GEOLOGY OF THE CHEMAINUS RIVER–DUNCAN AREA, VANCOUVER ISLAND*
(92C/16; 92B/13)

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KEYWORDS: Regional geology, Vancouver Island, Sicker Group, McLaughlin Ridge Formation, Karmutsen Formation, Nanaimo Group, Cowichan uplift, thrusts, massive sulphides, rhodonite, gold.

INTRODUCTION

In 1986, a program of 1:50 000-scale regional mapping was initiated by the Geological Survey Branch in southern

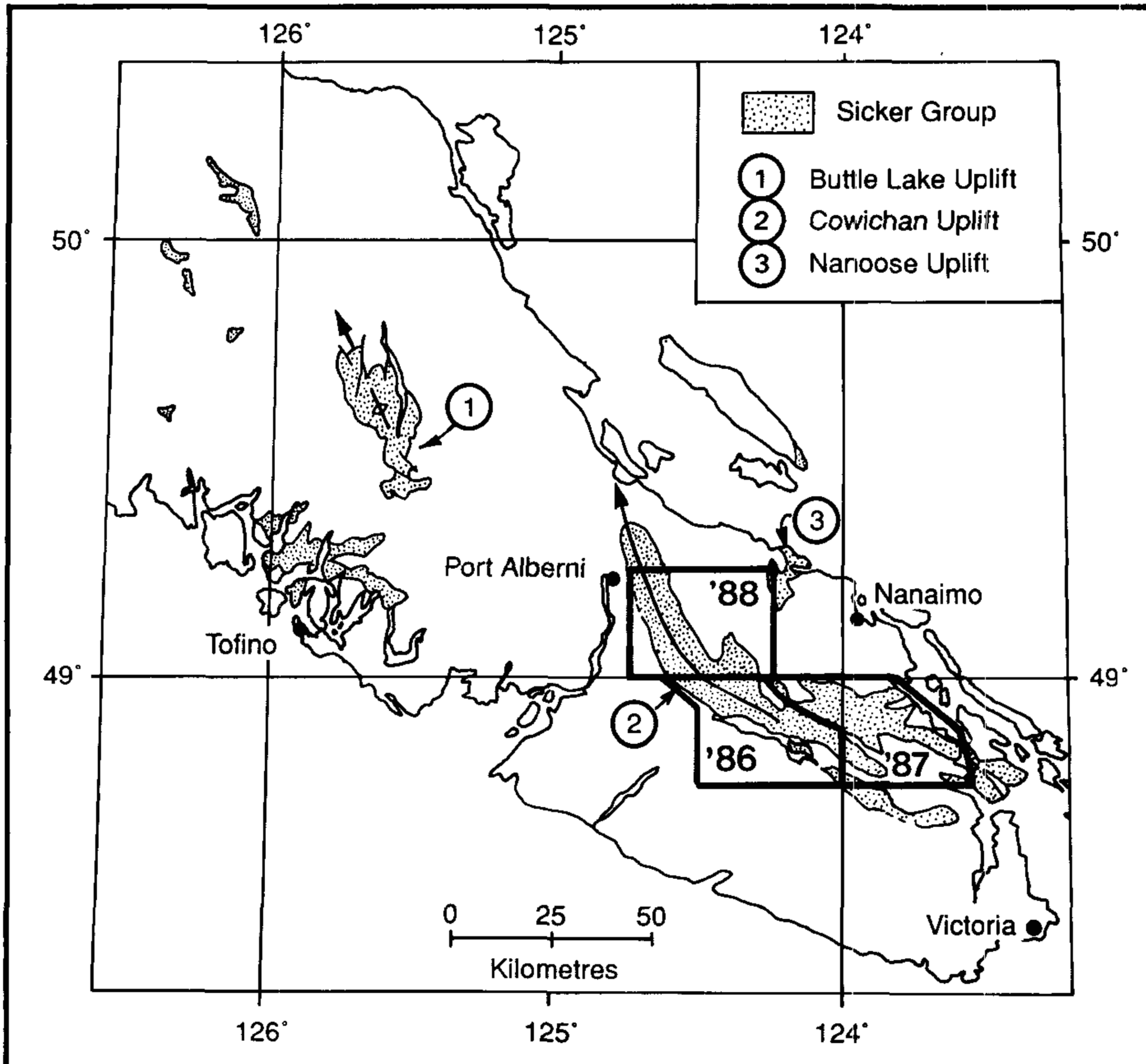

Figure 1-6-1. Location of the Sicker Project area, southern Vancouver Island, in relation to the three major geanticlinal uplifts cored by Sicker Group rocks (after Brandon *et al.*, 1986). Planned field seasons are indicated.

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British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1987, Paper 1988-1.

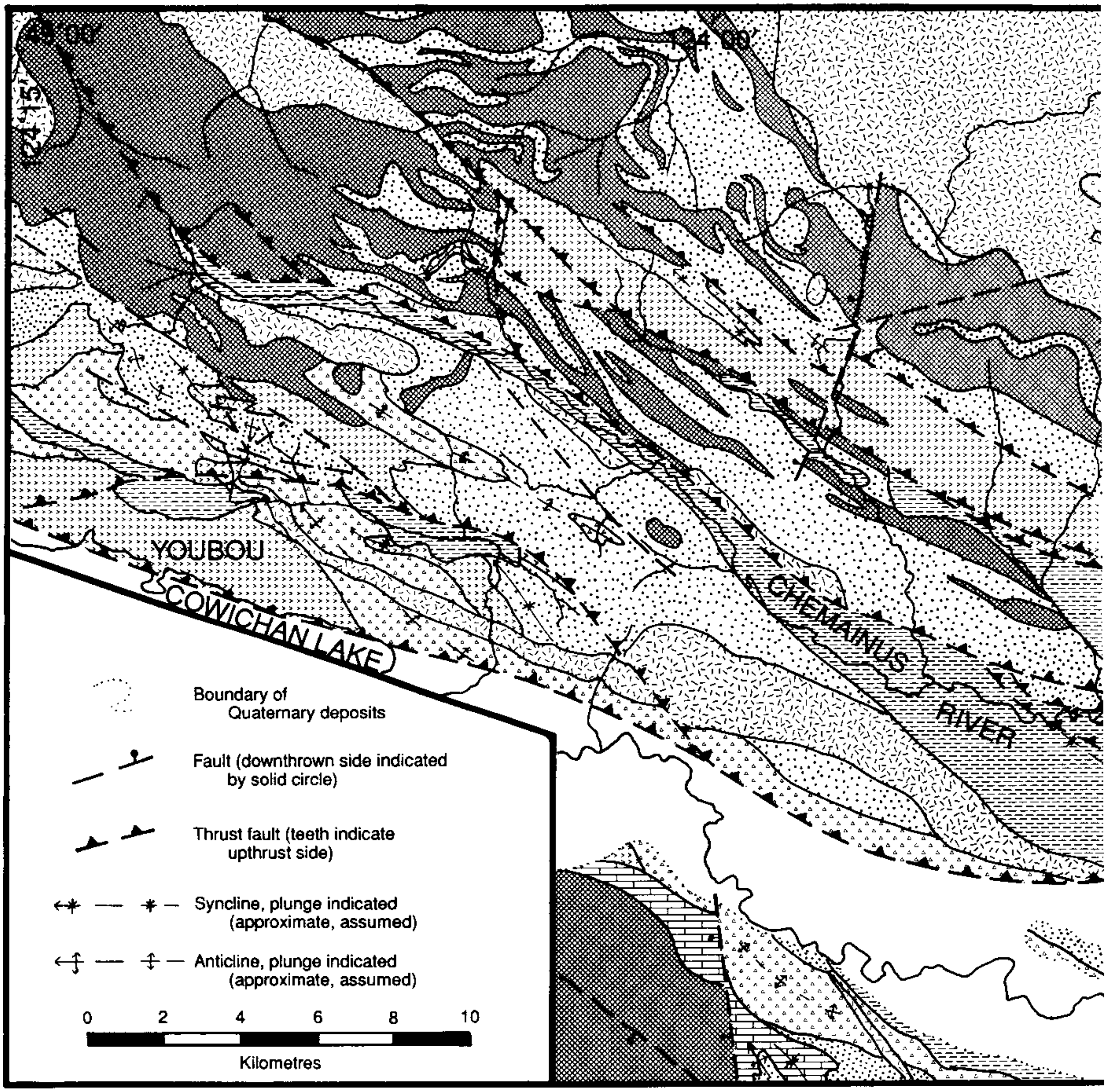


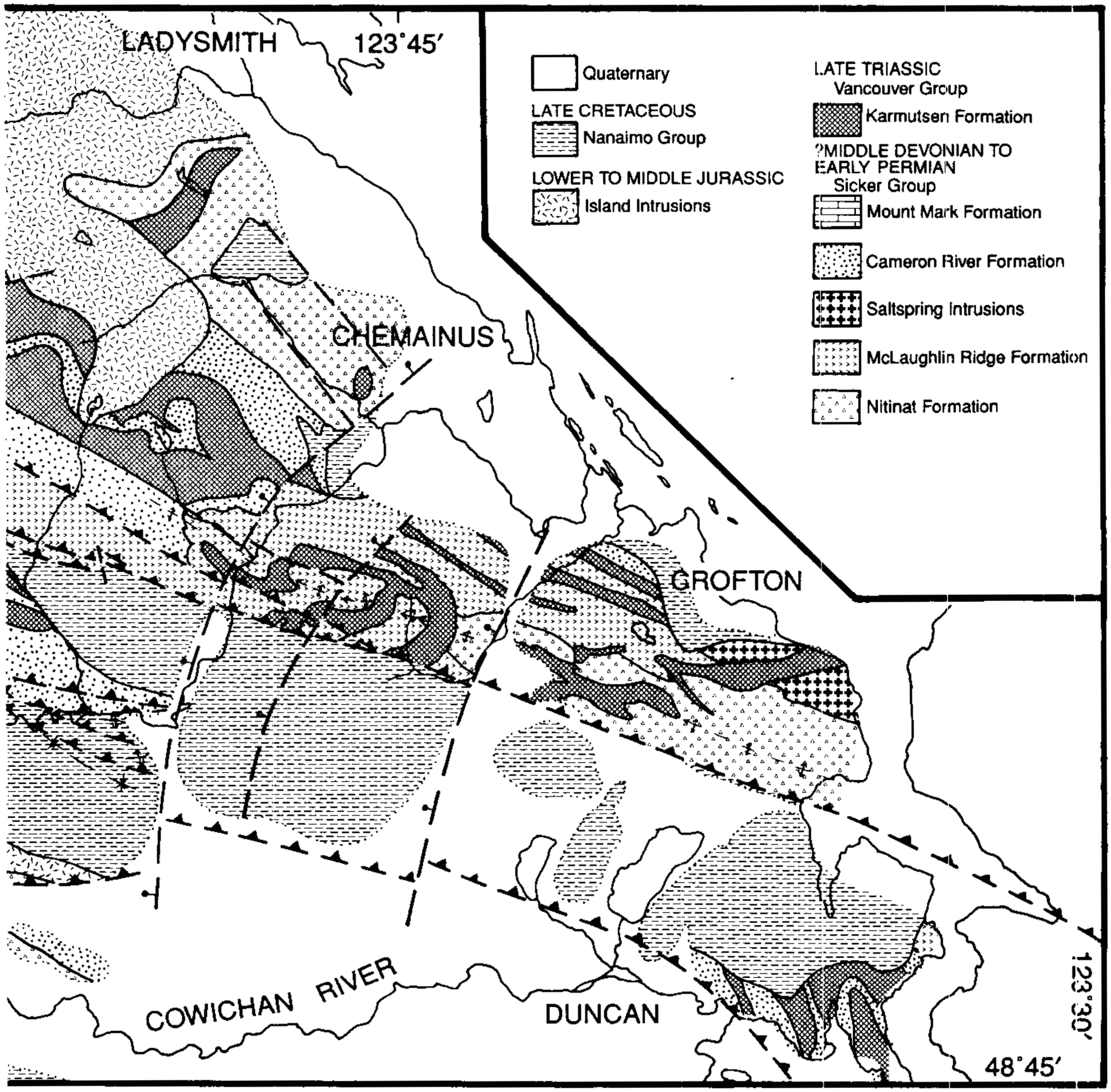
Figure 1-6-2. Geology and structure of the Duncan and Chemainus River areas (see also facing page).

Vancouver Island, emphasizing the Paleozoic Sicker Group. A 4-year program was planned, covering three 1:50 000 NTS sheets centred on the main Sicker Group outcrop area within the Cowichan uplift (Figure 1-6-1). Initial mapping in the Cowichan Lake area (92C/16) was reported on last year (Massey and Friday, 1987) and released as Open File 1987-2 (Massey *et al.*, 1987).

During the 1987 field season, fieldwork was extended into the northeastern quadrant of the Cowichan Lake sheet and eastwards into the Duncan map sheet (92B/13), excluding the Gulf Islands. Road access in the area is excellent with the main Island Highway running northwards through the eastern margin of the area. Many other paved roads are present in the east and south within the municipalities of North Cowichan and Ladysmith. Access to the western half of the area is provided by an extensive network of logging roads in various states of upkeep. Shoreline exposures are easily accessible by boat.

PREVIOUS WORK

The Sicker Group was first defined as the Mount Sicker Series by Clapp (Clapp, 1912; Clapp and Cooke, 1917) within the Duncan area, although erroneously interpreted as



younger than the Karmutsen Formation (Vancouver Series). Later workers in the Buttle Lake and Cowichan Lake areas recognized that the Sicker Group is indeed older (Gunning, 1931; Fyles, 1955). Muller and colleagues mapped large portions of Vancouver Island including the Duncan and Cowichan areas (Muller, 1982, 1985). Detailed investigations of small areas around Duncan have also been reported on by Eastwood (1979, 1980, 1982).

Stratigraphic studies of the Sicker Group were conducted by Yole (1964, 1965, 1969) and Muller (1980). A major revision of the stratigraphy of the Sicker Group of the Cowichan uplift has been suggested by Sutherland Brown, based on 1:50 000-scale mapping in the Alberni-Bamfield corridor undertaken by the Geological Survey of Canada in support of the LITHOPROBE 1 Project (Sutherland Brown and Yorath, in preparation; Sutherland Brown *et al.*, 1986). A similar revision has also been made, independently, by Juras in the Buttle Lake uplift (Juras, 1987). 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 Chemainus River–Duncan area straddles the eastern end of the Cowichan uplift, one of a series of major geanticlines typical of the structural fabric of southern Vancouver Island (Figure 1-6-1). The area lies within the Wrangellia terrane which on Vancouver Island comprises three thick volcano-sedimentary cycles (Paleozoic Sicker Group, Upper Triassic Vancouver Group and Jurassic Bonanza Group) overlapped by Upper Cretaceous sediments of the Nanaimo Group.

STRATIGRAPHY

The oldest rocks in the area belong to the Paleozoic Sicker Group (Figure 1-6-2) which contains volcanic and sedimentary units ranging in age from Middle Devonian (?) to Early Permian. These are intruded by mafic sills coeval with overlying basaltic volcanics of the Late Triassic Karmutsen Formation. All of these sequences have been subsequently 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 work of Clapp (1912) there have been several attempts to formally subdivide the Sicker Group. Muller (1980) proposed four subdivisions which, in ascending stratigraphic order, 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), have thrown some doubt on these subdivisions and their applicability in the Cowichan uplift. New stratigraphic subdivisions have been proposed by Sutherland Brown (in preparation) based on work in the Alberni area. These formational subdivisions have proven to be applicable in the Cowichan Lake and Duncan areas also and have been adopted for this project.

NITINAT FORMATION

The lowermost unit in the Sicker Group is a volcanic package characterized by pyroxene-feldspar porphyritic basaltic andesites, typically occurring as agglomerates, breccias, lapilli tuffs and crystal tuffs. However, extensive pyroxene-phyric, amygdaloidal flows are developed in the Banon Creek area. Pyroxenes are large, up to 1 centimetre diameter, are euhedral to subhedral, and comprise 5 to 20 per cent of the rock. Plagioclase is equally abundant, but phenocrysts are usually smaller, ranging up to 5 millimetres in diameter. Amygdules present in flows and some clasts in coarser pyroclastics are infilled with chlorite, quartz, epidote or calcite. Minor laminated tuff and tuffaceous sandstone are present locally. Massive and pillowed aphyric and diabasic mafic flows are also developed, particularly on the north slope of Coronation Mountain and Fairservice Mountain.

This volcanic unit is equivalent to the Nitinat Formation of Muller (1980).

MCLAUGHLIN RIDGE FORMATION

The Nitinat Formation is overlain, apparently conformably, by a heterogeneous sequence of intermediate to felsic volcanics and volcaniclastic sediments. In the Alberni and Cowichan Lake areas, the McLaughlin Ridge Formation is characterized by the development of thickly bedded, massive tuffites and lithic tuffites with interbedded laminated sandstone, siltstone and argillite. Associated breccias and lapilli tuffs are usually heterolithic and include aphyric and porphyritic (feldspar ± pyroxene ± hornblende) lithologies, commonly mafic to intermediate in composition. Felsic tuffs are rare.

However, within the Duncan area, the McLaughlin Ridge Formation is dominated by volcanics with only minor tuffaceous sediment. The volcanics are predominantly intermediate to felsic pyroclastics, commonly feldspar crystal-lapilli tuffs and heterolithic lapilli tuffs and breccias. A thick package of quartz-crystal, quartz-feldspar-crystal and fine dust tuffs is developed in the Chipman Creek–Mount Sicker area and is host to polymetallic sulphide mineralization. This package thins to the west where it interfingers with andesitic lapilli tuffs and breccias. It appears to be stratigraphically high within the formation. A distinctive maroon schistose heterolithic breccia and lapilli tuff forms the uppermost unit within the McLaughlin Ridge Formation and is seen in the Chipman Creek–Rheinhart Creek area. Most contacts with overlying formations are faulted.

The McLaughlin Ridge Formation is equivalent to the lower parts of the Myra Formation of Muller (1980).

CAMERON RIVER FORMATION

The upper part of the Sicker Group is made up of a dominantly epiclastic sedimentary package. This is found most often in fault contact with the lower volcanic units, but is conformable on the McLaughlin Ridge Formation south of Sansum Point and in the Chipman Creek–Rheinhart Creek area. The Cameron River Formation sediments lie unconformably on the Nitinat Formation on Hill 60 Ridge, near Paldi and Fairservice Mountain. A similar unconformable relationship is suspected west of Banon Creek.

In the south of the area (Hill 60 and the Paldi inlier) 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 continues westward into the Cowichan Lake area. This sequence passes upwards into monotonous thinly bedded, turbiditic sandstone-siltstone-argillite intercalations. The basal ribbon cherts are absent north of the Chemainus River, where the thinly bedded turbiditic clastic sediments dominate. However, cherty tuffs and argillites are found at the base of the formation at Sansum Point. Thicker beds of sandstone, granule sandstone and conglomerate containing clasts of cherty material, volcanic lithic clasts and feldspar and pyroxene crystals are also found within the formation. Thin crinoidal calcarenites and limestones are interbedded with sandstone and argillite near the top of the formation at Mount Brenton, at Separation Point and in the Haslam Creek area.

In contrast to the Alberni–Cowichan Lake area, limited volcanism appears to have continued during early Cameron

River Formation sedimentation in the Mount Whymper–Rheinhart Creek area. This produced a bimodal suite of aphyric basalts and rhyolites, generally forming sills and dykes though some amygdaloidal basalt flows occur. Similar aphyric basaltic dykes also intrude the underlying McLaughlin Ridge volcanics.

The Cameron River Formation is equivalent to the upper parts of Muller's Myra Formation together with the sediments of the informal sediment-sill unit (Muller, 1980).

Mount Mark Formation

Massive and laminated crinoidal calcarenites with chert and argillite interbeds occur in the Fairservice Mountain area, south of the Cowichan River. They directly overlie Nitinat Formation volcanics in the west but are underlain by Cameron River Formation sediments to the east. The limestones are the uppermost unit in the Sicker Group of the map area, though they are absent north of the Cowichan River where the Cameron River Formation is overlain unconformably by Karmutsen Formation basalts or Nanaimo Group sediments.

The Mount Mark Formation is the equivalent of the Buttle Lake Formation of Muller (1980) and other authors (for example, Yole, 1969).

VANCOUVER GROUP

Karmutsen Formation

Basaltic volcanics of the Karmutsen Formation underlie Mount Whymper and the Mount Landalt–El Capitan area. They comprise pillowed flows, pillow breccias and hyaloclastite breccias interbedded with massive flows and sills. Typically the basalts are feldspar-phyric, often with ragged or glomeroporphyritic feldspars in a fine-grained groundmass. Amygdules are common and are infilled with chlorite, calcite or epidote.

The intrusive component increases toward the base of the sequence, which passes downward into diabase and gabbro bodies with intervening screens of Cameron River Formation sediments (Figure 1-6-3). These mafic sills and dykes are widespread in the area, occurring at deeper structural levels, though they are most commonly found intruding the Cameron River Formation (in the informal "sediment-sill unit" of Muller, 1980). They are medium to coarse-grained diabase, gabbro and leucogabbro with minor diorite, commonly porphyritic with feldspar phenocrysts often being glomeroporphyritic clusters up to 3 centimetres in diameter. Mafic phenocrysts are generally absent. Equigranular gabbros are also common and coarse varieties contain frequent pegmatitic veins and pods. Thick gabbro bodies under Mount Hall and Coronation Mountain show layering of porphyritic and nonporphyritic lithologies.

The intrusive bodies vary in size and form. Sill-like bodies are subconcordant with bedding within the sediments, though they usually follow the foliation where this is strongly developed. They thus show a variety of attitudes from shallow dipping to vertical. They may be as little as a few metres or up to 200 metres thick. Discordant dykes are also common, varying from 10 centimetres to about 50 metres wide.

The numerous intrusions are believed to have occurred during dilation of the Sicker Group basement in the Late Triassic, and acted in part as feeders to the overlying volcanics (Figure 1-6-3). Elsewhere in Wrangellia the Karmutsen Formation volcanics overlap onto the basement and evidence of the rifting is covered.

NANAIMO GROUP

Clastic sediments of the Nanaimo Group unconformably overlie older volcanic units and the Island Intrusions. They are most thickly developed in the Maple Bay to Mount Prevost area, the Cowichan and Chemainus River valleys and the shoreline from Crofton to Ladysmith. The sediments of the Nanaimo Group constitute major fining-upward cycles (Muller and Jeletzky, 1970), of which the first two, the Comox–Haslam and Extension-Protection–Cedar District, are developed in the Duncan map sheet.

Comox Formation

The basal Benson member of the Comox Formation is a coarse, poorly bedded cobble and boulder conglomerate varying from about 100 metres thick in the Mount Tzuhalem and Stone Hill area in the east to absent in other locations.

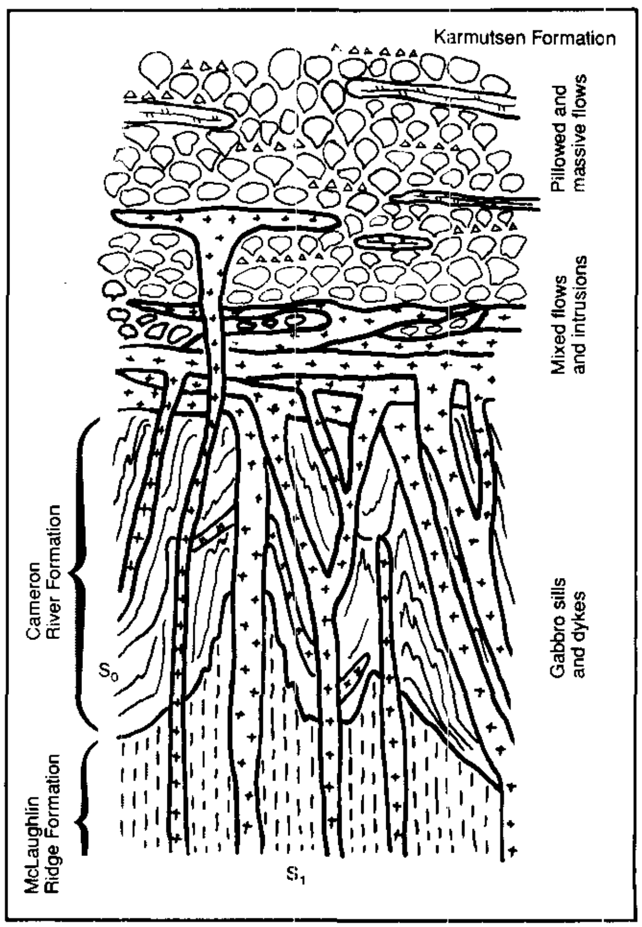


Figure 1-6-3. Diagrammatic cross-section, not to scale, showing the relationship of Karmutsen Formation volcanic and intrusive rocks to the rifted Sicker Group basement in the Mount Whymper–Rheinhart Creek area.

The conglomerates have rounded clasts which consist of a variety of volcanic and intrusive lithologies of immediate local origin; larger boulders are often angular.

Overlying 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. Calcareous cement is common and locally concretions up to 1 metre diameter are developed. A few granule and pebble conglomerate beds are interbedded with the sandstones. Several sandstone beds yielded abundant fossil faunas, including gastropods, pelecypods and possible broken ammonites and nautiloids. The thickness of the Comox Formation is estimated to vary from 0 to 350 metres.

Haslam Formation

The Haslam Formation consists of characteristic rusty weathering, black argillite and siltstone. It is fine to silty, often poorly bedded and friable, fracturing to pencil-shaped pieces. Interbeds of fine to medium-grained, grey silty sandstone are found within the argillites in the upper parts of the formation (Cowichan member, Ward, 1978). They vary in thickness up to 1 metre for massive to flaggy beds, though the more common graded sandstone-argillite turbidites average about 10 centimetres thick. Fossils are present within the Haslam Formation, though poorly preserved due to the ubiquitous pencil-and-rod fracturing, and include gastropods, pelecypods, ammonites and plant material. The thickness of the Haslam Formation may reach up to 600 metres in the Cowichan Valley (Ward, 1978).

Extension-Protection and Cedar District Formations

Conglomerates of the Extension-Protection Formation conformably overlie Haslam Formation argillites on top of Mount Prevost, representing the start of the second depositional cycle within the Nanaimo Group. Similar conglomerates are also found south of the Chemainus River and between Ladysmith and Chemainus. These pebble to cobble conglomerates are very similar to the Comox Formation conglomerates being polymictic, subrounded to rounded clasts in a coarse sandstone matrix. Perhaps the only significant difference is the presence of clasts of white quartz in the Extension-Protection Formation, which are rare in the Comox Formation. Grey, medium to coarse-grained sandstones are interbedded with and overlie the conglomerates.

Argillites of the Cedar District Formation, which overlie the Extension-Protection Formation, are not exposed within the map area. However, an unusual section of Nanaimo Group sediments is exposed in the incised gorge along the Chemainus River just below its confluence with Chipman Creek. Argillites assigned to the Haslam Formation coarsen upwards through turbiditic sandstones into pebble conglomerate which is in turn succeeded by a fining-upward sequence of sandstones and argillites lithologically indistinct from the lower beds. The stratigraphic position of this sequence remains uncertain. The coarse-grained beds may be the Extension-Protection Formation, though it usually has basal conglomerate sitting directly on Haslam Formation argillite without the intervening sandstones; the upper argillites may belong to the Cedar District Formation.

INTRUSIONS

Saltspring Intrusions

Coeval with the felsic volcanics in the McLaughlin Ridge Formation is a suite of granodiorite stocks and quartz porphyry dykes collectively known as the Saltspring intrusions.

The northern quarter of Maple Mountain is underlain by the westerly extension of the Mount Maxwell stock, centred on Saltspring Island. This body consists of light grey to green, weak to moderately foliated, medium-grained granodiorite with local fine-grained dacitic phases and a marginal feldspar porphyry. It intrudes Nitinat Formation volcanics and is itself cut by a large Late Triassic gabbro.

Quartz and quartz feldspar porphyry dykes, previously termed the Tyee Porphyry (Clapp and Cooke, 1917), are contemporaneous with the granodiorite, though never seen in contact with it. They were probably feeders for felsic crystal tuffs in the McLaughlin Ridge Formation in the Chipman Creek–Mount Sicker area. The porphyries are usually well foliated and difficult to distinguish from the crystal tuffs when contact relationships with host volcanics are not clear. Quartz phenocrysts are up to 1 centimetre in diameter, rounded to ovoid in shape, and may be stretched in the foliation. They comprise up to 20 per cent of the rock. Plagioclase phenocrysts are smaller and vary in shape from euhedral laths to rounded. They are sporadically altered to epidote.

Island Intrusions

Several granodioritic stocks of Middle Jurassic age occur in the area. With the exception of the large Ladysmith stock, these granodiorite bodies are elongate in shape. The dominant lithology is a medium to coarse-grained, equigranular granodiorite to quartz diorite with a characteristic salt-and-pepper texture. Quartz is usually irregular in shape, often interstitial to the feldspars. However, in the Ladysmith stock large (up to 8 millimetres) rounded quartz grains are ubiquitous. Feldspars are white, though some pink staining is seen on weathered surfaces, and usually form subhedral laths. Hornblende is the principal mafic mineral. It is tabular to acicular, black to greenish black in colour and may be slightly larger in size than the feldspars. Biotite is common in the Hill 60 and Ladysmith stocks. Chlorite replaces hornblende and biotite 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 cut the granodiorites.

Most of the stocks are rich in inclusions, particularly in marginal zones where agmatitic intrusive breccias are developed. The angular to subrounded xenoliths are of local country rock lithologies showing a range of amphibolitization and assimilation features. The xenoliths are normally randomly oriented, but within the Ladysmith stock some zones of inclusions have a parallel to subparallel arrangement.

Minor Intrusions

A variety of dykes and small irregular intrusions occur throughout the area. They are probably coeval with the Island Intrusions with which they are spatially related. Lithologically, they include intermediate feldspar porphyry, hornblende feldspar porphyry and minor diabase.

A suite of pale grey, fine-grained, aphyric dacite dykes of unknown age intrudes Cameron River Formation sediments and Triassic gabbro in the Sansum Narrows and Genoa Bay area.

STRUCTURE AND TECTONICS

Southern Vancouver Island has undergone a complex tectonic history involving at least six major deformational events, often rejuvenating previous structures. The present map pattern in the Duncan area is dominated by the effects of Late Cretaceous thrusting, though older events are important in establishing relationships within individual thrust slices.

PHASE 1: LATE DEVONIAN

Syn-Sicker Group deformation produced large-scale open folds in the Nitinat and McLaughlin Ridge Formation volcanics in the Cowichan Lake area and the southwestern part of the Duncan map sheet. Uplift and erosion subsequent to this event are reflected by the unconformity below the Cameron River Formation.

PHASE 2: POST-LOWER PERMIAN–PRE-MIDDLE TRIASSIC

The second deformational event affected all Sicker Group rocks producing a series of west-northwest-trending, southwest-verging, asymmetric folds with abundant parasitic minor folds. Major fold axes are often difficult to locate in the field but can be estimated from regional patterns and the results of exploration drilling programs. Overturning of beds is rarely observed. However, on the west slope of Rheinhart Creek, a sliver of McLaughlin Ridge Formation breccias occurs between Cameron River Formation sediments in an apparently overturned anticline. However, the structurally lower sediments are right-way-up suggesting a thrust and nappe structure is more likely.

Penetrative fabrics (schistosity in volcanics and cleavage in sediments) axial planar to the folds are well developed throughout most of the central part of the map area. They have moderate to steep northeasterly dips. Intense flattening normal to the foliation is observed within volcanic rocks, whereas Cameron River Formation sediments behaved more competently and lack flattening fabrics. Lineations due to bedding-foliation intersections and elongation of crystals and clasts are well developed. Plunges of the lineations are usually shallow, 5 to 15 degrees, and may be to the west-northwest or east-southeast. Within the more schistose volcanic rocks, a crenulation cleavage is sporadically observed normal or slightly oblique to the axial schistosity. This second foliation is particularly well developed in structural depressions and culminations marked by change in azimuth of lineations and appears to be axial to later broad open warps.

PHASE 3: LATE TRIASSIC

Extensive crustal dilation accompanied the evolution of Karmutsen Formation lavas and intrusions. Deformation specifically associated with this event has not yet been documented. Shear zones within gabbros, and especially along their margins, may be contemporaneous or later.

PHASE 4: POST-MIDDLE JURASSIC–PRE-LATE CRETACEOUS

Pre-Nanaimo Group deformation resulted in regional-scale warping of Vancouver Island, producing the three major geanticlinal uplifts cored by Sicker Group rocks (Figure 1-6-1), including the Cowichan uplift. Faulting, often axial, accompanied the folding and is most easily seen south of the Cowichan River in the Cowichan Lake map area. Pre-Nanaimo Group faults are suspected north of the Cowichan River but are obscured by later events. Uplift and erosion followed this deformational phase, establishing the pre-Nanaimo Group topography.

PHASE 5: LATE CRETACEOUS

Large-scale west-northwesterly trending thrusts cut the Cowichan uplift into several slices (Figure 1-6-4). Where exposed, these are high-angle reverse faults which dip between 45 and 90 degrees to the north-northeast, paralleling the earlier axial foliation in Sicker Group rocks. Slip planes are relatively sharp and narrow, though wide schistose zones have formed in receptive lithologies. The thrusts generally place older rocks over younger and become listric at mid-crustal depths (Sutherland Brown and Yorath, 1985). Displacements along fault planes are unknown but are probably small, of the order of 1 to 10 kilometres, so as to maintain the integrity of the Cowichan uplift. Direction of motion is also unknown. The regional map pattern suggests movement directed to the west-southwest; slickensides on fault planes indicate latest movement was horizontal and westerly directed. Minor imbricate faults are developed along most of the thrusts, particularly where Nanaimo Group sediments occur in the footwall.

The age of thrusting is believed to be Campanian (Dom, 1986) and certainly involves the Extension-Protection Formation and possibly the Cedar District Formation along the Chemainus River (*see* previous discussion of stratigraphy).

PHASE 6: ? TERTIARY

Several north-northeast crossfaults offset the Late Cretaceous thrusts within the Duncan area. They are all subvertical with downthrows to the west. The age of faulting is unknown, although the similar trending Yellows Creek fault in the Alberni area deforms a Late Eocene intrusion (Yorath, personal communication, 1987).

Regional tilting of all Vancouver Island has taken place since the Late Eocene emplacement of terranes outboard of Wrangellia.

METAMORPHISM

The metamorphic grade in the area is generally quite low, but increases with the age and structural position of the rocks.

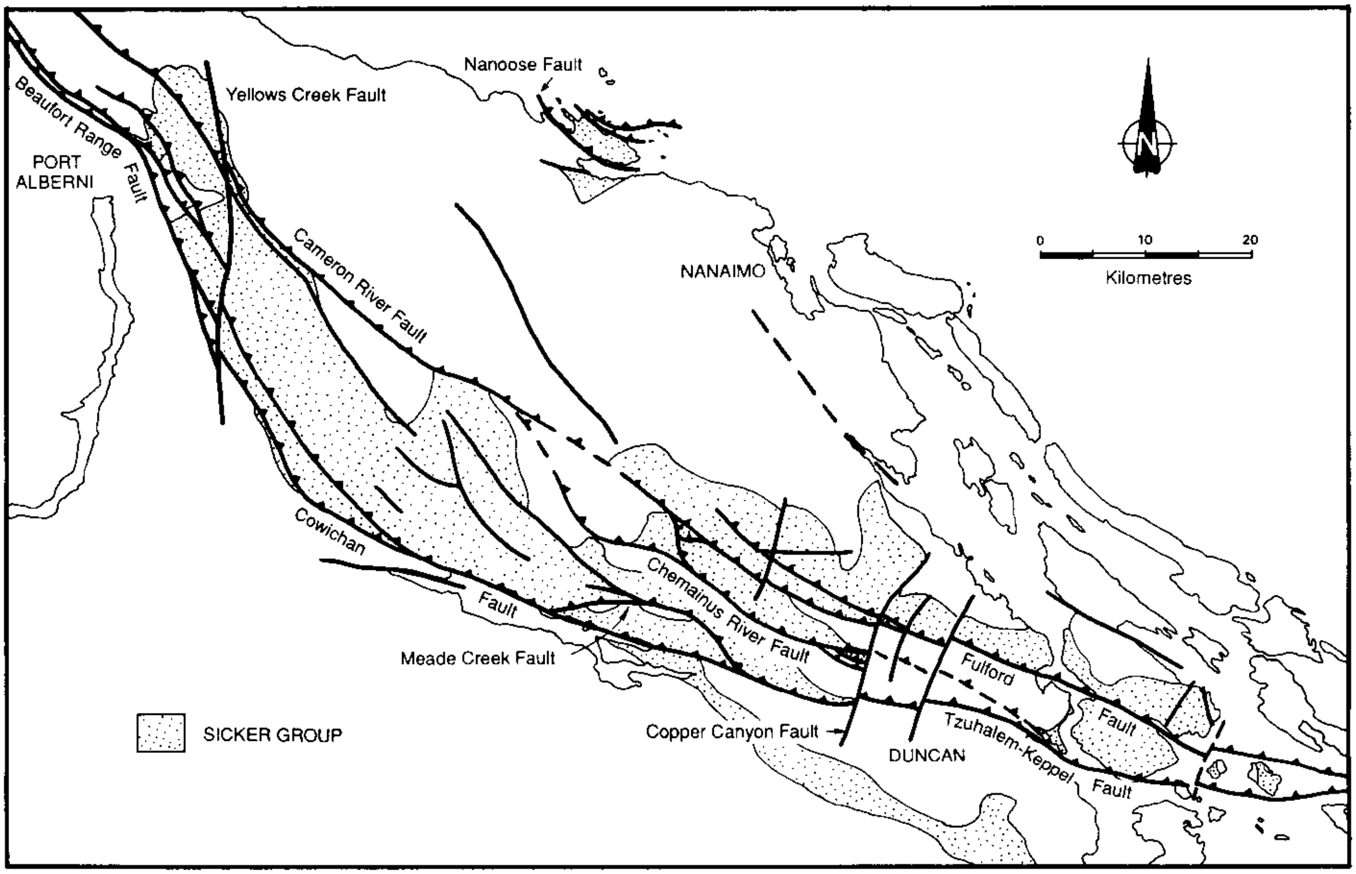


Figure 1-6-4. Late Cretaceous thrust system of southern Vancouver Island with Tertiary (?) cross faults. Sicker Group outcrop area includes younger intrusions.

Nanaimo Group sediments are essentially unmetamorphosed showing only diagenetic alterations in detrital iron oxides and calcareous cements. Basalts of the Karmutsen Formation show amygdule infillings and veins of chlorite, calcite, epidote and quartz, and alteration assemblages typical of the prehnite-pumpellyite facies. Intrusive rocks are unaltered except in chloritic shear zones.

Sediments of the Cameron River Formation are essentially unmetamorphosed except where involved in intense shearing when chlorite and sericite develop along foliation planes. Volcanic rocks of the McLaughlin Ridge and Nitinat Formations in the Chipman Creek to Maple Mountain belt, however, show the effects of greenschist facies metamorphism. The felsic volcanics develop sericite, talc and chlorite along foliation planes and are interbedded with minor chlorite schists. Intermediate to mafic rocks have chloritic schistose matrixes with epidote alteration of feldspars. Lithic lapilli may show almost complete replacement by epidote. Nitinat volcanic rocks in the Banon Creek area, however, are little altered though amygdules are infilled with chlorite, quartz and epidote.

Island Intrusion stocks often have contact metamorphic aureoles developed around their perimeters. Porphyroblasts of chiastolite or biotite are developed in Cameron River sediments around several stocks, and hornblende and pyroxene porphyroblasts are present in Nitinat Formation lapilli tuffs in contact with the Ladysmith stock near Holland Lake.

MINERAL DEPOSITS

Exploitation of the mineral resources of the Duncan area has been undertaken since the late nineteenth century, though originally restricted to nonmetallic deposits. The turn of the century saw commencement of exploration for gold and base metals, particularly in the Chemainus River and Copper Canyon areas. Production was limited except for three small mines on Mount Sicker (Lenora, Tyee and Richard III). A lull in activity occurred between the world wars and all mine production ceased. The Twin J (Lenora) mine on Mount Sicker was returned to production from 1943 to 1947. Over the next 30 years only sporadic exploration activity took place in the area for gold, base metals, manganese and iron ore. All areas of Sicker Group outcrop have since been staked and numerous exploration targets defined by major and junior mining companies and local prospectors.

Several types of mineral deposit are present in the Duncan area (Figure 1-6-5; Table 1-6-1):

Volcanogenic, polymetallic massive sulphides: These are the principal target in the Sicker Group rocks following the success of exploration at Westmin Resources Limited's Buttle Lake mine. The massive sulphides are hosted within the felsic volcanic tuffs of the McLaughlin Ridge Formation and restricted to a belt running from Chipman Creek to Mount Richards, in the hangingwall of the Fulford fault. Major occurrences are found on the Mount Sicker and Lara properties.

On Mount Sicker, massive sulphides were discovered in 1898 and production issued from three separate mines (Lenora, Tyee and Richard III) for several years. The combined property is presently under exploration by Minnova Inc. (formerly Corporation Falconbridge Copper). Baritic laminated sulphides are located within a distinctive thinly bedded package of intercalated siliceous argillaceous sediments and tuffs up to 70 metres thick. The local stratigraphy is, however, disrupted by folding, faulting (pre-Triassic as well as Late Cretaceous) and the intrusion of two thick Late Triassic gabbro sills.

Exploration by Abermin Corporation on the Lara property started in 1981. Volcanic rocks of the McLaughlin Ridge Formation in the northern part of the property are thrust over a panel of Cameron River Formation sediments, late Triassic gabbros and Nanaimo Group sediments to the south. The volcanic package contains a lower felsic tuff, a middle andesitic crystal-lapilli tuff and an upper felsic crystal tuff. Significant mineralization is hosted by the lower felsic tuff at two, possibly three, stratigraphic levels of which the Coronation zone is the most promising. Mineralization consists of disseminated and bedded pyrite-sphalerite-chalcopyrite-galena within quartz crystal tuffs. Silica and carbonate are the principal gangue minerals; barite is lacking. The Coronation zone has been delineated by drilling for about 2 kilometres along strike, with intersections up to 14 metres and averaging 6 metres. Low-grade sphalerite-pyrite-chalcopyrite mineralization is also found in the upper felsic crystal tuffs in which carbonate alteration is widespread.

Other massive sulphide showings have been reported in the Chipman Creek area (the Anita, MINFILE designation 37), in Copper Canyon (Sharon, 40; Copper Canyon, 86) and on Mount Richards (Yreka, 38; Jane [New Ironclad], 49).

Gold-bearing pyrite-chalcopyrite-quartz-carbonate veins along shears: Many of the faults and shears cutting the Sicker Group and late Triassic gabbros are veined by rusty weathering quartz-carbonate. The age of the veining is uncertain, several events being suspected. Some veins are localized along the Late Cretaceous thrusts and Tertiary (?) crossfaults, but others may be older structures and mineralizing events. The veins are variable in lateral extent, and range up to about 1 metre wide, although quartz-carbonate alteration along some faults may be several metres wide. Commonly reported sulphides are pyrite, pyrrhotite, chalcopyrite and arsenopyrite. The carbonate is principally ankerite and calcite. Carbonate appears to be less common to the east. Though numerous veins have been investigated in the past, none have proven economic potential.

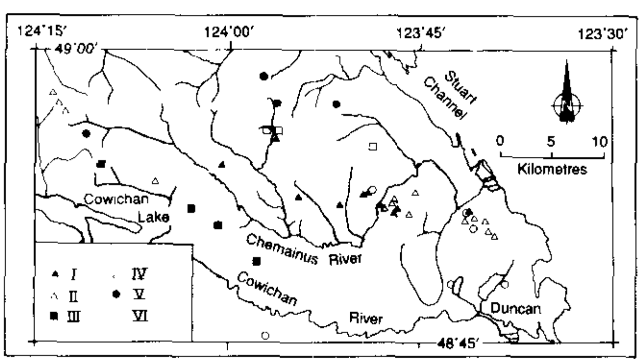


Figure 1-6-5. Distribution of mineral deposits in the Duncan–Chemainus River area. (I) Volcanogenic polymetallic massive sulphides; (II) Gold-bearing veins along shears; (III) Manganese (rhodonite) deposits; (IV) Jaspers; (V) Copper-molybdenum veins and skarns; (VI) Other mineral deposits.

TABLE 1-6-1.
MINERAL OCCURRENCES IN THE DUNCAN MAP AREA

Name	Minfile No.	Economic Minerals
I. Volcanogenic polymetallic massive sulphides		
(1) Mount Sicker	092B-001, 002	py, cpy, sphl, gln, ba
(a) Lenora-Tyee (Twin J)		
(b) Richard III	092B-003	py, cpy, sphl, gln, ba
(c) Victoria	092B-004	py, cpy, Au, Ag
(2) Anita	092B-037	cpy, py, Ag
(3) Sharon (Pauper, Mons, Brent)	092B-040	cpy, py, Au, Ag
(4) Waterpower-Brenton (Mildred)	092B-041	cpy, Ag
(5) Lara		
(a) Coronation Zone		sphl, py, cpy, gln, Au, Ag
(b) Coronation Extension Zone		sphl, py, cpy, gln, Au, Ag
(c) Randy North Zone		sphl, py, cpy, tet
(d) Hope	092B-110	cpy, py, sphl, gln, Au, Ag
(6) Pogo	092B-074	cpy, gln, sphl
II. Gold-bearing veins along shears		
(1) Mount Sicker area		
(a) Key City	092B-087	py, cpy
(b) Queen Bee (Seattle)	092B-088	py, Au
(c) Belle	092B-089	cpy
(d) Westholme	092B-090	?cpy
(e) Northeast Copper Zone	092B-099	py, cpy
(2) Mount Richards area		
(a) Cornucopia	092B-038	cpy, Au, Ag
(b) Yreka	092B-039	cpy, Au, Ag
(c) Jane (New Ironclad)	092B-049	cpy, sphl, talc
(d) Lucky Strike	092B-091	cpy
(e) Sally 2	092B-092	py, cpy
(f) Sirius	092B-096	cpy
(3) Copper Canyon	092B-076	cpy, py
(4) Candy	092C-076	cpy, po
(5) El Capitan — Landalt area		
(a) Cottonwood	092C-020	cpy, apy, erythrite, Au, Ag
(b) Silver Leaf	092C-021	cpy, apy, po, Au, Ag
(c) Paint Pot	092C-043	cpy, Ag, Au
(d) El Capitan	092C-019	cpy, Au, Ag
III. Manganese (Rhodonite) deposits		
(1) Hill 60	092B-027	rhodonite
(2) Rocky (Widow Creek, Cottonwood)	092C-113	rhodonite
(3) Meade	092C-115	rhodonite
(4) Stanley Creek (Lookout Locality)	092C-116	rhodonite
(5) Striker		rhodonite
IV. Jaspers		
(1) Lady A, A-B	092B-029	mag, spec, hem, jasper
(2) Lady A, C	092B-033	mag, spec, hem, jasper
(3) Fly	092B-076	mag, spec, jasper
V. Copper-molybdenite veins and skarns		
(1) BJ	092B-131	py, cpy
(2) Ant	092B-133	py, cpy, po, mo
(3) Coronation	092B-104	cpy, py, po
(4) Comego (Cascade, Anne, Kitchener)	092C-018	py, cpy, mo, mag, xo, tet, Au, Ag
VI. Others		
(1) Rose	092B-028	mica
(2) Sally	092B-093	limonite
(3) Skutz Falls	092B-120	limestone
(4) Duncan	092B-126	clay
(5) Quamichan Lake	092B-130	diatomite
(6) Jane (New Ironclad)	092B-049	talc

Manganese deposits: Manganese minerals have been reported in several places as fracture coatings or lenticular masses in the cherts of the Cameron River Formation. Rhodonite is the principal manganese mineral; manganese garnets, rhodochrosite and manganite have also been reported. All occurrences are in the aureoles of Jurassic granodiorite intrusions and owe their origin to the contact metamorphism of manganiferous sediments and are associated with ribbon chert. The protolith manganiferous sediment may have been of a exhalative origin (Cowley, 1979), though the lack of contemporaneous volcanism in the area mitigates against this. Oxidized deposits near Hill 60 were worked for manganese ore in 1919-20, but the main potential for these and other deposits is for lapidary uses.

Jaspers: Jasper occurs at many stratigraphic levels within the Sicker Group, principally associated with Nitinat Formation in the Banon Creek area (for example, Utah Mines Limited, JRM property) and McLaughlin Ridge Formation in the Chipman Creek–Rheinhart Creek area (for example, the Lady A [29] and Trek properties). Jasper beds are also found within the Cameron River Formation, often associated with manganese deposits, but also alone. The jasper deposits consist of laminated hematite and magnetite in red or grey chert. Several deposits were investigated in the 1950s for taconite iron ore but found to be too small. Recent exploration has concentrated on the potential for the volcanic-hosted jaspers to contain gold.

Copper-molybdenum quartz veins: Sulphide-bearing quartz veins occur in granodiorite and adjacent country rock on several properties in the Cowichan Lake area but are rarely reported from the Duncan area. However, chalcopyrite-pyrite veining is reported in Nitinat Formation tuffs at the RJ occurrence near Holland Lake, and a chalcopyrite-molybdenite-pyrrhotite-bearing skarn breccia is reported in a drill hole on the ANT property on Chipman Creek. Both of these occurrences are adjacent to the Ladysmith stock as is the Coronation showing described by Clapp and Cooke (1917).

Other deposits: Various nonmetallic deposits have been exploited in the Duncan area, particularly Quaternary clays for brickmaking and gravels for aggregate. Subeconomic grades of mica, talc, diatomite, limestone and limonite have been reported in the area.

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