Abstracts Volume 28
Canadian Tectonics Group
Annual Meeting 2008

Colonial Inn Moncton,
New Brunswick

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CTG 2008 Schedule of Events

Friday, October 17

7:00 pm Ice-breaker and registration in the Colonial Inn (A on map) meeting room (down the stairs from main lobby)

8:00-8:15 pm Information session: An introduction to the Caledonian Highlands region by Sandra Barr (Colonial Inn meeting room)

Saturday, October 18

7:00 am Breakfast in the Colonial Inn dining room

8:30 am Prepare for field trip departure from Colonial Inn lobby

5:00 pm Tentative time for return from field trip

7:00 pm Group dinner at Bogart's Bar and Grill (B on map) - 589 Main St, downtown Moncton

Sunday, October 19

7:30 am Breakfast in the Colonial Inn dining room

8:50 am Opening remarks for presentation session (Colonial Inn meeting room)

9:00 am **John W.F. Waldron* and James Hibbard**
Truncation and Translation of Appalachian Promontories, and the origin of the Maritimes Basin.

9:20 am **Jenn Marsh and Frank Fueten***
Variations in microstructures within the Lorrain Quartzite across the LaCloche syncline near Whitefish Falls, Ontario, Canada.

9:40 am **F. Fueten, R. Stesky, P. MacKinnon*, E. Hauber, T. Zegers’, K. Gwinner, F. Scholten and G. Neukum**
Stratigraphy and Structure of Interior Layered Deposits in West Candor Chasma, Mars, from HRSC Stereo Imagery and Derived Elevations.

10:00 am **Lori Kennedy*, Kelly Russell and Edward Nelles**
The origins of Mt. St. Helens Cataclasites: Experimental insights.

10:20 am **Coffee Break and Poster Session**

Posters: **Yvette D. Kuiper**
The dry-erase cube: an educational tool in structural geology for making three-dimensional visualization easy.

Adrian F. Park*, Andrew C. Parmenter, Sandra M. Barr, Chris E. White and Peter H. Reynolds
The ca. 390 Ma St, Martins-Stuart Mountain High-Strain Zone, Caledonian Highlands, New Brunswick: Relationship between Neoproterozoic and Paleozoic rocks, Little Salmon River – Long Beach area.

Deanne van Rooyen*, Sharon D. Carr and J. K. W. Lee
^{40}Ar/^{39}Ar dating in Thor-Odin dome, British Columbia, Canada: Excess Ar in high-grade migmatitic rocks.

Jian Zhang*, Shoufa Lin, Robert Linnen and Ryan Martin
Structural Geology of the Matachewan area, Powell Township: A Westernmost Exposure of the Cadillac - Larder Lake Deformation Zone?

10:50 am **Deanne van Rooyen* and S. D. Carr**
Revisiting Cariboo Alp, southwest flank of Thor-Odin dome, BC: implications of structural, metamorphic and thermochronology studies.

11:10 am **Phillip S. Simony and Sharon D. Carr**
Linked thrust and infrastructural flow tectonics.

11:30 am **Davide Zanoni, M. Iole Spalla, Guido Gosso**
Constraining the exhumation of the Internal Western Alps (Italy) by the study of late collisional plutons.

11:50 pm **Jian Zhang, Guochun Zhao, Sanzhong Li, Min Sun, Wenlue Shen, Shuwen Liu**
Structural, Geochronological and Aeromagnetic Studies of the Hengshan-Wutai-Fuping Mountain Belt: Implications for the Tectonic Evolution of the Trans-North China Orogen.

12:10 pm **Lunch and poster viewing**

1:30 pm **Annual GAC/SGTD business meeting (Colonial Inn meeting room)**

Truncation and Translation of Appalachian Promontories, and the origin of the Maritimes Basin

John W.F. Waldron[1]* and James Hibbard[2]

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Accreted terranes of the Appalachian Iapetan and peri-Gondwanan realms display structural trends that are mainly concordant with promontories and embayments in the Laurentian margin, indicating that during accretion, the shape of the continental margin acted as a template around which accreted terranes were molded. In North Carolina and Newfoundland, post-accretion transcurrent motion appears to be recorded by displaced outboard portions of promontories. In both areas, promontories were truncated and dextrally translated for ~250-300 km by a Devonian-Mississippian, orogen-parallel transcurrent system, which may well have extended for the length of the eastern Laurentian margin.

The Late Paleozoic Maritimes basin is a large (400 km long) and deep (>12 km) sedimentary basin superimposed across all terranes of the Appalachians, and characterized by extreme crustal thinning. The development of the basin is linked to the presence of major fault systems many of which display components of dextral strike-slip in Devonian-Mississippian time, and which may have accommodated the displacement that displaced promontories. The basin is located over a major offset in the Laurentian margin, which would have been subject to transtension during the postulated orogen-parallel strike slip. The amount of crustal thinning in the basin, based on estimates of the original thickness of the orogen, combined with seismic and gravity data, is consistent with a stretching factor (beta) of at least 2.6, leading to an estimate of dextral strike-slip motion of approximately 250 km, close to the predicted amount. Although much of the fill of the Maritimes Basin is somewhat younger than the proposed transtension episode, the subsidence history of the basin has been heavily influenced by post-depositional withdrawal of Mississippian evaporites. Hence, the Pennsylvanian sediments may be re-filling accommodation space generated in Mississippian transtension.

Variations in microstructures within the Lorrain Quartzite across the LaCloche syncline near Whitefish Falls, Ontario, Canada

Jenn Marsh and Frank Fueten*

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A regional north-south transect of the Lorrain Formation across the LaCloche syncline along highway 6, near Whitefish Falls, Ontario is studied. The stratigraphic sequence across the syncline is preserved, and present on each fold limb. The lithostratigraphic units with the smallest grains size and lowest mica content are located close to the core of the fold, while coarser grained, mica and feldspar rich units are situated at the northern and southern most extent of the transect. Deformation mechanisms vary with lithology and with position across the fold. Pressure solution appears to be the dominant deformation mechanism in the feldspathic, micaceous and ferruginous units. In the finer grained, mica poor white medium grained and cherty sandstone units, grain boundary migration (GBM) characteristics show dominance over those of pressure solution and show high amounts of fracturing which cut migrated boundaries and therefore post date GBM. All samples across the fold display a preferred orientation of quartz *c*-axes. The senses of asymmetry of fabrics are found to be similar across the syncline, with the exception of those in the ferruginous sandstone unit. The mica content appears to be related to the percentage of quartz lost due to pressure solution; the more mica present, the less quartz was lost. Calculations based on the shape of initial grains suggest that conservatively 30% of the quartz has been dissolved out of the Lorrain quartzite.

Stratigraphy and Structure of Interior Layered Deposits in West Candor Chasma, Mars, from HRSC Stereo Imagery and Derived Elevations

F. Fueten[a], R. Stesky[b], P. MacKinnon[a]*, E. Hauber[c], T. Zegers[d], K. Gwinner[c], F. Scholten[c], G. Neukum[e]

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Interior layered deposits (ILDs) within western Candor Chasma were studied by mapping lithologies, measuring layer attitudes and comparing the stratigraphy of two adjacent mounds. Layering dips down topography, but regionally consistent attitudes exist, suggesting post-depositional block rotations. Stratigraphy of two adjacent mounds correlates, but thicknesses of units differ. Most layered material appears to have been deposited conformably, but one major unconformity exists. Several regional fault populations are identified. Although most faults cut all stratigraphic units, some faults offset only layering in the stratigraphically lowest observable layered material. The data suggest that ILDs are ancient basin fill.

According to our model for ILD formation, ILDs are deposited syn-tectonically during basin collapse and individual mounds are remnants of sub-basins. Stratigraphic differences between mounds resulted from different subsidence rates of sub-basins. A significant change in depositional environment, from depositional to a near cessation of deposition and the onset of a major erosion event, coincided with the opening of the main Valles Marineris troughs. We further suggest that groundwater played an important role in the formation of sulfates. The youngest unit identified, not including surficial deposits, is likely the result of a post-tectonic, regionally limited volcanic event. If basin collapse continued following the cessation of deposition, this model can also account for mounds within closed basins, such as Hebes.

The origins of Mt. St. Helens Cataclasites: Experimental insights

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Thick (1-3 m) layers of fault rocks that formed during the 2004-2006 dome building events are interpreted to be linked to the 'drumbeat' microseismicity associated with dome building (Iverson et al. 2006).

We experimentally deformed Mt. St. Helen's dacite with the intent of reproducing the fault textures observed in nature and placing further constraints on their conditions of formation. Experiments were run at confining pressures of 0, 25, 50, and 75MPa, at room temperature and displacement rate of c. $2 \times 10^{-4} s^{-1}$. The dacite starting material has low porosity (7.29 and 7.73%), a uniform bulk composition (65 wt. percent SiO_2), is highly crystalline, containing 41-45% euhedral to subhedral phenocrsyts and microphenocrysts of plagioclase, hypersthene and amphibole set in a microcrystalline matrix.

The experimental run products show a progressive increase in peak strength with increasing confining pressure and all show brittle behavior, characterized by a rapid stress drop. Run products contain macroscopic fractures with deformation extremely localized around the shear fractures. Natural and experimentally deformed dacites show extreme grain size reduction. Total grain size distribution plots (wt%) show that natural gouge sieved to <63 µm contains a sharp peak at 1.9 µm and has a second, broad peak, at ~4 µm. The experimentally derived gouge has a peak 1.5 µm.

Our experiments were performed dry and at room temperature, whereas the temperature measured at fissures in the dacite domes at Mt. St. Helens, was ~ 730C (Iverson et al., 2006). Despite the lack of temperature, the microstructures from our run products are remarkably similar to those developed at Mt. St. Helens. Mode I fragmentation and shear fracture of grains and matrix, with subsequent cataclastic flow and grain size comminution occurred in both natural (Cashman et al. in press) and experimental fault rocks. Following Iverson et al (2006), we propose that the fault rocks generated at Mt. St. Helen's formed incrementally by rapid, small displacement faults, and that temperature did not greatly affect the mode of failure. We compare our experimental data (e.g. displacement, shear zone thickness, strain rate) to that obtained from Mt. St. Helen's to place constraints on the mechanisms of formation of the fault rocks.

To evaluate the role of porosity on failure mechanisms, Augustine dacite from the 2006 eruption (Power et al. 2006) was also deformed. The Augustine starting material is porous (~20 - 24% %) with a glassy matrix. In contrast to Mt. St. Helen's dacite, the Augustine dacites deformed by ductile strain. The mechanism of deformation for Augustine dacites is a combination of localized shear fracturing and cataclastic flow. We suggest that porosity is the most important factor in promoting distributed cataclastic flow (Augustine) over wholesale localized faulting (Mt. St. Helen's).

Cashman, et al., *in press*. USGS Prof. Paper. Iverson, et al. 2006; Nature, 444. P. 439-444. Power, et al., 2006. EOS Trans, AGU, vol. 87, no. 37.

The dry-erase cube: an educational tool in structural geology for making three-dimensional visualization easy

Yvette D. Kuiper

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Teaching structural geology and its three-dimensional aspects may be as much a challenge for the instructor to teach it as it is for the students to learn it. A cube made of white opaque high-density plastic, which serves as dry- (or wet-) erase material, makes teaching and learning three-dimensional geology much easier and fun. Maps, cross sections and block diagrams can be drawn (and erased!) and seen in three dimensions, and compared with their two-dimensional projections on paper. For example, the cubes are very useful for teaching the concept of apparent dips, which is essential in the construction of cross sections and block diagrams, and is confusing to many students. Plotting apparent dips on block diagrams is especially difficult, because of the distortion caused by the projection. The dry-erase cube provides an intermediate step. Students can first draw the actual apparent dip on the cube and subsequently construct the same angle on the projection of the block on paper. This can be made especially easy if the edges of the cube have the same length as the edges of an isometric block diagram on paper, so that they can simply be lined up.

Several dry-erase cubes can be placed adjacent and on top of each other, so that multiple levels of maps, and parallel and perpendicular cross sections can be constructed. The relationship between maps and cross sections is then clearly visible. The cubes are also an aid in the understanding of stereographic projections, because structural data can be made visible as three-dimensional planes and lines before they are plotted. The dry-erase cubes are not only useful for geoscience teachers, but or anyone teaching or dealing with geometries and block diagrams, e.g. engineers and mathematicians, geologists in the petroleum or mining industries, hydrologists and K-12 teachers.

The ca. 390 Ma St, Martins-Stuart Mountain High-Strain Zone, Caledonian Highlands, New Brunswick: Relationship between Neoproterozoic and Paleozoic rocks, Little Salmon River – Long Beach area

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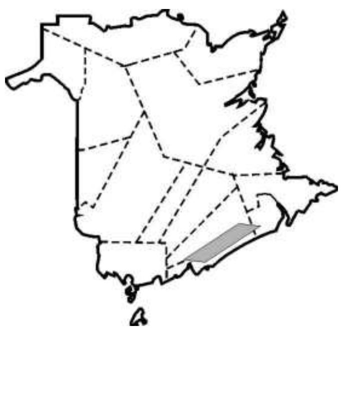
The Caledonian Highlands of southern New Brunswick consist mostly of two Precambrian-Cambrian supracrustal assemblages: the older Broad River Group intruded by the c. 620 Ma Pointe Wolfe River granitoid suite, and the younger Coldbrook Group, unconformable on the Pointe Wolfe River plutons, and intruded by the ca. 550 Ma Bonnell Brook and related plutons. This Neoproterozoic to earliest Cambrian assemblage is unconformably overlain by the Cambrian-Ordovician Saint John Group. A major high-strain zone with many splays, collectively named the St. Martins-Stuart Mountain high-strain zone, crosses obliquely through the Caledonia terrane from NE to SW. This zone has a complex evolutionary history. Deformation began before deposition of the Coldbrook Group with sub-solidus and high-temperature foliation of the Pointe Wolfe River granitoid suite. The supracrustal rocks of the Broad River Group were also deformed at this time. Later deformation incorporated rocks of the Coldbrook and Saint John groups.

North and east of Little Salmon River, Coldbrook Group rocks are preserved in a complex, asymmetric synformal structure, where a pervasive composite foliation (S_{0-1}) results from this early history of coaxial and progressive deformation. The synformal structure itself is a later fold (F_2) with axial planar foliation (S_2). Timing of this phase of deformation has been constrained by $^{40}Ar/^{39}Ar$ ages from micaceous phyllite at two widely separated places along the high-strain zone, one north of Fundy Park and the other near Little Salmon River. Twenty-three single muscovite grains were separated and dated from the first site. Seventeen of these ages are closely grouped about a mean value of ca. 390 Ma, our best estimate of the time of this deformation. The remaining six ages are higher and range up to a maximum value of ca. 620 Ma. Conventional $^{40}Ar/^{39}Ar$ age spectra obtained from whole-rock samples from both sites are variably discordant with minimum ages that approach the ca. 390 Ma age. Coarse detrital muscovite grains in a quartzite sample from close to the high-strain zone at a location between the two phyllite sample locations exhibit only partial resetting (down to apparent ages of ca. 480-500 Ma) from their original Neoproterozoic ages.

South and west of Little Salmon River the early structures are not as thoroughly transposed as to the NE, and more F_1 relics and other geometric elements survive. A complex fold interference pattern south of the main high-strain zone contains enclaves of Saint John Group infolded among Coldbrook and Broad River groups, preserved as isoclinal F_1 folds. These rocks have been refolded by upright F_2 structures, and they consistently form antiformal downward- or southward-facing folds.



Funding for the field aspects of this project was provided by a research grant to the University of New Brunswick from the Geological Surveys Branch of the New Brunswick Department of Natural Resources and an NSERC Discovery Grant to Sandra M. Barr (Acadia University).

$^{40}Ar/^{39}Ar$ dating in Thor-Odin dome, British Columbia, Canada: Excess Ar in high-grade migmatitic rocks

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$^{40}Ar/^{39}Ar$ hornblende and biotite dating was carried out in the core of the southern Canadian Cordillera to investigate the significance and behaviour of excess argon in migmatites, and to place constraints on tectonic models. High-grade rocks of the Thor-Odin dome, in the Monashee mountains, were deformed and underwent anatexis at mid-crustal levels during Late Cretaceous to Eocene orogenesis (Hinchey et al. 2006). The cause of Eocene denudation is controversial (e.g. extension, extrusion or diapirism). $^{40}Ar/^{39}Ar$ samples from an ~12 km thick structural section of cord-sil-Kfs-melt, sil-Kfs-melt and sil-st grade rocks coincide with U-Pb geochronology sample sites.

As is the case in Thor-Odin dome, $^{40}Ar/^{39}Ar$ cooling dates from migmatitic rocks may be unreliable indicators of cooling history because excess argon may cause cooling dates to be significantly older than is geologically reasonable. In the sampling transect, hornblende yields $^{40}Ar/^{39}Ar$ plateau ages ranging from ca. 88 to 52 Ma. In most samples, the release spectra show components of excess argon. There is an apparent correlation between increasing hornblende dates, an increasing component of excess argon and structural position of the samples, and the Late Cretaceous dates in the core of the dome are "too old" relative to the ca. 56-54 Ma timing of anatexis based on U-Pb geochronology studies from the same rocks (Hinchey et al. 2006). Excess argon may have originated within basement rocks and may be a consequence of short residence time of the rocks at high temperatures; this is under investigation. In contrast to the hornblende data set, the biotite cooling dates which range between ca. 51 and 53 Ma show little variation with respect to structural level, and their release spectra show no observable excess argon.

Interpretation of robust $^{40}Ar/^{39}Ar$ data, in conjunction with other data sets and geological observations, do not support detachment faulting on the southwest flank of the dome and support models whereby the domal geometry had formed prior to exhumation on bounding extensional fault systems.

Hinchey, A.M., Carr, S.D., McNeill, P.D. and Rayner, N. 2006. Paleocene – Eocene high-grade metamorphism, anatexis and deformation in Thor-Odin dome, Monashee complex, southeastern British Columbia. Canadian Journal of Earth Sciences 43: 1341-1365.

Structural Geology of the Matachewan area, Powell Township: A Westernmost Exposure of the Cadillac - Larder Lake Deformation Zone?

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The E-W-trending Cadillac – Larder Lake Deformation zone (CLLD) of the southern Archean Abitibi greenstone belt has been considered as one of the best hydrothermally altered high strain zones for gold deposits. The Matachewan area is located close to the western extension of the CLLD and is also characterized by intense deformation, pervasive alteration and gold mineralization. Recent studies have proposed that the Matachewan area may directly lie on the CLLD. However, this issue was poorly constrained because of insufficient structural data. Detailed structural studies in this area are essential for establishing the relationship between the Matachewan area and the CLLD and further understanding the tectonic evolution of the Abitibi greenstone belt.
Three stages of deformation (D_1 to D_3) were identified based on field investigation. D_1 deformation predated the Timinskaming assemblage and was due to nearly NE-SW-orientated compression, generating F_1 fold, S_1 foliation and L_1 lineation. F_1 fold and L_1 lineation are rarely preserved because of the strong overprinting by the subsequent D_2 deformation. S_1 foliation is generally penetrative and strikes NW-SE, overprinting S_0 bedding at a small angle. Associated with the D_1 deformation is the development of the greenschist facies metamorphism. D_2 deformation occurred under a dextral transpressional environment and is characterized by top-to-the-NW oblique thrusting and dextral shearing. F_2 folds deform S_1 foliation and include variable scales of tight to isoclinal 'S'-type or 'Z'-type folds. F_2 fold hinges plunge moderately to steeply to the SW or S. S_2 foliation, axial planar of F_2 fold, dominantly strikes NE-SW to nearly E-W and dips steeply to the south, which is consistent with the D_2 fabrics of the CLLD. L_2 mineral stretching lineations have two orientations. The first one, defined by chlorite or mica aggregates, trends NW and plunges moderately to steeply, and is kinematically related to the D_2 reverse faults. The second one is defined by nearly E-W-orientated elongated clasts or mineral aggregates, and is kinematically related to the E-W-orientated dextral shearing. D_2 deformation also developed under a regional greenschist facies conditions. D_3 was characterized by a sinistral ductile to brittle deformation. F_3 folds are generally open and overprint the F_2 fold and S_2 foliation into 'S'-type folds. S_3 foliations are mostly NW-SE-trending subvertical kink bands, indicating their development under a lower temperature condition than that of the D_1 and D_2 deformations.

In general, the structural, geometric and metamorphic features of different stages of deformation in the Matachewan area can be well correlated with those of the CLLD in the Kirkland Lake area to the east. Therefore, the Matachewan area is most possibly the westernmost exposure of the CLLD, which is characterized by intense deformation, extensive alteration and metamorphism. The theory of structural control for gold mineralization in the CLLD can thus be used to help exploration in the Matachewan area.

Revisiting Cariboo Alp, southwest flank of Thor-Odin dome, BC: implications of structural, metamorphic and thermochronology studies

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Cariboo Alp, a well-exposed 2x3 km belt of rocks on the southwestern flank of Thor-Odin dome, has been the focus of much interest in Cordilleran research because of its location between domal and overlying mantling gneisses and its appearance of high strain. Mapped by Reesor and Moore (1971) as the "contorted zone" of infolded slices of Thor-Odin dome basement and cover gneisses, it has been interpreted as: i) a ductile duplex within the Monashee décollement, a Cretaceous to Late Paleocene northeast-directed ductile thrust zone linking hinterland ductile deformation with the basal décollement of the Cordilleran foreland thrust and fold belt (McNicoll and Brown 1995); ii) part of a Cretaceous to Paleocene – Eocene zone of mid-crustal channel flow (Williams and Jiang 2005); or, iii) an Eocene ductile extensional shear zone, bounding the western and southern flanks of Thor-Odin dome, termed the Thor-Odin high strain zone (Kruse and Williams 2007). Although the lithology, structure and geometry of Cariboo Alp have been well mapped by Vicki McNicoll (McNicoll, née Coleman, 1990), the area was chosen for re-examination to: address fundamental questions about the age and origin of the rocks; document the relationships between progressive metamorphism and structures, with a focus on anatexis; and carry out $^{40}Ar/^{39}Ar$ thermochronology studies to characterize the cooling history of a structural transect through Cariboo Alp and its under- and overlying rocks.

There are striking bands of "rusty" orange-coloured sillimanite garnet biotite gneiss and "grey" migmatitic gneiss at Cariboo Alp. They have been correlated with rocks within Thor-Odin dome, specifically supracrustal cover rocks and Paleoproterozoic North American basement rocks, respectively. Close comparison of the "rusty" cover gneiss and "grey" apparent basement rocks reveals that both are paragneiss, however, they have predominantly different protoliths and migmatite textures. The rusty gneiss, metamorphosed pelitic, siliciclastic and carbonate rocks, contains predominantly lens-shaped stromatic leucosome that makes up less than 20% of the rock. Peritectic garnet and sillimanite make up 40-50% of the rock, and biotite restite comprises 30-40%, implying the rocks have undergone significant melting but have lost much of their leucosome. The "grey" gneiss, a migmatitic biotite hornblende quartzofeldspathic gneiss with minor interlayers of amphibolite and calcsilicate, is a metamorphosed greywacke characterized by extensive stromatic and phenocrystic vein leucosome that makes up 30-60% of the rock. Although the appearance of the grey gneiss is similar to that of Thor-Odin basement rocks, the similarity is that of leucosome texture rather than lithology. On the basis of protolith lithology, the grey gneiss just as likely to be a part of the metamorphosed equivalents of Proterozoic – Paleozoic sedimentary strata deposited on the western margin of North America as it is to be basement. Detrital zircon geochronology studies are in progress to try to place constraints on protolith ages since it is important to know whether or not basement rocks are infolded and/or imbricated at Cariboo Alp when constructing tectonic models.

Prominent structures at Cariboo Alp include well-developed foliations dipping moderately to the south and south-west, southwest plunging sillimanite and hornblende mineral lineations and stretching lineations, north-east verging folds as well as transposed and boudinaged layering. These structures were formed or transposed during progressive top-to-the northeast flow and the resulting transposition foliation is a composite structure. Deformation was ongoing at ca. 62 Ma, during thermal-peak sil-Kfs-melt metamorphism, and had mainly ended by ca. 58 Ma (Carr 1992). Northeast-directed kinematic indicators, in the motion plane parallel to the SW plunging sillimanite and stretching lineation, include shear bands, S-C fabrics, fold vergence and the shape fabrics of pegmatites and leucosome relative to the shear plane (Coleman; 1990; McNicoll and Brown 1995; this study). Questions remain about the significance of this deformation and its relationship to over and underlying rocks (Norlander et al. 2002; Carr and Simony 2006; Hinchey et al. 2006; Williams et al. 2006) and this is an ongoing topic of research.

$^{40}Ar/^{39}Ar$ thermochronology studies at Cariboo Alp do not support the interpretation of a regional-scale extensional shear zone such as the Thor-Odin high strain zone proposed by Kruse and Williams (2007). $^{40}Ar/^{39}Ar$ thermochronology studies were carried out on biotite and hornblende bearing rocks collected from an ~12 km thick structural section through southern Thor-Odin dome, Cariboo Alp and structurally overlying rocks (van Rooyen et al. 2008). If the Thor-Odin high strain zone is a regional-scale Eocene extensional fault that accommodated exhumation of the dome (Kruse and Williams 2007), then hanging wall rocks with older cooling dates would have been juxtaposed against footwall rocks with younger cooling dates. However, this is not the case. Hornblende cooling dates throughout the structural section consistently range between ca. 53-56 Ma, and biotite cooling dates from ca. 51-53 Ma, regardless of the lithology or structural level dated. Pegmatites from different structural levels also show remarkably consistent biotite cooling dates around 50-52 Ma. Similarly, structural evidence does not support the presence of an extensional shear zone or significant extensional reactivation at Cariboo Alp. There are rare coarse sillimanite lineations that plunge to the west, shear bands between pegmatite boudins that indicate down-to the-west shear sense and rare decimeter-scale steep brittle normal faults. These could be related to regional extension mainly accommodated by the Columbia River and/or Okanagan Valley extensional fault systems. The cooling history indicates that any juxtaposition of rock packages that may have occurred at Cariboo Alp predated exhumation of the complex. Together, the structural evidence and the $^{40}Ar/^{39}Ar$ thermochronology data do not support a significant syn- or post-metamorphic break at Cariboo Alp.

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Linked thrust and infrastructural flow tectonics

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Thrust sheets have zones of ductile deformation. This is true even for seemingly simple sheets in the external portion of fold and thrust belts. For example, isoclinal folds, bed thickening in fold hinges and penetrative cleavage are present in many locations within thrust sheets in the front ranges. The abundance of ductile deformation zones and the importance of internal deformation – a form of flow – within thrust sheets increases from the external to the internal parts of thrust belts in an irregular manner, such that, at depth, in the internal portion, in lower amphibolite facies, thick zones of ductile shear and complex folding are found together with buckle folds and thrust faults with ramps and flats. These thrust faults are sharply defined where units of contrasting lithology and age are juxtaposed, but they are associated with mylonite zones. Such relationships have been documented in the Esplanade Range and other areas in the Selkirk Mountains. In the internal portion of the orogen, locally (e.g Cariboo mountains and southern Valhalla complex), a transition is preserved from a suprastructure at low metamorphic grade, with upright folds, to an infrastructure, where, at high grade, the same folds are recumbent and accompanied by migmatite and transposition foliation. There is thus a complete transition from foreland fold and thrust style of deformation to "infrastructure" flow under a suprastucture. Infrastructural metamorphism and flow may be the same age as suprastructural deformation or it may be younger and overprinted on older structures. The various complex age relationships have to be taken into account.

Where infrastructural flow in the orogenic core is important in orogenic evolution, the flow has to be related to deformation in the thrust belt of the same age, and there are several possible linkages. In the case of detachment flow, infrastructural detachment flow might simply accommodate the accumulated shortening of the thrust belt, or the base of the detachment flow may be carried up over the evolving thrust belt. Similarly with channel flow, there are a number of possible linkages including flow of the channel out from the internal part of the orogen and extending overtop the evolving thrust belt. Where the channel "tunnels", and has a fixed subsurface tip line, channel flow is limited; only the detachment portion of the flow is readily linked to the evolving thrusts. The forward flow in a tunneling channel could also contribute to increasing the taper of the thrust belt to the critical angle, driving thrust propagation.

Constraining the exhumation of the Internal Western Alps (Italy) by the study of late collisional plutons

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Key Words: Western Alps; Sesia-Lanzo Zone; Late orogeny pluton emplacement; HP-LT rocks exhumation.

Intrusive mechanisms and timing of late orogeny pluton emplacements may be a key to unravel the late-orogeny evolution of collisional belts. Biella and Traversella Late-Alpine (Tertiary) plutons are intruded in the innermost part of the Sesia-Lanzo Zone (SLZ), a HP-LT early-alpine metamorphic continental complex, close to the inner boundary of the Alpine metamorphic units (Periadriatic line), which belongs to the subducted Adria margin. The study of the tectonic and metamorphic history, of the aureole and of the margins of the plutons, is aimed to contribute to a better definition of the late exhumation of the SLZ.

The two plutons are hosted in eclogitised continental crust rocks of the SLZ, which generally is characterised by a pervasive foliation marked by mineral assemblages indicating HP-LT conditions and related to the Alpine subduction; only some metagranitoids in the Biella aureole show a pervasive foliation marked by HT mineral assemblages, related to the pre-Alpine lithosphere thinning. Intrusions postdate the ductile deformations of the country rock, including the last ductile deformation stages, which are coeval with the regional re-equilibration under greenschist facies conditions and are related to the Alpine exhumation. Only locally syn-intrusive ductile deformation took place. The most of the brittle deformation postdates the intrusion of the plutons, but some mineralized fracture sets developed during magma cooling. In both plutons the most of the structures are magmatic; post magmatic structures are mainly brittle. According to thermobarometric estimates in the country and intrusive rocks, plutons crystallised at a depth between ≈ 3.5 (roof) and ≈ 7 (bottom) km for T ≈ 700 - 750°C.

Structural analysis highlights that in the Western Alps, HP-LT complexes are exhumed to shallow crustal conditions before the intrusion of the late orogeny plutons. An average pre-intrusive exhumation rate of ≈ 2 km/Ma has been envisaged on the base of the known P-T estimates and ages for the eclogitic peak in the SLZ, and pluton ages. During the last 30 Ma the lower exhumation rate of Biella and Traversella plutons (≈ 0.2 km/Ma) with respect to that of the Bergell pluton (≈ 0.6 km/Ma) may suggest that in the Internal Central Alpine belt a larger volume of the Oligocene intrusives should have been eroded, and, on the contrary, in the Internal Western Alps the most part of the these intrusives should have been still buried.

Structural, Geochronological and Aeromagnetic Studies of the Hengshan-Wutai-Fuping Mountain Belt: Implications for the Tectonic Evolution of the Trans-North China Orogen

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Key words: North China Craton; Trans-North China Orogen; Hengshan-Wutai-Fuping; Deformation; SHRIMP; Aeromagnetic.

Major advancements in understanding the Precambrian geology of the North China Craton (NCC) have led to a broad consensus that the Trans-North China Orogen (TNCO) is the site where the Eastern and Western Blocks amalgamated to form the North China Craton. However, controversy has surrounded the timing and tectonic processes involved in the amalgamation of the two blocks. One school of thought proposes a westward-directed subduction with final collision at ~2.5 Ga, whereas others suggest an eastward-directed subduction with final collision at ~1.85 Ga. This contribution aims to present structural, geochronological and aeromagnetic data for the Hengshan-Wutai-Fuping mountain belt, the best basement exposure of the TNCO, to examine current models and establish a reasonable scenario for the evolution of the TNCO.

Structural data indicate that the structural framework of the Hengshan-Wutai-Fuping belt is characterized by a fan-shaped orogenic wedge where the Hengshan Complex and the northwestern Wutai Complex exhibit the NW-directed sense of thrusting, whereas the Fuping Complex and the southeastern Wutai Complex display the SE-directed sense of thrusting. Such structural patterns and opposite thrusting senses are determined on the basis of detailed structural investigations on three phases of deformation (D_1-D_3) that the Hengshan, Wutai and Fuping Complexes underwent during collision between the Eastern and Western Blocks. D_1 is represented by isoclinal rootless folds and associated foliations and lineations restricted to mafic granulites, amphibolites and BIF. D_2 is the major phase of deformation in the three complexes, forming folds of variable scales, thrust faults and ductile shear zones that affected different crust levels. D_1 and D_2 are interpreted to be related to the early collision and crustal thickening. D_3 formed upright open folds and low-angle detachment faults in the three complexes, related to later exhumation and extension.

To constrain the timing of the three episodes of deformation, the SHRIMP technique was applied to date different phases of leucocratic dykes that formed at different stages of deformation in the Fuping Complex. Two leucocratic dykes that did not experience D_1 but underwent D_2 yielded SHRIMP ages of 1843±12 Ma and 1844 ±18 Ma, which define the minimum and maximum ages of D_1 and D_2, respectively. Two post-D_2 leucocratic dykes yielded SHRIMP ages of 1815±45 Ma and 1817±14 Ma, constraining the timing of D_2 between 1845-1815 Ma. Considering the age of 1799±9 Ma for an undeformed pegmatite dyke, D_3 should have occurred at a time between 1817-1800 Ma. These new data support the conclusion from metamorphic ages that the collision between the Eastern and Western Blocks occurred at ~1.85 Ga.

Aeromagnetic data suggest that the lithological boundaries, folding structures and shear zones of this region continuously extend from the surface downwards into deep crustal levels. In addition, aeromagnetic data also reveal that the crust of the Hengshan Complex is thicker than that of the Fuping Complex, indicating that the former is situated closer to the subducted slab than the latter. This conclusion is supported by the distribution of high-pressure granulites and retro-eclogites that are only present in the Hengshan Complex but absent in the Fuping Complex.

Structural, geochronological and aeromagnetic data presented in this study, combined with other available geological data for the Hengshan-Wutai-Fuping mountain belt support the recently proposed model that the Trans-North China Orogen developed from a continental magmatic arc that formed at the western margin of the Eastern Block by the eastward subduction of an oceanic lithosphere between the Eastern and Western Blocks, which collided to form the coherent basement of the North China Craton at ~1.85 Ga.

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