



GEOLOGY OF THE SWAKUM MOUNTAIN AREA, SOUTHERN INTERMONTANE BELT (92I/7)

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INTRODUCTION

Fieldwork begun in 1988 along the LITHOPROBE Southern Cordillera Transect in the Intermontane Belt (Moore, 1989) was continued in 1989, with the dual objectives of resolving the stratigraphy and structure of the Nicola Group and gaining a better understanding of the architecture of the Nicola horst. West of the horst (Figure 1-7-1) the Nicola Group has been mapped at 1:25 000 scale as far north as 50°15' (Preto, 1979; McMillan, 1981) but farther north there was only reconnaissance coverage (Cockfield, 1948; Monger and McMillan, 1984). Because of the large number of former small mines and mineral occurrences on Swakum Mountain (Figure 1-7-1), this area was selected for more detailed study. Excellent access is afforded from Merritt by the Coquihalla Highway and Mamit Lake road and a number of seasonal forest-access roads. Three weeks were devoted to mapping, using 1:15 000 aerial photographs and compiling at the same scale on a base enlarged from the 1:50 000 topograph map. The geology of the area has proven much more complex and diverse than expected, and the new data obtained this season have implications for regional structure and metallogeny. In this paper we present a preliminary account of the stratigraphy and structure; a more comprehensive treatment of the mineral occurrences and potential will be presented by the authors with R.E. Meyers in *Exploration 1989*.

REGIONAL SETTING

The study area lies within the Western Belt of the Nicola Group, comprising primarily calcalkaline arc volcanic rocks (Preto, 1979). It is bordered on the west by the Late Triassic to Early Jurassic Guichon Creek batholith (McMillan, 1978) and on the east by the Nicola horst. The Nicola horst (described in Moore, 1989 where it is referred to as the "Central Nicola horst") comprises Nicola Group rocks, sedimentary rocks of unknown age, tonalite and tonalite porphyry, all strongly deformed, metamorphosed to low amphibolite facies and intruded by granitoid rocks ranging in age from at least Early Jurassic to Paleocene. It is separated by normal faults from surrounding Nicola Group rocks that are of subgreenschist and greenschist grade and lack penetrative deformation. The Swakum Mountain rocks exhibit continuity with Nicola Group units mapped to the south (McMillan, 1981) but may be separated by a northwest-trending fault from those to the north on Mount Guichon (Figure 1-7-1).

LITHOLOGY

A generalized geological map of the area is presented in Figure 1-7-2; the legend is given in Figure 1-7-2a. To date there are no paleontological age determinations in the study area, so all age assignments are tentative, but the relative ages of the major units are evident from field relationships.

Rocks of the Nicola horst are not subdivided on the map but will be treated in a later publication. As noted above, they are in part age-equivalent to units on Swakum Mountain.

The Nicola Group is divided into five units based on predominant lithology, without implication of relative age. There is very little continuity of any unit in the area and given the limitations of exposure and traverse density, the nature of most of their contacts remains uncertain. Lava flows (NF) are most abundant in the western half of the area; they are predominantly plagioclase-phyric andesites. Phenocrysts reach 2 centimetres or more in length and constitute up to 30 per cent of flow rocks. Fresh augite phenocrysts are present in places, particularly around Revelle Lake and Saxon Lake but are generally much subordinate or absent; a few samples contain hornblende phenocrysts. Most flows contain less than 5 per cent amygdules; where present these are filled with quartz, chlorite and/or calcite. Flow contacts are generally not visible; a few flows interbedded with breccia are 2 to 10 metres thick. Flows are in part intercalated with monolithologic flow or pyroclastic breccias, from which they are difficult to distinguish in the field.

Fragmental volcanic rocks are predominant in the Nicola Group. Breccias and tuffs (NB) are of similar composition to flows, and are distinguished from definite epivolcaniclastic rocks (NC) by their monolithologic character, coupled with the absence of layering or rounding of fragments. Some of the breccias contain abundant aphanitic chips, now converted to dark green chlorite, that resemble hyaloclastite, and many breccias may be epiclastic debris flows with a relatively homogeneous source. Agglomerate (NBA) *sensu stricto* is of mappable thickness only south of Dartt Lake, where it contains maroon scoriaceous, rounded and spindle bombs in a calcite-rich lapilli-tuff matrix. Most of the volcanoclastic rocks are probably laharic deposits. They are heterolithic, containing a variety of andesitic and in places more felsic clasts, massive and unsorted, angular to subrounded, with modal fragment size varying from less than 1 centimetre to 5 centimetres. In a few places the finer facies are well layered and show features of turbidite wackes. Distinctly felsic rocks are generally subordinate to the intermediate volcaniclastic. Laharic breccias in the southwest part of the area consist predominantly of quartz-feldspar-phyric fragments, and a lenticular rhyolite or dacite welded tuff (NTW) north of Dartt Lake is at least 500 metres thick.

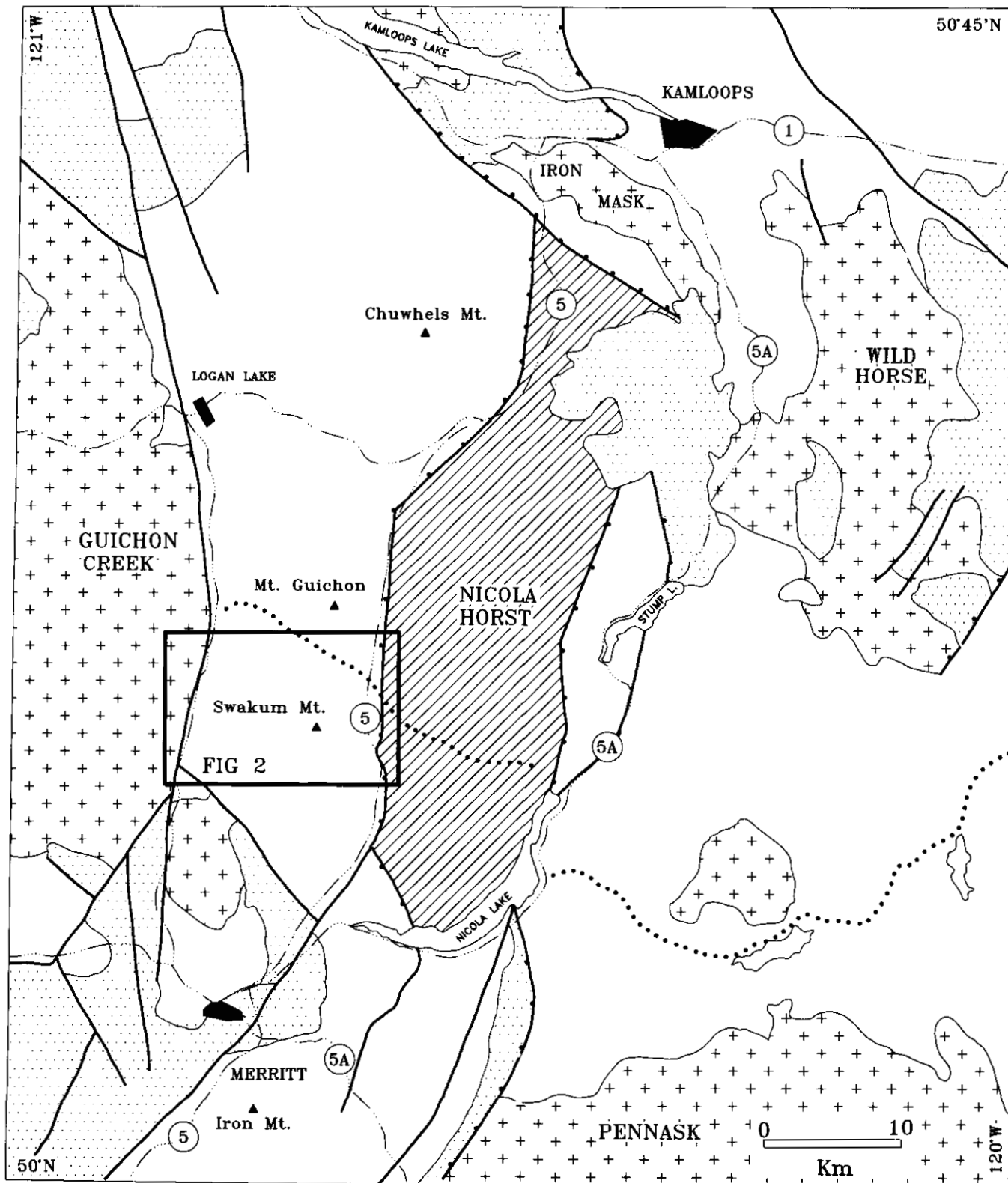


Figure 1-7-1. Location and access map of the Swakum Mountain area. Nicola Group and minor pre-Nicola stratified rocks are unpatterned; undifferentiated igneous and metamorphic rocks of the Nicola horst are hatched. Crosses: Late Triassic-Jurassic plutons, with names of batholiths. Stipple: post-Nicola volcanic and sedimentary rocks. Heavy lines are faults, with dots on downthrown side. Main roads and LITHOPROBE transect are also shown.

LEGEND

LITHOLOGY

QUATERNARY

Q Glacial, fluvio-glacial and fluvial gravel, sand and clay

TERTIARY

Miocene (?)

TB Olivine basalt flows with ultramafic inclusions

Eocene (Kamloops Group) (?)

KR Flow-laminated rhyolite flow rocks and breccia or dome

EARLY TO MIDDLE JURASSIC

Ashcroft Formation (?)

AC Polymict boulder conglomerate (V: volcanic clasts; P: plutonic and volcanic clasts); subordinate sandstone

AS Sandstone; pebble conglomerate

AL Limestone; subordinate siltstone interbeds

LATE TRIASSIC AND YOUNGER (?)

Intrusive Rocks

G Biotite granite with K-feldspar megacrysts (Rey Lake)

D Diorite: subvolcanic (?) bodies in Nicola Group

LATE TRIASSIC

Nicola Group (Western Belt)

NL Limestone; polymict volcanic conglomerate with abundant limestone clasts

NT Dacite or rhyolite tuff, tuff-breccia (W: welded)

NC Heterolithic andesite-dacite laharic breccia; wacke

NB Monolithic andesite breccia, tuff (A: agglomerate)

NF Andesite and basalt flows, flow breccia

TRIASSIC, JURASSIC (AND OLDER ?)

NH Undifferentiated metamorphic and plutonic rocks of the Nicola Horst

SYMBOLS

- Lithologic contact (defined, inferred)
- Fault (defined, inferred; dots on downthrown side)
- Topographic lineament
- Strike and dip of bedding (inclined, vertical)
- Extent of skarn alteration

Mountain peak

Main road, highway

Lakes:	DL	Dartt	Former Mines:	A	Old Alameda
	EL	Eve		B	Bernice
	HL	Helmer		C	Corona
	REL	Revelle		L	Lucky Mike
	RYL	Rey		S	Sunshine
	SOL	Sophia		T	Thelma
	SXL	Saxon			

Figure 1-7-2a. Legend for Figure 1-7-1 and 2.

Thin grey limestone lenses (NL) are a minor but distinctive part of the Nicola succession. The greatest thickness mapped, in the southeast corner of the area, is 100 metres. More typically, limy units consist of intercalated limestone up to a few metres thick and heterolithic volcanic breccia conglomerate, with limestone clasts up to metre-scale. The limestone is invariably bioclastic, containing in places well-preserved molluscs and coral fragments. One such layer, east of the Lucky Mike deposit, is hematitic with large coral heads, and resembles the red reefoid limestone mapped on Iron Mountain south of Merritt (McMillan, 1981).

All the Nicola volcanic rocks have fine-grained or aphanitic matrices with abundant chlorite and epidote; biotite and amphibole are not evident in hand specimen. An exception is the skarn alteration zone, approximately delineated in Figure 1-7-2, where limestone is converted to coarse pyroxene-garnet rock and volcanic facies to fine-grained magnetite-bearing epidote amphibolite, locally with garnet and pyroxene(?). At numerous localities within and beyond the skarn zone, the volcanic rocks are altered to rusty weathering carbonate-rich rocks containing fine ankerite and pyrite, with or without calcite. Generally these are elongate and associated with northerly trending topographic lineaments; the zone at Corona (Figure 1-7-2) is 600 metres long and up to 50 metres wide. Where carbonate alteration occurs within the skarn zone, magnetite is generally absent and appears to have been converted to pyrite.

The Nicola rocks are intruded by small bodies of augite or hornblende diorite (D) and, near Rey Lake, by coarse biotite granite (G). The diorite is massive, medium to coarse and magnetite bearing. Near Revelle Lake numerous small carbonate alteration zones occur near diorite bodies that generally appear less altered than the enclosing rocks. The granite is coarse and massive with subhedral quartz and potassic feldspar megacrysts. It resembles the Paleocene granite of the Nicola horst to the east (Moore, 1989) and has yielded a Paleocene K-Ar date of 68.9 ± 2.5 Ma (Preto *et al.*, 1979). In the light of early Tertiary K-Ar dating of Mesozoic plutonic rocks elsewhere in the region in and around the Nicola horst (see, for example, the isotopic age data in Monger and McMillan, 1984) this figure may not represent the age of intrusion. Granite dikes, that are similar to the Rey Lake

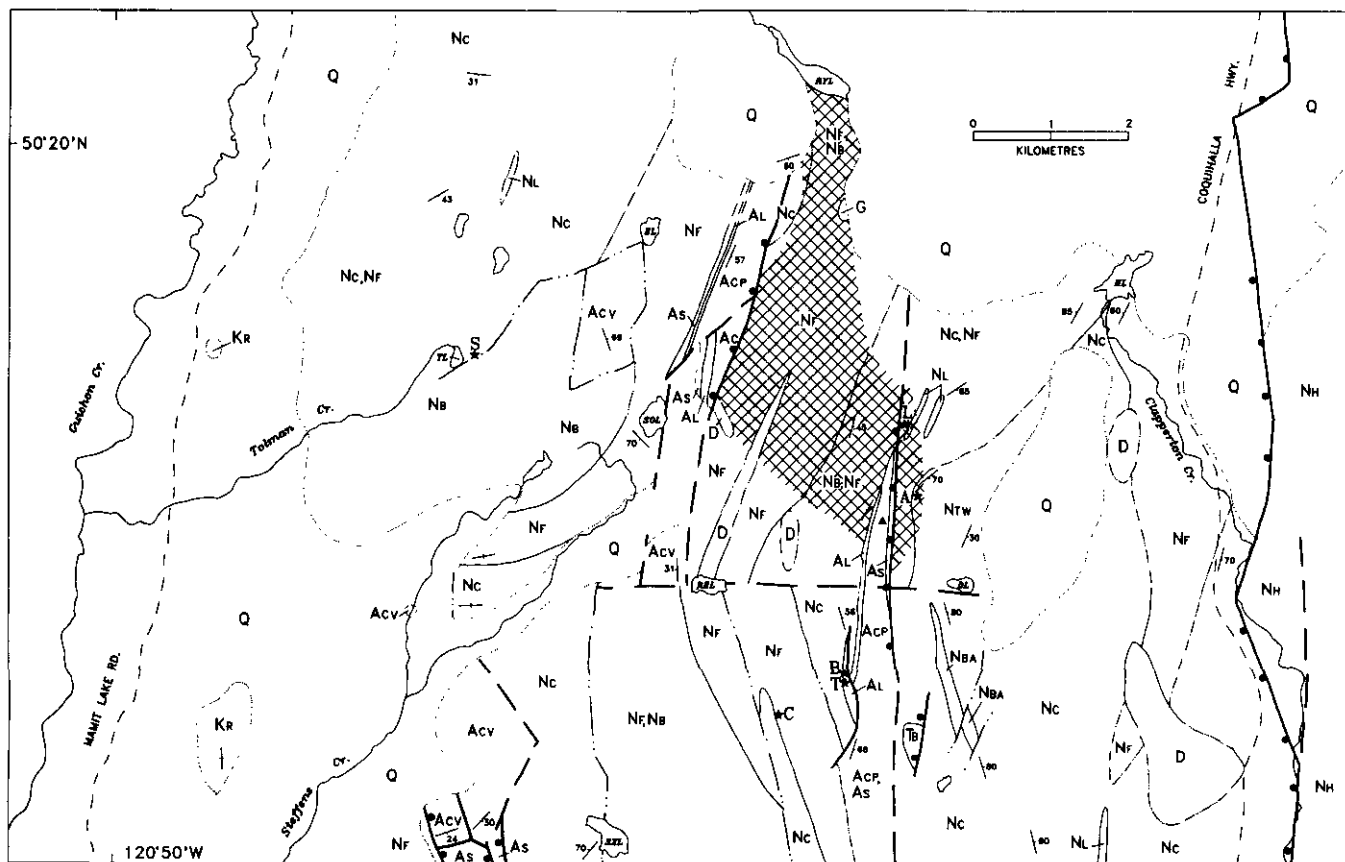


Figure 1-7-2. Geology of the Swakum Mountain area. For legend see Figure 1-7-2a.

granite but less coarse and more distinctly porphyritic, are seen cutting skarn in drill core at Rey Lake, and in outcrop at the northwest corner of the map area, where the host breccias are not conspicuously altered.

Clastic and carbonate rocks previously included in the Nicola Group, that occur in at least three and probably five separate locales in the map area, are tentatively correlated with the Early to Middle Jurassic Ashcroft Formation. The most striking examples are two steeply dipping, fault-bounded slices that extend through the crest of Swakum Mountain and northward from Sophia Lake. These contain similar successions that pass eastward and upward from limestone (AL) with thin pebbly, sandy and silty layers to thick, massive to weakly stratified coarse boulder conglomerate (AC) containing poorly sorted, but rounded to well-rounded clasts in a dark green matrix with abundant volcanic plagioclase. Clasts comprise mainly porphyritic intermediate and felsic volcanic rocks, with medium-grained diorite and biotite granite that locally predominate, and minor sedimentary rocks. The succession on Swakum Mountain is topped by up to 80 metres of uniform, siliceous, pyritic sandstone (AS). The stratigraphy as a whole is distinct from that of the adjacent Nicola rocks by virtue of its relative continuity. The limestones contain fine to coarse fossil debris like the Nicola limestone, but in contrast they weather buff and are consistently fetid, whereas the Nicola carbonates are rarely so. Conglomerate clasts are notably more rounded, coarser and the matrix less lithified than in typical coarse Nicola clastics;

although some epidote is present the clastic plagioclase is milky white rather than grey or green as in the Nicola rocks. Many of the more felsic volcanic clasts appear less altered than typical Nicola rocks. The presence of plutonic rocks is also distinctive, as are abundant chert pebbles and sand in some layers. Altogether the conglomerate and finer clastics resemble those of the "Clapperton conglomerates" that occur to the south near Merritt (Cockfield, 1948; McMillan, 1981), that have been assigned to the Jurassic Ashcroft Formation by Monger and McMillan (1984). It is evident from Figure 1-7-2 that the skarn alteration of Nicola carbonate volcanic rocks around Swakum Mountain does not affect the immediately adjacent carbonate-clastic successions, indicating that they are younger than the alteration event.

In the extreme southwest corner of the area, west of Saxon Lake, is a fault-bounded succession of mainly coarse clastic rocks that resemble those on Swakum Mountain except that they are easterly striking, contain no plutonic clasts and have abundant coarse fossil debris in the matrix. At one locality they rest on hornblende-phyric (dacite?) flows and are inter-layered with and succeeded by volcanic sandstone, also bioclastic, fining upward to black siltstone with minor limestone. One fault block at this locality contains distinctive grey felsic welded tuff and breccia and hornblende dacite(?), with a conformable layer of the volcanic sandstone. Near Revelle Lake and Eve Lake are coarse volcanic conglomerate and sandstone that resemble the Saxon Lake rocks, but lack the finer facies or carbonate rocks.

The Ashcroft succession has been intruded by a few augite-phyric mafic dikes west of Saxon Lake. At Sophia Lake and Swakum Mountain, distinctive dikes of tan-weathering, coarse quartz feldspar porphyry cut sandstone and conglomerate.

Tertiary volcanic rocks, also unrecognized before the present work, are of minor extent. They include a small outlier of olivine basalt south of Dartt Lake and two isolated exposures of rhyolite near Guichon Creek, at the western margin of the area. The basalt is downfaulted against Nicola volcanoclastics to the east; it is at least 30 metres thick and minor variations suggest the presence of several flows. Although no flow contacts are recognized, flow features indicate a moderate easterly dip. Some flows contain peridotite nodules a few centimetres across, similar to those seen in basalt mapped as Miocene north of Lac Le Jeune (Monger and McMillan, 1984). The rhyolite is best exposed on ridges near the southwest corner of the area where it is grey, strongly flow-laminated and contains open lithophysae up to 3 centimetres in diameter. The lamination is steeply-inclined and the rock is locally brecciated. As contacts are not exposed it is not possible to state whether the rocks are flows or a dome.

Areas largely underlain by unconsolidated Quaternary cover occupy all major depressions as well as the flanks and down-ice ends of ridges and mountains.

STRATIGRAPHY AND STRUCTURE

Nicola Group rocks in the area mostly strike northerly and dip steeply (Figure 1-7-2); scarce bedding indicators show that the beds dip predominantly toward the east and are upright. As a whole they are bounded on the east and west by major fault systems that occupy the valleys of Clapperton Creek and Guichon Creek, respectively (Monger and McMillan, 1984; Moore, 1989). The Clapperton fault system appears to be normal, with a net dip-slip of at least several kilometres, in order to have exhumed the relatively deep-seated rocks seen in the Nicola horst. The west-northwest trending linear valley containing Rey Lake, at the north side of the map area, may also contain a major break, as the Nicola Group on Mount Guichon to the north includes well-bedded wackes and coarse laharic deposits without close counterparts along strike to the south; poor exposure on the south flank of the mountain and in the valley precludes a definite conclusion.

The lack of continuity or consistent succession within the Nicola Group suggest strongly that the stratigraphy has been broken into a large number of easterly tilted fault blocks, of unknown sense and displacement, hence an estimate of total thickness is not possible. In the study area there is a predominance of flows west of Swakum Mountain and volcanoclastic rocks to the east. However carbonates and thick felsic units occur to both sides. Most of the units south of a line through Revelle and Dartt lakes have a north-northwest trend, whereas those to the north strike north-northeast. There is also a lack of continuity in at least some of the units, notably near Dartt Lake, that reinforces the proposal of an easterly striking fault along this line. There is, however, sufficient similarity between the units to the north and south to preclude

the drawing of a lithologic boundary in this vicinity, such as shown by Monger and McMillan (1984).

The Ashcroft rocks at Swakum peak and Sophia Lake strike northerly and dip moderately to steeply east. On their west sides the successions contain thin, immature clastic layers near the base that include fragments of Nicola volcanic rocks; these, and scarce top indicators, indicate eastward facing of the succession and suggest that the western contact may be an unconformity. As the conglomerate and sandstone are succeeded structurally to the east by Nicola rocks, they must be downfaulted against them on the east, thus the successions lie in east-facing half-grabens. Relationships at the Thelma and Bernice properties (Figure 1-7-2) indicate the limestone is repeated by normal faulting. Faulting across the main graben structure is also required to juxtapose the thick limestone segments with the sandstone/thin limestone/conglomerate sequence north of Sophia Lake. The clastic rocks west of Saxon Lake occupy a small graben enclosed by Nicola rocks; it is plausible that the other occurrences described are in a similar setting, and the one at Revelle Lake may occupy a southerly extension of the same structure that contains the Sophia Lake succession. The similarity of the Swakum and Sophia Lake stratigraphy demands correlation and suggests that they are parts of the same succession, dismembered by extensional faulting. It should be emphasized that this interpretation is distinct from that put forth by Cockfield (1948, pages 59-60) and commonly quoted in subsequent exploration reports. He inferred that the limestones of Swakum Mountain and Sophia Lake, all of which he assigned to the Nicola Group, occupy the limbs of an asymmetric, southerly plunging anticline. The lack of continuity between these localities, coupled with the similar facing of the succession at each, does not support Cockfield's hypothesis. The differences between these and the other three occurrences, given their close proximity, argue that they are not simply lateral correlatives, but are of different age and may represent a different formation. It is possible, for example, that one correlates with the Cretaceous Spence's Bridge Group. Paleontology may answer this question.

The Ashcroft succession on Swakum Mountain lies on a variety of Nicola rocks and is not displaced across the proposed fault between Revelle and Dartt lakes, indicating that it was deposited on a relatively flat erosion surface that postdates some of the deformation of the Nicola Group. Its less altered character, particularly the absence of skarn development adjacent to strongly altered Nicola rocks, also demonstrates a significant time gap between the two successions.

The occurrence of felsic tuff and flow rocks in conformable contact with the volcanoclastic rocks west of Saxon Lake, the general presence of euhedral clastic feldspar in all the Ashcroft rocks, and the relatively fresh appearance of some of the volcanic clasts, all indicate the existence of volcanic activity contemporaneous with clastic sedimentation in post-Nicola, possibly Early to Middle Jurassic time.

The Tertiary volcanic rocks also appear to occupy tilted fault blocks; flow lamination in the rhyolite may be in a steep primary orientation, but more probably has been rotated on a Tertiary fault separating the Guichon Creek batholith from the Nicola Group.

DEPOSITIONAL ENVIRONMENTS

Some Nicola volcanic features, such as red agglomerates and rounded clasts in debris flows, are clearly indicative of subaerial processes. The scarcity of well-defined bedding in the volcanoclastic rocks and the prevalence of massive, ill-sorted deposits implies they are subaerial lahars. Other criteria, such as the presence of reefoid limestone and hyaloclastite, demonstrate subaqueous deposition, as does the low incidence of oxidized, ropy or brecciated flow tops. All of these features are consistent with a transitional subaerial to shallow submarine environment, characterized by tectonic instability and ephemeral shorelines. At least some lahars flowed into the sea, burying patch reefs and carrying shore-worked debris with them. Synvolcanic faulting must have been an important control on deposition and may explain the abrupt termination of some units, such as the welded tuffs north of Dartt Lake. It would also permit the accumulation of relatively thick successions of subaerial and shallow subaqueous rocks. A similar scenario is indicated by the Western Belt succession on Iron Mountain near Merritt, mapped by McMillan (1981), and was also envisioned by Preto (1979) for Nicola rocks to the south and east of the present area.

The strata assigned to the Ashcroft Formation also present evidence of a transition, upward in the succession, from a submarine to a subaerial environment, accompanied by a substantial increase of relief in the source area. The continuity of succession over at least two separate blocks, as well as the occurrence of sandstone adjacent to the fault on Swakum Mountain, suggest that sedimentation was not related to the present boundary faults. The tabular character and continuity of the finer units suggest deposition on a well-established, stable erosion surface, and the composition of the conglomerate clasts indicates unroofing of at least some (synvolcanic?) plutons. The structures in the conglomerate are consistent with high-energy fluvial deposition; although this environment cannot be conclusively established in the map area, high-angle planar crossbeds seen in similar Ashcroft sandstones to the south, near Merritt, are supportive.

METALLOGENIC IMPLICATIONS

Since the discovery of the Lucky Mike deposit in 1918, the Swakum area has been recognized as a mining camp that has yielded small but significant quantities of base and precious metals (Cockfield, 1948). Although none of the early discoveries remain in production, exploration is active to the present day. There are two principal deposit types, both polymetallic: copper-bearing skarns within the alteration zone shown on Figure 1-7-2 and lead-zinc-copper-silver-gold quartz-stockwork veins associated with iron-rich carbonate alteration zones, both within and outside the skarn zone. The former type is exemplified by the Lucky Mike, where copper is accompanied by subordinate tungsten, silver, gold, lead and zinc. Old Alameda and the other deposits shown on Figure 1-7-2 are of the latter type.

Pending a fuller account of these deposits, to be given in a later publication, a few important conclusions may be drawn.

Field relationships described above show that the skarn alteration predates the Ashcroft sedimentary rocks. Similar reasoning indicates that the granite near Rey Lake, despite its spatial association with skarn, is also later than the alteration. In the absence of direct evidence, it may be suggested that an unexposed intrusive body is responsible for the alteration zone.

In contrast, the carbonate alteration and associated mineralization are younger than the Ashcroft limestone at the Thelma and Bernice properties and also north of Swakum peak, where limestone is mineralized and, together with Nicola rocks and post-Ashcroft porphyry, silicified and altered to iron carbonate. Dating the sedimentary rocks is required to place an upper limit on the age of this mineralizing event, but it is clearly younger and distinct from skarn formation.

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