressure data show that rocks exposed in the younger zone were buried deep in the crust and did not cool through the hornblende Ar blocking temperature (~500EC) until differential uplift occurred. The $^{40}Ar/^{39}Ar$ ages in the zone (~425-415 Ma) thus date shear zone movement. In contrast, rocks in the older zone were shallowly buried before differential uplift and cooled through the blocking temperature soon after the emplacement of ~565-555 Ma plutons in the area, long before shear zone movement. The transitional zone corresponds to the Ar partial retention zone before differential uplift. The $^{40}Ar/^{39}Ar$ age pattern thus reflects a Neoproterozoic to Silurian cooling profile that was exposed as a result of differential uplift related to movement along the shear zone. A similar K-Ar age pattern has been reported for the Alpine fault in New Zealand. It is suggested that such isotopic age patterns can be used to help constrain the ages, kinematics, displacements and depth of penetration of shear zones.

Tectonometamorphic evolution of the southern Quebec Appalachians: $^{40}Ar/^{39}Ar$ evidence for middle Ordovician crustal thickening and Silurian/Early Devonian exhumation of the internal Humber zone.

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Published age constraints on deformation and metamorphism from the southern Quebec Appalachians converge toward Middle to Late Ordovician times. This paper presents the results of a regional-scale geochronological study by the 40Ar/39Ar laser step-heating method of 70 amphibole and mica single grains, which brings forward a more complete Middle Ordovician/Early Devonian tectonometamorphic evolution of the Quebec Appalachian Humber zone.

Biotites have plateau ages varying between 420 and 411 Ma. Amphiboles areoften compositionally rimmed and/or contain biotite inclusions. Their age spectra are generally disturbed, but may suggest the occurrence of two distinct events: Silurian (429-424 Ma) and Middle Ordovician (462-460 Ma). Two main groups of muscovite ages have been obtained: Middle Ordovician (469-461 Ma) and Silurian-Early Devonian (431-411 Ma), but Middle Devonian (387-376 Ma) ages are also locally present. Middle Ordovician ages are interpreted to record crustal thickening by nappe emplacement during regional Taconian metamorphism. Silurian-Early Devonian ages are attributed to consequences of backthrusting and normal faulting. A statistical analysis of Silurian-Early Devonian muscovite age spectra reveals an irregular, but constant decrease in weighted apparent age maxima across the internal Humber zone. This age-decreasing trend is interpreted to result from the temporal (ca. 431-411) and possibly spatial (NW to SE) progression of deformation, recrystallization and fluid circulation during tectonic exhumation of the internal Humber zone in southern Quebec. Viable tectonic models for the Northern Appalachian internal Humber zone should take into account the strong body of evidence for Silurian/Early Devonian hinterland-directed and extensional deformation as documented in southern Quebec.

Tectonique néoprotérozoïque et paléozoïque le long de la rive nord du golfe du Saint-Laurent entre Baie-Comeau et Blanc Sablon.

par Serge Perreault, Géologie Québec

La bordure nord du golfe du Saint-Laurent est lacérée par de nombreux linéaments rectilignes qui sont associés au développement du graben du Saint-Laurent. Ces structures ont fait l'objet d'études dans les régions de Québec et de Montréal. Toutefois, elles sont méconnues et très peu étudiées sur la Côte-Nord. Cette conférence a pour but de présenter les grands éléments de la tectonique néoprotérozoïque et paléozoïque associés aux développement du graben du Saint-Laurent et au détroit de Belle-Isle. Voici les principaux éléments qui seront présentés :

Certaines failles du graben du Saint-Laurent montrent des épisodes de réactivation le long de structures grenvilliennes et possiblement pré-grenvilliennes.

Les dernières structures grenvilliennes (néoprotérozoïque) sont caractérisées par des zones de cisaillement fragile, associées à des veines de quartz, minéralisées en pyrite et molybdénite et associées à des altérations hydrothermales de basses températures.

La région de Blanc Sablon et la côte du Labrador sont caractérisés par un volcanisme mafique, la mise en place de dykes mafiques et la déposition des premiers dépôts clastiques vers 600 Ma.
Au Cambrien inférieur, nous notons la mise en place du Complexe igné de Sept-Îles, de la suite syénitique de Baie-des-Moutons et de dykes de diabase le long de la côte-Nord.
Dans la région de Blanc Sablon, déposition de séquences gréseuse et de calcaire à archéocyatidés au Cambrien supérieur ;
Absence de sédimentation marine au Cambrien, pour la majeure partie de la Côte-Nord ;
Développement de la plate-forme carbonatée d'Anticosti de l'Ordovicien moyen au Silurien supérieur ;
Plissement ou développement de grandes ondulations dans la plate-forme d'Anticosti lors de la formation de la chaîne appalachienne;
Activation de failles normales post-déposition de la plate-forme d'Anticosti, ces failles normales sont visibles dans la région de Blanc-Sablon, de Sept-Îles et à la Bai-des-Homards (au sud-ouest de Port-Cartier). Ces failles sont caractérisées par des mouvements normaux, avec des stries de failles développées sur les plans. Les plans sont généralement chloritisés et hématisés.
Mise en place de veines de carbonate, de carbonate-fluorine, de carbonate-sulfures, de dykes de grès (remplissage de fractures) et de brêches à matrice carbonatée qui recoupent le socle grenvillien.

Extension in the Omineca belt of southern Yukon Territory

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Charles F. Roots Geological Survey of Canada - Vancouver; seconded to Yukon Geology Program, Whitehorse, Yukon Territory

Mapping in parts of the Laberge (105/E; part of Lithoprobe-SNORCLE) and Wolf Lake (105/B; part of the Ancient Continental Margin NATMAP project) map areas in the Omineca belt of southern Yukon territory has revealed the existence of a variety of mesoscopic and macroscopic structures which indicate late-stage, predominantly (S)W-(N)E-directed ductile to brittle extension of the pre-existing transposition foliation. These include (i) top-to-the-SW,-S, and conjugate shear bands and boudins up to decameter scale, (ii) progressively more brittle-ductile and brittle, commonly conjugate shears and normal faults, and (iii) joints and dilational veins at high angle to S_T. These structures are typically localized at all scales, however, occur throughout the region and affect most or all of the tectonostratigraphic units.

It is proposed that the extensional fabrics record a period of lithospheric thinning (active continental extension) in the mid-Cretaceous, subsequent to Late Paleozoic-Early Mesozoic crustal thickening / obduction. The distribution of amphibolite facies versus lower grade metamorphic rocks in the Omineca belt of southern Yukon may suggest the presence of at least two metamorphic core complexes (though relatively modestly developed compared with core complexes to the south in British Columbia). The d'Abbadie fault (system) has previously been considered a terrane boundary, separating the Teslin zone from the Cassiar terrane. Given the present data, the d'Abbadie fault system is believed to be a young structure, and it is reinterpreted as a subsidiary zone of normal faults above a main detachment, possibly reactivating an earlier transcurrent fault (of limited(?) regional extend).

Structure and seismic modeling of the oil sands near Ft. McMurray

Willem Langenberg

Most of the bitumen resources in the Athabasca Oil Sands Area are contained in estuarine and fluvial channel deposits of the Lower Cretaceous McMurray Formation. Stratigraphic sections were measured in detail along a 5 km stretch of the Steepbank River. Synthetic sonic logs were constructed for these outcrops with the help of logs of nearby wells. Core in the area correlates log response with lithologies observed in outcrop. Three structural cross sections with 6 times vertical exaggeration were constructed through this area. At least 4 flow units are outlined by dipping surfaces of lateral accretion stratification in the largely estuarine middle McMurray Formation. The lower parts of these flow units are characterized by trough cross beds, which generally contain the highest bitumen contents. A steep NE trending normal fault can be interpreted from the NW trending cross section. The seismic response along these 3 cross section lines through these data points was modeled by ray-tracing.

The seismic lines obtained from this modeling were compared with four high-quality seismic lines, which the Alberta Geological Survey obtained from Mobil Oil Canada in the Clarke Creek area, 20 km southeast of the Steepbank River area. In this area flow units are well-defined on the seismic lines. Our modeling confirms that these flow units can be seismically imaged. From such seismic lines the bitumen contents may possibly be predicted. This prediction will be of high importance in areas of in-situ production, where the best production could be obtained from cross-bedded flow units.

Archean and Paleoproterozoic fault history of the Big lake shear zone, MacQuoid-Gibson lakes area, Kivalliq Region, Nunavut

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The Big lake shear zone (Blsz) in the MacQuoid-Gibson Lakes area transects Archean gneisses derived from metavolcanic, metasedimentary, and diverse plutonic suites. The shear zone has an exposed strike length of 50 km, with abrupt termination to the west. Central and eastern segments of the shear zone consist of dextral, amphibolite facies, porphyroclastic, annealed mylonites and straight gneisses, derived largely from tonalite and monzogranite. The western segment of the Blsz is distinct because (i) it preserves granulite facies assemblages, (ii) it encompasses a wider compositional variety of rocks, (iii) the orientation of its fabric elements vary from those in the east, (iv) shear sense indicators show a more complex deformation history, and (v) the cross-cutting relationships of various intrusive bodies place better constraints on the timing of early displacement.

Rocks in the western segment, in order of decreasing abundance, include: tonalitic orthogneiss, homogeneous tonalite, paragneiss, augen monzogranite, mafic granulites (variably retrogressed to garnet-plagioclase amphibolite), anorthosite and diabase. The granulite facies mylonites (and their variably retrogressed equivalents) are thermally anomalous with respect to the amphibolite facies mylonites and wall rocks. The spatial association of granulites, anorthositic sheets and late-synkinematic diabases represents an anomalous magmatic suite, restricted to the western segment of the shear zone. We propose that these magmas were synkinematically intruded in the western segment of the Blsz, and that the residual heat from the intrusions induced the localized high-grade event. Thermal input from magma emplaced into a shear zone is likely to be a general principle, and not a phenomenon restricted to the Blsz. The ultramylonites are cross-cut by undeformed *ca.* 2.19 Ga MacQuoid dykes, constraining the high-grade, high-strain event to have occurred prior to ca. 2.19 Ga.

The western segment of the Blsz terminates abruptly at a NW-trending, till-covered lineament, that is interpreted as a fault. On the basis of regional aeromagnetic data, we correlate this fault with a structure that trends along South Channel in Baker Lake (South Channel fault; SCF). The SCF dextrally offsets the basal unconformity of the Baker Lake Group by 10 km, and thus records Paleoproterozoic displacement. A NE-trending magnetic anomaly which coincides with the Ippijjuag Bay fault (IBF) is also dextrally offset by 10 km. Tectonic reconstruction of the aeromagnetic data, through moving the block on the NE side of the SCF by 10 km NW along the SCF, results in a flat, wedge-shaped magnetic low. The low is cored by a sharp magnetic high, that is distinct from the more complex high amplitude magnetic pattern throughout the rest of the region. We interpret this low as a down-dropped, wedge-shaped graben, and the IBF represents one of the bounding faults, possibly an ancestral portion of the ca. 1.90 Ga Baker Lake basin.

Le chevauchement des roches de la Fosse du Labrador et de ces équivalents stratigraphiques: l'exemple de la séquence supracrustale de la région du lac Nagvaraaluk.

Nathalie Bouchard, Normand Goulet (UQAM) et Louis Madore (MRN).

Le terrain couvert par cette étude est situé sur la péninsule de l'Ungava, à quelques 60 km au nord de la rivière Arnaud et à environ 50 km au sud-ouest du village de Quaqtaq. L'examen détaillé porte principalement sur une séquence de roches traditionnellement interprétée comme étant un bassin autochtone d'âge Paléoprotérozoïque apparenté à la Fosse du Labrador et en discordance angulaire sur le socle archéen.

Le présent ouvrage vise donc (1) à produire un levé géologique de la séquence supracrustale paléoprotérozoïque de la région du lac Nagvaraaluk, (2) à caractériser le style structural de cette séquence et du socle sur lequel elle repose afin de reconstituer l'histoire tectonique du secteur, (3) à comparer ce style structural avec celui des roches de la Fosse du Labrador situées juste au sud, (4) à étudier l'effet de la déformation et du métamorphisme protérozoïque dans le socle archéen en utilisant les dykes paléoprotérozoïques de la rivière Payne comme marqueur et (5) à tenter de lier l'événement tectonique observé dans le secteur d'étude avec celui de la ceinture de l'Ungava (Cape Smith).

Les roches supracrustales paléoprotéozoïques de la région du lac Nagvaraaluk reposent tectoniquement sur un socle archéen tonalitique et/ou volcano-sédimentaire appartenant à la sous-province de Minto (Province du Supérieur). Ces roches supracrustales ont subit plusieurs phases de plissement (tectonique polyphasée). De nombreux indicateurs cinématiques, surtout rencontrés dans des schistes mylonitiques situés à la base de la séquence révèlent un transport tectonique du NW vers le SE. Le socle archéen est aussi affecté par cet événement tectonique et une déformation ductile à ductile-cassante y est associée. Des veines de quartz de dimensions métriques attribuées au cisaillement sont aussi observées. Cette zone de déformation correspond à un décollement majeur formé durant le transport tectonique des roches supracrustales paléoprotérozoïques de la région du lac Nagvaraaluk et celles de l'extrémité nord de la Fosse du Labrador sur le craton archéen. Ce "bassin" correspond donc à une klippe montrant des évidences de déplacements tectoniques (nappes ?) du NW vers le SE pouvant peut-être s'apparenter aux unités de la Fosse de l'Ungava, également allochtone par rapport au socle archéen. Un événement tardif D3 formant des traces axiales orientées NW-SE à N-S, replisse la klippe.

Crystallographic preferred orientation (CPO) of experimentally sheared anorthite aggregates

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Torsion experiments of synthetic anorthite (An) aggregates were performed in a Paterson gas-medium apparatus at confining pressure of 350 Mpa, temperatures from 1100 to 1200 °C, and strain rates from 1x10E-4 /s to 6x10E-4 /s. The An aggregates with <1% porosity were fabricated from An glass powder using hot isostatic pressing techniques. FTIR measurements showed that the hot pressed An samples had a water content of ~15000 H/106Si (~0.1% wt%). The sheared An samples developed pervasively C-S-C' structures. The S plane (foliation) is defined by a strongly preferred alignment of lath-shaped An crystals. The angle (a) between the S and C (the shear plane) planes varied with the bulk shear strain (G) and follows approximately a relationship: G=2ctg(2a). The C' plane which dissect and offset the foliation is a Riedel shear surface in an orientation between 12° and 20° to the shear direction. The angle between C and C' does not appear to vary with the bulk shear strain. Conjugate Riedel shear planes R2 did not develop. The sense of obliquity between C and C' is everywhere the same in a given specimen and consistent with the applied

torsion sense. Measurements of An LPO in the sheared samples were performed using electron backscatter diffraction (EBSD) techniques and showed that the (010) poles and [100] directions developed a strong preferred orientation parallel to the shortest and longest axes of the finite strain ellipsoid, respectively. The CPO rotated with respect to the flow plane and was enhanced with progressive strain. Both optical and TEM observations suggested that recrystallization-accommodated dislocation glide using (010)[100] system is the dominant deformation mechanism for the sheared An.

Plasticity of Fine-Grained Garnetite at High Temperature: Implications for the Strength of the Earth Lithosphere

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Garnet is a widespread metamorphic mineral in the middle and lower crust, and one of the major mineral phase in the subducting oceanic crust and the mantle transition zone. Therefore, the rheology of garnets have important effects on the dynamics of the subducting lithosphere and the mantle transition zone. Although silicate garnets are usually considered as rigid (undeformable) or brittle in the crust and the uppermost mantle, plastically deformed garnets have been frequently reported. To understand the deformation conditions and mechanisms of garnets, we studied experimentally the plasticity of fine-grained pyrope garnet aggregates (garnetite) at temperatures (T) of 1109-1350 C and total pressure (P) of 0.1 MPa in a controlled atmosphere (f_{O2}) of 10^{-17}-10^{-8} MPa with focus on flow strength of polycrystalline garnetite deformed in diffusion regime.

Samples used are fine-grained pyrope garnetite synthesized through hot-pressing technique in a gas-medium high-T and high-P apparatus. The starting material was prepared from centimeter-size garnet single crystals (from Dora Maria massif, Western Alps, Italy) with the composition of $prp_{0.89}alm_{0.09}(sps+grs)_{0.02}$. The polycrystalline garnetites were hot isostatically pressed at P=300 MPa and T=1250 C for 5 hours, and showed homogeneous microstructures with porosity lower than 1% and grain size (d) about 3-6 mm. Rectangular parallelepipeds, approximately 4x4x8 mm^3, were prepared from the center part of the large hot-pressed bulk sample.

The apparatus used for experimental deformation is a dead-load, 0.1-MPa creep rig, newly setup in the Université de Montréal. The following properties were investigated:

(1) Effect of stress on creep rate: The dependence of creep rate on applied stress was measured within stress range of 11-90 MPa at three different temperatures (T=1116 C, 1220 C and 1270 C). The creep rates were measured as a function of applied stress and fitted to a power law relation of = . We determine *n* within the range of 1.1-1.3, which suggests the dominance of diffusion creep in the entire temperature range of the study.

(2) Effect of temperature on creep rate: Experiments were performed within temperature range of 1100-1350 C at two stresses (36.6 MPa and 47.1 MPa) to see the creep rate as a function of T. The measured creep rates were fitted to the form of = exp($-Q/RT$) through the least-square method, which yields Q=352±34 kJ/mol. This value (Q) is

substantially lower than that determined for the single crystal with similar composition, but deformed in dislocation regime.

(3) Effect of fO_2 on creep rate: One garnetite sample was deformed at constant temperature (T=1188 C) and stress (=35.4 MPa), the creep rate was measured as a function of f_{O2} within the range of 10^{-17}-10^{-8} MPa. The obtained creep rates do not vary clearly with f_{O2} within the f_{O2} range.

The mechanical data suggests a grain size sensitive diffusion creep for the fine-grained garnetite at the study conditions, and the flow law can be expressed as:

$$= \frac{5.32 \pm 3.10 \text{ x } 10^{-6}}{T\mathrm{d}^{2.5\pm0.3}} \, f^{0}{}_{O2} \; \exp\left(- \frac{347 \pm 46 \; kj/mol}{RT}\right) \quad ^{1.1\pm.02}$$

with in s^{-1}, in MPa, f_{O2} in MPa, T in Kelvin, d in meter.

Mechanical data suggests diffusion creep dominants for fine-grained garnetite. This is supported also by microstructural observations on garnet grains in deformed samples. Grain size distribution is homogeneous, there is no clear evidence for flattening of individual garnet grains and most of the garnet grains remain equigranular in shape. TEM observations showed low dislocation activities. To determine the rate-control process, a comparison of the creep data obtained on garnetite with its single crystal counterpart is made. The activation energy for creep of polycrystalline garnetite is found as 347±46 kJ/mol and that for the single crystal garnet with identical composition in the stress regime of 74-498 MPa is about 583 kJ/mol. The fact that the difference in activation energies for creep of the single and polycrystal exceeds ~68% suggests that the rate-limiting process may not be the lattice diffusion of the slowest diffusing species as it could be in the case of single crystal. We further compared the diffusivity calculated from our experimental data with that calculated by assuming Nabarro-Herring mechanism. They do not agree with each other with differences over 2 to 8 order of magnitudes. Thus, we propose boundary diffusion as the preferred mechanism for the plastic flow of fine-grained garnetite at high temperature.

One of the most pronounced observation from this study is that fine-grained polycrystalline garnet does not show substantial high resistance to creep as it is indicated in the case of single crystal. This suggests that garnetite may not form strong layer if it deforms dominantly by grain boundary diffusion. To demonstrate this, normalized creep strength of fine-grained polycrystal garnet is compared with that of anorthite, olivine and perovskite aggregates deformed in the diffusion regime. We see clearly that garnet aggregate does not form the strongest phase but weaker than olivine. This is in contrast to the experimental results performed on the similar garnet and olivine deformed in the dislocation regime, where the garnet is invariably about two orders of magnitude stronger than olivine. The observed low creep strength of garnetite in diffusion regime has an important implication for the rheological properties of the upper mantle transition zone and the 660-km discontinuity. The garnetite resulted from subducted oceanic crust may not be strong enough to penetrate the 660-km discontinuity and likely accumulate over there if it is deformed in the diffusion regime. If the garnetite is deformed in the regime of dislocation creep, however, the subducting slabs could be stiff enough to penetrate the 660-km discontinuity. The transition between the dislocation and diffusion creep mechanisms is related to temperature and grain size. The garnetite within cold and thick slabs like the Mariana and Tonga slabs is more likely to deform by dislocation creep while that within warm and thin slabs like the Izu-Bonin and Japan slabs is more likely to deform by diffusion creep.

Is the Saint-Joseph fault the overturned Bennett Fault?

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Welcome to Bernierville and to the Domaine Fraser, site of UQAM's second year field school where, since 1989, more than 220 students have collectively mapped new parts of the internal Humber Zone of the Bois-Francs region. Inspired by earlier work carried out by Pierre Saint-Julien and co-workers, UQAM has generated forty detailed maps at a 1:5000 scale of a corridor that is approximately 3km wide and stretches 80km in a NE direction between the towns of Trottier Mills and Saint-Pierre-de-Broughton. We spent half of our mapping time documenting a stratigraphic entity loosely referred to as the Bennett Schists defining huge volumes of mica schists occurring eastwards of a much better defined sequence of the Oak Hill Group interpreted as Iapetus proto-rift sequence. Amongst critical features found to date: 1) the stratigraphy of the Oak Hill Group is very variable along strike due to rapid sedimentary facies variations; 2) the Bennett Schists comprise parts of Oak Hill Group and Rosaire Group stratigraphy that has been severely disrupted by thin skin tectonic features often outlined by serpentinite slivers; 3) the Oak Hill strata and Bennett schists were altogether affected by at least three phases of orthogonal ductile deformation; 4) the Oak Hill and the Bennett Schists are juxtaposed by a major syn- peak of metamorphism, phase 2, ductile shear defined as the Bennett fault which has been followed at least 80 km along strike. The Bennett fault is backthrusting to the SE towards the Thetford Mines ophiolitic sequence. Oak Hill Group stratigraphy along the trace of the Bennett fault is progressively dismembered north of Kinnear's Mills where serpentinite and peridotite lenses start occurring. Being one of the most outstanding reflectors on ancient seismic sections, the Bennett Fault seems to be rooting westerly to a minimum vertical depth of 6 km and most likely has large horizontal displacements making it one of the key features of the Internal Humber Zone. The Bennett Fault truncates ancient (syn-S1) thin skin shear surfaces northwards and seems to be converging towards the east edge of the Humber Zone where it is likely to be overturned, like most of the S2 fabrics, by third phase folding to finally dip easterly under the oceanic Dunnage Zone nearby where the Saint-Joseph Fault may be.

The La Grande, Opinanca and Ashuanipi sub-provinces, Eastern Superior Province: common tectonic features and metamorphic evolution, North-Central Quebec.

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A tectono-metamorphic study has led to the recognition of three Archean sub-provinces of the Superior Province in north-central Quebec: the La Grande to the north-west, the Opinaca to the south and the Ashuanipi to the north-east.

The La Grande sub-province consists mainly of middle amphibolite to upper amphibolite facies volcano-sedimentary sequences and of gneissic tonalite (2830 Ma). Volcano-sedimentary basins consist, from bottom to top, of mafic lavas, paragneisses, iron formation and polymictic to monomictic conglomerates containing detrital zircons which have been dated at 2770 Ma.

The Opinaca and Ashuanipi sub-provinces consist of granulite facies rocks. The paragneisses of the Opinaca sub-province shows two periods of granulite facies. The first metamorphism (M1, 2705 Ma) have assemblages of biotite+plagioclase +orthopyroxene+/-garnet+/-cordierite (8 Kb, 790 C) and biotite+plagioclase+orthopyroxene (6.5 Kb, 795 C). The second one (M2/M3) shows assemblages of biotite+plagioclase+orthopyroxene+/-garnet and is caracterised by lower pressure and higher temperature (6 Kb, 810 C). This M2/M3 period of granulitisation is dated at 2645 Ma and corresponds to the Gamart monzogranite suite (2647 Ma). The Opinaca contains ultramafic rocks which could be reflected fragments of an oceanic crust.

The Ashuanipi sub-province is composed of diatexites and shows assemblages of biotite+plagioclase+orthopyroxene+/-garnet (M2: 7 Kb, 780 C) dated at 2750 to 2650 Ma with a final stage of cooling estimated at 2633 Ma. This sub-province represents the product of partial melting of the Opinaca and the La Grande sub-provinces. Small volcano-sedimentary belts can be found with several syn- to late-tectonic (2647 to 2570 Ma) granitic intrusions.

A polyphase deformation has strongly affected the rocks of all three sub-provinces. La Grande sub-province features a major ductile D1 deformation, oriented N-S in the northern part of the area wich becomes E-W further south, near the contact with the Opinaca sub-province. The regional deformation D3, oriented E-W and overturned to the south, with a shallow plunge to the east or NE, is responsable for this major reorientation. The Opinaca sub-province shows the earliest significant folds (D1) which are isoclinal with axes plunging to the NE and overturned to the NW or W. This S1 foliation is folded by the regional D3 deformation. A late minor D4 deformation is locally observed. In the Ashuanipi complex, two sets of ductile to brittle-ductile folding have been recognized. The major D1 is visible in the enclaves of the diatexite. A D2 foliation, characteristic of the Ashuanipi, is refolded by D3.

The Asuanipi/La Grande contact, which coincides with a change from amphibolite facies to granulite facies rocks, is defined by the presence of monzogranite intrusions.
A major E-W zone of southerly-directed thrusting, constitutes the boundary between the La Grande/Opinaca and the Ashuanipi/Opinaca. A number of mineral showings have been identified, all of which are associated with a large area of D1 mylonite in the La Grande sub-province.

The Opinaca sub-province is now interpreted like a large sedimentary basin deposited in a rift environnement (>2710 Ma). The subduction of the La Grande beneath the Opatica could have caused the M1-D1 (2705-2675 Ma) and the M2-D2 (2675-2665 Ma), M3-D3

(2647-2633 Ma) events. During these periods of deformation, double vergence thrusting is re-using old extensional faults. The Opinaca is thrust northward on the La Grande and southward on the Opatica.

Appalachian foreland and platform architecture in Quebec, New Brunswick and Newfoundland: an up-to-date NATMAP contribution to the Geological Bridges of Eastern Canada.

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The Appalachian Foreland and Platform project is the NATMAP- funded component of a multi-disciplinary and multi-agency collaborative endeavour called the ***Geological Bridges of Eastern Canada***. The ***Bridges*** will traverse critical geological segments of southeastern Quebec, northwestern New Brunswick, and western Newfoundland. The objective of the ***Bridges*** is to use five narrow geological transects to bridge the knowledge gaps that exist between the St. Lawrence platform, the Appalachian foreland thrust-fold belt, the crystalline basement and successor basins, from the Neoproterozoic to the Quaternary. ***Bridges*** segments are regularly spaced, and were chosen to elucidate in 4D (from surface to depth, and through geological time) the complex, multi-phased history of basin formation, infilling, deformation and erosion that formed the outer parts of the Appalachians.

The NATMAP component consists of new bedrock and some surficial mapping in conjunction with planned provincial geological mapping projects, and a series of thematic studies to complement the mapping. Surface and subsurface thematic studies focus on: (1) stratigraphy (litho-, bio, chemo- and chrono-) and sedimentology of Neoproterozoic to Quaternary sections; (2) documenting structural styles through mapping, geochronology, remote sensing, geophysics, and by the integration of bathymetric data, both onshore and offshore; and (3) diagenetic, petrographic, geochemical and thermal maturation studies, in order to help assess the mineral, petroleum and groundwater potential of these areas and so generate new exploration models for the resource exploration industry.

For the first year of the projet, new field work (maps and thematic studies) and compilation of existing data were made for the Montréal-Appalachians transect (#1), for the Quebec City - Appalachians transect (#2), for the Matane-New Brunswick transect (#3) and for the Western Newfoundland transect (#5).

An Outrageous Proposal: Quesnellia Is Not A Terrane

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The current and most popular model of Cordilleran tectonic evolution is predicated on the notion that a succession of arcs and accompanying accretionary complexes -- termed the orogenic collage -- was accreted onto the ancient Pacific margin as a result of oblique plate convergence during Early Jurassic through Tertiary time. The terrane accretion process figures prominently in conventional wisdom as a mechanism or driving force in interpretations of the Mesozoic and early Tertiary metamorphism and structural thickening of supracrustal rocks that now form the metamorphic complexes and fringing fold and thrust belts of the eastern Canadian Cordillera.

Within this broad context, the Canadian Cordillera can be depicted as three belts, a western one consisting of crust accreted during Mesozoic time (and making up almost fifty per cent of the Cordillera in breadth), an eastern belt consisting of folded and thrust- faulted strata that were deposited at the continental margin edge, and a central belt of deformed and metamorphosed sedimentary and plutonic rocks that are typical of those deposited at the continental edge but thought to have been moved to varying degrees along the margin from their original site of deposition.

Recent field work in the Vernon map area (82L), a region large enough to bridge the zone of supposed collision between the "collage" and the ancient Pacific margin, suggests that alternative hypotheses to the terrane accretion model are necessary to explain field relationships. For example, evidence supporting tectonic emplacement of an arc assemblage is lacking, and the region that should be underlain by juvenile crust -- crustal roots to the arc assemblage -- contains instead lithologically and geochemically distinctive rock units that can be tied to North American stratigraphic elements farther east. Our work suggests that the margin, at this latitude, extended several hundred kilometers west of where current interpretations would have it placed. Hence, our reinterpretation shows the southern Canadian portion of the North American margin extending west to at least the Fraser Fault system, and changes the 'collage' -- called Quesnel Terrane at this latitude -- to the status of Permian and Triassic volcanic arc built stratigraphically on the continental margin.

Strata that formed part of the ancient Pacific margin of south-central British Columbia have been mapped from east of the Okanagan Valley more than 100 kilometers west to the Nicola horst near Merritt. A distinctive pericratonic succession of quartzite- and granite-pebble metaconglomerate (~50 m), amphibole schist (~500 m), and marble (~40 m) of probable Lower Paleozoic age overlies a thick succession of quartzofeldspathic schist, quartzite, pegmatite and paragneiss (Silver Creek Formation) that forms part of the Neoproterozoic (Windermere) succession deposited along the continental margin about 550 to 750 million years ago. The pericratonic succession is overlain along a stratigraphic contact by Permian and Triassic volcanic arc and sedimentary rocks. This tripartite regional stratigraphy crosses the Okanagan Valley without significant offset.

The implications of these observations are huge. For example, the region west of the Okanagan Valley was until now thought to be underlain by juvenile crust belonging to Quesnellia. Mapping reveals instead that the pericratonic succession, i.e., North American rocks which are tied depositionally to the ancient margin, underlies a stratigraphic cover of

Quesnellia terrane strata. We see no reason why the stratigraphy that underlies the Nicola Group should end at the Nicola horst. To the west, metamorphic rocks that underlie the Nicola Group are known adjacent to the Fraser fault.

Our conclusion is that Permian and Upper Triassic volcanic arcs were active at a continental margin that extended at least as far west as the Nicola horst, likely as far as today's Fraser fault, and possibly beyond.

Preliminary U-Pb geochronologic constraints on metamorphism and deformation within the northern Selkirk Mountains, southeastern Canadian Cordillera

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In the northern Selkirk Mountains there is an excellent example of exhumed middle-crustal, polydeformed and metamorphosed rocks situated within the metamorphic hinterland of the southeastern Canadian Cordillera. Three dominant generations of structures have been mapped by various workers. Of particular importance are the second (F_2) and third (F_3) generation folds that diverge to the SW and NE, respectively, across a mappable fan axis. F_2 folds dominate the west side of the fan structure where they are tight to isoclinal, and are strongly overturned toward the SW. F_3 folds are primarily concentrated in the NE, with steep to vertical NE verging axial surfaces. This zone of structural divergence, termed the Selkirk Fan Structure (SFS), is orogen parallel and is continuous for more than 120 km across the extent of the northern Selkirk Mountains from the SE to NW. The northern half of the fan axis is coincident with a zone of high-grade rocks characterized by the appearance of sillimanite, which trends continuously from the Selkirk Mountains in the east, across the Columbia River, and into the Monashee Mountains to the west, with no known structural break. Metamorphic assemblages flanking both sides of the sillimanite zone become progressively lower grade (kyanite through chlorite). Understanding the thermotectonic evolution of this region is considered crucial when modeling the orogenic processes responsible for the formation of the Canadian Cordillera. However, the thermotectonic history of the northern Selkirk Mountains remains a hotly debated topic, largely due to the paucity of geochronologic data that constrain the timing of metamorphism and deformation.

Detailed U-Pb geochronology and SEM analyses of samples collected in the northern Selkirk Mountains during the summer of 1998 have been completed at Carleton University. U-Pb data for monazite and zircon separated from pelitic schists, pre- to syn- and post-tectonic pegmatite, granodioritic dykes, and a metavolcanoclastic horizon have provided some new insight into the ages of deformation and sillimanite metamorphism within the region. The following first order conclusions are based on the new data: 1) U-Pb monazite data suggest that the sillimanite metamorphism is diachronous, ranging in age from Early to Late Cretaceous, 2) the second generation of folding occurred between ~165 Ma to 155 Ma, and 3) formation of third generation folds is tentatively interpreted to have occurred between ~100 Ma and 81 Ma.

From these conclusions it appears as though the SW-verging folds, $F_{2,}$ occurred during a distinctly separate orogenic event relative to the much younger NE-verging F_3 structures. Additionally, the sillimanite metamorphism appears to have been coeval with F_3, suggesting a possible temporal link between the two. However, previous workers have demonstrated that F_3 deforms the sillimanite isograd. Furthermore, SEM photomicrographs of sectioned monazite and zircon display variable zoning within the dated minerals, suggesting that some of the ages produced may be more complicated than can be resolved using conventional U-Pb dissolution techniques. As a result the following questions come to mind: 1) Did F_3 outlast peak metamorphism? 2) Is the apparent temporal link between sillimanite metamorphism and D_3 fortuitous? 3) Could the monazites dated represent growth related to an overprinting fluid event? These questions need to be addressed before these interpretations can be confidently applied to the formulation of a tectonic model for the region, and are therefore the focus of ongoing research.