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Nicola Horst, southern British Columbia: window into the pre-Triassic margin of North America?[1]

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Abstract: The Nicola Horst, in the Intermontane Belt of British Columbia, is separated from surrounding volcaniclastic rocks of the Late Triassic Nicola Group by steep brittle Tertiary faults. It includes metavolcanic units correlative with the Nicola Group and quartzite metaconglomerate and graphitic metapelite that are probably older, intruded by mafic and granitic rocks ranging in age from Palaeocene to latest Triassic. Supracrustal rocks and early metatonalite are strained, metamorphosed to amphibolite facies, and truncated by less-deformed plutonic units. The horst provides a ‘window’ into the middle crust and perhaps below the base of the Nicola Group. Siliciclastic metasedimentary rocks are similar to units exposed to the east, in Vernon map area, postulated to represent a stratigraphic link between the Triassic rocks of Quesnellia and the late Proterozoic–early Paleozoic margin of North America. If the proposed correlations are valid, North American basement extends at least as far west as the Nicola Horst.

Résumé : Dans le Domaine intermontagneux de la Colombie-Britannique, le horst de Nicola est séparé des roches volcanoclastiques du Groupe de Nicola (Trias tardif) qui l’entourent par des failles fragiles à fort pendage du Tertiaire. Il se compose d’unités de roches métavolcaniques qui peuvent être corrélées au Groupe de Nicola ainsi que d’unités de formation probablement plus ancienne composées de métaconglomérats à fragments de quartzite et de métapélites graphitiques. Toutes ces roches sont recoupées par des intrusions mafiques et granitiques dont l’âge varie du Paléocène au Trias terminal. Les roches supracrustales et des métatonalites plus anciennes sont déformées et métamorphisées au faciès des amphibolites et sont recoupées par des unités plutoniques moins déformées. Le horst ouvre une «fenêtre» sur la croûte intermédiaire et peut-être sous la base du Groupe de Nicola. Les roches métasédimentaires silicoclastiques ressemblent à des roches qui affleurent plus à l’est, dans la région cartographique de Vernon, et qui constitueraient le lien stratigraphique entre les roches triasiques de la Quesnellie et celles du Protérozoïque tardif et du Paléozoïque précoce de la marge continentale de l’Amérique du Nord. Si les corrélations proposées s’avèrent justes, alors le socle de l’Amérique du Nord s’étendrait vers l’ouest au moins jusqu’au horst de Nicola.

[1] Contribution to the Ancient Pacific Margin NATMAP Project

INTRODUCTION

One of the important objectives of the Ancient Pacific Margin NATMAP Project is to establish the contact relationships between volcanic-arc assemblages of Quesnellia (including the Late Triassic Nicola and Stuhini groups) and rocks known to constitute integral parts of ancient North America. That is, are these rocks accreted exotic terranes or were they deposited on North American continental crust?

In Vernon (82 L) and Ashcroft (92-I) map areas, this question is being addressed by mapping and correlating successions that may constitute stratigraphic linkages between demonstrably North American rocks and the Nicola Group. A metamorphosed ‘pericratonic succession’ including coarse siliciclastic rock, black pelite, marble and mafic schist, belonging to the Tsalkom, Sicamous, Eagle Bay, Chapperon, and other groups, is suggested to be in stratigraphic contact with Late Proterozoic rocks of the North American craton (Erdmer et al., 1999). This assemblage has been traced in apparent structural continuity across the Okanagan Valley and appears to exist at least as far west as Salmon River canyon, where it is represented by the Chapperon Group, which is unconformably overlain by Late Triassic (late Carnian) sedimentary facies of the Nicola Group.

An additional 35 km west, in map sheet 92-I/SE, is the Nicola Horst (Fig. 1, 2), a Tertiary fault-bounded structure that exposes relatively deep-seated metamorphic equivalents of Nicola Group volcanic and sedimentary rocks, intruded by plutons of latest (?)Triassic to Paleocene age. Associated with the Nicola facies are undated quartzite conglomerate and graphitic mica schist units that are unlike any known facies of the Nicola Group (Monger and McMillan, 1989; Moore, 1989), but bear a strong resemblance to units of the pre-Nicola, pericratonic succession to the east. If the Nicola Group can indeed be shown to lie unconformably on North American cratonic rocks well into the Intermontane Belt, then the continental margin in Late Triassic time must have been farther west than previously inferred, thus imposing strong constraints on the tectonic transport of Quesnellia.

FIELD STUDIES

The first systematic mapping of the Nicola region was at four miles to the inch (1:253 440) by Cockfield (1948), who identified the Nicola Horst as comprising Jurassic and (?)later granitic rocks with subordinate metamorphic rocks of largely Paleozoic age. The Nicola Group has since been well studied by Preto (1979), Mortimer (1987), and others, mainly south of the Nicola Horst, where it is indicated that there are well defined northerly trending volcanic-facies belts separated by mainly tectonic contacts. Ewing (1980), in a study of the Tertiary tectonics of the region, recognized that the ‘Central Nicola Batholith’ is a horst bounded by early Tertiary extensional faults, and must have risen by at least several kilometres relative to its surroundings. Monger and McMillan (1989), on their map of the Ashcroft sheet (92-I) at 1:100 000 scale, distinguished metamorphosed rocks of both probable Paleozoic and Upper Triassic (Nicola Group) age in the margins of the ‘Nicola Batholith’ (herein termed Nicola Horst), as well as mafic and granitic intrusive rocks. More detailed mapping of the horst and its environs was carried out as supporting geoscience along the LITHOPROBE transect by Moore (1989) and Moore and Pettipas (1990). That work resulted in the recognition of a complex history of deformation, metamorphism, and magmatic emplacement. Given the rise of interest in the area in the context of the nature of the ancient continental margin, it was decided to perform further fieldwork in order to better understand the evolution of the Nicola Horst and especially the relationships of the metasedimentary and metavolcanic rocks therein.

PRELIMINARY RESULTS OF 1999 MAPPING

Fieldwork in 1999 was carried out to yield closer coverage than in the 1988–89 mapping (Moore and Pettipas, 1990) and to obtain a better understanding of the contact relationships both within, and at the margins of, the Nicola Horst. Data were plotted on British Columbia TRIM maps, with the aid of a GPS receiver and aerial photographs, and compiled at 1:50 000 scale. A reduced-scale preliminary version of the geologic map is presented in Figure 2. A summary of the new observations and their interpretation follows, in chronological order of the map units:

Triassic and (?)older

Additional exposures of metaconglomerate and associated staurolite-garnet-bearing black pelitic schist were mapped within the Nicola Horst, on Mount Bob (Fig. 1), and to the north-northeast along strike. These occur only in that area, save for one small exposure, at somewhat lower metamorphic grade (upper greenschist facies?), at the southernmost end of the horst on the south shore of Nicola Lake. The oligomictic composition of the conglomerate, comprising essentially rounded, varicoloured fine-grained quartzite clasts that are probably metachert, makes it atypical of Nicola Group coarse clastic rocks, but similar to some Paleozoic units in Vernon map area. In addition to quartzite clasts, there are minor vein quartz and granitic rock fragments. In the horst, these rocks are in contact with heterogeneous biotite-hornblende schist, probably of volcaniclastic origin, and a distinctive fine-grained felsic rock containing flattened fragments up to 20 cm long that are similar in composition to the matrix. Both fragments and matrix carry 1–4 mm plagioclase crystals. This latter unit, mapped in poor exposures, was termed ‘metatonalite porphyry’ in 1988–89, and was then believed to be a hypabyssal equivalent of the Clark Creek metatonalite, which is in concordant contact with the metasediments along their southwest boundary and is included in the same unit on Figure 2. As the fragmental structure appears to be primary, however, a supracrustal origin is required, and it is likely that the rock is a meta-ignimbrite. Uranium-lead zircon dating in progress at University of British Columbia (UBC; J. Gabites

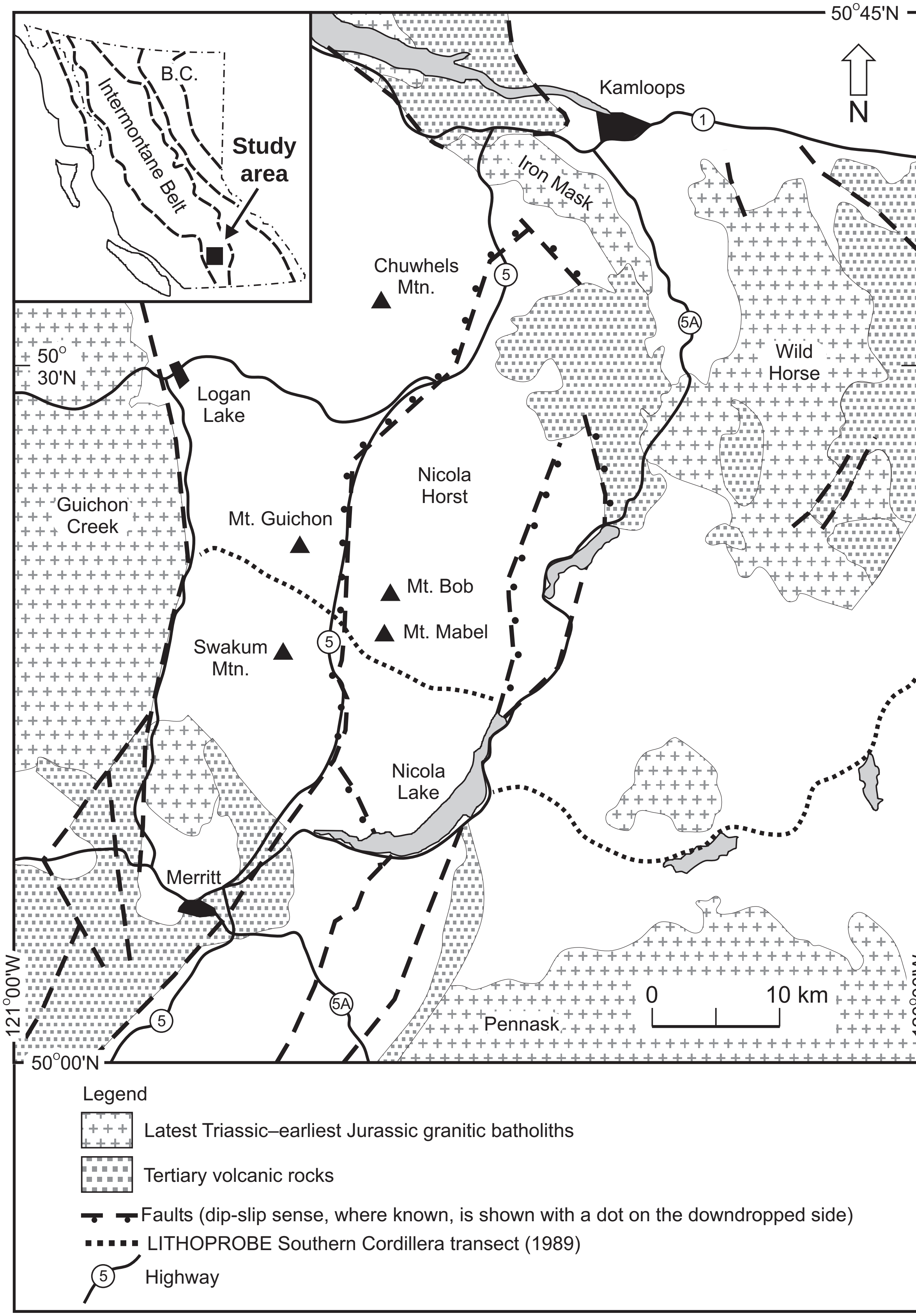

Figure 1. *Geological setting of the Nicola Horst in the southern Intermontane Belt, British Columbia.*

and R.M. Friedman, pers. comm., 1999) indicates that the metatonalite is late Triassic, whereas the fragmental rock may be significantly younger.

Unfortunately, to date no exposed contacts have been discovered between any of the above rocks. All exhibit a comparable development of strong planar and, commonly, linear fabric, shared by probable Nicola Group correlatives in the horst, with concomitant low-pressure mid-amphibolite-facies metamorphism (garnet-staurolite-andalusite in pelitic rocks). Inferred contacts strike subparallel to foliation and are thus probably tectonic.

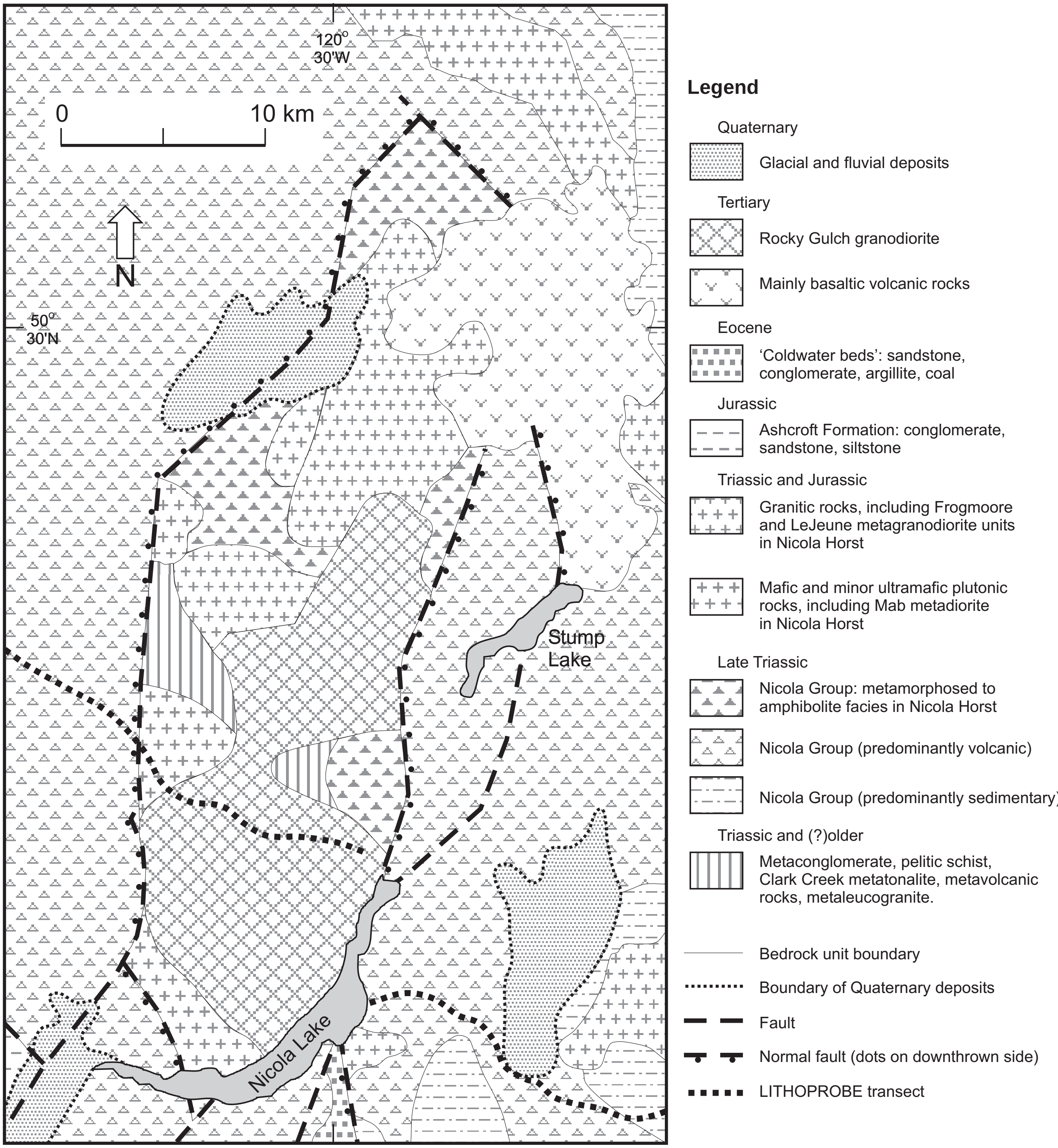

Figure 2. *Generalized geology of the Nicola Horst*, modified from *Moore and Pettipas (1990).*

Late Triassic Nicola Group

Mapping of the north end of Nicola Horst (north of 50°30′N, Fig. 2) reveals a sizeable body of metamorphosed, primarily clastic rocks that are hitherto undescribed. These comprise the following:

1. coarse mafic-intermediate debris-flow deposits with hornblende pseudomorphs after augite in both fragments and matrix, indicating a protolith very similar to Nicola Group rocks to the west of the horst;
2. layered biotite-hornblende schist units that appear to be derived from finer volcaniclastic rocks that occur in the Nicola Group east of the horst; and
3. interlayered coarse- to fine-grained metaclastic rocks that are mainly biotite rich, intermediate in composition, and include quartz-rich meta-arenites. These last do not have any clear equivalents outside the horst, but bear some similarities to the metaconglomerate-pelite association in the Mount Bob area. They differ, however, in that the conglomeratic facies comprises mainly fine-grained quartzofeldspathic clasts that appear to be felsic volcanic rocks, rather than metachert.

Triassic, Jurassic, and Tertiary plutonic rocks

Contact relations and intrusive sequence among petrographically and structurally distinct units, including the Clark Creek metatonalite, have been better defined in the present fieldwork. From oldest to youngest, they are as follows:

1. Mab metadiorite/gabbro (named for the type locality on Mount Mabel, Fig. 1) (relict primary structure common; local moderate to high strain);
2. Clark Creek metatonalite (high ductile strain);
3. Frogmoore and LeJeune granodiorite units (moderate, locally high, ductile strain);
4. Rocky Gulch granite/granodiorite (unstrained).

This sequence is based on fabric development and contact relations. The relation of 1 and 2 was unexpected, as penetrative fabric is much more consistently developed and more uniformly oriented in the metatonalite. However, dykes of the metatonalite, with contact-parallel foliation, cut metadiorite with relict igneous fabric and weak foliation. Thus, the greater preservation of the metadiorite must result from lower ductility. The only unit for which an absolute U-Pb zircon age has been published to date is the Rocky Gulch granodiorite at 64.3 ± 0.3 Ma (Monger and McMillan, 1989). Zircon dating in progress at UBC, in cooperation with J. Gabites and R.M. Friedman, will provide an absolute age framework for the other units.

DISCUSSION

It is evident that the question *Does the Nicola Horst provide a view into the pre-Triassic continental margin of North America?* cannot be answered using present information. It requires firm evidence of a) pre-Nicola age and b) continental signature to prove this proposition. Resolving this uncertainty requires answering some related questions:

1. *Is there evidence of pre-Nicola metamorphism and deformation?* Planar and linear fabrics of similar orientation to those seen in the metasediments also exist in metavolcanic units of the Nicola Horst that are at least lithologically correlative with Nicola units at much lower metamorphic grade outside the boundary faults. As yet there is no evidence of any difference in metamorphic grade between these 'meta-Nicola' rocks and the metasediments; the typically lower strain in them may be only a reflection of their composition. The existence of relict kyanite, enclosed in andalusite in the metapelitic rocks, however, suggests a multistage metamorphic history involving early high pressures. Mapping of minor structures in the highly deformed rocks by Moore in 1989 indicated contraction with easterly tectonic transport, but additional data collected in 1990 yielded a mix of shear senses. Samples have been collected for further fabric studies. What can be said with confidence at present is that ductile deformation detected to date in the horst is Mesozoic and thus predates Tertiary extension. Determining the metamorphic P-T-t path, and the strain regime, may tell whether they result from regional extension, the accretion of the Nicola Group to North America, or whether there is evidence of yet earlier events associated with the ancient continental margin.
2. *What is the provenance of the metasediments in the Nicola Horst?* Isotopic data are being collected at University of Alberta from similar rocks to the east in the Vernon area, in order to establish whether there is a continental signature. These studies need to be extended to the horst. The discovery of ca. 560 Ma granite in possible strained metaconglomerate of the Fowler Creek area (Erdmer et al., 1999) provides a potentially distinctive signature, because plutons of that age are as yet unrecorded in the region. The quantity of granitic clasts collected to date from metaconglomerate of the horst has been inadequate for age determination, but a bulk detrital-zircon sample might yield significant provenance-age data.
3. *What can the plutonic rocks of the Nicola Horst tell us about the tectonic history?* There are at least five distinct plutonic units; their field relations are yielding information on their relative ages. As a complement to the isotopic dating in progress at UBC, whole-rock geochemical study of this sequence could establish the nature of the source regions of the plutons and thus constrain the history of emplacement of the Nicola Group at the ancient continental margin.

A fuller understanding of the regional context requires asking *How is the Nicola Horst related to metamorphic complexes that lie yet further west, at the margin of the Intermontane Belt? Is it a metamorphic 'core complex'?* Nicola rocks metamorphosed to amphibolite facies are associated with the Eagle Plutonic complex (Greig, 1991), and deformed plutonic rocks in the Mount Lytton complex have been tentatively correlated with rocks in the Nicola Horst

(Monger and McMillan, 1989). These complexes record a history of mid-crustal plutonism and deformation ranging from Permo-Triassic (Mount Lytton) to mid-Cretaceous (Eagle). As such, they are also suitable places to search for evidence of the nature of the pre-Nicola basement. Comparison of structural, chemical, and metamorphic styles, between the Nicola Horst and these complexes, is also in order. The term 'metamorphic core complex' has been applied to the Monashee and other complexes to the east of the study area (e.g. Brown and Journeay, 1987), and extended to the Tatla Lake metamorphic complex on the western edge of the Intermontane Belt (Friedman and Armstrong, 1988). In these examples, Mesozoic contractional tectonics have been succeeded by important ductile extensional strain that accompanied the unroofing of the complexes during the Eocene. On present evidence, the Nicola Horst exhibits Mesozoic contraction and plutonism extending into Tertiary time, but without Tertiary ductile extension. The boundaries of the horst at the present erosional level are relatively narrow, brittle fault zones that are younger than ca. 64 Ma. Accordingly, the term 'core complex' as generally understood, is not applicable. The LITHOPROBE seismic data (Cook et al., 1992), however, indicate arching of subsurface planar features across the horst, suggesting that its emplacement is related somehow to a ductile strain history. It is possible that a carapace of rocks showing Tertiary ductile deformation has been eroded from the horst, but remains in the subsurface in the enclosing rocks.

FURTHER STUDIES

Petrographic and microstructural work will be carried out on material collected during the 1999 field season. In addition to the above-mentioned isotopic age determinations, it is planned to launch bulk-geochemical studies of both igneous and metasedimentary rocks, in hope of identifying their source regions, and particularly to seek evidence for or against continental derivation. A P-T-t framework for the Nicola Horst will be sought in order to assess the relative contributions of Mesozoic contraction and Tertiary extension in shaping its architecture.

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