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GEOLOGY ALONG THE LITHOPROBE TRANSECT BETWEEN THE GUICHON CREEK BATHOLITH AND OKANAGAN LAKE (92I/1, 2, 7, 8; 82L/3, 4, 5, 6)

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INTRODUCTION

This account is a progress report on geological mapping and field data compilation around part of the southern Cordillera LITHOPROBE transect in the Intermontane Belt. Objectives included integrating and improving the surface geological database for interpretation of the 1988 Vibroseis survey and reassessing the geological setting of mineral occurrences in the area. The transect route lies in the Nicola Valley and adjacent Nicola Plateau, crossing the Okanagan Highlands eastward to the northern end of the Okanagan Valley. The Coquihalla Highway, connecting Merritt and Kamloops (Figure 1-11-1), crosses the west side of the area and access is also provided by secondary, ranch and forestry roads. Low-lying regions are semi-arid grassland whereas highlands are forested; bedrock exposure is highly variable. Fieldwork, carried out in July and August of 1988, involved reconnaissance of the entire transect segment and local 1:50 000 mapping, mainly in the vicinity of the Central Nicola horst.

PREVIOUS INVESTIGATIONS

Regional mapping of the study area was first carried out by the Geological Survey of Canada at 1:253 440 scale. W.E. Cockfield (1948) mapped the Nicola area between 1939 and 1944 and A.G. Jones (1959) the Vernon map sheet from 1945 to 1951. These authors have summarized the earlier work in the area, including classic studies by G.M. Dawson and R.A. Daly. More recently, detailed mapping of parts of the Nicola Group was reported by Schau (1968), Preto (1979) and McMillan (1981). Okulitch (1979) contributed new reconnaissance mapping and recompiled the regional geology of the eastern part of the area at 1:250 000; Monger and McMillan (1984) published new regional mapping of the western part at 1:125 000. Church (1980) published a 1:50 000 map of the Tertiary volcanic rocks near Okanagan Lake. Ewing (1980, 1981) studied the Eocene volcanic rocks of the region and published an important synthesis of the early Tertiary tectonics.

REGIONAL GEOLOGY

The study area (Figure 1-11-1) is part of Quesnellia, extending almost to its eastern boundary where it is juxtaposed against high-grade metamorphic rocks of the Omineca terrane along the Okanagan shear zone (Bardoux, 1985; Parrish *et al.*, 1988). The western part of the area is underlain primarily by late Triassic arc-volcanic and volcanogenic rocks of the Nicola Group intruded by Triassic and Jurassic calcalkaline plutons, among which the Guichon Creek batholith (McMillan, 1976, 1978) bounds the western end of the transect segment. The eastern half of the area is underlain mainly by Paleozoic rocks of oceanic affinity, in both unconformable and faulted contact with the Nicola Group, that are cut by granitic plutons ranging in age from Triassic to Cretaceous. The Paleozoic and early Mesozoic stratified rocks are complexly faulted and typically metamorphosed to lower greenschist grade. They are overlain by relatively flat-lying clastic and volcanic rocks of Jurassic to Tertiary age; Eocene Kamloops Group volcanics underlie large parts of the Okanagan Highlands.

There are two main sets of major faults: northwest-striking, at least in part contractional features that are probably Mesozoic, and north to north-northeast-striking Tertiary extensional faults. The latter appear to have controlled Eocene sedimentation (Ewing, 1980) and are overlapped by Miocene(?) basalts. The eastern margin of the Guichon Creek batholith and both sides of the Central Nicola horst (Figure 1-11-2) are bounded by steep Tertiary faults.

CENTRAL NICOLA HORST

Termed the "Central Nicola Batholith" in earlier studies, the Central Nicola horst is actually a complex comprising at least Mesozoic and early Tertiary plutonic rocks as well as metamorphosed supracrustal rocks of several ages. It is separated from the surrounding Nicola Group rocks (uTn; Figure 1-11-2) by steep, brittle Tertiary faults: the Coldwater – Clapperton Creek fault zone on the west side, the Quilchena Creek – Stump Lake fault system on the east and unnamed faults to the south. The north end is overlain by Tertiary basalt. Fault zones exhibit complex, closely spaced fracturing, slickensides and local hydrothermal alteration (*see* Mineral Deposits, below). With one exception, no ductile strain is evidently associated with them: an extensional fault at the southwest end of Nicola Lake has an early history of ductile shear, overprinted by brecciation. The Central Nicola horst separates major contrasting facies of the Nicola Group (Preto, 1979) all of which are metamorphosed to lower greenschist facies. The western belt includes mafic to felsic volcanic rocks, clastic sediments and limestone; the central belt, principally augite porphyry flows and coarse vol-

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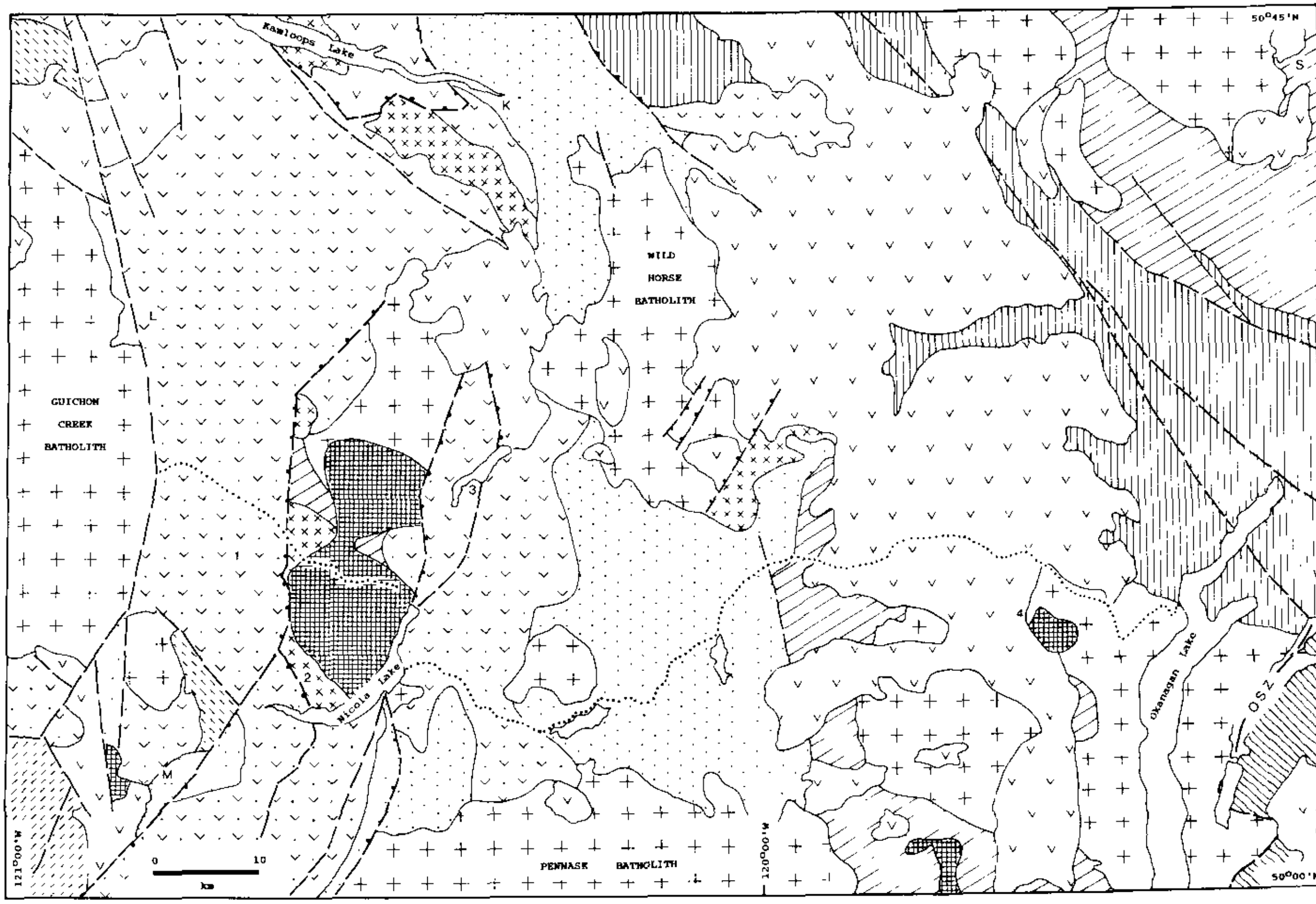

Figure 1-11-1. Regional geology around the LITHOPROBE transect (dotted line) in the eastern part of the Intermontane Belt. Compiled from Jones (1959), Okulitch (1979), McMillan (1981), Monger and McMillan (1984), and field data of B.J. Johnson, M. Bardoux and the writer, not previously published. Tertiary volcanic rocks on and west of the Wild Horse batholith may be as young as Miocene.

caniclastics, is mainly north and south of the horst; and the predominantly epivolcaniclastic eastern belt borders the horst on the east.

The apparently oldest rocks in the horst are highly strained quartzite/(chert?)-pebble metaconglomerate, black pelitic schist, and grey metatonalite and tonalite porphyry (Psm and tm, Figure 1-11-2; all plutonic rocks were identified on the basis of potassic-feldspar staining in the field). The metasediments are not comparable to any unit of the Nicola Group but do resemble certain rocks of the "Harper Ranch Group" to the east (J.W.H. Monger, personal communication, 1988), except that the latter are much less deformed. Metamorphosed augite porphyry and thin-bedded mafic volcaniclastics (uTnm), closely comparable to units of the nearby Nicola Group, but metamorphosed to lower amphibolite facies, contain the same fabric as the metasediments and metatonalite: a northwesterly striking foliation and moderately west-plunging stretching lineation that is consistent in orientation across the horst (Figure 1-11-2). Scarce kinematic indicators in these rocks suggest easterly directed thrusting.

On the west side of the horst the above-mentioned rocks are bordered by relatively uniform metamorphosed gabbro, diorite and minor quartz diorite (dm). Intrusive contacts are not exposed but the much less homogeneous and less intense strain in the metadiorite (restricted mainly to anastomosing ductile shear zones, centimetres to decimetres wide) implies that it is younger. At the one locality where the contact with metatonalite is closely defined, on the northwest shore of Nicola Lake (Figure 1-11-2), it is abrupt and appears to be faulted.

The bulk of the Central Nicola horst is occupied by medium to coarse-grained granitic rocks, predominantly granodiorite but ranging from biotite granite to hornblende-biotite tonalite, mainly as a function of the concentration of coarse potassic-feldspar megacrysts. Despite their superficial uniformity these rocks are of two distinct ages. Rocks in the northern third of the horst (Jgdm) have yielded a rubidium-strontium isochron at *circa* 190 Ma and are thus Early Jurassic (R.L. Armstrong, personal communication, 1988). Zircons from a sample from the southern part of the horst (Tgd), 6 kilometres west of the north end of Nicola Lake, are dated as Paleocene by uranium-lead (64.5 ± 0.5 Ma; R.R. Parrish, personal communication, 1988). The northern samples are all augen textured and exhibit transitional ductile-brittle deformation in thin section, whereas the southern samples are little strained (R.L. Armstrong, personal communication, 1988). Mapping by the writer confirms the Paleocene granodiorite is in sharp intrusive contact

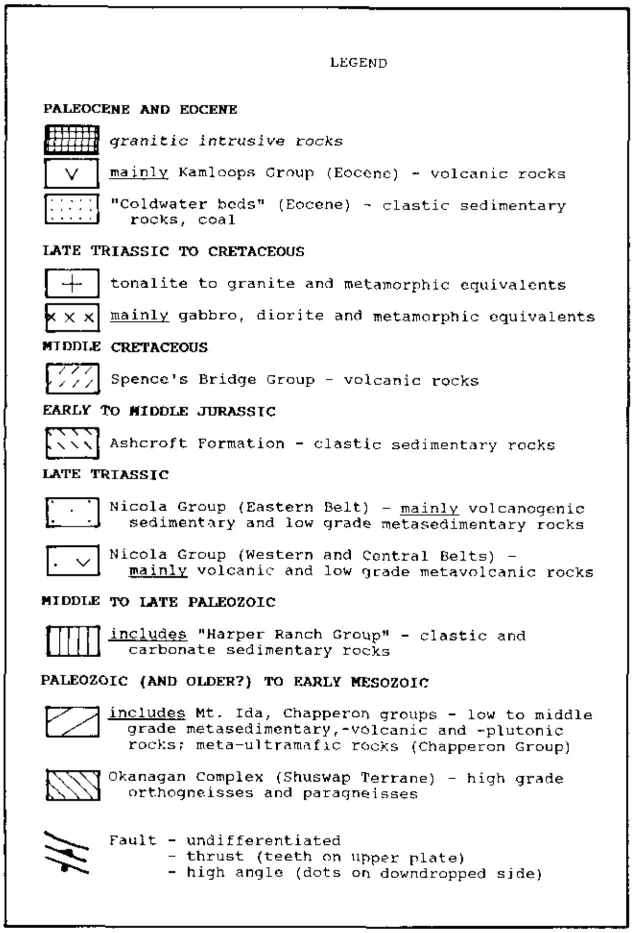

Figure 1-11-1a. Legend for Figure 1-11-1.

with adjacent units and is megascopically unstrained, save for one locality near its west contact where it contains gently west-dipping extensional shear bands. Its contact with the Jurassic body remains poorly defined. Rubidium-strontium (R.L. Armstrong, personal communication, 1988) and potassium-argon (Preto *et al.*, 1979; Monger and McMillan, 1984) hornblende and biotite dates from both units are almost all in the range of 52 to 70 Ma. The Rey Lake stock, a small body similar to the Paleocene granodiorite, but located near the LITHOPROBE transect 20 kilometres to the west, has a potassium-argon biotite age of 69 Ma (Preto *et al.*, 1979).

The Central Nicola horst was identified as a metamorphic core complex by Ewing (1980) and considered to result from early Tertiary extension in the southern Cordillera. Although the contrast in metamorphic grade between the horst and its surroundings, and the age of the bounding faults, are consistent with this proposal, it is apparent that most of the ductile strain in the horst is not spatially related to the Tertiary bounding faults, is no younger than Paleocene and, on the present evidence, is contractional. By contrast, the Tertiary ductile shearing in the Omineca terrane to the east is extensional and Eocene (45-58 Ma; Parrish *et al.*, 1988). It appears that the horst is providing a "window" into a deformed terrane below the present erosional level of the enclosing Nicola Group rocks; like the Mount Lytton complex 50 kilometres to the west (Monger, *in press*), it affords a view into the probable roots of the Nicola arc. It may be that its entire ductile history is Mesozoic and related not to Tertiary extension but rather to westerly subduction or, more probably, to easterly obduction of the arc complex. Reset mineral dates imply later uplift and cooling in Eocene time. Further age determinations are in progress in an attempt to better delimit the timing of intrusive and metamorphic events in the Central Nicola horst.

RELATIONSHIPS BETWEEN NICOLA GROUP AND CHAPPERON GROUP

Existing regional maps are inconsistent in their portrayal of the contact relationships of the Mesozoic and Paleozoic rocks near the LITHOPROBE transect. In the vicinity of 120° west (Figure 1-11-1), Jones (1959) mapped an unconformity in the Salmon River canyon between underlying schists, limestone and ultramafic rocks of the Chapperon Group (of unknown age) and overlying sedimentary rocks which he assigned to the Cache Creek Group on the basis of their lithology. He considered the younger rocks to extend westward into the Nicola map area where Cockfield (1948) had also given them a Permo-Carboniferous age, again without fossil control. South of the Salmon River, on the present transect route, Jones mapped the boundary between the two groups as a fault.

Read and Okulitch (1977) confirmed the Salmon River unconformity but the overlying rocks were correlated with the Nicola Group on the basis of Late Triassic conodonts. The Chapperon Group was suggested to be Middle Carboniferous. Okulitch (1979) identified clastic and carbonate

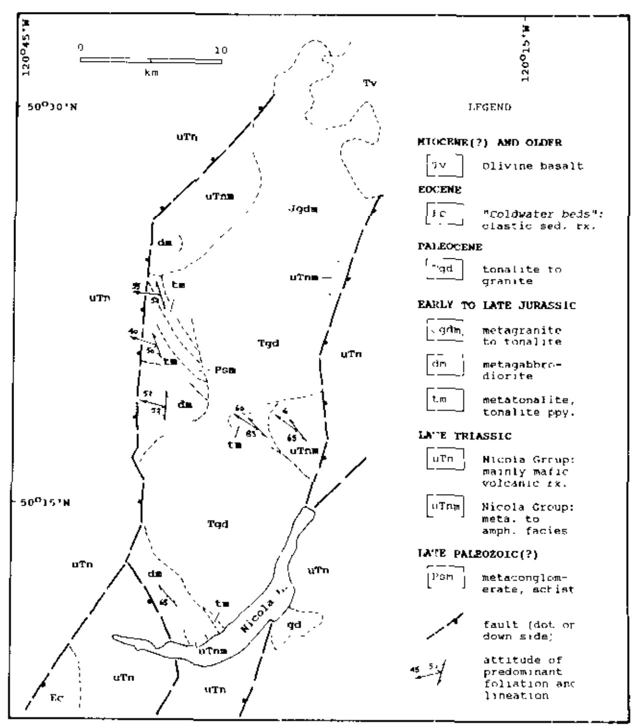

Figure 1-11-2. Geology of the Central Nicola horst. Compiled from Monger and McMillan (1984 and original traverse maps) and fieldwork by the writer.

sedimentary rocks of the Permo-Carboniferous "Thompson Assemblage", lying between the Nicola Group and the Chapperon Group south of the Salmon River and along the LITHOPROBE transect, but this age assignment is not supported by any fossil evidence. The nearest fossils bearing on the supposed Late Paleozoic age of these rocks were collected 20 kilometres to the south near Dome Mountain, from rocks lithologically correlated but not structurally continuous with the succession on the transect. Monger and McMillan (1984) assigned all the rocks in this area, west of 120° (virtually all the rocks immediately above the Chapperon Group) to sedimentary facies of the Nicola Group, again without local fossil control but on the basis of strong lithologic and structural similarity to dated Nicola rocks north of Kamloops, separated from those along the transect by the Wild Horse batholith (Figure 1-11-1).

As a result of the present study, volcaniclastic rocks of the Nicola Group (eastern belt) are believed to be in direct fault contact with the Chapperon Group. Reconnaissance mapping shows that Nicola volcanic wacke and siltstone, as they are traced eastward from Chapperon Lake (immediately south of the transect near 120° west, Figure 1-11-1), become deformed into recumbent mesoscopic folds. Siltstone develops a prominent cleavage that dips gently west, parallel to the fold axial surfaces. The deformed succession is very similar to unfolded rocks to the west except that it contains minor dark limestone beds. Chapperon Group rocks, mainly mafic and ultramafic schists near the contact with the Nicola Group, exhibit two generations of deformation. Pending more detailed mapping, it is tentatively concluded that the Nicola Group has been thrust eastwards over the Chapperon Group in this vicinity; to the north the thrust zone must cut either above or below the Salmon River unconformity.

MINERAL DEPOSITS

The LITHOPROBE transect passes near three major concentrations of mineral occurrences in and near the Central Nicola horst. As numbered on Figure 1-11-1, these are (1) Swakum Mountain, (2) Nicola Lake and (3) Stump Lake. A fourth locality, Whiteman Creek near Okanagan Lake, unlike the others, is currently the site of a major exploration program. There are important differences of geological setting among these four localities.

SWAKUM MOUNTAIN

The Swakum Mountain occurrences, not visited by the author, were described by Cockfield (1948) and in numerous assessment reports (for example, Kelly, 1984). The area has a history of exploration and small-scale mill testing dating from 1916. Polymetallic (copper, lead, zinc, tungsten, silver and gold) mineralization is found in Nicola Group mafic to intermediate flow and volcaniclastic rocks and limestone; on the south flank of the mountain, dacitic and rhyolitic rocks locally form part of the succession. The Last Chance (Lucky Mike) deposit consists of pyrite, pyrrhotite, chalcopyrite and scheelite, disseminated in a hematite-garnet-epidote skarn that has replaced limestone along its contact with volcanic rocks. Occurrences to the south are veins and replacements lacking scheelite and containing galena, sphalerite and tetrahedrite, with precious metals. The distribution of metals implies zoning, and a positive magnetic anomaly suggests, by analogy with the Guichon Creek batholith to the west, the presence of an intrusive body below surface. Skarn mineralization, similar to Last Chance, also occurs at Rey Lake, 6 kilometres to the north, where it is associated with a small granodiorite intrusion.

NICOLA LAKE

Mineral occurrences near the southwest end of Nicola Lake lie at the northern distribution limit of a large number of prospects, primarily for copper, in volcanic rocks of the Nicola Group. However, the association is primarily copper-molybdenum, with minor gold and silver, within a body of foliated metadiorite (dm, Figure 1-11-2). The principal deposit is the Copperado mine, that has seen underground exploration intermittently since 1949 but no significant production. Quartz veins, broadly synchronous with deformation, carry bornite, chalcopyrite and molybdenite; they are cut by quartz-feldspar porphyry that may relate to the Paleocene granodiorite. The Copperado and several smaller prospects show similarities to porphyry copper-molybdenum deposits in the Guichon Creek batholith (McMillan, 1976). They are within a kilometre of a major extensional, ductile-brittle fault zone that brings relatively undeformed Nicola volcaniclastic rocks against the metadiorite and which appears to connect across Nicola Lake with a fault that separates western belt from central(?) belt facies of the Nicola Group (McMillan, 1981). There are smaller copper occurrences in the hangingwall of the fault. A small separate mass of Nicola Group volcanic rocks on the lake at the south end of the metadiorite contains carbonatized and silicified shear zones with epidote, pyrite and chalcopyrite. Mineralization in both the Nicola rocks and the metadiorite may relate to the regional metamorphism and concurrent deformation displayed within the Central Nicola horst.

STUMP LAKE

North-striking, persistent gold-bearing quartz veins in the Nicola Group south of Stump Lake were actively worked from the late 19th Century to the 1940s (Cockfield, 1948). Although the host rocks were earlier described as primarily volcanic, examination of the property in 1988 reveals that they are a volcaniclastic sedimentary succession consisting mainly of greywacke turbidites with subordinate siltstone and conglomerate containing augite porphyry clasts. The west-dipping succession is broken into several blocks by brittle faults. Vein systems, typically less than a metre in thickness but persistent in some cases for as much as 500 metres along strike and 300 metres down dip (Cockfield, 1948), are surrounded by narrow carbonatized halos; sericitic alteration was observed on the dump of the Enterprise adit. Some of the alteration zones are sheared whereas others show no penetrative deformation; veins and shear zones dip predominantly east at a high angle to bedding. Metallic minerals observed in the veins (Cockfield, 1948) include pyrite, galena, sphalerite, tetrahedrite, chalcopyrite, bornite, scheelite, arsenopyrite, pyrrhotite and native gold. The age of the veins is not directly established. Faults in the host rocks have a similar strike to those mapped by the author east of the

Central Nicola horst at the north end of Nicola Lake, where they separate blocks of distinctly differing primary lithology and degree of penetrative deformation, and appear to be part of the set of Tertiary faults that bounds the horst. Although many small faults are reported in the underground workings at Stump Lake, few were seen to have displacements of more than a metre or so, suggesting that any major faulting either preceded or was coeval with the veins and thus that the veins are of Tertiary age. Alternatively, vein formation may be the result of low-grade regional metamorphism in Mesozoic time. Direct dating of the wallrock alteration would resolve this uncertainty.

WHITEMAN CREEK

Gold prospects immediately west of Okanagan Lake (4, Figure 1-11-1) currently being explored by Huntington Resources Inc. and Corona Corporation (Brett claims), and Brican Resources Ltd. (Gold Star claims), prompted considerable staking activity in the area in 1988. The host rocks are flat-lying basalts and tuffs of presumed Eocene age; vuggy, brecciated gold-quartz veins occupy faults striking north-northwest, dip steeply and are surrounded by clay-silica-pyrite and bleached propylitic alteration halos. Gold is associated with pyrite and minor galena and argentite (Meyers, 1988). Feldspar porphyry dykes, probably related to a nearby Eocene granitic stock (dated at 50 Ma; Church, 1980), have similar attitudes to the veins. Both dykes and stock are also altered, further supporting an Eocene or younger age for the mineralization. Mesozoic (Late Jurassic?) granite that forms the basement to the Eocene volcanic rocks is in steep, probably faulted contact with the lavas along the eastern side of the Brett property; a large alteration zone ("Gossan Zone") in the volcanics is close to this boundary. The epithermal mineralization may have resulted from circulating fluids driven by Eocene magmatic heat; however, the spatial association of the veins with the Okanagan shear zone that was active in Eocene time (Bardoux, 1985; Parrish *et al.*, 1988) indicates the possibility of another energy source. Ductile strain at upper amphibolite grade in the lower plate of the Okanagan shear zone, related geometrically to early Tertiary extension, affects rocks as young as 50 Ma and implies that the hangingwall rocks were juxtaposed against hot underlying gneisses of the Shuswap terrane that may have provided the necessary thermal energy for hydrothermal circulation. Tempelman-Kluit and Parkinson (1986) have called attention to the association of a number of gold prospects with the hangingwall of this major structure.

OTHER MINERAL OCCURRENCES

The western boundary of the Central Nicola horst, near the LITHOPROBE transect, exhibits intense quartz-sericite-pyrite alteration of Nicola Group volcaniclastic(?) rocks where they are exposed in roadcuts on the Coquihalla Highway. Because of limited exposure it is not certain whether this alteration is related to the main boundary fault of the Central Nicola horst or to an earlier structure; however, it is not typical of the nearby Nicola Group at greater distance from the boundary fault. This observation suggests that early Tertiary faults in the area, like those near Okanagan Lake, may be favourable locales for epithermal mineralization.

CONCLUSIONS

The main conclusions arising from the project to date are:

(1) The Central Nicola horst contains at least four distinct plutonic and metaplutonic units as well as regionally metamorphosed and highly strained supracrustal rocks, including siliciclastics that do not correspond to any known facies of the Nicola Group. It preserves a complex history that is not evident in the surrounding Nicola rocks, with a probable time span of at least late Paleozoic to early Tertiary. As such, it constitutes an exhumed part of the crust that underlies the present exposure of the Nicola Group and may represent the roots of the Nicola arc.

(2) The eastern contact of the Nicola Group with underlying, presumably late Paleozoic rocks of the Chapperon Group near the LITHOPROBE transect is an unconformity in at least one locality, but a probable thrust fault elsewhere.

(3) Mineral occurrences near the transect are of several different types and appear to be related to both Mesozoic magmatic and metamorphic processes as well as Tertiary extensional tectonics and volcanism.

LITHOPROBE seismic results, expected early in 1989, should cast more light on the relative importance of the fault systems mapped on surface and, in conjunction with isotopic dating and petrologic studies in progress, provide a clearer image of the deep structure and history of the Intermontane Belt and its associated mineral deposits.

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