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NUNA Conference: The Northern Intermontane Superterrane

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Conference Reports

NUNA Conference: The Northern Intermontane Superterrane

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A NUNA conference on "The Northern Intermontane Superterrane" was held 22-28 August 1993 at the Lakeview Marina in southern Yukon. There were 34 participants from across Canada and the United States. NUNA is an Inuvialuit term that, loosely translated, means "the earth around us." NUNA conferences are sponsored by the Geological Association of Canada (GAC) and are intended to address specific geological problems or problem areas. Participants are generally actively involved in research in that area. Three previous NUNA conferences have been held: "Greenstone Gold and Crustal Evolution" (Robert, 1991), "Late Proterozoic Glaciation, Rifting and Eustasy, as illustrated by the Windermere Supergroup" (Hein and Simony, 1991), and "High Resolution Sequence Stratigraphy" (Posamentier and Leckie, 1992). In this summary, we describe the Northern Intermontane Superterrane and some of the reasons for convening a conference on this topic, review the field trips held during the conference, and summarize areas of consensus and disagreement that arose out of discussions at the conference.

This NUNA conference addressed the tectonic evolution of the Northern Intermontane Superterrane (NIS). The Intermontane Superterrane was first recognized and described in southern and central British Columbia (Monger *et al.*, 1982) where it includes magmatic arc terranes (Stikinia and Quesnellia), oceanic or marginal basin assemblages (Slide Mountain and Cache Creek terranes), and continental slope and margin assemblages (Kootenay Terrane). Terrane linkages imply that at least some of the above-mentioned terranes amalgamated to one another prior to collision with ancient North America and thus formed a "superterrane."

However, extrapolation of the superterrane north into northern British Columbia, Yukon and Alaska has proved problematic. This is due, in part, to the paucity of recent detailed studies: only a small percentage of the northern Cordilleran has been mapped at 1:50,000 scale, many of the relevant 1:250,000 scale regional maps date from the 1940s and 1950s, U-Pb mineral age determinations are relatively rare, and many suggested stratigraphic correlations remain tentative and lack quantitative substantiation. Correlation to the north is also complicated by differences in the geology of the north portion of the superterrane.

The goals of the conference were to promote discussion among researchers and industry explorationists active in the northern Cordilleran and focus future research by identifying the areas that are most likely to reveal data critical to furthering our understanding of the tectonic evolution of the NIS. This is particularly important in light of the large, recently initiated multidisciplinary studies (ACCRETE in Alaska and the SNORCLE LITHOPROBE transect in Canada) designed to determine the crustal structure of the northern Cordillera.

The first three days of the conference consisted of day-long field trips originating from the Marsh Lake Marina. The field trips were designed to provide participants with an opportunity to observe the terranes that together define the NIS and some of the key field relations between these terranes. The field trips included an overflight from Whitehorse to Skagway, and a two-day transect that extended from the west margin of the NIS at Skagway to the Teslin Suture Zone in the east, where the NIS is in contact with rocks of ancient North America. A third day included a transect of the Triassic-Jurassic Whitehorse Trough, and a detailed examination of a lithological contact previously interpreted as a structure along which two disparate and far-travelled terranes (Stikinia and Nisling) were juxtaposed.

The remaining three days of the conference consisted of day-long seminars. Sessions began with an overview talk in which a framework for evaluation of the day's discussions was established. Subsequent presentations were, for the most part, brief (10 minutes) and informal, allowing for a significant amount of discussion and debate. Presentations ended by 3:30 p.m., at which point participants gathered into working groups to try and identify the most important points to arise out of individual sessions. Summaries of these points were presented at the end of the conference.

The sessions included terrane definition, terrane relationships, and tectonic models. The terrane definition session was aimed at identifying and evaluating the criteria used to distinguish the terranes that constitute the NIS. In the terrane relationships session, attempts were made to establish the structures which juxtapose adjacent terranes, the tectonic, isotopic and stratigraphic evidence linking the terranes, and the timing of the linkages. In the models sessions, the aim was to summarize the main constraints which any tectonic model needs to satisfy, to evaluate models in light of these constraints, and to suggest new models.

The first session, on terrane definition, was instrumental in shaping the subsequent sessions; in order to examine the structures along which terranes are juxtaposed, and then model their interactions, it is necessary to know the number and character of terranes involved. However, differences in opinion on the number and character of the terranes that comprise the NIS, and on the criteria by which terranes can be defined, are significant. Some of the suggested methods for distinguishing terranes include differentiation based on the absence of an assumed diagnostic unit or rock type (negative evidence) in otherwise similar crustal blocks, and characterization by isotopic methods, including cooling ages and isotopic signatures involving the U-Pb, Rb-Sr, and Sm-Nd isotopic systems. Others would prefer that these data be used in addition to classical methods of terrane analysis, namely the recognition of a distinct and regional stratigraphy or geological history, in a crustal block bound by significant faults.

During discussion of the pericratonic terranes, including the Nisling and Yukon-Tanana terranes, it was suggested that the latter consists of more than one terrane, and includes an "upper" terrane of amphibolite, argillite, graphitic quartzite and fine-grained siliceous rock, marble and pelite. This upper terrane is characterized by Late Triassic to Early Jurassic plutons, gives Early Jurassic cooling ages, and is correlated with Stikinia. A "lower" terrane, which consists largely of quartzite and pelitic schist with amphibolite, Paleozoic augen gneiss and marble, is thought to lack Jurassic plutons, be characterized by Cretaceous cooling ages, and occur below the "upper" terrane. The Nisling Terrane, although similar to the "lower" terrane, is distinguished only on the basis that it is intruded by Jurassic plutons and that it overlies "upper" terrane stratigraphy at one locality.

An alternative suggestion is that the Yukon-Tanana and Nisling are one terrane that includes the "upper" terrane stratigraphy. This is suggested by the pericratonic (siliceous) nature of all three assemblages, and by their common mid-Paleozoic and younger history, including deformation, metamorphism and intrusion in the Devonian, Mississippian, Permian and Jurassic. Furthermore, the assemblages cannot be shown to be separated by "major" faults.

Other terranes about which there was much debate included the Quesnellia, Stikinia, and Dorsey. Late Triassic augite-phyric calc-alkaline volcanic rocks of Quesnellia in south Yukon are distinguished from similar coeval volcanic rocks of Stikinia, which are exposed a short distance to the west in the Whitehorse Trough and which include Late Triassic reefal limestone, by the absence of associated Late Triassic carbonate. An alternative interpretation is that the lack of carbonate may indicate a facies transition and that all the Late Triassic calc-alkaline volcanic rocks in Yukon are Stikinia.

Other aspects of Stikinia were debated. Triassic and Jurassic rocks cropping out between the Nahlin and King Salmon faults in British Columbia (the King Salmon Assemblage) have previously been included in the Cache Creek Terrane. However, the King Salmon Assemblage is continuous and coeval with similar rocks in the Whitehorse Trough that are included in Stikinia. There was consensus that the King Salmon Assemblage be included in Stikinia, not the Cache Creek Terrane. However, the King Salmon Assemblage and strata in the Whitehorse Trough appear to overlie Paleozoic oceanic crust. Elsewhere in British Columbia, Triassic and Jurassic strata of Stikinia overlie a Devonian to Permian sequence of stacked magmatic arcs and related sediments (the Stikine Assemblage). Along the west margin of Stikinia, Triassic and Jurassic strata overlie a metamorphosed assemblage which is at least partly Paleozoic in age. These metamorphic strata had been previously included in the Nisling Terrane; their inclusion in Stikinia remains a matter of conjecture. It is far from clear how to reconcile these apparently significant changes in the nature of the Paleozoic section of Stikinia.

The Dorsey Terrane consists of a pericratonic assemblage that lies along the contact between the accreted terranes and ancient North America. The terrane is similar to coeval North American stratigraphy, however, it overlies volcanic rocks interpreted as part of the oceanic Slide Mountain Terrane. Recent mapping suggests that the volcanic rocks may be North American stratigraphy, implying that the Dorsey Terrane is itself of North American affinity. An alternative suggestion is that the Dorsey Terrane be included in the Yukon-Tanana Terrane; imbrication of the Yukon-Tanana and Slide Mountain Terranes is common elsewhere in Yukon, and intrusion of the terrane by Jurassic plutons distinguishes it from adjacent portions of ancient North America.

In the second session, terrane relationships were discussed. This included reviewing the evidence of the timing of accretion of terranes, and the structures along which terranes are juxtaposed. The timing of terrane accretion is commonly interpreted based on the recognition of sedimentary, igneous, metamorphic and/or structural linkages. Linkages are, however, divisible into "soft" and "hard" categories. Soft linkages may imply, but do not require, the previous amalgamation of two or more terranes. Examples include shared igneous suites, shared metamorphism, shared deformation, provenance linkages, and overlap assemblages consisting of widespread deep marine successions, including trench-filling assemblages. Hard linkages require the previous amalgamation of two or more terranes and include stitching plutons, isograds continuous across terrane boundaries, continuous structures, and overlap assemblages that consist of narrow subaerial formations. The timing of terrane amalgamation can be further complicated where the margins of a buoyant crustal fragment were oriented at a high angle to an encroaching convergent plate boundary; this geometry can result in diachronous accretion. A final complication concerns the structures along which terranes are juxtaposed; these structures are invariably not the structures responsible for the accretion of two terranes. The processes involved in the collision and accretion include the development of post-accretion faults that modify the convergent boundary along which terranes were initially juxtaposed (D. Thorkelson, pers. comm., 1993).

Three structures that were discussed included the Teslin Suture Zone (TSZ), the Crag Lake Fault (CLF), and the Tally-Ho shear zone (THSZ). The TSZ is a zone of steeply dipping tectonites that defines the boundary between rocks of the ancient North American margin to the east and rocks of the accreted terranes to the west, and is locally characterized by eclogite and blueschist. Fabric studies suggest that early developed fabrics that provide a record of dip-slip deformation are overprinted by younger strike-slip fabrics. These observations have led to the suggestion that the zone is a relic subduction zone, which provides a record of oblique transpressional collision with ancient North America. However, blueschists from the zone yield Permian cooling ages that significantly pre-date the juxtaposition of the accreted terranes with North America. Dip-slip fabrics indicate that rocks were thrust out of the zone to the east, onto North America, and to the west. Although blueschist and eclogite are present, they are rare and do not characterize the zone. These observations imply that it is premature to interpret the Teslin Suture Zone as the suture along which North America and the allochthonous terranes were accreted. It was suggested that the zone be renamed the Teslin Structural Zone, maintaining the acronym TSZ, until further studies are completed.

The Crag Lake Fault (CLF) trends east-northeast across southernmost Yukon and juxtaposes the Cache Creek Terrane, to the south, against Stikinia. The fault ends to the southwest, joining the Nahlin Fault, an east-dipping thrust fault along which the Cache Creek Terrane was emplaced to the west over Stikinia, probably in the Middle Jurassic. For much of its length, the CLF fault trace is linear, suggesting that the fault is a steep structure. However, near its east end, tongues of the Cache Creek Terrane extend northwest into Stikinia, suggesting a shallowly dipping contact. In Whitehorse Trough, Stikinia appears to overlie an oceanic basement similar to the Cache Creek Terrane. These observations led to the suggestion that, in northern British Columbia and Yukon, Stikinia overlies the Cache Creek Terrane and that uplift along the Nahlin Fault has resulted in uplift and exposure of the sub-Stikinian Cache Creek basement. The CLF is interpreted as a tear-fault or lateral ramp that accommodated displacement along the Nahlin Fault. The absence of Stikinia south of the CLF is assumed to result from erosion of the uplifted. An alternative suggestion is that the Cache Creek Terrane is everywhere allochthonous above Stikinia and the Cache Creek tongues that extend north into Stikinia are klippen of the Nahlin thrust sheet. The CLF is interpreted as a down-to-the-south normal fault that postdates and cuts the Nahlin Fault. The presence of the Cache Creek Terrane south of the CLF is assumed to result from its preservation in the hangingwall of the CLF.

The Tally Ho shear zone (THSZ) is a zone of steeply dipping tectonites characterized by multiple tectonic fabrics that separate Stikinia to the east from the Nisling Terrane to the west. An undeformed pluton, the Bennett Batholith, plugs the shear zone and stitches Stikinia and the Nisling Terrane together. U-Pb zircon age determinations for the batholith are equivocal; Pb-loss and inheritance limit interpretation of the age of crystallization to pre-175 Ma, but post-220 Ma. The THSZ may be coeval with the Wann River Shear Zone (WRSZ) in northwestern British Columbia along which Nisling Terrane has been thrust to the south over rocks correlated with Stikinia at about 180 Ma (the cooling age on tectonites from the shear zone). These two shear zones have been interpreted as the Early Jurassic structures along which Stikinia accreted to the Nisling Terrane. However, stratigraphic evidence, consisting entirely of soft linkages, has been used to suggest that the Nisling Terrane and Stikinia constituted a single terrane by the Late Triassic. This interpretation implies that the Tally Ho and Wann River shear zones postdate accretion and modify the terrane boundary.

Numerous other terrane relationships were discussed, including: the relationship of the Kluane Metamorphic Assemblage to the Nisling Assemblage and to the unmetamorphosed sediments of the Dezadeash Formation, part of the Gravina-Nutzotin Assemblage of the Insular Superterrane; and the possibility of there being terrane-bounding structures within the Yukon-Tanana Terrane. Only two speakers addressed the use of stratigraphic overlap assemblages: the component clasts of the Early and Middle Jurassic molasse sequences, the Inklin and the Bowser groups (both of which were deposited on Stikinia) were examined to determine what terranes were adjacent to, and shedding detritus onto, Stikinia.

The final day of the conference began with a discussion of the constraints that must be considered in critically reviewing or suggesting models of the tectonic evolution of the northern Cordillera. Models must be testable frameworks in which all the available data can be housed. A tectonic model that explains the distribution of terranes with distinct lithologic associations unrelated to adjacent crustal blocks must, therefore, consider: 1) the distribution of blueschist/melange/eclogite and magmatic belts; 2) paleomagnetic constraints on the relative paleolatitudinal displacements and rotations of terranes; 3) biogeographic zonation, including ammonite faunal provinces and the distribution of boreal *versus* tropical fauna; 4) geochemical data, including geochemical trends across and along strike, and the distribution of geochemically distinct assemblages (*i.e.*, shoshonitic volcanic suites); 5) isotopic signatures, including initial Sr and Nd ratios, cooling ages, and zircon inheritance; 6) metallogenesis (probably the most often overlooked data) including the character and the spatial and temporal distribution of porphyry, sedex, and volcanic massive sulphide deposits; and 7) crustal structure as indicated by geophysical data.

The ensuing discussion of models included reviewing previously published models and the presentation of unpublished ideas, including a model inspired by the conference proceedings. The most vexing questions posed by the models included: the origin and significance of the TSZ; the origin of pericratonic strata of the Nisling Terrane outboard of the Intermontane Belt (is the Nisling Terrane an allochthonous continental margin accreted to the outboard margin of the Intermontane Superterrane, or is this a fragment of the North American continental margin? If so, how did it end up outboard of the Quesnel, Stikine and Cache Creek terranes?); and the relationship of the Stikine and Quesnel terranes (were these terranes, which currently lie west and east of the Cache Creek Terrane, respectively, part of one continuous

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

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

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

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

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Terranes, Domains and Lithotectonic Assemblages Within the Grenville Province

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