GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA

PAPER 79-30



# THE PALEOZOIC SICKER GROUP OF VANCOUVER ISLAND, BRITISH COLUMBIA

J.E.MULLER

Energy, Mines and Resources Canada
Énergie, Mines et Ressources Canada

1980

**CORRECTION TO GSC PAPER 79-30**

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(Corrections requested by the author to the Résumé were inadvertently omitted from the published copy, the corrected version follows)


### *Abstract*

*The Sicker Group encompasses the entire sequence of Paleozoic volcanic and sedimentary rocks of Vancouver Island. It is exposed below its Mesozoic cover in three structural culminations: The Buttle Lake Uplift, the Cowichan-Horne Lake Uplift and the Nanoose Uplift. In this paper a new lower Nitinat Formation and a new middle Myra Formation with overlying informally named Sediment-Sill Unit are introduced. The overlying Buttle Lake Formation forms the upper part of the group. The Nitinat Formation, only exposed in the Cowichan-Horne Lake Uplift, is composed of dark, basic agglomeratic, locally pillowed lava, breccia and tuff with distinctive large phenocrysts of uralitized pyroxene. The Myra Formation contains interbedded massive and well bedded cherty tuff and commonly variegated maroon-and-green breccia in its lower part and alternating thinly laminated to thick bedded and massive black argillite and light coloured rhyodacite tuff and breccia. Porphyritic, partly intrusive rhyodacite, named Tyee Quartz Feldspar Porphyry, is an important component of the Myra Formation in the southeastern part of the Cowichan-Horne Lake Uplift. In the Buttle Lake Uplift quartz porphyry, rhyodacite and (?) rhyolite and associated breccia are the ore-bearing zones carrying the polymetallic (Cu-Zn-Pb-Cd-Ag-Au) sulphides being mined by Western Mines Ltd. The Saltspring Stock of south Saltspring Island and of Maple Mountain on Vancouver Island is a small intrusive body of sheared and altered granodiorite that appears to be related to the quartz-feldspar prophyry of the Myra Formation. Zircon U/Pb age determinations of quartz porphyry and rhyodacite yield a least-squares-fitted chord on the concordia plot with upper intercept of earliest Silurian 440 Ma age and determinations of the granodiorite yield an upper intercept of Early Devonian 386 Ma age. Alternatively, combined ages of porphyry, rhyodacite and granodiorite yield a chord with upper intercept of Early Devonian 410 Ma if a lower intercept of 180 Ma is used, similar to the metamorphic age of 180 Ma, obtained with K-Ar dating of sericite from the sericitic quartz prophyry sample. The Sediment-Sill Unit is composed of thinly bedded silicified argillite and greywacke, interleaved with thick sills of, commonly plagiophyric, diabase that may be related to the basalt of the younger, Triassic Karmutsen Formation. The Buttle Lake Formation is composed of crinoidal and calcarenitic limestone with chert lenses, interbedded with varying proportions of siltstone and argillite. It carries Middle Pennsylvanian fusulinids together with brachiopods and bryozoans that have been variously determined as indicating Pennsylvanian or Permian age. The structure of the Sicker Group shows commonly southwesterly verging, large- and small-scale asymmetric, overturned, and isoclinal folds. In steep and overturned limbs of folds the rocks are commonly highly sheared and metamorphosed to chlorite-actinolite and chlorite-sericite schist. Polymetallic ore deposits of the exhalite type in the Myra Formation are being mined in the Buttle Lake Uplift by Western Mines Ltd. and were formerly mined in the Mount Sicker area of the Cowichan-Horne Lake Uplift. Similar deposits may yet be found.*



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*Le groupe de Sicker comprend toute la séquence de roches volcaniques et sédimentaires du Paléozoïque de l'île Vancouver. Les roches affleurent en trois zônes structurales élevées, soit les soulèvements de Buttle Lake, Cowichan-Horne et Nanoose. L'auteur introduit ici la nouvelle formation inférieure de Nitinat et la formation médiane de Myra ainsi que l'unité sus-jacente, temporairement nommée unité Sediment-Sill. La formation sus-jacente de Buttle Lake forme la parti supérieure du groupe. La formation de Nitinat affleure seulement dans le soulèvement de Cowichan-Horne Lake, est constituée de laves foncées en agglomérats basiques, par endroits de laves en coussins, de brèches et de tufs caractérisés par de gros phénocrystaux de pyroxène uralitisé. La formation de Myra contient des tufs massifs alternant avec des tufs cherteux bien lités et des brèches de couleurs maron et vert communément bigarrées dans sa partie inférieure, ainsi que de l'argilite noire massive en couches épaisses alternant avec de la rhyodacite de couleur claire. La rhyodacite porphyrique partiellement intrusive, appelée porphyre quartzo-feldspathique Tyee, est un élément important de la formation de Myra dans la partie sud-est du soulèvement de Cowichan-Horne Lake. Dans le soulèvement de Buttle Lake, le porphyre quartzeux, la rhyodacite et la (?) rhyolite, ainsi que les brèches connexes, constituent les zones minéralifères à sulfures polymétalliques (Cu-Zn-Pb-Cd-Ag-Au) exploitées par la Western Mines Ltd. Le massif de Saltspring, situé dans le sud de l'île Saltspring et dans le mont Maple de l'île Vancouver, est un petit massif intrusif de grano-diorite fracturée et altérée qui semble associée au porphyre quartzo-feldspathique de la formation de Myra. Les datations au zircon U/Pb du porphyre quartzeux et de la rhyodacite donnent une courbe, établie par la méthode des moindres carrés, sur le graphique des âges, dont la limite supérieure indique 440 Ma, au tout début du Silurien; les datations de la grano-diorite indique une limite supérieure de 386 Ma, soit le Dévonien inférieur. Par contre, les âges combinés du porphyre, de la ryodacite et de la grano-diorite tracent une courbe dont la limite supérieure est de 410 Ma ou le début du Dévonien, si l'on utilise pour limite inférieure 180 millions d'années, obtenu par datation au K/Ar de la séricite de l'échantillon de porphyre quartzo-séricitique. L'unité Sediment-Sill est composée de minces couches d'argilite silicifiée et de grauwacke, entrecoupées d'épais filons-couches de diabase habituellement plagiophyrique, que l'on peut associer au basalte de la formation plus récente de Karmutsen, datant du Trias. La formation de Buttle Lake est constituée de calcaire à crinoïdes et calcarénitique et de lentilles de chert, disposés en alternance avec des lits de siltstone et d'argilite de diverses épaisseurs. Cette formation contient des fusulinidés du Pennsylvanien moyen ainsi que des brachiopodes et des bryozoaires qui pourraient être du Pennsylvanien ou du Permien. La structure du groupe de Sicker montre des plis isoclinaux renversés et asymétriques à petite et grande échelles, ordinairement se déversant vers le sud-ouest. Sur les flancs à pendage rapide et renversés des plis, les roches sont généralement très cisaillées et métamorphisées en schiste chloro-actinotique ou chloro-séricitique. Les gisements polymétalliques de type exhalatifs de la formation de Myra sont présentement exploités dans le soulèvement de Buttle Lake par la Western Mines Ltd.; autrefois, on a exploité ceux de la région du mont Sicker du soulèvement de Cowichan-Horne Lake. Il est possible que l'on découvre d'autres gisements semblables.*

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Available in Canada through

authorized bookstore agents
and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Hull, Québec, Canada K1A 0S9

and from

Geological Survey of Canada
601 Booth Street
Ottawa, Canada K1A 0E8

A deposit copy of this publication is also available
for reference in public libraries across Canada

Cat. No. M44-79/30E Canada: $3.50
ISBN 0-660-10606-X Other countries: $4.20

Price subject to change without notice

**Critical Reader**

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*Original manuscript received: 1979 - 06 - 07*
*Approved for publication: 1979 - 07 - 25*

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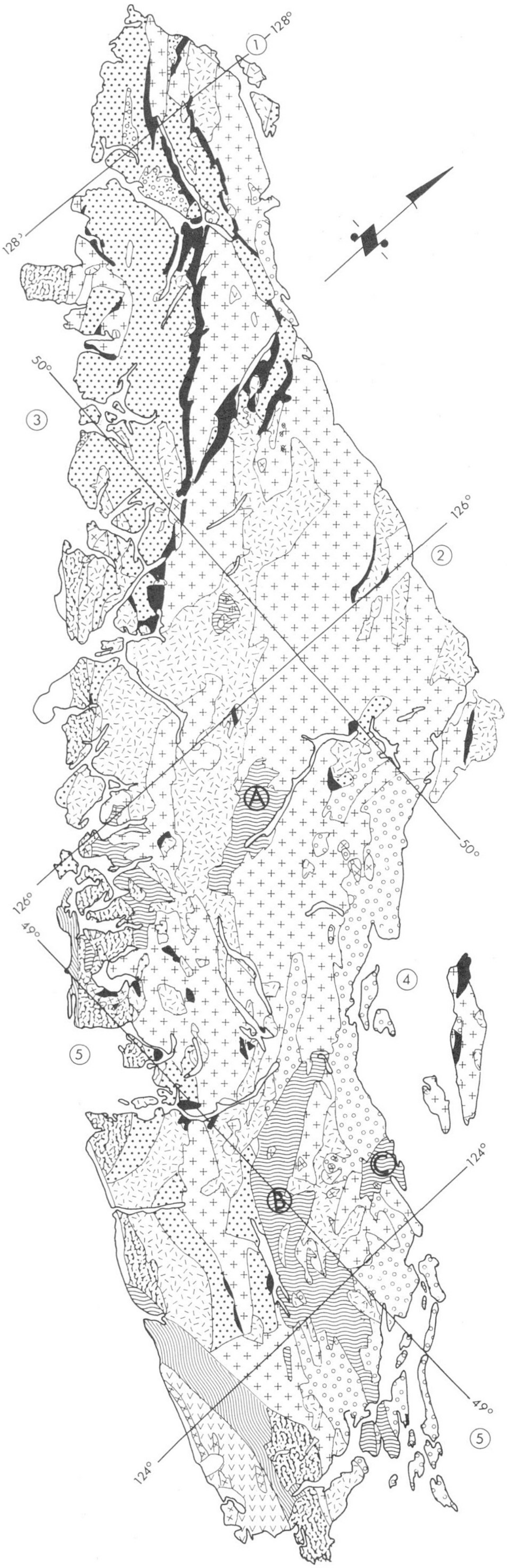


*Figure 1.*

*Geological sketch map of Vancouver Island.*

## LEGEND

| | | |
|---|---|---|
| CARMANAH GROUP | | MIDDLE TERTIARY |
| CATFACE INTRUSIONS | | EARLY TO MIDDLE TERTIARY |
| METCHOSIN VOLCANICS | | EARLY TERTIARY |
| NANAIMO GROUP | | LATE CRETACEOUS |
| QUEEN CHARLOTTE GROUP<br>KYUQUOT GROUP | | LATE JURASSIC TO EARLY CRETACEOUS |
| LEECH RIVER FORMATION<br>PACIFIC RIM COMPLEX | | |
| ISLAND INTRUSIONS | | EARLY AND (?) MIDDLE JURASSIC |
| BONANZA GROUP | | EARLY JURASSIC |
| VANCOUVER GROUP | PARSON BAY FORMATION<br>QUATSINO FORMATION | LATE AND (?) MIDDLE TRIASSIC |
| | KARMUTSEN FORMATION | |
| SICKER GROUP | | PALEOZOIC |
| METAMORPHIC COMPLEXES | | JURASSIC AND OLDER |

① ALERT BAY – CAPE SCOTT, 92 L – 102 I (G.S.C. PAPER 74–8)

② BUTE INLET, 92 K (IN PREPARATION), O.P. MAP 345

③ NOOTKA SOUND, 92 E (IN PREPARATION)

④ ALBERNI 92 F (G.S.C. PAPER 68–50)

⑤ VICTORIA, 92 B, C (FIELD WORK IN PROGRESS: SEE G.S.C. PAPERS 75–1A, p. 21–26: 76–1A, p. 107–111, 77–1A, p. 287–294.)

A — BUTTLE LAKE UPLIFT

B — COWICHAN – HORNE LAKE UPLIFT

C — NANOOSE UPLIFT

MILES

0 20 40

# THE MIDDLE TO LATE PALEOZOIC SICKER GROUP OF VANCOUVER ISLAND, BRITISH COLUMBIA

## INTRODUCTION

The Sicker Group, named after Mount Sicker near Duncan (Clapp, 1912) includes the entire Paleozoic rock sequence of Vancouver Island. It is composed mainly of basic and silicic volcanic rocks and less abundant clastic and carbonate rocks that have been affected by all phases of the complex history of deformation and metamorphism on the island. Economically it is important as the host rock to the polymetallic massive sulphide deposits of Western Mines, on Myra Creek west of Buttle Lake, and smaller past producers near Mount Sicker.

In 1977 and 1978 the writer carried out detailed studies designed to obtain a better knowledge of this economically and geologically significant rock group. The project was greatly enhanced by the greatly expanded network of logging roads in the Cameron and Nitinat valley systems, providing much better access and exposure than were available during geological reconnaissance work about 15 years ago (Muller and Carson, 1969). This paper is a progress report that summarizes the writer's and previous work. It is hoped that current detailed exploration and drilling by various mining companies will add substantially to the still imperfect understanding of this important major group of formations.

### *Acknowledgments*

Zircon-datings of the Tyee Quartz Porphyry and the Saltspring Stock by R.K. Wanless and the Geochronological Laboratories of the Geological Survey have provided much improved understanding of the age relationships of the Sicker Group.

Discussions with many exploration geologists regarding general and economic geology of these rocks have been helpful in supplying additional data and interpretations. In that regard management and staff geologists of Western Mines Limited, the only metal producer in the subject region, have been especially forthcoming with detailed information.

Managers and forest engineers of logging divisions of MacMillan Bloedel Ltd., Crown Zellerbach Ltd., Pacific Logging, and British Columbia Forest Products Ltd. have generously allowed access to logging areas and supplied the necessary and invaluable logging road maps.

### *Previous work*

Clapp, in the first geological reconnaissance of southern Vancouver Island (1912), recognized and named the Sicker Series and noted its special importance as "the country rock of various copper deposits, the largest and best known of which is the Tyee ore body, now largely worked out". His lithological descriptions of Sicker metavolcanics and metasediments (Clapp, 1912; Clapp and Cooke, 1917) leave no doubt about the correlation of these rocks with those mapped by the writer, but his sketchy geological maps reflect the difficulty of access at that time and the necessarily cursory nature of his reconnaissance work. He was uncertain of the relationship of Sicker Series to Vancouver Volcanics (= Upper Triassic Karmutsen Formation) but deemed them, erroneously, to be the younger of the two.

Gunning (1931) made a reconnaissance of Buttle Lake area and recognized a thick series of andesitic to basaltic flows, tuffs and coarse volcanic breccias with (as he thought) interbedded limestone and minor amounts of argillite and quartzite. Fossils, mainly bryozoa and minor brachiopods, from the "uppermost horizon of limestone" indicated Permian, or perhaps Pennsylvanian age. Gunning described the copper-zinc-lead deposits on Myra Creek, now being mined by Western Mines Ltd., and properly placed the Vancouver Group stratigraphically above the Sicker Group (although he did not use the latter name), a relationship readily apparent in Buttle Lake area.

More detailed mapping was carried out by Fyles (1955) in the area north of Cowichan Lake. He distinguished in the Sicker Group a medial "marker", composed of 200 m of thin bedded, cherty tuff and tuffaceous greywacke bounding an underlying sequence, about 1300 m thick, of massive green volcanics with minor flows. He also reported limestone with Permian fossils in the upper part of the group.

The writer has mapped the Sicker Group in all parts of Vancouver Island (Muller and Carson, 1969, Muller et al., 1974; see Fig. 1) and in earlier publications has divided it into a lower volcanic, a middle greywacke-argillite, and an upper limestone formation. The upper sedimentary formations have yielded Pennsylvanian and Permian fossils. However, granitoid rocks and related schistose quartz porphyry that intrude some Sicker rocks contain zircon crystals that indicate Devonian or older U/Pb ages.

## GENERAL DISTRIBUTION AND SUBDIVISIONS

The Sicker Group is exposed in three separate structural culminations, from west to east: the Buttle Lake Uplift, the Cowichan-Horne Lake Uplift and the Nanoose Uplift (Fig. 1). The Cowichan-Horne Lake Uplift exhibits the most complete stratigraphy of Sicker rocks, from Horne Lake in the northwest of Saltspring Island and the American San Juan Islands in the southeast (Fig. 2,3). A tripartite subdivision of the Sicker Group used informally in earlier publications (e.g. Fyles, 1955; Muller and Carson, 1969), consists of a lower volclanic unit, a middle clastic sedimentary unit, and an upper unit, the Buttle Lake (limestone) Formation. The following subdivision is now proposed, in order of increasing age:

<u>Buttle Lake Formation</u> (old name): limestone, calcarenitic, crinoidal, commonly recrystallized; interbedded with subordinate or equal thicknesses of calcareous siltstone and chert; some diabase sills
<u>Sediment-Sill Unit</u> (not a formational name): thinly bedded to massive argillite, siltsone and chert with interlayered sills of diabase
<u>Myra Formation</u> (new name): basic to rhyodacitic banded tuff, breccia and (?) lava; thinly bedded to massive argillite, siltstone, chert
<u>Nitinat Formation</u> (new name): metabasaltic lavas, pillowed or agglomeratic, commonly with large conspicuous uralitized pyroxene phenocrysts and amygdules of quartz and dark green minerals; minor massive to banded tuff.

The Sediment-Sill Unit is transitional between the Myra and Buttle Lake formations and may or may not be useful as a separate formation when better field correlations can be made.

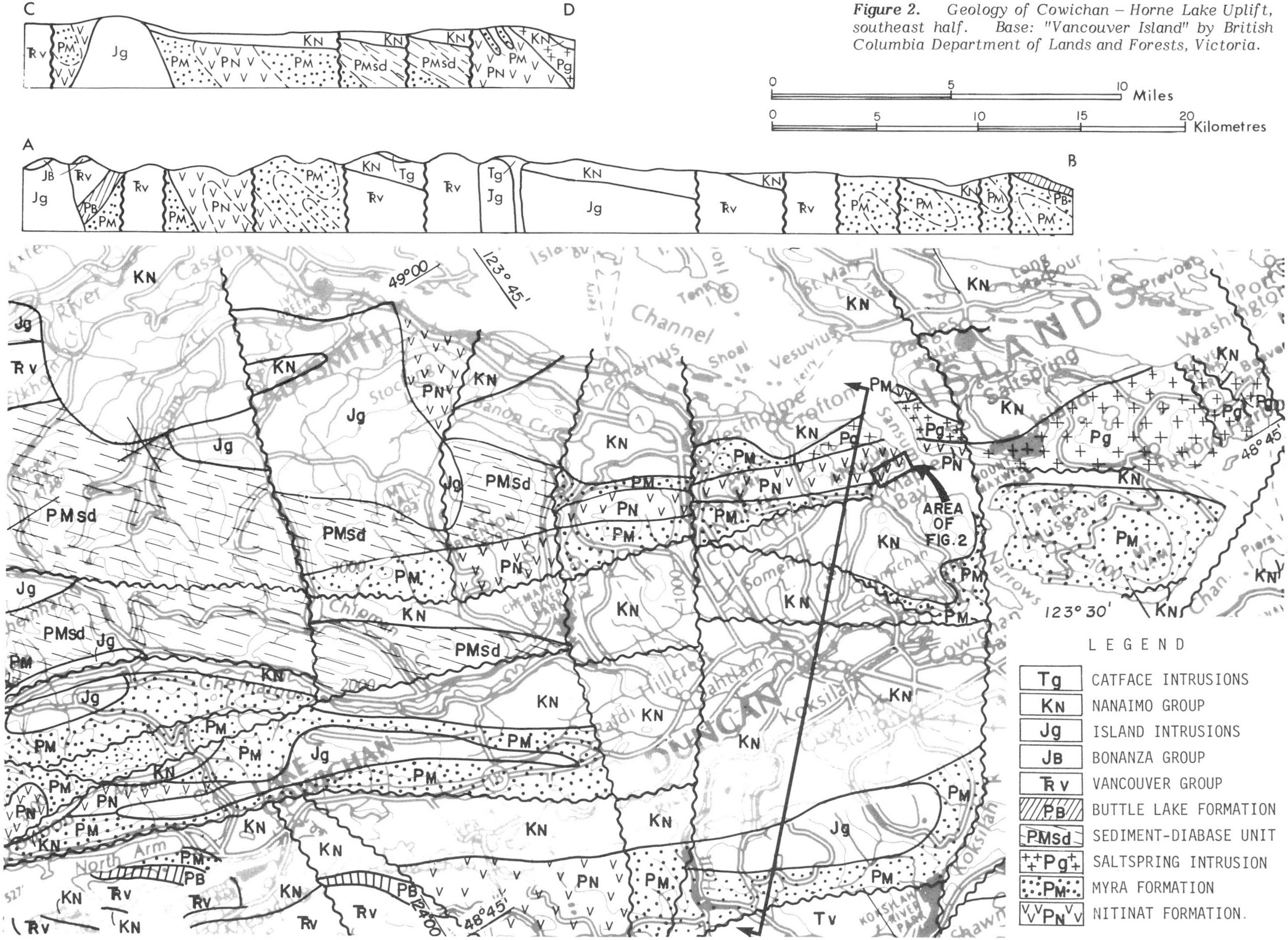


**Figure 2.** *Geology of Cowichan – Horne Lake Uplift, southeast half. Base: "Vancouver Island" by British Columbia Department of Lands and Forests, Victoria.*

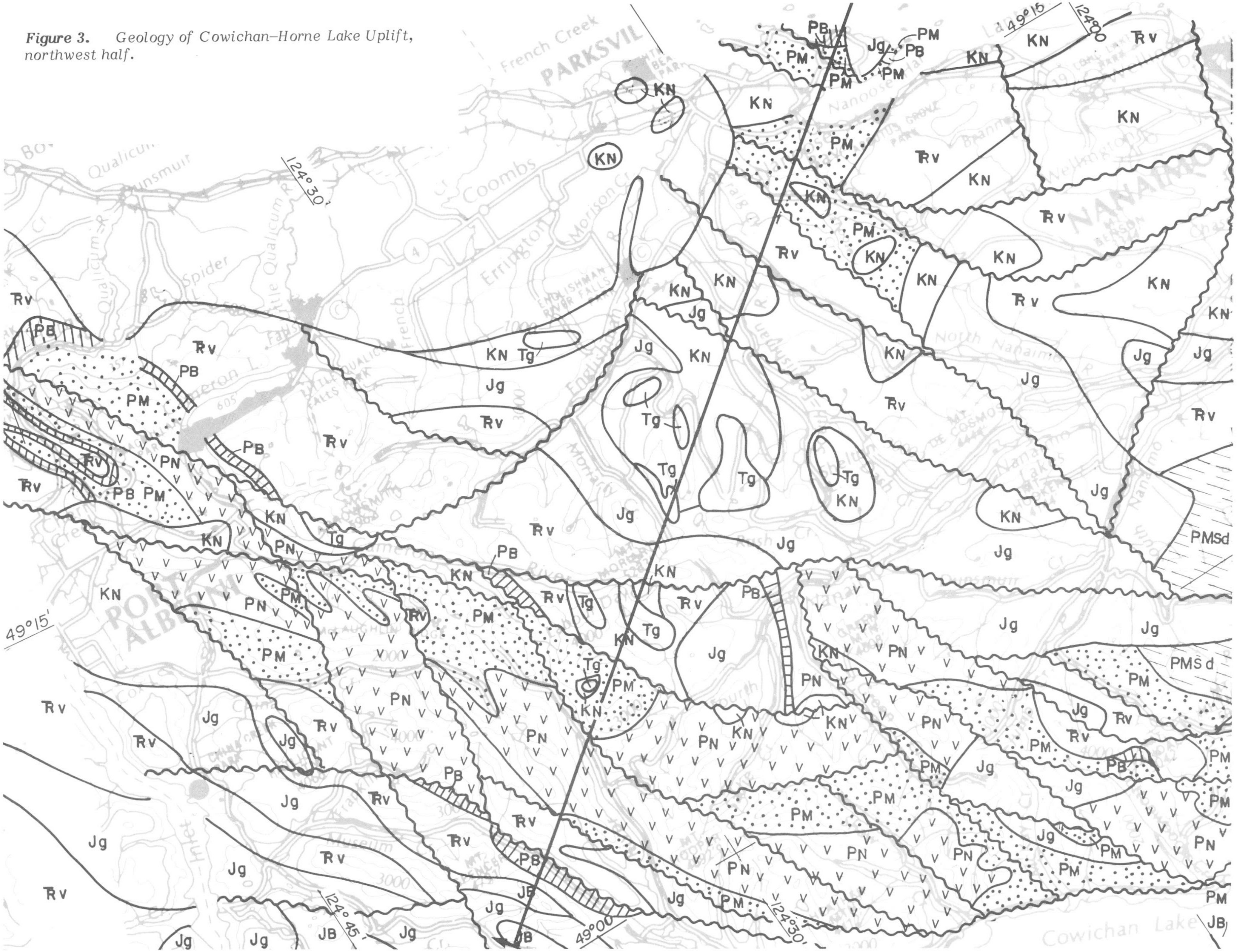


*Figure 3.* *Geology of Cowichan–Horne Lake Uplift, northwest half.*

## NITINAT FORMATION

### *Name and distribution*

The name Nitinat Formation was used by Clapp (1912, p. 44) for "masses of marble . . . separated by wide areas of intrusive granitic rocks, that underlie a broad belt, 10 to 12 miles wide . . . from the mouth of Gordon River to Barkley Sound". The limestone remnants in migmatitic terrane of the Westcoast Complex are derived either from the Buttle Lake Formation of the Sicker Group, or from the late Triassic Quatsino Formation. The definition does not conform to modern usage and the name has not been used by others since its introduction, nor does it serve any purpose for the limestones in question. It therefore seems best to abandon the old definition and to propose the name for the basal formation of the Sicker Group. That formation is most widely exposed in the valleys of the upper branches of Nitinat River and therefore Nitinat Formation appears to be the most suitable name.

The formation is present throughout the Cowichan-Horne Lake Uplift from Horne Lake to Saltspring Island and is most widely exposed in the structurally and topographically highest middle part of that belt in the Nitinat headwater region. No outcrop of the formation is known in the Buttle Lake and Nanoose uplifts or the more northerly exposures of Sicker rocks.

### *Lithology and thickness*

The rocks of the Nitinat Formation are predominantly basic volcanic rocks. Where original texture is preserved they are seen to be massive flows in part, but more commonly flow-breccia composed of fragments of dark green metabasalt with black pyroxene (or uralite) phenocrysts and black or white amygdules. Phenocrysts and amygdules range in size from 1 mm to more than 1 cm. Breccia fragments are subangular to rounded, in places up to 30 cm in length, and are embedded in a matrix of finer grained similar material. Brecciation, although in places tectonic, appears to be mainly autobrecciation in a viscous aa-type lava flow. Brecciated textures are most conspicuous on deeply weathered, old glaciated surfaces where fragments stand in relief and are of different colour than the matrix. The breccias and less common massive lavas are in places interbedded with medium grained basaltic tuff, but distinct bedding or flow banding is rare (Fig. 4). Contacts of flows and tuffs are undulant and may show rip-ups of tuff in the overlying flow.

In a few instances the basalts are clearly pillowed and one such example is well exposed on the ridge 1 km southwest of Stocking Lake and 4 km south of Ladysmith, at the end of branch 7c in the presently inactive Ladysmith logging area of Crown Zellerbach Co. Ltd. These outcrops were discussed in some detail by Clapp and Cooke (1917, p. 128) who called them flows of the "Ladysmith type". The rocks may owe their excellent preservation of megascopic textures (Fig. 5) to their metamorphism to amphibolite grade by adjacent Island Intrusions, for in lower grade Nitinat volcanic rocks pillows are rare and may have been obliterated by shearing. The pillows, widely spaced in a breccia of similar composition, are as much as 30 cm in diameter, with coarsely amygdaloidal cores and finely amygdaloidal rims (Fig. 6). They contain pseudomorphs of pyroxene phenocrysts that stand in relief on the weathered surface and large, irregularly shaped amygdules. In places flow-tongues, imbricated over one another, are also preserved. Pillow basalts are rare in the Nitinat Formation but are exceedingly common in the Karmutsen Formation. Distinguishing features in the Nitinat are pyroxene (uralite) phenocrysts, general shear foliation, which even in the Ladysmith exposures occurs directly adjacent to well preserved pillows, and low-greenschist or higher metamorphic grade.

Thin sections of Nitinat Formation rocks show mafic phenocrysts, 2mm to 5mm in size, composed either of colourless diopside, commonly with a rim of parallel oriented light green actinolite (with smaller extinction angle) or, in most instances, entirely altered to its actionolite pseudomorph, uralite. Plagioclase phenocrysts are less common and are as a rule converted to albite, containing small grains of epidote and rods of actinolite. The matrix may contain patches of very fine subtrachytic feldspathic material but is generally a diffuse mass of chlorite, epidote, prehnite, actinolite, albite, quartz and carbonate in variable proportions, together with scattered leucoxene skeletons. Amygdules also contain a combination of some of these minerals, varying according to grade of metamorphism.

In rocks of amphibolite grade, as for instance the pillow lavas south of Ladysmith, the pyroxene phenocrysts have been converted to green-brown pleochroic hornblende. The matrix consists of small euhedral crystallites of similar hornblende, dark brown biotite flakes and mostly untwinned plagioclase. Amygdules contain a fine grained mosaic of mainly untwinned plagioclase, which according to its refraction index is of andesine composition, and minor quartz.

The only known base of the Nitinat Formation are gabbroic rocks, that partly intrude and partly underlie it. In addition the formation is largely shearfolded and cut by many faults and has no marker beds. Bearing in mind these uncertainties the original thickness, based on widths of exposures, is estimated at about 2000 m. Fyles (1955) estimated a similar 1500 m for his basal unit of the Sicker Group.

### *Related intrusive rocks*

Nitinat volcanics are intimately related to medium- to coarse-grained uralite gabbro and diorite. Although contact relations are rarely visible these rocks very probably represent comagmatic feeder dykes, sills and magma chambers of the volcanics. Macroscopically they are medium- to coarse-grained diorite with relict diabasic texture. As in the volcanic phase pyroxenes are altered to uralite, plagioclase is albitized and the matrix consists of chlorite, actinolite, epidote and albite with ilmenite skeletons and leucoxene as opaque components.

### *Metamorphism*

Metamorphism of the volcanics is varied and complex and probably occurred in several stages. Low-grade metamorphism to epidote-actinolite-chlorite-albite rocks appears to be most common. Thermal metamorphism near intrusions has resulted in amphibolite-grade rocks with hornblende-biotite-plagioclase (= oligoclase-andesine) mineral assemblages. Complex granoblastic textures of the amphibolites suggest that they may have been derived from lower-grade albite-actinolite metavolcanics. Epidote-rich metavolcanics are also common near intrusions. They commonly exhibit conspicuous epidote-rich knots, to about 10 cm in diameter, that are perhaps the result of selective epidote enrichment in individual fragments in flow-breccia (Clapp and Cooke, 1917, Pl. IVA).

Nitinat volcanics are to a large extent shear-folded and commonly exhibit steeply dipping axial plane surfaces with gently plunging axial lineations. Foliated and lineated metamorphic fabrics are generally consistent in attitude within individual outcrops and far more prominent than original flow and bedding planes. Hand specimens and thin sections show crude alignment of platy and fibrous minerals and in some instances foliation in laminae of diverse composition. Mafic phenocrysts are preserved as small, dark green, flat lenticles of secondary minerals, aligned in the plane of foliation.

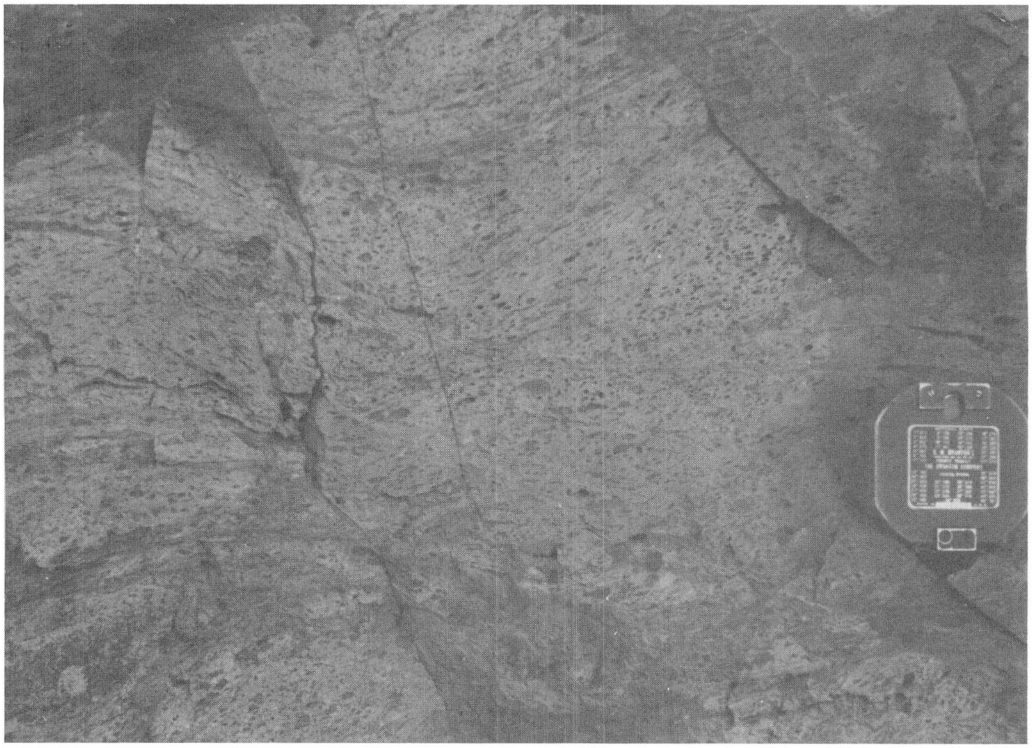

*Figure 4.* Rare flow layering in uralite porphyry basalt; Crown Zellerbach Nitinat Division, Branch 35A, just past Branch 35A7. (GSC 203549)

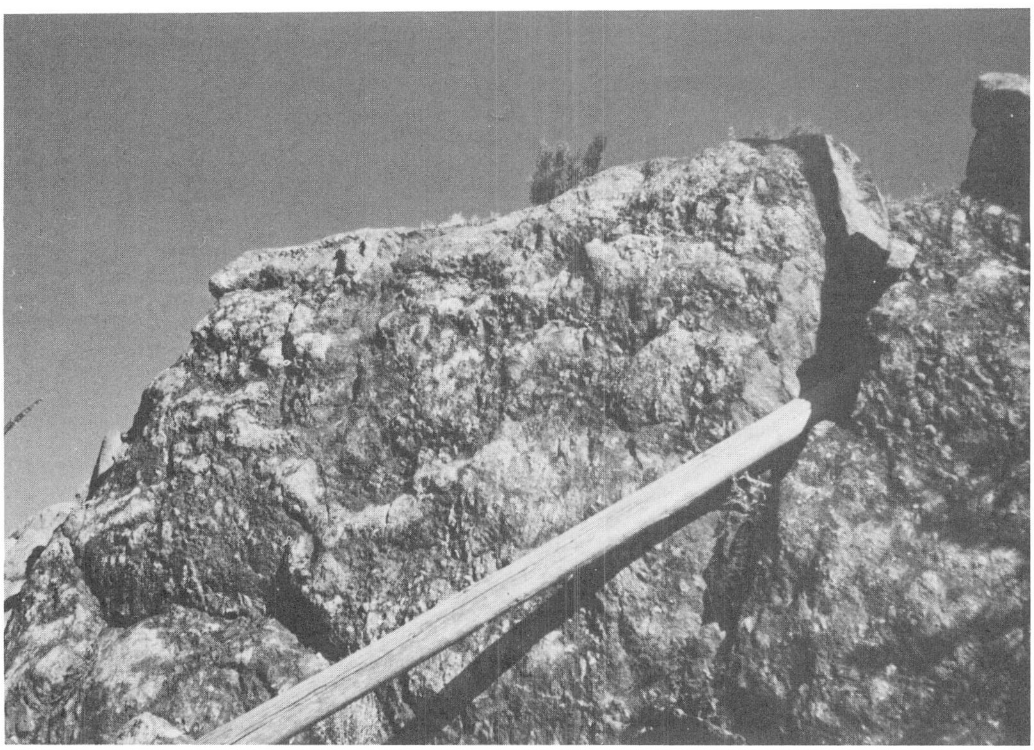

*Figure 5.* Amphibolized uralite porphyry pillow basalt; ridge south of Stocking Lake and 4 km south of Ladysmith; Crown Zellerbach Co. Ladysmith Division, near end of Branch 7C. (GSC 203549-A)

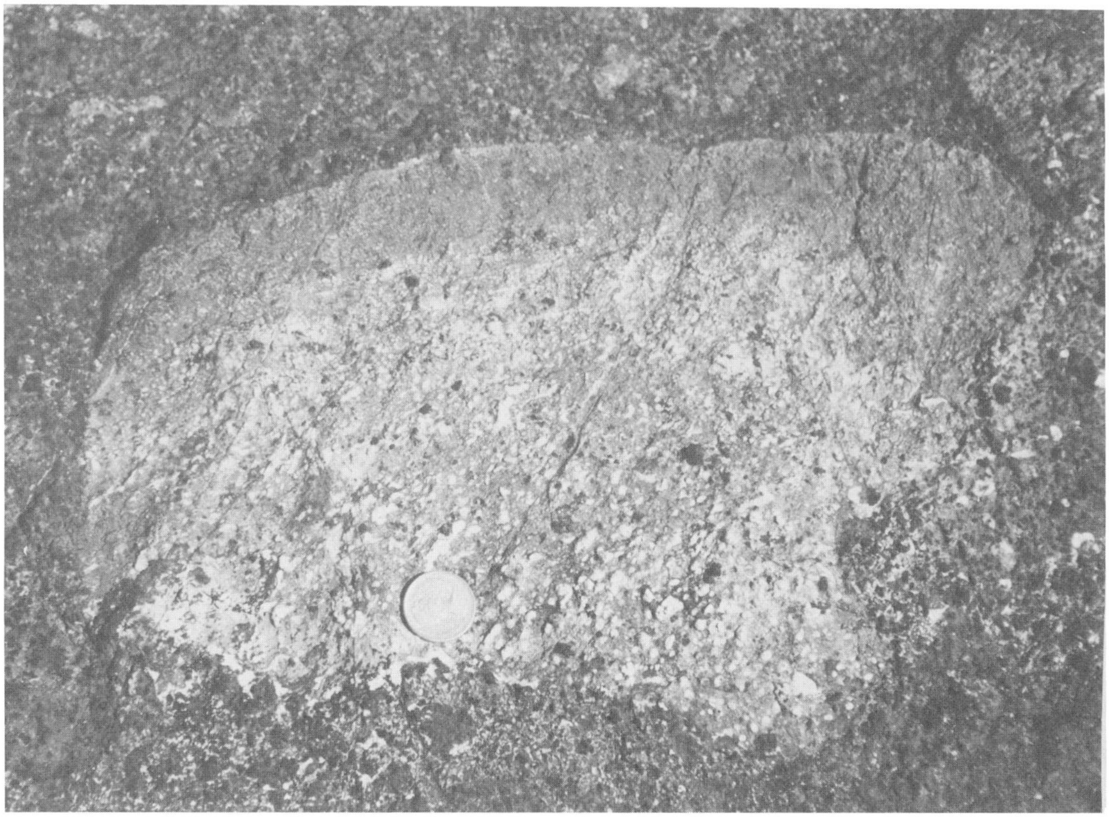

*Figure 6.* *Pillow fragment with rim, dark mafic phenocrysts (amphibolized pyroxene) and white amygdules (plagioclase and quartz); location as for Figure 5. (GSC 203549-B)*

## MYRA FORMATION

### *Name and distribution*

The name Myra Formation is here proposed for a thick succession of bedded volcanic and sedimentary rocks, including rhyolitic to dacitic breccia, tuff and flows and argillite, siltstone greywacke and minor conglomerate. The formation overlies the Nitinat Formation, possibly with minor unconformity. The name is taken from Myra Creek, where the formation is the host of the massive sulphide deposits, being worked by Western Mines Ltd. The mine is in the Buttle Lake Uplift, where the Nitinat Formation is not exposed and where the Myra, directly overlain by the Buttle Lake Formation, is the dominant formation of the Sicker Group. In the Cowichan-Horne Lake Uplift the formation can, in a general way, be divided into a southern and a northern belt, both broken into segments by faults. The southern belt includes the Cameron and Nitinat River areas, the Shaw, McKay and Meade Creek areas north of Cowichan Lake and the southwest part of Saltspring Island. The much smaller northern belt leads from Chipman Creek via Sicker Mountain and Maple Mountain to the middle part of Saltspring Island and includes a small separate area in the Nanaimo River headwaters region.

### *Lithology, Nitinat-Cameron area*

Massive and agglomeratic flows of the Nitinat Formation are succeeded by massive tuffs with local banding and heterogeneous volcanogenic breccias. The base of the Myra Formation is defined at the first appearance of bedded volcaniclastic rocks. The transition is fairly well exposed in consecutive roadcuts of the Crown Zellerbach Main Road and several branch roads (e.g. Br 44, Br. 47) along the northernmost part of Nitinat River and in the upper reaches of Shaw Creek. Maroon and green volcaniclastic greywacke, grit and breccia with crude general layering commonly form the basal part. The mottled green and maroon colours reflect partial oxidation and conversion of ferrous to ferric iron and formation of hematite. A thin section of maroon greywacke shows a fine aggregate of chlorite, albite and quartz, small chalcedony spherulites and scattered hematite, more or less in irregular layers. Much of the red material is also in the form of lenses, layers and fragments of jasper. In this region where rocks at higher altitudes commonly were deeply weathered after the last – possibly pre-Fraser – glaciation, it may be difficult to determine if the red alteration is of Quaternary or of much older age. However, green and maroon clastic rocks appear to have a stratigraphic position between massive Nitinat volcanics and more or less thinly layered volcaniclastic rocks of the Myra Formation. It is tentatively concluded that they represent a fossil regolith indicating an unconformity between the two formations.

Widely banded tuff and breccia, not necessarily of primary volcanic origin, succeed the maroon and green breccia. These are well exposed in the headwaters and divide area of Nitinat and Cameron rivers. They are composed of layers, 20 cm to about 20 m thick, of massive, medium grained, dark green to dark grey tuff, interlayered with alternating light and dark coloured thin bands of fine grained tuff (Fig. 7). The thinly bedded parts are undulating, lensoid and here and there exhibit loadcasts and slump structures. Locally fine and coarse breccias containing diverse subangular fragments of Nitinat Formation volcanic rocks, including uralite porphyry, varying in size from less than 1 to about 30 cm, form part of the unit. Thin sections show the apparent detrital fragmental nature of the rocks and contain angular fragments of single and clustered albitic plagioclase crystals, subtrachytic textured volcanic fragments, amygdaloidal and variolitic fragments and in several instances, broken and unaltered diopside crystals or diopside in feldspathic matrix. The matrix between fragments is mainly chlorite, albite, epidote, carbonate and/or quartz.

A sequence of light and dark banded feldspathic tuff and argillite forms the next higher unit of the Myra Formation in the divide region of Cameron and Nitinat rivers. The general appearance of these beds is that of graded greywacke-argillite turbidite sequences (Fig. 8). On joint faces perpendicular to bedding they show well defined alternating black to brown and yellowish white bands, generally only a few centimetres thick. The black bands are seen on close inspection to contain fine, light coloured laminae and black laminae may divide the light bands. Upper and lower contacts of the bands are on the whole equally sharp, size grading is obscure or absent, and tops of beds are difficult to determine. In its upper part the unit includes sections of black, thick bedded to massive, argillite. Thin sections show the black layers to be composed of a fine clay-size, difficult to determine substance, probably containing chlorite, quartz, albite and carbonate, in places with very small pyrite cubes. The light coloured layers contain broken crystals of albite, minor or no quartz and ellipsoidal pellets containing granular albite and quartz, probably derived from glass, all of silt size (0.05 mm). These are embedded in clay matrix similar to that of the dark bands. The light coloured bands are apparently albite trachyte (= keratophyre) tuff and the dark bands are marine argillite.

Thick bedded breccia, tuff and argillite overlie the thin bedded tuff-argillite sequence, and are also well exposed in roadcuts in the Nitinat-Cameron divide area, for instance on Crown Zellerbach branches 46 and 47 and subsidiary spurs. Fine and coarse crystal tuff occurs in layers up to 10 m thick. Fresh roadcuts show in several places good evidence of slumping of newly deposited ash accumulations that were probably charged with montmorillonite lubricant. Thin tuff layers commonly show nontectonic slump folds (Fig. 9), loadpockets (Fig. 10) and quasi-crossbedded imbricated layers (Fig. 11); rip-up clasts and slabs of argillite, up to one metre in length, can be seen embedded in broken and crumpled tuff. There are also synsedimentary breccias of light coloured volcanic fragments and chert in a matrix of black argillite (Fig. 12, 13). The tuffs are fine- to medium-grained rocks and the fine grained rocks have dark grey to black, fresh surfaces. Weathered surfaces are light grey and buff and show inclusions of darker coloured argillite lenticles and lenses.

***Figure 7***

*Alternating thinly laminated and massive wide-banded tuff; upper Cameron River, MacMillan Bloedel Co. Cameron Division. (GSC 203549-C)*


***Figure 8.*** *Laminated to thick-bedded argillite and tuff; Crown Zellerbach Co. Nitinat Division, Branch 46 at sharp south-to-east turn. (GSC 203549-D)*

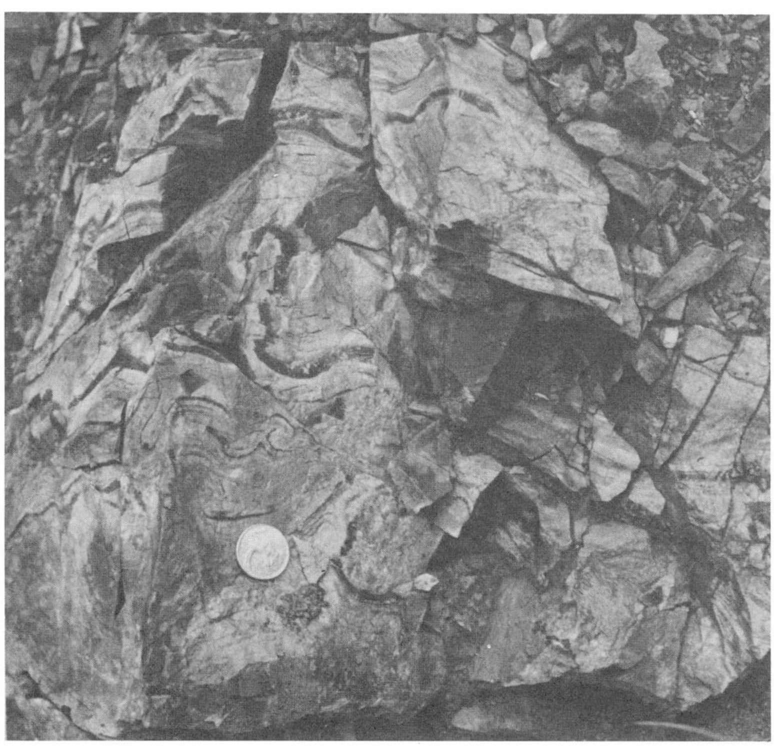

***Figure 9.*** *Slumpfolds in bedded and laminated tuff; MacMillan Bloedel Co. Cameron Division, near end Branch CM252. (GSC 203549-E)*

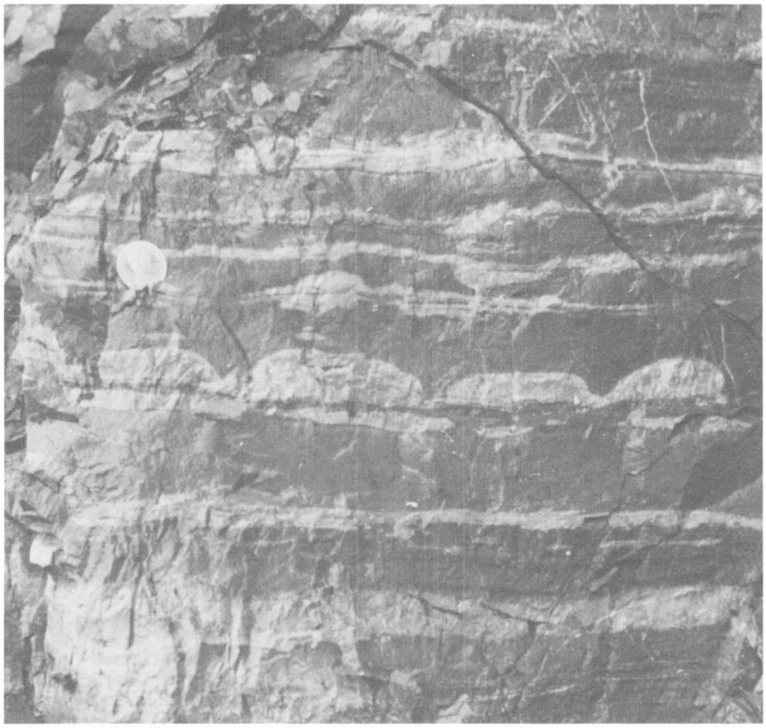

***Figure 10.*** *Loadpockets in wide-banded tuff; Crown Zellerbach Nitinat Division, Main road between Branches 62 and 63. (GSC 203549-F)*

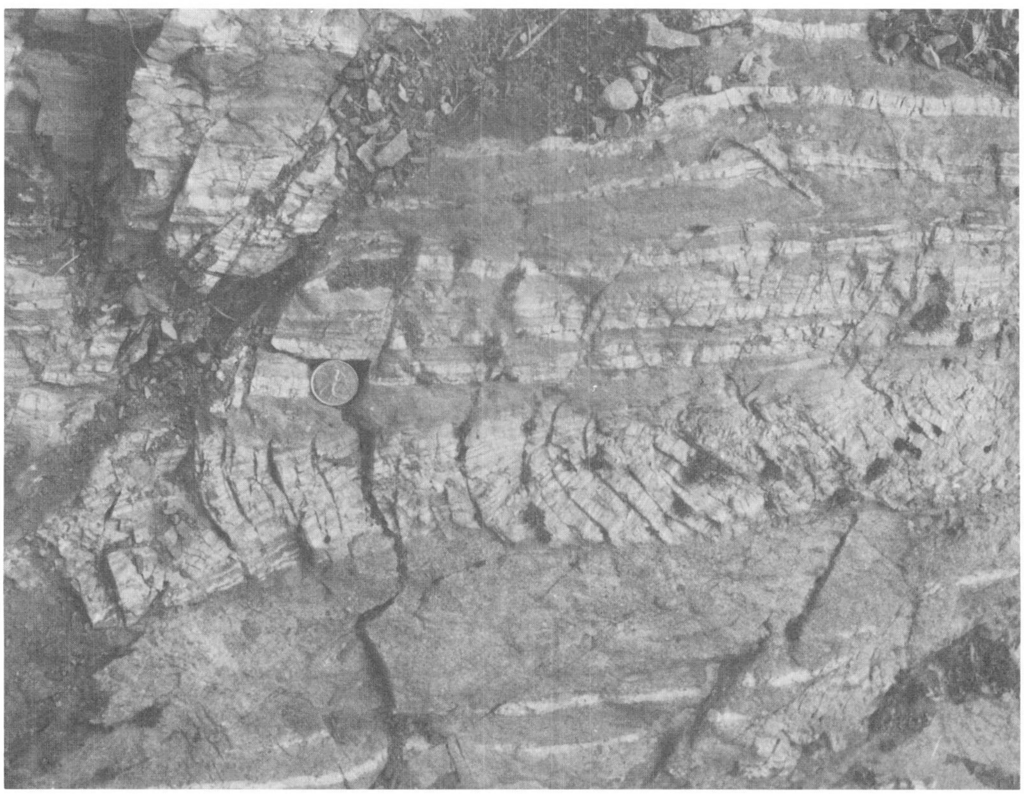

***Figure 11.*** *Thin- and wide-banded tuff, quasi cross-bedding due to slumping and imbrication in layers below coin; MacMillan Bloedel Co. Cameron Division near end of Branch E10. (GSC 205549-G)*

Thin sections show broken albite crystals, crystal clusters and fragments of trachytic, plagiophyric rock. Albite, possibly altered from more calcic plagioclase, is present everywhere but quartz only in a few samples. The matrix is composed of a fine mesh of albite, quartz, carbonate and not uncommonly prehnite. Some layers of argillite in this unit exhibit peculiar white speckles, one to two millimetres in size (Fig. 14). These are not, as might be supposed, lapilli but in thin section appear to be optically more or less continuous crystalline aggregates of prehnite that are overprinted on the texture of the sediment and were clearly not originally embedded in the argillite as discreet globes.

Thus the Myra Formation in the Cameron-Nitinat divide area consists of a lower, massive to widely banded basaltic tuff and breccia unit, a middle thinly banded pelitic albite-trachyte tuff and argillite unit, and an upper thick bedded, medium grained albite-trachyte tuff and breccia unit. The total thickness is estimated to be between 750 and 1000 m.

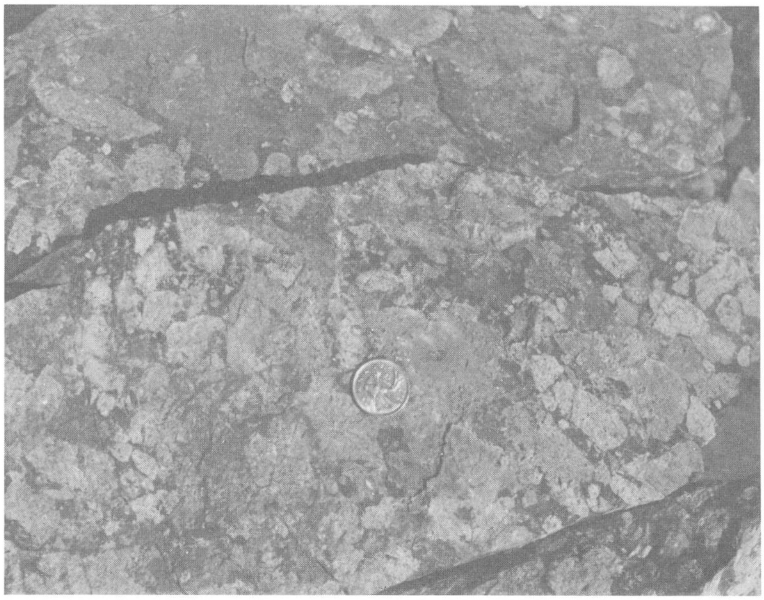

***Figure 12.*** *Rhyodacite breccia in argillite matrix; Crown Zellerbach Nitinat Division, Branch 46, south of Branch 47. (GSC 203549-H)*

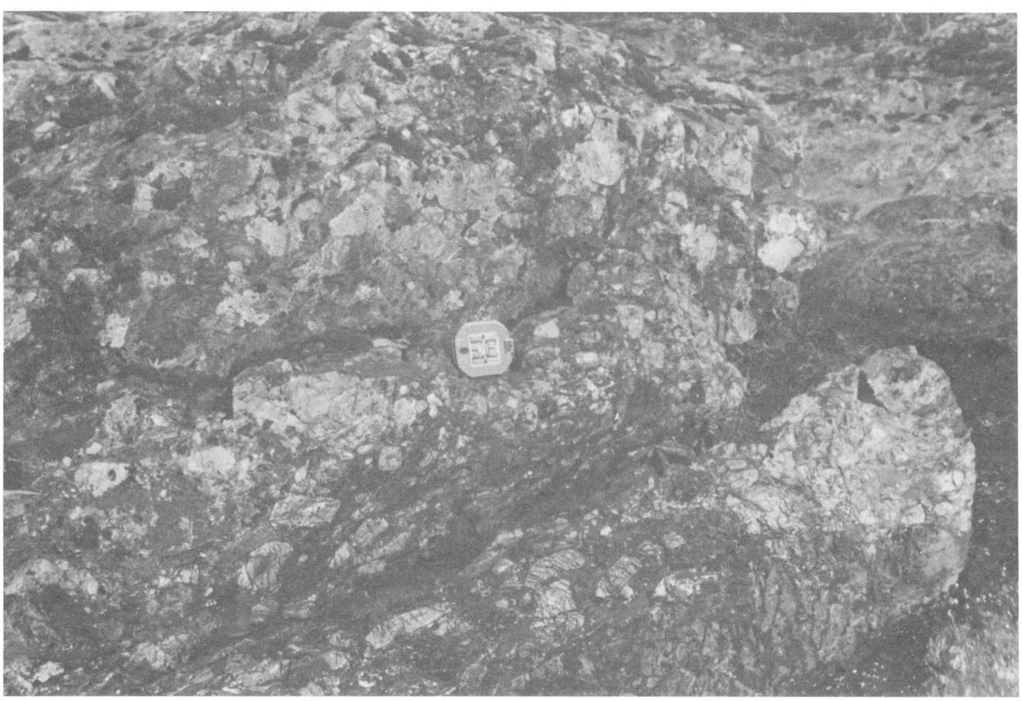

***Figure 13.*** *Chert breccia or conglomerate on upper Nanaimo River; Crown Zellerbach Nanaimo Lakes Division, near end of Branch N 25. (GSC 203549-I)*

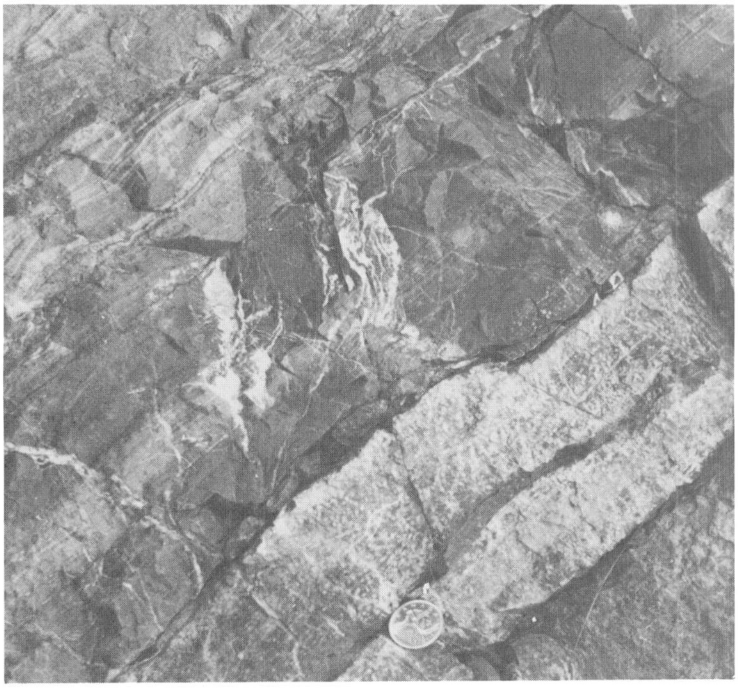

*Figure 14.* *Laminated to thick-bedded tuff and argillite with prehnite globules in some layers; Crown Zellerbach Nitinat Division, Branch 47 C2. (GSC 203549-J)*

***Lithology, north of Cowichan Lake***

Fyles mapped and described in some detail the stratigraphic sequence of the Sicker Group north of Cowichan Lake (1955, p. 18). At the base he found a sequence of mainly massive green volcanics, 1500 m thick or more, clearly identical to the Nitinat Formation. Above he recognized a 200 m sequence of thin bedded, cherty tuffs overlying a distinctive coarse breccia, several metres thick, containing fragments of amygdaloidal volcanic rock. This "marker" unit he could trace between Meade and Shaw creeks, and the rocks clearly correspond to the lower unit of the Myra Formation described above. Likewise, a unit 800 m thick of "grey to black feldspathic tuffs and argillaceous sediments, minor breccias" on Meade Creek is the middle thin banded argillite and tuff unit and probably includes the upper breccia, tuff and argillite unit as well.

***Lithology, southwest Saltspring Island***

Saltspring Island southwest of the valley that extends from Burgoyne Bay to Fulford Harbour is also considered to be part of the southern belt of the Myra Formation. The rocks are well exposed on both sides of the south half of Sansum Narrows and on the southeast coast of the island. They are generally deformed into steep folds and metamorphosed into light green to near white chlorite-sericite schist and internal stratigraphy is difficult to establish. However, they are apparently derived from basic or silicic tuff and breccia, and minor argillite and greywacke, similar to the rocks described for the Cameron and Nitinat areas. Sills of metadiabase are intercalated and are less strongly foliated. Thin sections of the silicic rocks show very fine, more or less layered quartz-albite mosaics, alternating with bands of chlorite and sericite, commonly showing microscopic crenulations. The metadiabases are composed of either chlorite, hydromica, carbonate and minor quartz, or contain uralite with light green actinolite or tremolite clusters and aggregates of epidote and zoisite replacing feldspars.

***Lithology, Sicker Mountain belt***

The northern belt of Sicker Group rocks, extending from South Nanaimo River and Reinhardt Lake through "Copper Canyon" of Chemainus River to Maple Bay and Saltspring Island, is more strongly deformed than the southern belt. It is largely composed of isoclinally folded rocks, mostly converted to chlorite (-sericite) schist. Clapp and Cooke (1917) mapped this belt in part as Sicker Volcanics and in part as intermixed "Tyee Quartz Feldspar Porphyrite" and Sicker Gabbro-diorite Porphyrite". The latter two units are categorized by them as "masses, sills and dykes". The coastal exposures at Maple Bay and Arbutus Point and the adjacent residential subdivision contain several more or less tabular, almost vertical bodies of schistose quartz porphyry. The quartz porphyry has been dated on contained zircons to be of Devonian age and was considered by Clapp and Cooke (1917) and by the writer (e.g. Muller, 1977) to be intrusive into uralite porphyry and also, on Saltspring Island, into sediments of the Sicker Group. More detailed mapping at Arbutus Point (Fig. 15), although not entirely conclusive, indicates that the quartz porphyry and related fine- to medium-grained quartzite are probably sills and (?) flows of metarhyolite (-porphyry), in the form of tight, near-vertical synclines, within uralite porphyry (Fig. 16). Thus five to seven synclines, 10 to 50 m wide, of quartz porphyry and related rocks of the Myra Formation occur between anticlines of uralite porphyry of the Nitinat Formation. On the other hand an exposure near Erskine Point on the opposite side of Sansum Narrows, on Saltspring Island, exhibits conformable as well as zigzagging crosscutting contacts of the quartz porphyry and schistose greywacke and argillite (Fig. 17). There, at least, some of the prophyry was apparently intruded into beds that may have been penecontemporaneous sediments of the Myra Formation. An earlier suggestion (Muller, 1977) that the intruded sediments may represent a pre-Devonian sequence is not supported by data obtained during the most recent fieldwork.

Chlorite-sericite schist, in part quartz-bearing and considered to be part of the Myra Formation, is also exposed in Copper Canyon of Chemainus River and adjacent slopes between Mount Brenton and Big Sicker Mountain. On the latter mountain they are the host rocks of the old Tyee, Lenora and Richard III copper mines (1898-1907), later reactivated as Twin "J" mine and referred to by Clapp and Cooke (1917) and Stevenson (1945a).

The quartz-albite porphyries are best exposed on both sides of Sansum Narrows near Arbutus Point and Erskine Point. They are light green, grey weathering rocks showing ellipsoidal, dull-glassy quartz augen, up to 5 mm long, and smaller, less conspicuous albite phenocrysts in very fine grained matrix with well defined gneissic foliation (Fig. 17, 18). In thin sections quartz phenocrysts are commonly cracked and show uneven extinction and in some, corroded edges and embayments, filled with very fine quartz-albite mosaic, are preserved. Albite phenocrysts, smaller than quartz, are complexly twinned and include shreds of sericite. The matrix is mainly an interlocking, very fine quartz-albite aggregate. Biotite, muscovite, epidote, zoisite and chlorite are scattered throughout and also form mafic clusters. The quartz-albite porphyry in places grades into fine grained metarhyolite and is interlayered with schistose tuff (meta-greywacke ?) and breccia. Some of these metamorphosed volcaniclastic rocks are light coloured and are composed mainly of albite, quartz, chlorite and sericite, others are dark and contain much epidote and/or actinolite together with albite and chlorite. These rocks may be compared to the light and dark tuffs and breccias in the Myra Formation of the Cameron-Nitinat area.

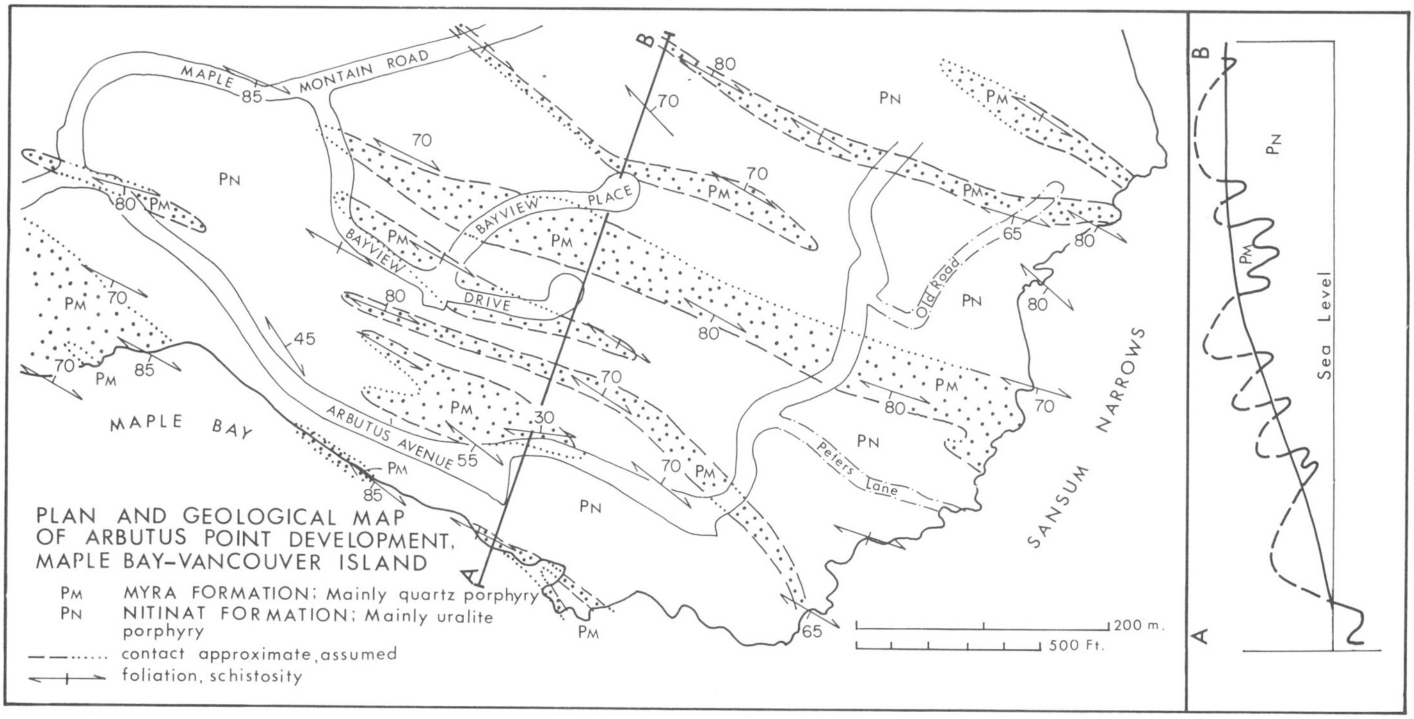


*Figure 15.* *Detaied geological map of Arbutus Point subdivision.*

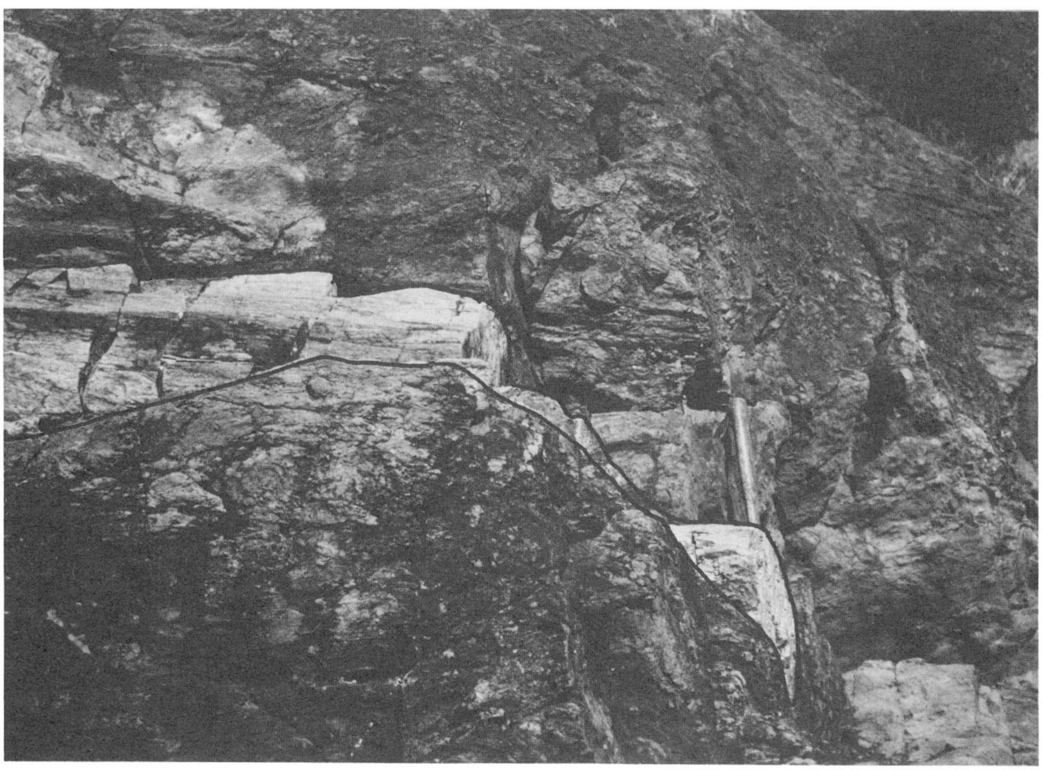

*Figure 16.* *Tight syncline of quartz porphyry in uralite porphyry, shoreline, Maple Bay. (GSC 203549-K)*

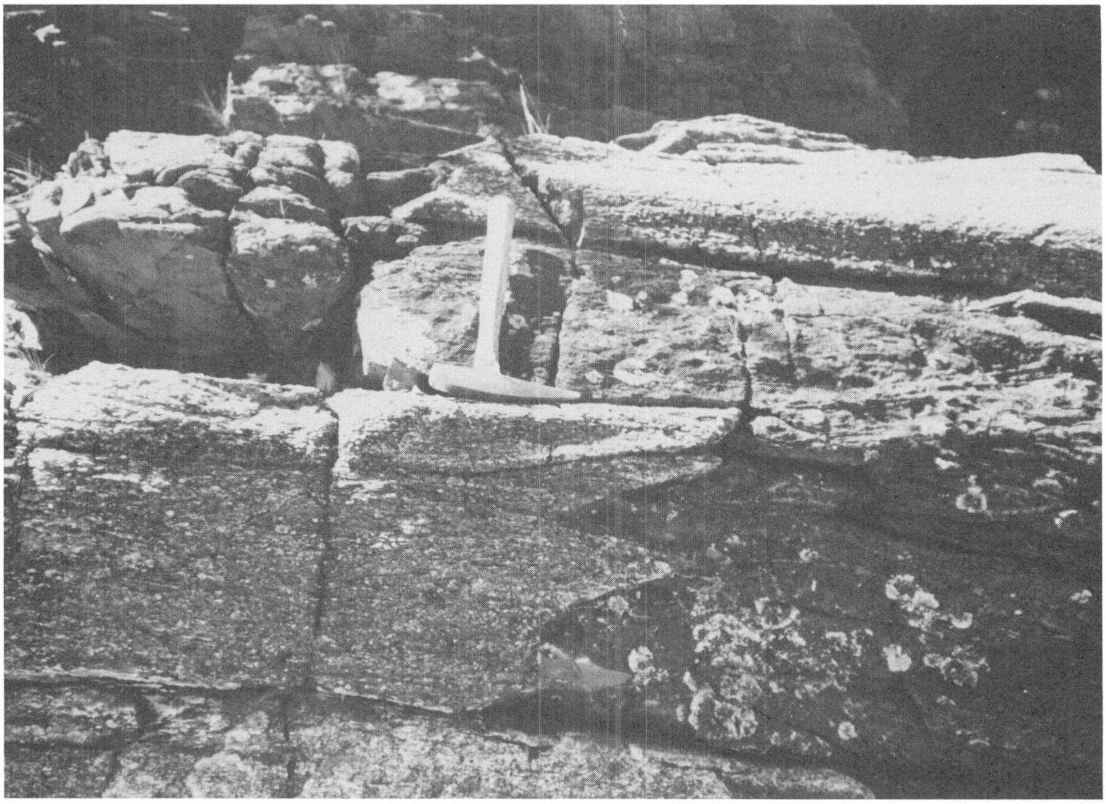

***Figure 17.*** *Crosscutting and parallel contacts of quartz porphyry and schistose metasediments. (GSC 203549-L)*

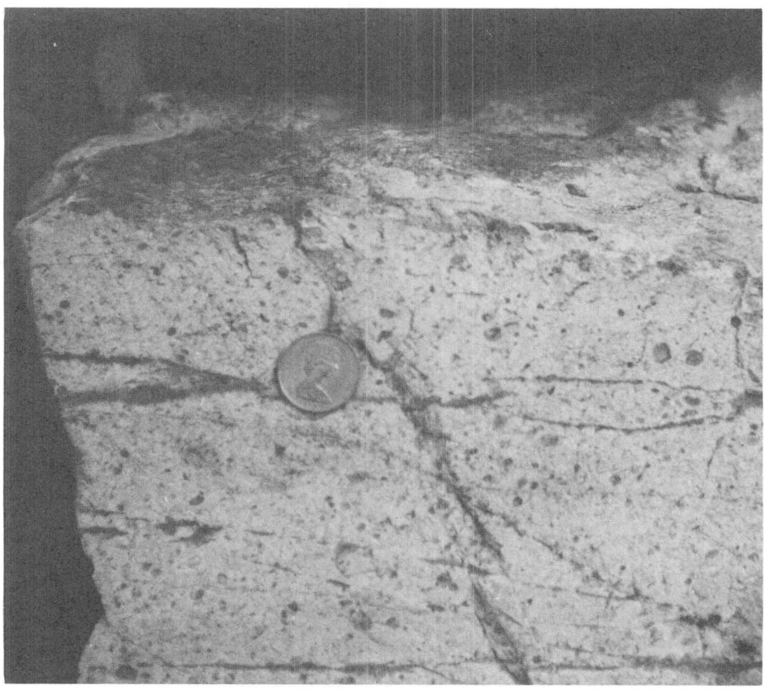

***Figure 18.*** *Quartz porphyry, Bayview Place, Arbutus Point subdivision. (GSC 203549-M)*

*Lithology, Buttle Lake Uplift*

The Buttle Lake Uplift, and in particular the Myra Creek area with the Lynx, Myra and Price mineral deposits of Western Mines Limited is herein designated the type area for the Myra Formation. Detailed stratigraphy of the formation is obscured by complex structure and limited exposures beyond the workings but is expected to be clarified in the near future. The following is a general account, based on the earlier work by Jeffery (1965) and information received from several Western Mines staff geologists, together with the writer's own observations. In view of ongoing exploration detailed stratigraphy at the mine is confidential at this time.

The Myra Creek Formation and its stratabound massive sulphide deposits has been folded into an asymmetrical, sharp crested, northwest striking fold with shallow plunge. One limb dips about thirty-five degrees northeast and the other limb dips seventy to ninety degrees southwest and is locally overturned. The ore deposits are in the crest and in both limbs. The "G-Zone" of the Lynx, the "High-grade orebody" of the Myra and part of its "Main Zone" are in the north limb. They are interpreted as exhalite deposits, related to rhyolitic flows, tuff and breccia that are the main components of the anticlinal structure.

According to Western Mines geologists the Myra Formation, as exposed in the mine is composed of varied, mainly volcaniclastic rocks. They range from very fine grained, thin bedded and cherty tuffs to thick bedded lapillistone and coarse breccia. They are predominantly heterolithic with fragments of basic, intermediate and acidic volcanic rocks, mixed in widely varying proportions. Volcaniclastic beds adjacent to ore zones commonly contain clasts of rhyolite and ore. There are some dark green flows, tuffs and breccias of basic composition and in some instances the ore is underlain by a rhyolitic volcaniclastic bed and overlain by a mafic flow. Beds of black argillite and argillaceous tuff are present locally at various stratigraphic levels but have little lateral continuity.

Jeffery (1965) described breccias at Myra Creek as follows. "A very distinctive breccia type contains purple fragments in a dark-green matrix. The purple colour persists and can be seen in mottled purple and green schists where the purple fragments have been stretched and elongated in an altered dark-green chloritic and micaceous matrix". Rhyolite (rhyodacite) is a light- to dark-grey, fine grained, locally laminated quartzite-like rock, not uncommonly isoclinally folded and with distinctly schistose and rodded fabric. Rhyolite breccia exposed just below the Price showing is composed of flat lensoid fragments of rhyolitic rock (Fig. 19), other breccias are variegated and contain blocks of rhyolite, quartz porphyry, feldspar porphyry, bedded tuff, massive greenstone and massive sulphide (Fig. 20). Thin sections of rhyolite from the mine show it to be composed of euhedral albite microphenocrysts about 0.2 millimetres long and small anhedral masses of quartz in a very fine, somewhat directional matrix of quartz and albite. A thin section of fine breccia shows fragments of quartz-mosaic and albite-trachyte in a quartz-sericite foliated matrix. Jeffery (1965) reported the presence of schists with quartz "porphyroblasts" in the Lynx Mine. These appear to be similar to quartz porphyries of the Sicker Mountain Belt.

Interbedded tuff and breccia in the upper part of the formation are well exposed on the paved road to the mine, on both sides of the bridge over the south end of Buttle Lake. There thin tuff bands, one to ten centimetres thick, with some channelling and colour gradation, alternate with medium grained massive tuff beds, up to about five metres thick. The layers of breccia, to about ten metres thick, contain clasts of rhyodacitic material and fragments of banded tuff to about 20 cm across.

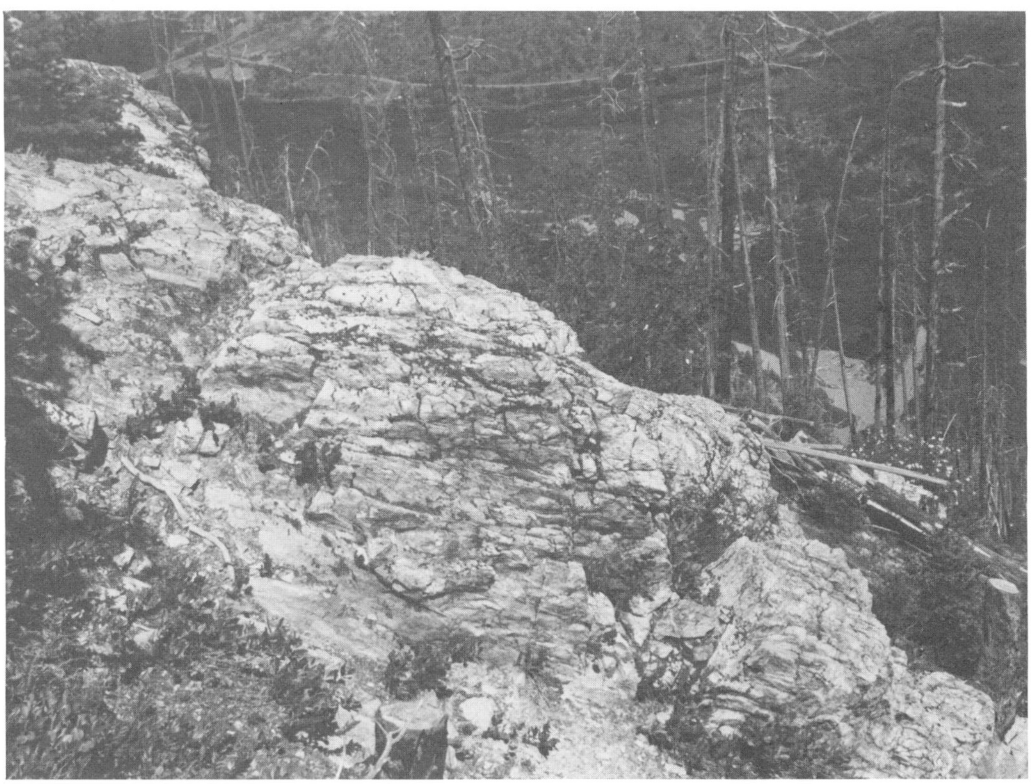

**Figure 19.** *Rhyolite breccia; southwest of south end of Buttle Lake, below "Price" showing. (GSC 203549-N)*

*Figure 20.* *Mixed breccia, below and south of breccia of Figure 19. (GSC 203549-O)*

## SALTSPRING STOCK

A body of granitoid rock occupies most of southern Saltspring Island between the inlets of Fulford Harbour and Ganges Harbour and continues with reduced width across Sansum Narrows into Vancouver Island. Although superficially similar to Jurassic Island Intrusions the rocks are clearly different in lithology and isotopic age and appear to have gradational contacts with Tyee Quartz Porphyry. The name "Tyee Intrusions" has been introduced earlier for these Paleozoic granitoid rocks (Muller, 1977).

Macroscopically the rocks are fine- to medium-grained, light coloured granitoid rocks. Quartz and feldspar, a few millimetres in size, are evenly medium grey and mafic minerals are altered to chlorite and epidote. Thus a dull, medium grey colouration is characteristically different from the distinctly mafics-speckled appearance of most Mesozoic and Tertiary granitoid rocks. Pervasive but indistinct gneissic foliation and agmatitic structures are exposed on both sides of Sansum Narrows. Thin sections show mainly quartz, albitized plagioclase and potash feldspar, locally in the habit of microcline. Cataclastic texture is general, but is most notable in strained and broken quartz. It constitutes about 40 per cent of the rock, in some instances mostly as inclusions in and intergrowths with feldspar. Plagioclase, forming 30 to 50 per cent of the rock is albitized and contains abundant sericite and chlorite. Microcline, with typical cross-twinning, contains wedges of microperthite. Micrographic, perthitic and myrmekitic intergrowths of felsic minerals are common and may be due to postintrusive recrystallization. Although Clapp and Cooke (1917, p. 168) mentioned the presence of hornblende and biotite, samples seen by the writer contain little chloritized biotite and only a few per cent of chlorite, epidote and sericite. On the basis of this secondary composition the original rock is inferred to have been a light coloured granite or granodiorite.

## SEDIMENT-SILL UNIT

The upper part of the Sicker Group is composed mainly of clastic sediments including argillite, siltstone, chert, greywacke and calcarenite. These beds are intruded by many sills of commonly plagiophyric diabase. The calcareous beds, with or without interbedded argillite and greywacke, are mapped separately as the Buttle Lake Formation. Elsewhere, as in the eastern part of the Cowichan-Horne Lake Uplift, interbedded argillite and siltstone, interlayered with basic sills but without carbonate are referred to as the Sediment-Sill Unit, in analogy to a similar unit in identical stratigraphic position in Alert Bay map area (Muller et al, 1974). The unit may be coeval with the Buttle Lake Formation or somewhat older and could also correlate in part to the upper sedimentary rocks in the Myra Formation. In view of the uncertain stratigraphic correlation no formal name is proposed. The unit was mapped by Clapp and Cooke (1917) as "Sicker Gabbro-diorite Porphyrite" Fyles (1955) mapped numerous intertonguing bands of Sicker Group sediments and diabase that he associated with Triassic Franklin Creek Volcanics (=Karmutsen Formation) in the upper Haslam Creek and Reinhardt Creek areas. As noted by Clapp and Cooke (1917) the diabase sills in places intrude Tyee quartz porphyry.

The sediments of the unit are generally thinly bedded, turbidite-like, massive argillite and siltstone that are much silicified and show conspicuous dark-light banding on joint faces. Silicification is in part diagenetic but in part probably due to contact reaction with the enclosed diabase sills. The petrography of the sills was described earlier by Clapp and Cooke (1917) amd Fyles (1955). In the Mount Brenton region, there are plagiophyric rocks with white feldspars, a few millimetres to more than one centimetre long, in a greenish black, fine grained matrix. In many places the feldspars are clustered in rosettes, several centimetres across, forming a very distinctive "flower gabbro". Thin sections show subophitic texture with euhedral crystals of labrodorite penetrating roughly equidimensional, anhedral pyroxene in finer matrix of feldspar, mafic minerals and ilmenite. The feldspars are commonly albitized and sericitized, the pyroxenes are uralitized and chlorite, epidote, clinozoisite and leucoxene are secondary minerals. Medium- to coarse-grained gabbro is also exposed in several places, for example on the shore near Grave Point where it intrudes cherty sediments that are in gradational intrusive or migmatic contact with Tyee Intrusions (only Tyee Intrusions are shown on Fig. 3).

## BUTTLE LAKE FORMATION

### *Name and distribution*

In the Buttle Lake region limestone, up to 150 m thick, forms the top of the Sicker Group and is overlain paraconformably by basaltic rocks of the Karmutsen Formation. It was named Buttle Lake Formation by Yole, following an earlier suggestion by Gunning (1931). Sparse brachiopods, bryozoans and microfossils indicate late Paleozoic age. Several northwest striking belts of correlative limestone with interbedded chert and siltstone are present in the Cowichan-Horne Lake Uplift north and south of Horne Lake, east of upper and of lower Cameron River, near Museum Creek and Green Creek and west and southeast of the town of Lake Cowichan. Small areas of Buttle Lake limestone are also exposed in Nanoose Uplift.

### *Lithology and thickness*

Yole (1963, 1969) described three sections of the formation. In the type area, near Azure Lake, west of Buttle Lake, he reported green-and-maroon mottled tuff and breccia at the base of the formation, overlying coarse grained porphyritic volcanic rocks. The Mount Mark limestone, north of Horne Lake, also lies on green-and-maroon calcareous and fossiliferous breccia. Similar breccia with maroon fragments, to 20 cm across, in a green matrix is also exposed below the bench of Buttle Lake limestone exposed on the upper Cameron River in a quarry on the Macmillan Bloedel Company Cameron East Main Road. Above the breccia the base of the type section comprises 3 m of fossiliferous sandstone, followed by 317 m of coarse grained crinoidal limestone, fine grained limestone with chert nodules and some dolomitic limestone with abundant brachiopods and bryozoans. The Mount Mark section on the north side of Horne Lake is 466 m thick and of similar lithology. Thinner limestone sections, together with argillite, siltstone and greywacke, are present south of Horne Lake, and on the east slopes of lower and upper Cameron River Valley. A well exposed section, about 300 m thick, faces east towards the lower part of Green Creek and the "K" Main Road of Crown Zellerbach Company Nanaimo Lakes operation. It is composed of interbedded, medium grained limestone and calcareous siltstone with some siliceous shell fragments. It has not been studied in detail. Farther south Fyles (1955) mapped lenses of limestone on the slopes of Mount Landalt and on the peninsula at the east end of Cowichan Lake. Lastly the third section described by Yole (1969) is on Fairservice or Chanlog Creek, southeast of the town of Lake Cowichan. Yole measured 786 m of faulted strata but estimated the true thickness to be a maximum 300 m. He listed mainly interbedded chert and limestone with only minor units, one metre or less thick, of coarse grained crinoidal limestone. Much of this section is now covered with vegetation but some of the rocks are exposed in the steep gully of Chanlog Creek (south of C.N.R. Chanlog rail-siding). They are mainly laminated, calcareous grey siltstone and black argillite containing lenses of grey brown, coarse grained calcarenite, with minor, about 1 m thick, massive beds of crinoidal limestone. Chert occurs as lenses and nodules. The beds show much evidence of intraformational slumping and brecciation. No occurrences of Buttle Lake limestone are known farther east in Cowichan-Horne Lake Uplift.

In the Nanoose Uplift the Buttle Lake Formation is exposed on the coast west of Nankivell Point, near residences on Blueback Drive. The strata consist of unevenly bedded argillite and calcarenite that exhibit pronounced slump folds. One fold, exposed in a small inward facing cliff on one of the properties, has an amplitude of about two metres. The beds overlie plagiophyric basalt and contain some angular clasts of similar rock. The argillite has been converted to hornfels by the small stock of quartz diorite that underlies the east part of the Nanoose Peninsula, but the limestone has undergone only minor recrystallization.

## AGE OF SICKER GROUP AND RELATED INTRUSIONS

### *Biostratigraphic age**

Fossils have only been found in limestone of the Buttle Lake Formation and they indicate Pennsylvanian and Permian age. Clapp and Cooke (1917) did not obtain fossils and appear to have erred in placing the Sicker sediments in the Middle Jurassic, above the Vancouver volcanics (=Vancouver and Bonanza groups). Gunning (1931) was the first to make collections from limestone in the headwaters of Marble Creek, west of Buttle Lake. They were largely bryozoa with a great variety of species, as determined by M.A. Fritz. She correlated this fauna with a fauna, described from Timor, of Permian age. G.H. Girty examined brachiopods of the collection and concluded they were more probably late Pennsylvanian than Permian. Brachiopods, collected by Fyles (1955) from limestone on the peninsula at the east end of Cowichan Lake were determined by P. Harker as early Permian. Crinoidal limestone from that locality yielded fusulinids according to M.L. Thompson also indicating early Permian age. The writer (Muller and Carson, 1969) collected brachiopods from Ballenas Islands, north of Nanoose Peninsula which C.H. Ross determined on the basis of fusulinids as middle Pennsylvanian. Significantly E.W. Bamber originally determined the age of brachiopods from the same locality as Permian but indicated that the Pennsylvanian age based on fusulinids should be accepted as more reliable. Since that time foraminifera from several localities including Cowichan Valley and northern Vancouver Island have been dated by B.E.B. Cameron as Pennsylvanian (Muller et al. 1974). Lastly, Sada and Danner (1974) recognized middle Pennsylvanian fusulinids in the limestone of Horne Lake. In conclusion the weight of evidence seems to point to middle Pennsylvanian age of the Buttle Lake limestones, but Permian age cannot be ruled out until a definitive study of all the generally sparse faunas has been made.

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* See Addendum, page 23.

### *K-Ar ages*

The few K-Ar age determinations made on Sicker Group volcanics only indicate ages of metamorphism. A whole-rock determination of quartz-sericite schist of the Myra Formation from the portal of the Twin J Mine, east of Chemainus River, was dated at 163 ± 20 Ma (Wanless et al., 1968). Fine muscovite from quartz porphyry-sericite schist of Arbutus Point (see: Lithology Sicker Mountain Belt) was dated at 180 ± 8 Ma (R. K. Wanless, pers. comm.). The dates suggest Early Jurassic dynamothermal metamorphism of the Myra Formation, apparently related to emplacement of Island Intrusions and perhaps orogeny at that time. Actinolite from uralite porphyry of southeastern Saltspring Island was dated by R. L. Armstrong (pers. comm. 1976) at 249 ± 10 Ma. This is the oldest K-Ar date obtained in the Vancouver and Gulf islands region; all other dates are less than 200 Ma. Tentatively the date is interpreted as indicating burial metamorphism of the Nitinat Formation.

### *U-Pb ages*

Preliminary references have been made earlier (e.g. Muller, 1977) to zircon dating of Tyee quartz porphyry from Arbutus Point. Since that time other samples of rhyolite and granodiorite from Saltspring Island have been processed by the Geological Survey Isotope Laboratory. The following results are given here to define the best current dating of these rocks.

| | $^{206}Pb/^{238}U$ | $^{207}Pb/^{235}U$ | $^{207}Pb/^{206}Pb$ |
|---|---|---|---|
| Metagranodiorite, Lake Stowell, Saltspring Island; Sample MEZ 76-3 | | | |
| size -105 to +74 µm | | | |
| nonmagnetic | 347 | 350 | 367 |
| magnetic | 340 | 345 | 379 |
| size -74 to +62 µm | | | |
| nonmagnetic | 345 | 349 | 372 |
| magnetic | 334 | 338 | 363 |
| average of four fractions | 342 | 346 | 370 |
| Meta-quartz porphyry, Mount Maxwell, Saltspring Island; Sample MEZ 77-1 | | | |
| size -105 to +74 µm | | | |
| nonmagnetic | 349 | 354 | 386 |
| magnetic | 350 | 353 | 371 |
| size -74 to +44 µm | | | |
| nonmagnetic | 342 | 347 | 370 |
| magnetic | 345 | 350 | 383 |
| average of four fractions | 347 | 351 | 380 |
| Meta-quartz porphyry, Maple Bay, Vancouver Island; Sample Wn 19-74 | | | |
| size -74 to +64 µm | 361 | 365 | 395 |
| -62 to +44 µm | 357 | 361 | 389 |
| average of two fractions | 359 | 363 | 392 |

The 206/238 and 207/235 apparent ages all differ by 1.5 per cent or less and may therefore be considered concordant. Thus the average 207/206 ages of the granodiorite and the meta quartz porphyry of 370, 380 and 392 Ma may be considered as minimum ages. Alternatively one may assume an episodic lead loss at 180 Ma, the time of metamorphism as indicated by the K-Ar age of the Maple Bay Tyee quartz porphyry. A discordia chord on the concordia plot, with lower intersect at 180 Ma, through the cluster of apparent ages cited above, intersects the concordia curve at 410 Ma.

Thus it may be concluded fairly reliably that the intrusions are of Late Silurian to Devonian age and that perhaps the meta-quartz porphyries are somewhat older than the meta granodiorite.

For comparison two zircon Pb/U sets of dates are given for Turtleback Complex quartz diorite of Orcas Island (J. M. Mattinson, as recalculated in Whetten et al., 1978).

| | $^{206}Pb/^{238}U$ | $^{207}Pb/^{235}U$ | $^{207}Pb/^{206}Pb$ |
|---|---|---|---|
| 68-20 | 354 | 360 | 409 ± 25 |
| 68-21 | 376 | 384 | 437 ± 10 |

The U/Pb ages are close to those of the Tyee quartz porphyry but Whetten et al. indicate upper and lower intersections with concordia of 189 ± 87 Ma and 475 ± 72 Ma. While the lower intercept is close to the assumed 180 Ma intercept of the Tyee quartz porphyry the upper intercept is higher but may be near that age within the large possible error.

### *Age of the formations*

On the basis of the above cited data it is probably fair to conclude that the Nitinat Formation and the Myra Formation with related intrusions are Devonian and/or older. The Buttle Lake Formation is probably Middle Pennsylvanian to Early Permian in age.

## CORRELATION

The Paleozoic complex that underlies Vancouver Island and has been incorporated into the Sicker Group is the remnant of a middle to late Paleozoic volcanic arc terrane that appears to have a northern continuation in St. Elias Mountains of Yukon and Wrangell Mountains of Alaska. This western Insular Belt of the Canadian Cordillera (now called "Wrangellia" by some authors) is believed to have originated farther south and to have been emplaced in its present geographic position in Jurassic or Early Cretaceous time (e.g. Muller, 1977). Davis et al. (1978) in their recent review concluded that the Mesozoic tectonic history of the western Cordillera was "fundamentally governed by right-lateral motion of Pacific plates along and obliquely beneath the continental margin". Thus "exotic terranes of initially more southerly derivation are now components of the (northern) orogen". That same review also restates the observation that in central and southern California all Paleozoic depositional and tectonic trends are truncated, probably by early Mesozoic transform faulting. The authors did not accept, or perhaps overlooked the possibility, suggested by Schweikert (1976) and Muller (1977) that the truncated Paleozoic miogeocline and arc terrane of southern California were shifted northward and incorporated in the western part of the northern Cordillera. In this writer's view that possibility deserves further consideration and is enhanced by the apparent similarities in the middle to late Paleozoic arc terranes of Vancouver Island and eastern Klamath Mountains.

### *Northern Insular Belt*

In Queen Charlottle Islands post-Paleozoic history is very similar to that of Vancouver Island. There remnants of the Paleozoic arc terrane might be expected to underlie Karmutsen volcanics of the Triassic Vancouver Group, but are not known to be exposed anywhere.

The Paleozoic rocks of the Alaska and Kluane ranges appear to have similarity to the Sicker Group and are likewise highly folded, faulted and metamorphosed to greenschist and amphibolite grade. Despite intensive fieldwork in St. Elias Mountains beginning 1973, following earlier reconnaissance mapping (Muller, 1967) no complete understanding of the Paleozoic succession has emerged (Campbell and Dodds, 1978). The two groups may represent distinct, not directly related geological terranes (R.B. Campbell, pers. comm. 1979) but the Skolai appears to be similar in lithology and upper age limit to the Sicker. In Alaska (Smith and MacKevett, 1970) the upper part of the Skolai is the sedimentary Hasen Creek Formation, very similar to Buttle Lake Formation and Sediment-Sill Unit. The lower Station Creek Formation, composed of a lower volcanic member and an upper volcaniclastic member, appears to correspond well to Nitinat and Myra formations.

### *San Juan Islands*

The geology of San Juan Islands, directly adjacent to Vancouver Island, is extremely complex. The Paleozoic and Mesozoic sedimentary, volcanic and granitoid rocks were first mapped by McLellan (1927). Danner (1957) found many new fossil localities and established Devonian, Pennsylvanian and Permian ages for various limestone lenses in the deformed and disrupted Paleozoic sequence. Most recent stratigraphic and structural data, with considerably varying interpretations, have been presented by Vance (1977), Danner (1978) and Whetten et al. (1978). Paleozoic rocks were divided by McLellan (1927) in the Devonian to Mississippian Orcas Group, composed of thinly bedded quartzite and argillite with lenses of limestone and the Mississippian to Permian Leech River Group of mainly greywacke, argillite, schist and limestone. The latter formation, as mapped by McLellan, is now known to include Mesozoic as well as Paleozoic greywacke-argillite-chert (-limestone) sequences (Whetten et al., 1978). McLellan's correlation with the Leech River Formation of Vancouver Island, now considered Jurassic to Cretaceous in age, was only partly correct. McLellan also distinguished a Turtleback Complex, a composite variety of granitoid, ultrabasic and volcanic rocks which he believed to be intrusive into Paleozoic sediments. Later workers restricted the definition of Turtleback Complex to granitoid and gneissic rocks which they believed to be a pre-Devonian basement (e.g. Vance, 1977, Danner, 1978). In addition they distinguished Devonian, Mississippian (?) Pennsylvanian and Permian sedimentary and volcanic rocks. Whetten et al. (1978) included in the Turtleback Complex intrusive, sedimentary and volcanic rocks and singled out a "Roche Harbor Terrane" that contains known Devonian and Permo-Pennsylvanian limestones, mixed with Turtleback rocks. The latter authors consider all rocks of San Juan Islands as imbricated slices of melange-terranes of various ages. Within such a structural framework the much deformed and disjointed Paleozoic rocks, mainly exposed on Orcas Island, seem to be correlative in lithology and age to the Sicker Group.

For instance, on the west coast of Orcas Island Pennsylvanian and (?) Permian as well as Devonian limestone have been identified with micro- and macrofossils (Danner, 1978). The limestones are associated with argillite, greywacke, siliceous tuff and breccia, and also pillow lava according to Danner's descriptions and the writer's own observations. They seem to be similar in lithology and age to the Buttle Lake and Myra formations, and perhaps the Nitinat Formation as well. On the northeast coast of Orcas Island, near Raccoon Point, argillite, siltstone, chert and calcarenite are exposed, a succession similar to the sediments of Nanoose Peninsula on Vancouver Island. Danner (1978) reported an Early Pennsylvanian microfauna from these beds and they appear to be correlative with the Buttle Lake Formation.

Turtleback Complex granitoid rocks are similar to those of Tyee Intrusions in general appearance and petrography. Although the few available U/Pb datings of Turtleback rocks yield numbers not greatly different from those of Saltspring Intrusion, their interpretation leads to an Ordovician age for the former (Whetten et al., 1978) as compared to a Late Silurian to Devonian age for the latter. McLellan (1927) reported small intrusions of rhyolite porphyry with vitreous phenocrysts of quartz in the Turtleback Complex of Orcas, Jones and Barren islands. These rocks, not referred to by later writers, are according to that description similar to Tyee quartz porphyry.

In summary the Paleozoic rocks of San Juan Islands, chiefly exposed on Orcas Island, are highly disrupted and may be a melange terrane as suggested by Whetten et al. (1978). However, the lithology and paleontological or isotopic ages are sufficiently similar to those of the Sicker Group to infer extension of the Vancouver Island Paleozoic terrane into San Juan Islands.

### *East Klamath Mountains*

The Shasta District of East Klamath Mountains (Kinkel et al. 1956; Albers and Robertson, 1961) is about 1000 km distant from central Vancouver Island. Although tectonic correlation between the two regions is uncertain they may have been in separate parts of the same Paleozoic volcanic belt. Both areas are distinguished by polymetallic massive sulphide deposits related to acid volcanism and extrusion or shallow intrusion of rhyolite and coarse grained quartz porphyry. In both regions too the acid volcanics are preceded by basic volcanics, largely converted to greenstone, and are followed by clastic and carbonate sediments with fossils indicating Pennsylvanian and Permian age (Table 1). Only in the Shasta District does Devonian limestone overlie the Balaklala Rhyolite, the ore-bearing formation of the West Shasta District. In the East Shasta District the broadly similar Bully Hill Rhyolite, considered to be of Triassic age, is also ore-bearing. No Triassic acidic arc-type volcanics are known from the Insular Belt. More detailed comparative studies of Paleozoic volcanic arc terranes of the western Cordillera are clearly required to elucidate their correlation and tectonic history. Such studies might also aid the exploration for massive sulphide deposits like those of Western Mines and the Shasta District.

Table 1

| Vancouver Island | Shasta District |
|---|---|
| Buttle Lake Formation: Bedded to massive calcarenite, crinoidal limestone. chert; calcareous siltstone; 150-450 m Middle Pennsylvanian to Early Permian | McCloud limestone: Thin- to thick-bedded fossiliferous limestone with chert nodules; 150-800 m Early Permian and (?) Late Pennsylvanian |
| Sediment-sill Unit: Bedded argillite, siltstone, chert; diabase sills | Kennett Formation: Siliceous siltstone, tuff; thick lenses of limestone in upper part; 0-12 m; Middle Devonian |
| Myra Formation: Bedded siliceous siltstone, argillite, rhyodacite tuff and breccia, quartz porphyry; 600-900 m Late Devonian to Early Mississippian | Balaklala Rhyolite: Porphyritic and non-porphyritic rhyolite and rhyolitic pyroclastic rocks; 300 m ± ; Middle Devonian |
| Nitinat Formation: Basaltic uralite-porphyry, agglomerate and pillow lava, actinolite-chlorite-albite schist | Copley Greenstone: Greenstone, keratophyre, pyroclastic rocks |

## STRUCTURE

The structure of the Sicker Group is the result of a complex tectonic history involving, folding, normal and transcurrent faulting and repeated intrusion. The general tectonic style and history has been defined broadly but has not been clarified in detail by recent investigation.

The oldest deformation apparently consisted of asymmetric folding. Thus the fold of Western Mines properties, mentioned in a foregoing section of this report, is an asymmetric southwest verging anticline with a near-vertical southwest limb and a moderately (± 30 degrees) dipping northeast limb. That type of structure is probably general throughout much of the Sicker Group. The structure in the Cameron-Nitinat area also indicates asymmetric, west to southwest verging folds. Further detailed mapping in that region, recently opened up by logging operations, might yield a more complete understanding of structural style. In the region north of Cowichan Lake, mapped in detail by Fyles (1955), areas exposed by logging at that time are now covered with underbrush but other areas have been opened up. Fyles also found asymmetrical, northwest trending folds with axial planes dipping southwest as well as northeast. Farther east, in coastal exposures near Maple Bay and on Saltspring Island, axial plane foliations have vertical, northeast, and southwest dips. Lineations on fold axes are generally well defined throughout the region and more or less horizontal. Refolding of these lineations and crenulations of axial plane cleavage are uncommon. Sediments of the Buttle Lake Formation do not exhibit the same degree of folding as the rocks of Nitinat and Myra formations but this may be a result of different lithology. Although the thick limestone sequences west of Buttle Lake and north of Horne Lake are almost flat lying, thinner beds of limestone south of Horne Lake and in the Museum Creek area appear to be closely folded together with underlying strata.

The Vancouver Group overlies the Sicker Group and also appears to be less intensely folded. In general the several thousand metres of basaltic lavas exhibit gentle monoclinal and domal structure. However, during recent fieldwork vertical, sheared sequences of Karmutsen pillow lava were noted that seemed to conform to the attitude of "underlying" Myra or Buttle Lake formations.

Two K-Ar datings on muscovite in phyllitic quartz porphyry (see section on K-Ar ages) have yielded Jurassic dates indicating dynamothermal metamorphism at that time. This substantial, and perhaps principal folding of the rocks concurrent with Jurassic plutonism, occurred long after their middle to late Paleozoic formation. An earlier orogeny, although inferred on circumstantial evidence (e.g. Muller, 1977) has actually not been documented.

Major faulting occurred in Tertiary time after deposition of Upper Cretaceous Nanaimo Group sediments. These rocks were substantially offset by northwest trending faults that can be traced more or less reliably for about 100 km. The Cowichan Lake Fault follows the north side of that lake, extends several branches westward to Alberni Inlet and eastward probably to Cowichan Bay, though partly obscured by Pleistocene deposits. The Cameron River Fault may extend from Horne Lake to Maple Bay but is not yet well defined in the upper Nanaimo River area. It separates what has been described as the northern and southern belt of Sicker Group rocks. Other northwesterly faults transect the basin of Nanaimo Group sediments. Northeastward thickening remnant wedges of Nanaimo Group sediments, abutting against the faults, demonstrate northeastward tilting of individual fault blocks. A set of northerly to north-northeasterly striking faults may predate in part the northwesterly ones but may be also related to them as second-order splays. Transcurrent movement probably occured on many of the faults but has not been demonstrated unequivocally. Northeasterly faults, particularly in the Cowichan Valley and Gulf Islands area, are late tear-faults that in several instances offset the northwesterly faults.

## POST-PALEOZOIC INTRUSIONS

Sicker Group rocks have been affected by several intrusive events. Tyee intrusions are the oldest and were probably emplaced in Devonian time, concurrently with deposition and extrusion of the Myra Formation. Diabase and gabbro are younger than Tyee Intrusions and were injected as dykes and sills, probably in conjunction with extrusions of Karmutsen basalt, in Late Triassic time. Island Intrusions are the result of Early Jurassic plutonism and formed elongate bodies of granodiorite, diorite and minor agmatite in Sicker Group and younger rocks. Lastly, light coloured sills and dykes of hornblende plagioclase porphyry were intruded in early Tertiary time and are especially abundant in Sicker Group rocks in the Cameron-Nitinat area.

## MINERAL POTENTIAL

The largest ore deposits known in the Sicker Group are the Western Mines Lynx and Myra properties, which in 1977 produced 632 075 g of gold, 34 909 727 g of silver, 2 856 881 kg of copper, 3 356 196 kg of lead, 18 607 822 kg of zinc and 72 139 kg of cadmium. Total production of the Mount Sicker mines, 1898-1907, was 1 107 285 g of gold, 22 954 974 g of silver and 8 653 780 kg of copper. Understandably many exploration programs have been conducted by various mining companies in the hope of finding other similar deposits. The two known deposits and adjacent mineral showings are now generally considered to be Kuroko-type exhalite massive sulphide deposits, related to the rhyolitic or rhyodacitic volcanics of the Myra Formation. Significant rock types are no doubt rhyolite and mixed breccias (Fig. 19, 20), quartz porphyries (Fig. 17, 18) and fine grained rhyolite. The coarse breccias are inferred to be close to the former volcanic vent and to the sulphides that issued from it.

To the writer's knowledge, they have only been found in the vicinity of Western Mines near Buttle Lake. The quartz porphyries and massive rhyolites, for a large part converted to quartz-sericite schist, were farther from the vent on the flanks of the volcano or intruded as sills in the substructure. Finer rhyolitic breccias and tuffs were deposited at considerable distance from the vent. Although ore deposits and rock types indicate the presence of a volcanic centre at Western Mines its location is obscured by severe deformation and has been interpreted in various ways. Far to the southeast the intrusive body of Saltspring Island may represent a lower structural level of another volcanic centre. Any sulphide deposits directly above this centre may have been removed by erosion but perhaps the Mount Sicker deposits, 25 km to the west, are distantly related to it. The China Creek area (Stevenson, 1945b) is about halfway between these two possible volcanic centres. It produced modest amounts of gold, silver and copper from Sicker Group volcanics and sediments. The deposits, generally described as vein deposits, may also be more remote products of volcanic exhalations. On the basis of present data it is suggested that geological and goephysical exploration with special emphasis on the three known centres of mineralization may yet discover additional ore reserves. However, the chance of finding an additional mineralized volcanic centre seems to be limited.

Brief mention should be made of manganese-bearing deposits in cherty tuffs of the Myra Formation. Most are located north of Cowichan Lake and these were investigated and described in detail by Fyles (1955). The deposits occur in the lower part of the Myra Formation, immediately above the "marker" horizon described by Fyles. They are in brick-red and pink jasper and cherty sediments of probable volcanogenic origin. Just a little over 1000 tons of ore averaging 50%-manganese was produced 1919-1920 from "Hill-60" north of Lake Cowichan. The manganese occurs in rhodonite, rhodochrosite and a manganese garnet, presumably formed out of primary sedimentary manganese oxides by thermal metamorphism. Some gem-quality rhodonite has been sold from a similar occurrence on Saltspring Island.

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## ADDENDUM

Two additional important data have become available since the preparation of this report.

From cherty rocks, interbedded with diabase 10 km SSW of Lake Cowichan (town), 48°44'25" N; 123°59'20" W, sample 79-42G, the following radiolaria were determined by E.A. Pessagno Jr. (University of Texas at Dallas):

**Albaillella** sp.

**Palaeoscenidium** sp.

**Cyrtentactinia** sp.

Pessagno concluded as follows: "Biostratigraphic determination. Mississippian: middle Kinderhookian to lower Meramacian. This determination is based on the first occurrence of **Albaillella** and the final occurrence of **Palaeoscenidum**. Fide Holdsworth." The cherts are part of the Sediment-Sill Unit.

From a limestone quarry 1/2 km past entrance East Main Road, West Fork of Cameron River, MacMillan Bloedel Cameron Logging Division; 49°10'10" N; 124°32'35" W, sample 78-31A. The following comments and determinations were made by B.L. Mamet (Université de Montréal):

Recrystallized bryozoan-echinoderm packstone. Chertified packstone. Extensive pressure solution. Some dolomitization. Rare calcareous sponges. Some pockets of sponge spiculites.

Apterrinellidae
**Biseriella**? sp.
**Bradyina** sp.
**Deckerella** sp.
**Endothyra** sp.
**Eolasiodiscus** sp.
**Globivalvulina** sp.
cf "**Hemigordius**" sp. (a new genus).
**Komia** sp.
**Nodosaria** sp.
Nodosariidae
**Orthovertella**
Porcellaneous foraminifers
**Protonodosaria** sp.
**Tetrataxis** sp.

Age. Presence of numerous nodosariids exclude possibility of a Carboniferous age. This is certainly Permian, (probably Early Permian)