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METALLOGENIC STUDY OF VANCOUVER ISLAND WITH EMPHASIS ON THE RELATIONSHIPS OF MINERAL DEPOSITS TO PLUTONIC ROCKS

by

DAVID JOHN TEMPLE CARSON, B.Sc., M.A.Sc.

A thesis submitted to the Faculty of Graduate Studies in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Carleton University
Ottawa, Ontario
May, 1968

ABSTRACT

Most plutons of Vancouver Island are Middle Jurassic to early Late Jurassic granodiorite or quartz diorite. Tertiary plutonic rocks, mainly gabbro, quartz diorite, and dacite porphyry, are subordinate. There is a regional compositional zoning in a geographic sense, with the greatest variety of plutons, ranging from peridotite to granite, in the west.

During emplacement of the Jurassic plutons, maximum lateral spreading, in the form of irregularly-shaped apophyses, was in or near Quatsino limestone, whereas Tertiary plutons commonly spread laterally in the lower Nanaimo Group to form sills and laccoliths.

Numerous classes of metalliferous deposits, ranging in age from late Palaeozoic to Recent, occur on Vancouver Island. Many epigenetic deposits are related to post-tectonic plutons, and the greatest variety of these deposits is in the west of the island.

Zinc-copper-lead massive sulphide deposits are restricted to the late Palaeozoic Sicker Group and are probably derived from their host rocks. Most copper and iron skarn deposits are in close proximity to Quatsino limestone and are related to Jurassic plutons. Molybdenum-quartz veins and stockworks are related to potassic Jurassic and Tertiary plutons. Arsenic, copper-arsenic, gold-quartz, and porphyry copper deposits occur in linear zones of Tertiary

intrusive activity which probably coincide with zones of Tertiary faulting. Most are spatially, and probably also genetically, related to Tertiary quartz diorite or dacite porphyry.

The metallogenic scheme of Bilibin (1955) is not readily applicable to Vancouver Island, because it relates all epigenetic mineral deposits to intrusive rocks, and considers that both the intrusions and metals were derived from the same source.

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Chemical analyses, potassium argon age determinations, and preparation of samples for microscopic studies were done by the Geological Survey of Canada. R. N. Delabio of the same institution made numerous X-ray identifications for the writer. Many thin sections were made by W. Yzerdraat of Carleton University.

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I - INTRODUCTION

PURPOSE OF THE INVESTIGATION

The main purpose of this study is to develop an overall metallogenic scheme for Vancouver Island with emphasis placed on the relationships of plutonic[1] rocks to metalliferous deposits. No special attempt is made to apply previously developed schemes to Vancouver Island. However, some aspects of such schemes (Bilibin, 1955) are applicable and have been utilized.

This thesis may serve as a guide for the application of metallogenic principles to other areas, especially those within the Canadian Cordillera.

SCOPE OF THE INVESTIGATION

The summer of 1964 was spent collecting samples of the intrusive rocks and metalliferous deposits throughout Vancouver Island. Samples of mineralized rocks, gangue, host rocks, and related intrusions from approximately eighty mineral occurrences of widely varying types were taken for laboratory study, including potassium-argon age determinations. Mining companies provided structural and stratigraphic data concerning many of the mineral deposits.

Systematic sampling of most of the major granitic bodies on Vancouver Island was carried out

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1 The term "plutonic" is used in this thesis to denote igneous and/or metasomatic rocks which crystallized below the surface of the earth.

for modal and chemical analyses. Samples of granitic rocks suitable for potassium-argon age determinations were also collected.

On the basis of information obtained during the 1964 field season, four localities were chosen for detailed geological investigation in the summer of 1965. This work included underground mapping of Sunro Mine, and plane-table mapping of a copper-bearing skarn deposit near Fourth Nanaimo Lake, the Merryth copper zone near Sooke, and the zinc-copper-lead deposits of Western Mines Limited at Main Creek near Buttle Lake. A locality containing several Tertiary intrusions, the Mt. Washington-Constitution Hill area, was mapped at a scale of 1 inch = 1/2 mile with the aid of aerial photographs. Laboratory study, plotting of maps and the final preparation of this thesis were carried out in Ottawa at the Geological Survey of Canada and Carleton University from September 1965 until the summer of 1967.

GEOLOGY OF VANCOUVER ISLAND

1 GENERAL STATEMENT

The main rock units and orogenies of Vancouver Island are shown in table 1, as well as some of the Cordilleran time-equivalent units and orogenies of White (1959). Distribution of the various rock units is shown in figure 1 (in pocket) which also includes generalized columnar sections (Sutherland Brown, 1966) from three localities which indicate lithology of the various units.

Era		Age	Rock Units	FAULTING, OROGENIES (plutons)	Some Probable Equivalent Units of White (1959)
Cenozoic	Tertiary	Pliocene			Kamloops
		Miocene	Sooke Formation	BLOCK FAULTING	PUGET OROGENY
		Oligocene	(Tertiary Plutons)	OROGENY (?) (Tertiary Plutons)	White Lake
		Eocene	Metchosin Formation and (?) other volcanics		
		Palaeocene			ROCKY MT. OROGENY
Mesozoic	Cretaceous	Late	Nanaimo Group		Upper Cretaceous
		Middle		MID CRETACEOUS OROGENY — (?)	
		Early	Unnamed Unit, Quatsino Sound		Nass
	Jurassic	Late	Unnamed Unit, West Coast	COAST RANGE OROGENY (Coast Intrusions)	COAST RANGE OROGENY (Coast Intrusions)
		Middle			
		Early	Bonanza Formation		Hazelton
	Triassic	Late	Quatsino Formation; Karmutsen Formation (Vancouver Group)		Takla
		Middle			
		Early	?		
Paleozoic	Permian		Sicker Group	CASSIAR OROGENY — (?)	CASSIAR OROGENY
	Pennsylvanian				Cache Creek

Table 1 - Formations and Orogenies of Vancouver Island with Approximate Equivalent Units of White (1959)

Metalliferous deposits are shown in figure 2 (in pocket), and plutonic rocks in figure 3 (in pocket).

2 SICKER GROUP

The Sicker Group is the oldest rock unit on Vancouver Island. It is of eugeosynclinal origin and is equivalent to part of the Cache Creek Group of mainland British Columbia. Sicker rocks are exposed in northerly and northwesterly-trending uplifted zones or horsts formed prior to the late Cretaceous (J. E. Muller, personal communication, 1968).

The lower and thicker part of the Sicker Group is composed chiefly of greenstones derived from volcanic breccias and tuffs of intermediate composition. These rocks generally occur in gently-plunging north-northwesterly-trending open folds of regional extent, but locally they are isoclinally folded and converted to chloritic and sericitic schists. Hornblende-plagioclase gneisses of the Tofino area are believed by Muller (1966) to have been derived from the lower Sicker Group. The lower Sicker Group in the Buttle Lake area is estimated to be at least 10,000 feet thick (Jeffery, 1965b).

The upper part of the Sicker Group is largely greywacke, argillite, and minor conglomerate overlain by limestone and chert. The limestone near Buttle Lake and Horne Lake reaches 1000 feet in thickness but in some localities it is missing. It is of Early Permian age (Yole, 1963). Unlike much of the younger Quatsino limestone, it is generally fine to medium grained, being

recrystallized to coarse marble and converted to skarn, at very few localities.

3 KARMUTSEN FORMATION

The Karmutsen Formation is the lowest of three formations of the Vancouver Group (table 1). It is the most widespread rock unit on Vancouver Island, and like the Sicker Group is of eugeosynclinal origin. It overlies the Sicker Group disconformably (Muller, 1965) and is composed largely of pillowed and porphyritic basalt with interlava pillow breccia (Carlisle, 1963) and tuff, and minor argillite and quartzite. Estimates of thickness vary from 5,000 feet (Gunning, 1931) to 12,000 feet (Muller, 1965), but it is believed by Sutherland Brown (1966) to have been at least 10,000 feet thick in most localities.

Diabase dykes and sills up to several hundred feet thick intruding the Sicker Group are believed to be intrusive equivalents of Karmutsen volcanics.

Most of the Karmutsen Formation is only weakly metamorphosed and pumpellyite is a common constituent of the amygdules (Jambor, 1960). A narrow zone of plagioclase-hornblende hornfels is common adjacent to plutons. In places, the Karmutsen Formation has been gently folded along north-northwesterly-trending axes but structural adjustment most commonly occurred by large-scale block faulting, and dips are rarely steep.

The Karmutsen Formation is probably of middle to late Triassic age; it is correlative with the Takla

and Nicola Groups of mainland British Columbia.

4 QUATSINO FORMATION

Overlying the Karmutsen Formation, apparently conformably, is the Quatsino limestone. It is up to 3,000 feet thick and is Upper Karnian (J. E. Muller, personal communication, 1968). In places near some plutons it is dolomitic. Apophyses of granitic plutons are common within and near to it, and near the contacts the limestone has been converted to coarse marble and skarn.

The limestone over large areas is flat-lying or gently dipping. Elsewhere, especially near faults and intrusions, it has been greatly deformed and is isoclinally folded.

A thinner intervolcanic limestone layer, until recently not distinguished from the Quatsino Formation, occurs several hundred feet lower in the Karmutsen Formation (J. E. Muller, personal communication, 1968).

5 BONANZA FORMATION

The Bonanza Formation, consisting of a lower sedimentary member and an upper volcanic member, conformably overlies the Quatsino Formation. It is in part correlative with the Hazelton Group of mainland British Columbia.

Carbonaceous shale, calcareous shale, and greywacke are the commonest rocks of the lower member, whereas dacitic to andesitic lavas, tuffs and breccias

constitute the bulk of the upper member which is lithologically similar to rocks of the lower Sicker Group.

Rocks of the Bonanza Formation have been metamorphosed in many places to the greenschist facies.

The upper Bonanza Formation may be as young as middle Jurassic (Jeletzky, 1954a). In the Quatsino area it is estimated to be 9,000 feet thick (figure 1, in pocket).

6 MIDDLE TO LATE JURASSIC PLUTONS ("COAST INTRUSIONS")

Plutonic rocks of Vancouver Island are described in detail in chapter II. Most are middle to late Jurassic batholiths and stocks which vary in composition from gabbro to quartz monzonite, but are mainly granodiorite and quartz diorite. They intrude the Bonanza Formation and all older rocks, and in many localities are unconformably overlain by late Cretaceous sedimentary rocks of the Nanaimo Group.

Contacts of the Jurassic plutons with the Sicker Group and Bonanza Formation are in places gradational, with gneisses and migmatities common, but with the Karmutsen Formation contacts are generally steep, with a narrow hornfelsic zone in the host rocks. Near Quatsino limestone the plutons are commonly in the form of tongues and irregularly-shaped apophyses.

Muller (1966) has mapped gneisses, diorites, and amphibolites in the Tofino area, which he believes

are the products of recrystallization at depths of mainly Sicker Group rocks.

7 UNNAMED UNITS -- LATE JURASSIC AND EARLY CRETACEOUS SEDIMENTS

Greywacke, congolmerate, and minor argillite occur along the west coast near Tofino. They are believed by Muller (1966) to be correlative with similar rocks of Callovian age near Kyuquot described by Jeletzky (1950). The conglomerates contain granitic pebbles derived from Jurassic plutons. Greywackes near Tofino are intruded by a Tertiary stock.

Clastic sedimentary rocks of Aptian age, including conglomerates with granitic pebbles, occur in the Quatsino Sound area (Jeletzky, 1954b).

8 NANAIMO GROUP

Along eastern Vancouver Island, rocks of the Sicker and Vancouver Groups and Jurassic plutons are unconformably overlain by the Nanaimo Group, a thick succession of clastic marine and continental rocks containing several coal seams. This group is of late Cretaceous age, and attains a thickness estimated to be about 10,000 feet near Nanaimo (figure 1, in pocket).

Rocks of the Nanaimo Group are unmetamorphosed except adjacent to some Tertiary plutons where sandstones and shales are converted to quartzites and argillites. On the whole, the rocks are little deformed. However, the group has been involved in extensive

Tertiary block-faulting, and near faults the rocks are sheared and crumpled (Buckham, 1947).

9 TERTIARY VOLCANIC ROCKS

The late Eocene Metchosin Formation of the Sooke-Jordan River area (Clapp and Cooke, 1917) consists largely of submarine sodic basalts. They are equivalent to the Eocene volcanics of the Olympic Peninsula. In places they are albitized, but they are little metamorphosed, except immediately adjacent to Oligocene plutons.

Dacite-tuff and ignimbrite near Kennedy Lake, and basalt, rhyodacite, tuff and breccia near Holberg Inlet are also believed to be early Tertiary (J. E. Muller, personal communication, 1968).

10 TERTIARY PLUTONS

Tertiary plutons are fully described in chapter II. They include quartz diorite and gabbro stocks and dykes in rocks as young as Eocene, and dacite porphyry sills and laccoliths cutting the Nanaimo Group. These are Oligocene-Eocene and many may be of subvolcanic origin.

11 TERTIARY SEDIMENTS

The late Oligocene Sooke Formation, mainly sandstone and shale, unconformably overlies Tertiary plutons and volcanics in the Sooke area (Clapp and Cooke, 1917) and similar sedimentary rocks occur at places along the west coast. They are unmetamorphosed, but are

cut by major faults.

12 OROGENIES AND/OR PERIODS OF DEFORMATION

In most areas of Vancouver Island, such as Cowichan Lake (Fyles, 1955), Sooke-Duncan (Clapp and Cooke, 1917) and Zeballos-Nimpkish (Hoadley, 1953), the main episode of regional deformation is believed to have occurred during the Jurassic, after the deposition of the Bonanza Formation and immediately prior to the emplacement of granodiorite plutons. The interval which included the deformation and granodiorite emplacement corresponds to that of the Coast Range Orogeny. In those areas where Late Cretaceous Nanaimo Group sedimentary rocks are present, a second interval of deformation is indicated, involving mainly block-faulting along pre-existing breaks (Buckham, 1947; Muller, 1965). Intrusion of quartz diorite and porphyry may have occurred during this deformation which, in part, corresponds to the Puget Orogeny. There is ample evidence to suggest that the Jurassic orogeny and the Tertiary faulting occurred with varying intensities throughout all of Vancouver Island.

An intermediate period of deformation which may be an extension of the Coast Range Orogeny probably occurred during the middle Cretaceous. No rocks are known to have been deposited during this time and it may have been a time of uplift and metamorphism, or orogeny. Sutherland Brown (1966) believes that the

Leech River Formation, which is of unknown age and occurs to the north of the Metchosin Formation, may be early Cretaceous. In places it is schistose and its metamorphism may have occurred during the middle Cretaceous. The occurrence of late Cretaceous clastic sedimentary rocks on much of the island and evidence that they were formerly of much greater extent suggests that this orogeny was separated in time from the Tertiary faulting. Widespread alteration, including prehnitization, of Jurassic plutonic rocks (Ch. II) may have occurred but there are no known Cretaceous plutons. Support for a middle Cretaceous orogeny is afforded by the occurrence of major thrust faulting and metamorphism, though without granitic intrusion, in the Northern Cascades at that time (Misch, 1966).

The Sicker Group is in many places highly sheared whereas much of the Karmutsen Formation is little deformed. This would appear to indicate an episode of deformation, possibly the Cassiar orogeny, in the interval between the deposition of the two groups. However, in those areas in which the two contact, the contact appears to be disconformable, and the two units exhibit no great differences in degree of deformation.

The Karmutsen Formation consists largely of massive basic volcanic rocks which have been shown to be resistant to deformation during forcible intrusion (Gunning, 1932; Carson, 1960). The varied

rocks of the Sicker Group may have yielded more readily to stresses. At Price property (Ch. III), andesitic volcanic rocks of the Sicker Group are relatively undeformed whereas axial plane cleavage is highly developed in adjacent cherty tuff and breccia of the same group, which are tightly folded. It may also be significant that the Mesozoic deformational episodes affecting the Vancouver Group at Open Bay near Campbell River (Carlisle and Susuki, 1965) appear to correspond to those which affected the Sicker rocks at Price property.

Granitic plutons of Vancouver Island are probably of middle to late Jurassic and early to middle Tertiary ages (Ch. II). Plutons are generally considered to be closely related to orogenies.

The above features suggest that the Cassiar Orogeny had little effect on Vancouver Island, and that the three main episodes of deformation occurred during the middle to late Jurassic, the middle Cretaceous, and early to middle Tertiary. The first and last of these episodes are stressed in this project.

SUITABILITY OF VANCOUVER ISLAND FOR APPLICATION OF METALLOGENIC PRINCIPLES

Vancouver Island is well suited for the first application of metallogenic principles to the western Canadian Cordillera for the following reasons:

(1) geologically, the island is a complete unit displaying all the major stages of development of orogenic belts. The eugeosynclinal stage occurred in the late

Palaeozoic and early Mesozoic when the Sicker and Vancouver Groups were deposited. Uplift, folding and intrusion of large volumes of granitic magma followed closely during the main orogenic stage in the middle to late Jurassic. Synorogenic Flysch was deposited in the late Jurassic along the west coast, and the late Cretaceous Nanaimo Group and Tertiary Sooke Formation represent, in part at least, post-orogenic molasse. Large-scale block-faulting, the intrusion of sub-volcanic (?) plugs and stocks, and extrusion of related volcanic material, were among the final major tectonic events.

(2) the geological evolution of Vancouver Island is, in physically-condensed form, roughly typical of the Cache Creek (late Palaeozoic) and younger western Cordillera. Many of the rock units and tectonic events of Vancouver Island can be correlated with those of the mainland. Thus, it is possible to apply knowledge gained from the study of the island to other parts of the western Cordillera.

(3) a great variety of metalliferous deposits occurs on Vancouver Island.

II - PLUTONIC ROCKS OF VANCOUVER ISLAND

GENERAL STATEMENT AND BRIEF SUMMARY OF PREVIOUS WORK

A variety of types of plutonic rocks can be distinguished on Vancouver Island on the basis of composition, texture, structure, alteration, age, and physical form.

The plutons ranging in composition from peridotite to granite, but consisting mainly of granodiorite and quartz diorite, occupy approximately one-tenth of the surface area of Vancouver Island (figure 3, in pocket). They range in size from dykes less than one foot wide to the combined Bedwell-Ucona batholith which is fifty miles long and five to twelve miles wide.

Most of the plutons are elongated in a northwesterly direction roughly parallel to the regional structure. Many are composite whereas others are relatively homogeneous.

Before this project, few quantitative data on the plutons were available, and the only Tertiary intrusions known were those of the Sooke area (Clapp and Cooke, 1917), Mt. Washington (Carson, 1960) and some dacite porphyry sills cutting the Nanaimo Group. The granitic intrusions were commonly called granodiorites and included in the "Coast Intrusions".

In the Sooke-Victoria-Duncan area, Clapp (1912, 1913, 1914c) and Clapp and Cooke (1917) distinguished three types of batholithic rocks. They were

assigned to the late Jurassic or the early Cretaceous. The oldest unit, called Wark gabbro diorite gneiss, extends northwest from Victoria to Sooke Lake and forms the southern portion of a composite batholith. Wark gneisses are fine to coarse grained, and dark grey to black. They contain calcic oligoclase or andesine or sodic labradorite, amphibole, pyroxene, quartz (up to 15 percent), biotite, ilmenite, magnetite, and in some cases, minor potash feldspar. The minerals were crushed and altered. In places Wark gneisses grade into amphibolites.

Closely associated with the Wark gneisses are the Colquitz quartz diorite gneisses which have minor aplitic, pegmatitic, and granitic apophyses extending into Wark gneisses. Colquitz gneisses are strongly banded, light to dark grey and medium to coarse grained. They contain plagioclase (An_{30}), quartz, hornblende, biotite and/or muscovite, magnetite, apatite, titanite and, in leucocratic bands, microperthite. They are moderately to strongly altered.

Intruding the Wark and Colquitz gneisses are plutons of granodiorite which contain local quartz diorite and aplitic and pegmatitic varieties. The type pluton is on Saanich Peninsula and this and all similar granodiorite plutons were called Saanich granodiorite by Clapp (1912). This rock is medium grained, light grey to pink and contains plagioclase (An_{10} to An_{45}), quartz, hornblende, biotite, magnetite, pyrite and

potash feldspar which is commonly perthitic. Alteration is common and minerals are strained. Basic contact zones, called Beale diorite, or quartz diorite are common, and weak foliation in places parallels contacts or regional structures.

Clapp and Cooke (1917) also described "gabbro-diorite porphyrite" intrusions which cut the Sicker Group. Fyles (1955) mapped similar rocks near Cowichan Lake as diabase related to Karmutsen volcanics, and diabase sills occurring in the Buttle Lake area are believed to have a similar origin (Jeffery and Merrett, 1964).

Bodies of quartz-feldspar porphyry in the Sicker Group were mapped by Clapp and were named the "Tyee porphyrites". They are schistose in places and their intrusive nature is not clear. They have been found only in the Sicker Group and on the basis of field and microscopic inspection the writer believes that they are probably part of that group.

Small stocks or dykes of unaltered gabbro, quartz diorite porphyry, and altered hornblende porphyry also occur in the Victoria-Duncan area.

In the Sooke area Clapp and Cooke (1917) mapped two types of intrusions both of which cut the late Eocene Metchosin volcanic rocks. They named them the Sooke intrusions. The first type consists of stocks of olivine- or augite-gabbro with minor anorthosite; the stocks are up to five miles long by two and one half miles wide.

Small bodies of "granite", some of which are border facies of the gabbros, comprise the second type.

The augite-gabbro is dark green, and medium to coarse grained with chilled borders. It contains labradorite, augite, magnetite and apatite. Augite is replaced by hornblende. Olivine-gabbro contains bytownite diopsidic augite, olivine, and ilmenite and is equigranular fine to medium grained. Neither type of gabbro is greatly altered.

The Tertiary Sooke "granites" are light grey, fine to medium grained and contain quartz, oligoclase, hornblende, albite, magnetite, titanite, apatite and, in some cases, potash feldspar.

Fyles (1955) described the granodiorite plutons of the Cowichan Lake area which are similar to the Saanich granodiorite. In places they are overlain by late Cretaceous Nanaimo Group rocks. They are steep-walled dyke-like bodies up to 8 1/2 miles long by 1 1/2 miles wide and contain no linear or planar structures. An aplogranitic roof facies occurs in one body. In the eastern part of the area many of the plutons are quartz diorite, as are the borders of many of the granodiorite bodies in the west. Moderate alteration of the rocks is indicated by widespread chloritization of biotite which may also contain lenses of prehnite, and by the replacement of plagioclase by sericite and epidote.

Sargent (1941) described the quartz diorite, granodiorite, and dykes of Bedwell River area, and

Stevenson (1945a) described quartz diorite, diorite, and feldspar porphyry of the China Creek area.

Gabbro, diorite, granodiorite, and quartz diorite, all members of the Zeballos batholith, were mapped by Stevenson (1950). The quartz diorite is the youngest member and occurs as a body eight miles long by two miles wide. It has a breccia zone 2,000-3,000 feet wide at its northwestern end.

Gunning (1930; 1932a) and Hoadley (1953) have described the Nimpkish area intrusions. They are similar to Saanich granodiorites and are mainly granodiorite and quartz monzonite with lesser amounts of granite and quartz diorite.

The Nootka batholith described by Hoadley (1953) is quartz monzonite or granite of very uniform composition. The nearby Ehatishat batholith, on the other hand, is variable in composition, ranging from granite to gabbro, and has a migmatite zone along its contact.

Jeletzky (1950) described small bodies of granodiorite, aplite, and pegmatite near Kyuquot on the west coast. They intrude the early and possibly middle Jurassic Bonanza Formation, and pebbles similar to these granitic rocks occur in Callovian conglomerates (Jeletzky, 1954a).

The Coast Copper stock is mainly diorite, with gabbro, monzonite and quartz diorite phases, and minor alaskite and granodiorite apophyses (Jeffery, 1961a).

A medium grained fresh hornblende quartz diorite stock with marginal breccias (figure 4, in pocket) intrudes Karmutsen volcanic rocks and late Cretaceous sedimentary rocks at Mt. Washington (Carson, 1960). Dykes, sills, laccoliths, and irregularly-shaped bodies of quartz diorite porphyry or dacite porphyry have intruded the late Cretaceous and Karmutsen rocks for several miles to the east and southwest of Mt. Washington (Gunning, 1931; Muller, 1965; figure 4, in pocket). Dacite porphyries occur in Nanaimo Group sedimentary rocks at Haslam Creek (Clapp, 1913), at China Creek, Englishman River, and Nanaimo Lakes (Muller, 1964), and at Browns River (Muller, 1965).

METHODS AND CLASSIFICATION USED IN THIS STUDY

The writer collected more than 1,000 samples from most of the larger plutons and from dykes. Plutons mapped were those in the Mt. Washington area and those at the mineral deposits which were mapped in detail (Ch. III). Several samples suitable for K-Ar age determinations were collected.

Modal analyses were made of thin sections of 227 representative specimens and are presented in table 2 (in pocket). Potassium feldspar was stained in all sections. Most of the rocks are homogeneous, medium grained, and relatively equigranular so that the point-count method proved very useful.

Four-fifths of the modal analyses were made

from extra large thin sections in which the area counted was approximately 800 square millimeters. Areas counted on smaller, standard-sized thin sections averaged about 450 square millimeters. The minimum number of points counted per slide was 500 and in most cases the number of points counted totalled either 500 or 800.

Granitic pebbles collected from Aptian conglomerates were sliced and stained for potash feldspar. They were point-counted under a binocular microscope with the aid of 1/10 inch square grid.

Chemical analyses of 38 selected samples were made in the laboratories of the Geological Survey of Canada. X-ray fluorescence methods were used to determine most major oxides[1] excepting FeO, P_2O_5, CO_2, and H_2O which were determined by chemical methods. The oxide Na_2O was determined by flame photometry. These analyses, and 24 from previous publications are used in this report and are presented in table 3 (in pocket). Norms of all 62 analyses were calculated by computer and are also presented in table 3.

Proportions of quartz, alkali feldspar, and plagioclase (oligoclase or more calcic plagioclase) in

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1 Standard deviations in the range of oxide percentages of the analysed rocks are as follows: 0.15 Na_2O, 0.23 CaO, 0.10 K_2O, 0.56 MgO, 1.0 SiO_2, 1.0 Al_2O_3, 0.2 FeO, 0.25 Fe_2O_3, 0.07 TiO_2, 0.01 MnO. (J. A. Maxwell, personal communication, 1967).

the rocks largely determine the names applied to the rocks in this report. Some factors used in the classification are as follows:

(1) plagioclase in diorite is $An_{<50}$ and in gabbro is $An_{>50}$

(2) in diorite the ratio of Qz[1]/ Qz + Kf[2] + Pc[3] is <.05 whereas in quartz diorite it is >.05

(3) trondhjemite is oligoclase quartz diorite

(4) in granodiorite the ratio of Kf/Qz + Kf + Pc is >.05 whereas in quartz diorite it is <.05

(5) quartz monzonite has Kf > 1/3 total feldspar; granodiorite has Kf < 1/3 total feldspar

(6) granite has Kf and/or albite > 2/3 total feldspar; in albite granite, albite predominates; in Kf granite, potassium feldspar predominates.

AGES OF THE PLUTONIC ROCKS

1 GENERAL STATEMENT

The granitic plutons of Vancouver Island may be divided into two age groups on the basis of stratigraphic data. The first group contains those which are overlain unconformably by the Nanaimo Group and are therefore pre-late Cretaceous, and the second group consists of those which intrude the Nanaimo Group and are therefore post-late Cretaceous, or Tertiary (figure 3).

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1 Qz = quartz
2 Kf = potassic feldspar
3 Pc = plagioclase

Further evidence for the ages of these plutons and for those not in contact with the Nanaimo Group is given in this section.

2 PRE-LATE CRETACEOUS PLUTONS

The following evidence suggests that the stratigraphically-dated pre-late Cretaceous plutons and most other plutons on Vancouver Island are middle to early-late Jurassic in age.

(1) As shown in table 4, many rocks dated by K-Ar methods yield middle or late Jurassic ages according to the Geological Society of London time scale[1] (Wanless et al, 1967). Further, all stratigraphically-dated plutons of Vancouver Island which have been dated by K-Ar methods yield the appropriate ages.

The age of 148 ± 8 m.y.[2] from skarn may give the upper limit of the Jurassic intrusive activity. The only younger age obtained (143 ± 60 m.y.) is from poikilitic hornblende in a sample for which biotite yielded the age of 151 ± 14 m.y. Feldspar inclusions in the hornblende (Wanless et al, 1967) may be responsible for some argon loss. The nearby Bonanza batholith, which Gunning (1932a) considered to be of the same age as the Nimpkish batholith, yields two ages on the same biotite sample of 150 ± 8 m.y and 152 ± 7 m.y.

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1 in this scale the Jurassic extends from 136 to 190-195 million years, and the middle Jurassic from 162 to 172 million years.

2 m.y. - millions of years

Table 4 - Data for K-Ar Age Determinations of Vancouver Island

NUMBER (Collector) (TP)- this project	ROCK	LOCATION	% K	Ar^{40}/K^{40}	% RAD. ARGON	CONCENTRATE	SOURCE OF DATA	AGE IN MILLIONS OF YEARS
GSC-64-2 (G.E.P. Eastwood)	Granodiorite batholith	3/4 mi. N. of Brynnor Mine pit 49°-03' N 125°-25' W	6.13	0.0102	65	reasonably clean brown biotite; 50% of flakes altered to chlorite and contain epidote inclusions; total chlorite = 30% ; minor hornblende	Wanless et al, 1966	167 ± 10
GSC-64-3 (G.E.P. Eastwood)	Feldspar porphyry dyke	Brynnor Mine pit 49°-03' N 125°-26' W	4.29	0.0073	35	reasonably clean orange-reddish biotite with inclusions of zircon; chlorite = 30% ; some altered hornblende	Wanless et al, 1966	121 ± 35
GSC-65-11 (D.J.T. Carson) (TP)	Quartz diorite stock	E. side of Catface Peninsula 49°-14'-35" N 125°-57'-00" W	7.35	0.0029	73	clean pale olive-green biotite; some flakes altered to chlorite on edges; some clourless inclusions; < 1% quartz + feldspar + hornblende	Wanless et al, 1967	48 ± 12
GSC-65-12 (D.J.T. Carson) (TP)	Quartz diorite stock	Central Zeballos Mine 50°-02'-07" N 126°-47'-04" W	4.28	0.0022	56	clean relatively fresh biotite; < 5% flakes slightly chloritized; a few colourless inclusions; minor quartz, feldspar; trace of hornblende	Wanless et al, 1967	38 ± 14
GSC-65-13 (P. Henry Macsan Expl. Ltd (TP)	Quartz diorite-trondhjemite stock	E. of Sunro Mine 48°-26'-55" N 124°-00'-00" W	5.70	0.0023	25	relatively impure dark olive-green biotite; 10% flakes chloritized on edges; 10% free chlorite; 5% hornblende; 1% quartz + feldspar + opaques	Wanless et al, 1967	39 ± 10
GSC-65-14 (D.J.T. Carson) (TP)	Granodiorite batholith (Nimpkish)	1 mi. N. of Nimpkish Iron Mine 50°-16'-35" N 126°-51'-21' W	5.23	0.0092	74	relatively clean, two types of biotite; one is olive-green, unaltered; other is olive-green, altered and bleached in places, chloritization slight to complete; chlorite = 30 % ; hornblende <5 %	Wanless et al, 1967	151 ± 14
GSC-65-15 (D.J.T. Carson) (TP)	Same sample as GSC-65-14	as GSC-65-14	0.36	0.0087	24	clean somewhat altered dark green hornblende; opaque inclusions < 5 % ; colourless inclusions < 1 % ; attached biotite = 1%	Wanless et al, 1967	143 ± 60
GSC-65-17 (J.E. Muller)	Granodiorite batholith (Ucona)	Roadcut along Heber River 49°-49-15" N 125°-58'-25" W	6.91	0.0099	79	relatively clean slightly altered olive-green biotite; some needle-like inclusions; chloritization of edges of flakes; chlorite = 10 % ; hornblende = 1%	Wanless et al, 1967	162 ± 9
GSC-65-18 (J.E. Muller)	Granodiorite batholith (Ucona)	Ucona River 49°-43'-30" N 125°-56'-25" W	5.83	0.0102	77	relatively clean altered light brown biotite; chloritization weak to intense; chlorite = 15% ; hornblende = 3%	Wanless et al, 1967	166 ± 8
1162(A) (D.J.T. Carson) (TP)	Granodiorite batholith (Bonanza)	Bonanza Lake 50°-22'-15" N 126°-45'-40" W	6.01	0.0092	85	clean highly altered biotite; chloritization of flake edges; chlorite = 20%	R.K. Wanless, personal communication, 1967	150 ± 8
1162(A)-2 (D.J.T. Carson) (TP)	Same sample as 1162(A)	as 1162(A)	6.01	0.0092	86	clean highly altered biotite; chloritization of flake edges; chlorite = 20%	R.K. Wanless, personal communication, 1967	152 ± 7
1194 (D.J.T. Carson) (TP)	Sericite schist (Sicker)	Twin "J" Mine portal 48°-52-00" N 123°-47'-30" W	3.98	0.0100	74	whole rock mica schist	R.K. Wanless, personal communication, 1967	160 ± 20
1221 (D.J.T. Carson) (TP)	Phlogopite in skarn	FL orebody of Zeballos Iron Mine 50°-02'-58" N 126°-49'-56" W	5.47	0.0090	84	clean very pale green phlogopite; green colour probably due to chlorite in crystal structure and is not due to alteration	R.K. Wanless, personal communication, 1967	148 ± 8
1219 (D.J.T. Carson) (TP)	Quartz diorite stock	Mt. Washington 49°-46'-04" N 155°-17'-24" W	7.33	0.0021	78	clean unaltered khaki biotite; 1 % chlorite	R.K. Wanless, personal communication, 1967	35 ± 6
1233 (D.J.T. Carson) (TP)	Quartz diorite stock	Faith Lake 49°-39'-12" N 125°-24'-41" W	4.73	0.0023	71	relatively clean brown biotite; 10% of flakes have chlorite on edges, 1 % contain colourless inclusions; free chlorite = 2%; total chlorite = 8 % ; hornblende = 2 %	R.K. Wanless, personal communication, 1967	39 ± 7
1243 (J.E. Muller)	Granodiorite batholith	Nanaimo Lakes road 49°-05'-15" N 124°-16'-15" W	6.32	0.0098	92	clean, relatively unaltered khaki biotite with slight chloritization of flake edges; chlorite = 2 % ; hornblende = 2 %	R.K. Wanless, personal communication, 1967	160 ± 8
1244 (J.E. Muller)	Granodiorite stock	Stubbs Is. near Tofino 49°-09'-25" N 125°-55'-30" W	6.87	0.0030	71	relatively clean bleached reddish-brown biotite; 1/3 of flakes have colourless inclusions with pleochroic halos, < 10% of flakes have colourless acicular inclusions; chloritization of flake edges; chlorite = 10%; hornblende < 3 %	R.K. Wanless, personal communication, 1967	50 ± 5
1245 (J.E. Muller)	Quartz monzonite porphyry stock	Paradise Ck., S. of Kennedy Lake 49°-01'-25" N 125°-29'-10" W	7.14	0.0035	79	relatively clean, slightly altered khaki biotite; < 2% of flakes contain apatite inclusions and a few others contain colourless inclusions with pleochroic halos; < 1% of flakes contain opaque inclusions; chlorite = 1% ; hornblende = 3%	R.K. Wanless, personal communication, 1967	59 ± 3

K^{40} Decay Constants Employed in Age Calculations

$\lambda_e = 0.585 \times 10^{-10}\ yr^{-1}$ $\lambda_{total} = 5.30 \times 10^{-10}\ yr^{-1}$

(Procedure for calculating analytical errors given in Wanless, et al, 1965)

The age of 160 ± 20 m.y obtained from sericite schist at Twin "J" Mine probably dates the same period of intrusion and deformation which corresponds to the "Coast Range Orogeny".

(2) The youngest rocks cut by granitic intrusions on the west coast of Vancouver Island, near Kyuquot, are those of the early and possibly middle Jurassic Bonanza Formation. Also, Callovian (latest middle Jurassic) conglomerates contain granitic pebbles (previous section). Pebbles shown to the writer by J. A. Jeletzky are medium grained, pink, hornblende granodiorite or quartz monzonite and very coarse orthoclase-quartz pegmatite with minor muscovite and amphibole. They are thought to have been derived from the roof facies of plutons which during the Callovian were exposed by erosion (J. A. Jeletzky, personal communication, 1966). The writer has observed granodiorite and quartz diorite pebbles typical of the Jurassic plutonic rocks in Callovian (?) conglomerates near Tofino (Ch. I).

(3) Where the order of emplacement of plutons has been established mafic gneisses are the oldest followed by diorite and then granodiorite.

At Zeballos, Stevenson (1950) established the order of emplacement of granitic rocks to be gabbro and diorite, granodiorite, and quartz diorite from oldest to youngest. The quartz diorite is probably Tertiary since it yields a K-Ar age of 38 ± 14 m.y.

(Wanless et al, 1967). The granodiorite is probably middle-late Jurassic because phlogopite from skarn alongside it is 148 $\pm$ 8 m.y. in age (table 4).

Where gabbro gneisses, diorite gneisses, or quartz diorite gneisses are present they are invariably intruded by granodiorite and are therefore older. This is true in southern Vancouver Island (Clapp and Cooke, 1917) and in several localities along the west coast of the island. The gneisses are probably post-Triassic since in places they appear to have been derived from the Vancouver Group.

(4) Modes plotted on the Qz-Kf-Pc and Qz-Maf[1]-Fp[2] diagrams for 227 samples from plutons of Vancouver Island (figures 7, 8) have distributions somewhat similar to those of pebbles from Aptian (late lower Cretaceous) conglomerates from Holberg Inlet and Rupert Arm (figure 9, p. 46). Two main differences are apparent but may be explained. They are: (a) on the whole the pebbles have higher Kf content. Quartz diorite pebbles are rare, quartz monzonite pebbles are common. At the time of deposition of the conglomerate the plutons were eroded to shallower depths than at present so that many pebbles were probably derived from potassium-rich roof facies. (b) there are no (quartz-free) gabbro or diorite pebbles and no gneissic pebbles, probably because such rocks are

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1 Maf = Mafic minerals (hornblende, pyroxene, biotite, chlorite)
2 Fp = Kf + Pc

rare in the vicinity of the conglomerates (figure 3).

The occurrence of granodiorite and quartz monzonite pebbles in Aptian conglomerates indicates that these rock types were present in large quantities in the early Cretaceous. This, and the additional data given in (1), (2), (3) above indicate that the pre-late Cretaceous plutons are probably of middle to middle-late Jurassic age.

3 TERTIARY PLUTONS

Tertiary K-Ar ages obtained from biotites of Vancouver Island are given in table 4 and shown on figure 3. Stratigraphically-dated Tertiary plutons are also shown in figure 3.

The time range indicated for Tertiary plutons is 59-35 m.y.; middle Palaeocene to early Oligocene according to the Geological Society of London time scale (Wanless et al, 1967).

The quartz diorites excepting that from Catface Peninsula give ages from late Eocene to early Oligocene which is the age of the Sooke plutons as determined by stratigraphy. As there is an experimental error of ± 14 m.y. for the Catface sample, it is possible that the quartz diorites are all late Eocene or early Oligocene.

The Stubbs Island granodiorite and Paradise Creek quartz monzonite are early Eocene and middle Palaeocene. They have experimental errors of ± 5 m.y. and ± 3 m.y. respectively and could not therefore be

of the same intrusive period as the quartz diorites. They may belong to an earlier period of intrusion. However, differentiation trends on the An[1]-Ab[2]-Or[3] diagram (figure 12) suggest that all the Tertiary plutons belong to a single magmatic series.

PETROGRAPHY AND DISTRIBUTION OF JURASSIC AND PROBABLE JURASSIC PLUTONS

1 GENERAL STATEMENT

On the evidence presented above, the majority of Vancouver Island plutons are middle to early-late Jurassic. They have been fully described in previous publications so that only their distinguishing characteristics are dealt with here.

2 SAANICH-TYPE GRANODIORITES OF EASTERN VANCOUVER ISLAND

Medium grained, pale pinkish grey, hypidiomorphic-granular hornblende and/or biotite granodiorite (plate 1) is the main rock type in nearly all the large plutons which are several miles from the northeast coast of Vancouver Island and extend southeast from Nimpkish Lake to Victoria (figures 3, 5). In places they contain minor quartz monzonite which may be partly coarse grained. Quartz diorite occurs locally, especially near the borders of plutons. The average content of potassium feldspar in

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1 An = anorthite
2 Ab = albite
3 Or = orthoclase

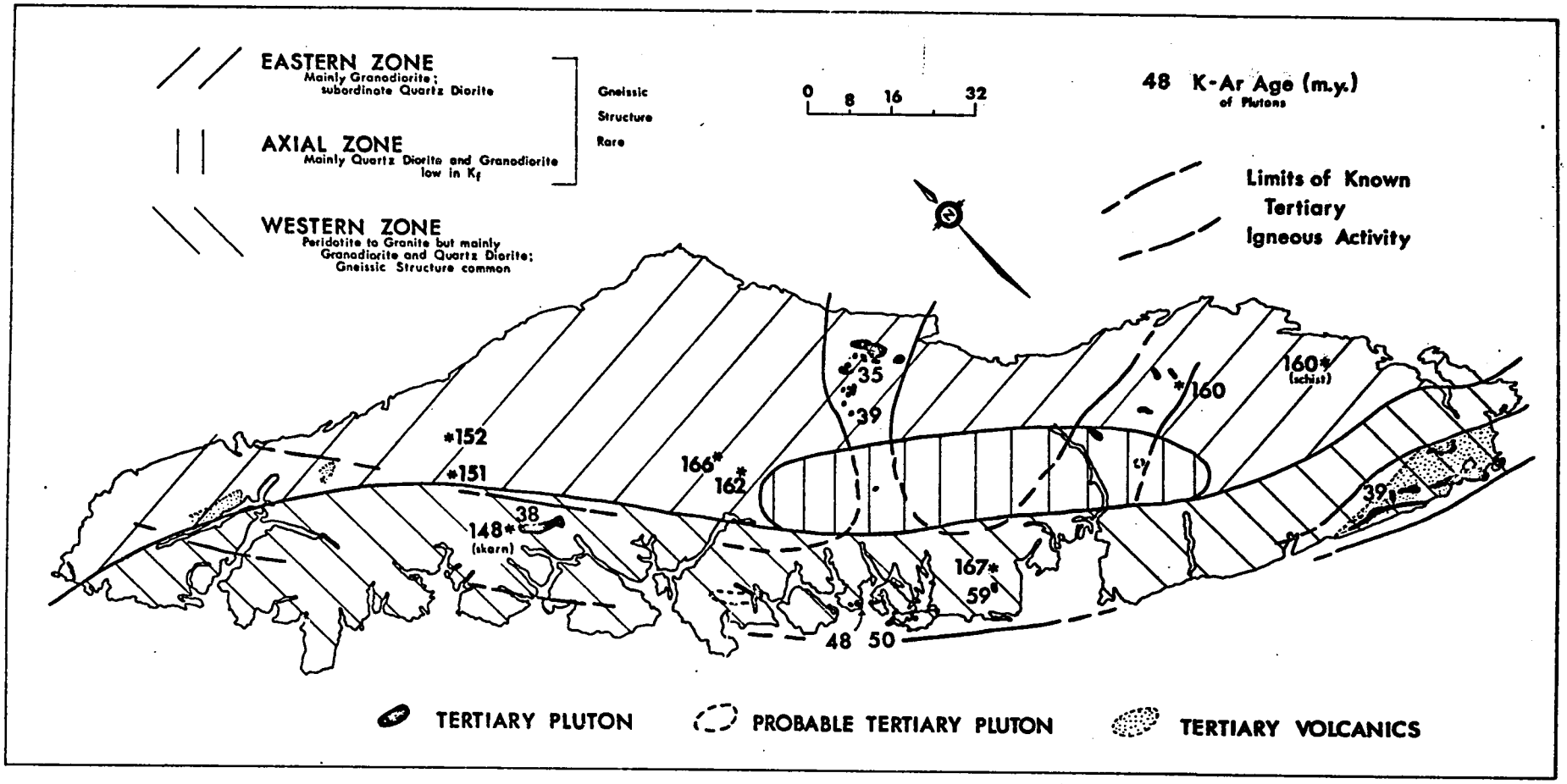

Figure 5 - Compositional Zoning of the Plutonic Rocks, and Zones of Known Tertiary Igneous Activity

67 samples is 13.1 percent. Plutons included in this zone are the Nimpkish-Bonanza plutons, Ucona batholith, Quinsam batholith, Nanaimo River batholith and Saanich granodiorites of the Cowichan Lake and Victoria areas. All of these are known to be pre-late Cretaceous and most are known to be middle or early-late Jurassic. They contain no known Tertiary phase, although Tertiary sills occur in Nanaimo Group sedimentary rocks overlying the Nanaimo River batholith, and it is possible that their feeder is a phase of that batholith.

Most of these rocks are moderately altered (table 2) by clouding of plagioclase with sericite and kaolin, chloritization of mafic minerals and occurrence of prehnite lenses (plate 1) in biotite or in chlorite pseudomorphs of biotite. Biotite is commonly dusty and may be bent or torn. Potash feldspar is commonly perthitic and the lamellae appear to decrease in average width with increasing anorthite content of the plagioclase (Roddick, 1965).

3 QUARTZ DIORITES AND SUBORDINATE GRANODIORITES OF THE CENTRAL AXIS

Most rocks of the Bedwell batholith and Alberni plutons (figure 3, in pocket) of central Vancouver Island are quartz diorites and granodiorites low in potash feldspar. The average content of potash feldspar in 32 samples is 7.5 percent. No quartz monzonite or granite has been reported or was observed by the writer in these plutons. Two of the Alberni plutons

are overlain by Nanaimo Group sediments and are probably Jurassic.

Bedwell batholith is characterized by conspicuous quartz "eyes" (plate 2) which are up to 9 millimeters in diameter but are commonly 4-6 millimeters. They are rare or only weakly developed elsewhere on the island. The border of the batholith near Della Lake is porphyritic and quartz "eyes" (phenocrysts) are abundant.

Most rocks of the Bedwell batholith, including the porphyritic border at Della Lake, are strongly altered. This is revealed by the extremely cloudy nature of plagioclase, which is saussuritized, and by strong chloritization of mafic minerals (plate 2). Biotite is dusty and commonly contains prehnite lenses and opaque streaks. Torn and bent biotite and chlorite and fractured quartz indicate that the rocks are somewhat deformed.

Alberni plutons have textures and alterations similar to those of the Saanich granodiorites.

Quartz diorites which may be Tertiary occur in the central axis area at Big Interior Mountain and south of Alberni Inlet near Corrigan Creek (p. 37).

4 WIDE VARIETY OF PLUTONIC ROCKS IN THE WESTERN ZONE

All the main compositional types of plutonic rocks from peridotite to granite occur associated with one another along the western third of Vancouver Island

between Brooks Peninsula and Barkley Sound (figures 3, 5). The most common type however, is probably granodiorite since the average content of potash feldspar in 67 samples is 12.0 percent. Many of the gabbro, diorite, and quartz diorite plutons are gneissic. Most of the plutons are believed to be Jurassic but the largest and most varied of the known Tertiary plutons are also found in this area, and it is not possible to estimate the number of plutons of unknown age which may be Tertiary.

The rocks studied exhibit wide variations in degree of alteration. Most are moderately to strongly altered.

Rocks in the Zeballos-Esperanza Inlet area ranging in composition from gabbro to granite have been described by Hoadley (1953). Modes determined for specimens of these rocks are given in table 2 (in pocket). A similar wide variety of rocks is present in the Nootka Sound area as is shown by table 2 and figure 3. Quartz monzonite from the Nootka batholith, containing negligible mafic minerals and with potash feldspar greater than 50 percent of the total feldspar, is medium grained fresh, pink hypidiomorphic-granular and contains large twinned perthitic potash feldspar crystals. These enclose plagioclase crystals with albitized borders.

Gneissic diorites and gneissic quartz diorites of the Sidney Inlet-Ahousat area have highly clouded plagioclase and exhibit extreme development of prehnite

lenses in biotite. Quartz may be highly fractured. Quartz diorite from Tofino Inlet and Wark and Colquitz gneisses of the Victoria area are very similar to them in most respects.

5 JURASSIC (?) AND CRETACEOUS (?) DYKES

A hornblende andesite dyke with small amounts of biotite is the only dyke from Vancouver Island which has been dated by K-Ar methods. It cuts the Brynnor orebody and yields an age of 121 $\pm$ 35 m.y. (table 4). Such hornblende andesite dykes are common near many skarn and vein-type metalliferous deposits.

Relatively salic porphyritic dykes, including feldspar porphyry, quartz-feldspar porphyry, and hornblende-feldspar porphyry, from Coast Copper Mine, Alice Lake Group, Lynx Mine, Price deposit (Ch. III), Buccaneer Mine, and Comego were studied under the microscope. Most are moderately to strongly altered to sericite, kaolin, and chlorite. Many have been described in previous publications. Except for the dyke at Price, which is believed to be related to the Jurassic (?) Bedwell batholith (Ch. III), it was not possible for the writer to deduce much new information on their ages other than that they are unlike any known Tertiary dykes, and are probably therefore related to Jurassic stocks and batholiths.

Sutherland Brown (1962) noted the abundance of pre-ore feldspar porphyry dykes near skarn deposits. The writer has noted that at Zn-Pb skarns in particular,

pre-ore (?) feldspar porphyry dykes are common (Ch. III).

PETROGRAPHY AND DISTRIBUTIONS OF TERTIARY AND PROBABLE TERTIARY PLUTONIC ROCKS

1 GENERAL STATEMENT

Tertiary plutonic rocks are here described in some detail because they are the least known of the plutonic rocks of Vancouver Island and are closely associated with some of the important classes of mineral deposits (chapter III). Also, prior to this project, many Tertiary plutons were believed to be Mesozoic. The distribution of known and possible Tertiary plutonic rocks is shown in figure 3, and their modes are given in table 2 (in pocket).

2 QUARTZ DIORITES AND SOOKE TRONDHJEMITES

Unaltered quartz diorites yielding Tertiary K-Ar ages from Zeballos and Sooke, and from Catface Peninsula (plate 3), Faith Lake, and Mt. Washington, are very similar in most respects. The Zeballos quartz diorite was fully described by Stevenson (1950) and the quartz diorite stock at Mt. Washington by Carson (1960).

Zeballos quartz diorite (no. 54)[1] is typical. It is light grey, fresh, fine to medium grained, hypidiomorphic-granular biotite-hornblende-quartz-diorite. It contains 54.8 percent subhedral plagioclase (An_{18-45}),

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1 numbers refers to the number of the specimen in figure 3 and table 2.

with intricately oscillatory zoning, 11.0 percent anhedral biotite pleochroic from dark brown to light yellowish-brown, 5.0 percent subhedral to anhedral amphibole pleochroic from dark green to medium greenish-brown, 28.6 percent anhedral quartz, 0.6 percent apatite, less than 1 percent clear green chlorite intergrown with biotite, and less than 1 percent opaque minerals.

The content of plagioclase in the Tertiary quartz diorites varies from about 50 percent to 70 percent. In all cases it is strongly zoned with intricate oscillations (Carson, 1960) and maximum ranges in composition are from approximately An_{15} to An_{65}. Most crystals are almost entirely free from the clouding which is so common in Jurassic plagioclases.

Biotite is rare in the Mt. Washington quartz diorite but most other Tertiary quartz diorites contain fresh biotite and hornblende totalling approximately 10 percent. Biotite replacing hornblende at Sooke and Faith Lake is believed to have formed by late magmatic reactions. Clear green chlorite may be intergrown with some of the biotite at most localities. It may also be late-magmatic.

Quartz may or may not exhibit strain shadows but shows no signs of granulation or recrystallization (Stevenson, 1950 p. 31).

Apatite and magnetite are the common accessory minerals but very small amounts of sphene and epidote

may also be present. Potash feldspar is present in small amounts (< 5 percent) in quartz diorites at Catface Peninsula (plate 3) and Zeballos, possibly as the result of minor assimilation of host rocks. It is rare in the other quartz diorites. The only potash feldspar observed in numerous samples studied from Mt. Washington was in a one inch wide aplitic dyke cutting quartz diorite.

Most of the small granitic plutons of the Sooke area (figure 6) are trondhjemite. They are more highly altered than other Tertiary plutons and coarse epidote is espeically abundant. Gradational contacts with their host rocks are common. The interiors of two of the larger plutons are quartz diorite which is petrographically very similar to those elsewhere on Vancouver Island. Gradations between Sooke trondhjemite and typical Tertiary quartz diorite or dacite porphyry have been observed in the large pluton west of Sunro mine, and the pluton six miles north of Sooke (figure 6); "granitic" zones in Sooke gabbro at Merryth copper deposit are quartz diorite (Ch. III).

Relatively unaltered, seriate, hornblende-biotite quartz diorite occurs in two small patches in the cirque of Big Interior Mountain; it may be Tertiary. These patches are cut by quartz diorite porphyry dykes which are probably Tertiary (next section). Unaltered quartz diorites which may be Tertiary also occur at

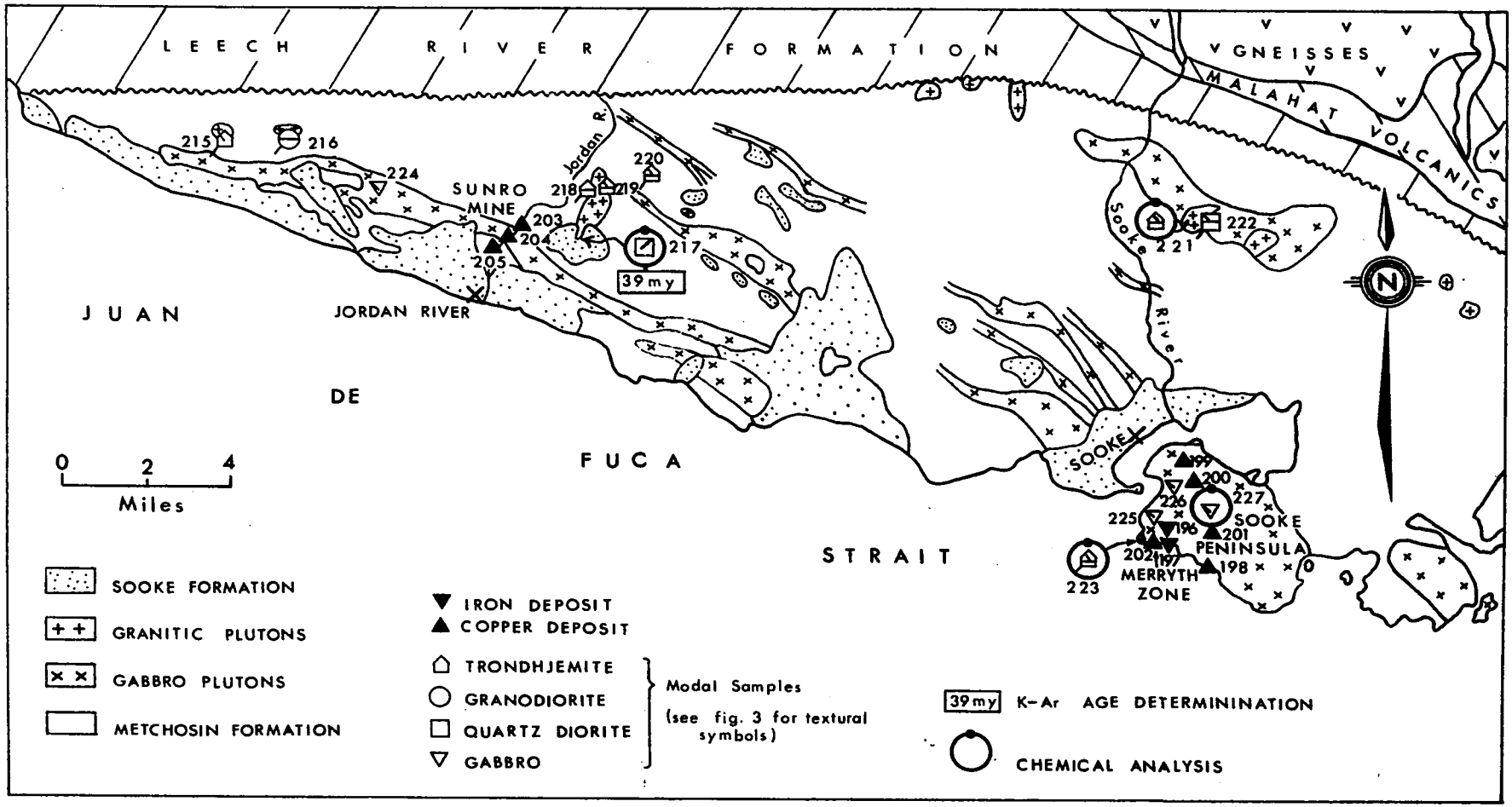

Figure 6 - Geology of the Sooke-Jordan River Area

(after Clapp and Cooke, 1917 and unpublished map of Macsan Expl. Co. Ltd.)

Corrigan Creek south of Alberni Inlet.

The quartz diorites at Catface Peninsula, Big Interior Mountain, Faith Lake, Gem Lake, and Mt. Washington are alike. They occur in a northeast-trending zone which contains many gold-quartz veins and porphyry copper deposits which are believed to be Tertiary (Ch. III).

Unaltered granodiorite with highly zoned plagioclase from Hesquiat-Sidney Inlet (nos. 70, 71, 72) and Rock Bay (no. 116) may also be Tertiary.

3 DACITE PORPHYRIES

Hornblende dacite porphyry dykes, sills, laccoliths, and irregularly-shaped bodies of the Mt. Washington-Constitution Hill area (figure 4, in pocket) have been described in detail by Carson (1960). Texturally they grade into quartz diorites. Concordant sill-like bodies of hornblende dacite porphyry occur in the Nanaimo group at several other localities (figure 3). Dykes and irregular bodies of known Tertiary age occur at Zeballos, Catface, Sooke and Faith Lake.

Typical dacite porphyry is a light grey porphyritic or seriate rock with abundant hornblende and plagioclase phenocrysts which range in size up to 9 millimeters, but average 1 - 2 millimeters in length. Some porphyries at Mt. Washington contain broken phenocrysts. The fine grained matrix consists

of quartz, plagioclase and hornblende. Quartz phenocrysts are present in some porphyries (plate 4). Plagioclase may range from oligoclase to labradorite and generally exhibits strong oscillatory zoning. Some crystals are composite (plate 4); some are highly saussuritized. Biotite and potash feldspar are rare.

Unaltered dacite porphyry dykes believed by the writer to be of Tertiary age have been observed at Big Interior Mountain and Warn Bay. Seriate or porphyritic quartz diorite forms portions of the small plugs at Faith Lake and Gem Lake (figure 3).

4 GRANODIORITE AND QUARTZ MONZONITE

Small granodiorite and quartz monzonite plutons occur at Tofino and Paradise Creek respectively. They yield Tertiary K-Ar ages of 50 $\pm$ 5 m.y. and 59 $\pm$ 3 m.y. respectively. Another small plug of unknown composition occurs at Barkley Sound and has been mapped as Tertiary (Muller, 1966). Other small granodiorite porphyry plutons such as the stock at the east end of Rupert Arm, may also be Tertiary.

The Tofino pluton has a medium grained equigranular core, but is porphyritic with a very fine grained matrix along its eastern edge. Both varieties (nos. 86, 87) are greyish-pink. They contain more than 25 percent quartz, approximately 40 percent plagioclase which is more calcic in the porphyritic variety, 18 percent potassic feldspar, several percent biotite, and approximately 1 percent accessory minerals.

Most plagioclase crystals are unaltered but a few are highly clouded. They occur as zoned phenocrysts up to 5 millimeters long in the porphyritic rock. They are only moderately zoned in the equigranular phase. Very fine grains of potash feldspar are interstitial in the porphyry, but are up to 2.5 millimeters long in the equigranular rock where they are finely to coarsely perthitic.

An unusual occurrence for granitic rocks of Vancouver Island is that of radioactive haloes up to 0.04 millimeters in diameter around minute decomposed zircon (?) crystals enclosed in biotite in the equigranular granodiorite from Tofino. Some biotite crystals contain chlorite streaks and prehnite lenses. Small amounts of pyroxene (cores in amphibole crystals) and rutile (?) are also present in the rock.

The Paradise Creek quartz monzonite porphyry is fresh pink, fine to medium grained, and inequigranular. It is the only rock of Vancouver Island seen by the writer which contains phenocrysts or porphyroblasts of potash feldspar (plate 5). These crystals are up to 5 millimeters in diameter, and larger than any of the phenocrysts of quartz, biotite, or plagioclase. They are commonly twinned (Carlsbad).

Moderately zoned oligoclase, and biotite and quartz crystals reach maximum lengths of approximately 3 millimeters. Biotite is deep brown to pale yellow. The occurrence of zoned poikilitic tourmaline

crystals (plate 5) which are pleochroic from light brown to very deep green is unusual. This mineral was noted in only one other rock studied, a diorite from Sharp Point (no. 73).

5 GABBRO

The elongate gabbro plutons at Sooke have been fully described by Clapp and Cooke (1917), Cooke (1919), and Stevenson (1951). Modes of four specimens are given in table 2 and their localities are shown in figures 3 and 6.

These Tertiary gabbros are in most localities relatively unaltered except for amphibole replacing pyroxene and some saussuritization of plagioclase. Similar gabbro plutons of possible Tertiary age occur in the Cowichan Lake area (Fyles, 1955), and at Rock Bay, Tahsis, and Zeballos (nos. 115, 59, and 58, respectively).

6 BRECCIAS RELATED TO TERTIARY PLUTONS

Breccias of various types are known to be present at the Tertiary quartz diorite plutons. Two types occurring near the forcibly intruded Mt. Washington stock (figure 4, in pocket) are closely akin to explosive diatreme, and to collapse breccias. Breccia believed to be a result of forcible intrusion occurs at the north end of the Zeballos quartz diorite pluton. Similar breccia occurs at the edges of the Sooke plutons (plate 6).

The Murray breccia of Mt. Washington is an oval pipe-shaped mass which has been shown by diamond drilling to extend downward at least 700 feet (deVoogd, 1964). Similar breccia occurs at Murex Creek. These breccias consist of angular and rounded fragments of dacite porphyry, Nanaimo Group sedimentary rocks, Karmutsen Formation volcanic rocks, and broken and unbroken crystals of plagioclase, quartz and hornblende in a comminuted matrix of similar but much finer material (plate 7). The matrix and finer sedimentary rock fragments and cores of some plagioclase phenocrysts in the Murray breccias are commonly biotitized. However, most plagioclase, and quartz, hornblende and dacite porphyry fragments are unaltered. In many places the breccia exhibits crude layering.

The Washington collapse (?) breccia at Mt. Washington occurs in narrow, steeply dipping zones at the fringes of the stock (figure 4). It differs from Murray and Murex breccias in possessing abundant angular fragments, few rounded fragments, and a magnetite-rich matrix. Identical breccia containing magnetite and minor ilmenite in its matrix occurs at Gem Lake (plate 8).

A breccia associated with Tertiary (?) quartz diorite at the north face of the cirque at Big Interior Mountain may be a diatreme or may be of the same intrusive type which occurs at Zeballos. Its extent is not known. It contains fragments of fine to medium grained quartz diorite, dacite porphyry, plagioclase, quartz and

radiating amphibole, in a matrix of finer similar material plus calcite and chlorite.

MODAL COMPOSITION OF THE PLUTONIC ROCKS AND COMPARISON WITH COAST INTRUSIONS AND SOUTHERN CALIFORNIA BATHOLITH

Modes of 227 samples are given in table 2 (in pocket), and their locations are shown in figure 3 (in pocket). Omitting numbers 123, 127, 128, and 130 in order not to give undue weighting to small Tertiary quartz diorite plutons, the percentage of rock types present according to the classification used (p. 21) is as follows:

Peridotite	0.5	Granodiorite	41.6
Gabbro	7.2	Quartz Monzonite	10.0
Diorite	5.0	Albite Granite	2.2
Quartz Diorite	27.1	Potash Feldspar	
Trondhjemite	5.4	Granite	1.0

On the Qz-Kf-Pc diagram (figure 7) the granitic rocks of Vancouver Island are concentrated in three areas. The first contains granodiorites with between twenty-five and forty percent quartz, most of which are Jurassic. A large number of Tertiary quartz diorites with twenty to thirty-five percent quartz are present in the second area of concentration and the third area, of less intense concentration, contains both Jurassic and Tertiary diorites and gabbros at the

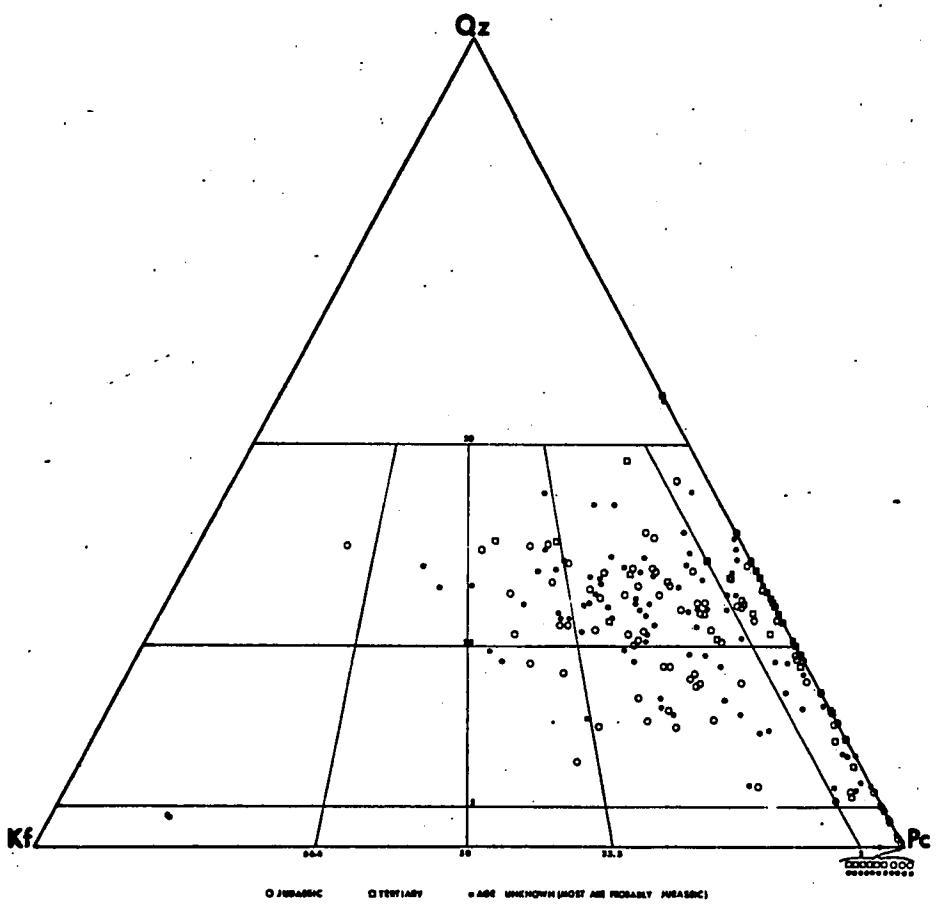

Figure 7 - Qz-Pc-Kf Diagram for Plutonic Rocks of Vancouver Island

Pc apex. Most of the few quartz monzonites and the only granite are Jurassic.

The Qz-Maf-Fp diagram (figure 8) indicates that as the quartz content of the rocks increases, the mafic minerals decrease and feldspars remain approximately constant. There is a preferred composition of about 30 percent quartz, 60 percent feldspars and 10 percent mafics. There is no obvious separation of Jurassic and Tertiary plutons on this diagram.

Modes of granitic pebbles from Aptian conglomerates (figure 9), from Rupert Arm on northern Vancouver Island, are similar to those of the Jurassic intrusions of all of Vancouver Island (figures 7, 8). Certain differences have been discussed previously (p. 25).

If adjustments are made so that the classification used for Vancouver Island plutonic rocks corresponds with that of Roddick (1965) an overall comparison can be made between the granitic rocks of Vancouver Island and those of the Coast Range near Vancouver. Table 5 lists the relative percentages of various granitic rock types for the Vancouver North and the Pitt Lake areas (Roddick, 1965), the Southern California batholith (Larsen, 1948), and Vancouver Island.

The relative abundances of Vancouver Island and Vancouver North plutonic rocks are very similar, though the Vancouver Island rocks appear to be slightly richer in potassium feldspar. Vancouver Island is to

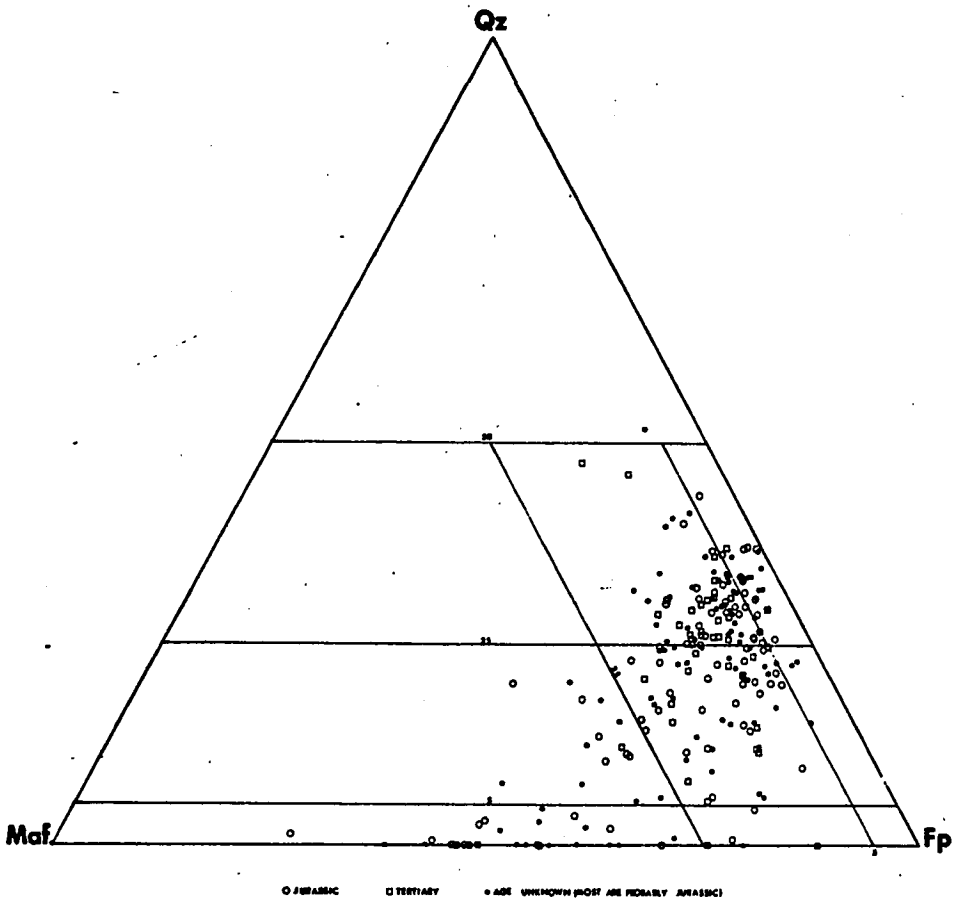

Figure 8 - Qz-Maf-Fp Diagram for Plutonic Rocks of Vancouver Island

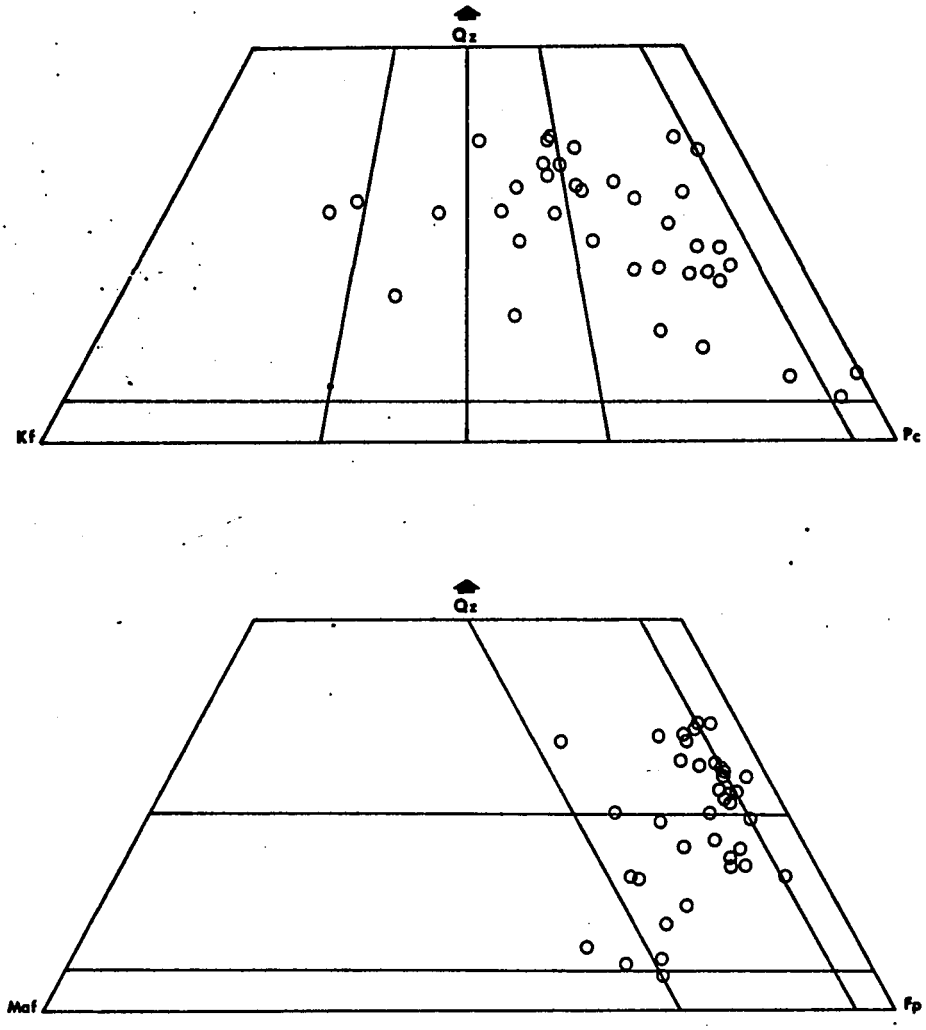

Figure 9 - Modes of Pebbles from Aptian Conglomerates

	Vancouver Island (this project)	Vancouver North (Roddick, 1965)	Pitt Lake (Roddick, 1965)	S. California batholith (Larsen, 1948)
Gabbro, Diorite, Migmatite, Peridotite (very minor, Vancouver Island)	19.0	19.7	27.0	7
Quartz Diorite, Trondhjemite	41.1	51.4	58.4	63
Granodiorite, Quartz Monzonite	36.2	26.5	14.2	28
Granite	3.7	2.4	0.4	2

Table 5 - Relative Abundances of Plutonic Rock Types of Vancouver Island, Vancouver North, Pitt Lake, and the Southern California Batholith (numbers are percentages)

the west of the main Coast Intrusions whereas Vancouver North is along their western edge. Both areas contain higher porportions of granite and granodiorite and smaller porportions of quartz diorite, diorite, and gabbro than the Pitt Lake area which is closer to the axis of the Coast Intrusions. From these facts it appears that there is a slight rise in the content of potash feldspar in granitic rocks to the west of the axis of the Coast Intrusions. This rise is however much less pronounced than that to the east of the axis. In this connection it is worth noting here that potash feldspar in most rocks of Vancouver Island is interstitial whereas plagioclase commonly forms larger crystals. Only one porphyritic intrusion containing potash feldspar phenocrysts has been found. It is Tertiary tourmaline-bearing granodiorite at Paradise Creek near Kennedy Lake (previous section).

It is apparent from the previous section that the central axis of Vancouver Island contains mainly quartz diorite, with minor granodiorite and no granite. To the northeast of this axis the dominant rock type is granodiorite, while to the west the rocks vary from granite to peridotite but probably have an average composition close to that of granodiorite. A great majority of the plutonic rocks are Jurassic. Most of the complex plutons containing more than one type of granitic rock occur to the west of the axis. Strongly gneissic rocks are abundant only in the western and southeastern portions

of Vancouver Island. This overall compositional zoning by area is indicated in figure 5. It may reflect differences in the sub-surface crustal rocks of the three areas. However, the axial area may be similar to the eastern area and merely more deeply eroded, whereas in the west the major fault systems (Sutherland Brown, 1966) may have been the control. They extend to deep levels, thereby allowing for intrusion of basic magma. Further, in fault-controlled chambers, some of the granitic magma may have been able to reach advanced stages of differentiation. The faults may also have been conduits for heat and fluids with the resulting formation of gneisses (Sutherland Brown, 1966).

Despite the facts that Tertiary plutons are much less abundant and were emplaced about 120 million years later than the Jurassic plutons, available data suggest that they too reflect this compositional zoning by area. The only known Tertiary quartz monzonite and granodiorite, Sooke gabbros, and Zeballos and Catface quartz diorites occur in the west whereas the only Tertiary plutons found elsewhere are quartz diorite and dacite porphyry.

The distribution of granitic rocks about the central axis of Vancouver Island is similar to that about the axis of the Coast Intrusions in the Pitt Lake and Vancouver North areas. However, although quartz diorite is the dominant type along both axes, the most salic intrusions occur to the east of the axis of the

Coast Intrusions but to the west of the Vancouver Island axis; yet, because the most mafic plutons also occur to the west on Vancouver Island the average compositions of the eastern and western zones on the island are about the same. Vancouver Island plutons on the whole may be considered as constituting a smaller version of the Coast Intrusions. The central axial zones of both areas contain quartz diorite and are structurally elevated and deeply eroded.

The granitic rocks of the Southern California batholith and of Vancouver Island are strikingly similar in some chemical aspects (next section). The larger porportion of quartz diorite and smaller proportion of granodiorite for the former as reported by Larsen (table 5) may be caused by different methods of calculating the proportions. For example, whereas the writer considers individual samples, Larsen considered map units. Portions of Larsen's tonalite plutons are granodiorite.

CHEMICAL AND NORMATIVE COMPOSITIONS

1 GENERAL STATEMENT

Chemical compositions of 62 granitic rock samples from Vancouver Island are listed in table 3 (in pocket) which also lists the corresponding norms. Many of the analysed samples are from known Jurassic and Tertiary plutons but the number of samples from each type is not indicative of its relative abundance. In figures 10 to 13, the different ages of intrusion are

distinguished from one another by the use of different symbols.

2 VARIATION DIAGRAMS

Variation diagrams of the types proposed by Nockolds and Allen (1953) and which are believed to illustrate trends of differentiation, are given in figures 10 and 11. Relatively uniform trends are indicated for all elements plotted.

A separation of known Jurassic and known Tertiary[1] plutons is indicated on the Na, K, Fe, and Ca diagrams. It is absent on the Mg, Al, and Si diagrams. The fact that curves either lie close together and parallel, or else overlap, probably indicates that the Jurassic and Tertiary plutons have somewhat similar origins.

Most known Jurassic plutons have a higher content of Ca and Fe than do known Tertiary plutons of the corresponding stage of differentiation. Higher Ca and Fe may be caused by contamination (next section) of the Jurassic plutons by their host rocks, which were largely basic volcanics and limestone of the Vancouver Group and rocks of the Sicker Group. Tertiary plutons

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1 It should be noted that the two most potassic Tertiary members which plot near the end of the series yield the oldest K-Ar dates. This is not considered to nullify the validity of the diagram since it is believed that separate chambers of magma undergoing differentiation may have been present in various places and at various times during the early Tertiary.

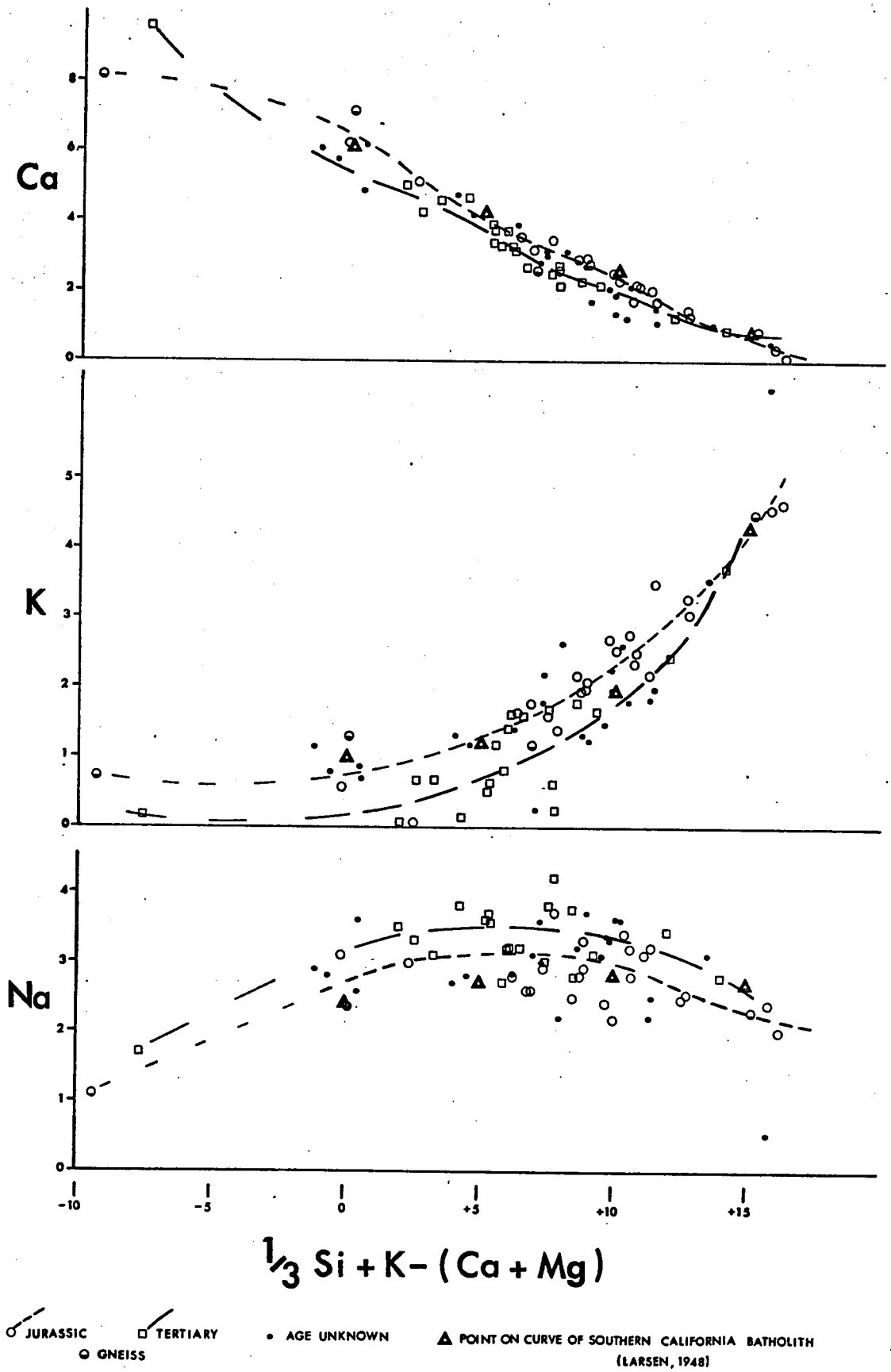

Figure 10 - Na-Ca-K Variation Diagrams for Plutonic Rocks of Vancouver Island

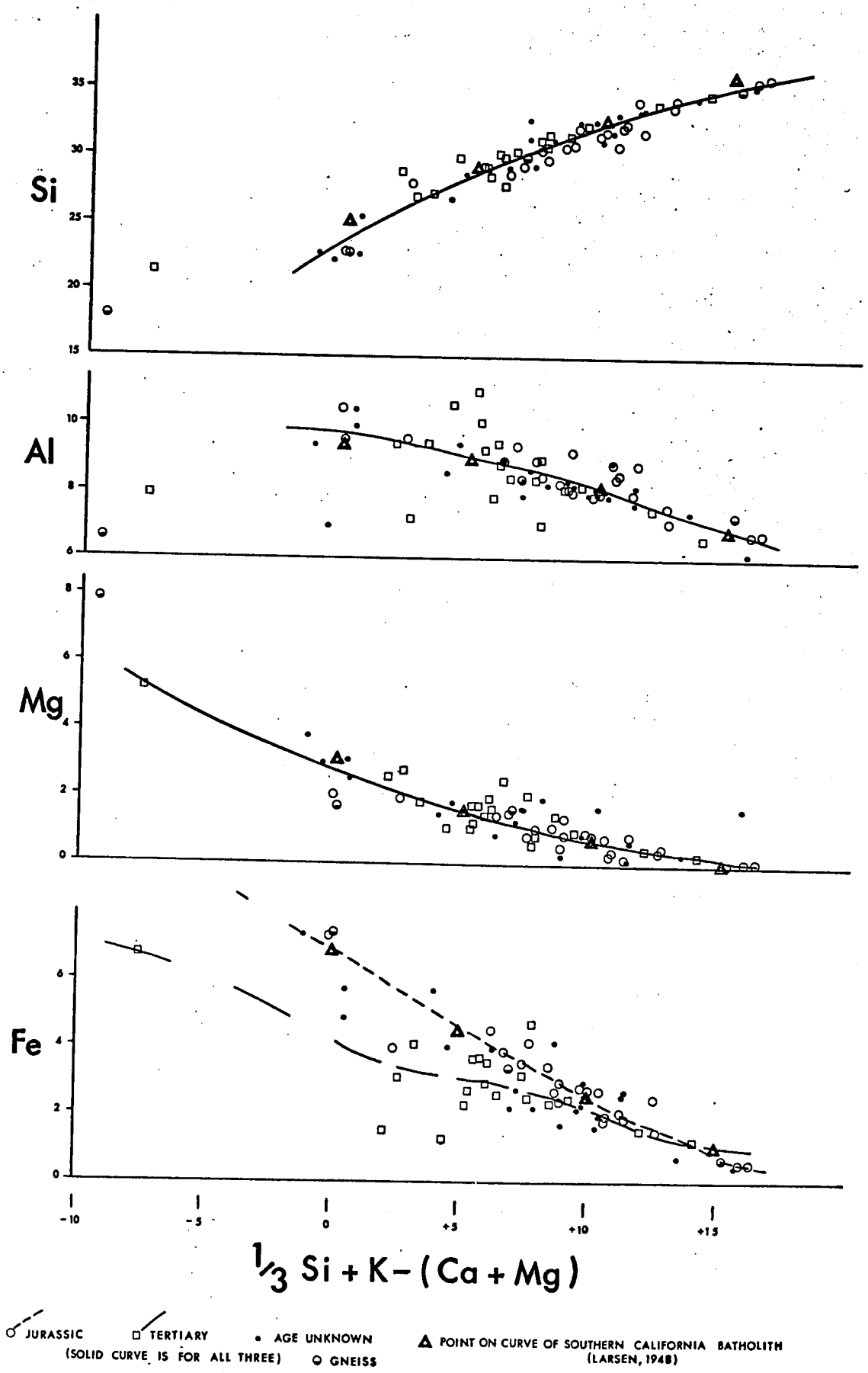

Figure 11 - Fe,Mg,Si,Al Variation Diagrams for Plutonic Rocks of Vancouver Island

are smaller and were probably less able to incorporate large quantities of their host rocks.

The K content of known Jurassic plutons is generally higher and the Na content lower than that of known Tertiary plutons, and a greater number of the Jurassic plutons are more highly differentiated. The differences in K and Na may be reflections of slight differences in the parent rocks. The Jurassic plutons are larger and formed at greater depths (p. 72). This probably enabled them to reach more advanced stages of differentiation over a longer period of cooling.

Chemical similarities between plutons of Vancouver Island, especially the Jurassic plutons, and those of the batholith of Southern California (Larsen, 1948) are suggested by the close correspondence of variation curves.

3 TERNARY NORMATIVE DIAGRAMS

The separation of Na, K, and Ca on variation diagrams (previous section) for known Jurassic and Tertiary plutons is emphasized by the normative An-Ab-Or diagram (figure 12a).

Tertiary plutons plot principally near the An-Ab or Ab-Or joins whereas Jurassic plutons plot closer to the centre of the diagram. The areas occupied by Tertiary and Jurassic plutons correspond roughly to the one feldspar field and the two feldspar field of the system respectively. This is in accord with their

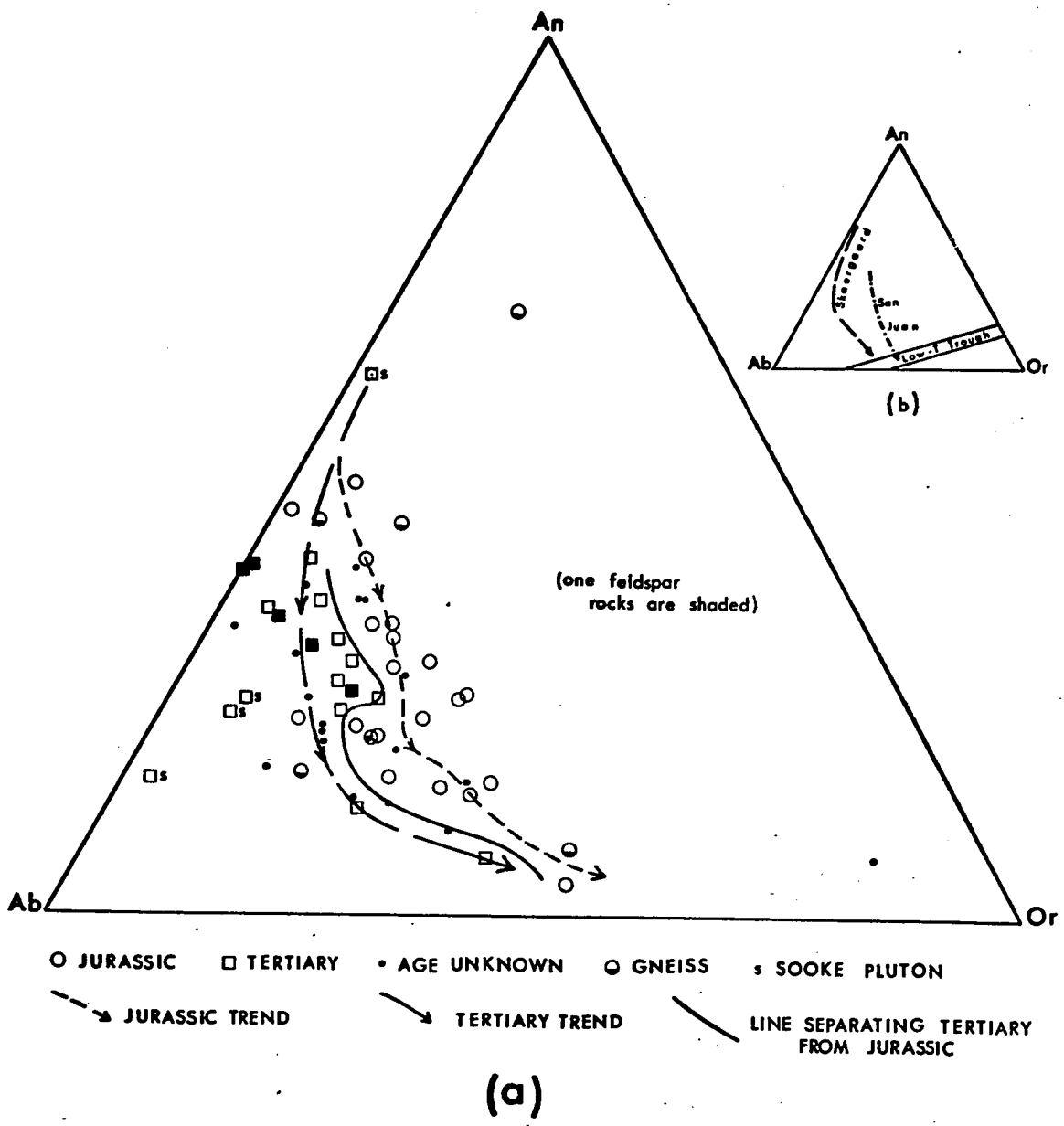

Figure 12 - An-Ab-Or Diagram

(a) Plutonic Rocks of Vancouver Island

(b) Differentiation Trends after Kleeman(1965)

mineralogy. None of the known Jurassic rocks in figure 12a contains only one feldspar. On the other hand, several Tertiary plutons contain only plagioclase feldspar, yet possess considerable normative orthoclase, much of which is probably in solid solution in plagioclase. Stevenson (1950, p. 43) believed that plagioclase in the Zeballos quartz diorite must contain considerable potassium. This pronounced solid solution is indicative of crystallization at high temperatures and/or low water vapour pressures.

Jurassic and Tertiary differentiation trends appear to begin at approximately the same position on the diagram, indicating that the rocks probably were derived from somewhat similar basic parental material.

Kleeman (1965) discussed the An-Ab-Or system and its bearing on the origin of granites. For most rock series differentiation proceeds from near the An-Ab join towards the low temperature trough near the Ab-Or join (figure 12b). Kleeman believed that the trend for the San Juan Province differs from that of the Skaergaard (figure 12b), because large volumes of salic host rocks were incorporated in the former during emplacement, causing contamination and modifying the differentiation trend. There is a similarity between trends of the uncontaminated Skaergaard and the Tertiary Vancouver Island plutons and between the San Juan Province and Jurassic plutons. This suggests that contamination by host rocks may have been important during emplacement

of the Jurassic plutons but that the Tertiary plutons are mainly uncontaminated differentiates. Support for these conclusions may be provided by the following:

(1) Sangster (1964) and Eastwood (1965) believed that the iron of the contact metasomatic magnetite deposits, most of which are related to Jurassic plutons (Ch. III) was derived from Karmutsen volcanic rocks due to incorporation of the volcanics by magmas. The relatively high calcium and iron contents of Jurassic plutons has been discussed and may be a result of this contamination.

(2) many Jurassic plutons possess basic border zones, and gradational contacts with their host rocks, indicating the possibility of contamination. The contacts of Tertiary plutons, other than Sooke trondhjemites,[1] are generally sharp.

(3) gold-quartz veins and Tertiary plutons are spatially and probably genetically related (Ch. III). The gold-quartz veins of all areas are very similar in composition. Their composition has been little influenced by their host rocks and this probably holds true for the associated Tertiary plutons.

If contamination did modify the Jurassic trend, salic material (which melts at relatively low temperatures) may have been derived by partial assimilation, especially

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1 three Sooke plutons plot towards Ab and to the left of the Tertiary trend in figure 12a. The Sooke plutons occur in a special environment, being associated with Eocene spilites. Their high sodium content may reflect this association.

of Sicker and older rocks. The residual, more basic material, may be represented by gneisses such as the Wark gabbro-diorites and Colquitz quartz diorites. Muller (J. E. Muller, personal communication, 1967) believes that many of the gneissic rocks on Vancouver Island were formed by metamorphism of the Sicker Group.

Some Tertiary plutons plot towards the center of the An-Ab-Or diagram and are the cause of the sharp projection of the line of separation between the known Jurassic and the known and probable Tertiary plutons. They include the largest Tertiary and possible Tertiary plutons at Zeballos, Hesquiat-Sidney Inlet and Catface Peninsula (figure 3, in pocket). Copper-iron deposits occur in skarns developed alongside the first, and possibly also the second of these plutons (figure 2, in pocket, nos. 37, 67, 68, 70). These intrusions may have been large enough to assimilate their host rocks and acquire copper and iron from them.

Distribution of known and probable Tertiary plutons and known Jurassic plutons on the Qz-Ab-Or diagram is shown in figure 13. Most Jurassic plutons and the potassium feldspar-rich Tertiary pluton at Paradise Creek (figure 3) are relatively near to the minimum for a water vapour pressure of 1,000-2,000 bars (Tuttle and Bowen, 1958), and within the low temperature area. Most other Tertiary plutons are near the Qz-Ab join, and many plutons of unknown age occur in both the Tertiary and Jurassic areas.

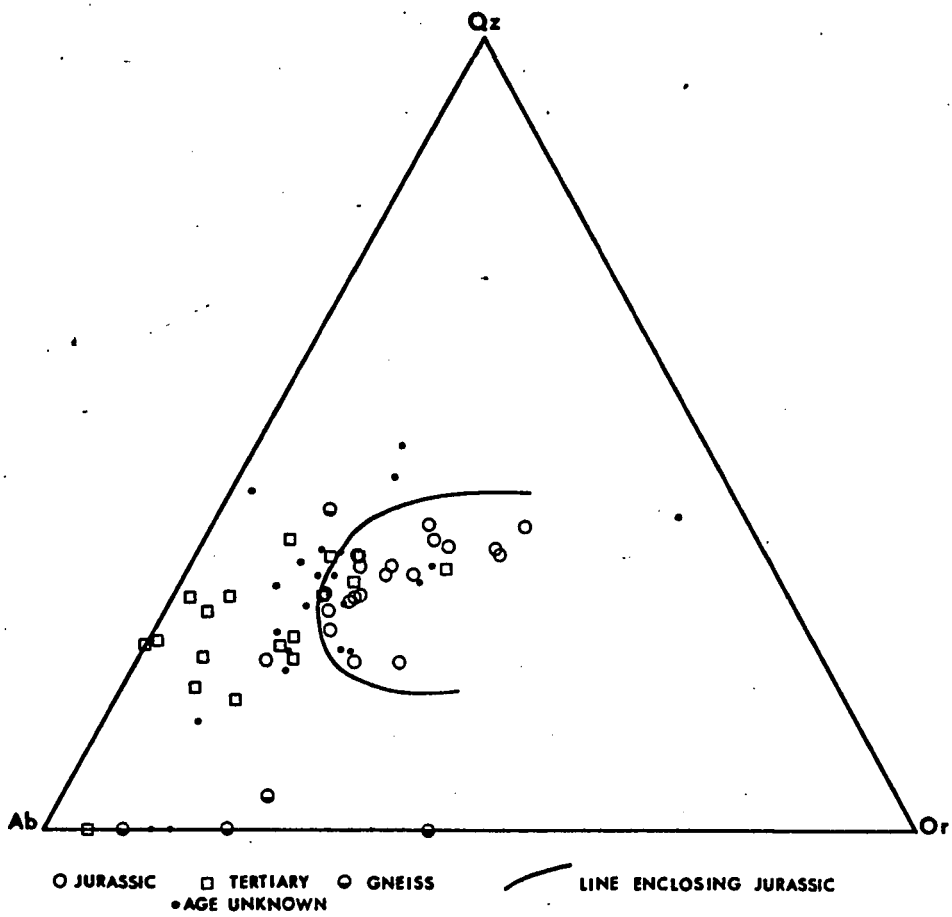

Figure 13 - Qz-Ab-Or Diagram for Plutonic Rocks of Vancouver Island

The above facts support the conclusions that most Jurassic plutons completed crystallization at lower temperatures than did Tertiary plutons, and that they are at a more advanced stage of differentiation and/or have assimilated more salic material.

PHYSICAL FORMS

1 MID TO LATE JURASSIC PLUTONS

a. GNEISSES

Wark, Colquitz, and similar gneisses (Clapp and Cooke, 1917; Muller, 1966) may grade into their host rock so that in many places their contacts with older rocks are concordant. These rocks are believed by Sutherland Brown (1966) to be syntectonic. They have many of the characteristics of plutons of the catazone (Buddington, 1959). These include prominent gneissosity and extensive border migmatite zones which are especially common in the Tofino-Hesquiat area, where the rocks are commonly of the amphibolite facies of regional metamorphism (Muller, 1966).

b. GRANODIORITE AND QUARTZ DIORITE

Saanich-type granodiorite plutons of the Cowichan Lake area (Fyles, 1955) are post-tectonic, northwest-trending dyke-like bodies with steeply-dipping contacts. They intrude the Sicker Group and the Karmutsen Formation.

The physical form of the Nimpkish batholith

at Kinman copper property has been studied by Gunning (1932a). The main body of the batholith is elongated in a northwesterly direction and is believed to have steeply-dipping contacts. However, at the Kinman property where the batholith intrudes Quatsino limestone, there are numerous concordant and/or discordant tongues, some of which dip at very low angles.

Most of the granitic plutons in the Zeballos-Nimpkish area (Hoadley, 1953) have been emplaced in the Quatsino and Bonanza Formations. They are northwest-trending bodies reaching batholithic proportions and some, such as the Bonanza batholith, appear to be generally concordant.

Sangster (1964) studied many plutons associated with the contact metasomatic magnetite deposits and concluded that they are transitional between epizonal and mesozonal types. His work was restricted to those parts of the plutons close to bedded rocks, including limestone of the Quatsino Formation. It is apparent from his work that at this stratigraphic horizon the plutons have varied forms. In places they underlie deposits in a concordant or discordant manner; elsewhere they occur as concordant or discordant tongues.

Drill records (Laanella, 1964) show that the south contact of the granodiorite pluton at Skarn property (Ch. III) dips moderately to steeply to the southwest. It truncates the northward-dipping Sicker Group rocks, but some small concordant apophyses of the main

pluton have been intruded into the bedded host rocks, which include limestone.

From the foregoing it is apparent that in general the granodiorite plutons have steep contacts, except in the vicinity of incompetent bedded rocks, especially limestone, where concordant and/or discordant apophyses occur. In the great majority of cases, these apophyses are within or near to Quatsino limestone. Some reach batholithic proportions.

The Bedwell quartz diorite batholith (Jeffery, 1965a; Muller, 1965) and several other plutons in the Alberni and Tofino areas (Muller, 1964, 1966) are in many places bounded by steeply-dipping faults. These probably formed after the emplacement of the plutons due to Tertiary uplift, which involved block faulting of the Nanaimo Group and older rocks.

2 TERTIARY PLUTONS

Tertiary plutons are epizonal and are post-tectonic.

The Tertiary quartz diorite stock and dacite porphyry dykes, sills, laccoliths, and irregularly-shaped bodies of the Mt. Washington-Constitution Hill area have been described by Carson (1960). Further mapping for this project is presented in figure 4 (in pocket).

Drilling results at Mt. Washington reported by deVoogd (1964) show that the northwest contact of the Mt. Washington stock is steeply-dipping but the

southwest contact may have more gentle dips. Dacite porphyry bodies in the Nanaimo Group sedimentary rocks surrounding the stock are essentially concordant. They occur at several horizons and are from a few feet to several hundred feet thick. The main "sill" which extends southeast from the stock past the summit of Mt. Washington, and the tongue-shaped projection of the stock which is exposed in cross-section one quarter of a mile west of the mine (figure 4) are very similar to laccolithic tongues in the Henry Mountains (Gilbert, 1877) and La Sal Mountains (Hunt, 1958) of Utah. The dacite porphyry body at Constitution Hill is underlain by nearly horizontal sediments but appears to have domed the rocks overlying it (figure 4). It is therefore probably a laccolith. Sill-like bodies occur in the Nanaimo Group between Mt. Washington and Constitution Hill and to the west of Mt. Washington. A generalized cross-section from Constitution Hill to Strata Mountain is shown in figure 14.

Dacite porphyries in the Nanaimo and Alberni areas (Muller 1964) occur as generally concordant sill-like bodies in the Nanaimo Group sedimentary rocks. A dacite porphyry dyke at Skarn property (Ch. III) is probably Tertiary. Many others may exist in regions of known Tertiary igneous activity.

The small pluton at Faith Lake (McDougall, 1963) is approximately 1,500 feet long in an east-west direction and a few hundred feet wide. It occurs in a

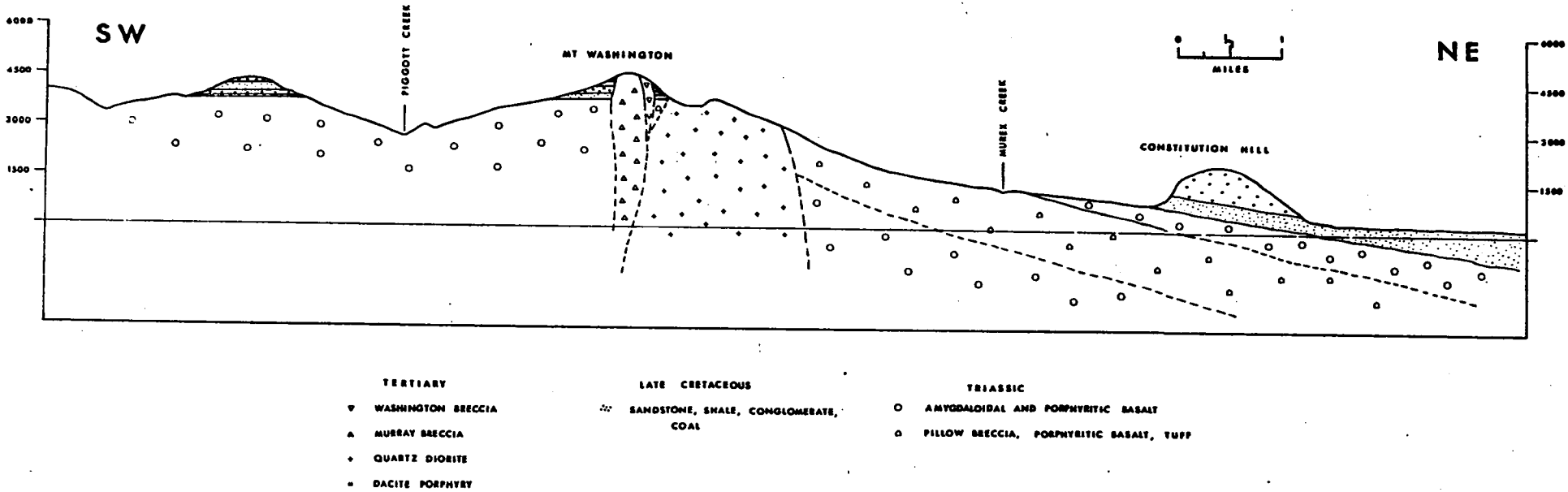

Figure 14 - Generalized Cross Section of the Mt. Washington-Constitution Hill Area

valley possibly along a major east-west fault and may widen at depth. Karmutsen Formation host rocks of the valley walls surrounding and above it are highly fractured, metamorphosed to hornfels, and pyritized. They contain numerous dacite porphyry dykes and quartz veins. Many of the dykes and quartz veins are nearly horizontal, are up to several feet in width, and occur between Karmutsen flows.

The small dacite porphyry pluton at Gem Lake (McDougall, 1961) has steeply-dipping contacts. A vertical breccia zone similar to the Washington breccia of Mt. Washington occurs alongside it.

The quartz diorite pluton at Catface (McDougall, 1962) is approximately one mile in diameter but probably underlies a much greater area as only the top appears to be exposed. Dacite porphyry occurs as steeply-dipping dykes and irregularly-shaped bodies up to several hundred feet in length cutting quartz monzonite at the center of Catface Peninsula.

Zeballos quartz diorite (Stevenson, 1950) forms a northwest-trending pluton approximately eight miles long by two miles wide. Its southwestern contact probably dips steeply to the southwest whereas moderate dips of approximately 60° to the northeast are indicated for the northeastern contact. The northern contact is marked by a zone of intrusive breccia 2,000 feet to 3,000 feet wide and is believed by Stevenson to dip gently to the southeast.

The forms of the probable Tertiary quartz diorites and breccia at Big Interior Mountain and of the small granodiorite and quartz monzonite plutons at Tofino and Kennedy Lake are unknown.

The Sooke quartz diorite and trondhjemite plutons were believed by Clapp and Cooke (1917) to be roof facies and apophyses of steeply-dipping gabbro stocks. More recent work by Stevenson (1951) and mapping by Macsan Exploration Co. Ltd. (figure 6) suggest that the gabbros are in part sill-like.

MODE OF EMPLACEMENT

1 JURASSIC GRANODIORITE AND QUARTZ DIORITE

Fyles (1955) cited several factors including the occurrence of rotated inclusions and variations in composition unrelated to the composition of host rocks, probably caused by differentiation, to conclude that the Cowichan Lake granodiorite plutons had a magmatic origin. There are no marginal breccia zones and the host rocks, which are mainly volcanic rocks of the Sicker Group and Karmutsen Formation, are only slightly disturbed. Fyles believed that the plutons were intruded in a passive manner along northwesterly-trending tension fractures.

The Skarn pluton (Ch. III) is similar in most respects to those at nearby Cowichan Lake. There are no marginal breccia zones. Isolated screens of chert are little disturbed but the limestone may have been disrupted. The pluton was probably emplaced in a manner

somewhat similar to those of the Cowichan Lake area with one main difference caused by a difference in host rocks. In the bedded Sicker Group rocks, especially the limestone, the Skarn pluton formed relatively small, generally concordant apophyses.

Gunning (1932a) discussed the mechanics of intrusion of the Nimpkish batholith. It is composed mainly of granodiorite similar to the Saanich types at Cowichan Lake. It is also elongated in a northwesterly direction. He (p. 303) proposed the following mode of emplacement for it:

"The magma ... arose along a northwesterly-trending line of weakness. It ascended through the competent Karmutsen volcanics in rather restricted form but under great pressure. Except in so far as stopping was operative at this stage, the magma found great difficulty in enlarging its chamber. But when the intrusion has pierced through the volcanics it encountered the less competent limestone and argillites which would yield more readily to compressive forces than the underlying volcanics. Once in the limestone the magma was able to enlarge its chamber by lateral extension. It overrode the underlying volcanics, pushing back the limestone into a series of more or less tightly compressed folds ..." .

Sangster (1964) noted an increase in the degree of deformation of host rocks as the plutons related to iron skarns were approached. He attributed this deformation to forceful intrusion.

In his report on the Zeballos-Nimpkish area, Hoadley (1953, p. 38-39) stated:

"The rocks of the Vancouver group are folded into broad, regional anticlinoria and synclinoria that strike northwesterly . ...

In the vicinity of major batholithic intrusive bodies, regional structures have been largely obliterated or masked by secondary structures imposed during intrusion.

Where the intrusions have invaded volcanic rocks, general upwarping and relatively mild folding are observed, and some of the smaller roof pendants have, apparently, been tilted en masse from their original position. However, where the intrusive bodies have invaded the Quatsino limestone or the sedimentary part of the Bonanza group, the degree of secondary folding is much more pronounced. The rocks are intricately folded and overturned, and, in places, recumbent folds are common."

Throughout Vancouver Island, there is a profusion of intrusive tongues and apophyses in and near Quatsino limestone (p. 6), but not in Sicker limestone. The controlling factors may have been lithostatic pressure and rock competency. In middle to early-late Jurassic the Quatsino Formation was approximately 10,000 feet[1] closer the the earth's surface than the Sicker limestone. Lithostatic pressure at the former was therefore lower, enabling ascending intrusions to spread laterally in the plastic limestone, once they had breached the top of the Karmutsen volcanics. Thus the ascent of many intrusions was halted near the Quatsino Formation. Direct results of this are the widespread recrystallization to marble, and abundance of skarn deposits in the Quatsino limestone. This mode of emplacement is depicted in figure 15a.

In figure 15a - (3) the line a-a' represents the erosional surface in the vicinity of a typical skarn deposit. Line b-b' represents a deeper erosional surface in a barren batholith such as the Bedwell batholith.

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1 thickness of Karmutsen Formation which occurs between the two limestone horizons (Sutherland Brown, 1966).

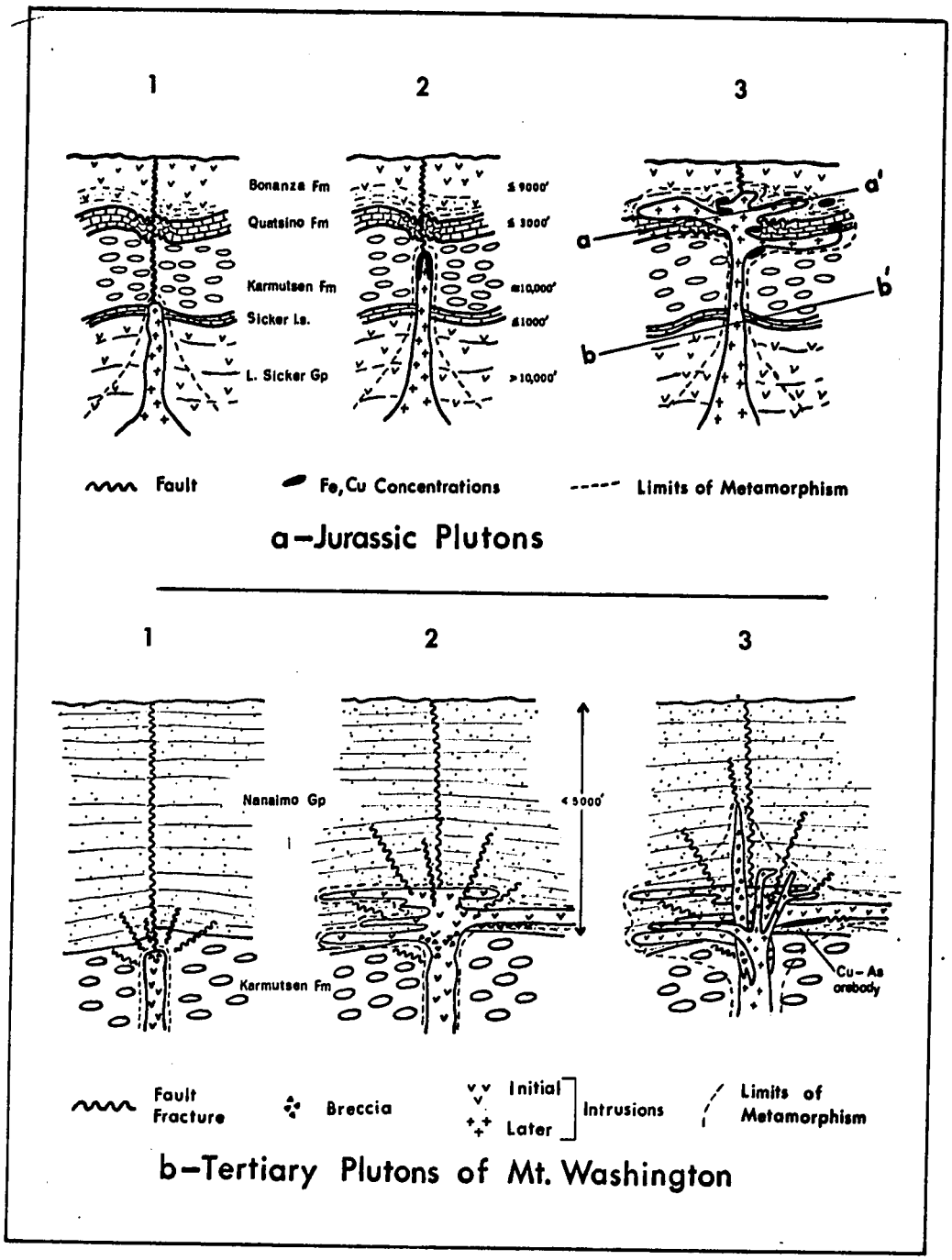

Figure 15 - Mode of Emplacement of Jurassic Plutons and Tertiary Plutons of Mt. Washington (diagrammatic)

The contacts of granodiorite plutons are probably steeply-dipping except in the vicinity of incompetent host rocks, especially limestones, where concordant and/or discordant apophyses occur.

Feldspar porphyry dykes which are abundant near Jurassic plutons, were probably emplaced at the peripheries of rising plutons during their ascent and during and in the late stages of their consolidation. Most dykes emplaced above the pluton would be metamorphosed and possibly mineralized by the pluton as it advanced upward.

2 TERTIARY PLUTONS

Tertiary plutons occur along the west coast of Vancouver Island and along two subsidiary linear zones trending across the island (figure 5). Their emplacement was in general probably controlled by major faults. In all cases where the plutons have been studied in detail they are found to contain porphyritic phases and breccias, and are thought to have been forcibly intruded.

The methods of emplacement of the quartz diorite stock, dacite porphyry sills and laccoliths, and the Washington and Murray breccias of the Mt. Washington-Constitution Hill area (figures 4, 15) are fully described by Carson (1960).

The Mt. Washington stock and dacite porphyry bodies appear to have been forcibly intruded in a manner

similar to that proposed by Gunning for the Nimpkish batholith (p. 67). Dacite porphyry magma arose in constricted form until it had breached the Karmutsen volcanic rocks. It then spread laterally in the Nanaimo sedimentary rocks to form dykes, sills, and tongue-shaped laccoliths. The configuration of the unconformity between the Karmutsen Formation and the Nanaimo Group, and the presence of a radial fracture pattern indicate that the host rocks above the stock were domed. Several pulses of intrusion occurred because the main porphyry sills at Mt. Washington are cut by similar but fresher porphyries. Also, the porphyries and the Nanaimo and Karmutsen host rocks are metamorphosed to hornfels in the vicinity of the stock, which probably remained active for some time after the initial intrusion of porphyry. The stock yields the youngest K-Ar age yet obtained from Vancouver Island (35 $\pm$ 6 m.y.). Origin of the breccias which formed after the intrusion of much porphyry, possibly due to a build-up of gaseous pressure from the still-active stock, has also been discussed by Carson (1960).

Extreme fracturing of the rocks of Faith Lake may have been caused by forcible intrusion of the quartz diorite pluton. The occurrence of thick, nearly horizontal quartz veins and dacite porphyry sills between Karmutsen flows in the valley walls above the pluton suggests that tension fractures were formed along S-planes by subsidence on the release of magmatic pressure. The

possibility remains, however, that the extreme fracturing is a side effect of fault movements.

Volcanic rocks and limestone occur around the fringes of Catface Peninsula whereas quartz diorite, quartz monzonite, and dacite porphyry form much of the core. It has been suggested by McDougall (1962) that during a prolonged period of intrusive activity the rocks of the peninsula were domed.

Concerning the emplacement of the Zeballos quartz diorite pluton, Stevenson (1950, p. 33) stated:

"The numerous quartz diorite dykes and the sharply fragmented contact breccias that characterize the contact zones of the quartz diorite intrusive, as compared with an almost total absence of these features associated with the hornblende diorite and granodiorite bodies, suggest that the quartz diorite intrusive was emplaced more forcibly and with less passive replacement of the wall-rocks than the hornblende diorite and granodiorite".

3 DEPTH OF EMPLACEMENT

On the basis of their epizonal and mesozonal characteristics, and on depth estimates for these types of plutons given by Buddington (1959), Sangster (1964) estimated that the depth of intrusion of plutons related magnetite deposits was 4.5 miles. There is no evidence suggesting that 4.5 miles of rock overlay the Quatsino Formation, which is the site of the deposits, in the middle to early-late Jurassic. The thickest Bonanza Formation section on Vancouver Island occurs in the Quatsino-Suquash area where it is estimated to be about 9,000 feet (figure 1). This may give a reasonable estimate of the depth of intrusion of some of the upper parts

of the Jurassic plutons since many appear to have halted their ascent at or near to the Quatsino Formation.

Carson (1960) has shown that when the Mt. Washington Tertiary intrusions were emplaced the sedimentary cover was much less than 10,000 feet. A closer estimate of the depth of intrusion may be obtained by considering estimates made by Gilbert (1877) and by Hunt (1958) for the relatively constant depth to which the numerous diorite porphyry stocks of the Henry and La Sal Mountains of Utah rose before spreading laterally to form laccoliths. Host rocks for the stocks are Cretaceous and Tertiary shales and sandstones which are physically similar to those of the Nanaimo Group. Hunt's estimate of the depth of lateral extension of the stocks is 5,000 feet. It is based on stratigraphic data. Gilbert arrived at a comparable figure mathematically.

The Mt. Washington stock rose through the massive and competent Karmutsen volcanics, breached their surface and immediately spread laterally in the Nanaimo sediments. If the comparison between the Henry Mountains and Mt. Washington is valid, this lateral movement probably occurred at depths of less than 5,000 feet. Had it been more than 5,000 feet the stock would have continued upward in the Nanaimo sediments.

From the foregoing it is apparent that both

Jurassic and Tertiary plutons commonly spread laterally once they had breached the top of the Karmutsen Formation.

SUMMARY OF MAIN DIFFERENCES BETWEEN JURASSIC AND TERTIARY PLUTONS

Table 6 summarizes the common differences between the known Jurassic and the known Tertiary plutons of Vancouver Island.

AGE	MODAL CLASSIFICATION	MAIN PHYSICAL FORMS	DEPTH CLASSIFICATION (Buddington, 1959)	DEPTH AND MODE OF EMPLACEMENT	MAIN CHEMICAL DIFFERENCES	COMMON TEXTURES	ALTERATION
Mid to Early - Late Jurassic	Gabbro to granite but mainly grano-diorite and quartz diorite.	Stocks batholiths, dykes.	Mesozonal-epizonal, mesozonal and mesozonal-catazonal	9000 feet and greater, forcible to passive.	Higher Ca, Fe, and possibly K, than Tertiary plutons of same modal type.	Medium grained, equigranular; porphyritic textures not common; gneissic structure common in western areas. Plagioclase weakly to moderately zoned.	Moderate to strong alteration; chloritization of mafics, clouding of plagioclase; biotite and chlorite dusty; prehnite lenses in biotite.
Mid Palaeocene to Early Oligocene	Mainly gabbro, quartz diorite, and dacite porphyry; subordinate grano-diorite and quartz monzonite	Stocks, sills, dykes, laccoliths.	Epizonal	< 5000 feet; forcible, breccias common.	Possibly higher Na than Jurassic plutons of same modal type.	Quartz diorites fine to medium grained; seriate and porphyritic textures common. Gabbros medium to coarse. No gneisses. Plagioclase strongly oscillatory-zoned.	Negligible to moderate alteration; plagioclase mainly clear; chlorite clear; prehnite lenses in biotite rare.

Table 6 - Main Characteristics of Jurassic and Tertiary Plutons of Vancouver Island

III - CLASSES OF METALLIFEROUS DEPOSITS

GENERAL STATEMENT

In this chapter, the metalliferous deposits of Vancouver Island are assigned to classes on the basis of their tenors, mineralogies, textures, alterations, stratigraphic and lithologic controls, structures, and times of formation. New classes recognized, such as the porphyry copper deposits (class H), are discussed in more detail than are the well-known classes such as the magnetite skarns (sub-class F-1). Great detail is available for few deposits, and the classification is therefore broad. Table 7 presents the classification and gives the most important characteristics of each class including spatially and/or genetically related intrusions which are considered in chapter IV. Additional data on deposits of some important classes are presented in tables 8 to 15 of this chapter.

The classification is not intended to be genetic and the writer employs terms such as "massive sulphide" rather than "hydrothermal" or "volcanic exhalative".

The features of more than 200 deposits ranging from small occurrences to producing mines (figure 2, in pocket) form the basis for table 7. Specimens were collected from more than 80 deposits and were studied under the microscope. Some deposits which have characteristics of more than one class, or are little known, are discussed at the end of the chapter.

Table 7 - CLASSES OF METALLIFEROUS DEPOSITS OF VANCOUVER ISLAND

	CLASS OF DEPOSIT	MAIN METALS AND TYPICAL TENOR	EXAMPLES OF DEPOSITS	MINERALOGY Mag Magnetite Cpy-Chalcopyrite Py-Pyrite Po-Pyrrhotite	HOST ROCKS OR ASSOCIATED FORMATIONS	IMPORTANT STRUCTURAL CONTROLS	ASSOCIATED ALTERATION MINERALS	RELATED INTRUSIONS Genetic and/or Spatial	KNOWN OR PROBABLE TIME OF FORMATION
N	PLACER GOLD	Au, low grade	Oyster R. Leech R.	Native Au	-------	---------	--------	--------	Recent
M	BOG IRON	Fe, 55%	Prince	Limonite, Py	Tertiary (?) Volcanics	---------	--------	--------	Recent
L	SODIUM HOT SPRING	Na	Sharp Point	NaCl - rich water	Diorite	Fissure	--------	--------	Recent
K	ALUMINIUM DEPOSIT	Al, Al_2O_3 = 12% - 20%	Kashutl Inlet	Alunite	Dacite tuff of Bonanza (?) Fm.	Zone of fractured and sheared rock	Sericite, silica, alunite.	(related to volcanism)	Tertiary
J	MERCURY BRECCIA-FILLING	Hg < 1%	Sechart	Cinnabar, native Hg, Py, hematite, limonite.	Andesite, limestone of Vancouver Gp., diorite	Fractures, breccia zones	Silica, carbonate	Unknown	Tertiary
I_2	COPPER OF SOOKE	Cu, 1% - 1.5%	Sunro Merryth	Cpy, Py, Po; minor Mag	Basalt of Metchosin Fm. and Sooke gabbro	Fractures, shear zones	Amphibole, scapolite	Sooke gabbro	Lt. Eocene or Oligocene
I_1	IRON OF SOOKE	Fe, low grade	Iron Mountain	Mag and/or Po	Sooke gabbro	Fractures, shear zones	Amphibole	Sooke gabbro	Lt. Eocene or Oligocene
H	PORPHYRY COPPER DEPOSITS	Cu < 1%; minor Au, Mo	Catface Copper Big I Faith Copper Corrigan Creek	Cpy, Py, Po, bornite; minor molybdenite.	Tertiary intrusive complexes and their varied host rocks.	Fractures and breccia zones, within and adjacent to intrusive complexes.	Several widespread minerals including silica, biotite, chlorite, kaolin.	Tertiary quartz diorite-dacite porphyry-breccia intrusive complexes.	Tertiary (Oligocene - Eocene)
G_8	GOLD-QUARTZ VEINS, FISSURES	Au, Ag; minor Pb, Zn, Cu, As	Privateer Musketeer Vulcan Vancouver Island Gold Rose Marie	Py, sphalerite, galena, Cpy, arsenopyrite, native Au.	Extremely varied. Sicker Gp., Vanc. Gp., Nanaimo Gp., intrusive rocks.	Fractures, faults, sheeted zones, fissure zones	Restricted silica, sericite, carbonate, chlorite.	Tertiary quartz diorite stocks and dacite porphyry sills, laccoliths.	Tertiary (Oligocene - Eocene)
G_7	COPPER-ARSENIC VEIN, BRECCIA ZONE	Cu; apprec. As; minor Au, Ag.	Mt. Washington Copper Macmillan	Cpy, bornite, Py, realgar, arsenopyrite, native As; some exotic minerals.	Nanaimo Gp., Karmutsen Fm., dacite porphyry	Fault or sheeted zone (Mt. Wash.), breccia zone (Macmillan)	Intense widespread silica, some carbonate	Tertiary dacite porphyry dykes, sills, laccoliths.	Tertiary
G_6	ARSENIC VEINS	As	Grizzly Wolf	Native As, realgar, arsenopyrite.	Argillite-Nanaimo Gp., basalt-Karmutsen Fm.	Brecciated fault zones.	Restricted carbonate, silica	Tertiary dacite porphyry sills, laccoliths.	Tertiary
G_5	TUNGSTEN STOCKWORK	W; some Sb	Victory	Scheelite; minor Py, stibnite	Limestone, marble, greenstone, or unknown age.	Fractures	Carbonate	Unknown	Unknown
G_4	ANTIMONY-QUARTZ VEINS	Sb; minor As	Silver Bell Lens	Stibnite; minor arsenopyrite.	Sicker greywacke, granitic rocks	Fracture	Restricted silica	None obvious	Possibly Tertiary
G_3	COPPER IN SHEAR ZONES	Cu; possibly Zn and minor Au	El Capitan Blue Ox Dauntless	Cpy, Py, possibly chalcocite; minor Po, sphalerite, arsenopyrite.	Karmutsen Fm., Bonanza Fm., granitic rocks.	Narrow shear zones	Restricted silica and/or carbonate	None obvious	Unknown - possibly during orogenies, metamorphism, in Jurassic, Tertiary.
G_2	COPPER-QUARTZ VEINS, STOCKWORKS	Cu; Mo, Au, Ag minor or absent	Mary Yankee Girl-Bay Independent	Cpy, Py; minor Po; possibly minor molybdenite.	Sicker Gp., Vanc. Gp., rarely granitic rocks	Single fractures or myriads of minor fractures near faults, contacts.	Minor to intense silica; possibly amphibole.	Granitic and porphyritic intrusions near some deposits.	Jurassic and Tertiary - ?
G_1	MOLYBDENUM-COPPER VEINS, STOCKWORKS	Mo; minor Cu	Allies Tofino Molybdenite Dry Gulch	Molybdenite, Py, Cpy	Intrusion, and possibly adjacent rocks	Single fractures or myriads of minor fractures	Widespread silica; some sericite; K-feldspar	Potassic stocks esp. in roof facies, borders.	Mid to Late Jurassic and E. Tertiary
F_4	ZINC-LEAD SKARNS AND ZONES IN LIMESTONE	Zn; major to minor Pb; minor Cu, Ag	Danzig HPM Alice Lake	Sphalerite, galena; minor Cpy, Py, arsenopyrite.	Skarn or siliceous zones in Quatsino, and rarely, Sicker limestones.	Bedding, dyke-limestone contacts.	Diopside-silica-calcite skarn, or silica alone	Feldspar porphyry dykes at deposits, granitic intrusions nearby.	Mid to Late Jurassic and/or Tertiary
F_3	MOLYBDENUM-COPPER SKARNS	Mo, Cu, both 1% - 2%	Sun West Comogo	Molybdenite, Py, Cpy, Po.	Skarnified sediments, volcanics of Sicker and Vanc. (?) Gps.	Intrusive contacts, favourable horizons, zones of fractured rock.	Skarn minerals garnet, epidote, actinolite, diopside, wollastonite. Silica	Quartz diorite intrusions.	Mid to Late Jurassic and (?) Tertiary
F_2	COPPER SKARNS	Cu 1% - 2.5%; apprec. to minor Au, Ag, Fe	Coast Copper Indian Chief Blue Grouse	Cpy, bornite, Po, Mag, Py	Skarn zones in volcanics and sediments (esp. Bonanza Fm.) near Quatsino and, rarely, Sicker limestones. Few deposits in limestone.	Intrusive and stratigraphic contacts, folds, fractures, breccia zones, favourable horizons	Skarn minerals garnet, epidote, diopside, actinolite.	Epizonal-mesozonal gabbro to quartz monzonite intrusions, most commonly granodiorite and quartz diorite.	Mid to Late Jurassic and (?) rarely Tertiary
F_1	IRON SKARNS	Fe 40% - 60%; apprec. to minor Cu	Brynnor Zeballos Iron Iron Hill Nimpkish	Mag; minor specularite, Py, Po, Cpy	Quatsino limestone and/or adjacent skarnified volcanic and intrusive rocks.	Same as for copper skarns (F_2)	Skarn minerals garnet, diopside, epidote	Same as for copper skarns (F_2)	Mid to Late Jurassic and (?) rarely Tertiary
E	NICKEL IN PERIDOTITE	Ni < 1%; minor Cu	Meares Island	Po, Cpy, siegenite, Mag, Py	Serpentinized peridot sill (?) in gneiss complex.	Unknown	Serpentine, amphibole	Mesozoic (?) peridotite sill (?)	Mesozoic (?) possibly Triassic
D	VANADIFEROUS SEDIMENT	V, V_2O_5 = 1% - 2%. Some Cu	Campbell River (Menzies Bay)	Volborthite, chalcocite, covellite, malachite, brochantite	Carbonaceous siliceous sediments of Karmutsen Fm.	---------	--------	----------	Triassic
C	COPPER IN BASIC VOLCANICS	Cu < 1%	Millington Coal Creek	Cpy, bornite, Py, chalcocite; minor native Cu, covellite	Basic volcanics of Karmutsen and Bonanza Fms.	Brecciated flow tops, amygdules, fractures, small shears	Limited chlorite, serpentine, amphibole, prehnite, epidote, etc.	None	Triassic - E. Jurassic
B_2	MANGANIFEROUS CHERT	Mn 14% - 30% (unoxidized); up to 50% oxidized; possible Fe	Hill 60 Lacy Lake	Rhodonite; minor rhodochrosite, Mn garnets, Mn oxides, Py	Cherty sediments of upper Sicker Gp.	Bedding; minor fractures	---------	----------	E. Permian and/or Pennsylvanian
B_1	FERRUGINOUS CHERTS	Fe 15% - 25%; possibly Mn	Lady A, B, C	Mag; minor hematite, specularite	Cherty sediments of upper Sicker Gp.	Bedding	---------	----------	E. Permian and/or Pennsylvanian
A	ZINC-COPPER-LEAD MASSIVE SULPHIDE	Zn 5% - 10%, Cu 1% - 2%, Pb 1%; Ag 3 oz/ton, Au 0.1 oz/ton, Ba	Lynx (West. M.) Price Twin J	Sphalerite, Cpy, Py, galena, tetrahedrite, barite, minor bornite.	Quartz-sericite schists derived from cherty tuffs and breccias of Sicker Group.	Major sheared zones, near-horizontal folds (crests), faults, cherty tuff beds.	Local abundant silica	None obvious	E. Permian and/or Pennsylvanian, or later

Four deposits which are important members of certain classes were studied in detail during this project. Each is described in the first part of the section concerned with the class to which it belongs. The second part of each section is concerned with the distinguishing features of the entire class and draws on the information of the first part, on data concerning deposits described in previous publications, and on any additional information including microscopic studies and data supplied by mining companies, obtained for this project.

CLASS A - ZINC-COPPER-LEAD MASSIVE SULPHIDE DEPOSITS

1 PRICE 2000 DEPOSIT

a. LOCATION AND GENERAL GEOLOGY

The Price deposits of Western Mines Limited are approximately one mile southwest of the south end of Buttle Lake (figure 2). The main occurrence, the Price 2000 deposit, is at an elevation of 2000 feet in a creek which will be referred to in this thesis as Main Creek. Two smaller occurrences are found at elevations of 850 and 1,300 feet (Price 1300 deposit) on the north side of the creek. The Price deposits and those of Paramount and Lynx to the northwest are described by Gunning (1931) and by Jeffery (1965b). The general geology of the Buttle Lake area is outlined by Gunning (1931), Muller (1965) and Jeffery and Merrett (1964).

The massive sulphide bodies at Lynx, Paramount and Price occur in volcanic rocks of the lower Sicker Group.

The overlying Sicker limestone, containing coarse grained gabbro sills which are probably intrusive equivalents of the Karmutsen volcanic rocks, is a few miles from the deposits (Jeffery, 1965a).

Bedwell batholith (Ch. II) is approximately two miles west of the Lynx, Paramount, and Price deposits.

The Sicker rocks are gently folded on a broad regional scale and dips are generally 20-40 degrees. Faults are more important structures. Three main sets of steeply-dipping faults and shear zones were recognized by Jeffery and Merrett (1964, p. 106). They trend northwesterly, northerly, and westerly. The northwesterly faults are the oldest and the westerly faults offset contacts of the Bedwell batholith.

The Price sulphide showings are little changed since Gunning first described them (1931, p. 67A-68A). The geology of the Price 2000 showing is presented in figure 16 (in pocket).

b. ROCK TYPES

SICKER GROUP VOLCANIC ROCKS

The Sicker volcanic rocks at Price 2000 are mainly varicoloured massive to schistose tuffs and breccias, and greenish-brown massive andesite. They belong to the greenschist facies of regional metamorphism and underlie approximately eighty percent of the area mapped. Massive tuffs and breccias are generally

pale greenish-brown to grey, but where moderately to strongly sheared they are commonly green, grey, or purple. In many cases the tuffs and breccias have a siliceous appearance and are probably dacitic in composition. The general dip of the Sicker rocks is about twenty degrees to the south-southeast, but in detail dips are erratic.

Tuffs and breccias are interbedded throughout the area mapped and there is a complete gradation from fine tuffs, some of which are thin bedded and contain cherty layers, to coarse breccias with angular and rounded fragments up to one foot in diameter. For these reasons it was not possible to map the tuffs and breccias separately. However, a north-northwest-trending zone of rust-coloured quartz sericite schist probably derived from fine grained cherty tuffs was mapped as a separate unit (figure 16).

In most localities the tuffs and breccias are sheared to some extent, but the intensity of shearing is greatest in the zone of quartz-sericite schist and in the vicinity of the major fault which follows Main Creek.

Microscopic examination of a moderately sheared coarse grained green tuff reveals coarse fragments of fine grained tuff, fragments of unidentified rock type(s), and angular plagioclase and quartz grains in a finer matrix of similar material. Fragments and matrix are greatly altered, and the present mineralogical composition of the rock is approximately as follows:

sericite	40 %
chlorite	25 %
quartz	10 %
plagioclase	5 %
calcite	15 %
opaques	5 %

Fine grained purple tuff examined under the microscope possesses crenulated layering which is clearly exhibited by streaks of iron and (?) manganese oxides, broken and unbroken quartz fragments varying from minute sized to 1.5 millimeters, lens-shaped patches of sericite, largely replacing plagioclase crystals leaving only the original core, and fragments of cherty material. An estimate of the composition of the rock is as follows:

sericite and (?) talc	55 %
quartz fragments	10 %
cherty fragments	5 %
opaques	15 %
brown oxides	15 %
plagioclase remnants	1 %

The zone of quartz-sericite schist is the host for the mineral deposits. It is truncated by the Main Creek fault and grades rather abruptly to less schistose chlorite-rich green tuffs to the south. Its eastern and western boundaries with normal tuffs and breccias are very sharp, and it appears to have

been derived from a single layer consisting of beds of very fine grained cherty tuff which graded along strike to andesitic tuffs. It is composed chiefly of sericite and quartz with minor calcite and chlorite, possibly some talc, and iron oxide is scattered sparsely throughout. The iron oxide, derived from sparsely disseminated pyrite, gives the rock a distinct rusty appearance.

Andesite occurs as a north-northwest-trending zone approximately 300 feet wide overlying the tuffs and breccias in the western portion of the area mapped. It is relatively massive, fine grained, and of diabasic texture. It is generally weakly epidotized. The andesite may be extrusive or intrusive but it is almost certainly part of the Sicker Group. Gabbroic sills in the Sicker Group which are believed by Jeffery and Merrett (1964, p. 106) to be related to the overlying Karmutsen volcanics, are darker and much coarser grained. The andesite appears to have withstood better the deformation which caused shearing of the tuffs and breccias. However, it is weakly lineated, and its contact with tuffs is, in places, folded.

Under the microscope, the andesite is observed to have the following approximate composition:

plagioclase	60%	---	weakly zoned euhedral to subhedral oligoclase
quartz	10%	---	clear crystals
amphibole	5%	---	crystals up to 0.5 millimeters long
chlorite	20%	---	after hornblende

epidote 5%--- veins and scattered crystals

TRAP DYKES

Narrow, irregulary-shaped, very fine grained, massive dykes of basaltic (?) composition, similar to the andesite band in appearance but slightly darker brown, cross-cut quartz-sericite schist and the andesite. Under the microscope a specimen from one dyke is observed to be strongly altered and to contain a matrix of strongly aligned semi-opaque material, sericite, calcite, and chlorite with fragments (?) of quartz and porphyritic-aphanitic andesite (?). These dykes are very similar in appearance both in the hand specimen and in thin section, to dykes on the 1,075 level of the Lynx mine.

PORPHYRY DYKES

Dykes of massive grey plagioclase porphyry averaging fifty feet in width intrude the Sicker rocks. They trend easterly to northeasterly roughly perpendicular to the structural trend of the Sicker Group. These dykes were intruded along steeply-dipping tension fractures and are not as deformed as their host rocks, although they are folded and are abruptly terminated at major faults (figure 16). They are also terminated at localities where it is difficult to show that faulting has occurred. These localities probably represent terminations in the original tension fractures, and may in some cases coincide with faults. Offshoots from the

dykes have formed along schistosity planes in the Sicker schists.

The rock is strongly altered and has a seriate texture. The matrix is very finely granular, and consists of quartz, plagioclase, and opaque minerals, with alteration products chlorite, epidote, calcite, and sericite. Plagioclase ranges from matrix-sized to phenocrysts 3.5 millimeters in length, but averages 1.0 millimeters in length. These phenocrysts are dusty pink, due possibly to adsorption of iron oxide on particles of fine clay mineral (Roddick, 1965). A few very fine intergrowths of chlorite and calcite occurring in straight-edged lots were probably former hornblende phenocrysts. The mineralogical composition of the rock is approximately as follows:

Matrix = 80%

plagioclase	40%
quartz	10%
chlorite	15%
sericite	5%
calcite	5%
opaques	2%

Phenocrysts = 20%

plagioclase An_{55-60}

Three small irregularly-shaped masses of quartz-plagioclase porphyry similar in appearance to the

plagioclase porphyry have intruded the andesite in the northwest part of the area mapped.

The plagioclase porphyry and plagioclase-quartz porphyry intrusions are probably related to the Bedwell batholith which is two miles west of Price 2000 showing. They are highly altered, unlike most known Tertiary dykes, and the plagioclase-quartz porphyry is texturally similar to the porphyritic contact zone and apophyses of the batholith near Della Lake (Ch. II).

c. STRUCTURAL DEVELOPMENT

FOLDS

The Price deposits occur on the east flank of a broad anticlinal structure trending north-northwest. According to Jeffery and Merrett (1964) this structure is composed of a number of gentle fexures giving an overall anticlinal structure but there is no single dominant anticlinal axis.

Older Folds The older fold structures are not readily observed at Price 2000 because bedding is not common, many of the rocks are highly sheared, and most exposure surfaces are parallel to the fold axes. In several localities, however, where steep exposures face north-northwest or south-southeast, it is possible to observe tight folds of up to several feet in amplitude whose axes plunge gently to the south-southeast (plate 9). Folds of the same type occur at Lynx where they plunge gently to the northwest or southeast (Jeffery, 1965b). Closely-spaced planes of steeply-dipping axial

plane cleavage approximate schistosity. These folds are observed in the finer tuffs and the quartz-sericite schists, and because lineations formed at the intersection of bedding with axial plane cleavage are very common, it is believed that in these rocks such tight folds are abundant. They have not been observed in the andesite or in massive breccias, although the contact of the andesite with tuffs is folded in a few localities. It appears that layers of fine cherty tuffs were most susceptible to crumpling during regional folding, whereas the more massive andesites and breccias were little disturbed except in the vicinity of finer tuffs.

The older folds are intruded by plagioclase porphyry dykes.

Younger Folds Drag folds with near vertical axes and amplitudes of about half an inch are very common in the quartz-sericite schist, the tuffs and the breccias. In most cases they are in previously-formed schistosity planes. A few have also been observed in the more massive andesite, and in the youngest rocks of the area, the plagioclase porphyry dykes.

The large steeply-dipping dyke which crosses the southern part of the area has been folded about near-vertical axes into two and one-half complete folds having amplitudes of approximately 150 feet and lengths of about 350 feet (figure 16). These large folds, and the smaller drag folds, appear to have formed by non-affine deformation. This probably involved differential slippage along

older schistosity planes.

SCHISTOSITY (AXIAL PLANE CLEAVAGE)

The average attitude of the schistosity planes, which are very common in the Sicker tuffs and breccias, is N 33° W/ 90° . These schistosity planes, excepting possibly those near faults, are in fact axial plane cleavage related to the older folds and (?) younger folds described above.

LINEATIONS

Lineations formed at the intersection of bedding planes with the axial plane cleavage are common in the tuffs, less common in breccias and rare in the andesite. They have a very constant attitude, over the entire area mapped, of approximately N 33° W, plunge 13° S. These are b-lineations and give the attitude of the older fold axes which are probably parallel to larger regional fold axes.

FAULTS

The only positively identified fault in the area is the Main Creek fault (plate 10). It follows Main Creek in a west-northwest direction and dips moderately to steeply to the north. In some places it consists of one or more distinct shear zones, and at most localities movement appears to have occurred along numerous schistosity planes. The fault is probably a left handed strike-slip fault since it appears to have

displaced the large steeply-dipping, southwest-trending plagioclase porphyry dyke a horizontal distance of about 600 feet. However, it is not certain that the plagioclase porphyries on the north and south sides of the fault are parts of the same dyke because dykes of plagioclase porphyry have been observed at lower elevations on the north side of Main Creek. The time of formation of the fault is unknown but movement has apparently occurred since the intrusion of the plagioclase porphyry.

The Price 2000 mineral deposits are located in or alongside the fault where it crosses the layer of quartz-sericite schist.

The smaller creek 400 feet to the north of Main Creek may be the locus of another north-northwest trending fault. The northern plagioclase porphyry dyke ends abruptly at the creek but no distinct fault plane is exposed there.

JOINTS

A very regular set of northeast-trending, steeply-dipping joints is present in rocks of the Sicker Group. Next to Main Creek they are commonly filled with white quartz. The plagioclase porphyry dykes appear to have been intruded into a very large tensional fracture belonging to this set.

The average attitude of thirty-two joints, or groups of joints in a single outcrop for which the average

attitude was recorded, is N 58° E/ 87° N.

STRUCTURAL DEVELOPMENT

The sequence of structural events at Price deposit may be summarized as follows:

(1) Deposition of the Sicker Group in the late Palaeozoic.

(2) Broad regional folding during which local incompetent fine grained tuff and cherty tuff layers were tightly folded along axes plunging gently to the south-southeast, and were converted to quartz-sericite schist.

The incompetent layers at Price were crumpled or rolled out between more competent layers which were less affected. Axial plane cleavage was developed. Tensional fractures formed after crumpling and perpendicular to compressional forces which were from the west-northwest and east-southeast.

The deformation probably occurred during the Coast Range Orogeny in the Jurassic.

(3) Intrusion of plagioclase porphyry into large tension fractures of the first deformation, probably during the Jurassic.

(4) Folding about vertical axes. This involved non-affine deformation by slippage along previously-formed cleavage. Large folds and small drag-folds in the plagioclase porphyry and Sicker Group, were

formed by compression from the northeast and southwest.

(5) Movement along the Main Creek Fault. The fault may have formed as early as late Palaeozoic but the last movement on it was probably Tertiary.

d. MINERAL DEPOSITS

DESCRIPTIONS

The Price 2000 mineral deposits occur in the layer of quartz-sericite schist where it abuts against the Main Creek fault. Sparsely disseminated pyrite is presented in the quartz-sericite schists to the south of the fault.

Gunning (1931) first examined the Price 2000 deposits and very fully described the occurrence of the sulphides. At that time the area was heavily forested and good exposures were limited to Main Creek. His original description (p. 67A-68A) is as follows:

"The highest working, 2,000 feet above sea-level, on the side of a narrow gulch, is an open-cut 50 feet long and about 10 feet high at the face. The cut runs south 70 degrees west. On the east there is 15 feet of slightly pyritic and partly schistified greenstone which was in part originally a cherty tuff. This is followed to the west by 6 feet of rusty weathering, light grey, pyritic, quartz-sericite schist bounded on the west by a pronounced fault wall striking north 50 degrees west and dipping 60 degrees northeast, parallel to the schistosity. West of the fault is 17 feet of greatly schistified material mixed with gouge, partly replaced by chalcopyrite, zinc blende, and pyrite and also cut by several irregular, lenticular, vein-like bodies of the same minerals with a maximum width of 30 inches. Zinc is the most abundant metal. Under the microscope numerous tiny specks of grey copper are visible in the ore and the chalcopyrite and zinc blende form a very fine-grained, intimate intergrowth.

Although the mineralization is very irregular in detail yet the whole 17 feet would probably constitute a fair grade of milling ore if the sulphides could be successfully separated. Clothier[1] gives the following assays: (1) across 18 inches near bottom of cut -- gold trace, silver 1 ounce, zinc 27.9 per cent, copper 2.4 per cent; (2) near top of cut -- gold trace, silver 1 ounce, zinc 28.7 per cent, copper 3.3 per cent. At the west side of this mineralized section a second wall trends north 70 degrees west and dips steeply northeast and beyond it is 10 feet of oxidized and leached pyritic schist containing, particularly, beside a third fault on the west which strikes north 40 degrees west and dips steeply northeast, a little residual copper and zinc. Thus, there is some 27 feet of mineralized material which seems well worth more extensive exploration. West of the cut, chlorite schist and quartz-sericite schist are exposed for about 150 feet up the steep creek bed. The schist strikes north 25 degrees west and is vertical, so that the mineralized zone appears to be cutting it at a low angle. In the creek, 50 feet above the workings, is a small, irregular band of zinc blende containing pyrite, chalcopyrite, a little galena, and considerable grey copper as tiny microscopic specks and veinlets. Barite is present in the gangue at this point. The showing has not been developed."

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1 Ann. Rept., Minister of Mines, B.C., 1929, p. 384.

Plate 10 illustrates the nature of the west end of the fifty foot open cut described by Gunning. Tight folds appear to be present in the mineralized rock. Massive barite "ore" from Price 1300 deposit (plate 11), which is very similar to that at Price 2000, has the following approximate composition:

barite	55 %
pyrite	20 %
sphalerite	15 %
chalcopyrite	5 %
galena	2 %

tetrahedrite-tennantite	1%
bornite	1%

The texture of massive barite "ore" from Price 2000 as observed under the microscope, is banded (plate 12) and the "ore" appears to be deformed. White pyrite crystals are rounded and partly replaced by sphalerite. They are strewn out in the sphalerite which forms a matrix for other sulphides. Sphalerite is light grey and displays strong internal reflection. Chalcopyrite occurs as veins in fractured pyrite, is intergrown with sphalerite, and exhibits mutual boundary relationships with tetrahedrite-tennantite. Galena blebs are scattered throughout. Bornite forms rare veinlets in pyrite and is intergrown with chalcopyrite.

STRATIGRAPHIC AND LITHOLOGIC CONTROLS

Mineral deposits at Price 2000 are entirely confined to the layer of quartz-sericite schist. This rock unit is believed to have been derived from a stratigraphic horizon consisting largely of fine grained cherty tuffs.

STRUCTURAL CONTROLS

The Price 2000 deposits occur within the quartz-sericite schists but only in close proximity to the Main Creek fault. Therefore the fault is a structural control. Later movements along the fault have disrupted the deposits.

As is the case at Lynx and at Twin "J" mine near

Duncan, tight folds in the quartz-sericite schist may be the locus for some of the mineralization at Price 2000. These may be crumple-folds formed during the first deformation of the original cherty tuffs, but which have been modified by movement on the Main Creek fault.

AGE OF DEPOSITS

The age of the Price deposits is unknown. The metals may have been deposited during the formation of their host rocks or at any time thereafter including the interval corresponding to the Coast Range Orogeny. In their present form they are controlled in part by the Main Creek fault. However, they may have migrated into the fault zone from older sites. Deformation of the sulphides (previous section) may have occurred at any time after the consolidation of the Sicker Group host rocks.

Further evidence for the age of the Price deposits is given in the next section in which characteristics of Class A deposits are discussed.

2 CHARACTERISTICS OF CLASS A (see tables 7, 8).

a. EXAMPLES OF CLASS A DEPOSITS

The five known deposits of Class A are Twin "J", Mt. Richards, Lynx, Paramount, and Price (figure 2, in pocket). Their characteristics are given in table 8. Little information is available on the Mt. Richards deposit

Examples with ref. no. for fig. 2	Zn %	Cu %	Pb %	Au oz/ ton	Ag oz/ ton	ORE MINERALOGY Py-Pyrite; Sp-Sphalerite; Cpy-Chalcopyrite, Ga-Galena.	COMMON TEXTURES	PHYSICAL FORMS	HOST ROCKS	STRUCTURAL CONTROLS, LOCUS OF ORE	MAIN REFERENCES (TP) - this project
Twin "J" 1	6.3	1.3	0.6	.08	2.9 (north orebody avg.)	Py, Sp, Cpy, Ga, bornite, quartz; minor tetrahedrite. No magnetite; pyrrhotite extremely rare. Barite common.	Bands of Cpy and Sp with brecciated and/or partly resorbed Py crystals throughout. Ga and tetrahedrite grains concentrated in certain layers.	Two parallel lenses 150' apart. North orebody 1700' x 120' x 1' - 10'; South orebody 2100' x 150' x 20' .	Quartz-sericite schist and graphite schist with calcite, barite, derived from cherty tuffs and breccias of Sicker Group.	Crests of horizontal drag-folds occurring in a major shear zone.	Stevenson (1945b)
Mt. Richards 2	Unknown					Py, Cpy, Sp, bornite, barite, quartz.	Unknown	Unknown	Schists derived from Sicker Group	Sulphides in center of shear zone.	Allan (1910)
Lynx 3	10.5	2.2	1.4	.06	2.9 (avg. grade of reserves 1965)	Same as Twin J with minor bornite.	same as Twin J	Lenses, irregular masses, tabular bodies up to 40' wide and 800' long. Dip length commonly about 100'.	Same as Twin J but talc and chlorite common, graphite absent.	Major sheared zone possibly where crossed by major fault. Horizontal drag folds. Bulges in hanging wall of sheared zone; upper flanks of masses of unsheared rock.	Gunning (1931) Jeffery (1965b)
Paramount 4	12.8	0.9	2.0	.16	5.9 (area 5' x 26.5')	same as Twin J but more galena and tetrahedrite.	same as Twin J	Tabular	Same as Lynx	Same as Lynx ?	Gunning (1931) (TP)
Price 5	8.6	.66	0.8	.02	.33 (avg. of 3 assays tot. width 13')	Same as Twin J	Same as Twin J	Lenses up to 5' wide; irregular zone of sulphides 17' wide.	Same as Lynx	Major zone of sheared rock where crossed by fault. Horiz. folds?	Gunning (1931) (TP)

Table 8 - Characteristics of Deposits of Class A - Zinc-Copper-Lead Massive Sulphides

but it is undoubtedly of Class A.

b. STRATIGRAPHIC AND LITHOLOGIC CONTROLS

All known deposits of this class occur in schists derived from andesitic and dacitic volcanic rocks of the Sicker Group (figure 17). In most instances they are cherty.

c. SIZE AND SHAPE OF THE SULPHIDE BODIES

Most of the massive sulphide bodies are lenses, irregular masses or tabular bodies which vary greatly in dimensions. Tabular and lens-like orebodies at Twin "J" and Lynx are concordant to bedding or schistosity.

d. MAIN METALS AND TENOR

The recoverable metals in these deposits, excepting possibly Mt. Richards, occur in roughly similar ratios. Zinc is most abundant and varies from 6.1 percent for the north orebody of Twin "J" to 12.8 percent at Paramount. It is approximately 5-15 times as abundant as copper or lead which occur in roughly equal amounts ranging from about 0.6 percent at Twin "J" north orebody to 2.2 percent at Paramount. Gold and silver averages are approximately 0.1 oz./ton and 3 oz./ton respectively.

e. METALLIC MINERALS

Massive sulphide samples from Twin "J", Lynx,

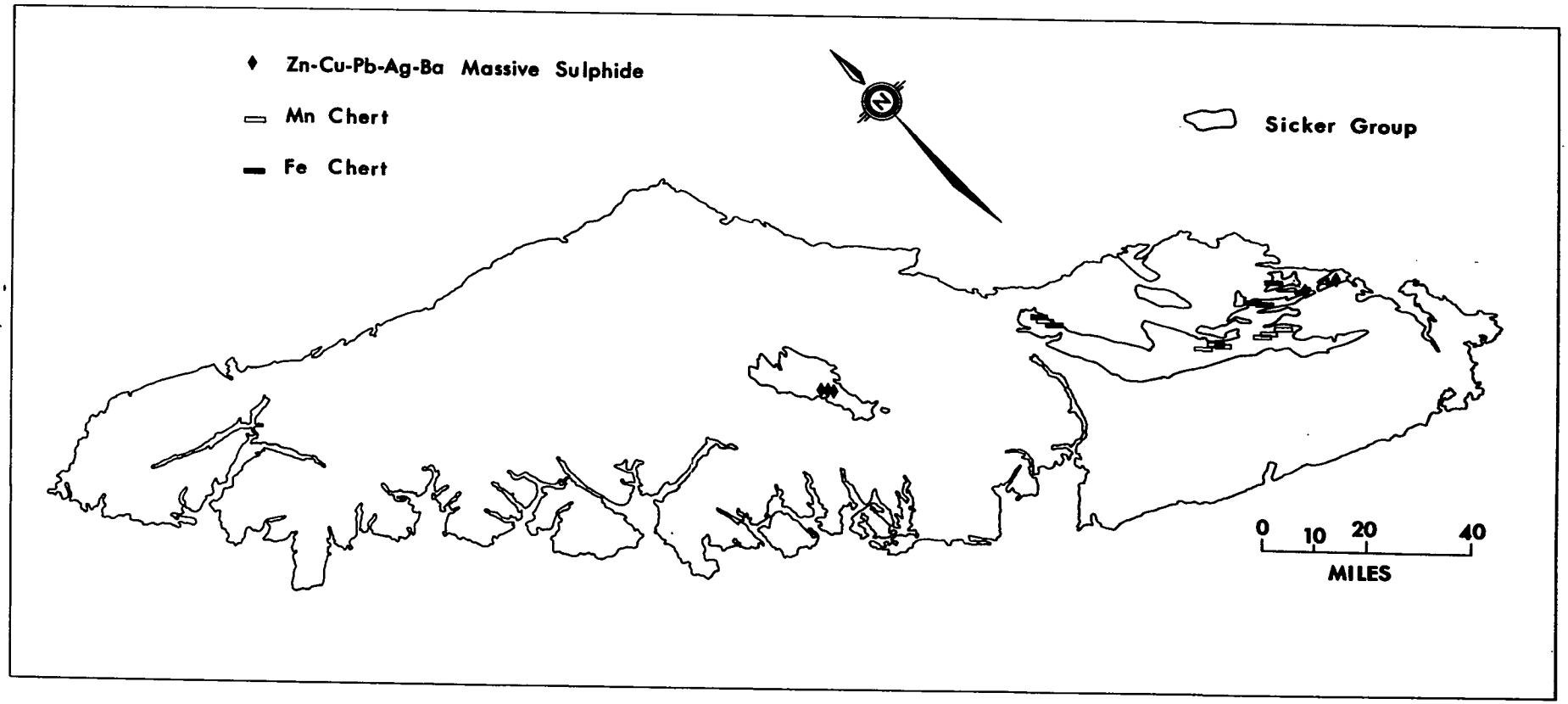

Figure 17 - Distribution of Sicker Group, Zn-Cu-Pb Massive Sulphide Deposits, and Fe-Mn-Bearing Cherts

Paramount and Price almost invariably contain pyrite, sphalerite, chalcopyrite, galena, and tetrahedrite-tennantite, in roughly that order of abundance. The average content of sulphides in the polished sections studied is approximately 60 percent. Magnetite, which is common in most deposits occurring in the Vancouver Group, is absent.

In addition, very minor amounts of pyrrhotite occur at Twin "J" and very minor amounts of bornite, pyrrhotite, and covellite have been observed in sections from Price, Paramount and Lynx. Jeffery (1965b) reported small amounts of digenite and stromeyerite in the Lynx ore.

f. GANGUE

The gangue is largely composed of constituent minerals in the host rocks, quartz-sericite schists, with or without chlorite and talc. Calcite is common and the occurrence of irregularly-distributed pockets and lenses of barite is a distinguishing feature of the deposits. Concerning the Lynx deposits, Jeffery (1965b, p. 162) stated:

> "Of all the gangue minerals, only barite is associated solely with the sulphides".

g. COMMON TEXTURES AND PARAGENESIS

Banding is the dominant texture of most of the mineralized rock at deposits of Class A (plate 12). In his description of the Twin "J" ores Stevenson (1945b,

p. 41) stated:

"A finely laminated or banded appearance produced by layers of chalcopyrite and pyrite alternating with layers of sphalerite is characteristic of much of the ore. ... This banding has been caused by preferential replacement of different bands in the laminated chert or cherty-tuff by the sulphides; small unreplaced remnants of schistose tuff and chert may still be seen in some of the ore".

Concerning the Lynx ores Jeffery (1965b, p. 163) stated:

"The main texture of the ore is the pronounced banding of the sulphides observed in many places. The bands are composed of sphalerite or chalcopyrite or pyrite, although pyrite may also be disseminated as an even granular constituent through ore that has sphalerite and chalcopyrite bands. The bands range in width from about one thirty-second inch to about 1 inch, though the broader bands are more sparse and variable. The bands are not purely one mineral but are a concentration of one sulphide mineral with minor amounts of others and there may be streaks of one mineral within a broader zone of another mineral. The boundaries between the bands are sharply transitional and are intergrown on a microscopic scale. Broadly, this banding in the sulphides is parallel to the adjacent schistosity. However, in a few places the banding cuts cleanly across the schistosity."

Pyrite occurs as embayed, commonly poikilitic and fractured crystals which are strewn out in layers. Sphalerite, chalcopyrite, and tetrahedrite-tennantite occur as veinlets in fractured pyrite. Exsolution lamellae of chalcopyrite in sphalerite have been observed in samples from Twin "J" and Lynx. Sphalerite invariably exhibits strong internal reflection. Blebs of galena exhibiting mutual boundaries with sphalerite or enclosed in pyrite are common.

Stevenson (1945b, p. 41) stated that the paragenesis of Twin "J" minerals is as follows:

"... barite, calcite, pyrite, chalcopyrite, and galena, quartz, and late calcite".

Regarding the Lynx ores, Jeffery stated (1965b, p. 163):

"... pyrite or some of the pyrite was earlier in age than the other sulphides.
The other ore sulphides have mutual textures that imply only one period or pulse of mineralization."

The writer found that in specimens from all the deposits pyrite is the oldest sulphide mineral but in many appears to have been granulated and strewn out in other sulphides at a later time. The rest of the minerals may be contemporaneous for they exhibit mutual or contradictory boundary relationships with one another.

h. STRUCTURAL CONTROLS

The structural controls for the various deposits are given in table 8. That near-horizontal folds are important controls has been demonstrated at Twin "J" and Lynx. Sulphides are localized in the crests.

Nearly horizontal folds occur ar Price (plate 9). It has not been proven that they control the location of sulphides, but it is probable.

The possible control that faults may have had on sulphide deposition is less clear. The fault in Main Creek appears to be the locus of the deposits but since the ore has probably also been disrupted by the fault, some movement along it is post-mineralization.

Steeply-dipping faults at Twin "J" are post-ore. At Lynx, steeply-dipping faults crossing the shear zone displace the ore up to tens of feet, and steep faults partly filled with gouge occur parallel to the schistosity but they have not been observed displacing the ore.

i. AGE OF THE DEPOSITS

Quartz-sericite schist from the Twin "J" mine yields a whole-rock K-Ar age of 160 ± 20 m.y. (table 4) representing the middle to late Jurassic "Coast Range Orogeny". Assuming this determination represents the age of formation of the schist and not a later recrystallization, and that the ore is post-schist (Stevenson, 1945b), the ore is younger than 160 ± 20 million years.

It seems reasonable to conclude that the formation of schistosity and near-horizontal drag-folds in the Sicker Group rocks at Twin "J" and at Lynx, Paramount and Price occurred during the same period of deformation.

At Paramount and Lynx, Jeffery (1965b) believed that evidence favoured the ore being post-schistosity but older than some of the faulting.

The Price deposits are probably, in part at least, post-schistosity. That they are localized by the Main Creek fault may suggest a post-fault, hydrothermal origin, or migration of pre-fault ore into the fault zone during a period of deformation.

From consideration of the present information on Class A deposits it is only possible to conclude that the metals were originally deposited either during deposition of the Sicker Group in the late Palaeozoic, or at a later time. In their present forms some deposits were emplaced after the period of deformation involving the Sicker Group which may have been during the Coast Range Orogeny. Other deposits or parts thereof may have been emplaced in fault zones during a later period of deformation, possibly the Puget Orogeny, and still others may owe their positions and forms to Tertiary movement on the faults.

Consideration of their overall uniformity, unique structural and mineralogical characteristics, restriction to the Sicker Group, and probable non-relationship to plutonic rocks (Ch. IV) leads the writer to believe that the metals were deposited at the same time as their host rocks, but were in part concentrated by migration to favourable structures during later periods of deformation.

CLASS B - BEDDED IRON AND MANGANESE DEPOSITS IN CHERTY SEDIMENTS

1 SUB-CLASS B-1 - FERRUGINOUS CHERTS (TACONITES)

Taconite deposits on Vancouver Island are restricted to the upper Sicker Group and are found near Ladysmith, Cowichan Lake, and Horne Lake (figures 2, 17). The characteristics of the Ladysmith deposits (Bacon, 1957)

are given in table 7. The "ore" is fine grained, crystalline, and banded. It occurs as steeply-dipping lenses with surface exposures up to 350' x 30' in dimensions (Lady A). The characteristics of the deposits near Cowichan Lake and Horne Lake have not been revealed in published reports but they are probably similar to those of the Ladysmith deposits. Lady A deposit is estimated to contain 360,000 tons with an average grade of 25 percent iron.

2 SUB-CLASS B-2 - MANGANIFEROUS CHERTS

Known manganiferous chert deposits, like ferruginous cherts, are restricted to the upper Sicker Group. Most occurrences are north and east of Cowichan Lake (figures 2, 17). Characteristics of the deposits near Cowichan Lake (Fyles, 1955) are given in table 7.

The manganese deposits consist of banded and finely crystalline manganese silicates. They are large lenses up to 40 feet long composed of finer lenses, veinlets and irregular masses. They have been folded and metamorphosed. Secondary oxides up to 15 feet deep may be present. The main deposit at Hill 60 has yielded approximately 1,000 tons of oxide ore and is a source of gem quality rhodonite.

Because of the similarity between Bonanza and Sicker rocks, it is possible that similar deposits may be found in the Bonanza Formation.

CLASS C - COPPER IN BASIC LAVAS

Bornite, chalcopyrite, chalcocite, and native copper occur in basalts of the Vancouver Group near Holberg Inlet, and near Campbell River and Cumberland (table 7). Chalcocite is also abundant in the vanadium deposits of class D. Regarding the copper deposits in basic lavas, Gunning (1930, p. 139 A) stated:

> "These deposits evidently belong to that group of mineral deposits in which native copper, and less frequently bornite and chalcopyrite is associated with quartz, calcite, zeolites, and other minerals in basic lavas. ... The most generally accepted theory of origin today is that the deposits have been formed as an after effect of eruptive action by circulating waters which produced a concentration of copper from the minute amounts of that metal that are generally present in basic lavas; ... Thus no deep-seated origin, connected with intrusive rocks, is assigned to them."

Volcanic rocks observed at Millington near Holberg Inlet are green and greenish-purple amygdaloidal basalts with some former vesicles only partly filled, and dark grey, buff and purple tuffs, some with graded bedding. They are probably members of the Bonanza Formation. At Coal Creek (Gunning, 1931) the volcanic rocks are green amygdaloidal basalts and green and purple agglomerates of the Karmutsen Formation.

The copper occurs in zones up to several tens of feet in width and length. Copper minerals are in veinlets, disseminations, patches, stringers, and amygdules. Some zones coincide with shears or faults.

Limited replacement of basalt outward from bornite-filled fractures was observed in some places on the Millington property. Microscopic examination of

bornite in amygadaloidal basalt has revealed exsolution (?) lamellae of chalcopyrite and small amounts of chalcocite in irregularly-shaped patches of bornite.

CLASS D - VANADIUM IN INTERLAVA SEDIMENT

The main characteristics of vanadium deposits in carbonaceous interlava sediment at Menzies Bay (Jambor, 1960) are given in table 7. The sedimentary layer occurs between basic flows at a very narrow horizon in the Karmutsen Formation. It is of fairly extensive areal distribution but less than seven inches thick, and is believed to have formed along with its host rocks in the Triassic. Some later migration of ore minerals has probably occurred (J. L. Jambor, personal communication, 1967).

CLASS E - NICKELIFEROUS PERIDOTITE

Two bodies of peridotite were observed during this project and a 75' wide peridotite dyke occurs near Bedwell River (Sargent, 1941). One body, at Meares Island, is known to contain nickeliferous deposits.

Medium grained dark green to black peridotite is exposed for several hundred feet along the south-western edge of Meares Island near Tofino. At one locality, the Meares showing (figure 2), serpentinized peridotite contains masses up to several feet long of pyrrhotite and chalcopyrite with up to 0.7 percent nickel (J. J. McDougall, personal communication, 1967).

To the north of the peridotite is coarse-grained gabbro. Both are probably part of the same intrusion. They are within a gneiss complex which is believed (J. E. Muller, personal communication, 1967) to have been derived from the Sicker Group. Muller also believes that the peridotite-gabbro intrusion is a sill and is equivalent to the basic sills in the Sicker Group at other localities on Vancouver Island. At several places the peridotite has been intruded by small dykes of grey granodiorite.

Under the microscope the peridotite is observed to contain at least 80 percent of closely-packed pyroxene and olivine crystals up to 4 millimeters long but averaging approximately 2.5 millimeters in length. They are altered to serpentine and chlorophaeite (?) along fractures and cleavages. Pyrrhotite and magnetite occur as interstitial strings and masses, in thin strings along pyroxene cleavages, and as rims on round olivine crystals. The mineral composition of the rock as determined by point counting is as follows:

unaltered olivine	13.2%
unaltered clino-pyroxene	32.6%
opaque minerals	10.4%
serpentine, chlorophaeite (?) (mostly after olivine)	43.8%

The texture and mineral composition of this rock are typical of a cumulate.

The gabbro exposed north of the peridotite has the following mineral composition:

pyroxene	28.2%
plagioclase (An_{80})	43.0%
amphibole	13.0%
alteration products (chlorite, fibrous amphibole (?))	15.8%

A sample of the mineralized rock studied under the microscope contains approximately 10 percent pyrrhotite, 5 percent chalcopyrite and small amounts of magnetite and siegenite-carrollite. Pyrrhotite occurs as disseminated irregularly-shaped blebs interstitial to mafic minerals, and as veinlets. It is fractured and bent and contains patches and veinlets of chalcopyrite. Chalcopyrite also occurs in interstitial blebs and veinlets throughout the rock. Euhedral to anhedral magnetite crystals are scattered throughout the pyrrhotite and chalcopyrite and partly replaced by both. Embayed siegenite-carrollite crystals are found in the pyrrhotite. They were identified by X-ray methods and are believed to be close in composition to the siegenite nickel-bearing end member since no other mineral was found in which nickel is a major constituent. Paragenesis is clearly as follows, oldest to youngest: siegenite and magnetite, pyrrhotite, chalcopyrite.

The nickel is undoubtedly genetically related to its host peridotite which according to Muller (above) may be comagmatic with the Karmutsen Formation and therefore

of Triassic age. However, it may be the same age as the peridotite dyke near Bedwell River which is described by Sargent (1941). This dyke intrudes the Bedwell batholith and is probably therefore post Jurassic.

CLASS F - MASSIVE SKARN DEPOSITS

1 GENERAL STATEMENT

Skarn deposits are the best known and most fully documented class of deposits on Vancouver Island, mainly because of the economic importance of magnetite and copper-bearing skarns. Their genetic relationship to granitic plutons has been recognized for a long time.

The contact metasomatic magnetite deposits (Young and Uglow, 1926; Sangster, 1964; Eastwood, 1965, 1966) or magnetite skarns, are economically the most important. Three sub-classes, in addition to the magnetite skarns, are recognized in this report (table 7). They are similar to the magnetite skarns in many respects but differ in their content of economically-important metallic minerals, and in certain other features which are outlined in the table. There is gradation from magnetite-rich skarns to copper-rich skarns and deposits of several classes may occur in close proximity to skarn deposits.

2 SUB-CLASS F-1 - IRON SKARNS

The main characteristics of the magnetite skarns are given in table 9. Much of the information

SUB-CLASS: Examples with ref. no for fig. 2	MAIN METALS, TENOR	ORE MINERALOGY, COMMON TEXTURES	SKARN MINERALOGY AND TEXTURES	HOST ROCKS AND ASSOCIATED FORMATIONS	PHYSICAL FORMS OF DEPOSITS	STRUCTURAL CONTROLS	MAIN REFERENCES
F-1-IRON SKARNS (25-47) Brynnor - 25 Iron Hill - 33 Iron Mike - 35 Head Bay - 38 Zeballos - 39 Nimpkish - 44 Empire Dev. - 45	Fe 40%-60% Concentrates 55%-64% Fe and relatively free from impurities	Magnetite. Minor pyrrhotite, specularite, pyrite, chalcopyrite, sphalerite. Rare marcasite, cobaltite, safflorite, smaltite. Magnetite occurs as fracture-fillings, vug-fillings, replacements of skarn and country rocks. Locally it is banded, colloform, massive, brecciated.	Abundant zoned garnet (andradite-grossularite), epidote (pistacite), pyroxene (diopside-hedenbergite). Less abundant actinolite, quartz, prehnite. Rare vesuvianite, wollastonite, axinite, chloritic phlogopite. Calcite, chlorite, amphibole, serpentine are common in the host rocks. Garnet and pyroxene intergrown and disseminated in one another. Epidote veins and patches in both. Earlier epidote is deuteric, later is of skarnification process.	Known deposits are in Quatsino or other U. Triassic limestone, or adjacent volc. and intrusive rocks. Mesozonal-epizonal intrusions ranging from gabbro to quartz monzonite nearby. Those of known age are mid to early-late Jurassic.	All sizes of magnetite bodies from few feet to more than 100' across, generally in clusters. Bodies are tabular, lens-like, spherical, pipe-like, cylindrical, etc., but mainly irregular in shape. Largest reserves 10,000,000 tons (Brynnor).	Local folds, generally synclines. Fractured rock in folds. Stratigraphic contacts. Intrusive contacts, esp. at tongues or cupolas. Faults, zones of brecciated rock. Local post-ore faults control limits of some bodies.	Young and Uglow (1926) Eastwood (1963; 1964; 1965; 1966) Sangster (1964) Min. of Mines, B.C., ann. repts. Jeffery (1961a; 1961b) Black (1953b) Sutherland Brown (1962) McKechnie (1957) Gunning (1930)
F-2-COPPER SKARNS (48-83) Nadira - 59 Blue Grouse - 61 King Solomon - 62 Skarn - 65 Indian Chief - 68 Yreka - 73 Coast Copper - 75	Cu 1.5% - 2% in economic deposits Fe, Au, Ag may also be recovered.	Chalcopyrite; Bornite common at some deposits. Pyrrhotite, pyrite, magnetite common. Minor sphalerite, galena, specularite, marcasite. Rare ilvaite, molybdenite, Fibrous intergrowths of actinolite and sulphides common. Chalcopyrite disseminated, in veinlets. Colloform pyrite, pyrrhotite.	As in Iron Skarns but more variable, actinolite common, rare sillimanite. Many garnets unzoned.	As in Iron Skarns except: (1) host rocks at 2 deposits are of Sicker Gp. (Skarn, Thistle) (2) host rocks are more varied and rarely pure limestone. (3) many deposits are further from granitic intrusions though dykes may be present. (4) one deposit known to be Tertiary.	All sizes of ore bodies up to > 500,000 tons (Coast Copper) Forms similar to Iron Skarns but massive bodies less common, tabular bodies parallel to bedding more common.	As for magnetite skarns. Contacts of dykes and sills, and bedding, may be more important.	

Table 9 - Characteristics of Sub-Classes F-1 - Iron Skarns, and F-2 - Copper Skarns

is taken from works by Sangster (1964) and Eastwood (1965, 1966); it requires little further explanation.

Safflorite, cobaltite, and smaltite were identified in samples of arsenopyrite-rich vein at Brynnor.

Phlogopite from Zeballos F.L. orebody has an X-ray diffraction pattern possessing some characteristics of the chlorite pattern, but appears to be a single mineral under the microscope, and is therefore believed to be a primary intergrowth of the two minerals. It yields a K-Ar date of 148 $\pm$ 8 m.y. (table 4). The Nimpkish batholith, believed to be the immediate source of iron for Nimpkish iron deposits is also early-late Jurassic. Many skarn deposits are related to pre-Nanaimo Group plutons (Ch. II). Where information is available the plutons related to the deposits are middle or early-late Jurassic (Ch. IV) and the associated limestone is late Triassic (figure 19).

3 SUB-CLASS F-2 - COPPER SKARNS

a. GENERAL STATEMENT

Magnetite-rich deposits and chalcopyrite-rich deposits may be found within the same skarn zone as at Skarn property, or in nearby skarn zones. There may be local gradations between the two classes within individual deposits, but at almost all mining properties one or the other dominates.

The two sub-classes differ in many respects

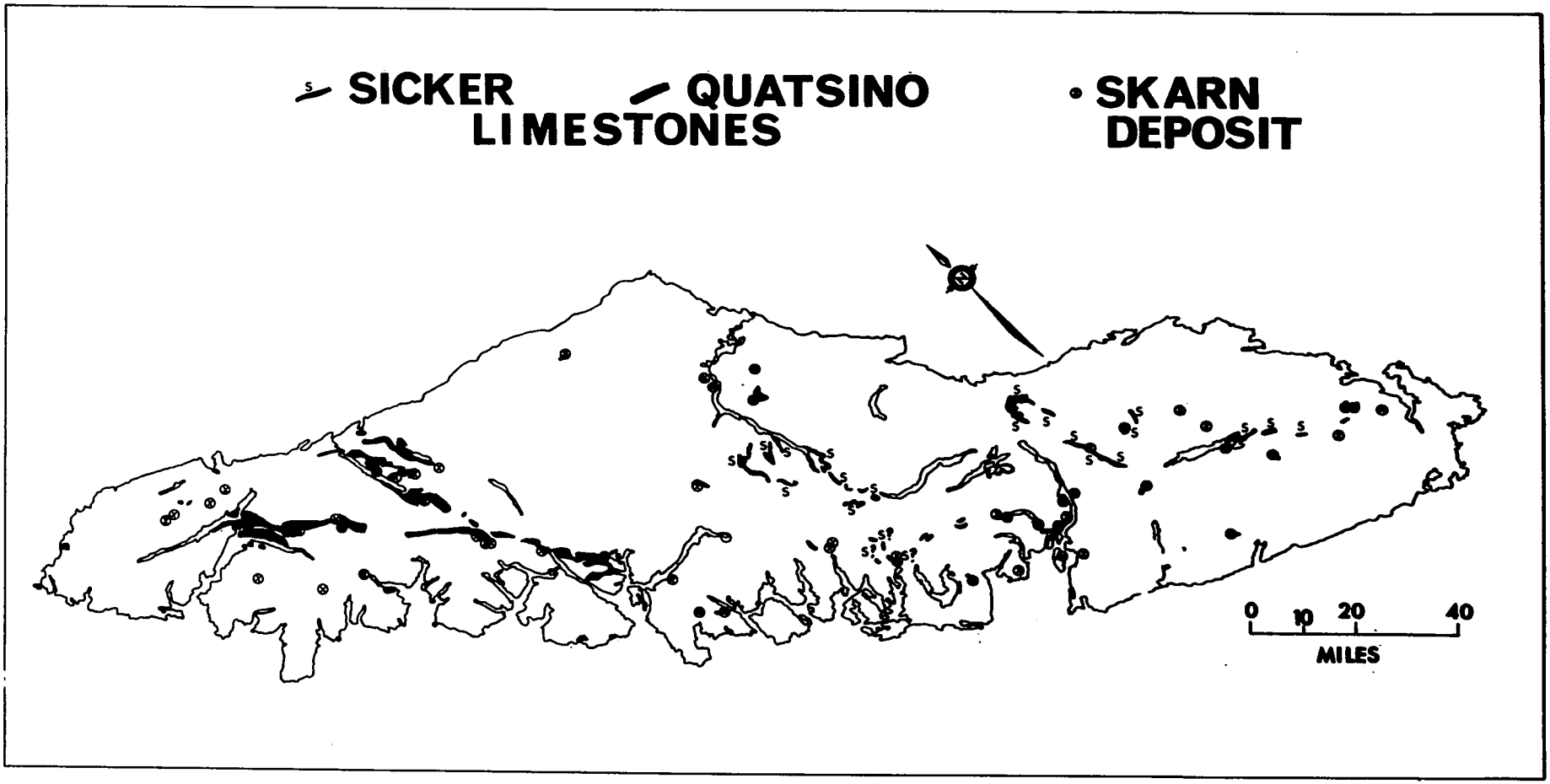

Figure 19 - Distribution of Skarn Deposits and Quatsino and Sicker Limestones

and are most important from an economic viewpoint.

b. "SKARN" PROPERTY

LOCATION AND GENERAL GEOLOGY (see figure 18, in pocket).

Skarn property is approximately three miles northwest of Fourth Nanaimo Lake (figure 2). It was mapped in detail as part of this project. Rocks in the immediate vicinity of the property are believed to belong to the Sicker Group (Muller, 1964). Similar rocks in the Cowichan Lake area have been described by Fyles (1955). Near Skarn they consist of a lower member, at least a few thousand feet thick and consisting mainly of andesitic lava and breccia, a middle member consisting largely of fine grained cherty sediments, and an upper member of limestone and chert. These rocks are cut by a granodiorite stock or batholith. Massive skarn containing scattered deposits of copper with minor iron occurs at Skarn property.

Less than one mile north of the Skarn property are late Cretaceous Nanaimo Group sedimentary rocks which overlie the granodiorite. They are cut by Tertiary dacite porphyry sills. Vancouver Group volcanic rocks are exposed within two miles to the northeast (Laanela, 1964).

ROCK TYPES

Andesite or Basalt Dark green aphanitic

andesitic or basaltic volcanic rocks underlie the southwestern portion of the area mapped. At most localities they are structureless but pillows observed at one locality indicate that they are upright and dip approximately forty-five degrees to the north. This is the general attitude of all rocks of the Sicker Group at Skarn.

Volcanic Breccia Mainly unaltered volcanic breccias very similar to those described by Fyles (1955, p. 14) underlie the areas to the south, southeast~~,~~ and southwest of the map-area.

Volcanic breccias near the granodiorite in the southeast are highly indurated and recrystallized. On weathered surfaces light greenish-grey epidotized fragments from less than 5 millimeters to 25 centimeters in width contrast with a darker greenish brown matrix. They are less readily observed on freshly broken surfaces. A zone of recrystallized and granitized volcanic rocks, including breccia, occupies the peripheral region of the granodiorite in the central part of the area. It has been mapped as a separate unit and is described below.

Layers of tuffaceous greywacke up to a few feet in thickness are present in volcanic breccias at a few localities in the southeast and indicate moderate to steep dips to the north-northeast.

Tuffaceous (?) Greywacke and Siltstone Thin-bedded brownish grey siliceous tuffaceous (?) greywacke

and siltstone occur in a layer approximately 200 feet thick in the east, where it is truncated by granodiorite, but which thickens to the west. These sediments generally overlie volcanic breccia and are overlain to the north by skarnified calcareous (?) sediments, volcanic breccia, and marble.

Graded bedding is common and invariably indicates that tops of beds are to the north.

Marble White to light grey, medium to coarse grained marble occurs in three isolated patches. Two are enclosed by skarn, granodiorite, or andesitic volcanic rocks, but the third and central band conformably overlies siliceous greywacke and siltstone.

In places near granodiorite the marble is silicified and contains narrow quartz veins along bedding planes. Elsewhere, very sparse epidote stringers are present, but the marble is everywhere very pure and nowhere does it grade into skarn.

Chert Contorted beds of white, grey, black, and pink chert (plate 13) averaging one inch in thickness occur in two isolated patches within granodiorite (figure 18). They dip steeply to the north and appear to lie above skarnified volcanic breccia which overlies (?) marble.

Under the microscope, a specimen of this chert is observed to contain interlocking quartz crystals averaging 1/25 millimeter in diameter criss-crossed by a

network of calcite veins averaging 1/5 millimeter in thickness. Another specimen of much finer calcareous argillaceous chert also contains calcite veinlets.

Tuffaceous cherts of the Sicker Group at Cowichan Lake described by Fyles (1955) are very similar to those at Skarn.

Diabase A dark green diabase dyke fifty feet wide intrudes greywackes and siltstones in the southern part of the area. In places it is cut by small dykes of granodiorite, and has been metamorphosed by the granodiorite batholith. It has a very fine grained semi-ophitic matrix of plagioclase and light green amphibole, with sparse clusters of plagioclase and amphibole up to 1.2 millimeters in diameter. Plagioclase, which is calcic oligoclase, contains numerous inclusions of amphibole and some epidote. Amphibole is weakly chloritized.

The dyke probably has the same origin as the Sicker gabbro-diorite porphyrite (Ch. II). It was probably a feeder for basic Triassic Karmutsen volcanic rocks.

Hornblende Granodiorite The hornblende granodiorite which crops out across the northeast part of the map-area is part of a pluton which extends for two miles to the east (Muller, 1964; figure 3). It is medium grained hypidiomorphic-granular and relatively homogeneous. A typical specimen (no. 179) taken from about 1,000 feet southeast of the easternmost contact

at Skarn property contains 14.3 percent interstitial anhedral quartz, 53.9 percent plagioclase (An_{35}), 15.0 percent interstitial potash feldspar which is finely perthitic, 12.4 percent fresh ragged poikilitic hornblende, and 4.5 percent opaques, sphene, epidote and apatite (plate 1). In places the rock contains biotite in excess of 1 percent.

The southern edge of the granodiorite pluton at Skarn property is very irregular in outline. Except for the bulbous southward extensions at the western and eastern parts of the area, this contact at the surface is roughly parallel to the bedding in the Sicker Group and nearly all exposed contacts are conformable. However, drilling records (Laanela, 1964) show it to have a steep contact which truncates the northward-dipping Sicker rocks and skarn zone. Chilled contacts between granodiorite and greywacke have been observed and granodiorite dykes cutting Sicker rocks, diabase and skarn are common near the pluton. In many places Sicker marble, greywacke, and chert are contorted adjacent to the granodiorite. Chert occurs as an isolated "screen" within the granodiorite.

Recrystallized and Granitized Volcanic Rocks

A zone of rocks which on freshly-broken surfaces are greenish-brown and fine to medium grained occurs along the edge of the granodiorite (figure 18). A thinner unmapped zone occurs at the extreme eastern end of the

map-area. On some weathered surfaces it is possible to discern amphibole-rich fragments of volcanic rocks which are of various grain sizes and textures. Where no fragments are visible, the rock has the appearance of gabbro.

Under the microscope (plate 14) a dark fragment is observed to consist of approximately 60 percent extremely poikiloblastic anhedral hornblende crystals up to three millimeters long, 5 percent yellow epidote crystals and 35 percent minute plagioclase granules in hornblende. The matrix contains approximately 40 percent unzoned to very weakly zoned plagioclase and 30 percent hornblende, both of which are in ragged subhedral crystals averaging 2 millimeters in length and enclosed by large areas of optically continuous finely perthitic potash feldspar (20 percent) up to several millimeters wide. Also present are abundant sphene crystals greater than 1 millimeter in width which are interstitial to plagioclase and hornblende, and opaques, epidote and biotite. The overall texture of the rock is granoblastic.

The fragmental rock appears to be recrystallized and granitized volcanic breccias. Somewhat similar rocks at Cowichan Lake were described by Fyles (1955). The gabbroic rocks may be meta-andesite or basalt.

Skarns -- General Statement Continuous outcrops of massive skarn occur in an east-west zone along the southern edge of the granodiorite. This zone

is 1,800 feet long and has an average width of approximately 500 feet (figure 18).

The skarn zone has been divided into two units. The first unit consists of layered skarn and associated skarn exhibiting no structure. Layering is not discernible in skarn of the second unit, but it invariably exhibits a fragmental texture.

Layered and Unstructured Skarn Skarn which exhibits layering, and associated unstructured skarn constitute roughly four-fifths of the skarn exposures. They occur in the eastern portion of the skarn zone. Alternating layers are each composed largely of one of garnet, epidote, or actinolite (plate 15). Reddish-brown garnet is the most abundant mineral and occurs in layers which are less than one foot to several feet wide. Similar but less common layers consisting mainly of bright green epidote are present. Fibrous actinolite generally occurs in thinner layers averaging about one inch in width.

In places layered skarn possesses a brecciated structure and pockets of pale green or white calcite, dark green serpentine, and black garnet are common (plate 15).

Layering in the skarn dips moderately to steeply to the north-northeast.

Outcrops of massive unstructured skarn consisting largely of reddish garnet, of bright green

epidote, or of both minerals, are found irregularly distributed throughout the eastern part of the skarn zone. Sharp contacts with both granodiorite and Sicker sediments are exposed at several localities.

As observed in thin sections, garnet in the garnet-rich skarns occurs as subhedral to euhedral interlocking crystals from less than 1 millimeter up to 5-10 millimeters in diameter. Also present are epidote, actinolite and minor diopside, phlogopite and sulphides. Calcite, quartz, and phlogopite occur as veinlets and large patches within garnets, and in interstitial masses. Most garnet crystals are skeletal and contain inclusions of calcite, epidote, quartz, and phlogopite. Some are largely replaced by quartz, calcite, and sulphides so that only optically continuous remnants remain. Crystals commonly have birefringent zones, especially in their outer portions and in some cases calcite is confined to certain zones.

Epidote-rich skarn has similar mineralogy to the garnet-rich skarn but euhedral to subhedral epidote crystals averaging 2-5 millimeters in length predominate. Where epidote and garnet occur together some epidote is generally found veining garnet crystals.

Conformity of layering in the skarn with bedding of the sedimentary rocks of the Sicker Group indicates that layered skarn consists of skarnified bedded Sicker rocks. Massive unstructured skarn represents skarnified unbedded rocks or former bedded rocks in which skarnification has obliterated bedding.

Breccia Skarn Skarn in which regularly-distributed faint to distinct pale green epidote-rich "nodules" less than 5 millimeters to 25 centimeters in diameter are contained in medium grained pinkish grey quartz, epidote and garnet-rich matrix (plate 16) makes up the western portion of the skarn zone. No layering was observed in this type of skarn, which is called breccia skarn because if its appearance. Where exposed, the contacts of breccia skarn with granodiorite are sharp, but there may be a gradation between breccia skarn and recrystallized and granitized volcanic breccia.

Breccia skarn may have been formed by skarnification of intrusive breccia or volcanic breccia. Its content of regularly-distributed round to angular fragments closely resembles that of Sicker volcanic breccias and the writer therefore believes that these were the original rocks. They may have been subjected to recrystallization and granitization including some epidotization, prior to complete skarnification. Clapp (Clapp and Cooke, 1917, p. 130) arrived at a similar conclusion for epidotized Sicker breccias of the Sooke-Duncan area.

In support of the derivation of breccia skarn from volcanic rather than intrusive breccia is the rarity of zones of xenoliths in the granodiorite.

Relationships of Layered Skarn to Breccia Skarn

The two skarn units abut one another abruptly along the general strike of the layers in the layered

skarn and bedding in Sicker sediments. They may originally have been interfingered bedded sediments and volcanic breccia.

Polymictic Breccia Highly indurated breccia containing angular to sub-angular fragments of chert, quartz, quartzite, siltstone, granodiorite, aplite, silicified marble, skarn, mineralized skarn, and amygdaloidal and porphyritic rocks occurs in an oval-shaped patch enclosed by a tongue of granodiorite in the southwest part of the map area. Fragments vary from less than 1 millimeter to 15 centimeters across. The finer material contains epidote and garnet fragments and has a brownish-green colour. On its northern edge the breccia is in vertical contact with granodiorite. Small "veins" of similar breccia occur in cracks in the granodiorite near to the oval breccia zone.

This breccia is probably late Cretaceous "sharpstone conglomerate" of the Nanaimo Group, which has filled a depression and cracks in the granodiorite. Such rocks occur within a mile to the north of Skarn property (Laanela, 1964).

Hornblende Dacite Porphyry Four light grey porphyritic-aphanitic dykes from two to fifteen feet wide intrude Sicker rocks, skarns, and granodiorite in the west-central part of the map-area. Chilled contacts and alignment of hornblende parallel to contacts have been observed. The dykes are distributed in a fan-shaped

pattern about the breccia skarn.

Hornblende dacite porphyry similar to that of the dykes intrudes late Cretaceous sedimentary rocks to the north of Skarn and elsewhere on Vancouver Island (Carson, 1960; Muller, 1965). The dykes at Skarn are therefore probably Tertiary.

STRUCTURES AND STRUCTURAL DEVELOPMENT

Folds Minor crumple folds occur in chert (plate 13) and greywacke next to intrusive contacts. The distribution of marble may indicate that a major synclinal structure surrounds the granodiorite tongue in the southwest portion of the map-area (figure 18). However, evidence for this fold is limited.

Faults and Fractures No faults were found at Skarn property. Small mineralized fractures have been observed in the skarn zone but no prominent fracture set was observed at any localities within the map-area.

Structural Development The structural evolution at Skarn may have been as follows:

(1) Deposition of Sicker Group

(2) Tilting of Sicker Group to the north-northeast during regional folding, probably in early to middle Jurassic time.

(3) Intrusion of granodiorite in the manner described in chapter II for Saanich-type granodiorite plutons. This probably occurred

during middle or late Jurassic. Southward-extending apophyses of granodiorite were intruded into incompetent limestone and chert. The formerly continuous (?) limestone bed may have been disrupted so that three separate masses were formed (H. Laanela, personal communication, 1964). Chert beds were locally crumpled. Some rocks near the granodiorite were granitized.

(4) The skarn zone may have developed in a general zone of weakness near apophyses of granodiorite (figure 18). This zone of weakness may have been located where volcanic breccia and bedded fine grained sediments were intercalated.

(5) Period of erosion followed by deposition of the Nanaimo Group and followed by another period of erosion.

(6) Formation (in Tertiary time) of tensional fractures some of which were filled with hornblende dacite porphyry.

MINERAL DEPOSITS

General Statement Erratic and discontinuous chalcopyrite-rich and magnetite-rich deposits occur at Skarn property. They are nearly all within the skarn zone.

The highest grade chalcopyrite-rich deposits are in the center of the skarn zone whereas the largest

magnetite-rich deposits are along the northeastern fringes of the zone near the granodiorite (figure 18).

Copper Deposits Extensive but erratic and discontinuous copper deposits consisting of lenses, layers, veinlets, and irregularly-shaped patches of chalcopyrite-rich skarn up to several feet wide, but separated from one another by barren skarn, occur on either side of the contact between the breccia skarn and the layered and structureless skarn. Chalcopyrite also occurs at other scattered localities throughout the skarn zone.

The highest grade deposits have been exposed by trenches and are in layered skarn. Chalcopyrite is concentrated along certain layers, and especially in those rich in actinolite. In both layered and unlayered skarn it occurs as lenses, irregularly-shaped masses, and in veinlets which are generally quartz-rich as well. In some instances it has replaced breccia fragments. The writer estimates that a channel sample taken along some of the trenches which are perpendicular to the layering would average about 1 percent copper.

Massive chalcopyrite from the large sinuous trench near the center of the map was studied under the microscope (plate 17). The following minerals and textures were observed:

chalcopyrite 70% -- intergrown with fibrous actinolite and garnet

pyrite 2% -- scattered euhedral to subhedral corroded crystals in chalcopyrite and gangue

sphalerite 1% -- blebs along grain boundaries of chalcopyrite and gangue and as exsolution blades and star-shaped clusters in chalcopyrite.

magnetite 1% -- scattered grains and interstitial patches in gangue

specularite 1% -- veinlets in magnetite, and veinlets and patches in gangue

actinolite, garnet, epidote, quartz, calcite 25%

Pyrrhotite occurs in a copper-bearing zone exposed in trenches at the southeast part of the skarn zone. It is intimately intergrown with sphalerite.

Magnetite Deposits Massive magnetite occurs in the form of narrow veins and isolated irregularly-shaped pods, most of which are less than a foot in width. Many are elongated parallel to layers in their host rocks. No large masses of magnetite have been found.

Except for their much greater content of magnetite, the mineralogy of these magnetite bodies is similar to that of the copper deposits. Massive magnetite studied under the microscope has the following mineralogy and textures:

magnetite 55% -- replacing and interstitial to epidote and garnet. Crystals have

radial fractures.

chalcopyrite 5% -- interstitial to, and as veinlets and patches within, magnetite and gangue minerals.

specularite 1% -- veinlets along fractures in magnetite and as crystals protruding from walls of fractures in magnetite and gangue.

pyrite 1% -- scattered embayed crystals.

sphalerite 1% -- star-shaped clusters in chalcopyrite.

garnet, epidote, etc. 37%

Stratigraphic and Lithological Controls for the Copper and Magnetite Deposits All copper and iron deposits at Skarn property are within or adjacent to skarn. The skarn was formed near a post-tectonic granodiorite intrusion a few miles in diameter and in close proximity to limestone of the Sicker Group. Skarnified rocks include bedded calcareous (?) sediments and andesitic volcanic (?) breccia. Pure limestone was converted to marble and does not appear to have been extensively skarnified. Relatively pure chert also appears to have escaped skarnification.

The richest copper deposits are in layered actinolitic skarn which was formed from bedded calcareous (?) sedimentary rocks. They occur in the center of the skarn zone near the contact between layered and breccia

skarn, and several hundred feet from the granodiorite.

Magnetite-rich pods and veins are most abundant in layered or structureless skarn within 200 feet of the granodiorite.

Structural Controls That secondary structures other than some minor fractures have exerted control on the localization of copper and iron mineralization cannot be proven. However, two, and possibly three structures probably had a great influence.

Distribution of the three isolated patches of marble suggests that they may occur along the limbs of a syncline (figure 18). Copper deposits occur in skarn along the edges of the marble on the limbs of this proposed syncline. However, the copper deposits occur around the fringes of the large apophysis of the granodiorite body at the west end of the map-area, and this apophysis may have been a more important control. This is supported by the occurrence of copper deposits near the noses of tongue-shaped apophyses of the granodiorite to the east and northeast (figure 18).

Magnetite-rich deposits may also have been localized near granodiorite apophyses. Their distribution appears to be closely controlled by the granodiorite-skarn contact.

The distribution of copper-rich deposits on either side of the breccia skarn - layered skarn contact may indicate that this contact was a zone of weakness

during deformation of the rocks by regional folding and/or granitic intrusion. Copper may have been introduced along fractures in the zone after deformation. The fan-shaped pattern of dacite porphyry dykes about this contact suggests that it was a zone of weakness during post-mineralization dilational deformation.

Age of Mineralization The copper-iron deposits are genetically related to the granodiorite and probably formed during or soon after its emplacement. The granodiorite is overlain by late Cretaceous sedimentary rocks and is probably of middle or late Jurassic age. The nearby Nanaimo batholith has yielded a K-Ar age of 160 $\pm$ 8 m.y. .

c. CHARACTERISTICS OF SUB-CLASS F-2 (see tables 7, 9).

Chalcopyrite is the most important copper mineral in the copper-rich skarn deposits but bornite is also important at Coast Copper, Nadira, and Indian Chief.

Pyrrhotite is present in nearly all deposits. Under the microscope it is commonly observed to contain colloform "bubbles" of pyrite or marcasite. Pyrite and magnetite are ubiquitous, and minor amounts of sphalerite, galena, specularite and marcasite occur in most deposits. Coarse orthorhombic crystals of ilvaite coated and veined by chalcopyrite and magnetite are found at Nadira. Molybdenite is reported to occur in minor amounts at Kinman

(Gunning, 1930).

There is a wider variation of gangue minerals in the copper-rich deposits than in the magnetite-rich deposits. This may be a reflection of the greater variety of ore-bearing host rocks and greater distances from plutonic rocks of many copper-rich deposits. Intergrowths of ore minerals with fibrous actinolite (plate 17) are common in many deposits and unzoned garnets are not rare.

At most deposits the limestones are of the Quatsino Formation, but at Skarn and Thistle it is Sicker limestone. Related intrusions which can be dated are mostly Jurassic, but at Ubell and possibly Indian Chief, and Hesquiat A and B the associated plutons are Tertiary.

Structural controls for the copper skarns are similar to those of the iron skarns. Large scale structural controls appear to be broad folds, facies changes (?) (Skarn property) and irregularities in the contacts of associated plutons.

As discussed previously (Ch. II), the overall control for the location of apophyses, which are structural controls for skarn deposits, are incompetent horizons such as limestones, in which plutons can extend laterally.

4 SUB-CLASS F-3 - MOLYBDENUM-COPPER SKARNS

Two chalcopyrite-molybdenite skarns, Comego

and Sun West, are found on Vancouver Island. The main features of each are listed in table 10.

At Comego the molybdenite occurs most commonly with pyrite as veinlets and irregular patches in siliceous skarn. Molybdenite crystals indent pyrite crystals, occur in veinlets with pyrite, or as separate flakes. The occurrence of chalcopyrite with or without molybdenite was described by Fyles (1955).

The occurrence of molybdenite, chalcopyrite, and magnetite at Sun West was described by Eastwood (1964). This property, unlike Comego, contains several small magnetite-rich lenses. Sphalerite, chalcocite, covellite and carrollite were identified in a bornite-rich sample in which exsolution blades of chalcopyrite occur in bornite.

Skarn at both deposits is actinolite-rich. Sun West skarn contains considerable wollastonite.

Host rocks at Comego belong to the Sicker Group (Fyles, 1955) and at Sun West they are probably members of the Vancouver Group which crops out on strike several miles to the southeast at Kennedy Lake.

Structural controls for these deposits are not well known but may be similar to those at other types of skarn deposits. A diabase sill at Comego may have acted as a barrier for mineralizing solutions.

Jurassic quartz diorite occurs near Comego, and quartz diorite of unknown age near Sun West.

SUB-CLASS: Deposits with Ref. no. for fig. 2	MAIN METALS, TENOR	ORE MINERALOGY, TEXTURES Cpy-chalcopyrite Sp-sphalerite Py-pyrite Ga-galena	SKARN OR GANGUE MINERALOGY, TEXTURES	PHYSICAL FORMS OF DEPOSITS	HOST ROCKS: ASSOCIATED ROCK UNITS	STRUCTURAL CONTROLS	MAIN REFERENCES (TP) -this project
F-3-MOLYBDENUM -COPPER SKARNS							
Comego 82	Mo, Cu both 1% - 2% across sev. ft. Au = <0.3 oz/ton Ag = <1.0 oz/ton	Molybdenite, Cpy, Py, pyrrhotite, magnetite, tetrahedrite. Rare bornite, arsenopyrite, Sp, scheelite. Molybdenite and tetrahedrite replace poikilitic pyrite.	Garnet, actinolite, quartz, calcite, epidote, chlorite. Skarn is siliceous. Garnets are zoned, replaced by quartz chlorite, calcite, and sulphides.	Molybdenite, Cpy, other sulphides, quartz, calcite in disseminations, lenses, veinlets within irregular zones several feet wide. Overall form of entire zone may be tabular, flat-lying.	Skarnified and silicified cherts, argillites, green sediments of Sicker Gp.; diabase sills of Karmutsen Fm.(?). Jurassic quartz diorite occurs 250' from showings.	Deposits may occur in open syncline with minor cross-folds. Diabase sill truncates one zone. Favourable beds mineralized.	Fyles (1955) (TP)
Sun West 83	Mo, Cu both 1% - 2% across sev. ft. Au, Ag unknown.	Molybdenite, Cpy, Py, magnetite, pyrrhotite. Minor covellite, bornite, chalcocite, powellite, Sp, Carollite. Molybdenite in walnut-sized radial crystal aggregates, intergrown with esp. wollastonite and prehnite.	Garnet, epidote, quartz, diopside, calcite, actinolite, wollastonite, prehnite, muscovite, sphene. Poikilitic calcite and quartz contain zoned garnet and epidote, diopside, sphene.	Erratic zones of irregular shape up to several feet wide separated by barren rock containing patches of molybdenite, veinlets and patches of Py, Cpy.	Skarnified porphyritic andesite and limestone of Vancouver Gp. (?) and quartz diorite and diorite. Post-mineralization hornblende andesite dykes very common.	Largely unknown. Mineralized zones highly fractured.	Eastwood (1964) (TP)
F-4-ZINC-LEAD SKARNS AND ZONES IN LIMESTONE							
Danzig 84	Zn, Minor Pb,Cu,Ag	Sp. Minor Ga, Py, Cpy. Rare magnetite, pyrrhotite. Banded Py, Ga, Cpy blebs in Sp.	Calcite, quartz, diopside. Minor garnet, chlorite, sericite, epidote.	Erratic pockets, stringers, lenses, few inches wide to 7' x 25' x 100' (Danzig), 100' long (HPH). General conformity to host limestone beds may give deposits overall lenticular forms.	Silicified and/or skarnified limestone of Quatsino Fm. or other U. Triassic limestone beds. Granitic stocks within 100' to 2500'. Dykes including, felsite, diorite, feldspar porphyry, andesite, quartz porphyry closely related to skarn and truncate "ore" at all deposits.	Bedding in limestone, dyke-limestone contacts, contacts of limestone with overlying rocks.	Min. of Mines, B.C. ann. repts. (1936), (1944) Gunning (1930) Gunning (1932b) (TP)
Alice Lake 85	Zn,Pb,Ag, Au. Minor Cu	Sp,Ga,Py, Arsenopyrite. Minor tetrahedrite, native gold. Banded. Sp and Py intergrown. Ga patches, blebs in Py. Arsenopyrite rims on Py. Cpy blades in Sp.	Calcite				
Pilgrim 86	Zn. Minor Pb, Ag	Sp, pyrrhotite, arsenopyrite. Minor Ga, Py.	Calcite, quartz				
Dorlon 87	Zn. Minor Pb,Ag,Au	Sp. Minor Ga,Py.	Calcite, quartz				
HPH 88	Zn, Pb, Ag Minor Cu, Au.	Sp, Ga. Minor Cpy, Py, pyrrhotite, magnetite, arsenopyrite, Ga, Sp, intergrown in patches, veinlets. Some banding.	Calcite, quartz; diopside, actinolite, garnet, epidote, chlorite, sericite.				

Table 10 - Characteristics of Deposits of Sub-Class F-3 - Molybdenum-Copper Skarns and Sub-Class F-4 - Zinc-Lead Skarns and Zones in Limestone

5 SUB-CLASS F-4 - ZINC-LEAD SKARNS AND ZONES IN LIMESTONE

The main characteristics of deposits of Sub-Class F-4 are given in table 7. Data on individual deposits are set out in table 10.

All deposits contain abundant sphalerite and abundant to minor galena, which are intimately intergrown with host calcite and quartz. Silver and gold may be important but iron and copper are minor to absent. Crystalline Quatsino limestone is the host rock for all deposits so that calcite is the main gangue mineral, but only at Alice Lake is the limestone not extensively silicified.

Stratigraphic controls include confinement to limestone and, in some cases, to certain beds within the limestone. Structural controls are unclear. However, pre-ore (?) dykes appear to have acted as barriers for mineralizing solutions at Danzig (Min. of Mines, B.C., ann. rept. 1949, p. 219) and Alice Lake (Gunning, 1930), and possibly at the other deposits, all of which contain conspicuous porphyritic dykes of various compositions.

Massive sphalerite-galena bodies assume irregular to lens-like forms. The overall configuration of mineralized rock is controlled by limestone layers and is therefore roughly tabular.

The deposits have a spatial and probable genetic relationship with granitic plutons but are at least several hundred feet from them. The plutons have

not been dated.

CLASS G - COPPER-MOLYBDENUM-ANTIMONY-ARSENIC-GOLD-QUARTZ -CARBONATE-BEARING VEINS, STOCKWORKS, SHEETED ZONES, SHEAR ZONES, FAULT ZONES

1 GENERAL STATEMENT

Deposits of this class contain metals and generally some quartz or carbonate, introduced into favourable tabular structures of various types. Many have a close spatial relationship to plutonic rocks. The deposits are subdivided into classes mainly on the basis of their metal and gangue content and their physical forms. Characteristics of the classes are given in table 7. Brackets indicate that the mineral, metal, or feature may or may not be present.

2 SUB-CLASS G-1 - MOLYBDENUM(-COPPER)-BEARING QUARTZ AND/OR PEGMATITE VEINS, STOCKWORKS

Deposits of this class consist of networks of small molybdenite-bearing quartz and/or pegmatite veinlets or single large veins. They comprise the only subclass of Group G in which the main economic mineral is molybdenite. Characteristics are set out in table 11.

The Molly, Allies and Moly deposits are probably related to Jurassic plutons. A Tertiary deposit of this class occurs near Tofino, where a network of quartz veins occurring in Tertiary granodiorite porphyry (Ch. II) contains molybdenite, chalcopyrite, pyrite

SUB-CLASS: Deposits with ref. no. for fig. 2	MAIN METALS	MINERALOGY	TEXTURES, OCCURRENCE OF ORE MINERALS	PHYSICAL FORMS	HOST ROCKS, ASSOCIATED ROCK UNITS	ALTERATIONS	MAIN REFERENCES (TP) - this project
G-1-MOLYBDENUM-QUARTZ VEINS AND STOCKWORKS Molly 89 Allies 90 Moly J 91 Dry Gulch 92 Tofino 93	Mo. Minor Cu in most deposits.	Molybdenite, pyrite, chalcopyrite. Minor bornite, pyrrhotite, sphalerite in some deposits. Quartz; minor sericite, chlorite.	Molybdenite flakes on fracture surfaces; rosettes in quartz; replacing pyrite. Paragenesis is pyrite-chalcopyrite-molybdenite.	Single veins (Molly average 4" width) to stockworks 1800' x 6500' (Allies).	Within potassic intrusion or adjacent host rocks which belong to Sicker Gp., Karmutsen Fm., Bonanza Fm. Intrusions include those of both Jurassic and Tertiary ages.	Silicification, sericitization, chloritization, K-feldspathization.	Laanela (1964) Stevenson, (1940) Bancroft, (1937) (TP) Fyles, (1955)
G-2-COPPER - QUARTZ VEINS, AND STOCKWORKS Jane and Sally 94 Sansum 95 Independent 96 Delphi, Lorry 97,98 Ormond 99 Copper King 100 Yankee Girl-Bay 101	Cu. Minor Mo in some deposits. Au, Ag very minor to negligible	Chalcopyrite, pyrite. Minor pyrrhotite. Molybdenite minor to absent. Quartz.	Chalcopyrite in masses or bands in veins; fracture-filling and disseminated in stockworks.	Single veins up to tens of feet long and wide (Sansum); lenses up to 1 ' x 4' x 6' (Jane and Sally); ribbon veins; stockworks of unknown dimensions (Y. Girl-Bay).	Sicker Gp., Vancouver Gp., granitic rocks. Some deposits near or within granitic intrusions, including porphyry dykes.	Moderate to strong silicification.	Min. of Mine, B.C. Ann. Rept. (1949) Laanela (1964) Fyles (1955) Gunning (1930)
G-3-COPPER SHEAR ZONES Bush Creek 103 El Capitan 104 Silver Leaf 105 Cottonwood 106 Qualicum 107 Three Musketeers 108 Blue Ox 109 Rainier 110	Cu- appreciable to minor. Au, Ag minor to negligible	Chalcopyrite, pyrite. Minor pyrrhotite, sphalerite, arsenopyrite. Minor quartz, calcite at some deposits. Chalcocite is main mineral at Qualicum. Minor erythrite at Cottonwood; ilmenite at Three Musketeers.	Sulphides disseminated or in stringers or lenses.	Narrow shear zones up to 20' wide containing lenses, stringers, disseminations of sulphides.	Varied; Karmutsen basic volcanics (104-108) Vancouver Gp. argillite, quartzite (109,110); Saanich granodiorite (106) Dacite porphyry dyke near 108.	Very limited or negligible silicification and/or carbonatization.	Laanela (1964) Fyles (1955) Gunning (1930) Gunning (1931)

Table 11 - Characteristics of Sub-Classes G-1 - Molybdenum-Quartz Veins and Stockworks, G-2 - Copper-Quartz Veins and Stockworks, G-3 - Copper Shear Zones

and minor sphalerite.

3 SUB-CLASS G-2 - COPPER-BEARING QUARTZ VEINS, STOCKWORKS

Deposits of this class, unlike those of sub-class G-1 and porphyry copper deposits of class H are not obviously related to plutons. They are distinguished from gold-quartz veins by their apparent lack of appreciable gold or silver, and of sphalerite, galena, arsenopyrite, and other sulphides. None of the veins is as persistent along strike as are many gold veins.

The age of these deposits is not known but some may be related to Jurassic and Tertiary plutons since they occur in the vicinity of Saanich-type granodiorites or near Tertiary (?) dacite porphyry dykes and stocks.

4 SUB-CLASS G-3 - COPPER-BEARING SHEAR ZONES

Their occurrence in very local shear zones up to twenty feet wide, generally containing some carbonate and little or no quartz, distinguishes these deposits from those of sub-class G-2 and from most gold-quartz veins. The minor to negligible content of gold and silver in samples from those deposits assayed, and lack of galena and rarity of sphalerite further distinguish them from the gold-quartz veins.

Their ages of mineralization are unknown but Bush Creek (no. 103, figure 2) occurs in Saanich-type granodiorite and is therefore late Jurassic or younger.

Most deposits, however, are in the Karmutsen or Bonanza Formations. They have no obvious relationship to plutons and may have formed by migration of metals from host rocks to shear zones during orogenies.

5 SUB-CLASS G-4 - ANTIMONY-QUARTZ VEINS

The Silver Bell stibnite-quartz vein at Horne Lake is very similar in structure and gangue to a typical gold-quartz vein. It is six inches wide and at least seventy feet long. A smaller parallel vein occurs 150 feet east of it. The vein assays 56.6 percent Sb, Cu-trace, Pb-trace, Zn-trace, As 0.1 percent, Au 0.005 oz/ton, and Ag 0.2 oz/ton[1] across a well mineralized part. Its high content of antimony but low content of gold and silver, very minor sphalerite and chalcopyrite and apparent lack of pyrite make it a unique type of deposit. In this deposit stibnite and quartz are intimately intergrown (plate 18). Small amounts of arsenopyrite are also present. One other deposit, Lens, occurs south of Cowichan Lake.

No granitic plutons occur at surface near Silver Bell.

Because of their similarities to gold-quartz veins in structures and gangue, and because of the close relationship between antimony and arsenic, the latter of which is mainly Tertiary (sub-classes G-7, G-8), the

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1 Courtesy of Mr. C. Bush, Cumberland.

antimony-quartz veins may also be Tertiary.

6 SUB-CLASS G-5 - TUNGSTEN STOCKWORK

The Victory deposit (Black, 1953a) is the only scheelite deposit known to the writer to occur on Vancouver Island, although a very minor amount of tungsten occurs in wolframite at Mt. Washington. It consists of a stockwork of scheelite-calcite-quartz veinlets mostly less than one-eighth inch wide, in a zone of undetermined size. Across a total of five feet it assayed 0.26 percent WO_4.

7 SUB-CLASS G-6 - ARSENIC-CARBONATE VEINS

Native arsenic at Grizzly and realgar at Wolf are the economic minerals of this class (table 12).

Both deposits are in steeply-dipping brecciated fault zones and have close spatial relationships with Tertiary dacite porphyry sills or laccoliths intruding the Nanaimo Group. Grizzly is Tertiary because it occurs in argillites of the Nanaimo Group. Wolf is also probably Tertiary because of its spatial relationship to Tertiary dacite porphyry (Gunning, 1931) and because it occurs in a fault which has offset Nanaimo sedimenatry rocks (figure 4, in pocket).

8 SUB-CLASS G-7 - COPPER-ARSENIC-QUARTZ VEIN AND BRECCIA ZONE

Three distinguishing features of the two members of this class, Macmillan and Mt. Washington Copper (table 12) are the copper-arsenic content, the exotic mineral

SUB-CLASS: Examples with ref. no.s for fig. 2	METALS, TENOR	MINERALOGY, TEXTURES (important newly-reported minerals underlined)	TEXTURES, PHYSICAL FORMS	HOST ROCKS, ASSOCIATED ROCKS	ALTERATIONS	STRUCTURAL CONTROLS	MAIN REFERENCES (TP) -this project
G-6-ARSENIC VEINS							
Grizzly 114	As; negligible Au, Ag.	Native As, Arsenopyrite, carbonate, quartz.	Arsenopyrite stringers, disseminations and native As "kidneys" in veins up to 2' wide, 50' - 60' long.	Argillites of the Nanaimo Gp., Tertiary dacite porphyry sills nearby.	Limited carbonatization and silicification of wallrocks.	Vertical fracture or fault with brecciated wallrocks.	Laanela (1964) Muller (1964)
Wolf 115	As	Realgar, arsenopyrite; minor native As; calcite, quartz.	Realgar masses up to 4' x 9", lenses of calcite up to 6' wide, stringers of arsenopyrite, all in steeply-dipping veins 2'-12' wide and 250' long.	Andesite of Karmutsen Fm.. Nanaimo Gp. sediments and Tertiary dacite porphyry sill nearby.	as for Grizzly	Steeply-dipping brecciated fault.	Hurst (1927) Gunning (1931)
G-7-COPPER-ARSENIC VEIN, BRECCIA ZONE.							
Mt. Washington Copper 116	Cu 1.40 % As-apprec. Au 0.015 oz/ton Ag 1.20 oz/ton	Abundant quartz and minor calcite, dolomite with main ore minerals chalcopyrite, pyrrhotite, pyrite, arsenopyrite, realgar. Minor orpiment, bornite, tetrahedrite, molybdenite, marcasite, sphalerite, magnetite, galena, chalcocite, covellite, native arsenic, malachite. Rare hessite, wehrlite, native Au, chalcostibite, molybdite, Cu.	Nearly-horizontal quartz-filled vein or sheeted zone 250' x 600' x 7'-15'. Sulphides are in quartz and also replace wallrocks. Banded, crustiform, vuggy, brecciated.	Argillite and quartzite of Nanaimo Gp. and Tertiary dacite porphyry sills, and dykes near border of quartz diorite stock.	Intense silicification of wallrocks.	Nearly flat-lying fracture or sheeted zone, possibly a fault. Located near Nanaimo-Karmutsen unconformity, a zone of weakness. Nanaimo sediments and dacite sills may have been impermeable cappings.	Carson (1960) deVoogd (1964) (TP) McKechnie (1961b)
Macmillan 117	Cu < 1 % As < 1 % Au and Ag = trace	Abundant calcite, quartz, with bornite, tetrahedrite, covellite chalcocite, corynite. Very minor chalcopyrite, hematite, native As (?).	Breccia zone 335' x 60' surface area but unknown depth or origin. Ore minerals dissem. or in veinlets in the breccia. Bornite intergrown with tetrahedrite. Chalcopyrite blades in bornite.	Siliceous calcareous breccia zone in Karmutsen andesite. Contains porphyritic fragments (Tertiary dacite ?) in sheared crushed rock. Nanaimo sediments nearby.	Intense silicification and carbonatization of breccia.	Breccia zone formed near Nanaimo-Karmutsen unconformity. May be a tectonic breccia.	Laanela (1964) (TP)

Table 12 - Characteristics of Deposits of Sub-Class G-6 - Arsenic Veins, and G-7 - Copper-Arsenic Vein and Breccia Zone

suite, and occurrence at or near to the Karmutsen-Nanaimo unconformity.

Macmillan deposit is in a silicified breccia zone of unknown form in Vancouver Group volcanics carrying altered fragments of Tertiary (?) dacite porphyry (Laanela, 1964). Arsenic is present in corynite (plate 19) and tetrahedrite. Minute blebs in chalcocite, which could not be positively identified, may be native arsenic. Upper Cretaceous sandstones with shell fragments occur within a few hundred feet to the north of the exposed mineralized zone. Laanela (1964) suggested that the breccia may be tectonic or a breccia pipe.

The Mt. Washington orebody is a gently-dipping tabular body of quartz and sulphides in Upper Cretaceous sedimentary rocks and dacite porphyry within a few hundred feet of the Karmutsen-Nanaimo unconformity (Carson, 1960; figure 4, in pocket; figure 15). It, as well as Macmillan, may have formed in faults or within zones developed during movement in the vicinity of the unconformity, which may have been a zone of detachment. Movement may have been initiated by faulting of the Nanaimo Group or, in the case of Mt. Washington, by forcible intrusion of the quartz diorite stock (Ch. II).

At both the Macmillan and Mt. Washington deposits, Upper Cretaceous sedimentary rocks and dacite porphyry sills within them may have acted as barriers to mineralized solutions.

Chalcostibite, native arsenic (plate 20) and native gold were identified in samples from Mt. Washington during this project.

9 SUB-CLASS G-8 - GOLD-QUARTZ VEINS, FISSURE ZONES

Gold-quartz veins of certain areas have been described in detail by Bancroft (1937), Sargent (1941), Stevenson (1945a, 1947, 1950), and in the B.C. Minister of Mines Annual Reports for several years. Carson (1960) and McDougall (1963) have described the gold-quartz veins of the Forbidden Plateau (plate 21). Table 13 is a compilation of these descriptions as well as of additional data obtained by the writer.

The gold-quartz veins of various parts of Vancouver Island are remarkably alike in all aspects, although in some areas, such as Zeballos, they are more persistent along strike than in other areas. Gold-quartz veins occur in zones of Tertiary igneous activity (Ch. IV) and many are close to arsenic-rich deposits (sub-classes G-6, G-7) and porphyry copper deposits (class H). Thus the original discoveries at Mt. Washington were the No. 1 (Domineer) and No. 2 veins but the Mt. Washington Copper Co. orebody is of sub-class G-7 (copper-arsenic) and the occurrence of scattered zones of disseminated sulphides and breccia zones in the general vicinity of the Mt. Washington stock give it the characteristics of class H(porphyry copper). Gold-quartz veins and disseminated copper deposits also

MAIN AREAS OF OCCURRENCE with ref. no.s for fig. 2	TENOR Au oz/ton Ag oz/ton	MINERALOGY	TEXTURES, PARAGENESIS	PHYSICAL FORMS	HOST ROCKS, ALTERATIONS	STRUCTURAL CONTROLS	MAIN REFERENCES (TP - this project)
Zeballos Area 122-140	Au .44 Ag .19 (avg. grade of ore mined). Pb, As < 1%. Highest grade is in sulphide -rich veins, esp. those with abundant galena and sphalerite.	Pyrite, Sphalerite, Arsenopyrite, Chalcopyrite, Native gold. Some pyrrhotite, marcasite.	Banding, comb-texture, brecciated vein and wallrocks; ubiquitous exsolution blebs of chalcopyrite in sphalerite. Paragenesis (oldest first) is pyrrhotite-sphalerite-arsenopyrite-pyrite-sphalerite-chalcopyrite-galena-native Au.	Massive quartz or ribbon quartz in veins or sheeted zones mostly <1' wide, uniform for several 100' and vertical. Some sheeted zones contain lenses of quartz up to 4' wide.	Spatially related to Tertiary quartz diorite stock. Occur in quartz diorite, granodiorite, diorite, gabbro, skarn, and dacite, andesite, tuff of Vancouver Gp. Limited sericite, chlorite, silica alteration of wallrocks.	Fractures, shears, sheeted zones, near NW nose of quartz diorite stock, possible locus of deformation due to NNW - SSE tension.	Stevenson (1950) Stevenson (1947)
Herbert Arm Area 142-146	Mainly lower grade than Zeballos	Similar to Zeballos but sulphides generally less abundant.	Similar to Zeballos	Similar to Zeballos but discontinuous lenses of quartz traceable only few tens of feet common.	Dacites, andesites of Vancouver Gp. and younger porphyries.	Fractures, fissures, sheeted zones.	Bancroft (1937) Min. of Mines, B.C., ann. rept. (1935)
Bedwell-Big Interior 147-159	Similar to Zeballos for mines	Similar to Zeballos. Arsenopyrite less abundant.	Similar to Zeballos	Moderately to steeply-dipping veins, fissures, sheeted zones up to 20' wide. Some persistent.	Quartz diorite, volcanics of Sicker Gp. and Vancouver Gp.	Fractures, fissures, sheeted zones.	Sargent (1941) Sargent (1940) McKechnie (1961a)
Kennedy Lake Area 160-173	Mainly lower grade than Zeballos	Similar to Zeballos but some tetrahedrite reported, less arsenopyrite. Some ankerite.	Similar to Zeballos	Similar to Zeballos but most << 1' wide; a few traceable, several 100'.	Andesitic volcanics of Karmutsen Fm. Near fine grained diorites.	Fractures, fissures, sheeted zones.	Bancroft (1937) Min. of Mines, B.C., ann. rept. (1935) Dolmage (1920)
China Creek Area 174-181	Au .3 Ag .9 (avg. grade ore mined)	Similar to Zeballos but no pyrrhotite or marcasite reported, more carbonate including ankerite.	Similar to Zeballos	Moderately to steeply-dipping veins, many containing quartz lenses up to a few feet wide.	Volcanics, chert of Sicker Gp. and feldspar porphyry. Feldspar porphyry stocks, dykes near.	Fractures, fissures, sheeted zones.	Stevenson (1945)
Forbidden Plateau 188-190	Lower grade than Zeballos	Similar to Zeballos but more arsenopyrite, minor tetrahedrite. Rare carrollite, native arsenic at Domineer (no. 188)	Similar to Zeballos	Nearly flat-lying and moderately to steeply-dipping veins up to sev. feet wide, some traceable for several 100'.	Nanaimo sediments, Tertiary breccia, Karmutsen Fm., quartz diorite. Tertiary quartz diorite spatially related.	Fractures, sheeted zones. Flat-lying veins in fractures formed at stratigraphic and conformable intrusive contacts.	Carson (1960) McDougall (1963) (TP)

Table 13 - Characteristics of Deposits of Sub-Class G-8 - Gold-Quartz Veins

occur in close proximity at Faith Lake and Big Interior Mountain.

Pyrite, sphalerite, arsenopyrite, chalcopyrite, galena, and minor pyrrhotite and marcasite are found in most veins of all areas. High content of sphalerite and galena appears to be related to high gold values (Bancroft, 1937). Under the microscope, native gold was observed in samples from all the main areas. It occurs mainly as blebs and veinlets (plate 22) in pyrite or along grain boundaries, but was also observed in sphalerite, arsenopyrite, galena and pyrrhotite. Tellurides have not been reported[1] and none was positively identified during this project, although minute segmented veinlets, probably consisting of tellurides, were observed in samples from Abco, Privateer and Fil. A ubiquitous microscopic texture in the gold-quartz veins is that of exsolution blades and blebs of chalcopyrite in sphalerite (plate 22). Arsenopyrite and marcasite commonly replace pyrite. Marcasite replacing pyrrhotite is a less common occurrence. In some veins, pyrite, in particular, is brecciated.

Structural controls for the gold-quartz veins are fractures in rocks of widely varying types including those of the Sicker Group, Karmutsen Formation, Bonanza Formation, Nanaimo Group, skarn, and various types of

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1 the only tellurides reported to occur on Vancouver Island are wehrlite and hessite in the Mt. Washington Copper, copper-arsenic orebody (Carson, 1960).

intrusive rocks. Many of the richer veins are steeply dipping and strike northeasterly.

The Zeballos deposits and the Domineer and Faith Lake deposits are related to early Oligocene quartz diorite (Ch. II) and nearly all other deposits are found in areas of known or probable Tertiary intrusive activity (Ch. IV). They are therefore all believed to be Tertiary.

CLASS H - PORPHYRY COPPER DEPOSITS

Characteristics of deposits of this class are given in table 14. The deposits occur at Mt. Washington, Catface, Faith Lake, Gem Lake, and Big I. An additional deposit for which information is limited occurs at Corrigan Creek south of Port Alberni. It is discussed at the end of this chapter (p. 160).

All members of this class consist of large scattered zones of low grade disseminated and fracture-filling chalcopyrite with minor to negligible gold and very minor molybdenum, occurring in and alongside intrusive complexes.

Gold-quartz veins (sub-class G-8) are known to occur near all deposits. A copper-arsenic deposit (sub-class G-7) is found at Mt. Washington and minor occurrences of mineralized skarn at Catface and Big I.

All five deposits are closely related to quartz diorite-dacite porphyry-breccia complexes, three of which are known to be Tertiary, and the other two are probably

Deposit with ref. no. for fig. 2	TENOR	MINERALOGY Cpy-chalcopyrite Py-Pyrite Bn-Bornite	TYPE OF MINERALIZED ZONE	HOST ROCKS	STRUCTURAL CONTROLS	ASSOCIATED ALTERATIONS	MAIN REFERENCES (TP) - this project
Catface 191	Cu < 1% Very minor Mo, Au.	Cpy, Py, Bn. Minor molybdenite, pyrrhotite, magnetite, chalcocite, cuprite, native Cu, azurite, malachite.	Zones of low grade Cu up to several 100' long and wide, consisting of seams, disseminations, veinlets. Cpy, Py, Bn replace mafic minerals in intrusions and volcanics. Bn masses up to several inches wide. Cpy veins up to 6" wide. Py, Molybdenite disseminated in all rocks.	Intrusive complex of older quartz monzonite and quartz diorite, fresh Tertiary quartz diorite and dacite porphyry, and the country rocks - Karmutsen (?) Fm., - basic volcanics.	Fractures within or adjacent to intrusive complex possibly emplaced along major north-northwest fault. The complex occurs in domal uplift occupying Catface Peninsula. Volcanics may have acted as impermeable capping.	Silicification, kaolinization, hematitization of quartz monzonite. Chloritization of mafic minerals in volcanics and quartz monzonite. Quartz diorite and dacite porphyry largely unaltered.	McDougall (1962) (TP) Carr (1964a)
Big I 192	Cu << 1% Very minor Mo, Au.	Cpy, Pyrrhotite, Py. Minor molybdenite, malachite.	Very large zones of << 1 Cu. Disseminations, seams, veinlets of Cpy, Py with minor molybdenite in places. Cpy locally replaces xenoliths in quartz diorite. Pyrrhotite masses up to 3' wide cut by Py-Cpy-Quartz veinlets.	Probable Tertiary quartz diorite and intrusive breccia, and volcanics and sediments of Sicker Gp. Dykes of dacite porphyry and diabase common.	Fractures in quartz diorite, intrusive (?) breccia and adjacent Sicker Gp. rocks.	Silicification, minor skarnification.	Sargent (1941) (TP)
Faith Copper 193	Cu < 1% Minor Au, As. Very minor Mo.	Cpy, Py, Pyrrhotite. Minor molybdenite, arsenopyrite.	Large zones of very low-grade Cu in volcanics near quartz diorite plug; zones of low grade Cu and Mo several tens of feet wide in the plug. Disseminations seams, veinlets.	Tertiary quartz diorite, dacite porphyry and intrusive breccia, and Karmutsen Fm.	Fractures within the plug and adjacent volcanics.	Silicification, Chloritization and pyritization of volcanics.	McDougall (1963) (TP)
Gem Lake 194	Cu <1% Very minor Mo, Au.	Cpy, Py. Minor bornite, molybdenite, magnetite, hematite, ilmenite, pyrrhotite.	Large zones of very low grade Cu in brecciated volcanics, quartz diorite, breccia pipe. Ilmenite and magnetite replace matrix of breccia. Disseminations, seams, veinlets, breccia fillings.	Same as Faith Copper	Same as Faith Copper	Same as Faith Copper	Gunning (1931) McDougall (1961) (TP)
Mt. Washington - Murex 195	Cu < 1% Very minor Au, Mo.	Cpy, Py, Pyrrhotite, Bn. Very minor molybdenite, molybdite, native copper, specularite, magnetite; rare wolframite.	Large zones of low-grade Cu. Disseminations, seams, veinlets, breccia fillings. Magnetite part of matrix of Washington breccia, specularite of Murex breccia.	Tertiary quartz diorite stock, dacite porphyry sills, dykes, irregular bodies, breccias; Karmutsen Fm. basic volcanics; Nanaimo Gp. argillite and quartzite.	Fractures in quartz diorite stock or adjacent rocks near the Karmutsen-Nanaimo unconformity. Stock is located in structural dome. Nanaimo sediments may have acted as impermeable capping.	Silicification Chloritization and biotitization of mafic minerals. Sericitization widespread but weak. Intense local argillitization	Carson (1960) de Voogd (1964) Gunning (1931) (TP) Carr (1964b)

Table 14 - Characteristics of the Porphyry Copper Deposits of Class H

Tertiary (Ch. II). They occur along a northeast-trending zone which may be the locus of a major fault system.

Fracturing of the outer portions of the complexes, and doming, fracturing, and brecciation of the host rocks due to forcible intrusion and/or faulting, have provided favourable zones for mineral deposition at Mt. Washington, Catface, Faith Lake, and possibly at Gem Lake and Big I.

Pyrite and chalcopyrite are the most abundant minerals in all deposits. Pyrrhotite is less common, and bornite and molybdenite are minor.

During the present investigation, wolframite was found filling small fractures in quartz veinlets in dacite porphyry at Mt. Washington, and considerable amounts of magnetite and minor ilmenite were identified in the matrix of the Washington-type breccia at Gem Lake (plate 8). Magnetite forms a large part of the matrix of the Washington breccia at Mt. Washington (Ch. III) and magnetite and specularite form part of the matrix of the Murex breccia at the same mountain.

CLASS I - COPPER AND IRON DEPOSITS OF SOOKE

1 GENERAL STATEMENT

Characteristics of copper and iron deposits of this group, which occur in the Sooke area (figure 5) are given in tables 7 and 15. The geology and mineral deposits of this area have been fully described by the authors referred to in table 15 so that only certain

SUB-CLASS: Examples with reference no. for fig. 2	MAIN METALS, TENOR (%)	MINERALOGY (METALLIC)	TEXTURES	PHYSICAL FORMS	HOST ROCKS, ALTERATIONS	STRUCTURAL CONTROLS	MAIN REFERENCES (TP) - this project
I-1-IRON IN SOOKE GABBRO							
Iron Mountain 196	Fe low grade	Magnetite, pyrrhotite; minor pyrite, chalcopyrite.	Massive, disseminated	Lenses containing disseminations, stringers, irregular masses.	Sheared, amphibolitized Sooke gabbro (early Oligocene).	Shear zones	Clapp and Cooke (1917)
Merryth Iron 197		Magnetite	Massive, disseminated	Vein networks	Massive anorthositic Sooke gabbro	Network fractures	Cooke (1919)
I-2-COPPER DEPOSITS OF SOOKE							Fyles (1949)
Griffith 198 King George 199 Cooke 200 Huestis 201 Merryth 202 Sunro 203 Bend 204 Caulfield, Robertson, Tiger 205	Cu 1 % - 1.5 %, Au, Ag 0.1 oz/ton in high grade zones. Ni, Co, Mo <0.05 % to trace.	Chalcopyrite, pyrrhotite, pyrite; minor magnetite; very minor molybdenite, sphalerite, cubanite, pentlandite.	Chalcopyrite in veinlets; in masses intergrown with pyrrhotite. Pyrite as cubes or colloform after pyrrhotite. Rare pentlandite wisps and blades in pyrrhotite. Rare cubanite blades in chalcopyrite. Minor sphalerite associated with chalcopyrite. Magnetite grains throughout gangue.	Lenses, zones of gash veinlets, disseminations; along fractures in vertical zones between or near intersecting fractures. Width of ore grade zones 3' - 100'; generally < 50'.	Sooke olivine and augite gabbro, and basalt of Metchosin Fm. near Sooke gabbro. Amphibolitization of gabbro and basalt weak to intense. Amphibole veinlets common. Highest grade Cu in coarse amphibolite. Oligoclase-scapolite-quartz-epidote veinlets common near deposits.	Vertically-dipping "shear" zones of closely fractured to massive amphibolized rock up to 250' wide and 3000' long, generally bounded by major fractures and containing irregular zones of sulphides. Sulphides are in fractures and extend into wallrocks. Highest grade copper where fractures intersect or come close together. The "shear" zones trend NNE or NE at Sooke Pen., NW at Sunro. Gabbro-basalt contact at Sunro zone of weakness intensely fractured.	Stevenson (1951) (TP)

Table 15 - Characteristics of Sub-Classes I-1 - Sooke Iron, and I-2 - Sooke Copper Deposits

aspects will be dealt with in this report.

The deposits occur as disseminations with veinlets in fractured and sheared gabbro and basalt along vertical linear zones of weakness up to 3,000' long. They are within or adjacent to Sooke gabbro intrusions. Smaller, mainly vertical fractures control local distribution of sulphides.

Grade of copper in mineable deposits is 1 - 1.5 percent but some high grade zones also occur. Molybdenum, nickel, and cobalt are present in amounts insufficient to be of economic value.

Two types of alteration are associated with the deposits, but both occur in some unmineralized areas as well. The first involves weak to intense amphibolization of pyroxene and plagioclase in gabbro and basalt. The second consists of feldspathization and scapolitization of basalt and gabbro and consists of stringers of plagioclase, with smaller amounts of scapolite, and minor epidote and quartz (plates 23, 24).

2 MERRYTH ZONE

Merryth zone (figure 20, in pocket) was mapped by Fyles (1949) who described it fully as follows (p. A169 - A170):

"The Merryth zone is on the south-west shore of Sooke Peninsula ... . The main altered zone, containing hornblende and masses of unaltered gabbro, trends up the hill from the shore at about north 25 degrees east for 1,500 feet. The zone is irregular in width but averages 100 feet wide. It is not known to be continuous, as a drift-covered area separates the showings on the hill from those on the shore.

Hornblende is present not only in the main zone, but also in irregular masses several hundred feet on either side of the main zone. ... the mineralized zone is well exposed on the sea cliff ... . An area about 100 feet wide and possibly 200 to 300 feet long has been partly altered to hornblende. It is bounded on the east and west by vertical faults striking about north 20 degrees east and is cut by cross-faults, the most prominent of which strike north 60 degrees east and north 20 degrees west. ... The mineralized zone contains irregular bodies of fine-grained relatively unaltered gabbro with increase in size away from the shore. Fine-grained magnetite, pyrrhotite, pyrite, and chalcopyrite occur in the hornblende and less commonly in the unaltered gabbro. Sulphides are relatively massive near the centre of the zone, but toward the edges they become disseminated and occur as tiny veinlets throughout the hornblende. ... On top of the sea cliff the rocks are covered by overburden, but hornblende and sulphides are less abundant in exposures there than on the shore ... Samples* were cut along two lines on the face of the sea cliff. The lower line about 10 feet above high-tide mark averaged 0.83 per cent copper across a width of 28 feet. ... The upper line of samples was taken across 16 feet of heavily oxidized material, and ... these samples may not be truly representative. They averaged 0.31 per cent. copper. ... It appears from the assays and from field observation that the grade of the mineralization decreases upward and away from the shore.

Irregular masses of hornblende containing some sulphides lie west of the main zone and to a lesser extent east of the main zone. They apparently formed along cross-faults, especially where they intersect each other."

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* All samples on the Merryth zone were taken by cutting equal chips at 1 - foot intervals across the face.

Detailed mapping of the Merryth zone (figure 20), and of parts of Sunro "C" orebody (figures 21, 22) was carried out in order to clarify the controls which major and minor fractures and alterations have on the distribution of copper mineralization. The intensity of sulphide mineralization is indicated in the figures by the density of dots.

Although rocks are generally amphibolized at or near to mineralized zones it is apparent from figure 20 that intensely amphibolized rock does not necessarily contain sulphides and that sulphide zones may or may not be in amphibolized rock. Also, intensely fractured rock may or may not be amphibolized or mineralized with sulphides. Amphibole veins are common in relatively unaltered gabbro.

Sulphides tend to occur along certain fractures or in fairly massive rock bounded by distinct fractures as at localities A, B, C, in figure 20. One outcrop to the northwest (locality F, figure 20) is composed of massive pyrrhotite with some chalcopyrite. The overall controls at Merryth appear to be fractures trending NNE. Fractures of other orientations have a more local control. Places where fractures with a rough radial pattern converge, as at D of figure 20, may be well mineralized.

Zones containing closely-spaced, narrow, white plagioclase-scapolite veins grading into massive granitic material (plate 25) occurring in lenses up to several feet in width and containing little or no scapolite, are scattered throughout the Merryth zone. In places these alternate with parallel hornblende veins and both types of veins have been observed to cut one another. At several localities the white veins contain sulphides. A sample of granitic material from location G (figure 20) revealed the following mineralogy under the microscope (plate 25):

35.8%	Quartz	58.4%	Plagioclase An_{15-45}
5.0%	Amphibole	0.8%	Opaques, chlorite, apatite.

It is quartz diorite. Samples from other granitic zones contain up to 60 percent scapolite, probably after plagioclase.

The gabbro at Merryth was divided into two main types, augite gabbro to the west and anorthositic gabbro to the east. The latter type contains a higher plagioclase/mafic minerals ratio and is lighter and commonly coarser grained than the former. Except in some amphibolized zones, the gabbro is medium grained. Also, amphibole occurs in veins and isolated porphyroblasts in the anorthositic gabbro rather than in large alteration zones. The contact between the two types is not exposed. They appear to be separate intrusive units or layers within the large Sooke Peninsula gabbro pluton. At one locality a xenolith of fine grained gabbro or recrystallized basalt was observed in the anorthositic gabbro. Under the microscope anorthositic gabbro was observed to have the following mineralogy:

75%	Plagioclase	An_{25-50} (gradational normal zoning)
10%	Hornblende	-- after pyroxene, brownish yellow
10%	Pyroxene	-- crystals and remnants of crystals in hornblende
5%	Magnetite	

Some magnetite-amphibole, magnetite-pyroxene, magnetite-quartz, and massive magnetite veins up to six inches wide are found in the anorthositic gabbro and are

probably genetically related to it.

3 SUNRO "C" OREBODY

The Sunro "C" ore zone is in massive, fine grained, black amphibolized Tertiary Metchosin basalt. It is several hundred feet from a sill-like body of Sooke gabbro (Stevenson, 1951). Mapping was done of a portion of the "C" orebody on two adjacent levels (figures 21, 22). As in figure 20 the intensity of sulphide mineralization in figures, 21, 22, varies roughly with the spacing of dots. The mapping yielded information not only on the controlling influence of fractures on sulphides but also on the vertical continuity of individual fractures and fracture systems.

The control on sulphide distribution as seen on the backs[1] in two dimensions is similar to that of Merryth but is more distinct. Sulphides commonly fill major or minor fractures and extend outward into the wallrock. They are also abruptly terminated by fractures. In places sulphides are sheared along fractures. They also occur in zones between main fractures and in some cases become more abundant where such fractures converge.

It is apparent from figures 21 and 22 that certain sulphide-controlling fractures extend from one level to the next, a vertical distance of 100 feet, and that the overall fracture patterns on adjacent levels are similar.

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1 "ceiling" of a mine level.

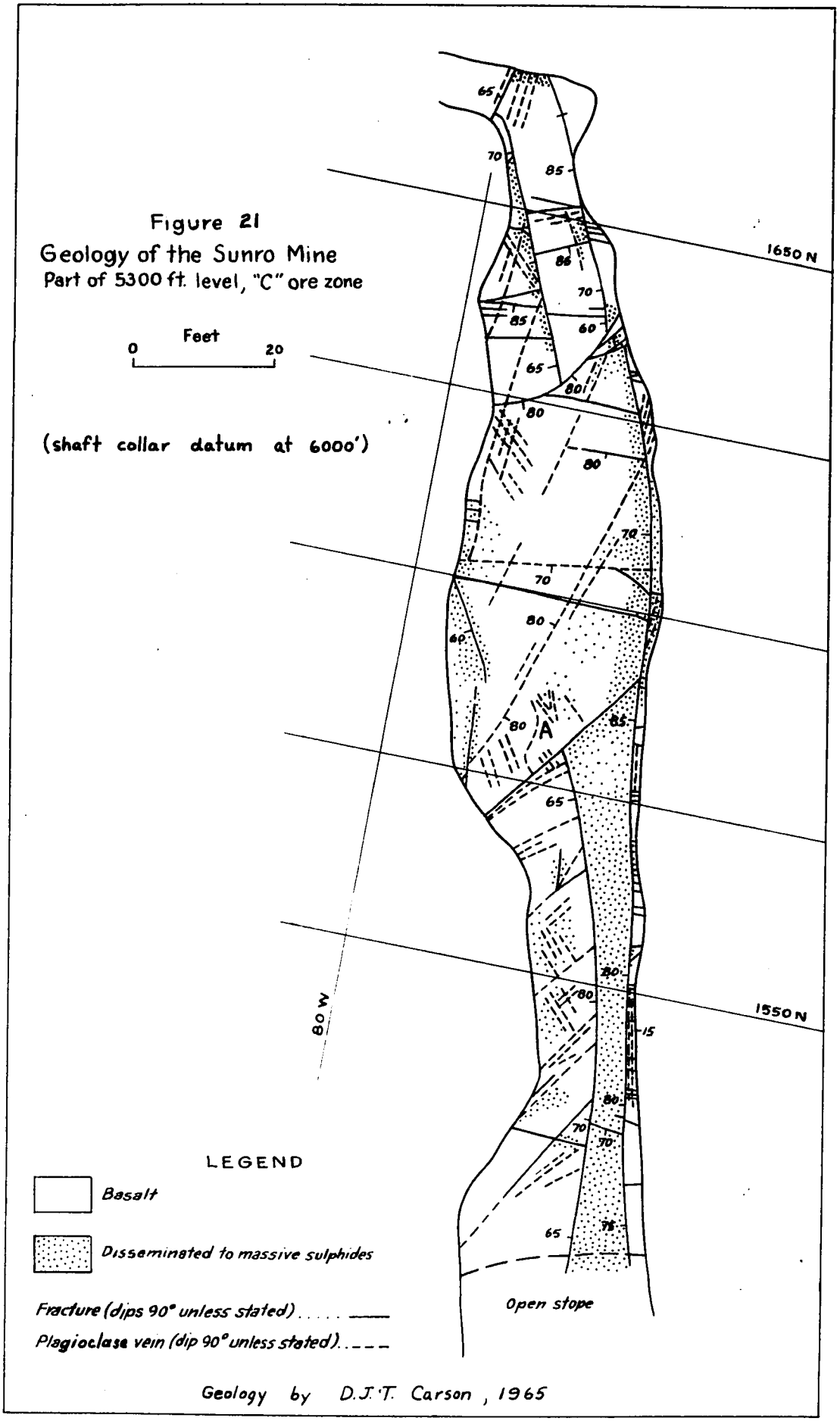
Figure 21
Geology of the Sunro Mine
Part of 5300 ft. level, "C" ore zone
Feet
0
20
(shaft collar datum at 6000')
1650 N
1550 N
80 W
A
Open stope
LEGEND
Basalt
Disseminated to massive sulphides
Fracture (dips 90° unless stated)
Plagioclase vein (dip 90° unless stated)
Geology by D.J.T. Carson, 1965

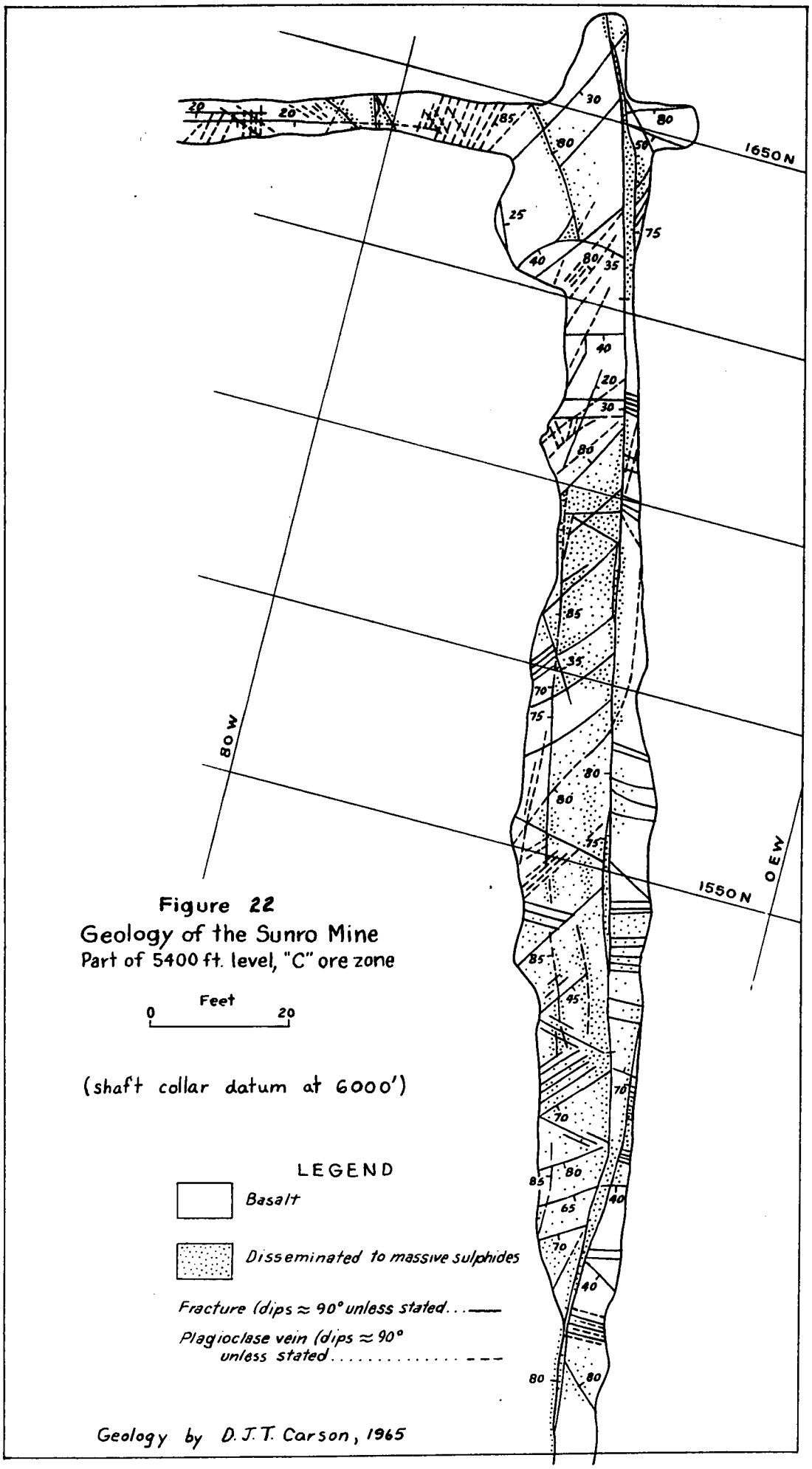

Figure 22
Geology of the Sunro Mine
Part of 5400 ft. level, "C" ore zone

A few horizontal or gently-dipping fractures are present but do not appear to have had a great controlling effect on sulphide distribution.

CLASS J - MERCURY DEPOSIT

The only known mercury deposit on Vancouver Island is at Sechart (figure 2; table 7). It was described by Dolmage (1920) who reported that limited mining had taken place prior to his investigation. Cinnabar occurs as a replacement of quartz and limestone fragments in siliceous breccia. A composite sample taken by Dolmage across the ore dump averaged 0.38 percent Hg.

Dolmage believed that the mercury was derived from Tertiary magma (Ch. IV), although no Tertiary intrusions had been found at that time. Major Tertiary faults are present along the west coast of Vancouver Island and the mercury deposit is probably related to one of these faults.

CLASS K - ALUMINIUM DEPOSITS

Characteristics of alunite deposits (Clapp, 1914b) in acidic volcanics of the Bonanza Formation (?) at Kyuquot Sound are given in table 7. They have been considered as possible sources of alumina. However, the highest grade material, approximately 20 percent Al_2O_3, appears to be found only in the small tonnage of oxidized rocks above sea level which have been leached by descending meteoric waters.

Alunite constitutes approximately 20 percent - 40 percent of the rock and is the variety natroalunite. It occurs in a zone of fractured and sheared volcanic rocks as grains varying in diameter from 0.005 millimeters to 0.3 millimeters. These replace plagioclase phenocrysts, amygdules, and matrices of rock fragments in tuffs and breccias. Quartz, sericite and minor diaspore and pyrite are also present. Limonite and kaolin are common in the oxidized zone.

The main zone, from which some material was shipped in the early 1900's for use in the manufacture of roofing tiles, contains 600,000 tons and has a surface area of 4.5 acres.

Clapp (1914b) considered the deposits to have been formed by ascending sulphuric solutions related to volcanic activity during or soon after deposition of the host rocks. These rocks are similar to those of the Bonanza Formation and occur on strike between two mapped areas of Bonanza Formation (Stevenson, 1950; Hoadley, 1953). They are therefore probably part of the same group.

Muller (1967) mapped highly altered Tertiary volcanics of the Port Hardy area which contain dumortierite (J. E. Muller, personal communication, 1967). He considers that the Kyuquot alunite deposits are similar and were probably formed by alteration of the Bonanza volcanics during Tertiary volcanic activity. This suggestion is supported by the following facts:

(1) the deposits were obviously formed near the surface and are probably young to have been preserved from erosion.

(2) the west coast of Vancouver Island was the locus of much Tertiary faulting (figure 1), intrusive activity (figures 3, 5), and volcanic activity as is shown by the occurrence of Tertiary volcanic rocks near Kennedy Lake (J. E. Muller, personal communication, 1968) and the presence of the Sharp Point hot spring (figure 2).

CLASS L - SODIUM CHLORIDE HOT SPRING

The Sharp Point hot spring (Clapp, 1914a) is probably a manifestation of the final stages of Tertiary volcanic activity.

Water containing as dissolved matter 28.4 percent Na, 44.9 percent Cu, 4.1 percent Ca, 0.2 percent Mg, 0.4 percent K, 9.8 percent SO_4, 12.2 percent SiO_2, and a trace of organic matter (Clapp, 1914a) issues at a rate of about 100 gallons per minute from a fissure six inches wide and several feet long in diorite gneiss.

CLASS M - BOG IRON

Two bog iron deposits, Quatsino and Prince (Young and Uglow, 1926) occur as residual concentrations of Tertiary volcanics (Muller, 1967) at Quatsino Sound (figure 2). They are limonite-rich layers, generally less than five feet thick but up to 18 feet thick at

Prince, which extend downward into fissures in the volcanics. The Prince deposits occur over an area of one square mile. Assays across two open cuts averaged about 55 percent Fe, 0.3 percent S, 0.4 percent P, and 2 percent insoluble matter.

In these deposits, limonite occurs as cellular, gritty and honeycombed masses, flocculent gelatinous scum, as a replacement of rock fragments and organic material, and as a cement in glacial drift.

CLASS N - GOLD PLACERS

Small amounts of gold have been recovered from placer deposits at Oyster River, Bedwell River, Zeballos River, Leech River, China Creek, and Wreck Bay.

MISCELLANEOUS DEPOSITS

1 GENERAL STATEMENT

Most known deposits of Vancouver Island are included in the classification presented in table 7. Ten other deposits of interest are discussed in this section. They include those for which available information is limited or which have characteristics of more than one class. In each case, however, it is possible tentatively to assign the deposit to a class.

2 TOFINO NICKEL (no. 217, figure 2, in pocket)

Nickel, copper, silver, and palladium occur in a gneiss complex at Tofino Nickel deposit (Eastwood,

1964). The gneiss complex consists of granodiorite and greenstone. No peridotite or gabbro was reported by Eastwood, but they may be present. If they are, the deposit is of class E, the only established deposit of which is several miles from Tofino Nickel in a peridotite sill (?) contained in the same gneiss complex (Muller, 1966).

3 THISTLE (no. 218, figure 2)

Thistle deposit was described by Stevenson (1945a, p. 17) as follows:

> "The Thistle deposit consists of two chalcopyrite replacement ore-bodies found along shear-zones about 130 feet apart ... in a band of altered limestone, 200 feet wide ... enclosed on three sides ... and in part underlain, by fine-grained diopside ... .
>
> The ore consists mainly of chalcopyrite and some pyrite in a gangue of dirty grey calcite and little quartz. Very fine magnetite is dispersed through much of the calcite; ... ."

From this it is apparent that Thistle has most of the characteristics of sub-class F-2 (copper skarns), although the skarn does not contain abundant garnet or epidote and the chalcopyrite bodies occur in strong shear zones such as characterize class A (massive sulphide) and sub-class G-3 (copper shear zones). However, the abundance of magnetite and lack of sphalerite, galena, tetrahedrite, and barite in Thistle contrast sharply with deposits of class A, and the close association with the diorite intrusion and skarnification of limestone set it apart from deposits of both class A and sub-class G-3. Thistle deposit is therefore assigned to sub-class

F-2 (copper skarns). It is one of the few skarn deposits in Sicker limestone.

4 P.D. (no. 219, figure 2)

P.D. deposit (Min. of Mines, B.C., ann. rept. 1927, p. c351) is a sphalerite-arsenopyrite "vein" up to 24 1/2 feet wide in limestone of the Sicker Group near Horne Lake. A shaft was sunk on the "vein" at some time before 1927. The "vein" is reported to assay approximately 1 percent zinc, and traces of gold and silver.

Although no extensive silicification or skarnification is reported to occur, the deposit is probably a replacement in limestone and belongs to sub-class F-4 (zinc-lead skarns or zones in limestone).

5 SR (no. 220, figure 2)

SR deposit (Min. of Mines, B.C., ann. rept. 1966, p. 77) consists of molybdenite in fractures, shears and quartz veins in felsite, diorite, monzonite, and feldspar porphyry. It belongs to sub-class G-1, molybdenum-bearing quartz veins and stockworks.

6 MARY (no. 221, figure 2)

Mary deposit of Gunnex Limited on Mt. Spencer (McKechnie, 1967) consists in part of an extensive zone of chalcopyrite-pyrrhotite-filled fractures in the matrix portion of Karmutsen basalt breccia. Fragments in the breccia are amphibolized but the matrix is little altered. Feldspar porphyry dykes occur in the mineralized zone and

may be genetically related to the sulphides.[1] This deposit is probably of sub-class G-2 which includes copper-bearing stockworks.

7 MT. SKIRT (no. 222, figure 2)

The Mt. Skirt deposits were briefly described by Clapp and Cooke (1917, p. 382). They occur in five parallel rusty shear zones in silicified dacite tuffs and interbedded cherts of the Malahat volcanics which may be part of the Vancouver Group. They consist of pyrrhotite, chalcopyrite, chalcocite and pyrite in a gangue of quartz and calcite.

These deposits are tentatively assigned to sub-class G-3, copper-bearing shear zones.

8 SHARON (no. 223, figure 2)

Sharon (Pauper) deposit (Min. of Mines, B.C., ann. rept. 1927, p. c339) consists of a pyritized "schist zone" about 60 feet wide in Sicker volcanics, containing very minor chalcopyrite. The sulphides are most abundant in local zones up to six feet in width.

This deposit is very similar to pyritic zones formed near Zn-Cu-Pb massive sulphide deposits. The host rocks are quartz-sericite-chlorite schists of the Sicker Group, similar to those at Twin "J", Price, and Lynx. However, because no massive Zn-Cu-Pb mineralization or barite have been found, the deposit is tentatively assigned to sub-class G-3 (copper-bearing shear

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1 personal communication from K. Rose of Gunnex Ltd.

zones).

9 MAL AND S (no. 224, figure 2)

Chalcopyrite, sphalerite and pyrite occur in a shear zone in altered granitic rock at Mal and S (Min. of Mines, B.C., ann. rept. 1966, p. 78). The deposit is of class G-3 (copper-bearing shear zones).

10 CORRIGAN CREEK (Andy and Pak, 225, figure 2)

Fairly extensive zones of low grade disseminated chalcopyrite-pyrite-pyrrhotite mineralization occur in fresh fine to medium grained quartz diorite (no. 168) at Corrigan Creek. This quartz diorite is intruded by numerous feldspar porphyry dykes[1] and may be Tertiary.

Minor amounts of molybdenite, magnetite and sphalerite have been observed by the writer in quartz diorite near the main mineralized zones.

The Corrigan Creek deposit is a porphyry copper deposit similar to those of class H.

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1 unpublished map of Noranda Exploration Company Limited

IV - RELATIONSHIP OF MINERAL DEPOSITS TO PLUTONIC ROCKS AND THE IMPLICATIONS ON GENESIS

GENERAL STATEMENT

In this chapter an attempt is made to establish the relationships or non-relationships of plutons to the various classes of mineral deposits. It is first determined whether a close spatial relationship exists. If so, the characteristics of plutons given in chapter II, and especially their modal and chemical compositions, ages, and physical forms, are used further to define the relationships.

BROAD SPATIAL RELATIONSHIPS

It is apparent from figures 2 and 3 (in pocket) that on Vancouver Island there is an overall spatial relationship between plutons and mineral deposits. The great number of skarn and vein-type deposits contribute largely to this overall relationship.

Other broad spatial relationships which occur are:

(1) The greatest variety of mineral deposits (skarns, gold-quartz veins, alunite, hot spring, mercury, porphyry copper, molybdenum veins, nickel, etc.) occurs along the western third of the island and this is the locality of the greatest variety of plutonic rocks (Ch. II).

(2) Skarn deposits are common in the eastern and the

western belts in which plutonic rocks have average compositions of granodiorite, and are much less common in the axial quartz diorite which are believed to be more deeply eroded (Ch. II).

(3) Gold-quartz veins and porphyry copper deposits are almost entirely confined to the zones of known and probable Tertiary intrusive activity (figure 5).

(4) Bedded deposits (excepting bog iron and placer gold) and Zn-Cu-Pb-Ag-barite massive sulphide deposits show no obvious relationship to plutons and are confined to the Sicker Group.

(5) Plutons of established type and which are known to be related to mineral deposits are post-tectonic. Syntectonic gneisses show no close relationship to mineral deposits. They contain few mineral deposits, and like most other host rocks they probably owe the presence of these few to later plutonic or structural events.

CLASS A - ZINC-COPPER-LEAD MASSIVE SULPHIDE DEPOSITS

Jeffery (1965b) mentioned the possibility that the Lynx and Paramount deposits formed in shear zones and were derived from hydrothermal solutions emanating from either the Bedwell batholith or diabase sills of the Karmutsen Formation, which are both about one mile from the deposits, but the same author later discounted the diabase sills as a source.

Stevenson (1945b) believed that the Twin "J"

ores were formed from solutions emanating from an unexposed body of granodiorite postulated to underlie the deposits, and that the solutions deposited the metals in favourable rocks in a shear zone. The closest exposed granodiorite pluton is three miles from the deposits.

Present studies of the Price property are inconclusive. The sulphides may have been deposited along with their host rocks and later deformed and remobilized, or they may have been deposited later and then deformed.

In reviewing the relationship or non-relationship to plutons of the massive sulphide deposits the following should be considered:

(1) The Bedwell quartz diorite batholith a mile west of Lynx, Paramount and Price, which is the only logical plutonic source, is one of the most barren batholiths of the entire island. No deposits known to be genetically related to it have been worthy of detailed exploration. The gold-quartz veins and porphyry copper deposits near Big Interior Mountain several miles to the southeast are spatially related to it but are almost certainly genetically related to younger Tertiary quartz diorites and dacite porphyries (p. 38). Further, this batholith is texturally and compositionally unique for Vancouver Island (Ch. II). No plutons occur near Twin "J" deposit and those

closest to it are of the Saanich granodiorite type which are texturally and compositionally unlike the Bedwell batholith.

(2) The deposits, like the iron and manganese cherts, are restricted to the Sicker Group (figure 17). They all occur in stratigraphically similar environments. Host rocks are all of a dominantly volcanic environment. Andesitic volcanic rocks overlie less basic volcanic rocks and cherty tuffs at Price and Paramount, and possibly also at Lynx. These three deposits occur along the strike of the Sicker Group rocks, possibly within a single stratigraphic horizon or in a limited stratigraphic interval. Rhyolite porphyry occurs north and south of the Twin "J" orebodies which are in a horizon of cherty tuffs and graphitic schists. Andesite occurs to the south of this horizon. These facts suggest that there is a close stratigraphic control for deposits of this class.

The change from acidic volcanics below to more basic volcanics above is typical of many massive sulphide deposits of the Canadian Shield (J. M. Franklin,[1] personal communication, 1967; Roscoe, 1965). The massive sulphide deposits in Cyprus are probably of syngenetic volcanic exhalative origin

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1 University of Western Ontario. Franklin is conducting a metallogenic study of parts of northern Ontario and Quebec.

(Hutchinson, 1965) and occur in pyritic tuff bands which thicken toward the sulphide bodies. Hutchinson considers that the deposits of the Canadian Shield are similar in most respects to those of Cyprus but have been metamorphosed. During metamorphism sulphides may be remobilized and redeposited in favourable structures.

(3) Structures formerly considered to be linear shear zones favourable for the deposition of sulphides from hydrothermal solutions may in fact be local zones of tight folds with closely-spaced axial-plane cleavage. These structures developed in incompetent Sicker cherty tuffs and sediments, and in breccias adjacent to them. This appears to be the case at Price (figure 16) where the "shear zone" of tightly-folded rock grades along strike into unsheared rocks and is overlain by massive relatively undeformed andesitic volcanic rocks. It is possible that their original content of sulphides rendered the rocks more susceptible to deformation.

Faults crossing the tightly-folded zones have disrupted the previously-formed axial-plane cleavage at Lynx, Paramount, Price, and Twin "J". They, and the crests of folds may have been favourable sites for the migration of sulphides during deformation and metamorphism. Banded and folded (?) textures of the sulphide bodies, with pyrite crystals granulated and strewn out, may be the result of this

deformation.

(4) The deposits are mineralogically unique for Vancouver Island. Their content of lead, zinc, copper, silver, and barite, and lack of magnetite suggests that they had a common origin involving uniform processes occurring at widespread localities.

The writer believes that consideration of the overall features described above reveals that the massive sulphide deposits are unrelated to plutonic rocks and that the metals were originally deposited with their host rocks They are possibly of volcanic exhalative origin. They were probably deposited in cherty tuff beds of the Sicker Group but were in part further concentrated by migration to favourable structures during later episodes of deformation or metamorphism.

CLASS C AND CLASS D - COPPER AND VANADIUM DEPOSITS

There is no evidence to suggest that deposits of these classes are related to plutonic rocks. Both the copper deposits in basic lavas (Gunning, 1930) and the vanadium deposits in carbonaceous sediments (Jambor, 1960) are considered to be syngenetic. Some migration of economic minerals during diagenesis or later deformation has probably occurred.

CLASS E - NICKELIFEROUS PERIDOTITE

The Meares nickel deposit is undoubtedly genetically related to its host peridotite which may be

comagmatic with the Karmutsen Formation and therefore Triassic. On the other hand, it may be post Jurassic (p. 107). The peridotite is within a gneiss complex which also contains the only other nickeliferous deposit on Vancouver Island, Tofino Nickel (Ch. III).

CLASS F - SKARN DEPOSITS

Skarn deposits are by definition genetically related to plutonic rocks.

As previously stated, skarn deposits are most common along the eastern and western belts of plutonic rocks which have the average composition of granodiorite.

Ternary diagrams of the modal and normative compositions of plutons related to the various subclasses of skarn deposits are given in figure 23. Samples chosen[1] included only those believed to be from the part of each pluton which is genetically related to the deposit. For example, the iron and copper skarn deposits related to the Nimpkish batholith, are Nimpkish, Kinman, Smith, Bob Lake, and Little Joe. The corresponding samples of the Nimpkish batholith plotted in figure 23a are nos. 16, 17, 18, 19, 20, 21, 22. Many of the points plotted on the normative diagrams are those calculated from the chemical

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1 Modal analysis samples plotted if figure 23a are: 2, 4, 5, 6, 10, 11, 16, 17, 18, 19, 20, 21, 22, 54, 55, 56, 59, 69, 70, 71, 72, 92, 99, 100, 101, 102, 103, 104, 111, 117, 118, 119, 120, 121, 122, 172, 178, 179, 180, 191, 192, 194, 195, 196, 197, 198 (see figure 3, table 2).
Normative samples plotted in figures 23b, 23c are: 1, 3, 7, 10, 11, 12, 13, 26, 32, Zeb c, Zeb d, SP-49, MW-8, 352A, 391A, 458 (see figure 3, table 3).

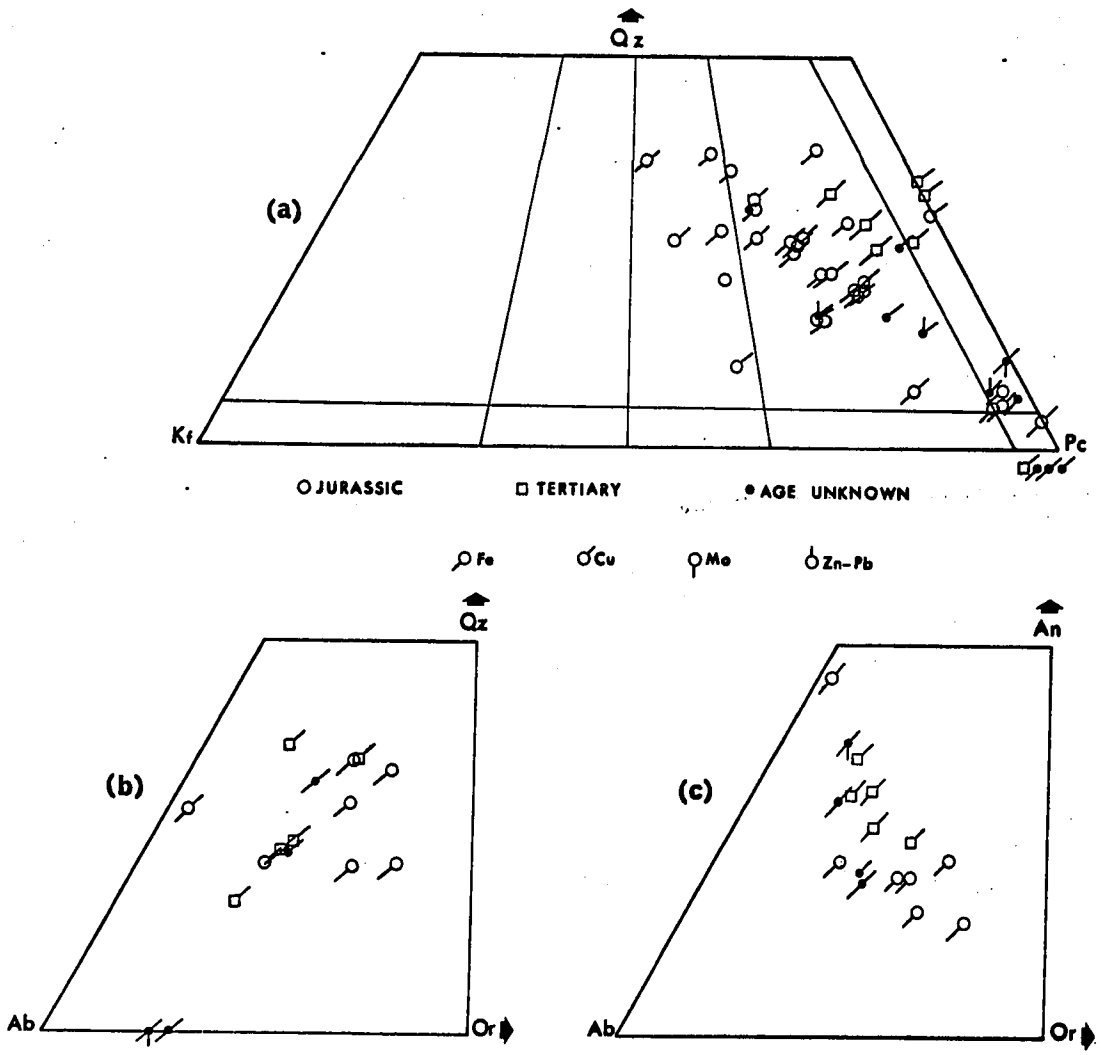

Figure 23 - Modal (a) and Normative (b,c) Diagrams for Plutons Related to Skarn Deposits

analyses of plutons related to magnetite deposits by Sangster (1964).

It is apparent from figure 23 that skarn deposits are related to a wide variety of plutonic rocks. Included are nearly all the compositional types of Vancouver Island (see figures 7, 12, 13). Further, there is no one compositional type of pluton which shows an obviously close relationship to any of the four sub-classes. Copper and iron skarns are at many localities related to the same pluton (Coast Copper stock, Nimpkish batholith, etc.) and the zinc-lead replacement deposits of Alice Lake and Pilgrim and the copper skarn at June are developed along the contact of the same pluton.

Comparison of figure 23b with figure 13 and of figure 23c with figure 12 reveals that the group of plutons related to skarn deposits does not include those relatively sodium-poor rocks which plot near the minimum on the quartz-feldspar cotectic in figure 13 and near the Ab-Or join in figure 12. This relationship may not be due to composition of the pluton but may occur because the few such plutons present are not in contact with limestone.

Plutons of known age which are related to the skarn deposits are nearly all middle or early-late Jurassic. One Tertiary skarn, Ubell, occurs in skarn developed at the margin of the Zeballos quartz diorite. Three other deposits, Indian Chief, Hesquiat A and Hesquiat B may be related to another Tertiary pluton

(Ch. II). In figure 23, five analyses of rocks from these Tertiary plutons as compared to thirteen of Jurassic or unknown plutons should not be taken to indicate the relative abundances of Jurassic and Tertiary plutons related to skarn deposits.

Skarn deposits are commonly located at or near irregularities in intrusive contacts, especially near apophyses (Ch. III). Iron and copper were apparently concentrated at the edges of plutons and especially in apophyses. They were released during or soon after crystallization of the pluton and deposited by solutions which reacted with limestone (Sangster, 1964).

Nearly all skarn deposits are related to late Triassic limestone, mainly the Quatsino Formation. Skarnification associated with Sicker limestone is very rare. Also, unlike the Quatsino Formation, it is rarely coarsely crystalline, and contains few granitic intrusive bodies (Mathews and McCammon, 1957). Only three skarn deposits, Comego, Thistle, and Skarn, all of which are uneconomic, are known to be related to limestone of the Sicker Group (figure 19), although small exposures of mineralized skarn occur in Sicker rocks at Big Interior Mountain,[1] and very minor unmineralized skarn occurs in Sicker limestone of Fourth Nanaimo Lake (Laanela, 1964). The following two proposals have been made to explain the

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1 the skarn is probably related to Tertiary quartz diorite (Ch. II).

abundance of skarn deposits associated with the Quatsino limestone, and rarity of such deposits associated with Sicker limestone:

(1) Quatsino limestone is more abundant and therefore more likely to be intruded by plutons than is the Sicker limestone (Sutherland Brown, 1962).
This proposal could account for the association of a larger number of skarn deposits with Quatsino limestone but cannot explain their almost exclusive association with it, because Sicker limestone, especially in the southern half of Vancouver Island, is abundant (figure 1). At the time of emplacement of Jurassic plutons it was therefore widespread.

(2) The Karmutsen Formation underlying the Quatsino limestone is richer in iron and copper than the volcanics underlying the Sicker limestone and could therefore have contributed more iron (Sangster, 1964; Eastwood, 1965) and copper to rising intrusions.
Higher Ca and Fe in Jurassic plutons as compared to Tertiary plutons, as well as their probable power to assimilate host rocks (Ch. II) support this proposal.
Although it has not been proven quantitatively, observation of rocks of the Sicker Group and those of the Karmutsen Formation leads the writer to believe that the latter are richer in iron. Karmutsen volcanic rocks are almost entirely

medium to dark green or greenish-black. Lighter bleached varieties occur locally in the vicinity of plutons. At these localities iron may have migrated from the volcanics into the plutons.

The Sicker Group as a whole is lighter coloured and contains much light-coloured tuffaceous sedimentary rock. Iron-bearing cherts occur but are of very limited extent; and even those few considered to be near ore grade contain only about 15 percent - 20 percent Fe (table 7) whereas volcanic rocks of the Karmutsen Formation probably average about 8 percent[1] Fe. They may contain up to 14 percent Fe (Eastwood, 1966).

The abundance of copper in the Karmutsen Formation and the Sicker Group is unknown, but syngenetic copper deposits are common in the Karmutsen Formation (class C) but are not known to occur in the Sicker Group.

The second proposal could account for the great abundance of iron and copper-bearing skarn deposits associated with the Quatsino limestone as compared to the Sicker limestone, except that it does not explain the rarity of skarn, whether mineralized or unmineralized, associated with Sicker limestone. If the controlling factor was simply the occurrence of iron-copper-rich volcanics below Quatsino limestone but not below Sicker

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1 the average of 3 analyses of Karmutsen volcanic rocks near magnetite deposits is 7.90 percent Fe (Sangster, 1964).

limestone, both limestones would be equally skarnified and recrystallized to marble, but only those skarns near the former would contain chalcopyrite and magnetite. Although they may be exceptions to the rule, the Thistle and Skarn deposits are in Sicker limestone and contain appreciable quantities of both minerals.

The writer believes that the original source of most iron and copper in the skarn deposits was the Karmutsen Formation. However, he believes that rock competence and lithostatic pressure were the factors which ultimately controlled the relative abundance of skarn deposits in the Sicker and Quatsino limestones, because they determined the amount of crystallizing granitic magma which came into contact with the limestones. The lithostatic pressure at the site of the Sicker limestone was great because it was approximately 10,000 feet further from the earth's surface than the Quatsino limestone (Ch. II). Plutons rising through the Sicker Group, probably along fault zones, passed upward through the Sicker limestone without spreading laterally and reacting with it (Ch. II). They continued upward in the Karmutsen Formation. Upon reaching the Quatsino-Karmutsen conformity they may have possessed much greater magmatic pressure than the lithostatic pressure because of the massive and competent nature of the Karmutsen Formation which restricted their lateral

development.[1] They breached its surface and immediately spread laterally as apophyses in or near to the incompetent Quatsino limestone (Ch. II). Thus their upward progress was stopped near the Quatsino Formation, allowing reaction with limestone to form skarn deposits (figure 15).

CLASS G

1 SUB-CLASS G-1 - MOLYBDENUM-BEARING VEINS AND STOCKWORKS

Molybdenum(-copper)-bearing quartz and/or pegmatite veins and stockworks of sub-class G-1 are all closely related spatially, and almost certainly genetically, to plutons. In the two cases in which the compositions of the plutons are in part or well known, they include some of the most potassic of the Jurassic (Allies) and Tertiary (Tofino) phases (figure 24a). Allies is related to the roof facies of a Saanich granodiorite pluton, and the sparse information available on Moly and Dry Gulch suggests that they occur in a similar environment. Tofino occurs in the porphyritic border zone of a Tertiary granodiorite stock.

2 SUB-CLASS G-2 AND SUB-CLASS G-3 - COPPER-QUARTZ VEINS AND STOCKWORKS, AND COPPER-BEARING SHEAR ZONES

Many deposits of these two sub-classes have a

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1 there is probably no such sharp difference in competence between the Sicker limestone and the cherty tuffs which in most places underlie the limestone.

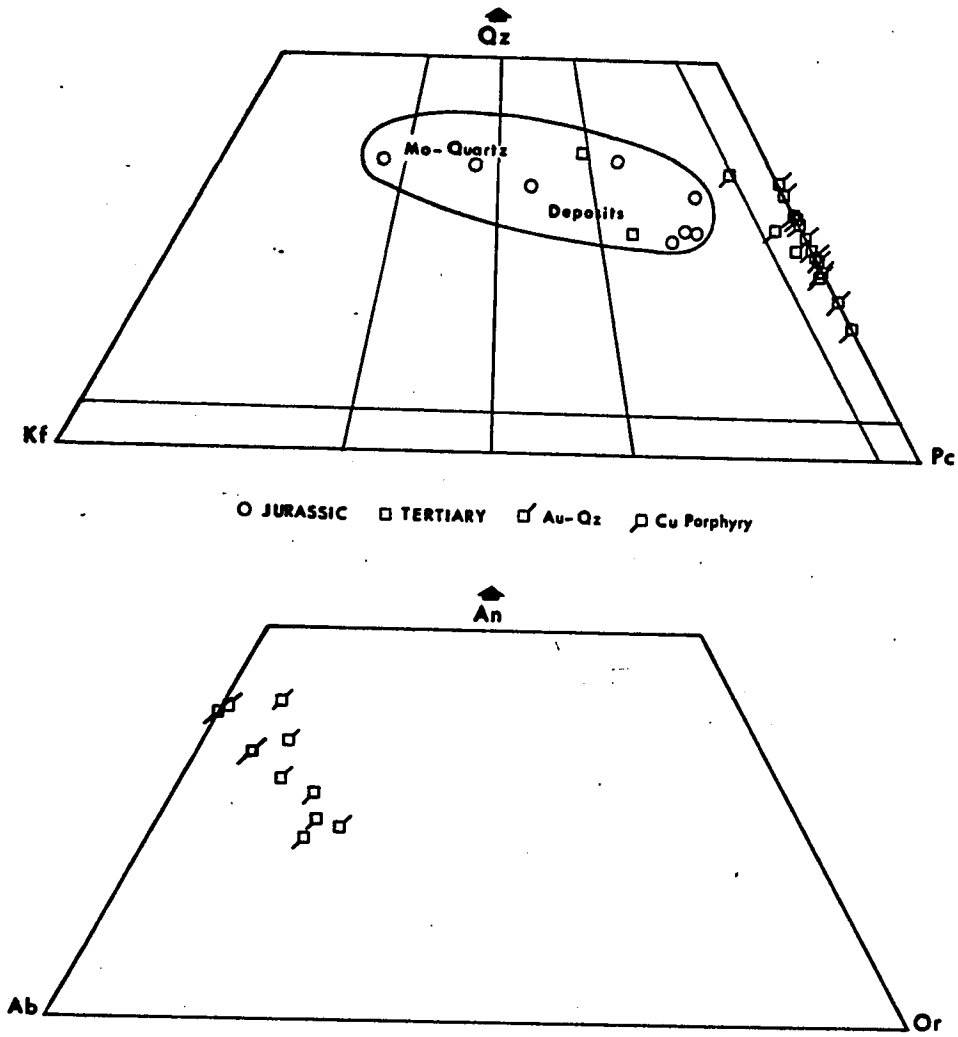


Figure 24 - Modal (a) and Normative (b) Diagrams for Plutonic Rocks Related to Gold-Quartz, Porphyry Copper and Molybdenum-Quartz Deposits

possible spatial relationship with Saanich-type granodiorite (figures 2, 3). The Three Musketeers shear zone is located near Tertiary plutons, and Yankee Girl-Bay is near a stock of granodiorite porphyry. Several shear zone deposits are not close to plutons.

Metals of these deposits may have been derived from intrusions, or from their host rocks by a process of secretion during deformation and/or metamorphism.

3 SUB-CLASS G-4 - ANTIMONY-QUARTZ VEINS

The Silver Bell antimony-quartz vein, the only one for which information is available, does not occur near to any known plutonic rock.

4 SUB-CLASS G-5 - TUNGSTEN STOCKWORK

It is not known if the only deposit of this class, Victory, is spatially related to plutonic rocks.

5 SUB-CLASS G-6 - ARSENIC-CARBONATE VEINS

Both Grizzly and Wolf are Tertiary (Ch. III). They occur very near to dacite porphyries but are not necessarily derived from them.

6 SUB-CLASS G-7 - COPPER-ARSENIC QUARTZ DEPOSITS

Mt. Washington Copper deposit is Tertiary and is probably genetically related to the Mt. Washington quartz diorites and dacite porphyries. It is in a fault or sheeted zone formed in part at the contact of a dacite porphyry sill and quartzite, possibly due to magmatic

subsidence or forcible intrusion of the Mt. Washington stock (figure 15).

Macmillan deposit is probably Tertiary but it is not known if it is related to the dacite porphyry which may occur as fragments in the breccia (Ch. III).

7 SUB-CLASS G-8 - GOLD-QUARTZ VEINS

Gold-quartz veins of Vancouver Island have an overall spatial relationship to Tertiary plutons (figure 25). Those deposits which can be shown to be spatially and probably genetically related to plutons of known age occur at Zeballos, Faith Lake, and Mt. Washington. The associated plutonic rocks at these deposits are Tertiary quartz diorites and dacite porphyries (figure 24). The distribution of the deposits and the quartz diorite plutons suggests that there is an overall control by major fractures striking parallel to and perpendicular to the regional structures.

Many deposits at Bedwell River occur in the Bedwell batholith which may be Jurassic but they are probably related to Tertiary dykes and plugs some of which are well exposed near Big Interior Mountain (Ch. II). Accroding to Stevenson (1945a), the gold-quartz veins in the China Creek area occur along a belt of feldspar porphyries of undetermined age, and at Kennedy River the gold deposits were believed by Dolmage (1921, p. 19A) to be related to diorite plutons which intrude granodiorite of the "Coast Range batholith". Dolmage stated:

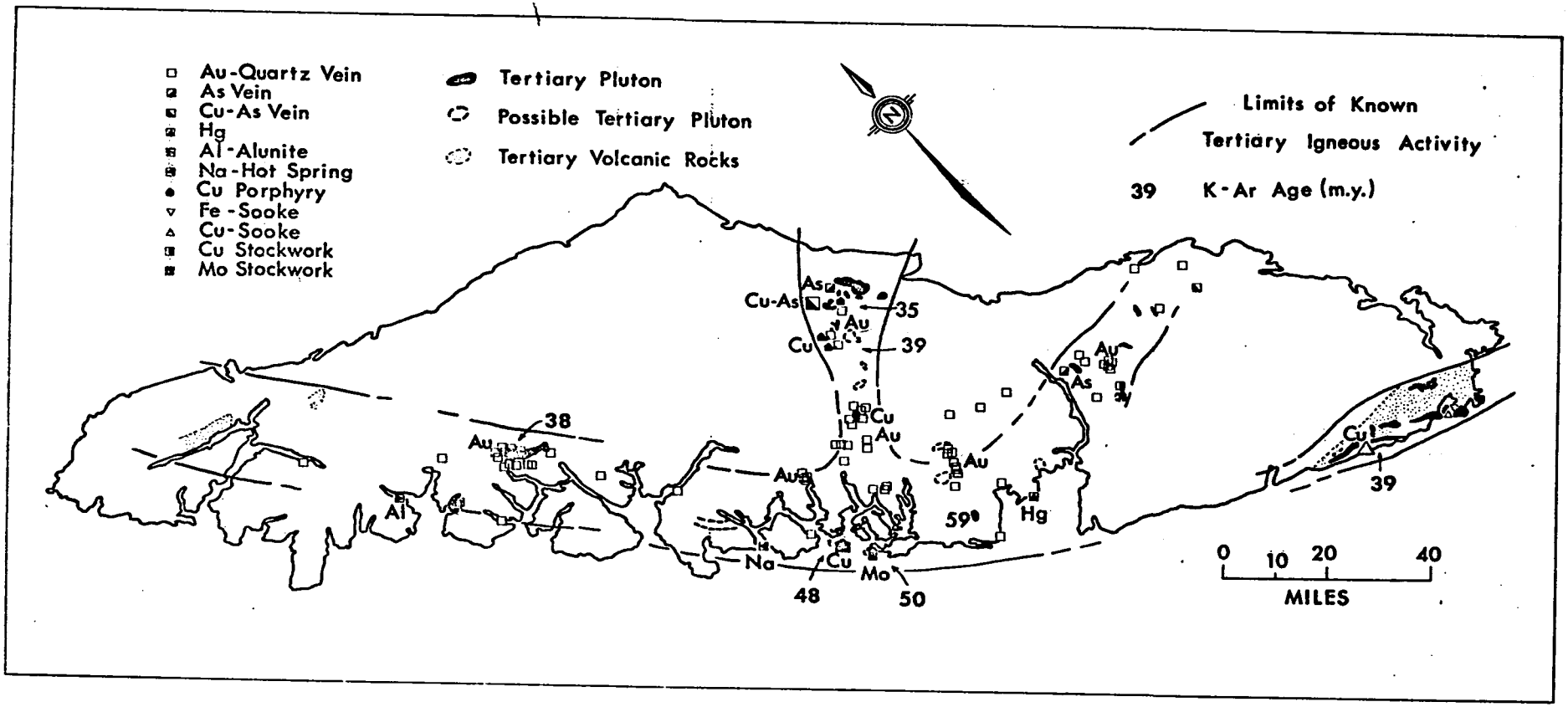


Figure 25 - Distribution of Tertiary Igneous Rocks and Known and Probable Tertiary Mineral Deposits

"The diorite ... belongs either to an exceedingly late phase of the batholithic period or to some subsequent period of intrusion."

Despite these local uncertainties the overall spatial and probably genetic relationship of gold-quartz veins to Tertiary plutons, both of which are probably related to Tertiary faults, is indisputable. Further, the conspicuous absence of gold-quartz veins near Jurassic potassic plutons (i.e. - Saanich granodiorites, Nimpkish and Bonanza batholiths, etc.) is noteworthy. Most of the lode gold deposits of Washington State are similarly related to Tertiary quartz diorites (Huntting, 1966).

Regarding the gold-quartz veins of the Zeballos mining camp Stevenson (1951, p. 33) wrote:

"... They are younger than the quartz diorite and have also a close spatial relationship to it, and it is probable that, thought the vein matter need not have come from the quartz diorite, it may be genetically related in coming from the same deep source."

In considering the origin of the gold-quartz veins of Vancouver Island, the following facts should be noted:

(1) Host rocks for the deposits are extremely varied. They include:

a -- Quartz Diorite (Tertiary) - Spud Valley, Prident, Zeballos Pacific, Central Zeballos, etc. of Zeballos area; Faith Lake.

b -- Quartz Diorite and Granodiorite (Jurassic ?) - O.K., Joker, Musketeer, Buccaneer, etc.

c -- Diorite - Black Lion

d -- Gabbro - Golden Portal, Answer

e -- Gneisses - Lemay

f -- Skarn - Privateer

g -- Sicker Volcanics - Golden Eagle, B and K, Vancouver Island Gold, etc.

h -- Sicker Sediments - Regina

i -- Undifferentiated Sicker Rocks - Della, Sherwood, P.D.Q., etc.

j -- Karmutsen Volcanics - numerous deposits

k -- Bonanza Formation - Van. Isle, Boden, Peerless, etc.

l -- Nanaimo Group - No. 2

m -- Tertiary Breccia - Domineer

(2) Related quartz diorites are very uniform in composition. They probably originated at considerable depth, as they were intruded along major fault zones and there is no evidence of widespread regional metamorphism at the time they were emplaced. Comparable intrusions in Washington State are believed by Misch (1966, p. 141) to be products of fusion at deep crustal levels.

(3) The mineral content of gold-quartz veins is extremely uniform at all areas in which the veins occur (Ch. III), and the veins from different areas are alike. Further, at all deposits studied an increase in the amount of galena and sphalerite appears to be accompanied by an increase in the gold content.

The overall uniform mineralogy of the gold-quartz veins despite widely varied host rocks indicates that the host rocks had little effect on the composition of the veins. An origin involving secretion of gold from the host rocks into fractures is therefore highly unlikely. Rather, the veins were probably derived from solutions originating in a homogeneous source outside their host rocks, and possibly at great depths.

CLASS H - PORPHYRY COPPER DEPOSITS

Deposits of class H are related to Tertiary quartz diorite-dacite porphyry intrusive complexes. They therefore have close spatial and genetic relationships to gold-quartz veins. However, whereas some gold-quartz veins are at some distance from quartz diorite or dacite porphyry plutons, porphyry copper deposits occur within and immediately adjacent to them. Modal and normative plots of specimens from plutons related to porphyry copper deposits are given in figure 24.

CLASS I - COPPER AND IRON DEPOSITS IN TERTIARY VOLCANICS AND GABBROS

Deposits of class I have close spatial and probably genetic relationships to Sooke gabbro plutons (figure 6).

CLASS J - MERCURY DEPOSIT

Dolmage (1919) believed that the Sechart mercury deposit is probably related to Tertiary magma.

The Sooke plutons, the Sharp Point hot spring, and the occurrence of Tertiary volcanics at Kennedy Lake (p. 9) support his suggestion that Tertiary magmas could have been present. Dolmage also reported the occurrence of unaltered granodiorite dykes one quarter mile from the deposit. Recent work by Muller (1966) has revealed the presence of a Tertiary intrusion at Paradise Creek several miles west of the deposit.

The Sechart deposit is within the zone of Tertiary igneous activity (figure 25) and is probably of Tertiary age, but its possible relationship to Tertiary plutons is not established. Like most mercury deposits of British Columbia (Armstrong, 1966), it is probably fault-controlled.

CLASS K - ALUMINIUM DEPOSIT

The Kashutl alunite deposit is believed to be related to Tertiary volcanic activity (Ch. III).

V - METALLOGENY AND ITS APPLICATION TO VANCOUVER ISLAND

METALLOGENIC PRINCIPLES

Metallogeny is that science which is concerned with the distribution of metalliferous deposits in space (metallogenic provinces) and time (metallogenic epochs). Metallogenic provinces are geological and generally geographical regions which are characterized by the concentration of certain metals or groups of related metals. Metallogenic epochs are intervals of geological time during which deposition of certain metals or groups of metals was pronounced.

Lindgren (1933) summarized the main concepts of metallogenic epochs and Turneaure (1955) made an exhaustive study of metallogenic provinces. Two other important works on metallogenesis are those of Bilibin (1955) and Sullivan (1948). These works were outlined by Ney (1966) who attempted to determine their validity when applied to copper deposits of British Columbia. Ney (p. 297) summarized the two schemes as follows:

"... Sullivan emphasizes the composition of the stratigraphic column through which the intrusions make their way upward. He attaches importance to the timing of the intrusions with respect to orogeny only insofar as this may be related to their mechanism of emplacement. Bilibin implies that intrusions owe their specific ore-forming capacity to metal content inherited from the source region in which they were generated. The source is considered to be a function of the stage of development of the geosyncline".

Sullivan (1956) presented a classification of mineral deposits in which the important feature is

the association of metals with particular rock types. He believed, for example, that (p. 599)

"basalts may yield important copper provinces when folded and re-heated".

Sullivan's ideas are well-known in Canada and are not discussed further but a summary of the less well-known ideas of Bilibin is warranted here.

McCartney and Potter (1962) have studied the Russian beliefs, mostly Bilibin's on the development of fold-belts. They offered a table summarizing fold-belt development and its relation to plutonic rocks and mineral deposits.

Bilibin compiled the post-World War II Soviet research on metallogenic provinces and epochs. His work was an attempt to derive metallogenic principles from a semi-quantitative study of endogenous metalliferous deposits of the entire world, but with emphasis on the Soviet Union. It has formed the basis for much of the later metallogenic research done throughout the world. Bilibin believed that, since mobile belts contain the most varied endogenous mineral deposits, they provide the best basis for studying metallogeny. In his scheme, which was therefore concerned mainly with mineral deposits of mobile belts, he considered structural controls, time of formation, stage of development of the district, type of related intrusions, sequence of intrusions and type of mineralization. He divided mobile belt development into five stages and drew the

following conclusions:

(1) even widely separated districts have similar mineral complexes

(2) certain mineral complexes are related to certain intrusive complexes

(3) intrusive complexes and related mineralization occur in cycles

(4) like stages of intrusive activity and related mineralization in mobile belts of different ages can be related on the basis of the stage of tectonic development of each belt

(5) some mineral complexes are confined to structural zones within mobile belts.

The five stages of development of fold-belts are the Initial, Early, Middle, Late, and Final stages.

During the Initial or eugeosynclinal stage, thick sequences of basic volcanic rocks with subordinate amounts of sedimentary rocks including siliceous shales, jaspers, tuffs, greywacke, and limestone are deposited. Deformation is localized near major fractures.

The Early stage involves subsidence followed by local folding and then uplift and erosion. Rocks deposited are greywacke, shale, chert, and basic volcanics which are less abundant than in the Initial stage.

During the first part of the Middle stage Flysch-type sediments including calcareous shales, and limestones, and acidic to intermediate volcanics are deposited in local basins. Uplift and intense folding accompanied by

batholithic intrusion follow and continue until the end of the stage.

Consolidation of the fold-belt occurs soon after the end of the Middle stage and deposition is mainly non-marine during the Late and Final stages. In the Late stage there are strong epeirogenic movements and large faults are formed. Folding is minor or absent. In the Final stage, molasse is deposited in fault-bounded basins or grabens and finally, plateau lavas and some rhyolites are extruded.

Bilibin believed that the evolution of igneous rocks in fold belts follows a definite course and that there is a direct genetic relationship between many types of mineral deposits and certain intrusive rocks.

In the Initial stage basic and ultrabasic intrusions and related deposits of Pt, Cr, Fe, Ti, Cu, Ni, and asbestos are derived from the sima. Intermediate and acid magmas, differentiates of the Initial intrusions, are implaced in the Early stage. Some deposits related to them are magnetite, and copper skarns, Ag-Pb-Zn-Cu-pyrite-barite deposits, Au-Ag deposits and porphyry Cu-Mo deposits.

As a result of the first period of folding, granitic magmas independent of the sima and derived from the sial replace the differentiates during the Middle stage and continue into the Late stage when they become less acidic. Related to the first small plutons of the Middle stage are gold-quartz veins with scheelite,

arsenopyrite, pyrite and stibnite, and Au-Mo-scheelite skarns. Large batholiths of the later part of the Middle stage have associated Be, Li, Ta, Nb, Cb in pegmatites, and hypothermal Sn-W veins with Mo, Bi, F, which are related to potassic granites.

Late stage Au-quartz-pyrite veins or veins of Au-scheelite-arsenopyrite with or without Sb are related to small stocks of quartz diorite or granodiorite or their porphyries. Contact metasomatic magnetite deposits with Pb and Zn rather than Cu, as in the Early stage skarn deposits, and related to gabbro-diorite, syeno-diorite, and monzonite are formed, and W-Sn deposits in acidic intrusive or extrusive rocks may also occur.

At the end of the Late stage and long after the belt has become consolidated, basic intrusive and volcanic rocks and their differentiates reappear and typical mineral deposits are those of Pb-Zn, Cu, Ag, Co, Ni, Ba, Mn, and Fe.

Thus according to Bilibin the source of magmas and metals shifts upward from the sima to the sial and then back to the sima. As a result, basic intrusions of the Initial stage precede differentiates of the Early stage, whereas basic igneous rocks of the Final stage are preceded by differentiates of the Late stage. Three magma complexes and related mineralization are therefore recognized by Bilibin. They are:

(1) basic and ultrabasic magma complex with associated elements Pt, Cr, Fe, Ti, V, Ni, Co, Cu.

(2) granitic differentiates of basic magmas with associated contact metasomatic and hydrothermal deposits of Zn, Pb, Ag, Fe, Cu, Ba, Ni, Co, As.

(3) independent granitic magmas with associated hydrothermal pegmatitic, and contact metasomatic deposits of Sn, W, Mo, Au, Li, Be, B, Ta, Nb, Cb, etc.

To substantiate the theory that metals show preferential affinities for certain stages in mobile belt development Bilibin made a world-wide survey of metal distribution in endogenous mineral deposits, using production statistics. A ternary diagram illustrating his results for each metal studied is given in Figure 26.

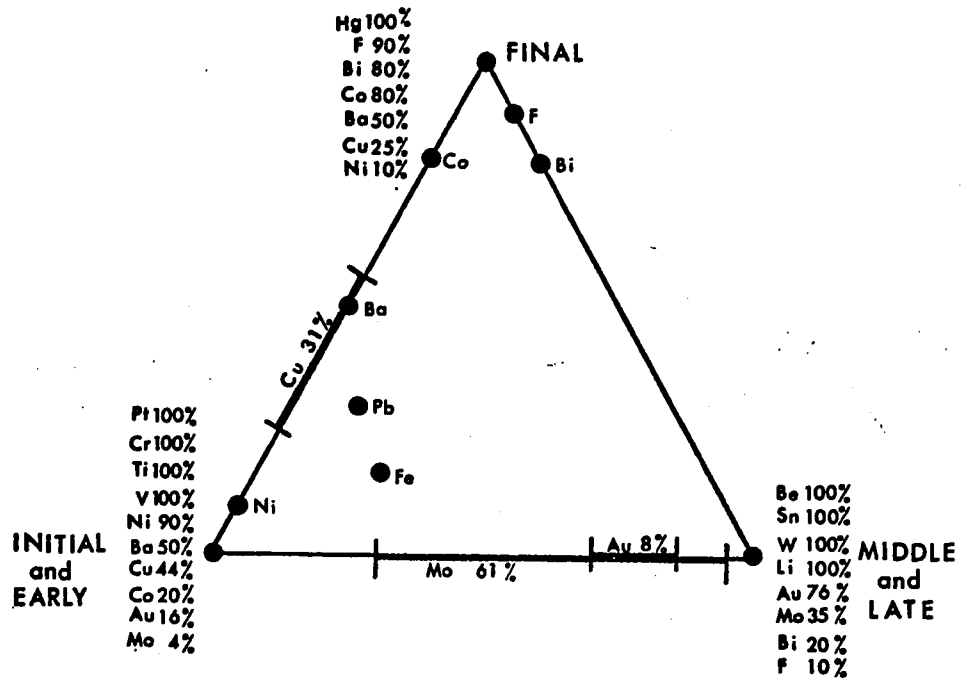


Figure 26 - Positions of the Major Metals During the Main Stages of Development of Mobile Belts (after Bilibin, 1955).

To simplify the diagram, Bilibin combined the Initial and Early stages and also the Late and Final since he believed that the members of both pairs are closely related. In this diagram, all metals are near the apices and the central right side is empty. Bilibin believed that this is a reflection of similarities (transitions) between Early and Middle (Au-Mo) mineralization and Early and Final (Ni, Co, Ba, Cu, Pb, Zn) mineralization, and lack of similarities between Middle and Late, and Final stages. He stated that these transitions are related to moderately acid granitic differentiates occuring as near surface intrusions in the two intervals between the emplacement of basic magmas and the independent granitic magmas.

The scheme of Bilibin represents a compilation of work done on several fold belts; it is not intended to apply fully to any individual fold belt which is likely to lack or show only weak development of some stages, while others are well represented. Bilibin himself noted that intrusive and mineral complexes of corresponding stages may vary from province to province, and that some such complexes may dominate whereas others are subordinate. Thus subvolcanic plutons and associated mineral deposits of the Late stage, and plateau basalts of the Final stage are better represented in the Cordillera than in the Appalachian fold belt. In the Ural belt the Initial and Early stages involving basic volcanics, ultrabasic intrusions and associated Pt, Cr, Ni, asbestos, etc. are highly

developed and other stages are missing.

Modifications of Bilibin's scheme which emphasize the influence that large scale structures or structural zones have on mineralization have been proposed by Semenov (1957) and Itsikson (1963).

McCartney (1964) has applied the basic principles of metallogeny of Bilibin to the Canadian Appalachians with considerable success.

POSSIBLE APPLICATION OF BILIBIN'S METALLOGENIC SCHEME TO VANCOUVER ISLAND

1 FOLD-BELT DEVELOPMENT

There is general agreement between the geological development of Vancouver Island and the generalized scheme for fold belts of Bilibin.

The Initial stage of Bilibin corresponds roughly to the late Palaeozoic-Triassic interval on Vancouver Island. Cherts, tuffs, greywackes, and basic to intermediate volcanics of the Sicker Group and basic volcanics of the Karmutsen Formation are typical of this stage. There is little evidence of deformation (Ch. I).

Most rocks of the Bonanza Formation appear to correspond to those of the Early stage. During the early and (?) middle Jurassic deposition became more restricted and the volcanic rocks less basic in response to the onset of the Middle orogenic stage.

The main period of deformation and batholithic intrusion, the Coast Range Orogeny, corresponds to the

Middle stage. Late Jurassic clastic sediments and limestones of the west coast were deposited during the latter part of the Middle Stage and may correspond to Bilibin's Flysch.

The Late stage and early part of the Final stage of Vancouver Island are represented by late Jurassic (?) and early and late Cretaceous molasse. Final stage deposits may include Tertiary sediments at Sooke and on the west coast. Deformation was typical and involved mainly block faulting. Subvolcanic Tertiary plutons were emplaced along major faults. Final stage continental plateau lavas are not known but may have been eroded away. Plateau lavas of this stage are common in central British Columbia. On Vancouver Island Tertiary basalt, rhyodacite, tuff and breccia occur in the Quatsino area, and dacite tuff and ignimbrite near Kennedy Lake (Ch. I).

The position of the Eocene Metchosin submarine volcanic rocks in the Bilibin scheme is of interest. They are probably not locally-developed marine equivalents of the Final stage plateau lavas because they do not correspond in age with known plateau lavas of British Columbia and the Columbia Plateau which are Miocene-Pliocene. Also, the equivalent lavas of the Olympic Peninsula (Turner and Verhoogen, 1960) are the oldest of a thick series of Tertiary volcanic rocks which includes the younger Columbia River Plateau lavas. They may represent a local return to the Initial, eugeosynclinal stage (Ney, 1966).

2 PLUTONIC ROCKS

There is not enough evidence to confirm or deny that the wide variety of plutonic complexes proposed by Bilibin occurs on Vancouver Island.

Ultrabasic plutons are rare but may be late Triassic (Ch. III) and of the Initial stage as proposed by Bilibin. The complex, Ti-rich (Sangster, 1964) Coast Copper stock with its related Cu-Fe skarn deposits may be a differentiate of Initial stage basic or ultrabasic magma.

Jurassic Middle stage batholith rocks are present on Vancouver Island and the youngest post-tectonic intrusions of this group may be of the Late stage which probably includes the late Jurassic. Other plutons of this stage may be represented by plutons of unknown age, but probably Jurassic, which have chemical characteristics common to both the Jurassic plutons and those of the Tertiary (Ch. II; figures 10, 11, 12, 13).

Tertiary plutons of Vancouver Island may have been derived from a basic parent by differentiation (Ch. II). For this reason, and since they intrude Upper Cretaceous Late stage molasse, they may correspond to the Final stage plutons of Bilibin. However, they have associated mineral deposits of Bilibin's Late stage plutons and have chemical characteristics which are rather close to those of the Middle stage "independent" Jurassic plutons. These facts would suggest their derivation from Jurassic plutons, but the wide difference

in age precludes this origin.

3 METALLIFEROUS DEPOSITS

a. SOME IMPORTANT CLASSES

Fe-Mn CHERTS

On Vancouver Island these deposits occur in the Initial stage as indicated by Bilibin.

Ag-Cu-Pb-Zn-BARITE DEPOSITS

Bilibin believed that these deposits are related to albite porphyries of the Early stage. Plagioclase porphyries are known to occur at Lynx and Paramount but are of very small quantity and are not believed to be related to the ore deposits (Jeffery, 1965). The plagioclase porphyry at Price contains labradorite phenocrysts and is also believed to be unrelated to the sulphides (Ch. II). Albite porphyries occurring at Twin "J" are probably part of the Sicker Group and were not believed by Stevenson (1945b) to be the source of the ore.

Deposits of this class are believed by the writer to be of syngenetic origin (Ch. III) and of the Initial stage of Bilibin.

NICKELIFEROUS PERIDOTITE

The relation of nickel to peridotite is well-known and agrees with Bilibin's scheme. The time of formation of the Meares deposit is unknown, but may have been during the Initial stage (Ch. III), as indicated by

Bilibin.

SKARN DEPOSITS

Fe and Cu skarn deposits are intimately associated with one another on Vancouver Island (Ch. III). Some, such as those of Coast Copper and Empire Development, may be related to differentiates of the Early stage as proposed by Bilibin but most are related to Middle or Late stage plutons (Ch. II). This relationship of Fe-Cu skarns to Middle or Late stage plutons is not recognized by Bilibin.

The only magnetite skarns recognized by Bilibin other than those of the Early stage are related to Late stage plutons and are characterized by the association of Pb-Zn rather than Cu with the magnetite. Magnetite skarns of Vancouver Island commonly contain appreciable copper but only small quantities of zinc. Zn-Pb and Cu skarns may be related to the same pluton (Ch. III).

GOLD-QUARTZ VEINS

All gold deposits, according to Bilibin, are related to Initial and Early or Middle and Late plutons (figure 26). All gold-quartz veins of Vancouver Island are probably related to Tertiary quartz diorites which by Bilibin's scheme are probably of the Final stage. Some gold is, however, recovered from Initial stage deposits such as Western Mines, and Middle stage Cu-Fe skarn deposits (not recognized by Bilibin) contain appreciable gold.

PORPHYRY COPPER DEPOSITS

These deposits, like the gold-quartz veins, are related to probable Final stage Tertiary quartz diorites and dacite porphyries on Vancouver Island, but are placed in the Late stage and related to plutons differentiated from Middle stage batholiths by Bilibin. The young age of Tertiary plutons of Vancouver Island precludes their formation by differentiation from Jurassic plutons.

SOOKE COPPER-IRON DEPOSITS

The Sooke deposits by Bilibin's classification are related to gabbro plutons of the Initial stage.

b. METAL DISTRIBUTION IN TIME

Even when allowance is made for the fact that certain mineral complexes are absent, the distribution of metals with time on Vancouver Island exhibits many variations from the distribution proposed by Bilibin (figure 26).

The main differences are in gold, copper, iron, and molybdenum, and are the direct result of the inapplicability of Bilibin's scheme to the skarn deposits, gold deposits, and porphyry copper(-molybdenum) deposits of the island. They are readily explained.

The richest iron deposits of Vancouver Island are skarn deposits related to Middle or Late stage plutons. Iron cherts of the Initial stage occur in the Sicker Group, and small quantities of magnetite occur in Tertiary breccias.

The greatest amount of iron however is present in Initial stage volcanic rocks and these are probably the ultimate source of iron for the skarn and breccias (Ch. III). However, Bilibin considers only commercial iron in his scheme and the fact that he places iron mainly in the Initial and Early stages is no doubt a reflection of the abundant Initial stage iron formations which occur throughout the world.

It is apparent from the above that if ultimate source is considered, the position of iron in Bilibin's scheme corresponds to that of Vancouver Island. The same may be true of copper which occurs mainly in Initial stage massive sulphide deposits, Middle stage skarn deposits and Late or Final stage porphyry deposits. The absence of copper in the Middle stage according to Bilibin is explained if it, like iron, is considered to be derived from Initial stage volcanics.

Gold, which by Bilibin is mainly Middle and Late with the remainder Initial, is Initial (massive sulphides), Middle (skarns), and Late or Final (gold-quartz veins) on Vancouver Island. Molybdenum is mainly Middle (sub-classes G-1, F-3) and Late or Final (sub-classes G-1 and porphyry-copper - H) on Vancouver Island but is Initial or Late according to Bilibin.

Some elements in deposits of Vancouver Island which occur at the exact stage indicated by Bilibin are V and Cu in basic lavas, Fe and Mn in cherts, and Hg.

Ni is believed to be Initial or Final by Bilibin

and may be Initial on Vancouver Island. Ba is Initial in both cases but Late Ba of Bilibin has not been discovered on the island. Co occurs in minor amounts in skarn deposits, in a gold-quartz vein (carrollite, Domineer), and in the Sooke copper deposits.

The only occurrence of Bi known to the writer is at Mt. Washington Copper which is a Late or Final deposit. This agrees with Bilibin.

Lead and zinc occur in deposits of all stages on Vancouver Island and this is also indicated by Bilibin.

CONCLUSIONS REGARDING BILIBIN'S SCHEME

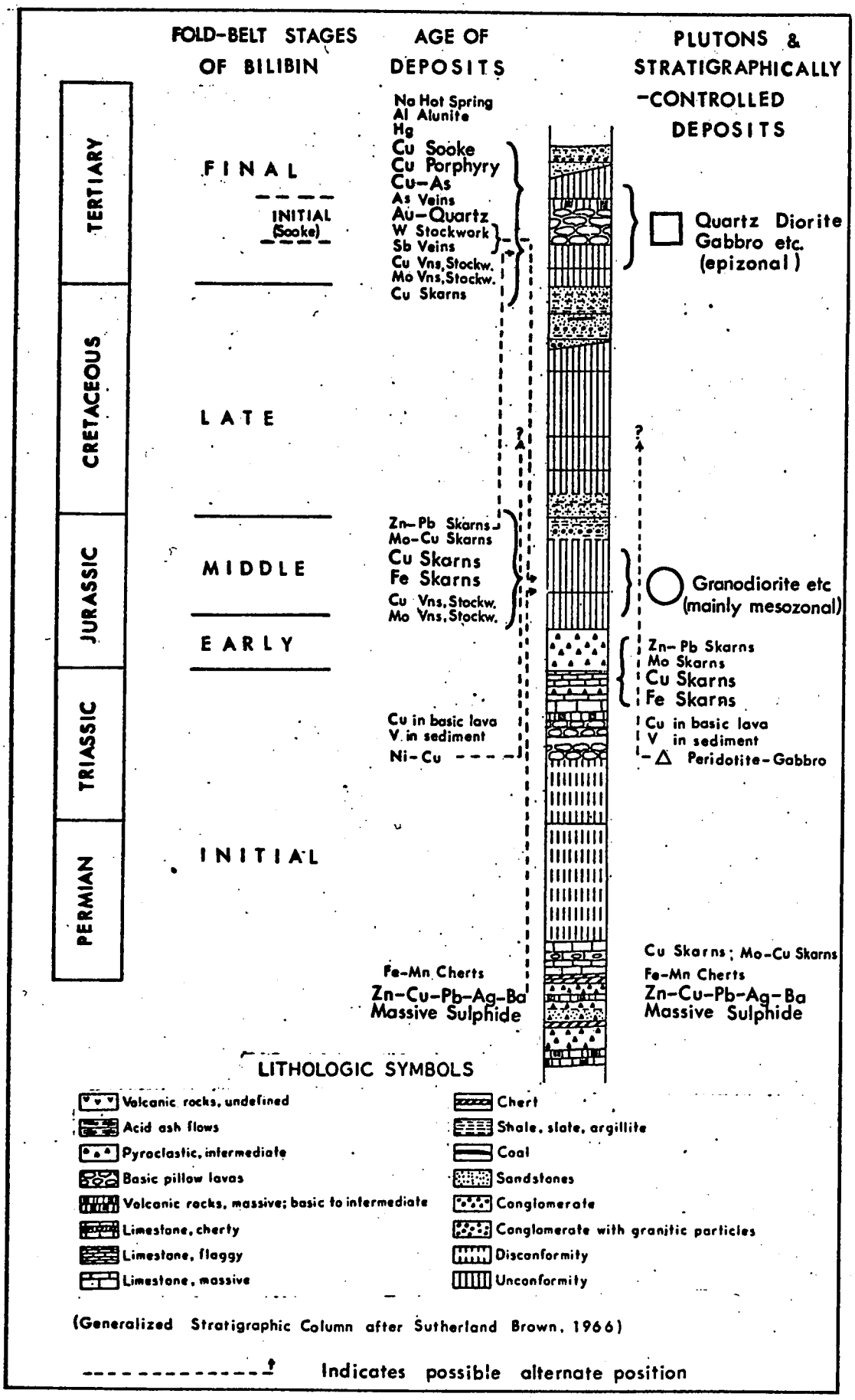
It is evident that three major difficulties other than lack of data arise if an attempt is made to apply Bilibin's metallogenic scheme to Vancouver Island. They are: (1) there is no place in the scheme for metalliferous deposits related to plutons which may have obtained their metal content by assimilation of host rocks. As a result the copper and iron skarns of Vancouver Island do not occur in the place allocated for them in the Bilibin scheme; (2) the exact relationship between the Tertiary and Jurassic plutons of Vancouver Island is not known. They are, on the whole, chemically distinct from one another, but transitional types of unknown ages do occur (figure 12a) and their variation curves (figures 10, 11) are close and parallel despite their probable wide difference in age. The evidence

favours their separate evolution at different times, but from similar parent material. If this is true, the Tertiary plutons are of the Final stage, but have associated mineral deposits of Bilibin's Late stage plutons; (3) most endogenous mineral deposits, by Bilibin's classification, are derived from igneous rocks, and both metals and magmas were derived from the same source. Deposits such as the Zn-Cu-Pb massive sulphides and many of the vein deposits of class G show no obvious genetic relationship to plutons.

The writer believes that if allowance is made for the influence which host rocks of plutons have on the nature of resulting mineral deposits (Sullivan, 1948, 1956) a useful scheme somewhat similar to that of Bilibin can be derived. A scheme based on these concepts which indicates the stratigraphic position, or associated formations, age, and type of related pluton for metalliferous deposits of Vancouver Island is presented in figure 27 and table 16, which are, in effect, summaries of chapters III, IV and V.

In the scheme the oldest metalliferous deposits are the Zn-Cu-Pb massive sulphides which were deposited with initial eugeosynclinal volcanic rocks of the Sicker Group. Ferruginous and manganiferous cherts were deposited near the top of the same group. Volcanism ceased, and Sicker limestone up to 1,000 feet thick was formed. Slight uplift and limited erosion of the Sicker Group occurred before the Karmutsen basic volcanics were

Figure 27 – Metallogenic Scheme for Vancouver Island



CLASS OF DEPOSIT	MAIN METALS	SOME EXAMPLES	ASSOCIATED FORMATION OR HOST ROCKS	RELATED INTRUSIONS	KNOWN OR PROBABLE TIME OF FORMATION
PLACER GOLD	Au	Oyster R., etc.	----------	----------	Recent
BIG IRON	Fe	Prince	Tertiary (?) volcanics	----------	Recent
SODIUM HOT SPRING	Na	Sharp Point	Diorite gneiss	----------	Recent
ALUMINIUM DEPOSIT	Al	Kashutl	Bonanza volcanics	(related to volcanism)	Tertiary
MERCURY BRECCIA FILLING	Hg	Sechart	Vancouver Gp. limestone	Unknown	Tertiary
COPPER OF SOOKE	Cu	Sunro Mine	Metchosin volcanics, Sooke gabbro	Sooke gabbro	Late Eocene or Early Oligocene
IRON OF SOOKE	Fe; minor Cu	Iron Mountain	Sooke gabbro	Sooke gabbro	Late Eocene or Early Oligocene
PORPHYRY COPPER	Cu; minor Mo, Au	Catface Faith Copper	Intrusive complexes and their varied host rocks	Quartz diorite - dacite porphyry stocks, plugs	Tertiary (Eocene-Oligocene)
GOLD-QUARTZ VEINS	Au, Ag; minor Pb, Zn, As, Cu	Privateer Musketeer Vancouver Island Gold	Extremely varied host rocks, late Paleozoic to Tertiary	Quartz diorite, dacite porphyry, in many cases	Tertiary (Oligocene)
COPPER-ARSENIC VEIN, BRECCIA ZONE	Cu; apprec. As	Mt. Washington Copper Macmillan	Nanaimo argillite, quartzite; dacite porphyry; Karmutsen Fm.	Dacite porphyry sills, dykes	Tertiary
ARSENIC VEINS	As	Grizzly Wolf	Nanaimo argillite; Karmutsen Fm.	Dacite porphyry sills, laccoliths	Tertiary
TUNGSTEN STOCKWORK	W; minor Sb	Victory	Limestone, greenstone, unknown age	Unknown	Unknown
ANTIMONY-QUARTZ VEINS	Sb; minor As	Silver Bell	Varied host rocks	None obvious	Tertiary (?)
COPPER SHEAR ZONES	Cu; possibly minor Zn, Au	Blue Ox El Capitan	Varied, generally Vancouver Group	None obvious	Possibly Jurassic and Tertiary
COPPER-QUARTZ VEINS, STOCKWORKS	Cu; possibly Mo	Yankee Girl-Bay Independent	Varied; host rocks rarely intrusions	Granitic and porphyritic intrusions near some deposits	Probably Jurassic and Tertiary
MOLYBDENUM-QUARTZ VEINS, STOCKWORKS	Mo; minor Cu	Allies Dry Gulch Tofino Molybdenite	Intrusions and adjacent rocks	Potassic stocks, roof facies of batholiths	Mid to Early-Late Jurassic, Early Tertiary
ZINC-LEAD SKARNS, REPLACEMENTS IN LIMESTONE	Zn ± Pb; minor Cu, Ag	HPH Alice Lake Danzig	Quatsino limestone, rarely Sicker limestone	Feldspar porphyry dykes, possibly granitic stocks	Mid to Early-Late Jurassic and/or Tertiary
MOLYBDENUM-COPPER SKARNS	Mo, Cu	Sun West Comego	Sediments, volcanics of Sicker and Vancouver Gps.	Quartz diorite	Mid to Early-Late Jurassic and (?) Tertiary
COPPER SKARNS	Cu; apprec. to minor Fe, Au, Ag	Coast Copper Indian Chief Blue Grouse	Quatsino and rarely, Sicker limestone	Stocks-gabbro to quartz monzonite	Mid to Early-Late Jurassic and rarely, Tertiary
IRON SKARNS	Fe; minor Cu	Brynnor Zeballos Nimpkish	Quatsino limestone	Stocks-gabbro to quartz monzonite	Mid to Early-Late Jurassic, possibly rarely Tertiary
NICKELIFEROUS PERIDOTITE	Ni; minor Cu	Meares Island	Peridotite in gneiss complex	Peridotite	Mesozoic (?) Possibly Triassic
COPPER IN BASIC VOLCANICS	Cu	Millington Coal Creek	Karmutsen and Bonanza basalts	None	Triassic, Jurassic
VANADIUM IN SEDIMENTS	V, Cu	Campbell River	Karmutsen carbonaceous sediment	None	Triassic
MANGANIFEROUS CHERT	Mn; possibly Fe	Hill 60 Lacy Lake	Sicker Group	None	Early Permian or Pennsylvanian
FERRUGINOUS CHERT	Fe; possibly Mn	Lady A, B, C	Sicker Group	None	Early Permian or Pennsylvanian
ZINC-COPPER-LEAD MASSIVE SULPHIDES	Zn, Cu, Pb, Ag, Au, Ba	Western Mines Twin J	Sicker Group cherty tuffs	None obvious	Early Permian or Pennsylvanian or later

Table 16 - Metallogenic Scheme for Vancouver Island

deposited, but a eugeosynclinal environment persisted. Nickeliferous peridotite-gabbro, possibly the intrusive equivalent of the Karmutsen basic volcanics, was emplaced in the Sicker limestone and volcanic rocks. Karmutsen basalts contained syngenetic copper, and interlava vanadiferous sediment was deposited during a very limited time interval. Once again volcanism ceased and a thick limestone unit, the Quatsino Formation, was deposited. The Early stage Bonanza Formation consisted largely of intermediate volcanic and sedimentary rocks. It was transitional between the Initial eugeosynclinal and Middle orogenic stages. Some basic lavas in the north of the island contained syngenetic copper.

Broad regional folding, followed by the intrusion of large volumes of granitic magma, occurred in the Middle stage during Middle to early-Late Jurassic. Much of the magma spread laterally thereby deforming its host rocks, and crystallized, near the Quatsino limestone. As a result, skarn deposits containing iron, copper and iron, molybdenum and copper, and zinc and lead, were formed. Copper veins and stockworks were deposited alongside or at some distance from the crystallizing magma and molybdenum veins and stockworks formed in roof facies and border zones of some of the more highly differentiated intrusions. Massive sulphide deposits and copper and vanadium deposits of the Initial stage were, to varying degrees, deformed and remobilized. Synorogenic Flysch was deposited along the west coast.

During the Late stage, post-orogenic coal-bearing molasse, mainly of the Nanaimo Group, was deposited unconformably on all previously-formed rocks.

In the Final stage, during Tertiary time, large scale block faulting, limited volcanism, and intrusion of epizonal stocks, sills, dykes and laccoliths occurred. Porphyry copper, gold quartz, copper-arsenic, and arsenic deposits were formed in zones of Tertiary intrusive activity. Arsenic and copper-arsenic veins were deposited near dacite porphyry sills and laccoliths. Porphyry copper and many gold-quartz deposits formed within or adjacent to quartz diorite-dacite porphyry-breccia intrusive complexes. Molybdenum was deposited in a stockwork in relatively potassic stocks, and copper-bearing veins and stockworks formed near some plutons. Mercury was deposited in a fault zone and alunite formed near a volcanic fumarole.

In the meantime, at the southern end of the island a return to the Initial stage occurred with the deposition of the Metchosin volcanics. Copper and iron were deposited in fractures within or near to gabbro intrusions.

The last deposits formed include a sodium hot-spring, placer gold, and bog iron.

VI - SUMMARY AND CONCLUSIONS

Plutonic rocks of Vancouver Island are mainly Middle to early-Late Jurassic, granodiorite and quartz diorite. These are mesozonal stocks and batholiths. Granite plutons are rare. Subordinate epizonal Tertiary plutons are quartz diorite, dacite porphyry and gabbro, with lesser granodiorite and quartz monzonite.

Quartz diorite predominates in the structurally-elevated axial zone of Vancouver Island. It is flanked to the east by a zone containing mainly granodiorite and to the west by another zone containing a wide variety of plutonic rocks ranging from granite to peridotite, but having the average composition of granodiorite. This overall distribution is somewhat similar to that of the Coast Intrusions in the Vancouver area.

Tertiary plutons occur along the western belt and in two linear zones perpendicular to the general structural trend of Vancouver Island.

Jurassic plutons contain more Ca, and Fe, and possibly K, and less Na than Tertiary plutons. Variation curves for Jurassic plutons are very similar to those of the southern California batholith.

Plutons of Jurassic granodiorite and Tertiary quartz diorite advanced upward in competent volcanic rocks but spread laterally in less competent sedimentary rocks. Maximum lateral development of Jurassic plutons was near Quatsino limestone rather than Sicker limestone

because the lithostatic pressure at its site was less, and the contrast in competency between it and the underlying Karmutsen Formation was very great. Laccoliths and sills were formed during lateral extension of Tertiary plutons, which occurred mainly in the lower Nanaimo Group and at depths of less than 5000 feet.

Many classes of metalliferous deposits, ranging in age from late Palaeozoic to Recent, occur on Vancouver Island. Many epigenetic deposits have close spatial relationships to post-tectonic plutonic rocks and the greatest variety of deposits occurs in the western belt, which also contains the widest variety of plutonic rocks. Syngenetic deposits include those of iron and manganese in the late Palaeozoic Sicker Group, vanadium and copper in the Karmutsen Formation, and nickel in Triassic (?) peridotite.

Zinc-copper-lead massive sulphide deposits are restricted to the Sicker Group and show no obvious relationship to plutonic rocks. They occur in tightly folded, incompetent, tuffaceous horizons in which axial plane cleavage is highly developed. The deposits are believed to be syngenetic but the sulphides have probably been deformed, remobilized and re-concentrated during periods of deformation.

Skarn deposits include those in which iron, copper, zinc and lead, and molybdenum and copper are the main economic elements. Most skarn deposits are in close proximity to Quatsino limestone and are related

to Jurassic plutons which range in composition from gabbro to quartz monzonite. More than one type of skarn deposit may be related to the same pluton. Iron and copper were possibly derived from the rocks intruded by the plutons and were concentrated at their edges, especially in apophyses. Most copper and iron skarns are in Quatsino limestone rather than Sicker limestone because ascending plutons spread laterally and crystallized at or near to the former limestone which was nearer to the surface.

Molybdenum-quartz deposits occur in the outer portions of potassic Jurassic and Tertiary plutons. Gold-quartz veins, porphyry copper deposits, and arsenic and arsenic-copper deposits occur in zones of Tertiary intrusive activity which probably coincide with zones of Tertiary faulting. Arsenic and arsenic-copper deposits are spatially related to dacite porphyry sills and laccoliths cutting the Nanaimo Group. Porphyry copper and many gold-quartz deposits are within or near to Tertiary quartz diorite-dacite porphyry-breccia intrusive complexes.

The distribution of copper in deposits of the Sooke area is closely controlled by fracture systems. These deposits are probably related to Tertiary gabbros.

The metallogenic scheme of Bilibin (1955) is not readily applicable to Vancouver Island, because it relates all epigenetic metalliferous deposits to intrusive rocks, and considers that there is a common source

for the magmas and metals.

The following previously unreported minerals were found during this project:

a - siegenite in peridotite at Meare's Island

b - safflorite in Brynnor magnetite skarn

c - smaltite in Brynnor magnetite skarn

d - carrollite in Sun West molybdenum-copper skarn

e - native gold in Alice Lake zinc-lead skarn

f - native gold in Mt. Washington Copper copper-arsenic deposit

g - chalcostibite in Mt. Washington Copper copper-arsenic deposit

h - native arsenic in Mt. Washington Copper copper-arsenic deposit

i - corynite in Macmillan copper-arsenic deposit

j - native gold in gold-quartz veins of all main gold-quartz areas

k - carrollite in Domineer gold-quartz vein

l - wolframite in Mt. Washington-Murex copper deposit

m - tourmaline in Tertiary quartz monzonite, Paradise Creek.

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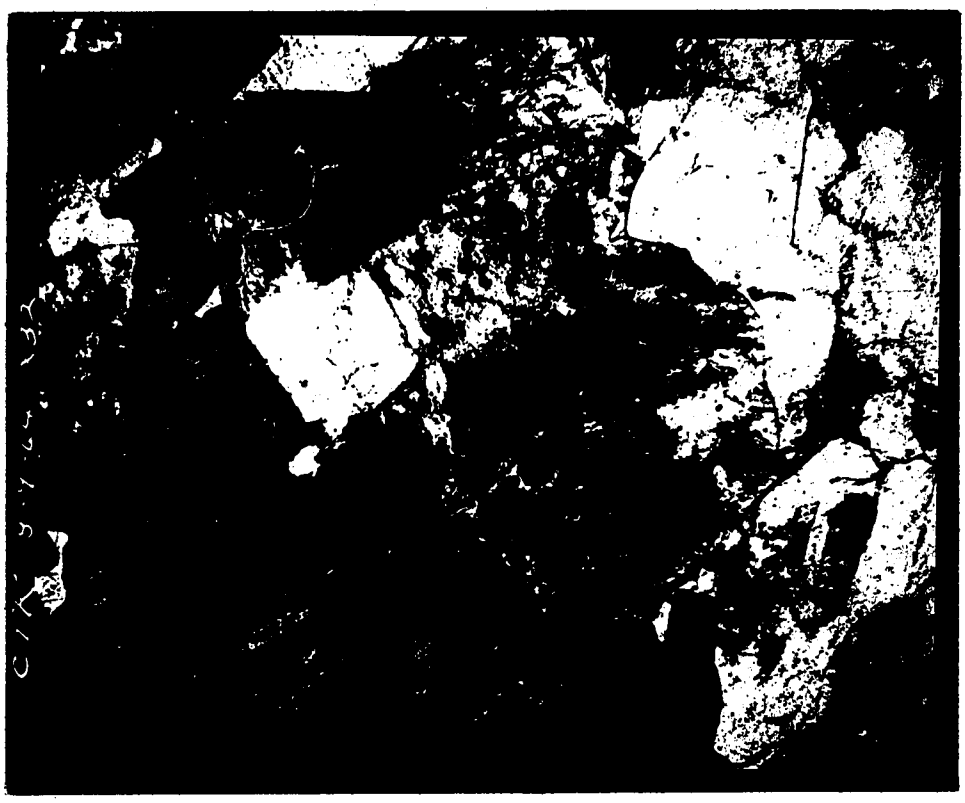


Plate 1

Photomicrograph of Saanich-type granodiorite from Skarn pluton. Plagioclase (Pc), perthitic potash feldspar (Kf), hornblende (Hb) and biotite with prehnite lenses (lower left). Spec. no. 178, table 7. Plane light, field length approx. 3.2 mm. (G.S.C. photo 200387-C).

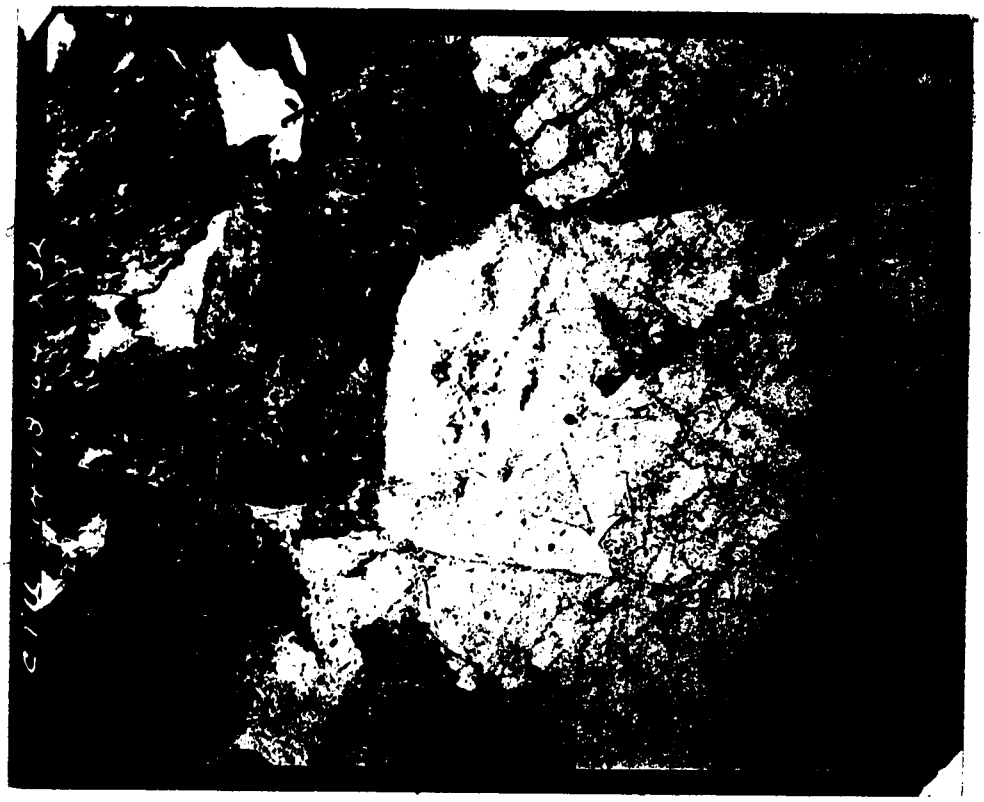


Plate 2

Photomicrograph of quartz-eye granodiorite from Bedwell batholith. Quartz eye (right), chloritized biotite (Bi), clouded plagioclase (Pc), iron oxide (lower left, upper center). Spec. no. 146, table 7. Plane light, field length approx. 3.2 mm. (G.S.C. photo 200387-B).

Plate 3

Photomicrograph of Tertiary quartz diorite from Catface Peninsula. Oscillatory-zoned plagioclase, quartz, biotite (lower right) and hornblende (upper right). Spec. no. 80, table 7. Crossed nicols, field length approx. 2.4 mm. (G.S.C. photo 200387-N).

Plate 4

Photomicrograph of Tertiary dacite porphyry from Mt. Washington showing fragment of coalesced plagioclase crystals. Crystals in fragment are in optical continuity, quartz phenocryst in lower left. Crossed nicols, field length approx. 3.2 mm. (G.S.C. photo 200387-E).

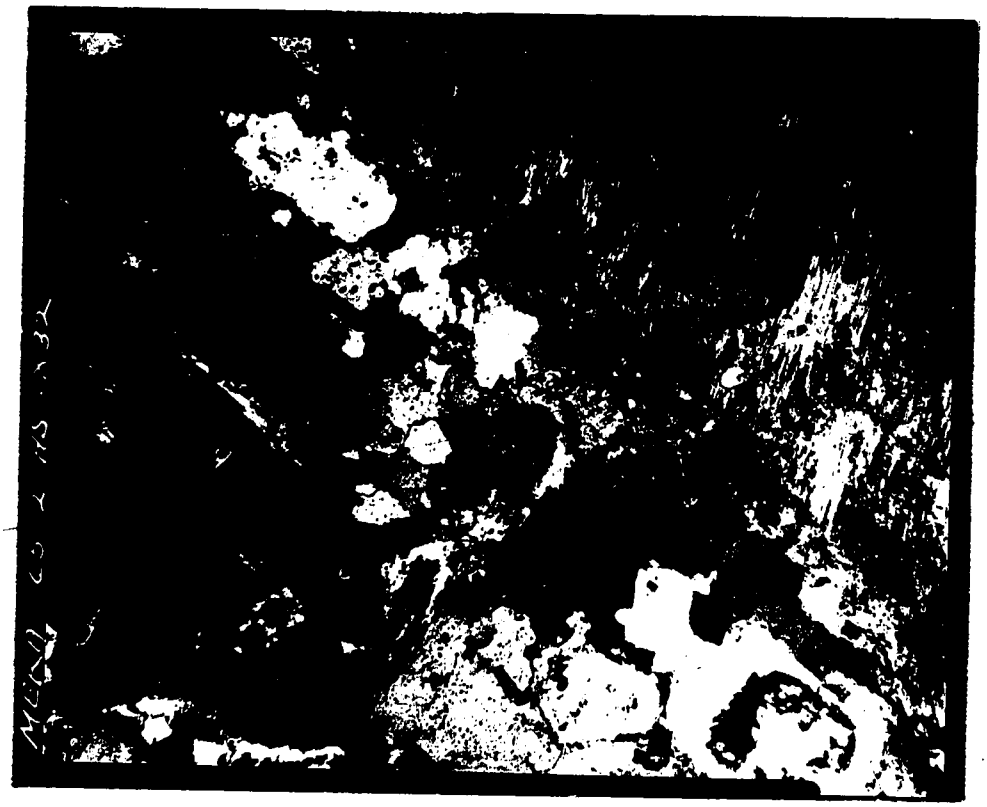


Plate 5

Photomicrograph of tourmaline-bearing Tertiary quartz monzonite porphyry from Paradise Creek. Potash feldspar phenocryst (upper right) and rounded triangular tourmaline crystal with apatite inclusions (lower left). Spec. no. 105, table 7. Crossed nicols, field length approx. 3.2 mm. (G.S.C. photo 200387-M).

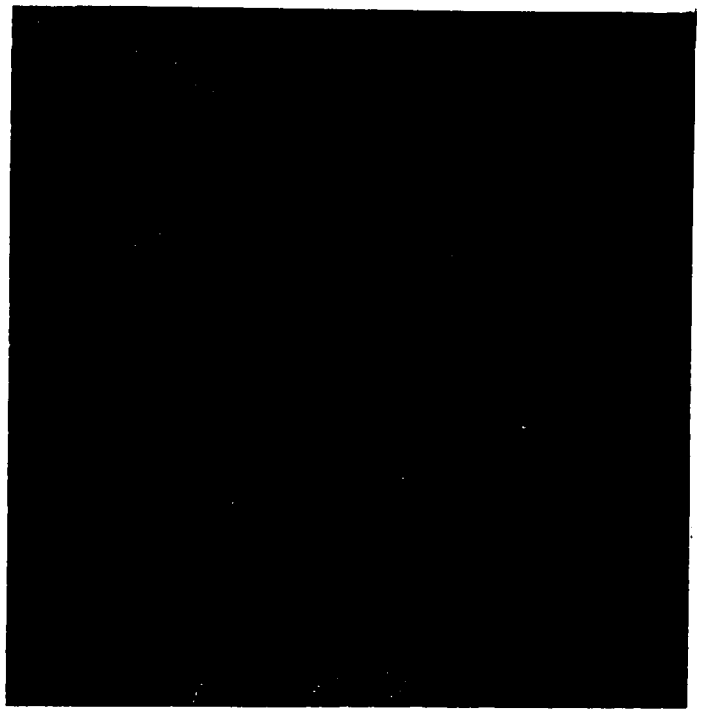


Plate 6

Intrusive breccia at a Sooke Tertiary granitic pluton. Abundant angular gabbro fragments and basalt fragments (lower right) in matrix of medium grained trondhjemite. (G.S.C. photo 4-8-65).

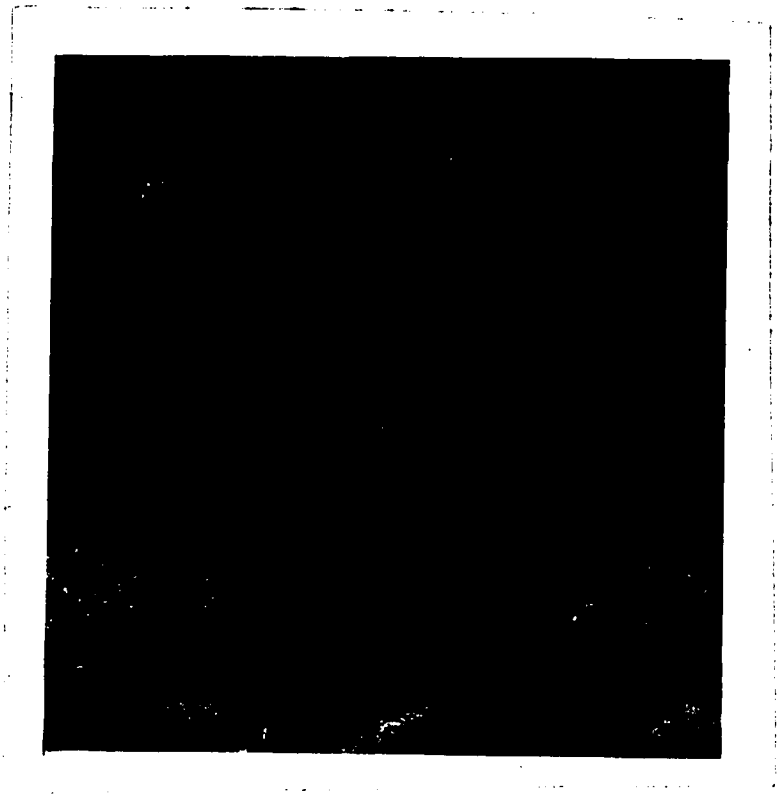


Plate 7

Murray diatreme breccia of Mt. Washington. Note rounded and angular fragments of dacite porphyry and dark rimmed sedimentary rock. (G.S.C. photo 1-3-65).

Plate 8

Photomicrograph of Tertiary Washington-type breccia from Gem Lake. Fragments of plagioclase, quartz, hornblende and volcanic rock (upper left) in magnetite-rich matrix. Crossed nicols, field length approx. 3.2 mm. (G.S.C. photo 200387-K).

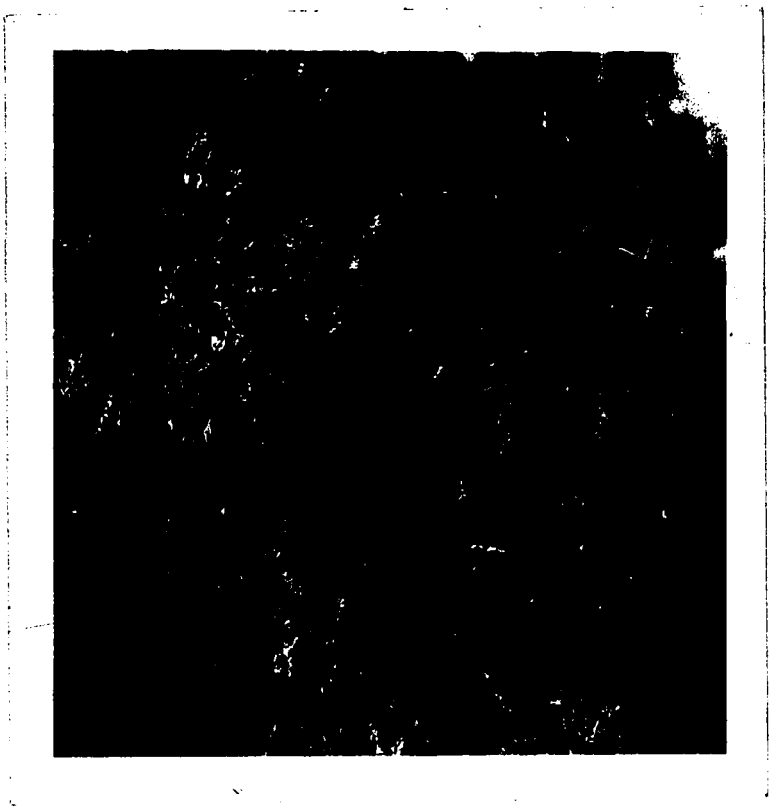


Plate 9

Tight folds in purple breccia and tuffs of the Sicker Group at Price 2000. Looking NNW parallel to the fold axes which plunge gently SSE. (G.S.C. photo 3-10-65).

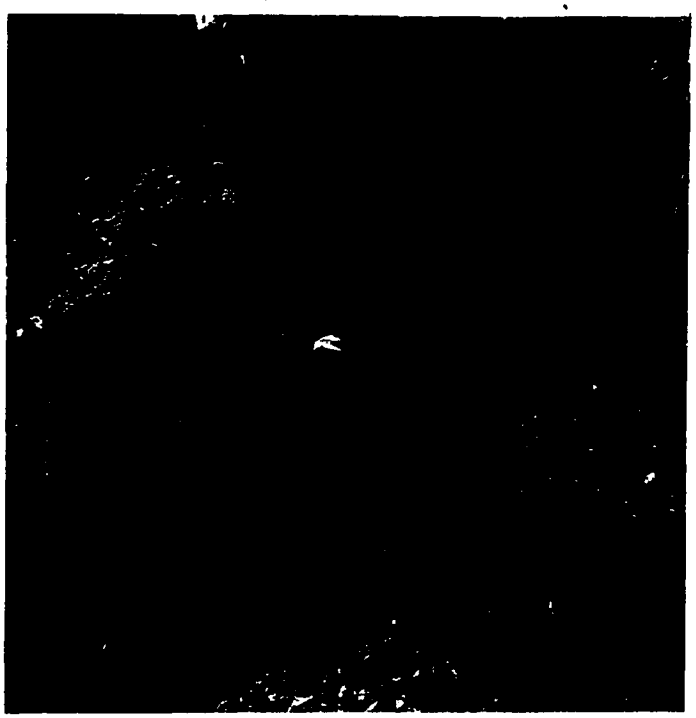


Plate 10

Main Creek fault at the Price 2000 showing. Looking west up Main Creek valley. At this locality the fault has brought tightly folded mineralized quartz-sericite schists on the south (left) into contact with schistose green and grey tuffs (lower right) and massive plagioclase porphyry dyke (upper right). (G.S.C. photo 5-2-65).

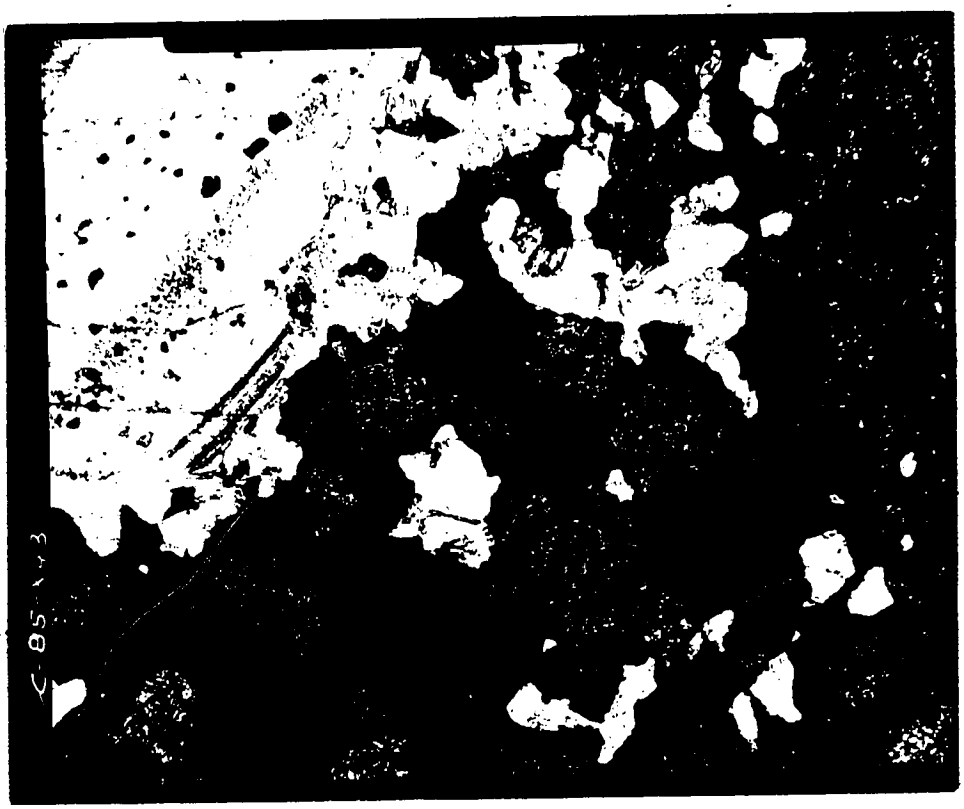


Plate 11

Photomicrograph of massive barite and sulphides from Price 1300 deposit. Barite is white, translucent sphalerite is grey, and chalcopyrite, pyrite, galena and tetrahedrite are black. Plane reflected light, field length approx. 2.4 mm. (G.S.C. photo 200387-D).

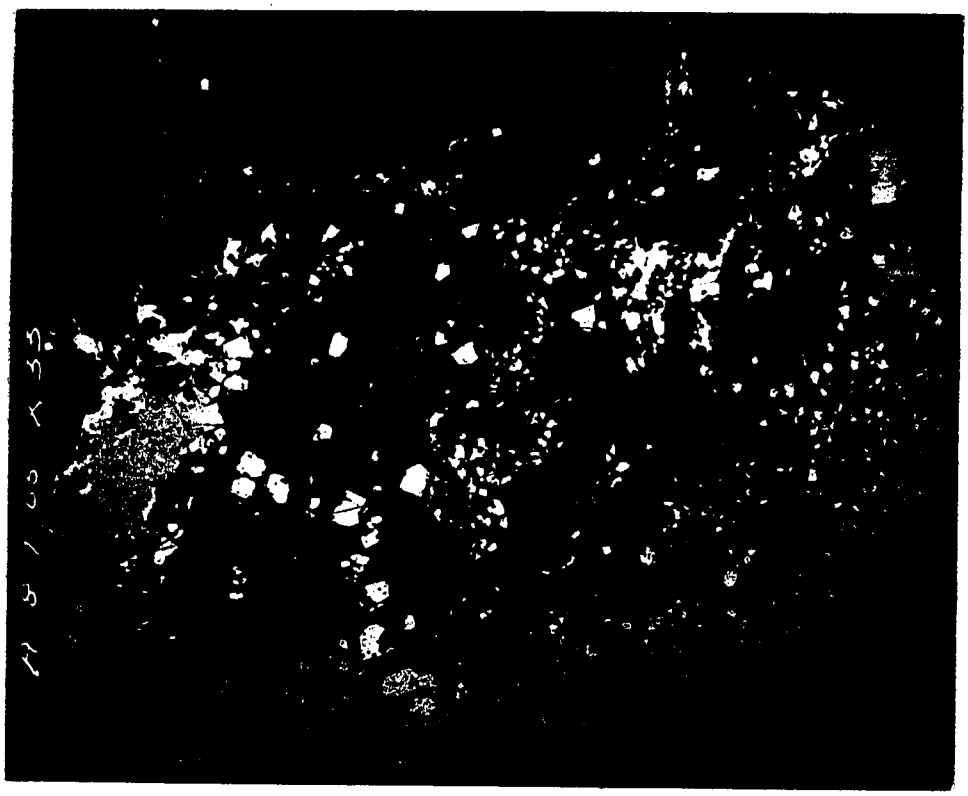


Plate 12

Photomicrograph of banded, folded (?) sulphides from Price 2000. Sphalerite (medium grey), pyrite (white, straight-edged crystals in sphalerite and gangue), chalcopyrite (white, in sphalerite), galena (white, in sphalerite) and tetrahedrite (light grey, left center), in dark barite gangue. Plane reflected light, field length approx. 3.2 mm. (G.S.C. photo 200386-E).

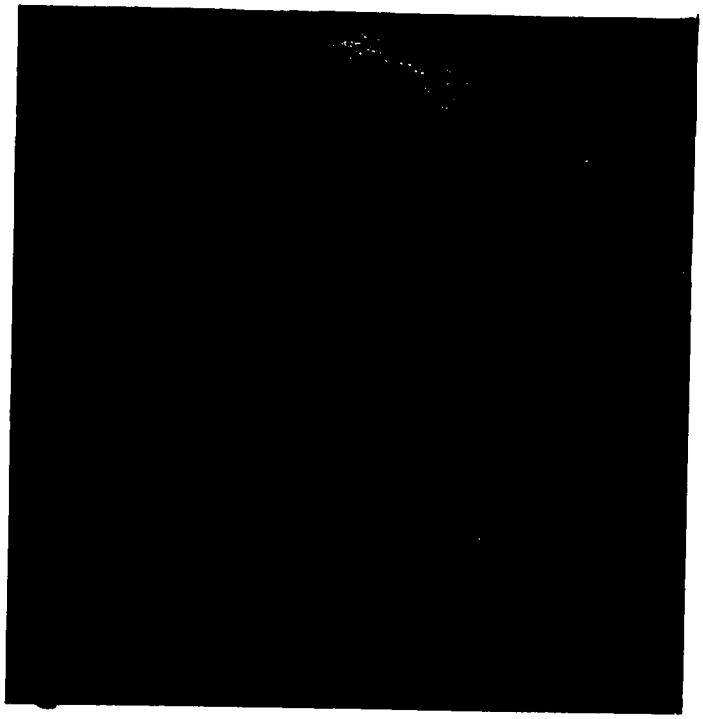


Plate 13

Contorted beds of chert at Skarn property. (G.S.C. photo 5-7-65).

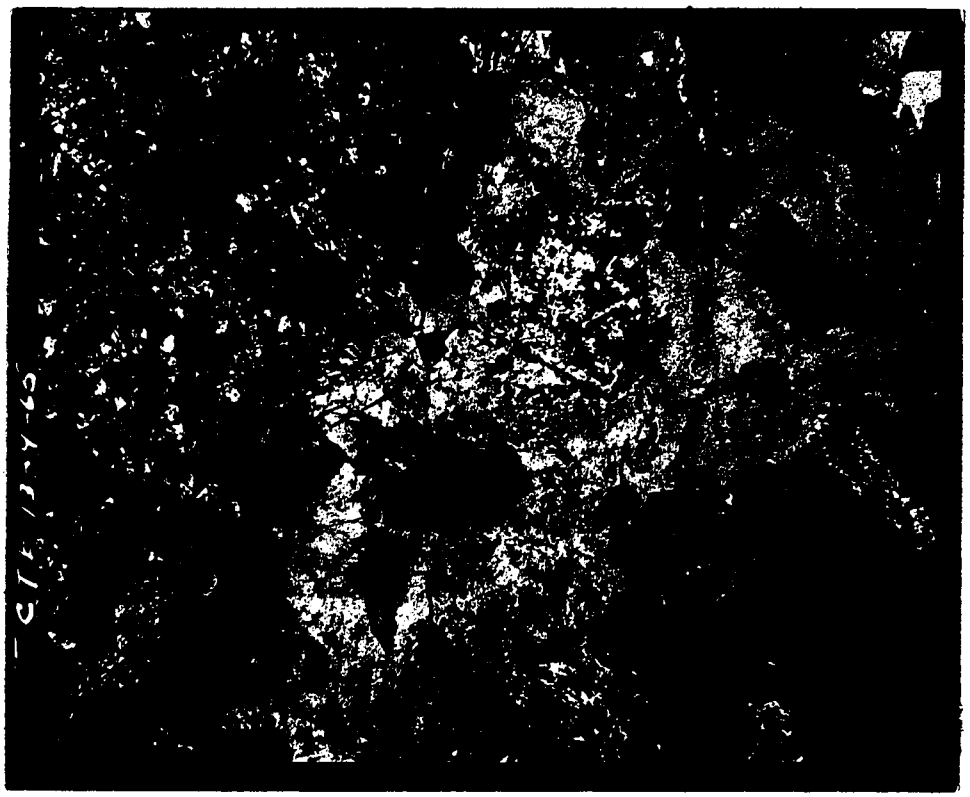


Plate 14

Photomicrograph of granitized volcanic breccia from Skarn property. To left is poikilitic hornblende-rich volcanic fragment. To right is granitized matrix containing large zones of perthitic potash feldspar (Kf), enclosing hornblende, clouded plagioclase (Pc), and magnetite (black). Plane light, field length approx. 3.0 mm. (G.S.C. photo 200387-W).

Plate 15

Layered skarn at the Skarn property. Layers consisting of actinolite crystals with their lengths perpendicular to edges of layers are enclosed by massive garnet-epidote-diopside-actinolite skarn. Note fragments of layered skarn below and to left of compass, and white and black pockets of calcite, quartz, black garnet. (G.S.C. photo 1-5-65).

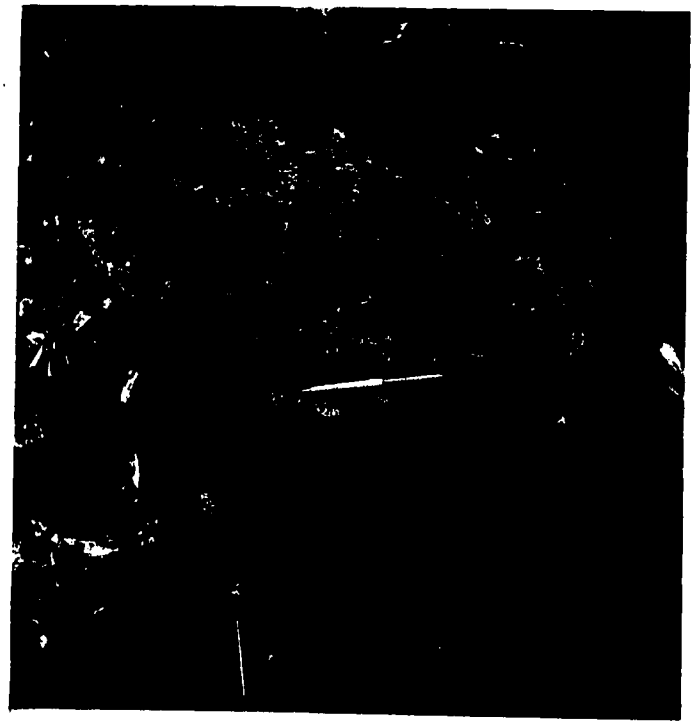


Plate 16

Breccia skarn at the Skarn property. Faint epidotized fragments are enclosed in quartz and garnet-rich matrix. (G.S.C. photo 1-11-65).

Plate 17

Photomicrograph of chalcopyrite-rich sample from Skarn property. Chalcopyrite (white to light grey), pyrite (Py), sphalerite (Sp) with exsolution blebs of chalcopyrite, and fibrous gangue (grey). Plane reflected light, field length approx. 3.0 mm. (G.S.C. photo 200386-L).

Plate 18

Photomicrograph of stibnite in quartz from Silver Bell. Etching shows zonal growth banding and lamellar twinning. Small bleb of sphalerite next to crystal in upper right. Plane reflected light, field length approx. 4.4 mm. (G.S.C. photo 200386-G).

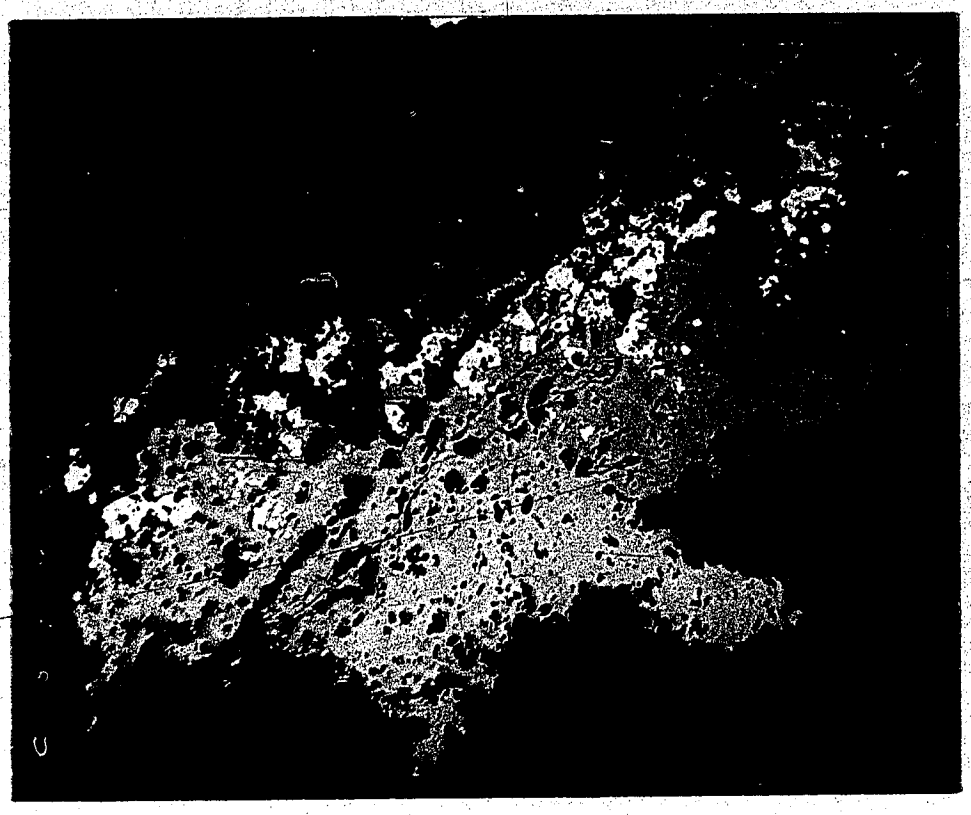


Plate 19

Photomicrograph of chalcocite and corynite in breccia from Macmillan. Chalcocite (grey) encloses corynite (white crystals). Plane reflected light, field length approx. 1.35 mm. (G.S.C. photo 200386-D).

Plate 20

Photomicrograph of arsenical ore from Mt. Washington Copper. Native arsenic (white), realgar (grey) and arsenopyrite (white, lower left). Plane reflected light, field length approx. 4.3 mm. (G.S.C. photo 200386-F).

Plate 21

Gold-quartz vein in Tertiary quartz diorite at Faith Lake on the Forbidden Plateau. Note comb texture and banding of quartz and sulphides. (G.S.C. photo 3-5-65).

Plate 22

Photomicrograph of gold-quartz sample from Lemay. Native gold (Au) veinlets and patches in pyrite (Py), and sphalerite (grey) with exsolution blebs of chalcopyrite, and arsenopyrite (Aspy). Plane reflected light, field length approx. 1.1 mm. (G.S.C. photo 200386-I).

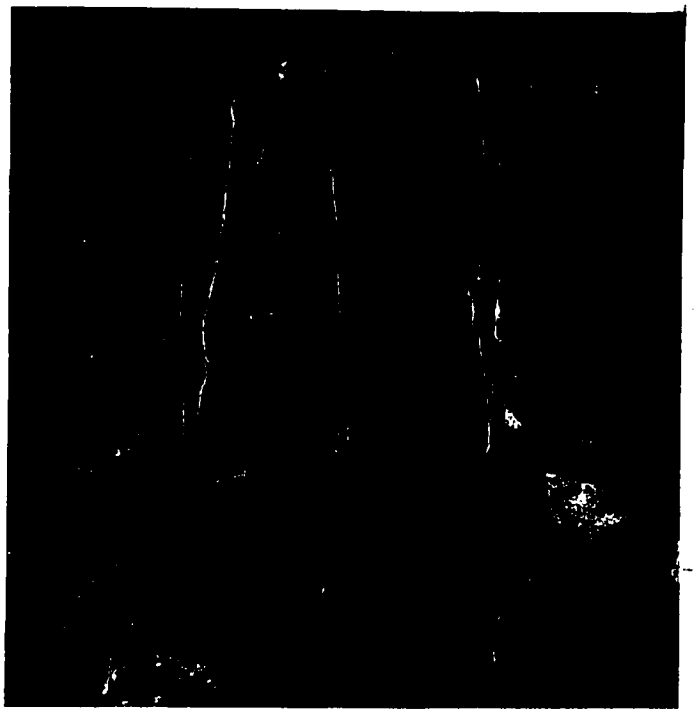


Plate 23

Plagioclase veinlets in basalt at Sunro Mine. The veinlets average about ¼" in width. (G.S.C. photo 2-3-65).

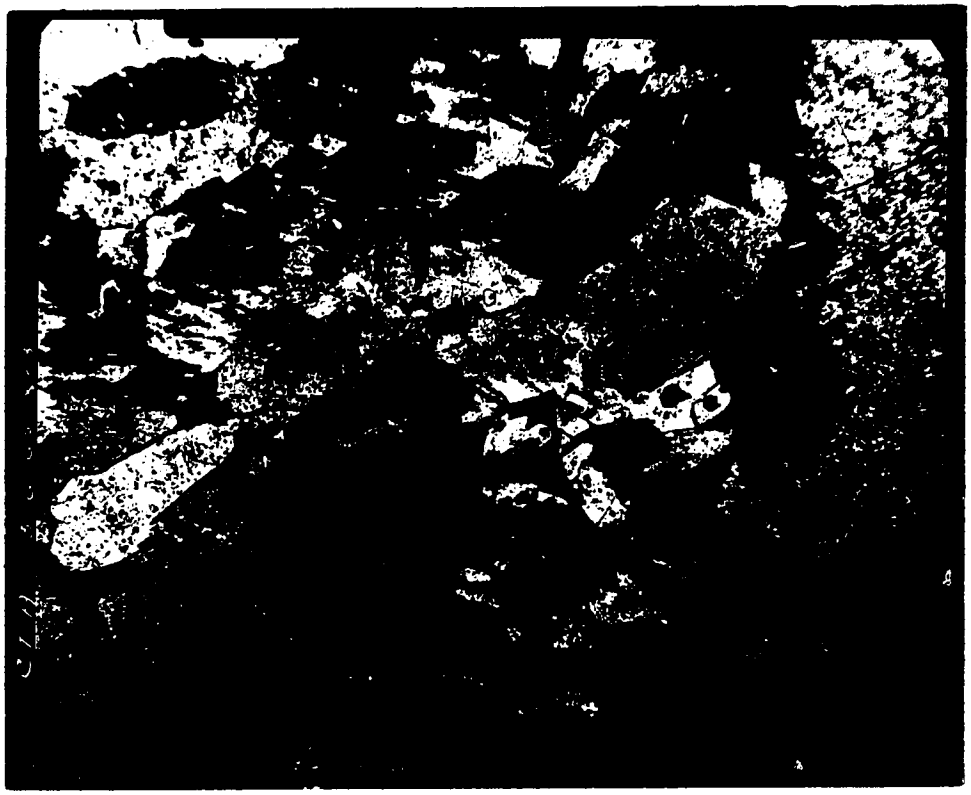


Plate 24

Photomicrograph of oligoclase-andesine vein from Sunro Mine. Photo is mostly of plagioclase which is twinned and partly scapolitized. Minor hornblende, epidote, opaques, and sphene. From locality A figure 21. Plane light, field length approx. 2.4 mm. (G.S.C. photo 200387-P).

Plate 25

Photomicrograph of granitic rock from Merryth. Zoned plagioclase, quartz, pyroxene, amphibole, and opaques are present. The rock is quartz diorite. Plane light, field length approx. 2.4 mm. (G.S.C. photo 200387-0).

Maps to accompany thesis: David John Temple Carson, Metallogenic Study of Vancouver Island With Emphasis on The Relationships of Mineral Deposits to Plutonic Rocks.
Figures 1,2,3,4,16,18, and 20 and tables 2,3.

METALLOGENIC STUDY OF VANCOUVER ISLAND WITH EMPHASIS ON THE RELATIONSHIPS OF MINERAL DEPOSITS TO PLUTONIC ROCKS

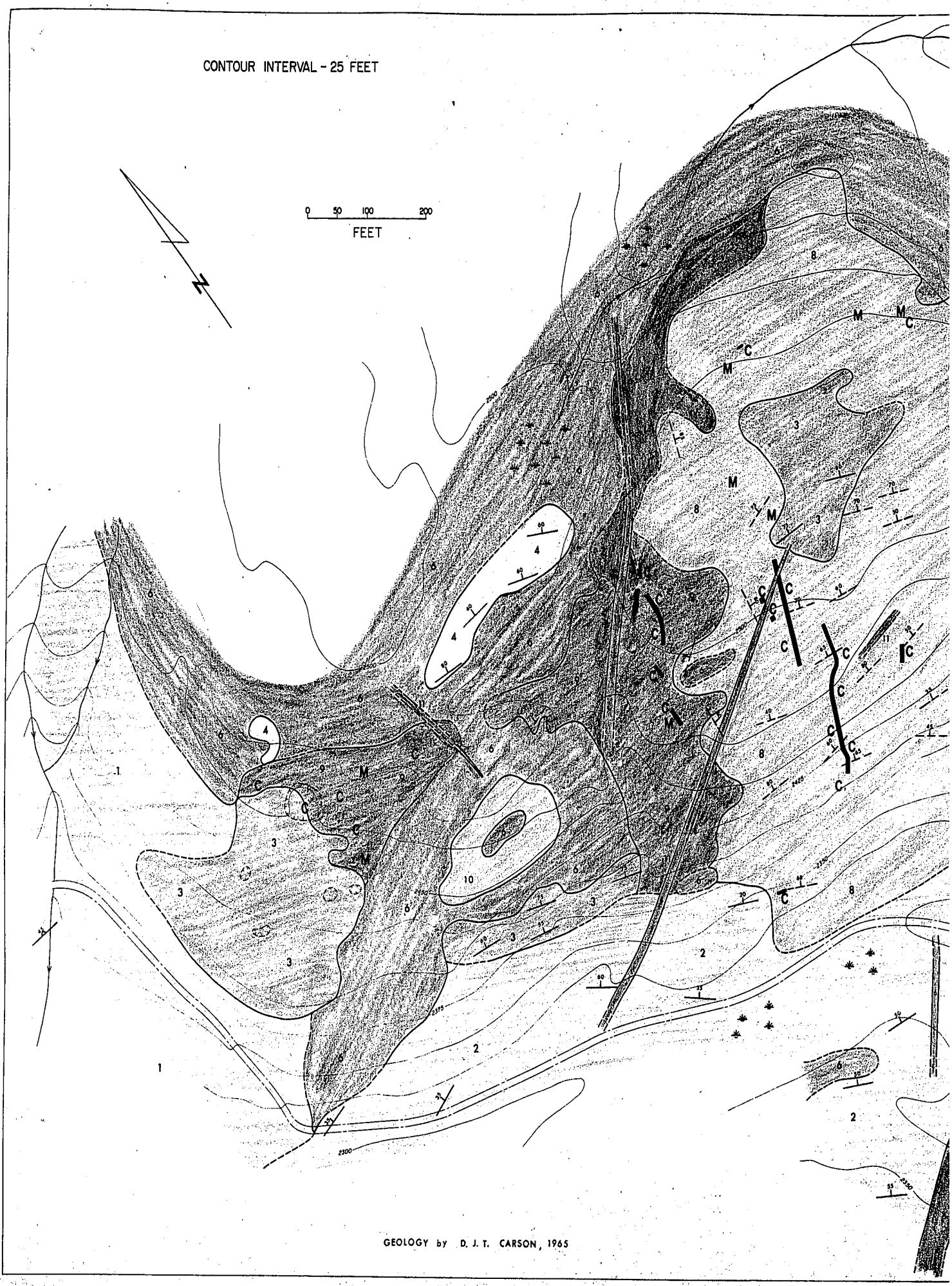
by

DAVID JOHN TEMPLE CARSON, B.Sc., M.A.Sc.

A thesis submitted to the Faculty of Graduate Studies in partial fulfilment of the requirements for the degree of Doctor of Philosophy

Carleton University
Ottawa, Ontario

May, 1968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0 50 100 200
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GEOLOGY by D. J. T. CARSON, 1965

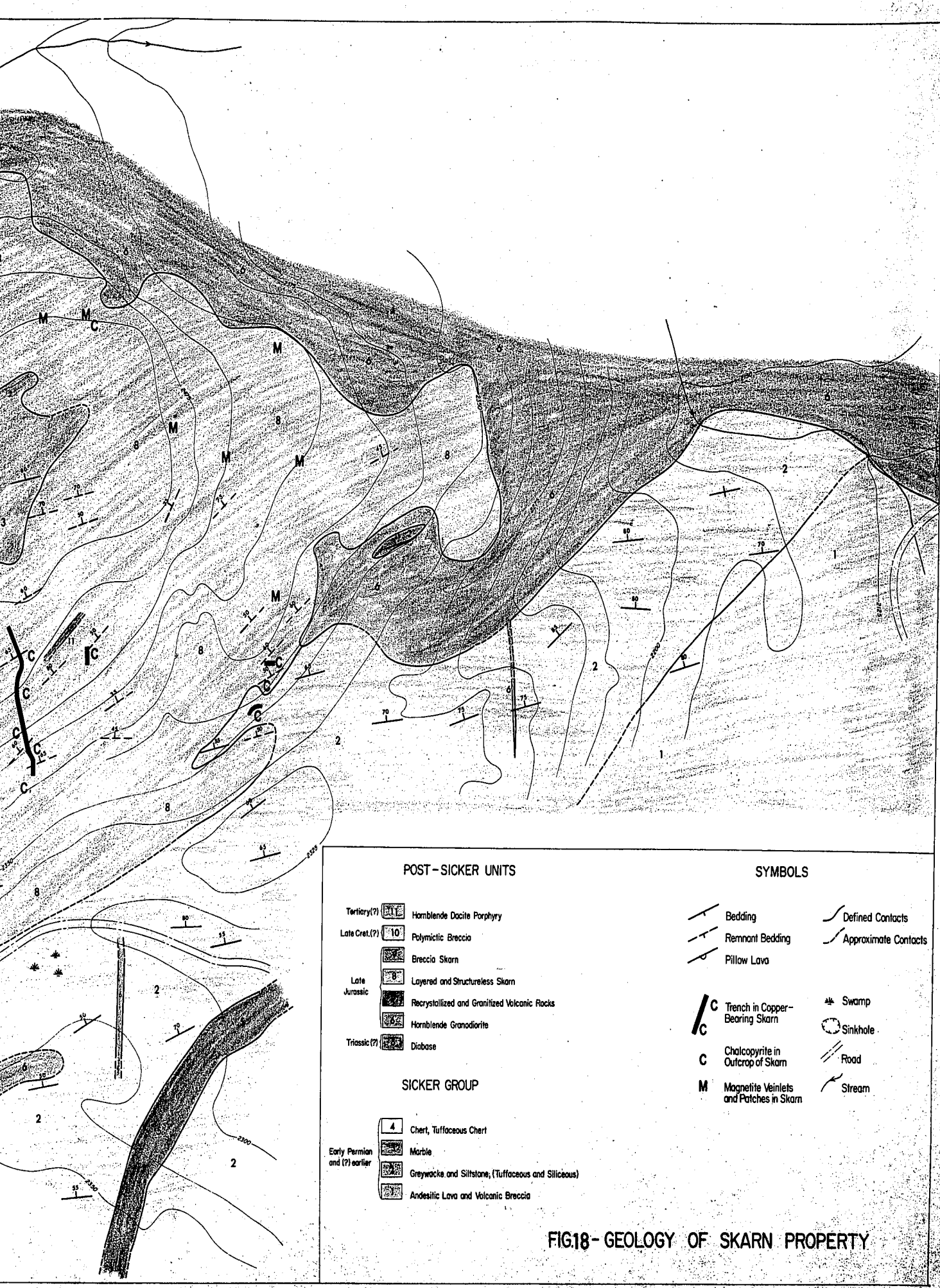


FIG.18 - GEOLOGY OF SKARN PROPERTY

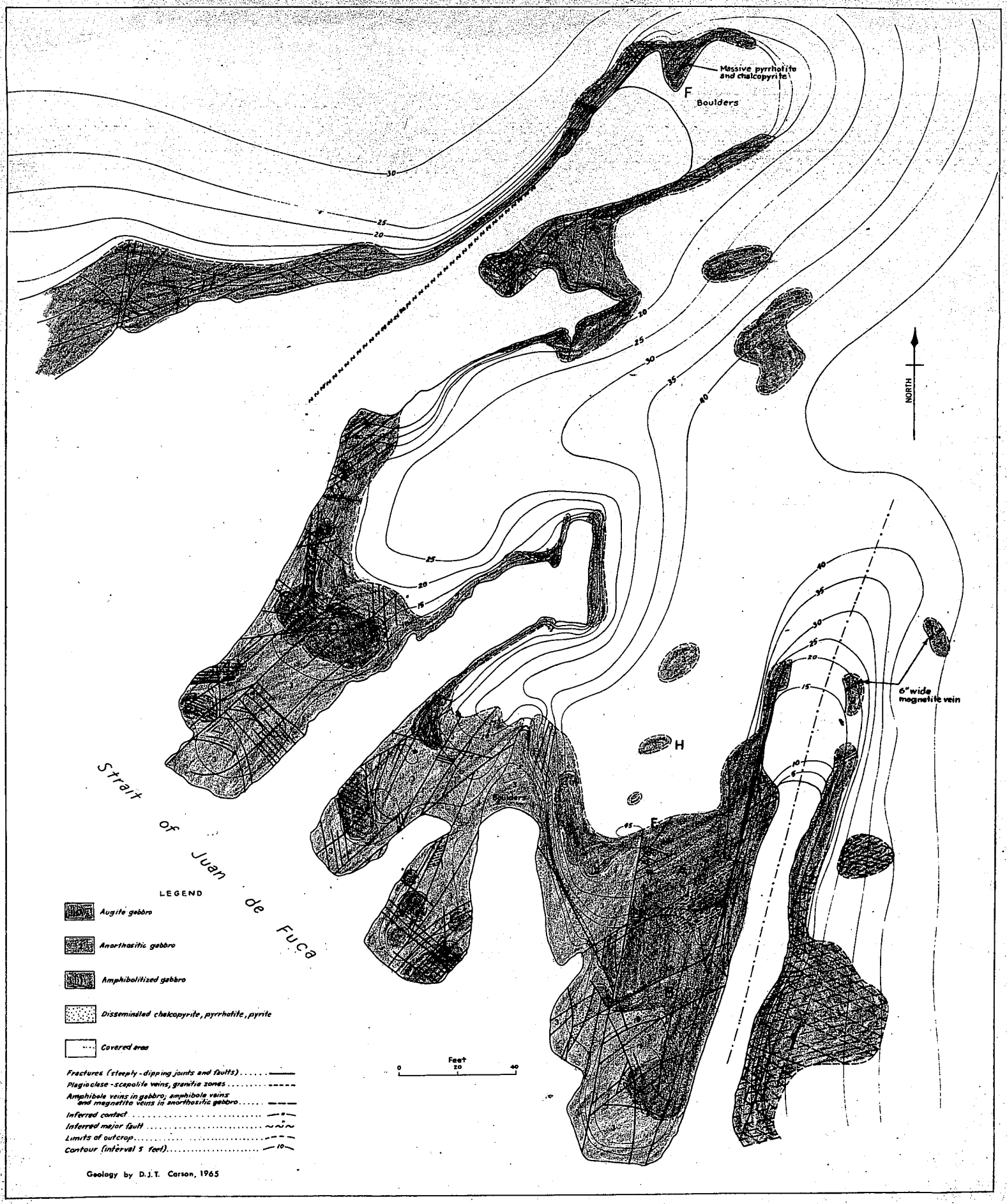


Figure 20. Geology of the Merryth zone, Sooke Peninsula

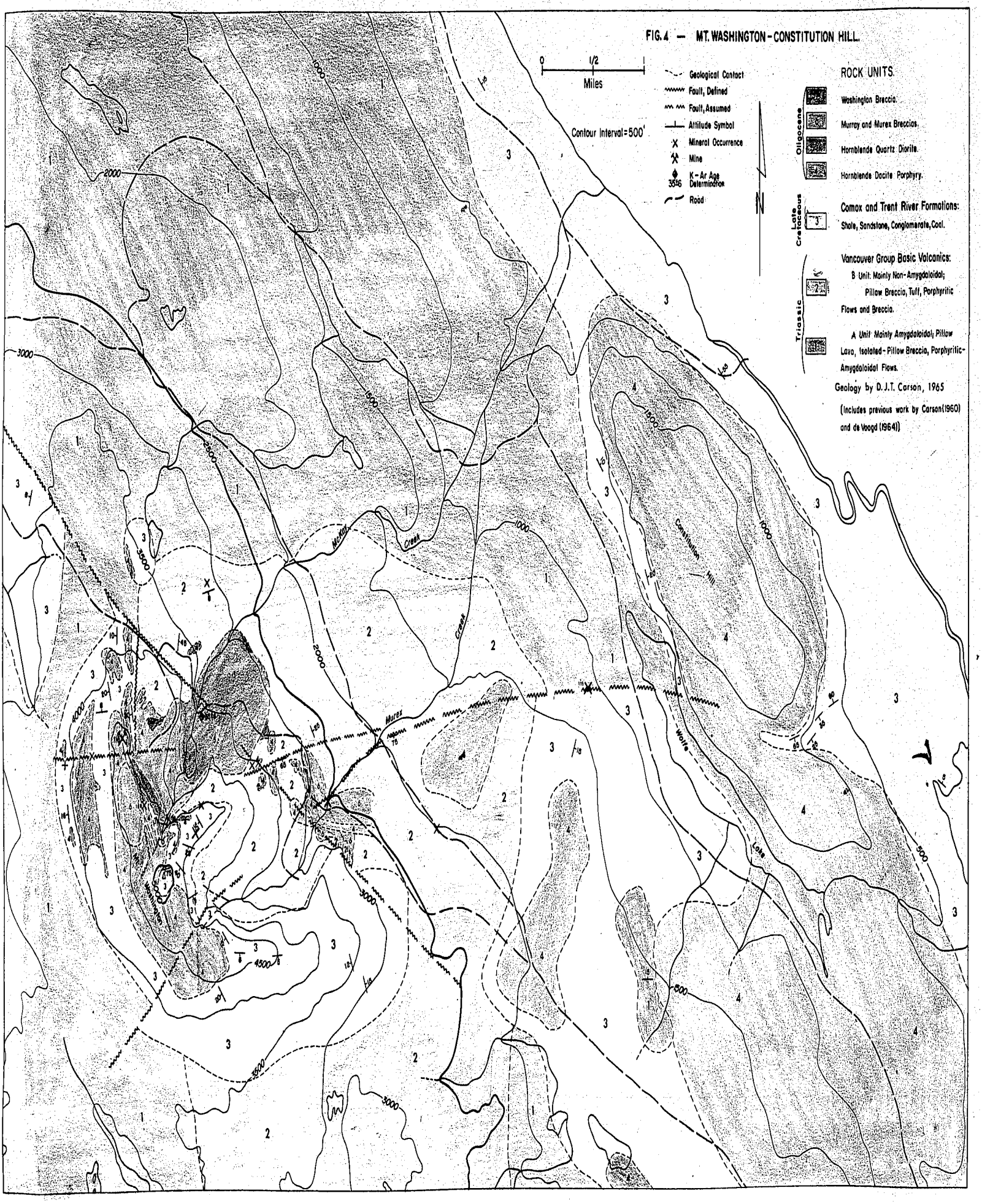


FIG. 4 — MT. WASHINGTON - CONSTITUTION HILL.

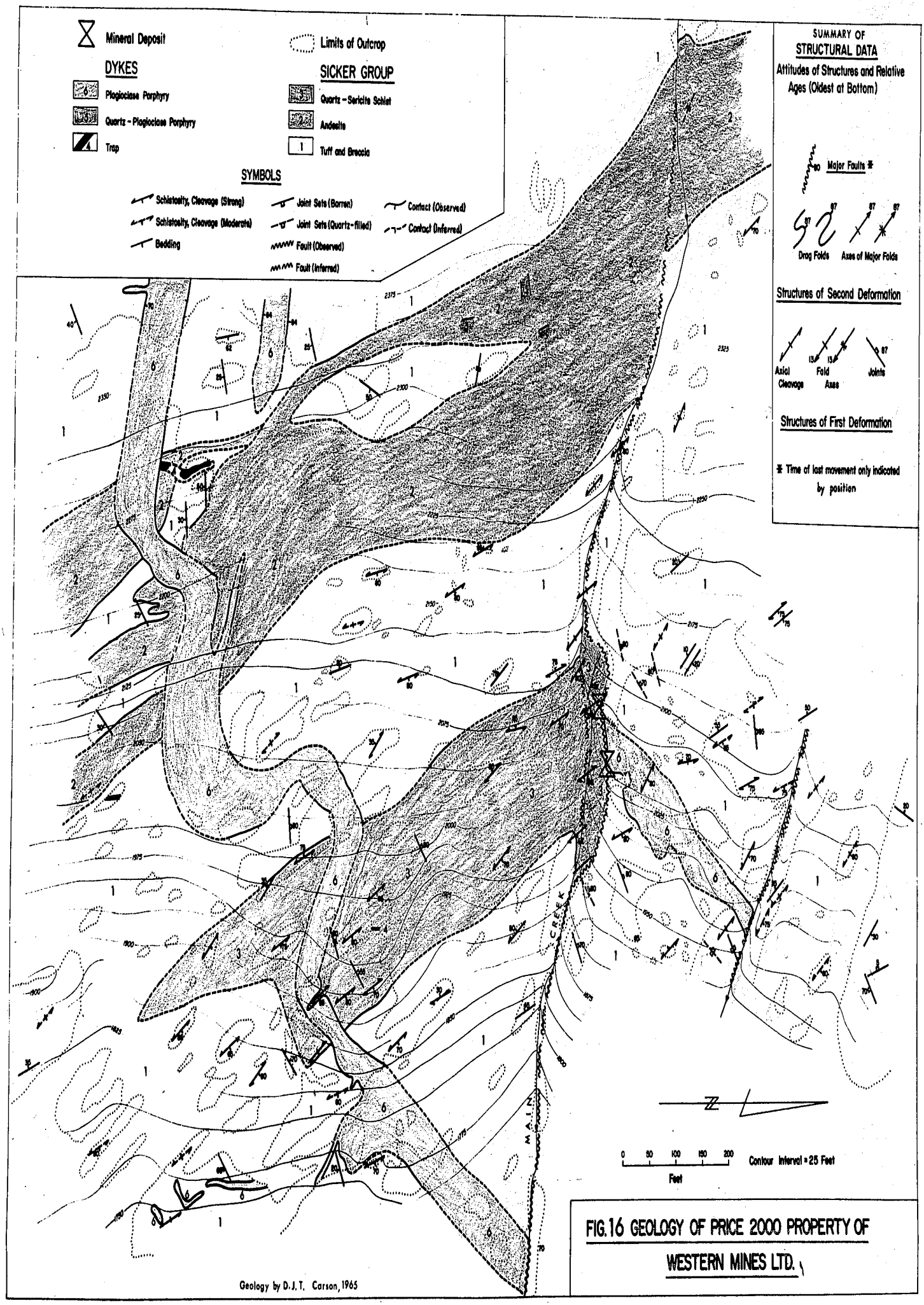


FIG. 16 GEOLOGY OF PRICE 2000 PROPERTY OF WESTERN MINES LTD.

Table 2 – Modes of Plutonic Rocks of Vancouver Island

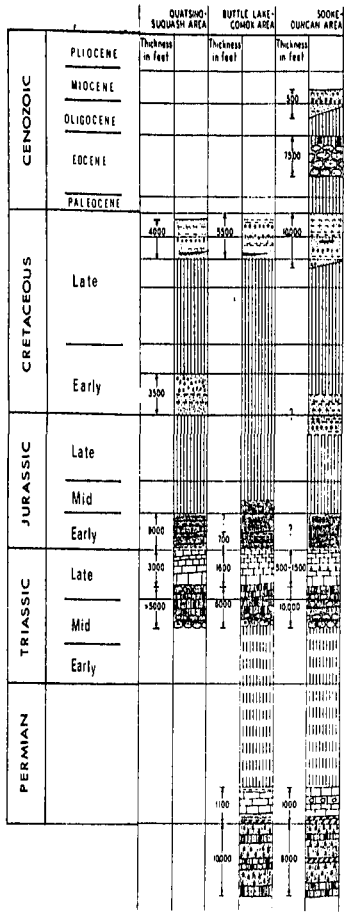
NUMBER ON FIGURE 3	NAME	Qz	Pc	Kf	Myrm	Bi	Hb	Px	Ch	Op	Acc. and Misc.		Total	Approximate Anorthite Content of Plagioclase	
	P -Peridotite Gb-Gabbro D -Diorite Q -Quartz Diorite T -Trondhjemite G -Granodiorite M -Quartz Monzonite A -Albite Granite B -Albite-K-feldspar Granite TEXTURES -g-gneissic -p-porphyritic -c-coarse grains common -f-fine grains common	e = eyes >5 mm x = highly fractured and strained	u = unaltered s = strong alteration z = strong oscillatory zoning	m = minor microcline twinning a = fine perthite (av. = 0.004 mm) b = med. perthite (av. = 0.012 mm) c = coarse perthite (av. = 0.04 mm) q = med. antiperthite		y = lensy x = strong chloritization			h=clearly after Hb b=clearly after Bi		tm -tourmaline sp -sphene ap -apatite ep -epidote ser -sericite ch -chlorite ol -olivine misc-miscellaneous ru -rutile ca -calcite al -alteration sa -saussurite serp-serpentine			Average or Overall	Range
MISCELLANEOUS NORTHWESTERN PLUTONS															
1	Q	14.8	58.9u	3.1	----	8.9	11.4	0.3	tr	2.5	0.2	----	100.1	45	28-52
2	G	28.9	46.5s	20.0a	----	0.1 y	0.9	----	2.1	0.4	1.1	----	100.0	27	10-45
3	G - pf	28.4	45.4s	20.5	----	0.3 y	----	----	3.0	1.4	1.2	----	100.2	28, 0	----
4	G - f	14.4	53.0s	16.0	(Kf+Qz)	7.8	----	----	3.2	3.8	1.8	----	100.0	27	15-40
5	G - f	11.6	61.0	6.5a	----	----	17.3	----	----	2.2	1.4	----	100.0	--	----
6	Q	6.1	71.1us	3.4	----	----	11.1	2.6	1.0	3.5	1.2	----	100.0	45	----
7	G - f	21.6	56.9s	11.6	(Pc+Qz)	----	----	----	5.1h	4.0	0.8	----	100.0	12	----
8	D	----	56.9	----	----	----	26.5	11.0	----	5.0	0.6	----	100.0	<50	----
9	G	21.5	48.5us	17.1ab	----	5.8	3.8	----	0.8	2.0	0.3	----	100.0	29	12-43
COAST COPPER STOCK															
10	Gb	----	76.8	----	----	----	4.0	15.4	----	2.8	1.0	ap	100.1	>50	----
11	Gb	----	31.9	----	----	4.5	8.0	38.5	2.8	14.4	0.6	----	100.1	52	37-65
BONANZA AND NIMPKISH BATHOLITHS AND SATELLITES															
12	G	31.6	48.8s	11.3a	----	5.0 y	----	----	0.2	1.1	2.0	----	100.0	32	20-45
13	Q	42.7	47.9	3.4a	----	2.0 y	0.3	----	2.0	0.7	1.0	----	100.0	36	18-52
14	G	31.2	49.0	10.4	----	6.8 y	1.2	----	----	1.2	0.3	----	100.0	22	----
15	G	28.4	57.9	8.1a	----	3.8	0.8	----	----	0.6	0.2	----	99.8	32	15-48
16	Q - pf	10.0	56.2	0.2	----	----	26.4	----	3.6b	3.1	0.5	----	100.0	40	30-50
17	G	25.1	53.1	15.5b	----	----	4.0	----	----	0.8	1.5	sp,op,ep	100.0	32	----
18	M - c	31.8s	38.9	18.8b	----	3.7	4.6	----	0.6	1.3	0.3	----	100.0	24	8-40
19	Q - f	5.0	67.0u	1.9	----	1.8	18.8	----	0.2	5.2	0.2	----	100.2	32	----
20	M - pf	36.6	39.0	21.5a	(Pc+Qz)	----	1.9	----	----	0.9	0.1	----	100.0	26	----
21	M - c	25.7	43.4	23.7b	----	3.6 y	2.0	----	0.7	0.6	0.3	----	100.0	25	----
22	G - c	36.1s	49.4	9.3b	----	3.0 y	0.5	----	1.8	0.3	----	----	100.2	31	24-38
23	D	0.8	68.0	----	----	----	24.1	----	2.5	4.0	0.5	----	99.9	45	28-55
24	M	34.9	35.8s	22.5a	----	----	----	----	4.1hh	1.0	1.8	----	100.1	32	----
25	Q	7.4	55.8us	0.8	----	----	31.1	0.6	2.1	1.5	0.7	----	100.0	40	25-55
26	B - pf	35.9	39.0	22.1	----	----	----	----	----	2.3	0.7	----	100.0	--	0-10
27	G - f	29.8	47.0	5.4	----	4.6	10.2	----	1.6b	1.2	0.2	----	100.0	38	28-48
28	Q	30.3	53.2	1.3ab	----	----	2.3	----	11.0b	1.1	0.9	----	100.1	30	24-36
29	G - f	40.1	41.2	13.7ab	----	2.2 y	----	----	1.2b	0.7	0.9	----	100.0	33	10-55
30	G	4.5	45.2	8.0a	----	----	40.2	----	0.4	0.9	0.8	----	100.0	30	22-36
31	G	26.5	41.8s	16.6a	----	5.3	7.9	----	----	1.5	0.5	----	100.1	30	20-50
32	Q	17.8	56.5s	2.3	----	----	15.5	----	6.0b	1.3	0.6	----	100.0	33	18-45
33	G	28.6	50.8	8.8	----	0.8 y	3.9	----	4.0b	2.0	1.1	----	100.0	25	12-38
34	G	27.9e	57.8	8.6a	----	2.0 y	2.3	----	0.6b	0.5	0.1	----	99.8	37	25-50
35	G - pf	31.4	44.1	17.9ab	----	4.8	1.1	----	----	0.5	0.1	----	99.9	37	25-50
36	Q - f	17.0	58.6	0.5	----	----	18.1	----	3.3h	2.1	0.4	----	100.0	45	24-75
BROOKS PENINSULA - KYUQUOT															
37	Q	32.5	51.9s	0.4	----	7.6 y	3.1	----	3.3b	0.7	0.5	----	100.0	--	0-38
38	G - f	16.8	56.8s	16.8b	----	----	7.8	----	----	0.8	0.9	----	99.9	--	0-40
39	Q - f	10.4	65.9	----	----	----	18.3	----	2.7b	2.7	----	----	100.0	40	20-60
40	G	36.0	50.2	5.6	----	5.2 y	1.6	----	0.2	1.0	0.2	----	100.0	29	15-43
41	B - pf	14.5	50.8	25.6	----	----	4.4	----	0.3	3.2	1.2	----	99.9	--	0- 5
42	B - f	23.2	38.3s	34.0	(Kf+Qz)	----	----	----	1.8h	0.6	1.9	----	99.8	--	0- 5
43	M	26.0	42.4s	23.1b	----	4.5 y	2.4	----	0.8	0.6	0.2	----	100.0	18	12-24
44	M - pf	22.0	40.2s	33.2	(Kf+Qz)	1.8	2.8	----	0.2	0.7	0.1	----	100.0	20	----
NOOTKA BATHOLITH															
45	A - pf	20.5	55.7	9.4	----	----	6.2	----	----	2.6	5.6ep	----	100.0	7	0-15
46	M	26.2	25.6s	46.4bc	----	0.2	----	----	0.8	0.4	0.4	----	100.0	15	2-28
47	B	31.7	30.1	36.4c	----	0.3 y	----	----	1.0	0.2	0.3	----	100.0	--	0- 5
48	A - f	23.1	51.7s	15.1ab	----	----	5.4	----	----	2.0	2.7ep	----	100.0	0	----
49	B	31.4	48.1s	12.3ab	----	5.2	----	----	1.9	0.4	0.7	----	100.0	26	15-38
50	M - f	32.9	39.2	23.9a	----	2.9 y	0.2	----	0.2	0.5	0.3	----	100.1	22	14-30
ZHATISAT BATHOLITH															
51	D - g	----	62.1s	----	----	0.1	34.6	----	----	3.2	----	----	100.0	45	----
52	M - f	28.8	39.4	27.4a	----	0.6	0.4	----	0.4	0.6	0.5	----	100.1	24	18-30
53	D - g	----	50.8s	1.4	----	----	37.6	----	----	1.6	8.6	ep,ser, ch, bi	100.1	48	32-64
ZEBALLOS BATHOLITH															
54	Q	28.6	54.8us	----	----	11.0	5.0	----	----	----	0.6	ap	100.0	32	18-45
55	Q - f	26.2	57.7us	3.0	----	11.5	0.3	----	0.3	0.3	0.7	ap	100.0	36	28-45
56	Q - f	29.0	58.4us	----	----	7.2	3.0	----	1.8	0.4	0.2	ap	100.0	33	12-45
57	D - f	1.9	49.4s	----	----	1.1	43.9	----	1.2	2.5	0.1	----	100.0	40	----
ZEBALLOS AND TAHSIS PLUTONS															
58	Gb - c	----	40.0u	----	----	----	8.8	28.4	2.4	19.6	tr	----	100.0	77	----
59	Gb - f	----	50.4us	----	----	0.6	29.2	13.2	0.6	5.4	0.6	ep	100.0	55	----
MUCHALAT ARM AREA															
60	M	32.9	41.0	21.6a	----	2.4	----	----	1.3	0.6	0.2	----	100.0	22	18-25
61	Q - gf	7.6	47.0s	----	----	0.8	37.9	----	4.7	0.6	1.4	ep	100.0	40	----
62	G - f	33.3	40.4s	19.9m	----	5.5	----	----	0.1	0.8	0.1	----	100.1	24	22-26
63	G	33.0	54.0	7.2a	----	3.5 y	----	----	0.7	0.5	1.1	----	100.0	28	----
64	T	33.2	59.6	----	----	5.4 y	----	----	----	----	1.8	----	100.0	25	----
65	G	24.5	51.5s	13.5a	----	0.4	0.5	----	7.4h	1.2	1.1	ep	100.1	22	18-25
66	G - f	12.1	65.9s	8.0ab	----	6.6 y	5.8	----	----	1.1	0.5	----	100.0	29	15-42
67	Q	20.4	55.1s	1.7	----	7.4 y	13.5	----	0.2b	1.6	0.1	----	100.0	45	----
68	M - f	31.4	32.6	32.2q	(Kf+Qz)	3.0 y	----	----	----	0.6	0.2	----	100.0	28	----
69	Q	5.8	75.6s	1.4	----	----	14.2	----	----	2.8	0.2	----	100.0	30	20-40
HESQUIAT - SIDNEY INLET															
70	G	26.0	56.0us	7.6a	----	5.8	4.6	----	----	----	----	----	100.0	35	20-55
71	G	30.6	52.1us	10.2a	----	5.5	1.1	----	----	0.3	0.1	----	99.9	34	18-50
72	G	21.6	54.5us	7.2	----	6.6	7.9	----	1.1b	0.5	0.5	----	99.9	35	20-50
SIDNEY INLET - AHOUSAT															
73	D - g	----	66.3s	----	----	----	22.0	----	6.2hb	4.4	1.1	tm(0.6)	100.0	42	----
74	Q - g	4.3	57.0	----	----	5.4 y	24.7	6.4	----	1.9	0.4	----	100.1	40	35-47
75	Q - g	17.4	57.7s	----	----	2.0 y	17.9	----	1.3	0.8	2.9	ser, ep	100.0	40	----
76	Q - gf	22.0	53.8s	2.4	----	7.5 y	9.8	----	0.6	0.6	3.4	ser, op, ep	100.1	40	----
77	Q - g	13.4	56.0s	----	----	----	18.6	----	11.6b	----	0.4	ep	100.0	30	----
78	G - g	24.0	49.2s	6.3	----	7.7 y	7.3	----	2.3b	0.4	2.9	----	100.1	30	----
79	D - g	1.2	25.4s	----	----	----	61.4	7.2	----	0.2	4.6	ep(4.0)	100.0	32	----
CATFACE PENINSULA															
80	Q - f	30.1	50.4us	4.2	----	8.7	5.0	----	0.6	0.4	1.0	----	100.4	36	14-58
81	M	26.4	41.6s	22.6a	----	8.6	----	----	----	0.8	----	----	100.0	14	----
82	Q - f	26.0	60.0us	----	----	12.2	----	----	1.6	0.2	----	----	100.0	--	20-50
83	Q - pf	25.2	58.4us	2.8	----	11.2	----	----	1.8	0.4	0.2	----	100.0	--	25-55
TOFINO - MEARES ISLAND															
84	Gb	----	43.0	----	----	----	13.0	28.2	----	----	15.8	ch, serp	100.0	80	----
85	P - c	----	----	----	----	----	----	32.6	----	----	54.2misc	13.2 ol	100.0	--	----
86	Q	35.9	33.7	18.9abc	----	5.0 y	----	----	----	----	1.5	ser, ap, ca	100.0	28	18-38
87	G - pf	25.4	46.2s	18.0	----	4.5 y	4.5	0.4	0.4	0.2	0.4b	ep,ap,ca,ru	100.0	36	18-55
WARN BAY - CLAYOQUOT ARM															
88	Q	11.1	72.0s	1.1	----	5.5 y	6.5	----	0.4	2.5	0.8	----	99.9	32	20-45
89	Q - g	26.7s	62.4s	----	----	6.9 y	----	----	0.5	1.0	2.6	ser,ep,ap	100.1	30	28-31
90	Q	17.0s	51.0s	----	----	5.8 y	14.1	----	6.6	2.9	2.6	ep	100.0	36	----
91	G - g	19.4s	40.2s	7.0	----	----	20.6	----	8.4b	1.6	2.8	ep, sph	100.0	33	----
92	Q	8.8s	69.4s	----	----	----	13.4	----	5.6b	2.2	0.6	ap	100.0	50	----
93	Q	21.1	67.6	3.0s	----	5.9 y	----	----	0.9	0.5	1.0	----	100.0	35	----
94	Q - g	23.6	56.6s	----	----	12.4 y	3.1	----	1.0	2.0	1.3	----	100.0	36	22-50
95	T	32.6s	58.8s	2.9a	----	4.1	----	----	----	0.1	1.5	ser	100.0	23	15-32
KENNEDY LAKE AREA															
96	G	28.1s	48.9s	14.0a	----	3.5 y	4.4	----	0.3b	0.5	0.3	----	100.0	27	15-40
97	Q - pf	5.8	64.6u	0.6	----	0.4	22.4	----	2.8b	2.6	0.8	----	100.0	--	45-50
98	G	29.4	52.8	11.7ma	----	3.7 y	1.5	----	----	0.4	0.5	----	100.0	22	18-28
99	G - f	20.0	54.4s	14.6b	----	0.2	4.6	----	3.8	1.0	0.6	----	100.0	17	----
100	Q - f	2.9	44.9s	2.4	----	----	47.5	----	----	1.4	1.0	sp,ap,ca,ep	100.0	40	25-45
101	G - pf	28.6	45.9	17.9a	----	2.4	3.2	----	0.9b	1.0	0.1	----	100.0	35	28-42
102	G - f	35.9	46.6	9.5a	----	6.6 y	1.0	----	----	0.2	0.2	----	100.0	26	----
103	G	14.0s	56.0s	15.8a	(Kf+Qz)	----	12.4	----	----	1.5	0.3	----	100.0	28	25-37
104	G	18.0s	56.8s	9.6a	----	----	10.9	----	2.3	1.3	1.1	----	100.0	27	----
105	M - pf	35.3	31.2u	26.3ab	----	5.9	----	----	0.3b	0.7	0.4	tm	100.0	17	12-22
106	G - f	18.3	46.1s	15.4a	----	0.9 y	9.0	----	9.4hh	0.5	0.5	----	100.1	25	----
107	M	40.8	33.8s	18.0a	----	----	----	----	6.0b	0.8	0.6	----	100.0	30	----
108	Q - f	11.6	56.8u	----	----	4.0 y	19.8	----	3.2	3.2	1.4	----	100.0	--	35-50
BARKLEY SOUND - NITINAT LAKE															
109	Q	11.3s	52.5s	1.9	----	1.6 y	27.3	----	3.9b	0.5	1.0	----	100.0	50	35-65
110	G - f	30.5	45.8	19.1a	----	3.0 y	0.6	----	----	0.8	0.1	----	99.9	33	15-50
111	D - g	----	58.6u	----	----	5.0	17.6	1.0	11.4	5.2	1.2	ep,ap	100.0	42	20-55
112	G - f	31.4	45.5	17.1a	----	4.3 y	0.1	----	1.0	0.5	0.2	----	100.0	31	24-38
113	T - f	29.6	61.6s	----	----	7.4 y	----	----	0.6	0.2	0.5	----	99.9	25	22-28
114	D - gf	1.9	59.9	----	----	0.5	32.4	----	0.1	5.1	0.1	----	100.0	45	35-55
ROCK BAY															
115	Gb - fc	----	52.8u	----	----	2.2	17.8	21.8	----	5.4	----	----	100.0	>70	----
116	G	30.9	46.7us	13.3a	----	6.4	1.6	----	0.5	0.5	0.1	----	100.0	40	24-55

NUMBER	NAME	Qz	Pc	Kf	Myrm	Bi	Hb	Px	Ch	Acc.	Misc.	Total	Anorthite Average	Range
QUINSAM BATHOLITH														
117	G	22.8	43.6s	18.8a	----	----	8.4	----	4.8b	1.0	----	100.0	--	5-85
118	G	19.3	53.4s	13.6a	----	----	7.0	----	3.1b	2.8	ep	100.0	40	24-55
119	Q - f	4.4	65.3s	2.1	----	tr y	23.4	----	3.6	0.4	----	99.9	--	28-80
120	G - f	21.2	47.8us	15.6a	(Kf+Qz)	----	9.2	----	3.8b	1.0	----		--	15-45
121	G	16.4	49.9s	10.3	----	3.1	16.3	----	2.0b	0.5	----	100.1	36	14-58
122	G - f	23.8	52.0s	16.0a	----	----	3.8	----	2.1hb	0.6	----	100.1	33	15-55
MT. WASHINGTON - FORBIDDEN PLATEAU PLUTONS														
123	Q - f	23.4	68.8us	----	----	----	7.8	----	----	----	----	100.0	35	18-52
124	Q - f	26.3	60.0us	----	----	4.6	7.1	----	1.0	0.1	----	100.1	35	18-52
125	Q - pf	22.2	66.6us	----	----	----	9.6	----	1.4		----	100.0	45	----
126	Q - f	26.8	61.6us	----	----	6.2	3.2	----	1.0b	0.8	----	100.0	42	20-65
127	Q	14.6	69.0s	0.6	----	0.2	11.8	----	2.2	0.2	----	100.0	47	25-70
128	Q - pf	5.0 Qz phenocrysts, 35.2us Pc phenocrysts, 11.4 Hb phenocrysts, 48.6 matrix (Qz+Pc+Hb+Op)												20-60
129	Q - pf	4.6 Qz phenocrysts, 50.2us Pc phenocrysts, 6.2 Hb phecorysts, 39.0 matrix (Qz+Pc+Hb+Op)												25-56
130	Q - f	23.8	61.4us	----	----	5.8	5.0	----	2.6	1.4	ser,ap,ca,ep	100.0	35	20-55
131	Q - fp	21.2	68.6us	----	----	3.4	5.3	----	1.1	0.2	----	100.0	42	18-66
CRUIKSHANK STOCK														
132	G	19.8	59.0s	8.4a	----	6.0 y	3.4	----	0.4	1.2	----	100.0	34	12-55
133	Q - f	5.2	62.4s	----	----	2.2 y	24.1	0.3	2.8	1.0	----	100.0	46	37-55
134	G	25.3	53.8	6.7a	----	6.5 y	4.7	----	1.0b	----	----	100.0	36	18-55
UCONA BATHOLITH														
135	M	31.0	40.5	22.6b	----	2.3 y	2.3	----	----	0.1	----	100.1	28	18-38
136	M - pf	25.4	43.5	22.9b	----	3.0	3.2	----	0.1	0.2	----	100.0	32	22-42
137	G	32.0	49.4s	10.7a	----	2.5 y	2.6	----	1.5b	0.1	----	100.0	35	20-50
138	M	21.3	42.5	29.2ab	----	3.6	2.0	----	0.3	0.3	----	100.0	17	10-24
BEDWELL BATHOLITH														
139	Q - fc	45.8s	37.2s	----	----	----	----	----	5.6hh	11.1	ep	100.0	35	25-45
140	G - e	32.4s	46.6us	13.8a	----	1.6 y	1.2	----	3.2b	0.6	ep	100.0	32	13-50
141	Q	29.0s	53.9s	4.4	----	2.1	----	----	3.5b	1.8	ep,ca	100.0	30	18-42
142	G	29.9	54.0s	5.9	----	3.1 y	----	----	4.0b	2.7	ep	100.0	24	12-37
143	Q - fc	39.0s	47.6s	2.4	----	----	0.2	----	5.4hb	5.8	ep,ser,ca	100.0	30	14-46
144	G - f	38.1s	40.5	10.9a	----	3.6 y	2.5	----	2.2b	0.8	ap,ep,ser	99.9	22	12-35
145	Q	18.1s	57.8s	4.4ma	----	1.6 y	----	----	5.6hb	1.3	ca,ep	100.0	35	15-40
146	G - fc	29.1s	46.0s	11.2a	----	5.6 y	----	----	2.5	5.4	ep	100.0	17	5-22
147	G - pf	23.6s	50.8s	14.4	----	----	1.5	----	5.6	3.6	ep	100.0	35	20-50
148	Gb	2.8	52.6	----	(Pc+Qz)	----	25.6	14.2	----	----	----	100.0	52	42-61
149	G - pf	31.4s	[illegible]	10.2	----	3.8	----	----	2.0	5.0	ep	100.0	35	----
150	Q - f	14.6	72.2us	----	----	----	11.0	----	----	1.6	ap,ap	100.0	41	20-62
151	Q - f	25.2	61.8s	----	----	1.8	6.6	----	3.6hb	0.6	ep,ap,sp	100.0	34	18-45
152	G	22.2s	51.0s	8.2a	----	0.5 y	10.9	----	4.7b	1.0	ep	99.9	--	----
153	Q	34.0	57.0s	0.8	----	0.2 y	3.4	----	3.0b	1.4	----	100.0	37	20-55
154	G - f	14.8	57.0s	9.3a	----	0.4 y	8.2	----	6.0	1.3	ep,ca,ser	99.6	40	18-65
ALBERNI PLUTONS														
155	Q	18.8	59.8	0.4	----	1.8 y	11.6	----	3.9b	1.7	ep,ca	100.0	41	23-60
156	G	26.0	39.9	14.8a	----	3.1 y	10.5	----	3.0b	0.7	ap	100.1	36	7-70
157	G - f	23.8	52.4	4.6a	----	3.4 y	12.0	----	2.2b	0.4	----	100.0	36	18-55
158	G - f	23.4	43.6s	12.8a	----	----	10.0	----	6.4	2.2	ep,ca,ep	100.0	--	15-60
159	G - f	24.4	45.5s	13.0a	----	5.4 y	10.3	0.3	----	0.7	----	100.0	--	15-48
160	G	26.2	49.3	15.0a	----	0.7 y	0.5	----	4.3hh	1.8	----	100.0	--	20-50
161	G	31.8	42.6s	14.0s	----	3.4 y	0.8	----	6.4hh	0.1	----	99.9	--	20-35
162	G	16.7	58.6	7.1	----	8.1 y	7.5	----	1.0b	0.2	----	100.0	31	20-42
163	G - f	30.0	51.4s	6.2	----	5.2 y	5.0	----	----	1.2	ep	100.0	--	22-55
164	G - f	26.1	48.4u	12.3a	----	7.6 y	4.4	----	----	0.2	----	100.0	--	25-55
165	Q - f	17.4	60.4us	0.6	----	4.2 y	11.2	----	4.2	0.4	----	100.0	--	10-58
166	Gb	----	54.6	----	----	----	6.8	20.0	----	12.4	5.4 ol	100.0	70	68-72
167	Gb	2.2	60.4s	----	----	----	7.8	20.0	----	9.2	ch,ser,sa	100.0	--	----
168	Q	26.6	56.6us	0.2	----	11.6	0.3	----	2.2	0.7	----	100.0	--	10-45
169	Q	15.2	56.0	0.6	----	1.0 y	19.6	----	6.0b	----	----	100.0	42	30-55
170	G	26.0	50.2s	13.8a	----	0.6 y	0.6	----	7.6hh	0.6	----	100.0	25	20-30
171	G	22.0	41.0	19.3a	(Kf+Qz)	3.6 y	10.6	----	1.1	1.4	----	100.0	35	20-50
172	G - f	13.2	57.0	9.2a	(Kf+Qz)	----	10.0	----	9.0	----	----	100.0	28	15-50
NANAIMO RIVER BATHOLITH														
173	Q - f	20.3	65.0	1.9	----	7.1 y	1.9	----	0.8hh	0.8	----	100.0	30	25-35
174	G	26.2	44.0	22.4a	(Kf+Qz)	2.2	3.2	----	0.2b	0.6	----	100.0	26	10-42
175	G - f	24.6	58.5	8.1a	----	4.0 y	2.8	----	----	0.5	----	100.0	35	28-45
176	G	11.5	51.3	14.5a	----	6.4	14.0	----	0.4	----	----	100.0	25	15-40
177	G - f	29.6	51.2	9.6ma	----	5.8 y	----	----	1.8	0.8	----	100.0	29	3-55
SKARN PROPERTY PLUTON														
178	M	19.5	34.9	25.3ab	----	17.1	5.1	----	0.5	1.7	ep	100.0	32	20-43
179	G - f	14.3	53.9s	15.0a	----	----	12.4	----	----	2.1	sp,ep,ap	100.1	35	----
180	M	24.0	37.9	28.5a	----	0.4	7.5	----	----	1.1	ep	100.0	31	18-45
TERTIARY SILL, ENGLISHMAN RIVER														
181	Q - pf	7.6	68.2s	0.4	----	----	20.2	----	0.6	----	----	100.0	--	28-70
LADYSMITH														
182	G - gf	10.9	43.7u	15.1ma	----	9.4	18.4	----	----	0.8	----	100.0	35	28-42
183	G - gf	14.4	45.0	15.4ma	(Kf+Qz)	5.0 y	18.4	----	----	0.8	----	100.0	40	----
184	G - gf	11.5	50.9u	10.2ma	----	6.5 y	18.1	0.2	----	1.2	sp,ap	100.0	35	25-38
185	T - f	18.6	40.6	----	(Pc+Qz)	2.8	31.0	1.0	----	1.6	ap	100.0	25	10-40
SAANICH GRANODIORITE PLUTONS (186, 187, 188, 189 after Fyles, 1955)														
186	D	36.6	26.8	45.5	----	0.6	----	----	----	----	----	100.0	10	5-20
187	G	29.1	47.7	13.7	----	4.9	3.8	----	----	----	----	100.0	38	20-45
188	Q	26.0	57.7	3.4	----	6.8	5.6	----	----	----	----	100.0	--	----
189	G	22.4	57.8	7.2	----	5.0	7.2	----	----	----	----	100.0	--	----
190	G	27.2	45.2	14.2a	----	6.6 y	4.0	----	0.4	1.6	ep	100.0	30	20-40
191	G	22.2	58.5s	5.1a	----	0.6	8.9	----	1.0b	2.0	ep,ap,ep	90.5	38	16-60
192	G	19.2	58.8s	12.8a	----	1.0 y	5.4	----	----	1.8	ap	100.0	37	21-52
193	G - f	17.7	57.3s	11.5	----	----	7.5	----	1.5	2.7	ap,ep,ser	100.0	31	5-56
194	M - pf	9.2	49.6	27.8	----	----	----	----	8.8	2.2	ep,ap,ca	100.0	40	25-55
195	G - f	5.8	60.2s	9.6a	----	----	14.0	----	6.2hh	2.0	ep	100.0	34	----
196	G	24.6	52.6	17.4a	----	----	1.2	----	3.8b	1.4	ep	100.0	37	15-60
197	M	36.4	32.4	29.0b	(Pc,Kf+Qz)	2.0 y	----	----	----	0.2	----	100.0	12	----
198	G	29.0	43.8	18.4a	----	5.6 y	----	----	1.8b	1.0	ep,ca	100.0	26	13-40
199	G - pf	24.8	52.2	7.4a	----	2.2	9.0	----	2.6	1.2	----	100.0	26	20-32
200	G	25.8	51.6	9.4a	----	2.4 y	7.0	----	2.0b	1.4	ep,ca	100.0	37	17-57
201	G - f	11.4	34.4s	21.2	(Kf+Qz)	----	10.0	----	7.2h	4.6	ep	100.0	25	0-50
202	Q - f	28.8	52.8	0.4	----	----	6.8	----	7.2hh	2.6	ep	100.0	37	15-60
203	M - f	29.0	35.6	27.2a	(Kf+Qz)	----	----	----	2.8b	5.4	ep,sp	100.0	28	----
WARK AND COLQUITZ GNEISSES														
204	D - gf	----	54.8s	----	----	0.4	41.6	----	7.6b	0.8	----	100.0	<60	----
205	Q - gf	20.6	45.6s	3.2	----	----	8.4	----	10.6b	11.2	ep	100.0	30	----
206	D - gf	2.2	43.2	----	----	----	43.6	----	1.6b	9.0	ep	100.0	30	----
207	Gb - g	0.4	75.2s	----	----	3.0	9.0	6.0	2.8	3.0	ep	100.0	>50	----
208	T - gf	17.6s	56.4s	0.2	----	0.4 y	17.0	----	0.6	6.8	ep,ep	100.0	20	0-40
209	T - gf	35.4	55.8s	----	----	0.4	----	----	1.2	7.0	sp,ep	100.0	23	----
210	G - gf	30.4	43.0s	15.4b	----	2.4	----	----	1.0	6.4	ep,ser	100.0	25	----
211	Gb - g	----	45.4	----	----	0.4	47.6	----	1.0	0.4	ap	100.0	>50	----
212	Gb - gf	0.4	42.4	----	----	----	55.0	----	----	1.0	ap,ep	100.0	52	----
213	Q - gf	13.8	52.4s	0.4	----	----	6.8	----	14.2hh	10.6	ep,ca	100.0	32	----
214	Q - gf	10.8	59.4s	----	----	14.2 y	12.2	----	0.6	2.2	ep,ep,ap	100.0	38	----
SOOKE GRANITIC PLUTONS														
215	T - f	11.8	74.2	----	----	----	7.0	----	2.0h	4.0	ep,sp,ap	100.0	18	8-28
216	G - f	45.6	42.2s	7.0mq	(Kf+Qz)	----	----	----	2.2	1.6	ep	100.0	15	5-25
217	Q	25.5	63.9us	0.3	----	9.2	tr	----	tr	0.6	ep,sp,ap	100.0	30	10-50
218	T - f	29.3	66.9s	----	(Pc+Qz)	----	0.5	----	----	0.7	ep,ap	100.0	16	0-32
219	T - f	38.0	29.5	----	(Pc+Qz)	----	12.5	----	----	15.0	ep	100.0	20	----
220	T - f	29.0	56.2	1.0	----	0.2	4.0	----	1.6	3.4	ep	100.0	35	0-22
221	T	26.4	57.2s	2.8	(Pc+Qz)	----	4.8	----	1.4	1.8	ep,ca	100.0	15	10-20
222	Q - f	29.5	55.5us	3.1a	----	----	10.0	----	----	0.1	----	100.0	45	25-75
223	T - f	31.9	57.5	----	----	0.4	7.1	----	----	0.3	----	100.0	20	7-33
SOOKE GABBRO PLUTONS														
224	Gb	----	48.4	----	----	----	11.7	35.1	----	4.0	ol,al	100.0	70	----
225	Gb	----	45.9	----	----	----	0.2	47.3	----	4.4	ol,al	100.0	>70	----
226	Gb - c	----	86.5	----	----	----	2.7	5.7	----	5.1	ol,ep,al	100.1	75	----
227	Gb	----	45.6	----	----	----	7.2	37.4	----	9.0	ol,al	100.0	>70	----

Table 3 - Chemical Analyses and Norms of Plutonic Rocks of Vancouver Island

No.	Total	H_2O	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	MnO	CO_2	S	FeS_2	BaO
ANALYSES OF THIS PROJECT (J. A. MAXWELL, PERSONAL COMMUNICATION, 1967; See Fig. 3 For Location)																	
1	100.2	0.5	66.9	15.9	0.1	1.7	2.8	4.4	4.9	2.14	0.53	0.15	0.03	0.4	----	----	----
2	98.5	0.8	68.6	15.1	1.1	2.8	2.3	3.3	4.4	2.37	0.39	0.17	0.11	<0.1	----	----	----
3	101.8	0.8	73.0	15.0	<0.2	3.0	<0.5	2.8	4.2	2.60	0.30	0.08	0.06	<0.1	----	----	----
4	100.2	1.6	54.3	18.8	2.1	5.4	4.2	8.5	3.4	0.77	0.87	0.15	0.14	<0.1	----	----	----
5	98.9	0.4	73.6	14.0	0.3	0.6	<0.5	1.5	4.1	4.17	0.10	0.02	0.03	0.1	----	----	----
6	100.6	1.4	61.1	17.8	1.7	3.6	3.0	5.9	3.8	1.39	0.64	0.10	0.10	0.1	----	----	----
7	98.5	0.8	61.0	17.5	<0.2	4.6	2.9	4.7	4.7	1.44	0.68	0.15	0.07	<0.1	----	----	----
8	100.0	2.4	48.6	17.7	3.8	6.0	6.3	8.4	3.9	1.40	1.22	0.14	0.15	<0.1	----	----	----
9	100.3	1.3	69.5	15.5	0.7	1.5	2.4	2.3	5.0	1.54	0.37	0.10	0.07	<0.1	----	----	----
10	98.6	0.8	64.9	15.9	0.6	2.8	4.1	3.7	4.3	1.88	0.48	0.10	0.07	<0.1	----	----	----
11	101.2	1.0	64.0	17.8	0.5	3.3	3.3	4.6	4.3	1.67	0.56	0.11	0.07	<0.1	----	----	----
12	99.2	0.6	69.1	15.9	0.9	1.5	0.5	3.0	4.4	2.84	0.30	0.10	0.08	<0.1	----	----	----
13	101.6	1.3	68.1	16.7	1.0	1.6	1.6	2.3	4.4	4.17	0.36	0.10	0.06	<0.1	----	----	----
14	100.3	1.9	66.8	15.7	1.3	4.1	<0.5	3.7	4.3	1.54	0.42	0.14	0.12	0.3	----	----	----
15	100.0	1.6	70.0	14.9	<0.2	2.6	1.4	2.9	4.2	1.79	0.31	0.08	0.12	0.1	----	----	----
16	100.3	1.6	69.9	14.9	0.9	2.0	2.1	3.9	4.2	0.27	0.37	0.09	0.09	<0.1	----	----	----
17	99.7	1.3	61.7	17.8	0.2	1.8	4.3	7.0	4.7	<0.05	0.48	0.14	0.06	0.2	----	----	----
18	99.4	1.9	62.1	16.9	1.5	3.7	1.4	5.5	3.8	1.65	0.59	0.12	0.12	0.1	----	----	----
19	98.8	0.6	62.4	19.0	<0.5	3.1	2.0	5.3	4.9	0.8	0.39	0.12	0.07	0.1	----	----	----
20	100.0	0.3	63.9	20.0	0.2	1.4	1.8	6.5	5.2	0.14	0.37	0.11	0.05	<0.1	----	----	----
21	101.1	1.6	62.3	20.8	2.2	0.9	1.7	5.4	4.8	0.58	0.38	0.13	0.07	0.2	----	----	----
22	99.8	0.8	63.8	16.6	<0.2	4.5	2.7	4.4	4.3	1.98	0.56	0.13	0.07	<0.1	----	----	----
22a	98.5	0.8	68.2	14.9	<0.2	1.9	2.7	1.7	4.8	3.09	0.28	0.06	0.03	<0.1	----	----	----
22b	100.7	1.0	66.6	15.8	0.7	3.2	3.4	3.4	4.0	1.98	0.50	0.10	0.05	<0.1	----	----	----
22c	99.1	0.8	69.1	15.5	0.6	2.6	1.6	3.0	4.1	1.97	0.40	0.07	0.04	<0.1	----	----	----
23	98.4	0.4	74.1	12.5	<0.5	1.2	0.5	1.2	3.7	4.5	0.25	0.05	0.04	<0.1	----	----	----
24	98.9	0.5	72.6	14.1	<0.5	1.6	0.7	1.7	4.6	2.9	0.15	0.05	0.04	<0.1	----	----	----
25	98.5	2.1	57.2	16.2	2.0	5.5	2.5	6.6	3.6	1.58	0.80	0.12	0.18	0.1	----	----	----
26	101.3	1.6	54.8	19.7	1.8	4.7	5.2	6.7	4.8	1.01	0.77	0.23	0.13	<0.1	----	----	----
27	100.1	0.8	68.2	15.2	1.6	2.2	1.0	3.3	4.4	2.69	0.42	0.17	0.11	<0.1	----	----	----
28	98.9	1.4	48.8	19.8	4.4	5.4	3.4	8.7	4.2	0.66	1.62	0.39	0.14	<0.1	----	----	----
29	97.9	1.1	62.6	16.3	0.9	2.7	2.7	4.2	3.9	2.64	0.46	0.21	0.06	0.1	----	----	----
30	100.9	1.3	65.3	16.9	1.6	3.1	1.3	4.8	3.9	1.94	0.43	0.10	0.11	<0.1	----	----	----
31	98.2	1.1	66.3	15.3	1.3	2.3	0.9	4.1	3.7	2.36	0.34	0.28	0.10	0.1	----	----	----
32	98.8	0.7	70.9	16.9	1.3	1.3	<0.5	2.9	4.8	2.15	0.32	0.11	0.09	<0.1	----	----	----
33	97.9	1.2	58.0	17.8	2.1	3.3	3.0	6.4	4.1	0.77	0.83	0.31	0.11	<0.1	----	----	----
34	100.7	1.0	66.8	17.4	1.1	2.1	1.4	3.9	3.9	2.57	0.31	0.13	0.10	<0.1	----	----	----
35	98.0	0.9	65.7	16.9	<0.2	3.1	0.9	3.7	5.1	0.78	0.35	0.13	0.04	0.4	----	----	----
36	99.3	2.4	57.7	13.6	3.7	4.7	4.6	5.9	4.5	0.8	0.88	0.25	0.15	0.1	----	----	----
37	99.1	0.9	67.5	13.2	2.2	4.1	1.4	3.0	5.7	0.3	0.55	0.13	0.07	<0.1	----	----	----
38	95.9	2.5	45.7	14.9	1.8	5.8	8.7	13.4	2.3	0.16	0.33	0.06	0.15	0.1	----	----	----
ZEBALLOS AREA (STEVENSON, 1950)																	
a	100.13	0.67	71.80	15.33	0.61	2.84	1.06	1.44	3.25	2.38	0.46	0.13	0.06	----	----	----	0.10
b	99.59	2.24	71.64	14.46	0.84	2.30	0.22	2.04	2.97	2.16	0.42	0.14	0.06	----	----	----	0.10
c	99.76	1.20	65.10	14.91	0.79	4.09	2.42	5.14	3.64	1.01	0.58	0.19	0.09	0.13	----	0.40	0.07
d	99.63	1.38	67.56	15.51	0.40	2.70	2.42	3.16	3.62	2.20	0.52	0.11	0.05	----	----	----	----
INTRUSIONS RELATED TO IRON SKARNS (SANGSTER, 1964)																	
SP-49	99.63	0.92	59.8	18.1	2.5	2.87	3.2	7.1	4.0	0.18	0.70	0.16	0.08	0.02	----	----	----
MW8	100.69	2.0	47.2	13.1	4.6	11.21	4.9	8.0	3.7	0.94	3.1	1.5	0.31	0.13	----	----	----
352A	99.84	0.32	65.9	16.7	0.81	2.75	1.3	2.4	4.6	3.3	0.51	0.11	0.08	0.06	0.01	----	----
391A	99.21	0.64	63.7	16.2	0.58	4.80	1.7	3.5	4.9	1.7	0.90	0.26	0.15	0.07	0.04	----	----
458	99.51	0.80	69.4	16.1	0.50	1.96	0.64	3.0	3.7	3.0	0.27	0.05	0.03	0.04	0.02	----	----
COWICHAN LAKE AREA (FYLES, 1955)																	
A	100.12	1.76	61.38	16.73	2.85	3.21	2.43	4.92	3.71	2.15	0.45	0.20	0.14	0.08	----	----	0.11
B	100.40	1.94	65.68	15.56	2.04	2.59	1.78	3.94	3.37	2.65	0.32	0.14	0.12	0.18	----	----	0.09
C	100.19	1.68	67.46	14.85	1.59	2.15	1.61	3.52	3.32	3.28	0.31	0.13	0.11	0.07	----	----	0.11
D	99.98	1.65	68.46	14.99	1.56	2.11	1.43	3.18	2.92	3.07	0.26	0.11	0.08	0.09	----	----	0.07
E	100.30	1.17	72.00	14.30	1.01	1.27	0.78	1.98	3.25	3.98	0.16	0.06	0.06	0.15	----	----	0.13
F	100.39	1.49	73.16	13.42	0.82	1.13	0.87	1.80	3.44	3.77	0.16	0.06	0.05	0.05	----	----	0.15
G	100.23	0.50	76.44	12.80	0.46	0.31	0.23	0.50	3.15	5.45	0.06	0.02	0.01	----	----	----	0.30
H	100.39	0.72	76.96	12.85	0.40	0.40	0.22	0.24	2.68	5.64	0.07	0.03	0.02	0.10	----	----	0.06
SOOKE - DUNCAN AREA (CLAPP AND COOKE, 1917)																	
Mark	99.59	2.40	48.68	18.05	3.41	6.44	2.82	10.00	3.18	1.60	0.80	2.01	0.20	----	----	----	----
Colquitz	99.31	1.60	68.04	15.83	2.16	2.40	2.72	3.60	3.52	1.43	0.30	1.56	0.15	----	----	----	----
Sann. Grd.	100.75	1.65	62.64	17.75	1.64	3.44	2.53	4.44	3.53	2.14	0.60	0.25	0.14	----	----	----	----
Colquitz Femic	98.94	2.85	38.80	12.50	6.56	8.20	13.10	11.42	1.60	0.81	1.60	1.26	0.23	----	----	----	----
Colquitz Salic	100.70	0.95	75.02	13.90	0.45	0.40	0.10	1.16	3.06	5.37	0.04	0.15	0.10	----	----	----	----
PERRY LAKE STOCK (SANGSTER, 1964)																	
1	98.99	----	66.8	15.5	1.24	1.63	3.27	4.40	2.93	3.22	----	----	----	----	----	----	----
2	99.12	----	75.7	11.7	0.25	0.31	2.82	0.76	0.73	7.55	----	----	----	----	----	----	----

No.	Qz	Ab	An	Or	Di	Fs	En	Mt	He	Il	Ap	C	Cc	Ne	Fo	Fa
ANALYSES OF THIS PROJECT (J. A. MAXWELL, PERSONAL COMMUNICATION, 1967; See Fig. 3 For Location)																
1	16.284	43.435	14.879	12.496	2.067	1.598	6.598	.103	.501	.729	.310	------	.999	------	------	------
2	20.583	39.267	14.365	13.933	.428	3.073	6.097	1.143	.216	.540	.354	------	------	------	------	------
3	28.244	37.698	13.367	15.374	------	4.323	------	------	------	.418	.167	.410	------	------	------	------
4	5.580	30.976	34.259	4.621	3.993	4.979	9.769	2.228	2.035	1.230	.319	------	------	------	------	------
5	28.833	37.506	6.806	25.130	------	.640	------	.320	------	.142	.043	.323	.258	------	------	------
6	14.253	34.396	27.636	8.288	.323	3.616	8.188	1.792	.143	.899	.211	------	.255	------	------	------
7	10.126	42.786	22.652	8.638	------	6.377	8.118	------	------	.961	.318	.027	------	------	------	------
8	------	31.765	27.094	8.415	8.835	------	------	4.037	2.632	1.727	.298	------	------	2.291	9.943	2.963
9	23.705	45.013	10.787	9.133	------	1.434	6.644	.734	------	.517	.210	1.823	------	------	------	------
10	15.885	38.683	17.741	11.142	------	3.367	11.342	.629	------	.670	.210	.332	------	------	------	------
11	14.602	38.238	21.895	9.783	------	4.055	9.023	.518	------	.773	.228	.885	------	------	------	------
12	23.505	40.136	14.459	17.066	------	1.427	1.402	.956	------	.425	.213	.412	------	------	------	------
13	17.213	39.135	10.658	24.433	------	1.362	4.376	1.036	------	.497	.207	1.085	------	------	------	------
14	25.209	39.725	15.957	9.372	------	5.195	------	1.399	------	.602	.302	1.418	.781	------	------	------
15	27.261	38.455	13.493	10.794	------	3.858	3.940	------	------	.440	.171	1.340	.258	------	------	------
16	30.246	38.394	19.104	1.626	------	2.135	5.903	.958	------	.525	.192	.917	------	------	------	------
17	12.825	42.122	27.433	------	3.447	1.770	10.126	.209	.602	.658	.293	------	.505	------	------	------
18	17.795	35.256	24.994	10.085	.681	3.831	3.654	1.621	.714	.849	.260	------	.261	------	------	------
19	13.750	44.276	25.041	4.762	------	4.397	5.557	------	------	.547	.253	1.162	.255	------	------	------
20	14.765	46.195	30.504	.819	.423	1.508	4.706	.207	.135	.510	.228	------	------	------	------	------
21	17.512	42.955	24.600	3.419	------	------	4.678	1.457	------	.528	.217	3.519	.504	------	------	------
22	13.881	38.838	20.269	11.781	.364	6.185	7.317	------	.308	.785	.274	------	------	------	------	------
22a	18.309	43.592	8.136	18.487	------	2.631	7.540	------	------	.395	.127	.784	------	------	------	------
22b	20.014	35.927	16.223	11.716	------	3.853	9.390	.732	------	.697	.209	1.238	------	------	------	------
22c	25.747	37.334	14.633	11.817	------	3.160	4.480	.636	------	.565	.149	1.479	------	------	------	------
23	27.233	41.974	8.241	17.432	------	2.371	1.964	------	------	.212	.106	.476	------	------	------	------
24	30.101	34.141	4.315	27.354	.549	1.304	1.144	------	.626	.358	.108	------	------	------	------	------
25	10.922	33.819	24.465	9.778	3.481	4.999	5.481	2.188	3.175	1.166	.263	------	.265	------	------	------
26	------	42.467	28.806	5.887	1.447	4.291	11.712	1.854	.530	1.057	.475	------	------	------	1.079	.395
27	22.048	39.971	13.941	16.098	.714	1.659	2.436	1.693	.487	.592	.360	------	------	------	------	------
28	------	38.771	34.171	4.014	4.507	1.656	4.765	4.730	1.566	2.320	.840	------	------	------	1.975	.686
29	15.270	36.033	19.382	16.068	------	3.096	7.671	.968	------	.659	.152	.140	.260	------	------	------
30	20.035	35.402	23.134	11.601	.124	3.245	3.846	1.691	.105	.606	.212	------	------	------	------	------
31	24.463	34.529	18.584	14.509	------	2.433	2.583	1.413	------	.492	.609	.121	.263	------	------	------
32	26.193	42.902	13.609	12.659	------	.800	------	1.353	------	.444	.229	1.812	------	------	------	------
33	12.290	38.010	28.808	4.703	1.143	2.568	7.980	2.267	.368	1.194	.670	------	------	------	------	------
34	21.409	35.190	18.594	15.276	------	2.223	3.884	1.156	------	.434	.274	1.560	------	------	------	------
35	21.713	46.924	15.351	4.728	------	4.486	2.546	------	------	.500	.279	2.437	1.037	------	------	------
36	10.171	41.740	15.034	4.888	7.966	2.671	9.137	3.997	3.238	1.267	.541	------	.261	------	------	------
37	22.541	52.392	9.779	1.817	1.768	3.309	3.073	2.355	1.904	.784	.279	------	------	------	------	------
38	------	18.842	31.610	1.002	22.964	------	------	1.992	7.177	.487	.133	------	.268	1.807	10.453	3.267
ZEBALLOS AREA (STEVENSON, 1950)																
a	35.610	29.812	6.431	14.382	------	3.502	2.990	.652	------	.655	.278	5.688	------	------	------	------
b	39.360	28.018	9.673	13.423	------	2.613	.638	.923	------	.615	.308	4.429	------	------	------	------
c	22.871	33.604	21.970	6.142	.965	4.894	6.387	.849	.740	.831	.409	------	.338	------	------	------
d	24.823	33.183	15.274	13.285	------	3.327	6.821	.427	------	.740	.235	1.885	------	------	------	------
INTRUSIONS RELATED TO IRON SKARNS (SANGSTER, 1964)																
SP-49	15.041	36.405	31.335	1.079	2.193	1.649	7.859	2.650	.460	.989	.340	------	------	------	------	------
MW8	------	34.670	17.081	5.803	6.474	7.041	9.481	5.020	4.808	4.508	3.278	------	------	------	1.051	.781
352A	26.334	33.888	14.852	18.101	------	2.406	1.802	.533	------	.384	.107	1.592	------	------	------	------
391A	16.923	41.798	11.324	19.754	------	3.148	3.632	.857	------	.719	.233	1.612	------	------	------	------
458	15.197	44.715	15.922	10.220	------	6.112	4.770	.616	------	1.274	.553	.620	------	------	------	------
COWICHAN LAKE AREA (FYLES, 1955)																
A	15.819	34.125	23.203	13.028	.270	2.591	6.738	3.053	.104	.642	.429	------	------	------	------	------
B	22.831	31.119	19.165	16.120	------	2.400	5.054	2.194	------	.459	.301	.357	------	------	------	------
C	23.859	30.594	16.347	19.912	.393	1.928	4.366	1.706	.173	.443	.279	------	------	------	------	------
D	28.724	27.075	15.553	18.752	------	2.009	4.077	1.684	------	.374	.238	1.514	------	------	------	------
E	30.312	29.842	9.647	24.075	------	1.161	2.202	1.080	------	.228	.128	1.324	------	------	------	------
F	31.438	31.614	8.740	22.824	------	1.068	2.458	.888	------	.228	.129	.613	------	------	------	------
G	33.755	28.766	2.390	32.786	------	.093	.646	.489	------	.085	.043	.947	------	------	------	------
H	36.720	24.550	1.015	34.035	------	.280	.620	.427	------	.099	.064	2.190	------	------	------	------
SOOKE - DUNCAN AREA (CLAPP AND COOKE, 1917)																
Mark	1.714	29.781	31.561	9.871	2.763	5.886	6.739	3.739	2.414	1.163	4.390	------	------	------	------	------
Colquitz	28.341	32.631	7.898	8.733	------	2.096	7.753	2.332	------	.432	3.372	6.412	------	------	------	------
Sann. Grd.	18.210	32.112	20.665	12.824	------	3.617	7.077	1.737	------	.847	.530	2.381	------	------	------	------
Colquitz Femic	------	6.780	25.549	4.988	16.957	------	------	7.152	2.933	2.321	2.747	------	------	4.906	21.882	3.785
Colquitz Salic	32.128	27.851	4.840	32.198	------	.413	.280	.477	------	.056	.318	1.438	------	------	------	------
PERRY LAKE STOCK (SANGSTER, 1964)																
1	23.497	26.585	8.174	19.247	------	4.246	12.276	1.310	------	------	------	4.665	------	------	------	------
2	34.458	6.675	3.841	45.478	------	.312	7.929	.266	------	------	------	1.042	------	------	------	------



GENERALIZED COLUMNAR SECTIONS

(after Sutherland Brown, 1966)

12 Sooke, Carmanah Fms

10 Metchosin Fm and other Tertiary Volcanics

9 NANAIMO GROUP

8 Unnamed Units

7 Callovian Seds.

5 Bonanza Fm

4 Quatsino Fm

3 Karmutsen Fm

VANCOUVER GROUP

2 Sicker Limestone

1 Lower Sicker

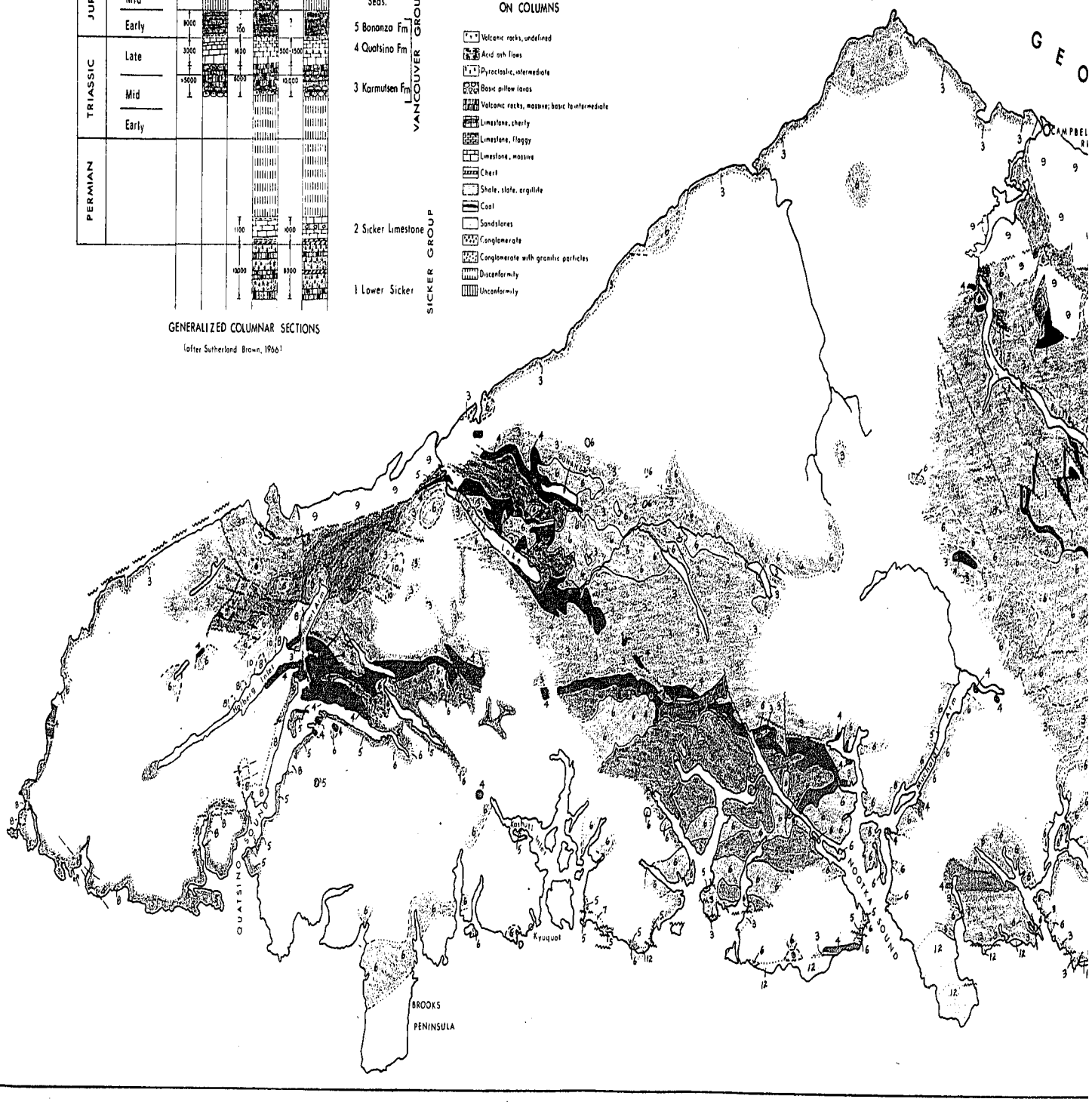
SICKER GROUP

GEOLOGY AFTER COMPILATION MAPS BY J.E. MULLER and W.G. JEFFERY with minor additions by D.J. CARSON

COLOURS ON COLUMNS AND MAP CORRESPOND except for Sicker (2) and Quatsino (4) limestones, black on map; Tertiary Plutons (11) Purple, Jurassic and Unknown Plutons (6) Red

LITHOLOGIC SYMBOLS ON COLUMNS

- Volcanic rocks, undefined
- Acid ash flows
- Pyroclastic, intermediate
- Basic pillow lavas
- Volcanic rocks, massive; basic to intermediate
- Limestone, cherty
- Limestone, flaggy
- Limestone, massive
- Chert
- Shale, slate, argillite
- Coal
- Sandstones
- Conglomerate
- Conglomerate with granitic particles
- Disconformity
- Unconformity



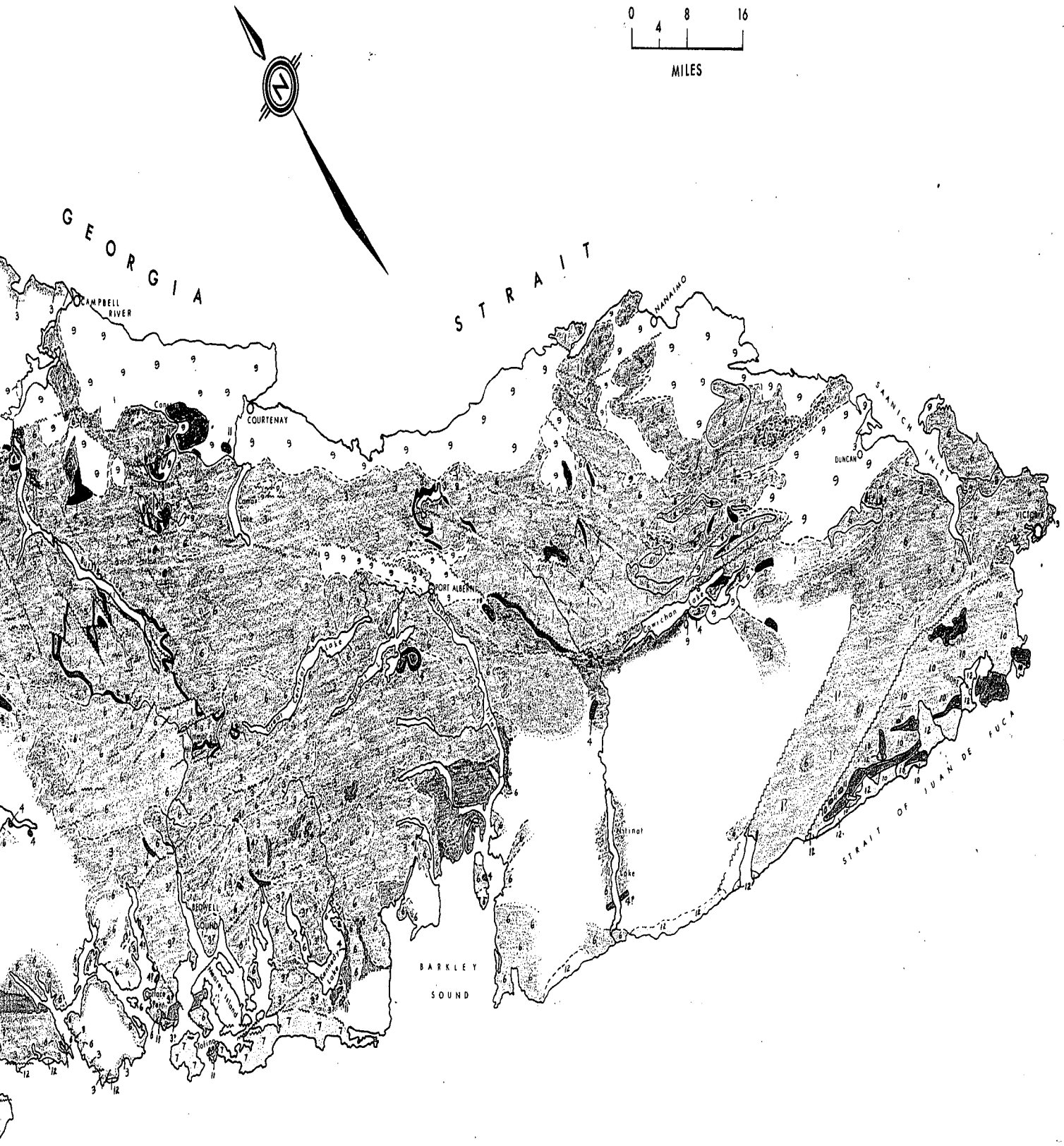
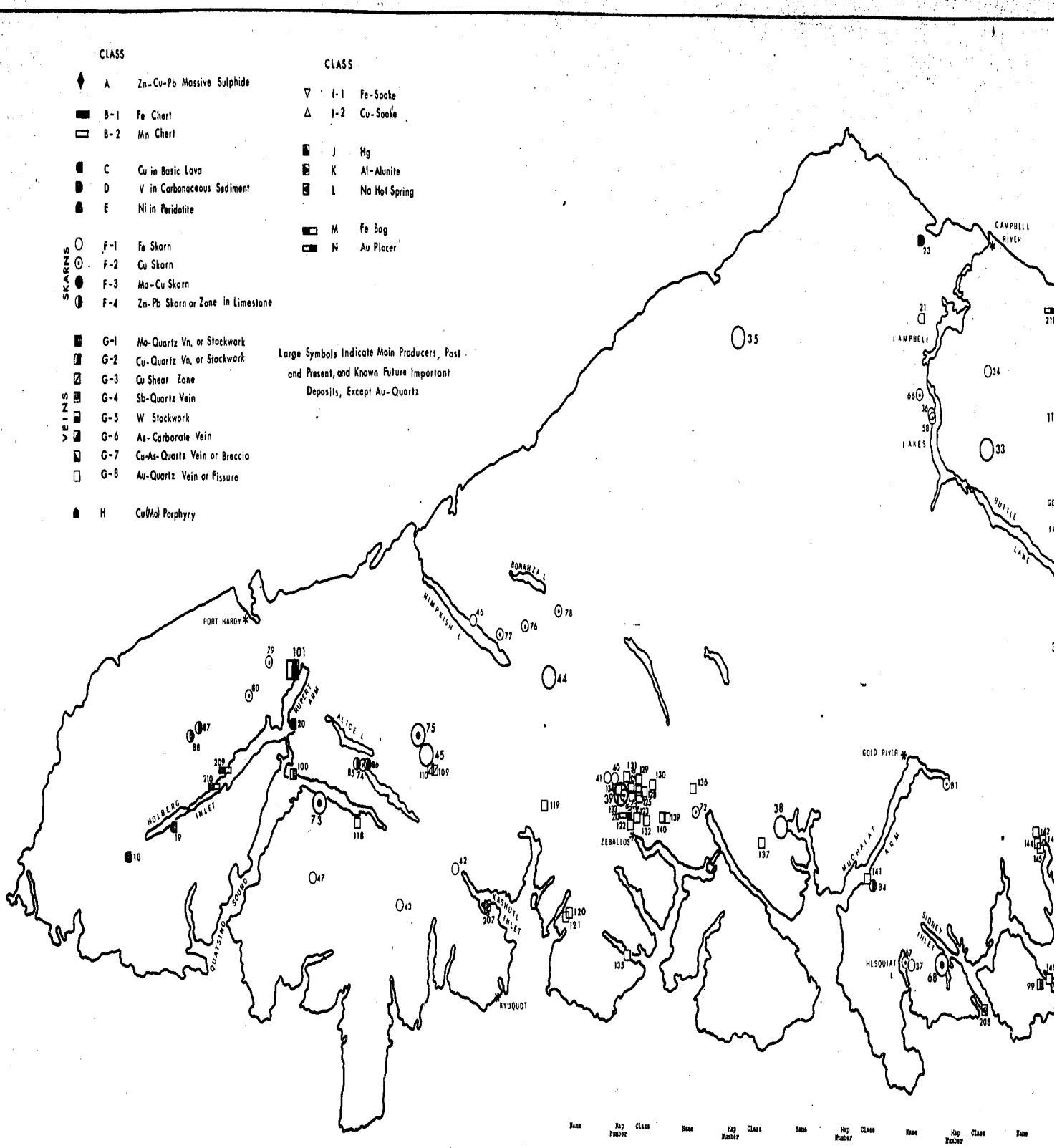
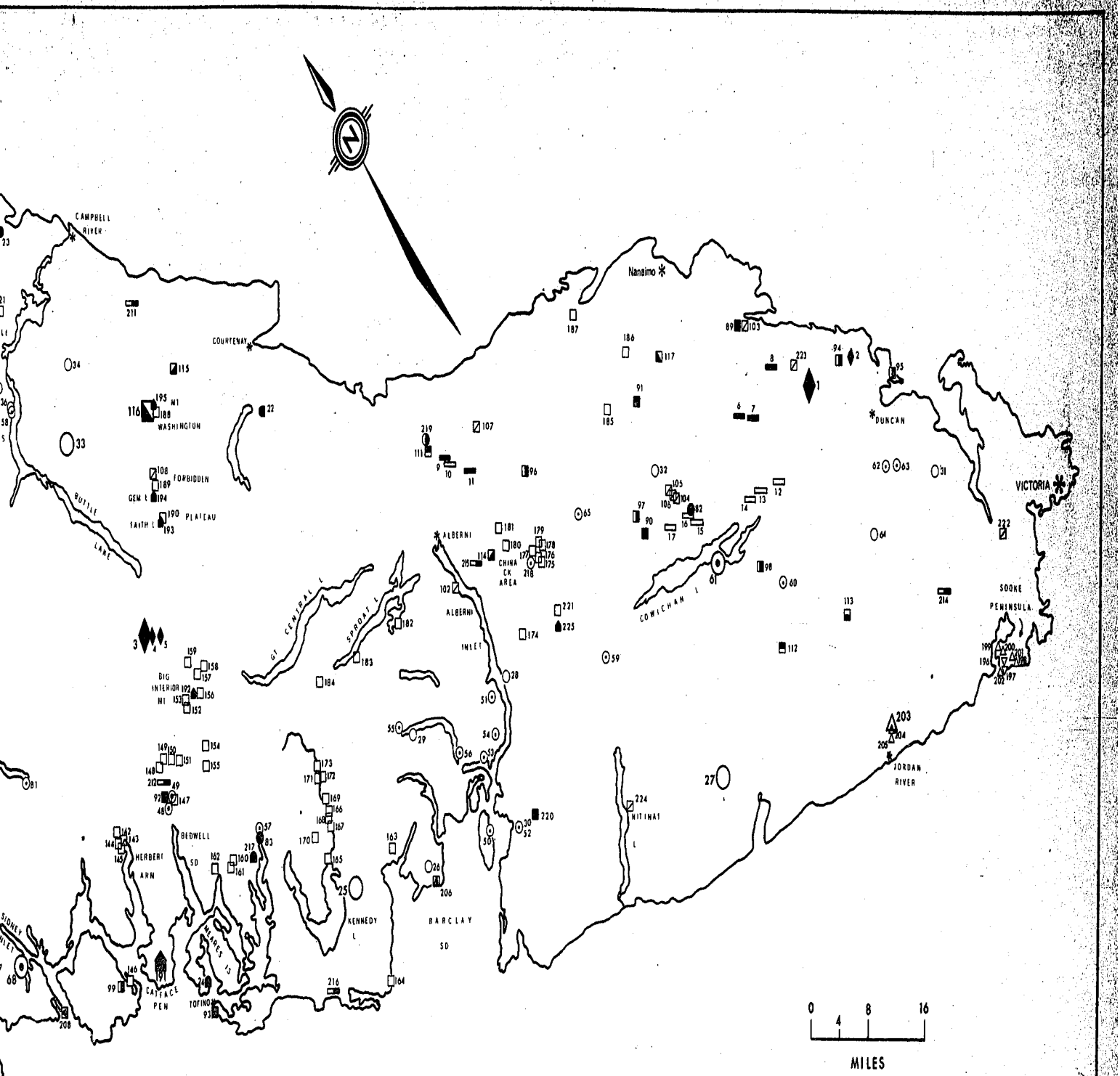


FIG. 1 – GEOLOGY OF VANCOUVER ISLAND

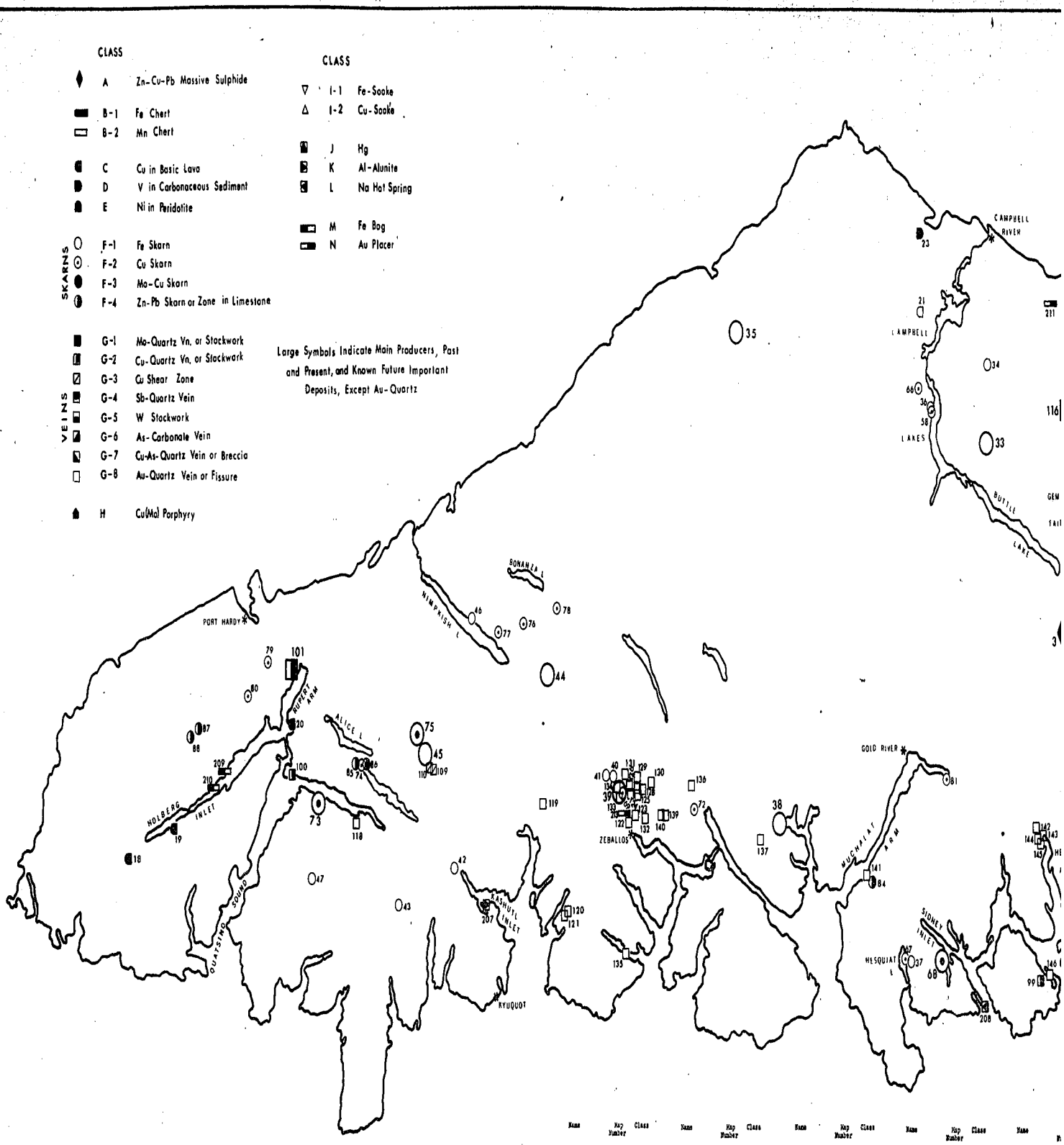


Name	Map Number	Class
Twin "J"	1	A
Mt. Richards	2	"
Lynx	3	"
Paramount	4	"
Price	5	"
Lady A	6	B_1
Lady B	7	"
Lady C	8	"
Unnamed	9, 10	"
Lacy Lake	11	B_2
Hill 60	12	"
Unnamed	13-17	"
Hillington	18	C
Holberg Inlet	19	"
Marble Creek	20	"
Lerx	21	"
Coal Creek	22	"
Menzies Bay	23	D
Nootka Island	24	E
Brynnor	25	F_1
Sechart	26	"
Bugaboo	27	"
Darby and John	28	"
Magnetic	29	"
Zarita	30	"
Willoron	31	"
Jump Creek	32	"
Iron Hill	33	F_1
Iron River	34	"
Iron Mike	35	"
Bacon Lake	36	"
Hesquiat A	37	"
Head Bay	38	"
Zeballos	39	"
Churchill	40	"
Artlish	41	"
Kashutl	42	"
Fever	43	"
Nimpkish	44	"
Empire Dev.	45	"
Magnet	46	"
Ingersoll	47	"
Seattle	48	F_2
Avon and Galena	49	"
Tartus	50	"
JJJ	51	"
Alberni	52	"
Nanaimo	53	"
Defiance	54	"
Gretna G	55	"
Rainy Day	56	"
B. C. Wonder	57	"
Sumpter	58	"
Medra	59	"
Alberta	60	"
Nine Grouse	61	"
King Solomon	62	"
Pallacio	63	"
Sterling	64	"
Skarn	65	F_2
Big O	66	"
Hesquiat B	67	"
Indian Chief	68	"
Shell and Scorpio	69	"
Central Zeballos (Cu)	70	"
Boxer	71	"
Star of West	72	"
Treka	73	"
June Group	74	"
Coast Copper	75	"
Kirman	76	"
Smith	77	"
Bob Lake	78	"
Little Joe	79	"
Caledonia	80	"
June	81	"
Conego	82	F_3
Sun West	83	"
Danny	84	F_3
Alice Lake	85	"
Pilgrim	86	"
Dorlon	87	"
EMS	88	"
Molly	89	G_1
Allies	90	"
Holy J	91	"
Dry Gulch	92	"
Tufino Molybdenite	93	"
Jane and Sally	94	G_2
Sarsum	95	"
Independent	96	"
Delphi	97	"
Lorry	98	"
Ground	99	"
Copper King	100	"
Yankee Girl-Bay	101	"
Dauntless	102	G_3
Bush Creek	103	"
El Capitan	104	"
Silver Leaf	105	"
Cottonwood	106	"
Qualicum	107	"
Three Musketeers	108	"
Nine Co	109	"
Rainier	110	"
Silver Bell	111	G_4
Lens	112	"
Victory	113	G_5
Grizzly	114	G_6
Golf	115	"
Mt. Washington Copper	116	G_7
Merrillan	117	"
Quatsino King, Paystreak	118	G_8
Scrutor	119	"
Fil		
Eclipse		
Tagore, Answer		
Golden Portal, Prosperity		
Privateer, Prident, XIX, Zeballos Fac., White Star		
Spud Valley, Britannia M, Mt. Zeballos		
Britannia		
CD, Hiny		
Big Star		
Central Zeballos		
Homeward, Monitor		
King Midas, Goldspring		
Friend		
Quags, Peerless, Bowden		
Barnacle, Rocky Strike		
Kuhshilts		
Mohawk		
Vivian		
Harlow		
Ubell		
Ubell Creek		
Baltic		

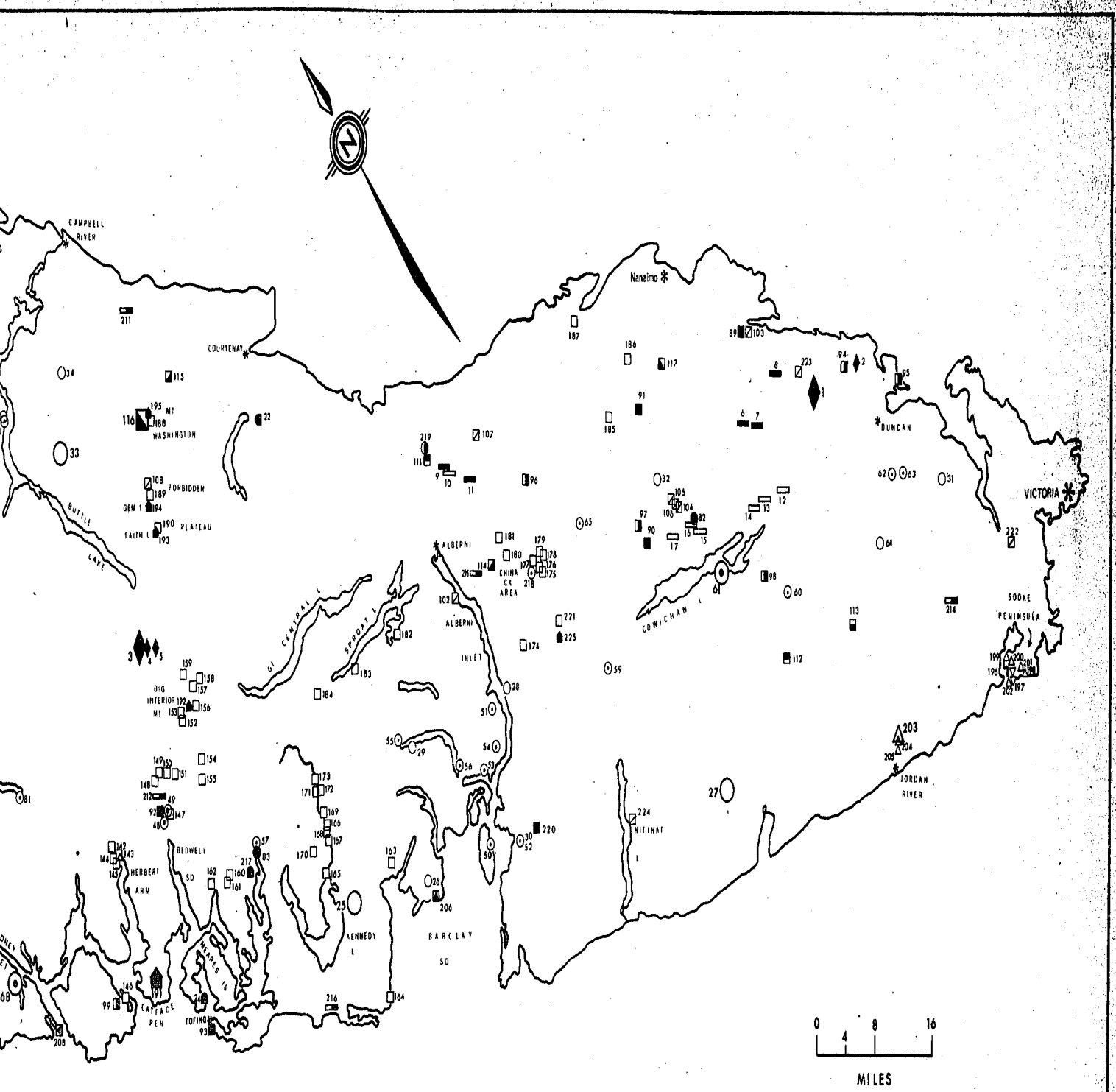


Name	Map Number	Class
Sally	94	G_2
	95	•
	96	•
	97	•
	98	•
	99	•
	100	•
	101	•
	102	•
	103	G_3
	104	•
	105	•
	106	•
	107	•
	108	•
	109	•
	110	•
	111	G_4
	112	•
	113	G_5
	114	G_6
	115	•
	116	G_7
	117	•
	118	G_8
	119	•
Fil	120	G_9
Eclipse	121	•
Tagore, Answer	122	•
Golden Portal, Prosperity	123	•
Privateer, Pridesk, ITL, Zeballos Pac., White Star	124	•
Spud Valley, Britannia M, Mt. Zeballos	125	•
Britannia	126	•
CD, Hwy	127	•
Big Star	128	•
Central Zeballos	129	•
Norward, Monitor	130	•
King Midas, Goldspring	131	•
Friend	132	•
Omega, Fearless, Rowden	133	•
Dartmile, Lucky Strike	134	•
Muchalits	135	•
Mohawk	136	•
Vivian	137	•
Harlow	138	•
Ubell	139	•
Ubell Creek	140	•
Baltic	141	•
Abco	142	G_3
Big Boy	143	•
Hoyahs, Tyee	144	•
High Boy	145	•
Lenny	146	•
Prosper	147	•
Noble, Noble B	148	•
O.K.	149	•
Macketeer, John	150	•
Buccaneer	151	•
You	152	•
Casino	153	•
Trophy	154	•
Thunderbird	155	•
Bella	156	•
Sherwood	157	•
FDQ	158	•
Cream	159	•
Pandora	160	•
Goldflake	161	•
Moscena	162	•
Toquart	163	•
Faith	164	•
Wanderer	165	•
Jo Jo	166	•
Laura	167	•
Rose Marie	168	•
Tommy K	169	•
Bear Group	170	•
Nine Bird	171	•
Grant	172	•
Gold Queen	173	•
WW	174	•
Black Lion	175	G_0
Black Panther	176	•
Havilah	177	•
B and K	178	•
Golden Eagle	179	•
Regina	180	•
Vancouver Island Gold	181	•
Ferguson	182	•
Murphy-Johnson	183	•
Apex	184	•
Vulcan	185	•
T-Bird and Lily	186	•
Georgina	187	•
Dominoy, No. 2	188	•
Brown	189	•
Faith Lake	190	•
Catface	191	H
Big I	192	•
Faith Copper	193	•
Gem Lake	194	•
Mt. Washington-Marex	195	•
Iron Mountain	196	J_1
Merryth Iron	197	•
Griffith	198	J_2
King George	199	•
Cocke Zone	200	•
Shastis	201	•
Merryth	202	•
Sunro	203	L_2
Beal Zone	204	•
Caulfield, Robertson, Tiger	205	•
Sechart	206	J
Kashutl	207	K
Sharp Point	208	L
Quatsino	209	M
Prince	210	•
Oyster River	211	N
Bedwell River	212	•
Zeballos River	213	•
Leech River	214	•
China Creek	215	•
Wreck Bay	216	•
Tofino Nickel	217	E
Thistle	218	F_2
FD	219	F_1
SR	220	O_1
Mary	221	O_2
Mt. Skirk	222	•
Charon	223	•
Hal and S	224	•
Corrigan Creek (Andy and Pat)	225	K

FIG. 2 – MINERAL DEPOSITS OF VANCOUVER ISLAND

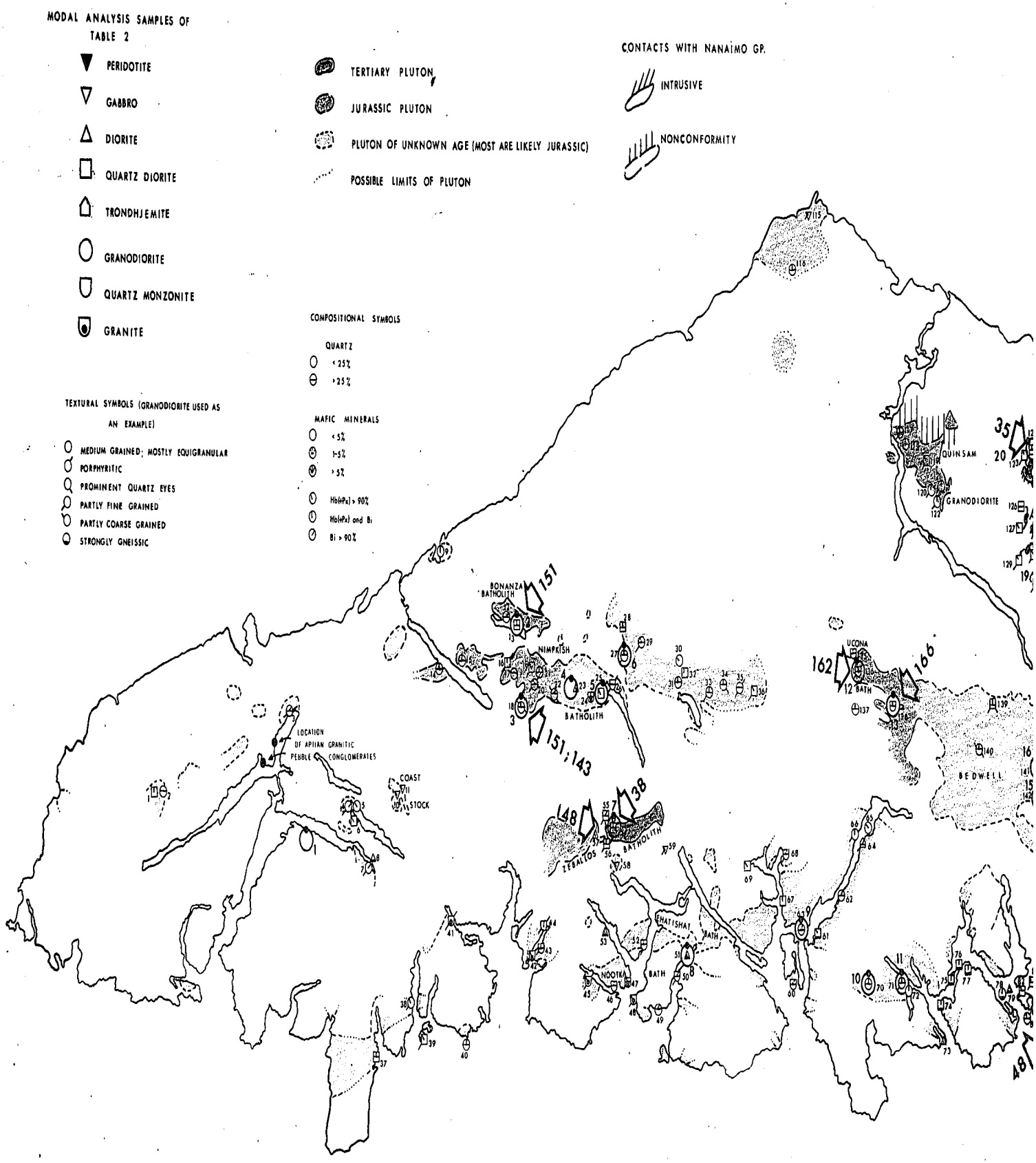


Name	Map Number	Class
Twin "J"	1	A
Mt. Richards	2	"
Lynx	3	"
Paramount	4	"
Price	5	"
Lady A	6	F_4
Lady B	7	"
Lady C	8	"
Unnamed	9, 10	"
Lacy Lake	11	F_2
Hill 60	12	"
Unnamed	13-17	"
Hillington	18	C
Holberg Inlet	19	"
Marble Creek	20	"
Lark	21	"
Coal Creek	22	"
Menzies Bay	23	D
Nearee Island	24	E
Brynnor	25	F_1
Sechart	26	"
Bugaboo	27	"
Jaby and Joan	28	"
Magnetic	29	"
Sarita	30	"
Willaron	31	"
Jump Creek	32	"
Iron Hill	33	F_1
Iron River	34	"
Iron Mike	35	"
Bacon Lake	36	"
Hesquiat A	37	"
Head Bay	38	"
Zeballos	39	"
Churchill	40	"
Artlish	41	"
Kashutl	42	"
Power	43	"
Nimpkish	44	"
Empire Dev.	45	"
Magnet	46	"
Ingersoll	47	"
Seattle	48	F_2
Avon and Galena	49	"
Tartus	50	"
JJJ	51	"
Alberni	52	"
Sunshine	53	"
Defiance	54	"
Gretta G	55	"
Rainy Day	56	"
B. C. Wonder	57	"
Sumpter	58	"
Nadire	59	"
Alberta	60	"
Blue Grouse	61	"
King Solomon	62	"
Palladio	63	"
Sterling	64	"
Skarn	65	F_2
Big G	66	"
Hesquiat B	67	"
Indian Chief	68	"
Uhell and Scorpio	69	"
Central Zeballos (Cu)	70	"
Bruno	71	"
Star of West	72	"
Texas	73	"
June Group	74	"
Coast Copper	75	"
Kirman	76	"
Smith	77	"
Bob Lake	78	"
Little Joe	79	"
Caledonia	80	"
June	81	"
Omega	82	F_3
Sun West	83	"
Danaig	84	F_4
Alice Lake	85	"
Pilgrim	86	"
Norlon	87	"
HPM	88	"
Molly	89	G_1
Allies	90	"
Molly 2	91	"
Dry Gulch	92	"
Tofino Molybdenite	93	"
Jane and Sally	94	G_2
Sacsum	95	"
Independent	96	"
Delphi	97	"
Lorry	98	"
Orcond	99	"
Copper King	100	"
Yankee Girl-Bay	101	"
Dauntless	102	G_3
Bush Creek	103	"
El Capitan	104	"
Silver Leaf	105	"
Cottonwood	106	"
Quallicum	107	"
Three Musketeers	108	"
Blue Cx	109	"
Rainier	110	"
Silver Bell	111	G_4
Lens	112	"
Victory	113	G_5
Grizzly	114	G_6
Wolf	115	"
Mt. Washington Copper	116	G_7
Macmillan	117	"
Quatsino King, Fayetreak	118	G_8
Scrutor	119	"
Fil	1	
Eclipse	2	
Tagore, Answer	3	
Golden Portal, Prosperity	4	
Privateer, Trident, XXL, Zeballos Pac., White Star	5	
Spud Valley, Britannia M, Mt. Zeballos	6	
Britannia	7	
CD, Ray	8	
Big Star	9	
Central Zeballos	10	
Honeyard, Monitor	11	
King Midas, Goldspring	12	
Friend	13	
Omega, Fearless, Bowlin	14	
Barnacle, Lucky Strike	15	
Muchalitz	16	
Mohawk	17	
Vivian	18	
Earlow	19	
Uhell	20	
Uhell Creek	21	
Baltic	22	



Name	Map Number	Class
Ely	94	G_2
	95	*
	96	*
	97	*
	98	*
	99	*
	100	*
Bay	101	*
	102	G_3
	103	*
	104	*
	105	*
	106	*
	107	*
	108	*
	109	*
	110	*
	111	G_4
	112	*
	113	G_5
	114	G_6
	115	*
	116	G_7
	117	*
	118	G_8
	119	*
Fil	120	G_9
Eclipse	121	*
Tagore, Answer	122	*
Golden Portal, Prosperity	123	*
Privateer, Prident, XXL, Zeballos Pac., White Star	124	*
Spud Valley, Britannia M, Mt. Zeballos	125	*
Britannia	126	*
CD, Ring	127	*
Big Star	128	*
Central Zeballos	129	*
Homeward, Monitor	130	*
King Midas, Goldspring	131	*
Friend	132	*
Omega, Fearless, Bowdon	133	*
Barnacle, Lucky Strike	134	*
Mechanite	135	*
Mohawk	136	*
Vivian	137	*
Harlow	138	*
Ubell	139	*
Ubell Creek	140	*
Baltic	141	*
Abco	142	G_{10}
Big Boy	143	*
Mystic, Tyee	144	*
High Boy	145	*
Lenay	146	*
Prosper	147	*
Noble, Noble D	148	*
O.K.	149	*
Musketer, John	150	*
Buccaneer	151	*
Yon	152	*
Casino	153	*
Trophy	154	*
Thunderbird	155	*
Della	156	*
Sherwood	157	*
FUG	158	*
Cream	159	*
Pandora	160	*
Goldflake	161	*
Moscena	162	*
Toquart	163	*
Faith	164	*
Vanderer	165	*
Jo Jo	166	*
Leora	167	*
Rose Marie	168	*
Tommy K	169	*
Bear Group	170	*
Blue Bird	171	*
Grant	172	*
Gold Queen	173	*
NWW	174	*
Black Lion	175	G_{11}
Black Panther	176	*
Havilah	177	*
B and K	178	*
Golden Eagle	179	*
Regina	180	*
Vancouver Island Gold	181	*
Ferguson	182	*
Murphy-Johnson	183	*
Apex	184	*
Vulcan	185	*
T-Bird and Lily	186	*
Georgina	187	*
Dominion, No. 2	188	*
Brown	189	*
Faith Lake	190	*
Catface	191	H
Big I	192	*
Faith Copper	193	*
Gem Lake	194	*
Mt. Washington-Marmo	195	*
Iron Mountain	196	I_1
Merryth Iron	197	*
Griffith	198	I_2
King George	199	*
Cooke Rock	200	*
Eurette	201	*
Merryth	202	*
Sunro	203	I_3
Bend Zone	204	*
Caulfield, Robertson, Tigar	205	*
Sechart	206	J
Kashutl	207	K
Sharp Point	208	L
Quatsino	209	M
Prince	210	*
Oyster River	211	N
Bedwell River	212	*
Zeballos River	213	*
Leach River	214	*
China Creek	215	*
Wreck Bay	216	*
Tofino Nickel	217	N
Thistle	218	P_2
PD	219	P_1
SX	220	Q_1
Mary	221	Q_2
Mt. Kirk	222	*
Sharon	223	*
Mal and S	224	*
Corrigan Creek (Andy and Pak)	225	H

FIG. 2 – MINERAL DEPOSITS OF VANCOUVER ISLAND


MODAL ANALYSIS SAMPLES OF TABLE 2
PERIDOTITE
GABBRO
DIORITE
QUARTZ DIORITE
TRONDHJEMITE
GRANODIORITE
QUARTZ MONZONITE
GRANITE
TERTIARY PLUTON
JURASSIC PLUTON
PLUTON OF UNKNOWN AGE (MOST ARE LIKELY JURASSIC)
POSSIBLE LIMITS OF PLUTON
CONTACTS WITH NANAIMO GP.
INTRUSIVE
NONCONFORMITY
COMPOSITIONAL SYMBOLS
QUARTZ
< 25%
> 25%
MAFIC MINERALS
< 5%
1-5%
> 5%
Hb(+Px) > 90%
Hb(+Px) and Bi
Bi > 90%
TEXTURAL SYMBOLS (GRANODIORITE USED AS AN EXAMPLE)
MEDIUM GRAINED; MOSTLY EQUIGRANULAR
PORPHYRITIC
PROMINENT QUARTZ EYES
PARTLY FINE GRAINED
PARTLY COARSE GRAINED
STRONGLY GNEISSIC
BONANZA BATHOLITH
151
NIMPKISH
BATHOLITH
151;143
LOCATION OF APTIAN GRANITIC PEBBLE CONGLOMERATES
COAST STOCK
148
138
ZEBALLOS
BATHOLITH
NOOTKA
BATH
EHATISHAT
BATH
UCONA
BATH
162
166
BEDWELL
QUINSAM
GRANODIORITE
35
20
48

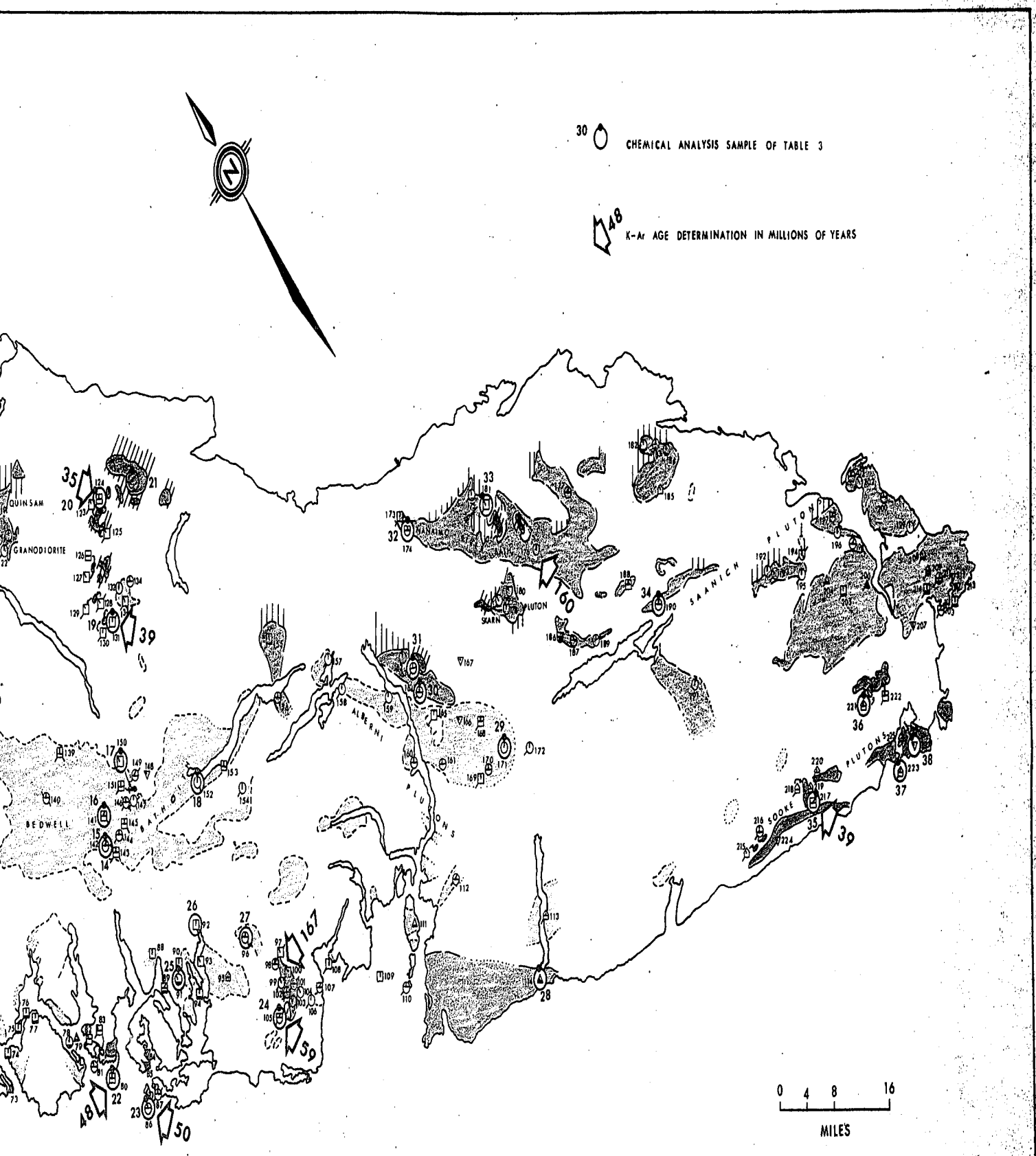


FIG.3-PLUTONIC ROCKS OF VANCOUVER ISLAND