British Columbia Geological Survey
Geological Fieldwork 1986

GEOLOGY OF THE COWICHAN LAKE AREA, VANCOUVER ISLAND* (92C/16)

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INTRODUCTION

The Paleozoic Sicker Group of Vancouver Island is host to several types of mineral deposits including polymetallic Kuroko-type massive sulphides such as Westmin Resource Ltd.'s Buttle Lake deposits. Much recent exploration activity has been concentrated in the Horne Lake-Cowichan uplift. With the initiation of 1:50 000 regional mapping by the Geological Survey Branch under the Canada/British Columbia Mineral Development Agreement, this area was selected for more detailed analysis than presently available. During the 1986 field season fieldwork was centred on the Cowichan Lake area (Figures 3-9-1 and 3-9-2). Access in the area is provided by an extensive network of logging roads in various states of upkeep. Roadcuts provide most of the exposure for mapping; rock units are poorly exposed under the thick forest cover or along creeks.

PREVIOUS WORK

The Sicker Group was first defined by Clapp (Clapp, 1912; Clapp and Cooke, 1917) as the Mount Sicker Series, although erroneously interpreted as younger than the Karmutsen Formation (Vancouver Series). Gunning (1931) recognized that the volcanics of the Sicker Group in the Buttle Lake area were older than the basalts of the Karmutsen Formation. This relationship was confirmed in the Cowichan Lake area by Fyles (1955), who also recognized the Buttle Lake limestone as the uppermost unit in the Sicker Group. Yole (1963, 1965, 1969), though principally concerned with the limestones, redefined the internal stratigraphy of the Sicker Group and made the first formal correlations between the Horne Lake-Cowichan and Buttle Lake uplifts. Muller and colleagues (Muller, 1982, 1985; Muller and Carson, 1968; Muller, Northcote and Carlisle, 1974) have extended mapping to all areas of Vancouver Island, formalizing stratigraphic nomenclature for Paleozoic (Sicker Group) and Mesozoic (Vancouver and Bonanza Groups) sequences. Detailed investigations of small areas around Duncan have been reported on by Eastwood (1979, 1980, 1982) and 1:50 000-scale mapping in the Alberni-Bamfield corridor was undertaken by the Geological Survey of Canada in support of the LITHOPROBE 1 Project (Sutherland Brown *et al.*, 1986). Biostratigraphic and radiometric dating of the rocks of southern Vancouver Island has been summarized by Muller and Jeletzky (1970), Brandon *et al.* (1986), and Armstrong *et al.* (unpublished preprint).

REGIONAL SETTING

The Cowichan Lake area lies on the southern flank of the Horne Lake-Cowichan uplift, one of a series of major geanticlines that make up the structural fabric of southern Vancouver Island (Figure 3-9-1). The area is underlain by all the formations typical of Wrangellia (Sicker Group, Vancouver Group and Bonanza Group) and its successor basin (Nanaimo Group). It lies between the two main study areas of the LITHOPROBE 1 Project.

STRATIGRAPHY

The oldest rocks in the Cowichan Lake area belong to the Paleozoic Sicker Group (Figure 3-9-3), which contains volcanic and sedimentary units ranging from Late Silurian to Early Permian in age. These are intruded by mafic sills, and overlain unconformably by basaltic volcanics of the Late Triassic Karmutsen Formation. Succeeding limestones, argillites and tuffaceous sediments of the Quatsino and Parson Bay Formations (which with the Karmutsen Formation make up the Vancouver Group) are conformably to disconformably overlain by marine sediments and marine to subaerial volcanics of the Early to Middle Jurassic Bonanza Group. All of these sequences have been intruded by granodioritic stocks of the Middle Jurassic Island intrusions. Late Cretaceous sediments of the Nanaimo Group lie unconformably on the older sequences.

SICKER GROUP

Since the initial definition of the Sicker Group by Clapp (1912), there have been several attempts at subdivision into formations. The most recent was that by Muller (1980), who proposed four subdivisions. In ascending stratigraphic order they are the Nitinat Formation, the Myra Formation, an informal sediment-sill unit, and the Buttle Lake Formation. Recent paleontological and radiochronological studies (Brandon *et al.*, 1986), coupled with newer mapping (Sutherland Brown *et al.*, 1986; Sutherland Brown and Yorath, 1985), has thrown some doubt on these subdivisions and their applicability in the Horne Lake-Cowichan uplift. Division is also hampered by the lack of significant, laterally continuous marker units, making correlation between fault slices often impossible. Consequently, formal stratigraphic subdivisions are avoided in this project for the time being. The thickness of the Sicker Group, or any of its constituent parts, is very difficult to determine due to repetition by folding and faulting, but must be at least 1500 metres.

Within the Cowichan Lake area, the lowermost unit in the Sicker Group is a volcanic package characterized by pyroxene-feldspar porphyritic agglomerates, breccias, lapilli tuffs and crystal tuffs. Pyroxenes are large, up to 3 centimetres diameter, euhedral to subhedral, and vary from 5 to 20 per cent of the rock. Plagioclase is equally abundant, but phenocrysts are usually smaller, ranging up to 1 centimetre. Clasts in coarser pyroclastics are frequently amygdaloidal with chlorite, quartz or calcite infillings. Pillowed and massive flows are also found, both aphyric and porphyritic. Minor laminated tuff and tuffaceous sandstone are present locally. This volcanic unit is probably equivalent to the Nitinat Formation of Muller (1980).

The volcanic unit is overlain, apparently conformably, by a sequence of volcaniclastic sediments and minor volcanic rocks. A variety of lithologies are developed including thickly bedded, massive tuffaceous sandstones and lithic sandstones with interbedded laminated sandstone-siltstone-argillite. Breccias and lapilli tuffs are usually heterolithic and include aphyric and porphyritic lithologies, commonly mafic to intermediate in composition, though some minor felsic tuffs were observed. Pyroxene-bearing breccias may be

* This project is a contribution to the Canada/British Columbia Mineral Development Agreement.

British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1986, Paper 1987-1.

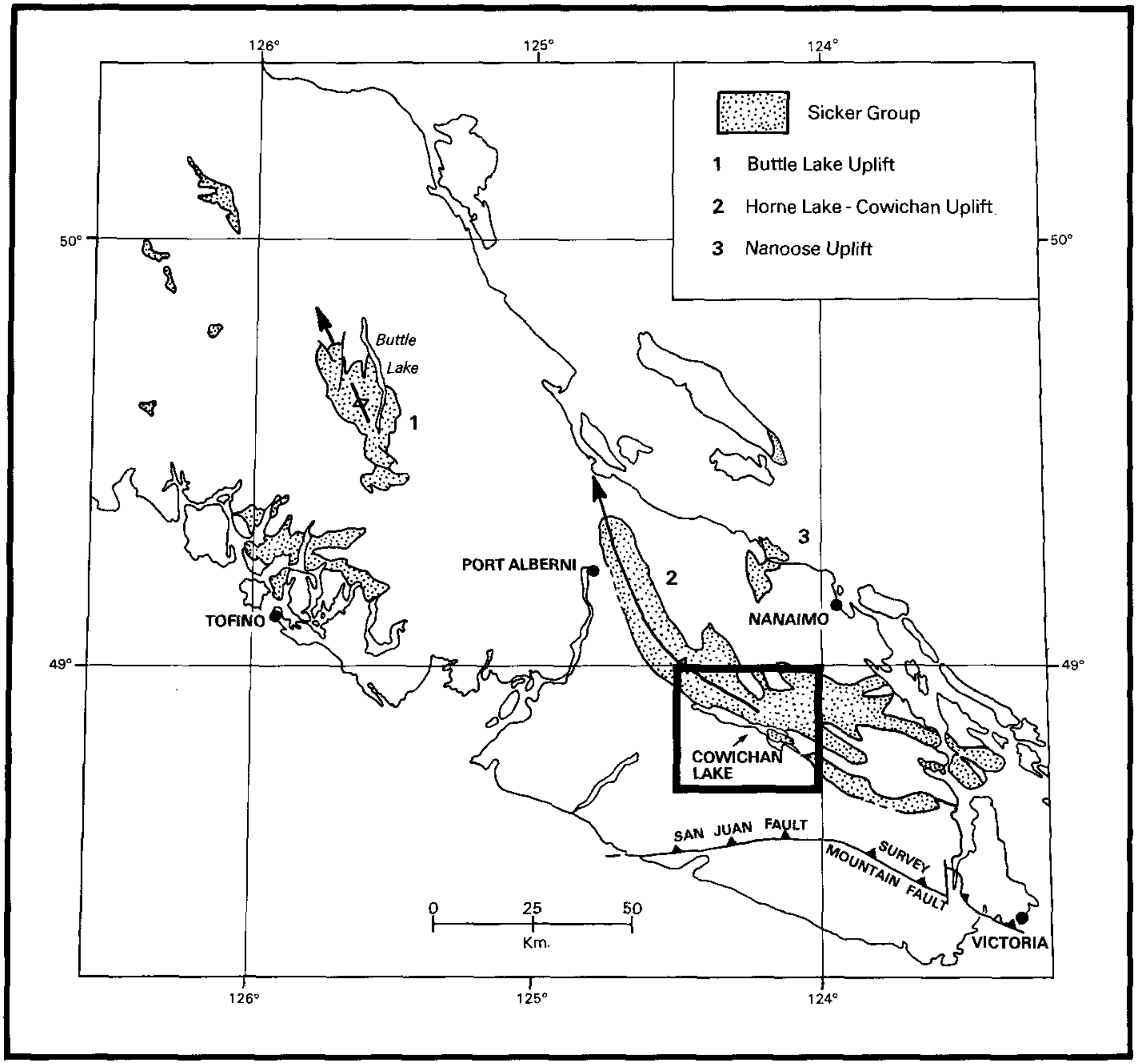

Figure 3-9-1. Location of the Cowichan Lake area, southern Vancouver Island, in relation to the three major geanticlinal uplifts cored by Sicker Group rocks (after Brandon *et al.*, 1986).

interbedded with tuffaceous sandstone in the lower part of the sequence, forming a transition zone into the underlying volcanics.

The upper part of the Sicker Group is made up of a dominantly epiclastic sedimentary package. This unit is often found directly in faulted or, more commonly, unconformable contact with the volcanics. *The base of the sedimentary unit is marked by a 100 to 200-metre-thick sequence of ribbon cherts, laminated cherts and cherty tuffs that constitutes the only marker horizon in the area.* It passes upwards into thinly bedded, turbiditic sandstone-siltstone-argillite intercalations. Thicker beds of sandstone, granule sandstone, breccia and conglomerate are also found, containing clasts of cherty material, volcanic-derived lithic clasts and feldspar and pyroxene crystals. Crinoidal calcarenite and calcirudite with chert clasts and interbeds occur in the Mount Franklin area as a fault-bounded block. They are overlain by thinly bedded cherty sediments. Similar bioclastic calcarenites, with porcellaneous micrite and tuffaceous limestone interbeds, also occur on the north side of Bald Mountain and Marble Bay where they form the top of the Sicker Group, and are directly overlain by Karmutsen Formation basalts. These limestone units are the equivalents of the Buttle Lake limestone of Muller (1980) and other authors.

VANCOUVER GROUP

KARMUTSEN FORMATION

The Karmutsen Formation consists essentially of basaltic flows that typically weather orange-brown. They generally form rounded bluffs and hills. Pillowed and massive flows occur interbedded, though there is a tendency for massive flows to be dominant toward the top of the formation and pillowed flows in lower parts.

Hyaloclastite, hyaloclastite breccia and pillowed breccia occur within pillowed sections, and may also be interbedded with massive flows. Lithologically the flows are dark grey, variably feldspar-phyric basalts. Feldspars are typically clumped and rarely single crystals. Coarser, glomeroporphyritic "daisy-flows" and hyaloclastite breccia are commonly seen at the top of the pile. Nearly all flows are amygdaloidal. The total thickness of the Karmutsen Formation in the area is difficult to estimate but is believed to be at least 2500 metres.

North of Cowichan Lake, a number of thick, massive, medium to coarse-grained diabase and gabbro sills intrude the Sicker Group sediments. They are equigranular to porphyritic, with feldspar phenocrysts often being glomeroporphyritic. These mafic intrusives are probably equivalent in age to the Karmutsen Formation volcanics that occur mainly to the south of the lake.

QUATSINO FORMATION

The Quatsino Formation is characterized by massive, thickly bedded, micritic limestone. It is fine grained, black in colour and often cut by a dense network of white sparry calcite veins. Weathered surfaces are grey and rough in texture due to secondary silica. Karst landforms are well developed. The micritic limestone is essentially unfossiliferous, but bioclastic micrite, oolitic limestone, calcirudite and calcarenite may occur locally.

The contact between the Karmutsen and the Quatsino Formations is often transitional with micritic limestones interbedded with massive flows and hyaloclastite breccias containing limestone clasts. A distinctive brick-red tuffaceous breccia or tuffaceous sandstone underlies the lowermost limestone in the Caycuse area. The Quatsino Formation is estimated to be no more than 75 metres thick, averaging 25 to 40 metres. It may be absent in some areas.

PARSON BAY FORMATION

In the Caycuse area the Quatsino Formation is immediately overlain, apparently conformably, by a 35-metre-thick sequence of thinly bedded sediments provisionally correlated with the Parson Bay Formation. The lowermost unit is a pale grey to maroon tuff and tuffaceous sandstone. It is overlain by flaggy limestone and limy argillites, with abundant ammonite, gastropod and pelecypod remains. This unit grades vertically into thinly bedded argillites with minor fossiliferous limestone interbeds. Maroon tuffs with flaggy sandy limestone and biohermal limestone ascribed to the Parson Bay Formation (Sutton Limestone Member) are also found on the

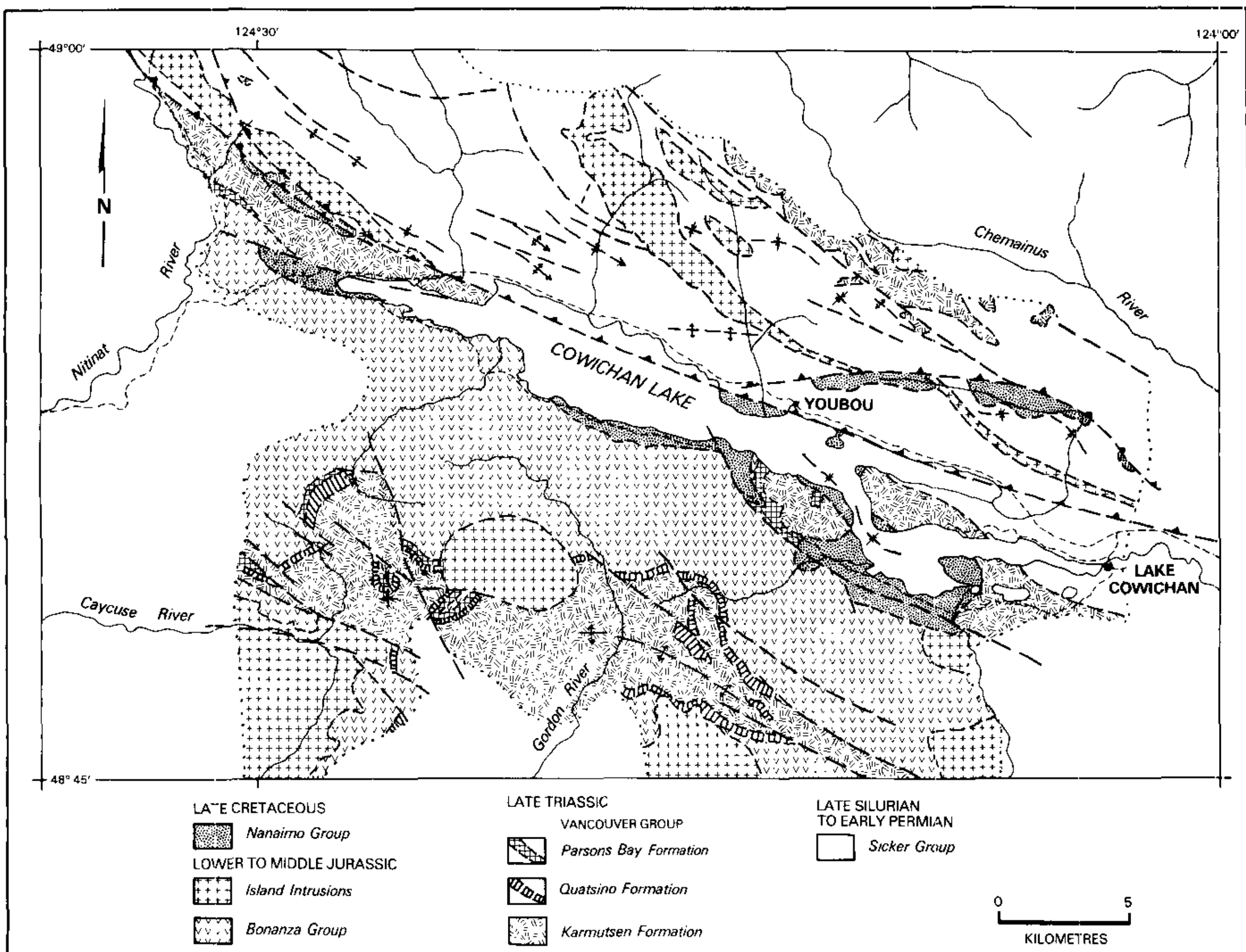

Figure 3-9-2. Geology and structure of the Cowichan Lake area.

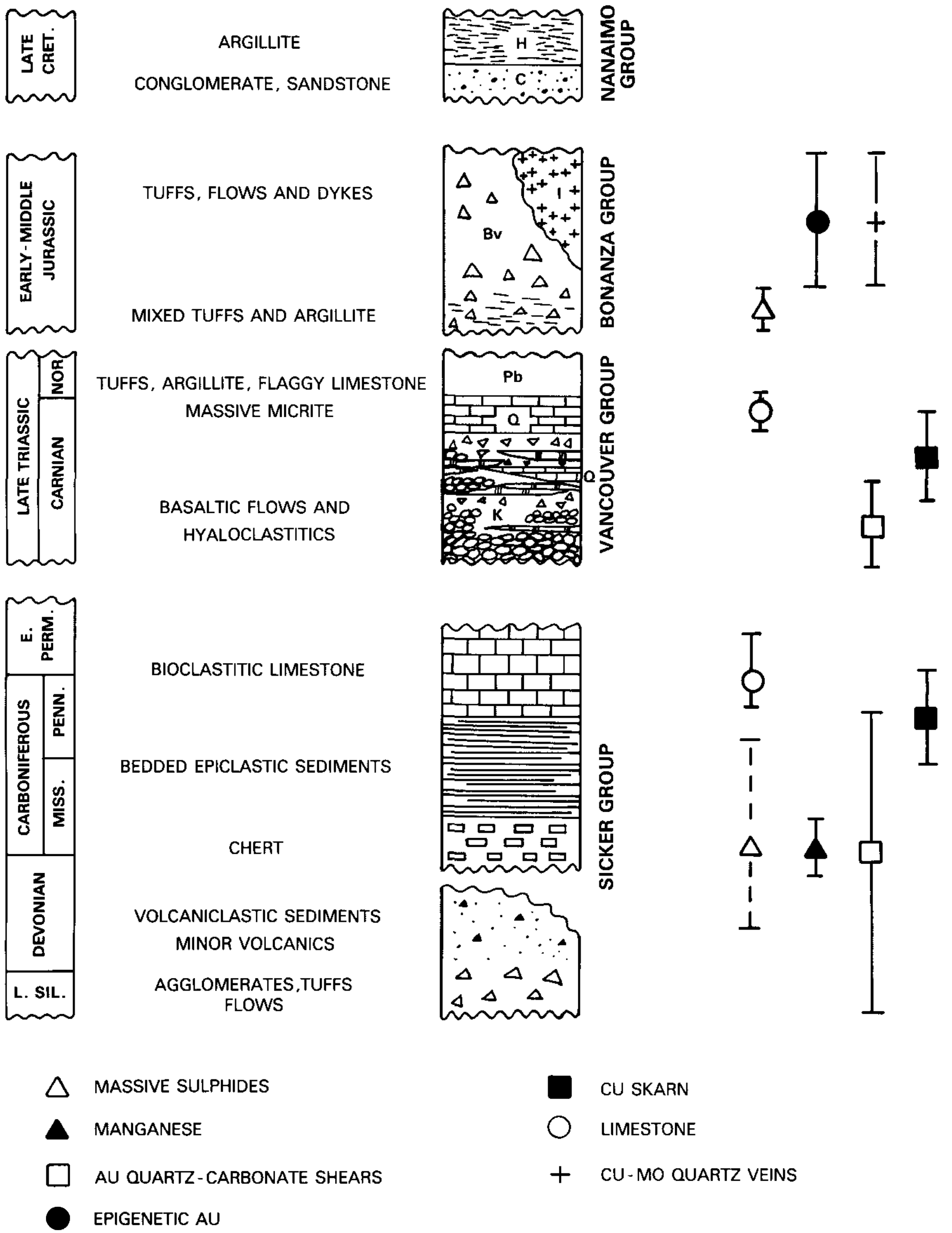

Figure 3-9-3. Diagramatic stratigraphic section, not to scale, of the Cowichan Lake area (K = Karmutsen Formation; Q = Quatsino Formation; P = Parson Bay Formation; Bv = Bonanza Group; I = Island intrusions; C = Comox Formation; H = Haslam Formation). Stratigraphic distribution of mineral potential is illustrated on the right.

south shore of Cowichan Lake, northwest of Blue Grouse Mountain. Here they rest directly on Karmutsen Formation flows.

BONANZA GROUP

Unlike northern Vancouver Island, where the Bonanza Group can be subdivided into a lower sedimentary unit (Harbledown Formation) and an upper volcanic unit (Bonanza Volcanics) (Muller *et al.*, 1974), no subdivision is yet possible in the Cowichan Lake area. The Bonanza Group consists of a variety of maroon to green-grey, feldspar-phyric basalt and andesite flows, lapilli and crystal-tuffs, feldspar-hornblende andesite flows, dacite and felsic lapilli tuff, and various minor basalt, andesite and dacite dykes. There is a lack of lithologic continuity between outcrops and distinctive marker beds are absent.

Within the basal part of the sequence, sedimentary beds are found interbedded with lapilli and crystal-tuffs. They include maroon tuffaceous sandstone, orange-grey sandstone, granule sandstone and conglomerate, laminated sandy tuffs and argillites, and minor limestone and chert. Several beds have yielded macrofossil remains (gastropods, pelecypods and ammonites). Unfortunately none of the sediments appear to have any great lateral extent.

Rapid facies changes and poor stuctural control make estimates of thickness very uncertain. However, the Bonanza Group is estimated to be at least 1000 metres thick.

NANAIMO GROUP

Clastic sediments of the Nanaimo Group unconformably overlie older volcanic units and the Island intrusions. They outcrop mainly around the shores of Cowichan Lake, but are also preserved in fault-controlled valleys to the north of the lake, for example Meade Creek. The sediments constitute a major fining-upwards cycle, with conglomerates and sandstones of the Comox Formation succeeded by argillites of the Haslam Formation.

COMOX FORMATION

Basal sediments of the Comox Formation are usually coarse, poorly bedded cobble and boulder conglomerates which pass upwards into moderately to well-bedded sandstones, with interbedded pebble and granule conglomerates. Conglomerates have rounded clasts, although larger boulders are often angular. They are polymictic, including a variety of volcanic and intrusive lithologies generally of local origin. Sandstones are medium to coarse grained, grey with rusty weathered surfaces. They contain feldspar crystals and abundant lithic fragments, mostly volcanic of local provenance. Black plant fragments are characteristic of many beds. Occasionally calcareous concretions are developed with internal structure matching the enclosing sandstone and differing only in the calcareous cement. Many sandstones, and a few granule and pebble conglomerate beds, yield abundant fossil faunas, including gastropods, pelecypods, echinoderms, and nautiloids. The thickness of the Comox Formation is estimated to vary from 0 to 200 metres.

HASLAM FORMATION

The Haslam Formation consists of a characteristic rusty weathering, black argillite. It is fine to silty, poorly bedded, and friable, fracturing to pencil-shaped pieces. Calcareous nodules are common, averaging 10 to 15 centimetres but ranging up to 1 metre. Fossils are present but usually poorly preserved due to fracturing. Occasional interbeds of fine to medium-grained, grey silty sandstone are found within the argillites. They vary up to 1 metre thick and are massive to flaggy. The thickness of the Haslam Formation is estimated to vary from about 50 to 400 metres.

INTRUSIONS

ISLAND INTRUSIONS

Several granodioritic stocks occur in the area. They are coeval with the Bonanza Group volcanics, although they intrude all Paleozoic and Mesozoic formations. The stocks are irregular to elongate in shape with steep sides. The major lithology is a medium to coarse-grained, equigranular granodiorite to quartz diorite with a characteristic "salt-and-pepper" texture. Feldspars are white, though some pink staining is seen on weathered surfaces. Hornblende is the principal mafic mineral. It is usually tabular to acicular, black to green-black in colour and may be slightly larger in size than the feldspars. Biotite is only rarely observed. Chlorite replaces hornblende in altered rocks. Colour index varies from 10 to 20 in the granodiorites, but may range up to 40 in diorites. White, fine-grained aplite dykelets and veins crosscut the granodiorites.

Most of the stocks are rich in mafic inclusions, particularly in marginal zones were agmatitic intrusive breccias are developed. The angular to subrounded xenoliths are of local country rock lithologies. They show a range of amphibolitization and assimilation features. Complete assimilation results in gabbro-diorite with ragged mafic clots that may also contain inherited pyroxenes with white reaction rims.

Stocks north of Cowichan Lake have an elongate outcrop pattern, often with different stratigraphic units on either side, as with the Mount Buttle-Meade Creek stock. This suggests that the emplacement of granodiorite was controlled by pre-existing structures such as faults and possibly the axial regions of anticlinal folds. Stocks intruded into the Mesozoic sequences to the south of Cowichan Lake are more rounded in outcrop shape.

MINOR INTRUSIONS

Several lithologies are found as dykes and small irregular intrusions. Ages are not always known and can only be surmised until radiometric evidence is available. Many of these minor intrusions are probably of Jurassic age and related to Bonanza Group volcanics and Island intrusions. These include intermediate feldspar porphyry, feldspar-pyroxene porphyry, hornblende-feldspar andesite and minor diabase. Some of the porphyritic andesite dykes may be Tertiary in age.

Feldspar-quartz porphyry intrudes Sicker Group rocks and may be contemporaneous. It contains abundant white subhedral feldspars and sparse quartz in a dark green-grey to black aphanitic matrix. Coarse pyroxene-feldspar dykes, similar to Sicker Group porphyritc flows and agglomerates, intrude the area north of Cowichan Lake. Though some are probably of Sicker age, they are difficult to separate lithologically from the Jurassic pyroxene-feldspar porphyries.

Abundant diabase and feldspar diabase dykes of Late Triassic age intrude Sicker Group rocks and crosscut Karmutsen Formation volcanics. They vary in width from centimetres to 50 metres.

STRUCTURE

The area is divided into two regions of differing structural style by a major thrust fault running along the north side of Cowichan Lake. The northern region is underlain by Sicker Group rocks forming the southwest limb of the Horne Lake-Cowichan uplift. It is cut into several slices by a set of west-northwesterly trending faults paralleling the Cowichan Lake thrust, a high-angle contraction fault with a north-northeasterly dip of 65-80 degrees. Schistosity may be developed parallel to the fault in hangingwall rocks and extend over a zone of some 100 metres. Smaller shears to the northeast of the main fault have similar steep north-northeasterly dips and may represent minor imbrication planes in the hangingwall. Other major faults in the northern region are also suspected to be contractional, although, except for the Meade Creek fault, evidence is inconclusive. The thrusting involves Nanaimo Group strata dating it at Late Cretaceous to Tertiary. Pre-Jurassic faulting events are also suspected and may have exercised control on the emplacement of Island intrusions. Whether these earlier faults are extensional or contractional is unknown.

The Sicker Group rocks within the fault slices are deformed by a series of northwesterly trending folds. Where the plunges of the folds can be determined they are generally to the east-southeast. The folds are upright and overturning is very rare. They appear to predate the Island intrusions, though some tightening of the folds may have accompanied the thrusting event.

Pre-Nanaimo Group sequences south of Cowichan Lake form a syncline-anticline pair plunging to the northwest. Small crossfolds are also developed but are only defined where suitable bedded strata are seen. Northwest-trending faults parallel the major folds and may be related to the same deformational event. Nanaimo Group sediments are unconformable on the older sequences and appear to have been deposited in structurally controlled topographic lows. Compression accompanying the Late Cretaceous-Tertiary thrusting event reactivated some of these faults and folded the Nanaimo Group.

METAMORPHISM

Metamorphic grade in the area is generally quite low, but increases with the age of the rocks. Bonanza Group rocks are veined and show minor replacement by laumontite, stilbite, calcite and minor quartz, assemblages typical of the zeolite facies. Basalts of the Karmutsen Formation show amygdule infillings and veins of chlorite, calcite, epidote and quartz. Similar assemblages are found in Sicker Group rocks. Contact metamorphism of the hornblende hornfels facies is locally developed around Island intrusion stocks, particularly in the McKay Creek area.

MINERAL DEPOSITS

No mines are presently active in the Cowichan Lake area, although several small deposits have been worked in the past. However, exploration is very active, particularly in areas underlain by the Sicker Group. Several types of mineral deposit (Figures 3-9-3 and 3-9-4) are present:-

(1) **Volcanogenic, gold-bearing massive sulphides** — These are the principal target in the Sicker Group rocks following the success of exploration at the Buttle Lake mine. The relatively poor development of felsic volcanics in the Sicker Group of the Cowichan Lake area may mitigate against repeating such finds, although sulphide-rich argillite is found interbedded with cherts. Potential for auriferous massive sulphides may also exist within the Bonanza Group volcanics; sulphidic argillites are found interbedded with tuffs in the basal part of the sequence in the Nixon Creek area.

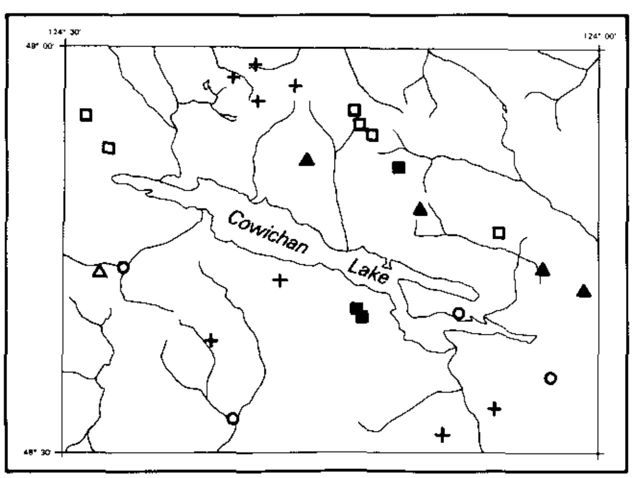

Figure 3-9-4. Distribution of mineral occurrences in the Cowichan Lake area. Symbols for mineral types as in Figure 3-9-3.

(2) **Manganese deposits** — Manganese minerals are found in lenticular masses in several places in the cherts of the Sicker Group. Rhodonite is the primary manganese mineral; manganese garnets, rhodochrosite and manganite have also been reported. Oxidized deposits near Hill 60 were worked for manganese ore in 1919-20, but the main potential for these deposits is for lapidary uses. Reported localities (with MINFILE designation) are Rocky-Widow Creek (113), Wardroper (114), Meade (115) and Stanley Creek-Lookout locality (116).

(3) **Gold-bearing, pyrite-chalcopyrite-quartz-carbonate veins along shears** — Many of the faults and shears cutting the Sicker Group and Karmutsen Formation sills north of Cowichan Lake are veined by rusty weathering quartz-carbonate. The veins vary in thickness up to about 1 metre, and are very variable in lateral extent. The carbonate is principally ankerite and calcite. Sulphides are common with pyrite, pyrrhotite, chalcopyrite and arsenopyrite reported. Occurrences investigated in the past include El Capitan (19), Cottonwood (20), Silver Leaf (21), Paint Pot (43) and Candy (76).

(4) **Epithermal gold-silver deposits** — Bonanza Group volcanics are intruded by abundant shallow and medium-level intrusives. This may have been favorable for the formation of epigenetic precious metal deposits. Faulting and fracturing of the rocks are ubiquitous, though usually accompanied by zeolite alteration only. At present the prospecting level within the Bonanza Group is low and an adequate assessment cannot be made.

(5) **Copper skarns** — Zones of chalcopyrite-bearing skarn have been worked at two localities. The Blue Grouse (17) and neighbouring Sunnyside (108) properties are underlain by Karmutsen Formation basalts and Parson Bay sediments, cut by numerous Jurassic feldspar and feldspar-pyroxene porphyry dykes. Skarns are developed in limy sediments apparently interbedded with the basalts. Garnet, epidote and actinolite occur as gangue in the skarn. On the Comego property (18), skarns are developed in Sicker Group sediments intruded by Karmutsen Formation diabase sills. However, mineralization may be related to the nearby Jurassic Reynard Creek stock. Chalcopyrite is accompanied by pyrite, pyrrhotite, magnetite and minor molybdenite. Quartz, calcite and garnet are the main gangue minerals. Other skarn occurrences are known in the area, especially in the area south of Cowichan Lake, but in general skarns have little economic potential today.

(6) **Limestone** — Limestones of the Sicker Group (Buttle Lake limestone) and the Quatsino Formation have been exploited for cement manufacture elsewhere on Vancouver Island. Although both limestones have been prospected within the map area [Buttle Lake limestone on Fairservice Creek (15) and Marble Bay (16) properties; Quatsino Formation in Gordon River (86) and Nixon Creek (87) areas], none have been worked.

(7) **Copper-molybdenum quartz veins** — Sulphide-bearing quartz veins occur in granodiorite and adjacent country rock on several properties. Chalcopyrite and pyrite, with or without molybdenite, are the principal sulphides; minor sphalerite, galena and arsenopyrite are also reported. Veins

are usually less than 1 metre wide. Reported prospects are Delphi (13), Mount Buttle-Allies (14), Lorry (35), Viking (42), Paget (46), AB (75) and Close (112).

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