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GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF ENERGY, MINES AND RESOURCES

PAPER 69-47

HOPE MAP-AREA, WEST HALF BRITISH COLUMBIA

(Report, 4 figures and P.S. Map 12-1969)

J.W.H. Monger

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HOPE MAP-AREA, WEST HALF (92 H W 1/2), BRITISH COLUMBIA

J.W.H. Monger

DEPARTMENT OF ENERGY, MINES AND RESOURCES

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ABSTRACT

Hope map-area in southwestern British Columbia covers some 3,200 square miles, almost entirely within the Cascade and Coast mountains. The Cascade Mountains, in the southern part, consist of a north-northwest trending gneissic and granitic core flanked by belts of sedimentary and volcanic rock. This core widens northwards and merges with the predominantly granitic and high-grade metamorphic rocks of the Coast Mountains, which occupy the northeast part of the map-area. Differences between the two mountain systems seemingly result from greater uplift and deeper erosion of the Coast Mountains.

Stratified rocks range in age from probable pre-Middle Devonian to Recent. The oldest are probable pre-Middle Devonian amphibolites and schists that form small fault slices in the western part of the map-area. Upper Paleozoic altered basic volcanic rocks, chert, pelite, limestone and minor sandstone containing Lower Pennsylvanian and Lower Permian fossils are widespread in the Cascade Mountains. Above these are Upper Triassic andesites, Upper Triassic, Lower and Middle Jurassic pelites and fine-grained sandstones, local Middle Jurassic acid to intermediate volcanics, Upper Jurassic and Lower Cretaceous sandstones, pelites, and conglomerates, and local Lower Cretaceous intermediate volcanic rocks. All of these rocks are marine, with the exception of uppermost Lower Cretaceous rocks in the easternmost part of the map-area. Above these, in places, there are coarse-grained, continental Lower Tertiary clastic rocks and acid to basic volcanic rocks. Thick Pleistocene to Recent deposits locally fill major valleys.

Granitic rocks appear to have been emplaced at three main times; the oldest, Upper Jurassic-Lower Cretaceous foliated granodiorite, outcrop in the eastern part of the map-area. Upper (?) Cretaceous, concordant, partly anatectic (?) quartz diorite occurs mainly along the axis of the Cascades. Discordant Tertiary granodiorite, emplaced mainly in late Eocene-Oligocene time, but as recently as Miocene, is the most abundant.

Orogeny took place in the map-area in mid-Cretaceous to Early Tertiary time. Earlier diastrophic events were metamorphism in pre-Middle Devonian time and uplift recorded by coarse clastic rocks in Permo-Pennsylvanian time and hiatuses between Lower Permian and Upper Triassic rocks and in Upper Jurassic and Lower Cretaceous rocks. The present structural pattern was established in mid-Cretaceous to Early Tertiary time. In the core of the Cascades gneiss, schist and granitic rock, perhaps mainly formed earlier in the Mesozoic, were folded (?) and faulted during mid-Cretaceous orogeny. Sedimentary and volcanic rocks on the west side of the Cascades were folded and thrust to the northwest and west; those on the east side were folded and reverse faulted, with a sense of movement from west to east. The only rocks not affected internally during this deformation were Upper Jurassic granitic rocks in the northwest of the map-area that apparently were merely uplifted. Normal and strike-slip faulting in Early Tertiary time, and uplift in Pliocene-Pleistocene time completed the structural evolution of the area.

Numerous mineral deposits are known from the area, although few have been exploited with any commercial success. Many are related to Cretaceous fault zones.

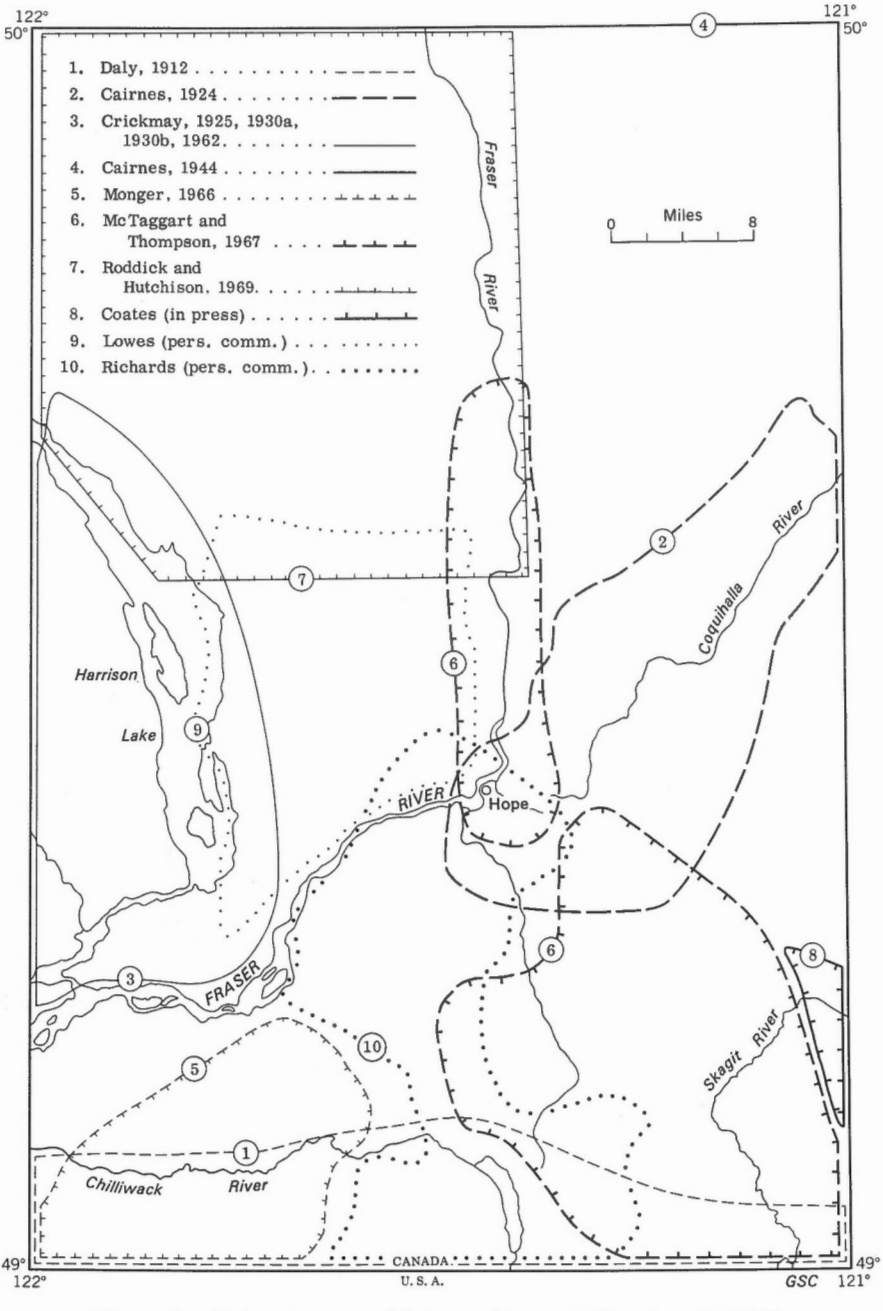

Figure 1. Major sources of data used in compiling Map 12-1969.

HOPE MAP-AREA, WEST HALF
BRITISH COLUMBIA

INTRODUCTION

This report on the geology of the Hope area (92H W/2, bounded by latitudes 49° to 50° N and longitudes 121° to 122° W) is a revision of Map 737A, published by the Geological Survey in 1944, and incorporates much data from recent studies in the area. C. E. Cairnes compiled Map 737A using field mapping by Daly, 1912; Cairnes, 1924; Crickmay, 1930a; Horwood, 1936; and W. E. Snow. Since 1944 much information has come from detailed work done by the Department of Geology, University of British Columbia in the southern part of the map-area (e. g. Read, 1960, McMillan, 1966, Monger, 1966, McTaggart and Thompson, 1967 and Coates, in press). T. Richards of the University of British Columbia and B. E. Lowes of the University of Washington, are currently (1969) doing field theses in the southern part of the area. The geology of the northwest part, incomplete on the original map, was mapped on a reconnaissance basis in the summer of 1968 by Roddick and Hutchison (1969). Finally, the writer, accompanied by Roddick and Hutchison, spent one week in the field in October, 1968, correlating units in the northern part of the map-area with those to the south.

Location of the major sources of data used in compiling this report are given in Figure 1. Other sources are referred to in the text. Unless otherwise stated, conclusions reached by the writer are his responsibility and are not necessarily those arrived at by other workers in the area.

Existing stratigraphic nomenclature has been retained. Even though the stratigraphic column probably could be simplified, the writer felt he was unable to make any changes in terminology without personally doing field work on the units involved.

Advice and information were given to the writer by Dr. K.C. McTaggart of the University of British Columbia and Dr. Peter Misch of the University of Washington. The latter's comprehensive synthesis of the geology of the Cascade Mountains immediately south of the map-area (Misch, 1966) has had considerable influence on this map and report. Acknowledgment must also be made to T. A. Richards and B. E. Lowes who gave freely of information from their thesis projects.

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PHYSICAL FEATURES

The Hope map-area lies almost entirely within the physiographic boundaries of the Coast and Cascade mountains. Exceptions are the flood plain of the Fraser River near Chilliwack, called the Fraser Lowland, and the northeasternmost corner of the map-area, part of the Interior Plateau (Holland, 1964).

The physiographic boundaries between the Coast and Cascade mountains and the Cascade Mountains and Interior Plateau are largely arbitrary. The former boundary is marked by the Fraser River and the latter by a gradual decrease in local relief from the Cascade Mountains to the Interior Plateau.

The area is generally rugged with an average local relief of 4,000 feet. The highest peak is Silvertip Mountain (elevation 8,530 feet) and there are several peaks with elevations of 7,000 feet or more. According to Holland (1964) the highest peaks represent monadnocks on an elevated Tertiary erosion surface of low relief. The minimum elevation, less than 100 feet, is in the Fraser Lowland.

The area has been intensely glaciated. The highest peaks and ridges stood above the level of Pleistocene ice and now bear evidence of alpine glaciation. Several peaks are horns, and cirques are common on their north and northeast sides. A few peaks such as Mount Breakenridge and Silvertip Mountain carry small permanent ice fields. Lower mountains, below about 6,000 feet, lay below the level of the Pleistocene ice sheet and are rounded. Valleys were glaciated and are commonly characterized by U-shaped profiles, truncated spurs and hanging side valleys. In contrast to these erosive features, the Fraser Lowland appears to have been largely a site of glacial and glaciofluvial deposition during the erosion prevalent elsewhere.

Most drainage is structurally controlled. The Fraser River above Hope follows a major fault zone. The valley containing Harrison Lake is partly excavated along the trace of a major fault zone. Drainage of the Chilliwack River and its tributaries in places has a reticulate pattern that parallels the trend of two sets of folds at right angles to one another.

GENERAL GEOLOGY

Hope map-area contains the junction between the Coast and Cascade mountain systems. The geology of the southern half of the map-area is typical of the Cascade System, with an axial core of gneiss and granitic rock flanked on east and west by belts of folded and faulted but little metamorphosed sedimentary and volcanic rocks of late Paleozoic to mid-Cretaceous age. Northwards the axial core broadens and the Cascade System merges with the predominantly granitic and high-grade metamorphic Coast Mountains.

The basic structural pattern results largely from intense deformation in mid-Cretaceous to Early Tertiary time, when five north-northwest trending belts, distinguished by their structure and lithology, were formed. From east to west these belts are:-

1. Eastern plutonic belt, composed largely of Upper Jurassic-Lower Cretaceous foliated granodiorite, with minor Upper Triassic, Cretaceous and Tertiary volcanic rocks. This belt differs from the others in that the

rocks composing it were apparently little deformed internally in mid-Cretaceous time but were merely uplifted. In addition, and perhaps in part reflecting this lack of Cretaceous deformation, the granitic rocks in this belt are older than any known from elsewhere in the map-area.

2. Eastern Mesozoic belt, composed of unmetamorphosed Jurassic and Lower Cretaceous sandstone, pelite and conglomerate and discordant mid-Tertiary granodiorite. This belt is separated from the one above by the Cretaceous Pasayten fault and is highly deformed internally, with major folds overturned to the east and west-dipping reverse and thrust faults.

3. Eastern Paleozoic belt, composed of upper Paleozoic chert, pelite, basic volcanic rock and limestone. These rocks have undergone low-grade (lowest greenschist facies) metamorphism, are complexly folded and faulted and locally intruded by Cretaceous quartz diorite and granodiorite. They are separated from the belt to the east by the early Upper Cretaceous Hozameen Fault.

4. Axial belt, composed of gneiss of uncertain age, Cretaceous (?) schist, and partly concordant Cretaceous quartz diorite, overlain unconformably by Lower Tertiary clastic rock and intruded by discordant mid-Tertiary granodiorite. Most of these rocks are complexly folded and cut by prominent north-south-trending Early Tertiary faults. They are separated from the upper Paleozoic rocks to the east by a narrow zone along which movement and intrusion of small granodiorite bodies has taken place.

5. Western belt, largely composed of Pennsylvanian and Permian pelite[1], sandstone, limestone and volcanic rock, Upper Triassic, Jurassic and Lower Cretaceous pelite, sandstone and minor conglomerate and Jurassic volcanic rocks. These rocks were folded, thrust and refolded in mid-Cretaceous to Early Tertiary time and metamorphosed to low greenschist facies. They were locally intruded by probable Cretaceous and mid-Tertiary granitic rocks. Their eastern contact is either a reverse fault or an intrusive contact with mid-Tertiary granitic rocks in the axial belt.

Although rock-units of similar age in different belts are of roughly the same lithology, the successions differ in detail and different stratigraphic names are given to them. The names of the units, their composition, thickness and age are given in Figure 2. In addition, the stratigraphic, plutonic, volcanic and diastrophic records are summarized in Figure 3.

DEVONIAN (?) TO PERMIAN STRATIFIED ROCKS

Hozameen Group

The Hozameen Group (unit 1) comprises greenstone, chert, pelite and minor limestone. It is the most extensive stratified unit in the map-area. The name originates from Mount Hozameen, which is about one mile south of the southeastern corner of the map-area (Daly, 1912).

---

[1] The term 'pelite' as used throughout this report is a general term referring to fine-grained clastic rocks, originally composed of clay-sized particles, that may be either shale, argillite, slate or phyllite.

Four stratigraphic divisions make up the Hozameen Group over most of its outcrop area (Daly, 1912, Cairnes, 1924, McTaggart and Thompson, 1967). The lowest division (1a) has an apparent thickness of about 5,000 feet and consists mainly of ribbon chert, local limestone bodies up to 1,200 feet thick (1e) and several hundred feet of greenstone. Overlying this is a division (1b), composed mainly of greenstone but with local chert and limestone lenses. This division is more than 4,000 feet thick in the southeastern corner of the map-area and thins to about 2,500 feet 12 miles north of the International Boundary. The third division (1c) comprises ribbon chert and pelite with an apparent thickness of 10,000 feet at the International Boundary and 6,000 feet 12 miles to the north. The uppermost division (1d) is more than 7,000 feet thick and consists of greenstone, chert, pelite and limestone pods (1e).

Lithology

Chert is probably the most abundant sedimentary rock in the group. It varies in colour from dark grey to white, and is mainly in 1/2- to 3-inch thick beds separated by pelitic layers, but locally is more massive. Rare spheroidal bodies of radiating quartz crystals in the chert may be recrystallized radiolaria.

Pelite is commonly dark grey and associated with chert. In addition to forming partings between chert layers, it occurs in beds up to several hundred feet thick.

Altered basalt, composed of andesitic basalt and spilite and commonly known as greenstone, is a major part of the Hozameen Group and in the western part of the outcrop area is intimately associated with serpentinite (unit Aa). It is dark green or greenish grey, massive, aphanitic, closely fractured and in places contains pillows. Intergranular, trachytic, subophitic, porphyritic and spherulitic textures are present. In little-altered rocks, plagioclase feldspar (albite to oligoclase) comprises 60 to 90 per cent of the rock and is associated with clinopyroxene (augite). In the altered rocks, the original nature of many feldspars can only be determined from grain shapes and textural relationships and any remaining feldspar is invariably albite. Typical alteration products are uralitic hornblende and actinolite, epidote, chlorite, calcite and saussurite. Alteration products found locally are prehnite, pyrite and pyrrhotite, and rarely pumpellyite and stilpnomelane.

Limestone (1e) is rare. It is typically interbedded with greenstone, and forms isolated, commonly lenticular, beds up to 100 feet thick. Exceptions are limestone in the lowest division (1a) that locally is up to 1,200 feet thick, and a limestone bed in the upper division (1d) that can be traced for 6 miles. Most limestone is fine grained but is recrystallized and the only primary structures known are rare oolites.

Structure and metamorphism

These rocks are deformed into folds with axes plunging gently to the northwest and southeast. The folds become tighter from southeast to northwest, with broad open and upright major folds in the southern part of the

outcrop area and tight and isoclinal folds farther north. Recumbent folds overturned to the northeast are developed in a few places, and a few northeast-trending small folds are known. The deformational style appears to be largely a function of lithology, as cherts are deformed into open wavy folds and complex crumples, or are locally brecciated, whereas greenstones are closely jointed, faulted and sheared.

The Hozameen Group is affected by general, low grade regional metamorphism, local higher grade metamorphism near the contact with the Custer Gneiss, and contact metamorphism near granitic intrusions. The regionally metamorphosed rocks contain generally fine-grained actinolite, epidote, chlorite, local prehnite and rare pumpellyite and stilpnomelane. They have undergone little textural modification and are considered to belong to the lowest part of the greenschist facies. The metamorphic grade of the Hozameen Group is comparable to that of the upper Paleozoic Chilliwack Group (unit 2) but differs slightly from it as the Chilliwack Group contains some minerals indicative of high pressure metamorphism. Near the contact with the Custer Gneiss the metamorphic grade reaches the middle part of the almandine-amphibolite facies. Cherts are metamorphosed to quartzite, pelites to garnet-biotite schist locally with kyanite, and greenstones to foliated amphibolites with actinolite alternating with layers of plagioclase (An_{25} to An_{40}). Near granitic intrusions, pelitic rock forms biotite, cordierite and andalusite hornfels. Calcareous rock forms marble containing garnet, vesuvianite, diopside and magnetite or wollastonite-labradorite-hornblende rock, and greenstone forms hornfels containing hornblende, plagioclase, garnet and biotite. Greenstones about 15 miles southeast of Hope, consist of biotite, actinolite and anthophyllite with mosaics of plagioclase granules (An_{30} to An_{35}) pseudomorphous after primary feldspar phenocrysts. This metamorphism may be either regional or due to granite intrusions.

The Hozameen Group is in fault contact with Jurassic rocks on the east. On the west it apparently grades over a very narrow zone, along which movement has taken place, into the Custer Gneiss (McTaggart and Thompson, 1967). It is intruded by Cretaceous and later plutonic rocks, and overlain by the Tertiary Skagit Formation.

Age and correlation

The age of the Hozameen Group is not known, as with the exception of possible brachiopods no fossils have been obtained from it (McTaggart and Thompson, 1967). It is believed to be of late Paleozoic age on the basis of certain lithological similarities to rocks of the Pennsylvanian and Permian Cache Creek Group north of the map-area, to the possibly Mississippian and Devonian Fergusson Group north-northeast of the map-area, and to the Chilliwack Group. The Cache Creek Group contains abundant chert and greenstone lithologically similar to that in the map-area, but differs in that limestone is a major part of it. The Chilliwack Group contains relatively abundant pyroclastic rock associated with greenstone, sandstone and limestone and far less chert, although the greenstone is similar to that in the Hozameen area. All of these differences could well be due to facies changes. Far more problematical is the absence of any fusulinids from limestones of the Hozameen Group, as these fossils are locally abundant in limestone of the

Cache Creek and Chilliwack groups and in many cases are preserved even when the rock is recrystallized. This absence would be accounted for if these rocks are pre-Pennsylvanian. Lithologically it is very similar to the Fergusson Group of the Bridge River area, 100 miles west-northwest of the map-area. This is composed of argillite, chert, greenstone and minor quartzite and limestone (Cairnes, 1937; Leech, 1953). The limestones similarly contain no fusilinids. The age of the Fergusson Group is possibly Mississippian and Devonian. Leech (p. 21) and H. W. Tipper (pers. comm.) found, respectively, probable Mississippian and Devonian fossils in limestone clasts in a Triassic or Jurassic conglomerate. According to Tipper the source of these clasts is the nearby Fergusson Group. If the two units are correlative then the problem of the age of the Hozameen Group is resolved.

Another alternative is that the Hozameen Group is stratigraphically equivalent to the Upper Triassic Nicola Group. This is considered to be unlikely as in addition to the Nicola Group containing an abundance of pyroclastic rocks and little chert, the volcanic flow rocks are lithologically unlike the greenstone in the Hozameen Group. The closest outcrops of Nicola rocks, just 20 miles east of the thick volcanic division (1b) of the Hozameen Group, are predominantly porphyritic andesites and although they range from acid andesite to basalts, both extremes are rare (Rice, 1947, p. 11), whereas the Hozameen greenstones are generally equigranular and altered basalts or andesitic basalts.

Chilliwack Group

The Lower Pennsylvanian to Lower Permian Chilliwack Group (unit 2) consists of little metamorphosed pelite, sandstone and minor conglomerate, pyroclastic rock, altered basic volcanic rock known as greenstone, limestone and minor chert. The group was named by Daly in 1912 from the extensive outcrop area of these rocks around the Chilliwack Valley, in the southwestern part of the map-area. Other rocks belonging to this group are exposed east of the southern part of Harrison Lake, near Agassiz, and on the south side of the Fraser Valley near Cheam View Station (Daly, 1912; Cairnes, 1944; Monger, 1966).

There are five stratigraphic and lithologic divisions in the group in the Chilliwack Valley west of the fault zone that runs approximately north-south and crosses the valley seven miles below Chilliwack Lake. The oldest division (2a) consists of pelite, siltstone and fine-grained sandstone whose stratigraphic base is nowhere exposed in the map-area. Its apparent thickness ranges from 1,000 to 2,500 feet. Overlying this division with a gradational contact is Lower Pennsylvanian limestone (2b) that is commonly about 100 feet thick and locally absent. Disconformably (?) above this is a clastic division (2c) of pelite, sandstone, and minor conglomerate and tuff, ranging in thickness from 450 to 800 feet. This division is conformably overlain by Lower Permian limestone (2d) whose thickness is generally 200 to 300 feet, but locally may be as much as 2,000 feet. The uppermost division (2e) consists of greenstone, pyroclastic rock and minor chert that in places conformably overlies the Lower Pennsylvanian limestone and elsewhere is stratigraphically equivalent to it. Thickness of this unit ranges from 200 to 2,000 feet.

Lithology

Pelite is most abundant in the lowest division (2a) but comprises the major part of the clastic sequence (2c) overlying the Lower Pennsylvanian limestone. It is hard, locally siliceous, dark grey to black and is either massive or thinly bedded.

Sandstone is prominent in the clastic division (2c) where it is typically coarse or medium grained and occurs in massive beds. In the lowest division (2a) it is fine grained, grades into siltstone and forms thin, graded beds within the predominant pelite. The sandstone is typically tan weathering, grey or grey-green, poorly sorted and composed of angular fragments derived mainly from volcanic rocks. Commonly predominating are fragments of basic to intermediate volcanic rock and plagioclase feldspar (mainly albite or oligoclase) that may be wholly or partly altered to carbonate or clay minerals. These are associated with chert clasts and pelite chips. Quartz is notably rare or absent. Sandstone near the top of unit 2c contains shards and pumice fragments and is gradational with lithic tuff.

Conglomerate, in unit 2c forms massive beds typically a few feet thick, but locally up to 100 feet thick. It consists of well-rounded cobbles of volcanic rock, chert, and locally limestone in a matrix of sandstone similar to that described above.

Limestone in the Chilliwack Group is mainly recrystallized. The Lower Pennsylvanian limestone (2b) is medium to dark grey, argillaceous, and where the primary texture is preserved, is a calcarenite (Powers, 1962). Most characteristic of this limestone are large crinoid columnals commonly an inch or more in diameter. The Lower Permian limestone (2d) is generally light grey, massive, locally dolomitic and contains large, dark grey chert nodules. Preserved textures indicate that the original rock was an aphanitic or calcarenitic limestone. The uppermost part is locally tuffaceous and contains numerous fusulinids and crinoid columnals.

Volcanic rock is of two main types, altered basalt or andesitic basalt, known as greenstone, and pyroclastic rock, some of which is dacitic. It comprises division 2e, although a few tuff beds occur just below the Lower Permian limestone (division 2d).

The greenstone is grey-green, massive and typically structureless, although pillows occur in a few places. It is commonly very fine grained and consists of randomly oriented, interlocking laths of altered plagioclase feldspar, making up 80 to 90 per cent of the rock, scattered intergranular or phenocrystic clinopyroxene grains, forming 10 to 20 per cent, and interstitial chlorite and opaque minerals. The feldspar is typically saussuritized and the composition of any plagioclase remaining is albite. The pyroxene is mainly fresh and may be highly fractured, and in many examples is in ophitic or subophitic relationship with the feldspar. Chlorite is common interstitial, fills veins and vesicles and in some rocks is associated with pumpellyite. Calcite occurs in vesicles or rarely, as patches in the groundmass. Skeletal ilmenite (?) displaying all stages of alteration to leucoxene and finely granular sphene is ubiquitous and may make up to 10 per cent of the rock. Some brownish grey or maroon varieties contain fine-grained hematite. Although no chemical analyses are available for these rocks, texturally and mineralogically they have more in common with basalts than andesites. Mineralogical assemblages are those of spilites, but typically this appears to be due to

saussuritic alteration of the anorthite part of the plagioclase, leaving albite pseudomorphs containing saussurite, rather than to any excess of sodium in the rock.

The most prominent pyroclastic rock is hard, massive, unsorted pale green to olive-green, quartz-bearing crystal-vitric dacite tuff. This rock consists of 40 to 60 per cent pale green altered euhedral to subhedral feldspar, 5 to 10 per cent euhedral, bipyramidal, embayed quartz and a variable but subordinate amount of lithic and vitric fragments, in a fine-grained matrix. It grades with decreasing grain size into pale green silicified tuff resembling chert. Other pyroclastic rock contains lithic clasts up to 6 inches in diameter, together with altered vitric clasts.

Pale grey, green, white and maroon thin-bedded chert with argillaceous partings is locally interbedded with these volcanic rocks, but is never abundant.

Elsewhere in the map-area the Chilliwack Group has not been subdivided. Rocks east of the fault crossing the eastern end of Chilliwack Valley, are amphibolites, some of which contain relict volcanic textures, cherty pelites and some limestone pods, in part contact metamorphosed by the Chilliwack Batholith. Structures in a hornfelsed rock of this sequence near the contact with the Chilliwack Batholith on Williams Peak and to the south, closely resemble altered Permian fusulinids (T. Richards, pers. comm.). Volcanic rocks and limestone outcrop southwest of Agassiz (Mathews, 1947, p. 507), an association that suggests that these rocks are correlative with Permian limestone and volcanic rocks (divisions 1d, 1e) exposed on the south side of the Fraser River, south of Agassiz. Limestone interbeds in cherty pelite on Bear Mountain at the south end of Harrison Lake, contain large crinoid columnals, and are probably of Pennsylvanian age (Crickmay, 1930a, p. 38). Phyllites and basaltic rocks outcropping on the south side of Fraser River near Cheam View Station, and rocks exposed on the east side of the southern part of Harrison Lake, called Slollicum Series by Crickmay in 1925, are tentatively correlated with the Chilliwack Group on the basis of lithological similarities (Orr, 1967; B. Lowes, pers. comm.).

Structure and metamorphism

The Chilliwack Group in Chilliwack Valley is highly deformed, having undergone at least two episodes of deformation. It was initially folded, together with Mesozoic rocks, and thrust to the northwest on at least two or possibly three major thrust faults. Folds related to this episode are tight and isoclinal and overturned to the northwest or recumbent, with fold axes trending northeasterly. A penetrative axial plane cleavage was developed in all clastic rocks during this episode. These structures were refolded and faulted during the later, minor, deformational episode, which caused the common northeast plunge of early fold axes, and the northeasterly dip of bedding and planar structures produced during the first episode (Fig. 4). Minor folds produced during the second episode are conjugate or chevron folds with northwest-trending axes, and major structures are large asymmetric antiforms and reverse faults with northeast-dipping fault planes. The structure of the rocks in the other outcrop areas is not known.

These rocks belong to the lowest part of the greenschist facies, perhaps transitional to the glaucophane schist facies reported from south of the map-area by Misch (1966, p. 109). Feldspars in volcanic rocks are saussuritized, pyroxenes little altered, chlorite ubiquitous and pumpellyite present locally. Some feldspars in dacite tuffs are altered to fine-grained, optically irresolvable lawsonite, a mineral that characterizes the glaucophane schist facies (Monger, 1966).

Textural alteration, mainly in clastic rocks, is due to the early deformational episode, and becomes more intense from west to east. A penetrative fracture cleavage parallel to the axial plane of early folds is developed in pelitic and tuffaceous rocks west of the thrust fault that crosses Tamihi Creek, whereas coarser sandstones are little altered. East of and above this thrust the pelitic rocks have a slaty or phyllitic axial plane cleavage and grains in coarser clastic rocks are flattened, producing a crude foliation.

Exceptions to this regional metamorphism occur along the contact with the Chilliwack Batholith, where pelitic rock is converted to cordierite-biotite hornfels. In addition, greenstones near the contact are fine grained amphibolites although this change may be due mainly to regional rather than the contact metamorphism.

The Chilliwack Group is overlain disconformably by Upper Triassic rocks of the Cultus Formation. Bedding on both sides of the contact is parallel and both Mesozoic and Paleozoic rocks appear to have undergone two deformational phases and the same degree of metamorphism. The basal contact of the group is not known from the map-area, as the oldest rocks in the formation overlie younger rocks on a thrust fault.

Fossils, age and correlation

Fossils occur in all divisions of the Chilliwack Group but are rarely abundant (Table I). Of these only fusulinids in the Lower Pennsylvanian and Lower Permian limestone give precise stratigraphic ages.

The fusulinid faunas allow fairly precise correlation with other units in the Western Cordillera. Lower Pennsylvanian limestone outcrops extensively in northwestern Washington, southwest of the map-area (Danner, 1957). Limestone of the Cache Creek Group at Harper Ranch, east of Kamloops, British Columbia and the Coffee Creek Formation of Suplee, Oregon are of the same age (J. W. Skinner, personal communication with W. R. Danner). Plant fossils of Pennsylvanian age, described by Merriam and Berthiaume (1943) and Maymay and Read (1956) in clastic rocks overlying the Coffee Creek Formation are possibly equivalent in age to the plant fossils in division 2c, that similarly overlies Lower Pennsylvanian limestone. Lower Permian limestone outcrops southwest of the map-area and contains similar fusulinids to those in division 2d (Skinner and Wilde, 1966). Lithologically the Chilliwack Group is somewhat similar to the Hozameen Group (unit 1), although it contains more clastic material.

TABLE I

Fossils in the Chilliwack Group

Division	Fossils	Age
2e	Fusulinids (Parafusulina ?), crinoids	Early Permian
2d	Fusulinids (Schwagerina, Pseudofusulinella Parafusulina), corals, bryozoa, brachiopods crinoids	Early Permian (Leonardian, possibly latest Wolfcampian)
2e	Plant fragments (Lepidodendron, Calamites), bryozoa, brachiopods, pelecypods, gastropods, cephalopods, crinoids[1]	Pennsylvanian or Early Permian
2b	Fusulinids (Millerella, Eostaffella)[2] corals, bryozoa, brachiopods, crinoids	Early Pennsylvanian (Probably Morrowan)
2a	Gastropods, pelecypods, crinoids	Early Pennsylvanian and (?) older

Detailed fossil localities given by Monger, 1966.

[1] Daly, 1912, pp. 511-512, collections 1512, 1514.

[2] Identified by J. W. Skinner, in personal communication with W. R. Danner.

UPPER TRIASSIC STRATIFIED ROCKS

Nicola Group

The small area of Upper Triassic Nicola Group (unit 3) in the northeast of the map-area is underlain by schistose, dark green, locally massive, altered intermediate to basic hornblende, augite and feldspar porphyry, associated with minor pelite, calcareous rock and quartzite (Cairnes, 1923, 1924, 1944). These rocks originally were assigned to the Tulameen Series of Camsell (1913). Subsequent mapping has shown them to be continuous to the east and northeast with the extensive Nicola Group in Princeton and Nicola map-areas (Rice, 1947; Cockfield, 1948).

The unit strikes roughly parallel to the contact with foliated granodiorite (unit 13) which intrudes it on the west, and dips northeasterly at steep angles. Near the contact the Nicola Group is cut by numerous sills, recrystallized, and locally mineralized with iron and copper sulphides. Northeast of the map-area it is overlain by late Lower Cretaceous volcanic rocks of the Kingsvale Group.

Fossils found in the Nicola Group to the east and northeast of the map-area are of Upper Triassic age (Rice, 1947 and Cockfield, 1948).

TRIASSIC AND JURASSIC STRATIFIED ROCKS

Cultus Formation

The Cultus Formation (unit 4) is an undivided sequence of pelites and predominantly fine-grained sandstones that contains Upper Triassic and Lower and Upper Jurassic fossils. It has an apparent thickness of 4,000 feet (Monger, 1966). The name was given by Daly (1912) to rocks exposed near Cultus Lake. No physical break has been recognized between Lower and Upper Jurassic rocks and as the sequence is relatively homogeneous it is all included in the same formation.

Lithology

Pelitic rocks are most abundant, followed by siltstones and fine-grained sandstones. Coarse sandstones and fine breccias are not uncommon, cherty pelites and limestone pods occur at a few localities and volcanic rocks are known from one outcrop.

The clastic rocks typically form regularly alternating graded beds ranging in thickness from siltstone laminations in pelites to sandstone beds about 4 inches thick. Small load casts are common at the base of individual graded beds and convoluted and crossbedded laminae are seen rarely at the tops of beds. The pelitic component ranges from argillite in the western (authochthonous) part of the outcrop area to phyllite in the eastern (allochthonous) part. It is typically dark grey and brown weathering. The sandstone component consists of varying proportions of angular volcanic fragments, plagioclase feldspars, shale chips and minor limestone fragments. Where volcanic clasts predominate the sandstone is dark grey or grey-green and where feldspar is abundant it is light grey. All these rocks weather brown, buff or brownish grey. The volcanic fragments show tuffaceous textures or are altered basic to intermediate lava fragments composed of saussuritized (?) feldspar microlites. Unaltered feldspars are albite and altered feldspars may be in part carbonate or, locally, optically irresolvable lawsonite. Some carbonate grains have the microstructure characteristic of echinoderm skeletal material. Typically quartz is absent or rare, although clear 'volcanic' (beta) quartz locally occurs. These rocks are typical volcanic sandstones, perhaps largely derived from a pre-existing volcanic terrane.

Other varieties in the sequence are rare. Hard cherty pelites occur near the basal contact in several places, and locally contain thin shaly limestone pods. Variolitic lavas, exposed at one outcrop 4 miles east-northeast of Vedder Crossing, consist of grey-green pillows composed of small radiating aggregates of plagioclase (An_0-An_{20}) in chlorite.

Rocks exposed on the west shore of the southernmost part of Harrison Lake, called the Camp Cove Series by Crickmay in 1925, are tentatively included in the Cultus Formation and mapped as unit 4?. The sequence consists of about 2,000 feet of sandstone and black argillite overlain by several hundred feet of tuff. In places above this is a conglomerate containing well-rounded cobbles of crinoidal (Pennsylvanian ?) limestone, green chert and green altered igneous rocks. The whole is overlain by Middle

Jurassic volcanic rocks. Possibly these rocks are correlative with the conglomerate-bearing division 2c of the Chilliwack Group, rather than the Cultus Formation.

Greenstone and phyllite on the east side of Harrison Lake that composed the Slollicum Series of Crickmay (1925, 1930a) are believed by B. E. Lowes (pers. comm.) to be part of the Chilliwack Group, and are mapped as such here.

Structure

The Cultus Formation is highly deformed, having undergone two phases of folding and faulting, and structures in it are comparable to those in the underlying upper Paleozoic Chilliwack Group (See Fig. 4). Although the lack of marker horizons prevents the definition of major structures, minor structures are common. The early phase of deformation produced tight northeast-trending folds, overturned to the northwest, and major thrust faults. Parallel to the axial plane of these folds is fracture cleavage (or reticulate cleavage of Crook, 1964) in the westernmost autochthonous, part of the unit and slaty or 'phyllitic' cleavage in the eastern allochthonous, part. The later deformation is evidenced by conjugate and chevron folds and reverse faults that trend northwesterly.

The Cultus Formation disconformably overlies the Chilliwack Group. Bedding at the base of the sequence conforms to that in the underlying rocks. The contact in many places is marked by a breccia apparently largely derived from underlying Permian volcanic rocks. No upper stratigraphic contact of the sequence in the Chilliwack Valley is known.

Fossils, age and correlation

Fossils diagnostic of the Upper Triassic (Upper Karnian and lower Norian), Early Jurassic (Sinemurian), and Late Jurassic (late Oxfordian-early Kimmeridgian) (one locality) have been found in the Cultus Formation (Monger, 1966).

The only other fossils known are rare, unidentified gastropods, clams, crinoid ossicles and trace fossils such as worm borings and trails. Daly (1912) found the ammonoid Stephanoceras and the pelecypod Aucella erringtoni, respectively of Middle and Upper Jurassic age, from 2 miles south of the International Boundary, south of Tamihi Creek, in rocks that he called the Tamihy Series. These rocks have been re-named Nooksack Group by Misch (1966) and are correlative with the upper part of the Cultus Formation.

The uniform lithology and paucity of fossils does not allow the formation to be subdivided into members or biostratigraphic units. The Upper Triassic part of the formation can be correlated with the Karnian to Norian Haro Formation of the San Juan Islands, Washington, to the southwest of the map-area, with Triassic rocks on Texada Island, 130 miles to the northwest and with the Nicola Formation (unit 3) to the northeast. The Haro Formation consists of volcanic-clastic rocks with some limestone, whereas

TABLE II

Fossils in the Cultus Formation

Location	Fossils	Age
3/4 mile southwest Mount Pierce	Pelecypod, Buchia, ex. gr. concentrica (Sowerby) (=B. bronni Lahusen, non? Rouillier, 1847)[1]	late Oxfordian-early Kimmeridgian (Late Jurassic)
3 miles east-southeast Mount Thurston	Ammonoid, Melanhippites?[2]	Sinemurian (Early Jurassic)
North side Church Mountain	Pelecypod, Halobia dilata Kittl[3]?	probably early, possibly middle, Norian (Late Triassic)
Northeast side Liumchen Creek, 4 miles south of Chilliwack River	Ammonoid, Hannaoceras c. f. H. (Sympolycyclus) nodifer (Hyatt and Smith) This ammonoid associated with fragmentary belemnites and pelecypods.	late Karnian (Late Triassic)
2 miles east-northeast of Mount Thurston, and 900 yards west-southwest of Monument 47, International Boundary	Belemnite Aulococeras c. f.[4] A. Carlottense Whiteaves	Late Triassic

Detailed localities are given by Monger, 1966.

[1] Identified by J. A. Jeletzky, Geological Survey of Canada

[2] Identified by H. Frebold, Geological Survey of Canada

[3] Identified by G. E. G. Westermann, McMaster University

[4] T. W. Stanton in Daly (1912) and author.

the rocks on Texada Island are a volcanic limestone assemblage and the Nicola Group is largely a volcanic sequence. The Lower Jurassic rocks can possibly be correlated with the lowest part of the Ladner Group of Coates (in press). Middle Jurassic volcanic rocks near Harrison Lake are tentatively correlated with the variolitic lavas in the Cultus Formation. Upper Jurassic rocks in the Cultus are of similar lithology to the Agassiz Prairie Formation

(unit 11), equivalent to the Dewdney Creek Group (unit 12) of Coates (in press) and to part of the Upper Jurassic-Lower Cretaceous Nooksack Group of Misch (1966).

LOWER AND MIDDLE JURASSIC STRATIFIED ROCKS

Ladner Group

The Jurassic Ladner Group (unit 5) is a sequence of pelite, less abundant volcanic sandstone, minor conglomerate and local volcanic rock with an apparent thickness of about 6,000 feet (Cairnes, 1924; Coates, in press). The name Ladner Series was given to this unit by Cairnes in 1924 from Ladner Creek, 12 miles northeast of Hope.

Lithology

Slate is the characteristic rock type in the unit between Boothroyd - 4 miles south of the northern border of the map-area in the Fraser Canyon - and a point 15 miles southeast of Hope. The slate is dark to light grey, weathers brown, and commonly contains paler grey siltstone laminae. Cleavage surfaces are lustrous and generally oriented parallel to bedding. The darker slates are carbonaceous and may contain pyrrhotite. Beds of massive sandstone interbedded with the slate are of two types. Most abundant are very dark grey volcanic sandstones composed of angular grains of volcanic and cherty felsitic rocks, abundant fresh feldspars, minor quartz grains set in a fine, dark, almost isotropic groundmass. The second type consists of feldspar fragments, quartz crystals and argillite chips in a fine-grained, grey siliceous matrix. Cairnes (1924, p. 48) believed that the two types originally were similar, with the second type derived from the first by silicification. Beds of conglomerate, one of which is close to the contact with the Hozameen Group, contain pebbles of siliceous rock, in part probably quartz porphyry, minor diorite and gabbroic rock in a slaty matrix.

In the southeastern part of the map-area and to the southeast, in Princeton map-area, the unit consists mainly of volcanic sandstones and pelites (Coates, in press). This part of the group is separated from the more southeasterly part by rocks shown as Dewdney Creek Group by Cairnes (1944), but which may well include Ladner Group, as detailed mapping by Coates has shown the Ladner Group to trend directly into this area. In addition to the pelites and volcanic sandstones are local, interbedded lava flows and pyroclastics. Graded beds, groove casts and flute casts indicate that the Ladner Group, like the Cultus Formation, was deposited by turbidity currents.

Structure

The unit appears to form a major syncline whose axis trends north-northwesterly. In the north the axis passes just east of the confluence of Ladner Creek and Coquihalla River (Cairnes, 1924). North of Coquihalla River the easterly limb is apparently cut off by granodiorite of unit 24. Here the southwesterly limb has an apparent thickness of 6,000 feet. Smaller folds

are associated with reverse faults, and bedding and slaty cleavage dip predominantly to the southwest and at high angles. In the southeastern part of the map-area the Ladner Group forms the steep-dipping western limb of a major syncline called the Gibson Pass Syncline (Coates, in press). This appears to be the south-southeasterly continuation of the syncline to the north. Where well exposed in southwestern Princeton map-area, the steep dipping western limb of the syncline is complemented by an eastern limb dipping southwesterly at moderate angles, which is truncated by reverse faults.

The contact of the Ladner Group with the Hozameen Group is believed to be a fault, although Cairnes (1924) stated that the Ladner unconformably overlay the Hozameen Group. In the southeast part of the map-area, detailed mapping by McTaggart and Thompson (1967) and Coates (in press) shows that the vertical or steeply dipping, reverse (?) Hozameen Fault separates the two units. In the north, near Boston Bar, a fault separates metamorphic rocks (unit Ba) from the Ladner Group. As the contact between the Hozameen and Ladner groups in the area between these two faults is remarkably straight and marked by serpentinite (unit Aa) for most of its length, the contact between two units is shown as an assumed fault rather than a stratigraphic contact.

The Ladner Group is separated from the overlying Dewdney Creek Group either by a disconformity or a low-angle unconformity in the southeast of the map-area (Coates, in press). Farther north, it appears conformably to underlie rocks mapped as Dewdney Creek Group (Cairnes, 1924). In the northern part of the map-area the Ladner Group is in contact with the Jackass Mountain Group. Discordant bedding attitudes on each side of the contact suggest that there is either an unconformity or a fault between the two (Roddick and Hutchison, 1969).

Age and correlation

The age of the group is problematical, at least in the northernmost three-quarters of the belt. In the southeast, the group contains ammonites of Early and early Middle Jurassic age (Bajocian, Toarcian and possibly Sinemurian; Coates, in press and Frebold, Tipper and Coates, 1969). Farther north Cairnes (1924, p. 52) collected belemnites of "probably either Jurassic or Lower Cretaceous" age. As fossils collected from the overlying Dewdney Creek Group were more probably Jurassic than Cretaceous, Cairnes concluded that the Ladner Group was of Jurassic age. However, Cairnes also noted that rocks here mapped with the Ladner Group from near Boston Bar had some lithological similarities to the Upper Triassic rocks east of the map-area.

In the map-area at least some rocks of the Ladner Group can be correlated with the lower part of the Cultus Formation, to which they bear a lithological resemblance, both sequences being predominantly fine-grained turbidites. Possibly some rocks presently mapped as Dewdney Creek Group should be included here as Cairnes (1924, p. 65) found float containing ammonites of probably either Triassic or Lower Jurassic age on Tulameen Mountain.

MIDDLE JURASSIC STRATIFIED ROCKS

Harrison Lake Formation

Intermediate to acidic pyroclastic rocks and flows of probable Middle Jurassic age make up the Harrison Lake Formation (unit 6). The type section, measured along the west shore of Harrison Lake between 5 and 12 miles north of the outflow at the south end, has an apparent thickness of 9,240 feet (Crickmay, 1925).

Lithology

Pyroclastic rocks appear to exceed flow rocks in abundance (Crickmay, 1925; Burley, 1954). They are dark green, locally red, rocks varying from poorly stratified volcanic breccias containing blocks up to 1 foot in diameter to well-bedded tuffs. Both lithic and crystal tuffs are represented, and consist of lithic fragments, feldspar, and quartz with a little glass; carbonate, chlorite and epidote are alteration products. The plagioclase (An_0-An_{10}), in many cases altered to white mica, carbonate, chlorite and epidote, may make up 80 per cent of the rock. The quartz is embayed and corroded (Burley, 1954).

Flows in the sequence are dark green or dark grey, massive and locally contain columnar joints. Crickmay (1925, p. 55) described flow rocks that are porphyritic in the lower part, grade up into nonporphyritic rock and are brecciated at the top. The commonest rock is porphyritic and contains variable amounts of feldspar with or without quartz phenocrysts set in a fine-grained spherulitic, intersertal or trachytic matrix composed largely of plagioclase (An_0-An_{10}) commonly contains carbonate and white mica alteration products but little epidote. The quartz phenocrysts are rounded and corroded and in many places surrounded by a reaction rim of sodic feldspar and quartz (Burley, 1954).

No consistent petrographic term is applied to these rocks. On the one hand, Burley (1954), working in the southernmost part of the outcrop area, 4 miles east of Harrison Mills, called them keratophyres and quartz keratophyres. He believed the albitic feldspar was primary and not the result of saussuritization, citing as evidence the lack of relict calcic feldspar textures and the presence of only minor amounts of epidote in the rocks. On the other hand, Roddick (1965 and pers. comm.) in describing essentially similar rocks from the Chehalis River valley immediately west of the main outcrop area of the formation used the terms meta-andesite and dacite. He believed that the original andesites were subjected to low-temperature sodium metasomatism as the feldspar, now albite, contains broad twin lamellae characteristic of andesine-labradorite plagioclases.

Structure

The unit is folded into broad, open, roughly northeast-trending folds. Dips range from horizontal up to 70 degrees. Faults are common. The base of the formation is exposed on the west side of Harrison Lake, above rocks

of unit 4? (the Camp Cove Series of Crickmay, 1925). The unit is conformably overlain by the Echo Island Formation.

Fossils, age and correlation

The Harrison Lake Formation contains brachiopods and cephalopods of Middle Jurassic age (Crickmay, 1930b, 1962; Frebold, pers. comm., below).

Three miles northwest of Harrison Hot Springs fossils in sedimentary strata both overlain and underlain by the Harrison Lake Formation were described by H. Frebold (pers. comm.) as follows:

"There are several fossil horizons in these beds. One, probably the oldest one hitherto found, contains predominantly pelecypods and poorly preserved gastropods. Among the pelecypods are pectinids, Oxytoma, Astarte, Parallelodon, Trigonia. Younger than this bed are beds with ammonites and a few pelecypods. About 20 feet above the ammonite horizon follow several beds with belemnites.

"The age of the fauna. Crickmay (1930, p. 38) mentioned from his locality 3 Rhynchonella sp., Entolium volcanicum Crickmay, and Cylindroteuthis themis Crickmay. He determined their age as Middle Jurassic (Crickmay, 1930b, p. 37). Entolium volcanicum Crickmay was placed in the Bajocian. 'The species was an inhabitant of the powerfully volcanic British Columbia of Bajocian times' (Crickmay (loc. cit., p. 52). The same age would apply to Rhynchonella sp. and Cylindroteuthis themis as they occur in the same bed as Entolium volcanicum.

"Crickmay's age-determination may have been considered as somewhat doubtful because it is based on two new species of two long ranging genera and indeterminable fragments of Rhynchonella.

"The ammonites found by the author are poorly preserved. No complete specimen was collected and neither the cross-section nor details of the keeled venter could be observed. Nevertheless the general outline and the ribbing assign most of them to various species of the Genus Fontannesia Buckman of the Family Sonninidae Buckman.

"Several species of this genus have been described, particularly from Western Australia (Arkell, 1956), and some of these 'species' are represented in the Harrison Lake fauna. There are specimens with rarely divided and more blunt ribs and others with more often biplicate ribs, but they are too poorly preserved to warrant specific identification. One of the smaller species found at GSC locality 25778 has an ear preserved. It compares very well with Buckman's (1887-1907) Fontannesia curvata (plate 47, figure 1) which shows the same kind of ear. Some of the 'species' have been found at all the here considered Harrison Lake ammonite localities thus demonstrating the same age of the beds concerned.

"Arkell (loc. cit., p. 597 and elsewhere) has already mentioned the great similarity of some species of Fontannesia to some Grammoceras of the Upper Toarcian. 'Between some of them there is almost perfect homoeomorphy'. Arkell's findings are fully substantiated by the author who was at first inclined to consider this Harrison Lake fauna as Upper Toarcian.

"Only at GSC locality 25782 = 27999 fragments of another ammonite were found which could belong to the Otoitidae.

"The genus Fontannesia is characteristic of the early Sowerbyi Zone of the Middle Bajocian.

The age of the volcanics

"As the Middle Bajocian Fontannesia beds form a marine deposit within the volcanic rocks (unit 6), as volcanics above the Fontannesia beds are overlain by Callovian their age is mainly Bajocian, perhaps also Bathonian. The part of the volcanics beneath the Fontannesia beds may also be in part of Early Jurassic (Toarcian?) age."

In the map-area the unit possibly can be correlated with the outcrop of variolitic volcanic rocks included in the Cultus Formation and with volcanic rock in the Ladner Group. Misch (1966) mapped andesite grading into keratophyre and dacite, called the Wells Creek volcanics, 24 miles due south of the southernmost outcrop of Harrison Lake Formation.

Echo Island Formation

The Echo Island Formation (unit 7) consists of tuff, with minor agglomerate, sandstone and argillite and is probably of Middle Jurassic age. It was named by Crickmay in 1925 from the southeastern part of Echo Island. The total computed thickness is 2,769 feet.

The formation is characterized by its excellent stratification, and contrasts with the conformably underlying Harrison Lake Formation in its predominantly fine-grained nature and absence of intercalated flows. It appears to represent the waning stages of the Middle Jurassic volcanism.

Fragmental pelecypods and belemnites in the formation are inadequate for correlation (Crickmay, 1925). However, as it is conformable to, and probably genetically related to, the underlying Harrison Lake Formation it is considered to be of probable Middle Jurassic age. It appears to be included in the Upper Jurassic-Lower Cretaceous Fire Lake Group in the adjoining Pitt Lake map-area (Roddick, 1965).

Mysterious Creek Formation

The lower Upper Jurassic Mysterious Creek Formation (unit 8) comprises 2,300 to 2,900 feet of uniform black argillite. The unit was named from Mysterious Creek (now Mystery Creek) which enters the west side of Harrison Lake about 16 miles north of its outflow (Crickmay, 1925, 1962).

The formation is extremely uniform. With the exception of rare thin sandstone and limestone beds, and an increase in the arenaceous content at the top, it is monotonous black argillite.

The Mysterious Creek Formation conformably overlies the Echo Island Formation. It is conformably overlain by the Billhook Formation near Mystery Creek on the west side of Harrison Lake and with a slight angular unconformity by the Kent Formation at the south end of Harrison Lake.

The unit is of Callovian age. It contains several faunas composed mainly of ammonites that are described by Crickmay (1930b, localities 8, 9, 10, 11, 12, 13, 14 and 15). It is included in the Fire Lake Group in the adjoining Pitt Lake map-area (Roddick, 1965). South of Fraser River it can possibly be correlated with rocks in the upper part of the Cultus Formation.

Billhook Creek Formation

The Upper Jurassic Billhook Creek Formation (unit 9) is composed of grey to green, fine-grained, well-bedded tuff and volcanic sandstone with an apparent thickness of 1,800 feet (Crickmay, 1930a, 1962). Originally Crickmay (1925) included this unit in his Kent Mountain Formation, although he expressed doubts about its equivalence. Later, in 1930, he introduced the name Billhook Formation and described the unit under this name in 1962. The term comes from Billhook Creek, which apparently is west of Long Island in Harrison Lake.

The formation conformably overlies the Mysterious Creek Formation. On the west side of Harrison Lake it is disconformably overlain by the Lower Cretaceous Peninsula Formation. A small area of tuff on the north slope of Mount Agassiz (Kent? Mountain) is correlated with the Billhook Formation and is overlain with slight angular unconformity by the Kent conglomerate of pre-Late Oxfordian (Argovian of Crickmay) age.

The unit contains cephalopods and pelecypods and is probably of Callovian age. The presence in it of "juvenile cadoceratoids" (Crickmay, 1962) indicates that it is of Callovian age (Frebold, pers. comm.).

UPPER JURASSIC STRATIFIED ROCKS

Kent Formation

The Upper Jurassic Kent Formation (unit 10) consists largely of conglomerate with minor interbedded shale and sandstone. It has a thickness of 3,060 feet and is named after the municipality of Kent (Crickmay, 1925, 1962).

The conglomerate is poorly sorted and contains clasts up to 8 inches in diameter. It contains cobbles of micropegmatite, quartz feldspar porphyry derived from the Harrison Lake Formation, tuff, quartzite, chert and argillite.

The formation lies unconformably on the Mysterious Creek Formation and is conformably overlain by the Agassiz Prairie Formation. No fossils are known from it, but as it is above Callovian and below Upper Oxfordian (Argovian) beds it is probably of early Late Jurassic age.

Agassiz Prairie Formation

Black, uniform, gypsiferous argillite with interbeds of sandstone, tuff and limestone make up the Upper Jurassic Agassiz Prairie Formation (unit 11). The total apparent thickness is 4,000 to 5,000 feet (Crickmay, 1925, 1962). The name is taken from Agassiz Prairie, on which the town of Agassiz is built.

The formation conformably overlies the Kent Formation. Black argillite, correlated with the Agassiz Prairie Formation, unconformably underlies Lower Cretaceous rocks on the west side of Cascade Peninsula, Harrison Lake (Crickmay, 1962).

The precise age of this formation is controversial although it is Upper Jurassic. Only poorly preserved indeterminate fossils are found in the main part of the Agassiz Prairie Formation, but black argillites included in the formation at the south end of the west side of Cascade Peninsula contain cephalopods and pelecypods that according to Crickmay (1962) are Argovian (late upper Oxfordian). Frebold (pers. comm.) feels that there is no proof of an Oxfordian age for the unit and it may well be younger, whereas Jeletzky and Tipper (1968, p. 68) believe it is early Oxfordian. This unit probably can be correlated with the upper part of the Cultus Formation south of Fraser River, which it resembles, with the lower part of the Nooksack Group of Washington State, the lower part of the Fire Lake Group in Pitt Lake map-area and the Dewdney Creek Group of Coates (in press).

Dewdney Creek Group

It is not possible to give a single generalized description of the Dewdney Creek Group (unit 12). Cairnes (1924) gave the name to a sequence of tuffs and tuffaceous sediments about 11,000 feet thick that overlie the Ladner Group. He assigned these rocks to the Upper Jurassic on paleontological, structural and lithological evidence, but noted that on paleontological grounds alone the unit could be Lower Cretaceous. Recently, Coates (in press), on the basis of numerous fossil collections, restricted the term Dewdney Creek Group to an Upper Jurassic sequence of volcanic sandstone and pelite. This restricted unit in the southeast of the map-area is shown as unit 12a. The Dewdney Creek Group of Cairnes (1924) adjoins Coates' unit to the north and is mapped as unit 12b. It probably includes rocks shown by Coates to be (his) Lower to Middle Jurassic Ladner Group and (his) Lower Cretaceous Jackass Mountain Group. The type area of the group is Dewdney Creek, which flows into the Coquihalla River 10 miles northeast of Hope.

Dewdney Creek Group in southeast part of map-area (unit 12a)

The Dewdney Creek Group of Coates is not more than 1,000 feet thick and consists of mainly fine-grained, well-sorted volcanic sandstone and sandy argillite with beds of pebble-conglomerate near the base. The rocks are derived in large part from volcanic rocks with just a trace of granitic material.

The unit overlies the Ladner Group disconformably or with low-angular unconformity. It is part of the east-dipping western limb of the Gibson Pass Syncline exposed in the adjoining Princeton map-area to the east.

Collections of pelecypods and cephalopods from this unit have been dated by J. A. Jeletzky (pers. comm. with Coates) as Upper Jurassic (upper Oxfordian to Portlandian). This enables the unit to be correlated with the upper part of the Cultus Formation and the Agassiz Prairie Formation in the eastern part of the map-area.

Dewdney Creek Group in northeast part of map-area (unit 12b)

The Dewdney Creek Group of Cairnes consists of 11,000 feet of thinly bedded to massive, extremely fine grained to coarse, waterlain tuffs and minor interbedded slate.

Cairnes divided the unit into three divisions. The lowest division, 4,000 feet thick, consists of green, mainly coarse grained crystal-lithic and lithic andesite tuff. Some rocks are granular and consist of lithic fragments, plagioclase feldspar and minor quartz together with fragments of black argillite and smoothly rounded felsitic grains. Others are massive, resemble lava flows in outcrop and consist of fragments of porphyritic lavas and minor feldspar. Both have a fine-grained, almost amorphous matrix containing microlites. The middle division, 3,500 feet thick, is dark grey to black, well-bedded, fine-grained crystal lithic tuff. Angular fragments of clear or partly altered feldspar, minor quartz and lithic fragments are in a fine-grained matrix that is more abundant than the matrix of tuffs of the lowest division. The upper division is 3,500 feet thick and is mainly fine grained vitric and crystal tuff with interbedded black slate. Some rocks are composed entirely of shards, whereas others consist of feldspar and quartz fragments in a fine-grained matrix.

These rocks lie in the core of a closely compressed syncline that is possibly the north-northeasterly extension of the Gibson Pass Syncline which is well exposed in the adjoining Princeton map-area. Numerous minor folds and faults in it are possibly related to the major syncline. In the area investigated by Cairnes (1924) the unit appears to be structurally conformable to the Ladner Group. It is overlain unconformably by rocks correlated with the Coquihalla Group of Cairnes (1924).

Cairnes assigned these rocks to the Upper Jurassic on the basis of paleontology, structural relationships and lithology. He collected cephalopods and clams from the unit. In addition to faunas which were "more likely Jurassic", he found fossils that occur in the Lower Cretaceous Pasayten and Jackass Mountain groups, and float with "probably either Triassic or Lower Jurassic" ammonites. Coates has shown that his Lower and Middle Jurassic Ladner Group, Upper Jurassic Dewdney Creek Group and Lower Cretaceous Jackass Mountain and Pasayten groups are separated by hiatuses in the area immediately south of the area mapped by Cairnes. It therefore seems probable that unit 12b is equivalent in part to all three units in the south, and that further mapping is necessary so that this unit can be subdivided. Possibly these pyroclastic rocks are in part equivalent to the Middle Jurassic Harrison Lake Formation to the west, and as such are older.

LOWER CRETACEOUS STRATIFIED ROCKS

Peninsula Formation

The Lower Cretaceous Peninsula Formation (unit 14) comprises 1,260 feet of sandstone and basal conglomerate. The type locality is Cascade Peninsula, Harrison Lake (Crickmay, 1925, 1962).

The bulk of the unit consists of dark grey to green, locally calcareous sandstone. At its base on Cascade Peninsula there is a white arkosic sandstone 185 feet thick that contains well-rounded pebbles of granite

(56 per cent), porphyry (19 per cent), chert (13 per cent) and quartzite (19 per cent). To the northwest where the formation crosses Mystery Creek on the west side of Harrison Lake, the pebble-bearing sandstone is replaced by a basal conglomerate 200 feet thick, in which the pale sandstone matrix forms a very minor part. Well-rounded pebbles in the conglomerate are mostly less than 4 inches in diameter and are composed of granite (37 per cent), porphyry (9 per cent), chert (23 per cent), black argillite (4 per cent) and sandstone (27 per cent). The porphyry, chert and black argillite clasts are similar to those in the Upper Jurassic Kent Formation, but the granite and sandstone appear in none of the earlier conglomerates in the area. The granite clasts consist mainly of quartz and orthoclase with minor plagioclase and hornblende as the only accessory. According to Crickmay (1925) the lithology of the granitic clasts is similar to that of the granitic rock exposed 7 miles west of Harrison Lake.

Tentatively included in this formation are conglomerates containing granitic clasts, sandstone, and pelites that outcrop on the east side of Vedder Mountain, in the southwestern part of the map-area.

The Peninsula Formation near Harrison Lake rests with slight angular unconformity on the Jurassic Agassiz Prairie, Kent and Mysterious Creek formations. It is conformably overlain by the Brokenback Hill Formation.

The formation is lower Lower Cretaceous in age. Abundant pelecypods and cephalopods in the sandy part of the formation are Neocomian (Crickmay, 1962) or more precisely Berriasian and lower Valanginian (Jeletzky, 1965, p. 65). Location and description of fossils are given by Crickmay (1925, 1930b, 1962). West of the map-area, the lower part of the Fire Lake Group of Roddick (1965) is probably equivalent to the Peninsula Formation.

Brokenback Hill Formation

The Lower Cretaceous Brokenback Hill Formation (unit 15) is composed mainly of pyroclastic rocks with minor sandstone and shales. It has an approximate composite thickness of 3,684 feet. The type locality is Brokenback Hill, which is the north-northeast trending hill on the west side of Harrison Lake, opposite the small lake on Long Island (Crickmay, 1925, 1962).

The formation contains both tuff and agglomerate, and conformably overlies the Peninsula Formation. Its top is not seen as it is in fault contact with older rocks to the east.

The age of the formation is Early Cretaceous. It contains a pelecypod and cephalopod fauna that is described by Crickmay (1925, 1930b, 1962). According to Jeletzky (1965, p. 65 and personal communication) the formation is of Valanginian and Hauterivian age, and may possibly include some still younger rocks. It is correlated with part of the Fire Lake Group to the west.

Jackass Mountain Group

The Lower Cretaceous Jackass Mountain Group (unit 16) consists largely of conglomerate and sandstone containing much granitic and gneissic detritus. It has a possible maximum thickness of 14,000 feet. The name was given by Selwyn in 1872 to conglomerate exposed in Fraser Canyon about 5 miles north of the map-area on the western slope of Jackass Mountain. There, marine and nonmarine strata form fault-bounded slices eroded by the Fraser River (Duffell and McTaggart, 1952). Cairnes (1944) showed the group extending from the northern boundary of the map-sheet, near the type locality, as far south as Coquihalla River. Rocks at the latter locality were originally mapped (Cairnes, 1924) with rocks of the Pasayten Group as "Lower Cretaceous rocks". Recently Coates (in press) on the basis of detailed mapping mainly just east of southern part of the map-area, restricted the term Jackass Mountain Group to marine Lower Cretaceous strata, and referred partly stratigraphically equivalent nonmarine strata to the Pasayten Group. As the Jackass Mountain Group in the northern half of the map-area may contain nonmarine strata, it is distinguished as unit 16a; the wholly marine strata mapped by Coates in the southeast of the map-area are called unit 16b.

Jackass Mountain Group in northeast part of map-area (unit 16a)

No detailed mapping has been done on the Jackass Mountain Group between Anderson River Mountain and the northern boundary of the map-area. Reconnaissance work by Roddick and Hutchison (1969) indicated that near Boston Bar the lithology of the group is comparable to that of Division C of Duffell and McTaggart (1952). The main lithology is dark, massive greywacke with local slabs and pebbles of black argillite and thinly bedded argillite and greywacke. Interbedded conglomerate consists of well-rounded cobbles of quartz-rich leucocratic granitic cobbles forming from 30 to 90 per cent of the whole rock, volcanic rock, argillite, quartzite, feldspar porphyry, chert and gneiss. The lithology of one gneiss cobble seen is identical to that of blocks forming the marginal phase of the quartz diorite pluton (unit 19) near Alexandra Bridge.

The Jackass Mountain Group near Boston Bar dips moderately to the east. Although the contact between it and the underlying Ladner Group is covered, the steeper dips of the latter suggest that the contact is either an unconformity or a fault.

Small, partly fault-bounded bodies of conglomerate and finer clastic rocks along Coquihalla River valley mapped by Cairnes (1924) together with rocks of the Pasayten Group were later shown by him (1944) as Jackass Mountain Group. The conglomerate consists of rounded cobbles up to 8 inches in diameter of granite and granodiorite, with a few basic pebbles, volcanic and sedimentary rock fragments and rare gneiss clasts.

Jackass Mountain Group in southeast part of map-area (unit 16b)

The Jackass Mountain Group in the southeastern part of the map-area consists largely of sandstone with minor conglomerate (Coates, in

press). The older beds consist of volcanic and metamorphic detritus whereas the younger rocks contain much granitic and gneissic material.

The group disconformably overlies the Dewdney Creek Group in the southeastern part of the map-area. Southeast of the map-area, it grades through a largely pelitic sequence into massive, coarse sandstone and conglomerate that intertongues with and is overlapped by nonmarine clastics of the Pasayten Group.

The age of the group is Lower Cretaceous. Unit 16b and its extension southeast of the map-area contains Hauterivian to Albian fossils (Coates, in press). North of the map-area, pelecypods, ammonites and plant fossils ranging in age from Barremian to Aptian have been collected from the group (Duffell and McTaggart, 1952).

Pasayten Group

The Lower Cretaceous Pasayten Group (unit 17) comprises 8,000 feet of conglomerate, sandstone and pelite (Cairnes, 1924). The name was given by Daly in 1912 to "Lower to Upper Cretaceous" rocks exposed on the International Boundary between 1 mile and 15 miles east of the southeast corner of the map-area. Coates (in press) has shown that the type-area of Daly's Pasayten Series included Lower to Middle Jurassic (Ladner), and Upper Jurassic (Dewdney Creek) rocks as well as Lower Cretaceous rocks. He restricted the Pasayten Group to nonmarine rocks and demonstrated that they intertongue with and overlie his marine Jackass Mountain Group. In the type-area, Coates' Pasayten Group has a thickness of up to 10,000 feet and is Albian or late Lower Cretaceous.

The Pasayten Group in the map-area contains no definite fossils but is so similar lithologically to some members of the Pasayten Group to the southeast that Cairnes (1924) had little hesitation in correlating them. However, since they are 10 miles to the northwest on strike with rocks belonging to both Jackass Mountain and Pasayten Group of Coates, they may well include both groups as defined by him. The unit consists of conglomerate containing volcanic, chert and greenstone clasts, that comprises about a quarter of the total section, and sandstone and pelite. The volcanic fragments in the conglomerate appear to have been derived from both Dewdney Creek (12b) and Hozameen Groups and the chert from the Hozameen Group.

On the west these rocks are in apparent fault contact with the Ladner Group (Cairnes, 1944). This fault is probably the northwesterly extension of the Chuwanten Fault of Rice (1947). On the east they are mainly in fault contact with the Eagle Granodiorite, but are locally intruded by a marginal diorite phase of the Eagle Granodiorite. They are intruded and contact metamorphosed by granodiorite (unit 24) of the Needle Peak Pluton on the north, and also overlain with marked unconformity by the Coquihalla Group (unit 23). To the south they are overlain by rocks tentatively correlated with rocks of the Coquihalla Group.

Kingsvale Group

Rocks correlated with the late Lower Cretaceous Kingsvale Group (unit 18) occur in the northeast corner of the map-area. This correlation is

made with confidence for these rocks are in continuity with rocks at the type locality, Kingsvale Station, located 7 miles south-southeast of the northeast corner of the map-area (Rice, 1947).

Rocks of the Kingsvale Group in the northeast of the map-area are basalt, andesite, agglomerate, tuff, minor arkose and greywacke (Cairnes, 1944). Adjacent rocks in Princeton map-area consist of a basal andesitic agglomerate containing clasts of older rocks and plant-bearing greywacke, arkose and tuffaceous sandstone. Overlying these rocks is pyroclastic breccia composed of angular fragments of green, pale buff or grey andesitic feldspar porphyry in a matrix of crystal lithic tuff, above which is purple, green, mauve, grey, black and dark brown andesitic and basaltic lava. The plant fossils found in the sequence are of Albian (late Lower Cretaceous) age.

CRETACEOUS AND/OR TERTIARY STRATIFIED ROCKS

Early Tertiary and ? Latest Cretaceous Clastic Rocks

Eocene conglomerate and finer clastic rocks form a series of small outcrop areas aligned in a north-south direction and extending from just north of Hope as far as the International Boundary and beyond (McTaggart and Thompson, 1967). These rocks were originally included by Cairnes (1924) in his "Lower Cretaceous rocks". In addition, a small outcrop of Early Tertiary rocks occurs near Vedder Crossing (Crickmay and Pocock, 1963).

Rocks near Hope

Conglomerate is the most abundant rock and forms almost all of the unit north of Hope. South of Fraser River, sandstone locally containing fossil plants becomes more common and is abundant near Chilliwack Lake. The conglomerate north of Hope contains well-rounded clasts up to 3 feet long, but averaging 0.3 to 1 foot, in an arkosic matrix. Clasts of plutonic rock are abundant and boulders of Custer Gneiss, mica schist, chert, limestone, white quartz and fresh sandstone resembling that of the Dewdney Creek Group are not uncommon. North of Hope these rocks are little metamorphosed; south of the river they are locally converted to hornfels and mylonitized.

North of Hope the unit is bounded on the east by a nearly vertical unconformity with gneiss, and on the west by the steep, north-south trending Hope fault (Read, 1960). Farther south, the eastern contact is with Custer Gneiss and dips at angles of up to 40 degrees to the west. The Hope fault locally bounds the unit on the east, as near Isolillock Peak, but elsewhere is destroyed by the Chilliwack Batholith, which is responsible for the contact metamorphism of the unit (T. Richards, pers. comm.).

Studies of pollen from the unit north of Hope, have shown these rocks to be Eocene (G. E. Rouse, in McTaggart and Thompson, 1967). They can possibly be correlated with the Chuckanut Formation to the southwest and the Princeton Group to the east.

Rocks near Vedder Crossing

Vertically dipping white feldspathic sandstone of latest Cretaceous or Paleocene age outcrops just east of Vedder Crossing (Crickmay and Pocock, 1963). The contacts with older rocks are covered. These rocks are correlative with the lithologically similar Chuckanut Formation to the south and southwest.

MIOCENE AND EARLIER STRATIFIED ROCKS

Skagit Formation

The Oligocene (?) Skagit Formation (unit 22) comprises at least 5,000 feet of andesitic to rhyolitic flows and pyroclastic rocks (Daly, 1912). The formation was named by Daly in 1912 from rocks exposed west of Skagit River.

The lower 4,000 feet of the formation consists of massive, andesitic breccias and tuffs, with interbedded flows and one conglomerate bed. The flows and lava fragments in the andesite are augite andesite composed of phenocrysts of plagioclase (An_{60}) and uralitized augite, in an altered matrix of chlorite, uralite, plagioclase microlites and possible altered glass. Other clasts in the pyroclastic rocks are fragments of the underlying rocks. A conformable conglomerate bed, 100 feet or more in thickness, was probably waterlain.

Acidic tuff, in the upper part of the sequence, is nearly white and very fine grained. In thin sections it is seen to be composed of a cryptocrystalline matrix of quartz and feldspar containing a few sanidine or orthoclase clasts.

These rocks are best dated as Oligocene. Immediately south of the map-area Misch (1966) found the formation to lie nonconformably on the 'main phase' of the Chilliwack Batholith, which there is dated radiometrically as probably later Eocene, and to be intruded by a late Oligocene phase.

These rocks can probably be correlated with the Coquihalla Group (unit 23). Cairnes (1923) noticed a general resemblance between the two units. In addition, both outcrop next to mid-Tertiary granitic rocks. Possibly these were the source of the volcanic rocks, as the granitic rocks are of about the same age.

Coquihalla Group

The Tertiary (?) Coquihalla Group (unit 23) is composed of basalt and rhyolite flows and pyroclastic rocks located around a dioritic plug that forms the peak of Coquihalla Mountain. The stratified rocks have a total thickness of approximately 4,000 feet. The unit was named and described by Cairnes in 1924.

The basalt flows have an aggregate thickness of several hundred feet, and occur at the base of the stratified rocks. They are dark grey, dark green to almost black, show excellent columnar jointing and consist of a matrix of calcic feldspar, pyroxene and alteration products containing phenocrysts of zoned calcic feldspar.

Rhyolite flows overlie the basalt and have a total thickness of about 1,500 feet. They are massive, hard, fine-grained, creamy white rocks that consist largely of quartz and altered feldspar. Youngest are pyroclastic rocks not less than 2,000 feet thick. These vary from fine, ashy tuffs to coarse breccias. They consist of glass fragments, quartz crystals and acid plutonic rocks in a soft ashy groundmass.

The core of Coquihalla Mountain is a medium- to fine-grained pyroxene diorite. This rock is grey, massive, and consists of about 70 per cent fresh plagioclase (andesine) and 20 per cent colourless pyroxene with magnetite and apatite as accessory minerals. Fine-grained intrusives are more porphyritic. This rock was believed by Cairnes (1924) to be the latest igneous phase in the group.

These rocks are only broadly warped in comparison to the Lower Cretaceous rocks in the area. They lie entirely on eroded plutonic rocks except where they overlap on to the Pasayten Group.

The Coquihalla Group was believed to be of Miocene age, on structural grounds (Cairnes, 1924). It was deposited upon a surface of moderate relief developed on Lower Cretaceous sedimentary and exposed plutonic rocks, prior to the peneplanation of the district in Pliocene time. Available evidence permits no more accurate dating than Tertiary (?).

Volcanic rock of uncertain age outcropping southeast of Treasure Mountain is of uncertain age and is mapped as unit 23? It was believed to be post-Eocene by Cairnes (1944), but its eastward extension in Princeton map-area was correlated with the late Lower Cretaceous Kingsvale Group (unit 18) by Rice (1947). According to W. E. Snow (letter to C. E. Cairnes, 1942) unit 23? consists of light grey to white rhyolitic to dacitic flows and pyroclastic rocks. The flows are porphyritic with quartz, plagioclase and locally orthoclase phenocrysts in a fine-grained to glassy matrix, which, where crystalline, appears to be made up of the same minerals as the phenocrysts. Ferromagnesian minerals probably make up less than 2 per cent of the whole and are largely altered to chlorite. Breccias comprise at least half the section and consist of a matrix similar to the flows, containing clasts of either porphyritic material similar to the flows, or sandstone of the Pasayten Group or argillites and tuffs of the Dewdney Creek Group. These rocks lie unconformably on sandstone of the Pasayten Group.

Rock of the same body in Princeton map-area is buff coloured volcanic breccia that differs from the breccia in the type-area of the Kingsvale Group only in its content of quartz phenocrysts. Therefore Rice (1947) correlated these rocks with the Kingsvale Group.

A Tertiary age for these volcanic rocks is considered to be likely on structural grounds. Unit 23? lies unconformably on the late Lower Cretaceous Pasayten Group and apparently overlies the Chuwanten Fault. Farther southeast this fault involves rocks ranging in age from Lower Jurassic to late Lower Cretaceous and is probably a mid-Cretaceous to early Late Cretaceous structure (Coates, in press). Therefore these rocks are probably younger than the Kingsvale Group. Lithologically they are similar to some rocks in the Coquihalla Group, although according to Snow (letter to C. E. Cairnes, 1942) these rocks are denser than those of the Coquihalla Group.

PLEISTOCENE AND RECENT DEPOSITS

Pleistocene and Recent deposits (unit 25) are unconsolidated gravels, clays and sands of glacial, glaciofluvial and fluvial origin together with talus accumulations. These deposits are confined mainly to valley bottoms, although a mantle of drift covers the lower slopes of many mountains. The only detailed study of these beds made in the area is by Armstrong (1960) who mapped the surficial geology in the southwestern part of the map-area. Regional Pleistocene stratigraphy is described by Armstrong et al. (1965).

In the past these deposits were of considerable economic importance. Much placer gold was recovered from gravel bars in the Fraser River in the 1850s and 1860s and these gravels have been exploited intermittently since then. Today numerous small gravel pits in the area are worked for fill.

A considerable thickness of these unconsolidated rocks has accumulated in some valley bottoms. A well drilled for oil in the Fraser Valley just east of the Chilliwack cloverleaf on Highway 401 reached a depth of 1,800 feet in unconsolidated material (S. Cosburn, pers. comm.). At Boston Bar the bedrock is hundreds of feet below the present floor of the Fraser Valley (Armstrong and Fulton, 1965).

Where unit 25 is best developed, in the Fraser Lowland near Chilliwack, Armstrong (1960) mapped beds laid down during two nonglacial episodes separated by a glacial period. Oldest rocks are gravels and sand believed to be channel and flood plain deposits deposited after the retreat of the Cordilleran ice sheet, which existed more than 12,000 years and less than 25,000 years ago in the area. Above this is sandy till, laid down by the Sumas ice sheet, which was apparently a valley glacier that originated in the Cascade Mountains about 11,000 years ago. This is followed by glaciofluvial gravel and sand. The youngest deposits are still being formed and consist of sand and silt flood plain deposits, clay and peat swamp deposits, gravel and sand stream deposits and fan gravel and sand formed by slope wash.

All of these rocks are nonmarine, with the possible exception of some rocks below the Sumas till. Marine fossils found in Pleistocene rocks near Harrison Mills (Crickmay, 1930b, 1962) occur below the Sumas till, and make the farthest inland occurrence of marine Pleistocene in British Columbia, according to Crickmay (1962).

ROCKS OF UNKNOWN AGE

Rocks of unknown age form three groups on the basis of lithological affinities. These groups are (a) serpentinite and other ultramafic rocks, (b) schist and amphibolite, and (c) gneiss. Included in each group are rocks whose ages may range from pre-Middle Devonian to latest Cretaceous, although most rocks in each group are possibly of similar age.

Ultramafic Rocks

Map-unit A comprises serpentinite, serpentinized peridotite, minor hornblendite, pyroxenite and dunite, and locally associated gabbro, diorite and altered volcanic rocks. Deposits of nickel-copper and gold in map-unit A make it the most economically important unit in the map-area.

Rocks of unit A form two belts, one on each side of the granitic and gneissic core of the Cascade Mountains, and a few smaller bodies. The eastern belt follows the probable trace of the Hozameen Fault and extends for about 40 miles from a point 16 miles southeast of Hope to Boston Bar. Small ultramafic bodies north-northwest and to beyond Lilooet mark the belt's continuation. This belt was called the Coquihalla Serpentine Belt by Cairnes (1930) and as mapped by him consists of serpentinite, serpentinized peridotite, gabbroic and dioritic rocks and locally included volcanic rocks belonging to the Hozameen Group. The western belt extends from Slesse Mountain, 20 miles southeast of Chilliwack, almost due north for over 30 miles to the vicinity of The Old Settler. It is less well-defined than the eastern belt, and composed of mainly small bodies of pyroxenite, peridotite, hornblendite, dunite and gabbroic rock aligned along a roughly north-south trending fault zone, that swings abruptly northwest near The Old Settler. Ultramafic rocks not in these belts are: (1) small bodies of serpentine along the fault between metamorphic and sedimentary rocks at Vedder Crossing; (2) a pyroxenite-peridotite-hornblendite body 7 miles northwest of Hope that is on strike with the rocks at The Old Settler; (3) a small hornblendite body 5 miles north of this; (4) partly altered peridotite (the Skagit Harzburgite of Daly, 1912) in gneissic rock composing unit C; and (5) small ultramafic bodies i volcanic rock of the Hozameen Group.

Lithology

Serpentine (Aa) is the most abundant ultramafic rock-type, and is predominantly in the eastern belt. In many places it shows all transitions to partly serpentinized peridotite from which it is not distinguished on the map (Cairnes, 1930; Osborne, 1966). The serpentinite and serpentinized peridotite are dark green to black, massive to highly fractured with shiny fracture surfaces and locally contain lustrous pale green patches of bastite psuedomorphous after enstatite. Discontinuous veins of chrysotile asbestos are sparsely distributed throughout the rock. All gradations exist from an aggregate of bladed low-birefringent serpentine containing a mesh of magnetite grains and no primary silicate minerals, to a rock composed of anhedral olivine and subhedral to euhedral enstatite grains with minor serpentinization along fractures. Magnetite and chromite are present in most serpentinite. Alteration of serpentinite is of three main types; talc, red-weathering carbonate-quartz-mariposite rock, and talc-carbonate rock. Secondary free gold associated with sulphides in shear zones in the talc has been of considerable economic importance.

Intimately associated with serpentinite in the eastern belt are altered basic volcanic rock or greenstone and local pyroclastic rock that belong to the Hozameen Group, and gabbro and diorite of uncertain age. On the map, all of these are included in the broad belt shown as unit Aa northeast of Hope. Thus the total amount of serpentinite in this belt appears to be greater than it is, but to differentiate all rock types present would require detailed mapping. The gabbroic and dioritic rock almost indistinguishable in the field from the greenstone, intrudes the greenstone and forms dyke-like bodies in the serpentinite. It consists of varying proportions of altered plagioclase feldspar (albite-oligoclase), diallage, hornblende (in part replacing pyroxene),

ilmenite (in part altered to leucoxene) and magnetite. Alteration products of these rocks, saussurite, epidote, chlorite and calcite, are very similar to those of greenstone of the Hozameen Group.

Pyroxenite (Ab) generally grades into hornblendite and peridotite. It forms the major part of several relatively small bodies in the western belt and the stock-like body 7 miles northwest of Hope (Cairnes, 1944; Aho, 1956; Orr, 1967). It is a grey-green to black rock composed of orthopyroxene (bronzite), subordinate augite and minor hornblende and olivine. Feldspar is absent. The hornblende is generally an alteration product of augite, and may replace all silicates in the pyroxenite so that the rock becomes a hornblendite. The body northwest of Hope consists largely of pyroxenite with cores of peridotite and patches of hornblendic pyroxenite with a hornblendite margin. Pentlandite and chalcopyrite are subordinate to pyrrhotite in this body and are of considerable economic importance.

Hornblendite (Ac) forms several small dykes or sill-like bodies in foliated amphibolite and diorite on Mount Urquhart, on the ridge north of Clear Creek, and on The Old Settler. Very small bodies of similar composition occur in amphibolites northeast of Mount Pierce, on both sides of the Chilliwack River and in quartzites on the east side of Slesse Mountain. Other occurrences of hornblendite are generally marginal alteration phases of pyroxenite bodies.

Structure

Most ultramafic rocks in the map-area are spatially related to major faults. Ultramafic bodies comprising the western belt occur along a north-south-trending fault zone, whose existence is shown both by mylonitization and juxtaposition of rocks of different metamorphic facies. Serpentinite forms small bodies along the fault separating metamorphic rocks from sedimentary rocks near Vedder Crossing. The relationship between serpentinite of the eastern belt and a fault is more tenuous. Southeast of the broad serpentinite belt northeast of Hope is the Hozameen Fault that separates low greenschist facies upper Paleozoic rocks of the Hozameen Group from unmetamorphosed Mesozoic rocks. North of Boston Bar a fault separates schists from Mesozoic rocks. The fault between is assumed from the existence of these faults, from the relative straightness of the contact between the Hozameen Group and Mesozoic rocks, and from the presence of serpentinite along this contact. Just south and northwest of Boston Bar the serpentinite diverges from the contact between upper Paleozoic and Jurassic rocks and lies within the upper Paleozoic rocks.

In the eastern serpentine belt the ultramafic rocks seemingly both cut and are cut by greenstone of the Hozameen Group, generally with a zone of shearing along contacts. Elsewhere the ultramafic rock appears to be intrusive. Small hornblendite bodies have concordant relationships with foliation in amphibolite and diorite on Mount Urquhart and The Old Settler. The stock-like mass 7 miles northwest of Hope cuts metamorphic rock and partly cuts and grades into Cretaceous diorite or quartz diorite (Aho, 1956).

Age and correlation

The age of these rocks is not known. The bodies related to the major faults were probably emplaced in mid-Cretaceous time, the most probable date of the faulting. Their ultimate age and origin is far more problematical. Misch (1966, p. 133) has interpreted ultramafic rocks along major faults on the west side of the Cascade Mountains in northern Washington as being probably derived from the mantle. On the other hand, ultramafic rock is intimately associated with greenstone in the eastern belt, a relationship common in upper Paleozoic rocks of the Western Cordillera (Roddick, et al. 1967) and in similar tectonic settings elsewhere in the world. Following Challis (1965), these ultramafic rocks may be differentiates in deep seated magma chambers from the primary basic magma that gave rise to the upper Paleozoic greenstones and thus be originally of upper Paleozoic age. Subsequently, these rocks were serpentinized and intruded cold along fault zones.

Other bodies may be Cretaceous in age. The body 7 miles northwest of Hope appears to be contemporaneous with partly enclosing diorite or quartz diorite (Aho, 1956). Quartz diorite of apparently the same pluton near Hope has been dated at 102 to 76 million years, or Late Cretaceous (McTaggart and Thompson, 1967; T. Richards, pers. comm.).

Metasedimentary and Metavolcanic Rocks

Unit B includes pelitic schist, phyllite and amphibolite near granitic plutons northwest of Boston Bar, west and northwest of Mount Urquhart and northwest of Hope. Also referred to this unit are dioritic and amphibolitic rocks exposed near Vedder Crossing and in the eastern part of Chilliwack Valley. These rocks probably result mainly from Mesozoic metamorphism of upper Paleozoic sedimentary and volcanic rock, although some of the parent rock may be of lower Paleozoic or Mesozoic age.

1. Rocks northwest of Boston Bar (unit Ba)

Rocks northwest of Boston Bar (unit Ba) are mainly dark grey, thinly laminated micaceous and graphitic phyllites, with irregular, finely crystalline quartzite layers oriented parallel to the phyllitic laminations. On Kookipi Creek the common rock is thinly bedded (?) micaceous quartzite, although biotite-quartz schist with local garnet, granulite and muscovite-quartz schist predominate in places (Roddick and Hutchison, 1969).

These rocks are intruded by Tertiary granitic rocks. The contact between granodiorite and schistose and phyllitic rocks in Kookipi Creek can be located to within a few feet. Apart from a coarsening of grains in the metasedimentary rocks, there is little contact metamorphism. Cutting these rocks are small serpentinite and talcose bodies aligned in a northwesterly direction. These probably represent the continuation of the serpentinite belt that is located south of Boston Bar. To the east the metamorphic rocks are in probable fault contact with laminated slates of the Ladner Group.

The age of these rocks is unknown, but lithologically they have more in common with Mesozoic than Paleozoic rocks in the northwest of the

map-area. The Jurassic Ladner Group in this part of the map-area consists of uniformly laminated phyllite, whereas the upper Paleozoic Hozameen Group exposed 5 miles to the southeast comprises volcanic rock, chert and argillite (Osborne, 1966). The relative homogeneity of unit Ba and the absence of metavolcanic rocks indicates that these rocks are probably Mesozoic rather than Paleozoic. This conclusion agrees with that of Duffell and McTaggart (1952) who studied the continuation of these rocks to the northwest in Ashcroft map-area.

2. Rocks west and northwest of Mount Urquhart (units Bb and Bc)

About 8 miles northwest of Mount Urquhart is fine-grained, dark grey, biotite-quartz schist that locally contains garnet, sillimanite and staurolite, and is interlayered with light coloured quartz-feldspar schist. Near the eastern contact with gneissic rocks amphibolite and granitoid layers are common (Roddick and Hutchison, 1969).

Just southwest of Mount Urquhart, the prevailing rock type is dark grey, fine grained, garnet-biotite-quartz schist (unit Bb). Sillimanite, some of which is pseudomorphous after kyanite, is irregularly distributed through this rock. A few beds of metaconglomerate enclosed in the schist consist of angular fragments of granite, gneiss, quartz-feldspar and pelite in a matrix of fine-grained greywacke. The matrix appears to be little metamorphosed in hand specimen yet contains randomly oriented sillimanite megacrysts.

Unit Bc is the migmatitic equivalent of unit Bb. Fine-grained biotite-quartz schist, commonly with garnet and locally with sillimanite, contains numerous concordant layers of granitoid gneiss 2 to 6 inches thick. The gneiss is of biotite granodiorite composition and commonly grades into pegmatite. It forms 30 to 70 per cent of the rock.

The narrow screen crossing Scuzzy Creek on the west side of Scuzzy Pluton is schist and gneiss, tentatively correlated with unit Bb.

Northwest of Mount Urquhart these schists form the flanks of a broad, northwest-trending, doubly plunging anticline or elongate dome, with gneiss (unit 6) exposed in the core. Where seen, the contacts with gneiss are sharp and concordant. To the east the schists are in contact with quartz diorite of Late Cretaceous age (unit 19) and mid-Tertiary (?) granodiorite (unit 24). The contact with the quartz diorite is marked by a zone of lit-par-lit migmatite about 100 yards wide. By contrast, that with the granodiorite is fairly sharp, with a transition zone only 5 to 25 feet wide containing abundant pegmatitic and aplitic material. To the southeast these rocks are separated by a narrow tongue of quartz diorite from lithologically similar rocks northwest of Hope. Southwards they seemingly grade into the complex of amphibolite, metachert, minor limestone pods and ultramafic rocks that form The Old Settler (B. Lowes, pers. comm.). The latter rocks have some characteristics in common with rocks of unit Bd, described below.

The age and history of these rocks and of the lithologically similar rocks northwest of Hope is considered below.

3. Rocks northwest of Hope (unit Bb)

Pelitic schist underlies 95 per cent of the outcrop area of metamorphic rocks northwest of Hope; the remainder is underlain by amphibolite (Read, 1960). The pelitic schists typically are dark grey and consist of a matrix of quartz, plagioclase (An_{35}-An_{38}), oriented biotite, and sericite and graphite containing porphyroblasts of garnet, staurolite, muscovite and locally kyanite that makes up 20 to 30 per cent of the rock. Stringers and lenses of quartz cut the matrix but not the porphyroblasts. Amphibolites associated with these rocks are light grey, very fine grained rocks, with hornblende and garnet porphyroblasts in a matrix of plagioclase (An_{35}), minor epidote and biotite. Quartz stringers cut the matrix. Thin scapolite-diopside layers probably represent limy beds. Rare breccias containing laminated sedimentary fragments appear little deformed though of high metamorphic grade (McTaggart and Thompson, 1967).

Pelitic schists of higher metamorphic grade occur only in the re-entrant in the intrusive contact 6 miles northwest of Hope where sillimanite is commonly developed and staurolite appears unstable. These rocks are pale grey, coarser grained than the pelitic schist described above and consist of porphyroblasts of kyanite, sillimanite, muscovite and garnet making up to 10 per cent of the rock, in a matrix of quartz, plagioclase (An_{37}) and poorly oriented biotite.

Some metamorphic minerals are developed only near intrusions. Pseudomorphs after andalusite composed of staurolite, quartz and muscovite in pelitic schist occur near the contact with the ultramafic body 7 miles northwest of Hope. Chlorite and muscovite porphyroblasts are near the contact with the quartz diorite.

The grade of metamorphism increases towards the west but appears to reflect regional metamorphism prior to emplacement of the quartz diorite, rather than any type of contact metamorphism (Read, 1960). The isograd between staurolite and sillimanite-bearing rocks does not parallel the contact with quartz diorite of the Spuzzum Pluton. The only effects of the intrusion are a slight coarsening of grain size and the formation of muscovite and chlorite porphyroblasts near the contact.

These rocks have been subjected to repeated folding apparently in a nearly constant direction. Foliation and bedding are parallel and disposed in open or recumbent and overturned folds that plunge northwesterly. On the west and north side the metamorphic rocks are intruded by Cretaceous quartz diorite, and on the east are in fault contact with Eocene conglomerate.

On the basis of composition these rocks appear to be derived largely from the upper Paleozoic Hozameen Group. Possibly they come in part from Mesozoic rocks as well, as granitic detritus known from one locality is rare in any pre-Cretaceous rocks in the region.

The age of metamorphism of these rocks is Mesozoic. The parent rocks appear to be largely upper Paleozoic but may be in part Mesozoic, and the metamorphic derivatives of these are in normal fault contact with unmetamorphosed Eocene rocks. McTaggart and Thompson (1967) suggested that metamorphism was contemporaneous with the formation of Late Cretaceous quartz diorite. Structures in the quartz diorite near Spuzzum and in inclusions and contiguous metamorphic rocks are concordant, and the quartz diorite may have been derived by fusion or metasomatism from the country rocks during metamorphism. However the Late Cretaceous radiometric ages

(76, 80 and 102 million years) obtained from the quartz diorite (McTaggart and Thompson, 1967; T. Richards, pers. comm.) can only be regarded as minimum ages as there was considerable mid-Tertiary thermal activity in the region.

4. Older (?) metamorphic rocks (unit Bd)

Metamorphic rocks (unit Bd) forming narrow fault slices in the southwestern part of the map-area, differ considerably from those above and may be part of a pre-upper Paleozoic basement complex. Near Vedder Crossing unit Bd is an assemblage of metamorphic and igneous rock composed of hornblendite, amphibolite, epidote amphibolite, garnet-mica, and garnet-sphene schist, foliated quartz diorite, diorite and pegmatite (McMillan, 1966). Farther east a group of rocks with a wide variety of textures and compositions but invariably containing abundant amphibolite is imbricated with Paleozoic rocks (unit 2) in a north-northeast trending belt running from the International Boundary at the south end of Slesse Creek as far north as The Old Settler. At the southern end of the belt are well-foliated rocks containing muscovite aligned parallel to the early foliation in an optically irresolvable fine-grained groundmass with actinolite and biotite partly mimetic after the foliation. On Slesse and Pierce mountains coarse- to fine-grained amphibolites and diorites that are locally well-foliated outcrop. Rocks composed largely of amphiboles grade into rocks with only 50 per cent amphibole. The latter consist of hornblende interlayered with epidote and sphene, or with plagioclase ($\sim An_{40}$). These rocks contain serpentinite lenses concordant with the foliation and are interlayered with contorted, layered, fine-grained quartzite. This assemblage is very similar to that exposed on The Old Settler, 32 miles due north. Mainly fine-grained unfoliated massive amphibolites composed of fine-grained epidote, small hornblende crystals, chlorite, rare primary (?) feldspar phenocrysts showing all stages of alteration to epidote, pyrite, pyrrhotite and partly altered skeletal ilmenite outcrop north of the Chilliwack River. Relict textures defined by epidote grains are similar to those of the upper Paleozoic greenstone (unit 2e). These rocks are cut in places by dyke-like bodies of coarse-grained amphibolite.

All of these rocks are associated with major faults. The igneous-metamorphic assemblage on Vedder Mountain is bounded on the east by a steeply dipping fault bringing it into contact with possible Lower Cretaceous greywackes and conglomerates. A fault buried by alluvium is probably present on the west side as well, as just west of the map-area small bodies of rock similar to the Chilliwack Group (unit 2) are in apparent fault contact with the Vedder igneous-metamorphic assemblage (McMillan, 1966). The belt of imbricated metamorphic rocks that crosses the eastern end of the Chilliwack Valley appears to mark a major break as it overlies little-metamorphosed Paleozoic and Mesozoic rocks to the west. The western contact, which is well-exposed on the ridge north of Slesse Mountain, is sharp and dips eastward at about 70 degrees. East of the imbricated belt are fine-grained amphibolite, slate and quartzite that are tentatively included in the Chilliwack Group. Amphibolitic rocks just south of the International Boundary near Slesse Creek, identical to those just to the north, are mapped by Misch (1966) as tectonic slices located immediately west of the root zone of his

Shuksan Thrust. Misch (pers. comm.) believes that amphibolites north of Chilliwack River do not delineate the main Shuksan Thrust but are imbricate slices located below the sole of the main fault. This interpretation is compatible with the presence east of the fault of rocks probably belonging to the Chilliwack Group.

These rocks may range in age from early to late Paleozoic. Rocks on Vedder Mountain and those at the south end of Slesse Creek and near Mount Pierce are lithologically identical to pre-Middle Devonian rocks in the San Juan Islands (P. Misch and W. R. Danner, pers. comm.). Such rocks have been called the Yellow Aster Complex in northern Washington and K-Ar dates indicate they are of Ordovician age (Misch, 1966, and pers. comm.). However, relict textures in fine-grained amphibolite north of Chilliwack River are very similar to those in late Paleozoic greenstones of the area, and some of the amphibolitic rocks could be metamorphosed equivalents.

Gneiss

Gneiss composing unit C forms a discontinuous belt extending from the International Boundary as far north as Stout, in the Fraser Canyon, and underlies an extensive area near Mount Breakenridge in the northwestern part of the map-area. In part the gneiss is possibly the migmatitic equivalent of schist of unit B, but in part it may be older.

1. Gneiss between the International Boundary and Stout

Gneiss composed of variable amounts of plagioclase, quartz, hornblende and biotite predominates south of Hope. This rock was called the Custer granite gneiss by Daly (1912) and subsequently has been described in some detail by McTaggart and Thompson (1967).

The gneiss consists of light layers rich in plagioclase (An_{30}-An_{40}) alternating with dark layers rich in biotite and/or hornblende. The layers are parallel and vary in thickness from fractions of an inch to several feet. The gneiss is commonly migmatitic with characteristic plagioclase porphyroblasts either scattered through the rock or coalesced into irregular layers up to 6 inches thick. The porphyroblasts are generally antiperthitic, with plagioclase (An_{23}) containing patches of K-feldspar. Locally, massive plagioclase pegmatite and coarse- to medium-grained trondhjemite underlie areas up to 1/3 mile across and foliated grey dykes and sills occur in many places. Dark rocks consisting of diopside-plagioclase, diopside-hornblende-plagioclase and hornblende-garnet-biotite-plagioclase alternating with white feldspathic layers, make up about 10 per cent of the unit. Feldspars in these rocks range in composition from An_{26} to An_{70}. Minor components of the unit are hypersthene-plagioclase-biotite gneiss, rather fine grained staurolite-kyanite-garnet schist, anthophyllite-talc schist, mylonite, quartzite which is locally clearly derived from ribbon chert, marble, and skarn.

Between Hope and Stout the gneiss is quite different in appearance, being chalky white and closely jointed, faulted and mylonitized so that the rock is rather friable.

Minor structures are north-northwesterly trending corrugations and small folds. Axial planes of these folds mostly parallel the foliation but in

places are folded into open folds. Pervasive shearing with the development of augen and mylonitization is common. North of Hope a broad major anti-form is superimposed on the minor folds, but elsewhere there are no obvious major structures in the unit.

The west side of the gneiss is in fault contact with schists of unit B in Fraser Canyon. Farther south it is unconformably overlain by Eocene sedimentary and volcanic rocks and intruded by Tertiary granitic rocks. On the east, in Fraser Canyon, it grades through a complex of numerous small granitic bodies (Yale intrusions, in unit 20) into the Hozameen Group. To the south, along Silverhope Creek, gneissic rocks are separated by a zone of highly deformed and sheared schistose rocks a few hundred feet wide from rocks of the uppermost division of the Hozameen Group.

2. Gneiss near Mount Breakenridge

Gneiss in the northwestern part of the map-area, near Mount Breakenridge and Cairn Needle was mapped by Roddick and Hutchison (1969). It is more homogeneous than that to the south and is mainly light coloured granitoid gneiss consisting of variable amounts of plagioclase, quartz, biotite and muscovite, and includes zones of regularly layered gneiss in which quartzofeldspathic layers alternate with amphibolite layers. It lacks the porphyroblastic feldspars characteristic of gneiss to the south. About 10 per cent of the unit consists of biotite-quartz schist locally containing garnet, kyanite and staurolite. Other common components are crosscutting and conformable pegmatite veins, zones of amphibolitic inclusions and rare agmatite.

A very well foliated gneissic granodiorite or quartz diorite, exposed in the core of the doubly plunging anticline or dome 8 miles east-southeast of Mount Breakenridge is probably equivalent. In it are layers of amphibolite and a zone of irregularly layered gneiss with bands of garnet-biotite schist.

Near Mount Breakenridge and Cairn Needle, foliation in the gneiss has a dominant northwest trend and generally dips 35 to 70 degrees to the northeast. Large folds with amplitudes and wavelengths up to 2 miles plunge at about 40 degrees in a northwesterly direction.

South of Mount Breakenridge the gneiss is in possible fault contact with greenstones, fine-grained amphibolites and pelites. The contact can be located to within 100 feet and appears to dip steeply to the northeast. This contact is probably a major fault, and may be the northerly extension of the fault zone running from the International Boundary near Slesse Creek to The Old Settler. In the anticlinal or domal area the gneiss is overlain by schist and migmatitic schist (units Bb and Bc). This contact is apparently sharp and concordant.

The only other gneissic rock in the area is a small body of chloritized quartz diorite gneiss (unit C?) exposed on the east side of the Fraser River near the northern margin of the map-area. It is possibly a fault slice in contact with phyllite of unit Bb.

The gneiss is probably in part Mesozoic and may in part be older. Between Stout and the International Boundary it is possibly post-late Paleozoic and pre-mid-Cretaceous. It appears to have been derived by metamorphism and metasomatism from the Hozameen Group (McTaggart and Thompson, 1967). Similarly Misch (1966) believed that the southern

extension of the gneiss in northern Washington, where it is called the Skagit Gneiss, could well have originated from upper Paleozoic strata. A minimum age for the gneiss in this part of the map-area is probably pre-mid-Cretaceous as the southern extension is cut and mylonitized by mid-Cretaceous faults, but it can only be dated in the map-area as pre-Eocene.

Gneiss in the Mount Breakenridge area may well be older as it underlies schists of unit Bc and Bd with sharp, concordant contacts. The schists were probably formed in Mesozoic time.

The age of the schist and gneiss is one of the major problems in the map-area and is discussed further under "Structural Geology".

GRANITIC ROCKS

An attempt has been made to subdivide granitic rocks in the map-area according to the time of their emplacement. They appear to have been intruded during three main periods: in Late Jurassic-earliest Cretaceous time (unit 13), in Late Cretaceous time (unit 19), and in mid-Tertiary time (unit 24). The composition and internal and external characteristics of rocks within each of these subdivisions are similar but differ somewhat from those of rocks in the other subdivisions (see Table III).

Varying degrees of confidence can be placed in the ages of the subdivisions. The structural and stratigraphic evidence of age for units 13 and 24 agrees reasonably well with the radiometric ages for these units. Unit 19 relies largely on radiometric data for evidence of age. These data, in an area such as this with a long history of thermal activity and deformation, can only be regarded as giving a minimum age. That is, they record the time of cooling below a certain temperature, rather than the time of emplacement. Therefore unit 19 may well be older than Late Cretaceous. The age of unit 20, dependent as it is on unit 19 for dating, likewise is doubtful.

Upper Jurassic and (?) Lower Cretaceous Granitic Rock

The Upper Jurassic and (?) Lower Cretaceous Eagle Granodiorite (unit 13) forms a large pluton in the northeast part of the map-area. This unit consists largely of moderately coarse grained equigranular granodiorite characterized by a variably developed foliation that trends roughly parallel to the margins of the pluton, which itself parallels the regional structural trend. The name was given by Camsell (1913) to rocks exposed on Eagle Creek (now Britton Creek), just east of the middle of the eastern margin of the map-area. Although this unit is extensive, the only description of it from the map-area is by Cairnes (1924).

Lithology

The typical rock is grey and composed of plagioclase (oligoclase), quartz, orthoclase, and biotite, which commonly but not always is more abundant than hornblende. Locally muscovite is abundant, to the exclusion of nearly all mafic minerals. Pegmatites are common in many places. A specimen examined by Cairnes (1924) consisted of 50 per cent oligoclase, 20

TABLE III

Granitic rocks, Hope map-area

Map-unit	General age	Areal percentage of total granitic rock	Names of individual plutons	Evidence of age: Radio-metric (m.y.)	Evidence of age: Stratigraphic/ Structural	Form of plutons	Characteristic textures and lithology
24	late Eocene to late Miocene	49	Chilliwack	16[2] 18[2],18[3],18[3] 23[2] 26[2],26[2],26[2] 28[2] 29[2] 35[2],35[2] 41[2],59[2]	Post-Eocene	discordant	Massive, nonfoliated, well-jointed. Highly variable composition, ranges from hypersthene tonalite to albite granite. Commonest rock is granodiorite. Sharp contacts.
			Hells Gate Scuzzy	35[3]	post-Late Cretaceous?		
			Needle Peak	39[1]	post-Lower Cretaceous		
	latest Cretaceous or Early Tertiary?	1	Yale Intrusions		post-Late Cretaceous?, pre-late Eocene or Oligocene	concordant	Small, foliated, sill-like bodies, range from quartz diorite to aplite granite. Commonest rock is granodiorite.
19	Late Cretaceous?	25	Spuzzum	76[2]		mainly concordant	Commonly foliated, hornblende > biotite quartz diorite. Gradational or broad contacts in larger bodies; numerous inclusions of country rock near margins.
			body west Hope	80[2] 102[2]	pre-Eocene		
			several small bodies	84[1]	post-Middle Jurassic, prob. post-late Lower Cretaceous		
13	Late Jurassic Early Cretaceous	25	Eagle Grano-diorite	143*[1] 98*[1]	post-Upper Triassic, pre-mid-Lower Cretaceous, outside map-area, pre-Lower Tertiary in map-area	concordant	Foliated granodiorite with local dioritic phases.

*Just east of eastern margin of map-area (*see* Leech *et al.* 1963, Wanless *et al.* 1967).
Source: [1]Geol. Surv. Can.; [2]University of British Columbia; [3]Baadsgaard *et al.* 1961.

per cent or less quartz, 5-10 per cent orthoclase and about 20 per cent of green hornblende and brown biotite partly altered to epidote and chlorite.

The foliation of these rocks may take various forms. Some may be well-banded, with coarser layers of felsic minerals alternating with darker layers of fine-grained dark minerals. Others are more uniformly gneissic, with oriented minerals and no segregation. Still others are massive.

A border phase, forming the western margin of the pluton near Coquihalla River was called the Eagle diorite by Cairnes (1924). It is a dark green, commonly foliated or gneissic rock, composed of 50 to 60 per cent plagioclase (sodic andesine), and 25 per cent hornblende, and 5 to 15 per cent quartz. Epidote and chlorite are common alteration products. The diorite appears to grade into the Eagle Granodiorite to the east, the transition zone between the two formations being about 100 feet wide.

External relationships

The Eagle Granodiorite intrudes the Nicola Group in the northeast part of the map-area and is overlain by the Kingsvale Group (Cairnes, 1924; Duffell and McTaggart, 1952). The western contact is mainly an assumed fault with Lower Cretaceous rocks of the Jackass Mountain and Pasayten groups. The fault is the probable northwesterly continuation of the Pasayten Fault of Coates (in press). One exception to this is the marginal diorite, which intrudes the Pasayten Group west of the fault, west of Coquihalla Mountain. The Coquihalla Group nonconformably overlies the Eagle Granodiorite and the bounding fault.

Age

Most rocks in this unit appear to be Upper Jurassic and (?) Lower Cretaceous, but some may be younger. In the map-area the granodiorite can be dated as post-Nicola Group (Upper Triassic) and pre-Kingsvale Group (late Lower Cretaceous). Assuming that the marginal diorite is nearly the same age as the Eagle Granodiorite, its intrusive relationship with the Upper Cretaceous Pasayten Group suggests that the pluton is of latest Early Cretaceous age, or earliest Late Cretaceous age, which is the conclusion reached by Cairnes (1924). Camsell (1913) assigned the Eagle Granodiorite to the Jurassic as it is overlain east of the map-area by Lower Cretaceous rocks and intrudes Upper Triassic (Nicola or Tulameen groups) rocks. Camsell's age is justified by a radiometric data (K-A) of 143 million years from near the type-area of the Eagle Granodiorite (Leech et al., 1963). However, 30 miles to the south-southeast the same body gave an age of 98 $\pm$ 6 million years, or early Late Cretaceous (Wanless, et al., 1967). North of the map-area, where the continuation of the Eagle Granodiorite is called the Mount Lytton Batholith, stratigraphic evidence shows that it was emplaced between late Late Triassic and mid-Early Cretaceous time (Duffell and McTaggart, 1952).

Late Cretaceous or Older Granitic Rocks

Map-unit 19 includes the Spuzzum Intrusions of McTaggart and Thompson (1967) together with smaller bodies of similar composition and age, some of which have been correlated with this unit by Roddick and Hutchison (1969).

Lithology

Quartz diorite or tonalite is the most abundant rock type in the Spuzzum Pluton and its probable continuation to the south, which crosses the Fraser River west of Hope. This is a striking black and white quartz diorite, in which hornblende is more abundant than biotite, generally massive or poorly foliated, although to the east near Fraser Canyon it is gneissic. Hornblende and biotite make up 15 to 25 per cent of the rock and quartz 3 to 15 per cent. The remainder is mainly plagioclase (An_{28} to An_{48}), with traces of K-feldspar and accessory minerals. In places diorite in which hornblende approaches 50 per cent of the rock is common and hornblendite occurs here and there. Aplite and pegmatite veins are abundant, particularly in Fraser Canyon, where the quartz diorite is highly sheared.

Smaller plutons are of generally similar composition. That south of The Nipple is a quartz diorite with a higher percentage of biotite and small garnets. The body on Mount Breakenridge is a biotite quartz diorite containing up to 10 per cent elongate inclusions. Hornblende-biotite quartz diorite and diorite east of the mouth of Big Silver Creek presumably is part of the Spuzzum Pluton to the east. Other small bodies shown as unit 19? are included because of lithological similarities, but may be of Tertiary age.

External relationships

Unit 19 is mainly confined to the belt of medium to high grade metamorphic rocks (unit B) that forms the axis of the Cascade Mountains in the map-area. Outside of this zone it intrudes rocks of Lower and Middle Jurassic age. According to McTaggart and Thompson (1967) the Spuzzum quartz diorite near Stout has a gradational and conformable contact with metamorphic rocks (unit C). This contact is such that the quartz diorite appears to have been formed either by fusion of the metamorphic rocks or else by metasomatism. Southwest of Hope, the quartz diorite is in fault contact with Eocene rocks and is intruded by Tertiary granite rocks (T. Richards, pers. comm.).

Age

Radiometric data of 76, 80, and 102 million years on the main part of unit 19 and 84 million years on a small isolated body, indicate that the unit is of Late Cretaceous age. Field relationships permit no more accurate dating than pre-Eocene for the main part of the body, and post-Middle Jurassic, probably post-Lower Cretaceous for the small body (McTaggart and Thompson, 1967; Coates in Wanless et al., 1967). As much of the unit

occupies the core of the Cascade Mountains, an area of Cretaceous metamorphism and deformation, its radiometric age may bear little relationship to its time of emplacement.

In age, lithology, and relationships the Spuzzum Pluton and similar rocks resemble the Black Peak Batholith of Misch (1966), which is about 35 miles south of the southeast corner of the map-area, and has a minimum age of latest Cretaceous.

Cretaceous or Tertiary Granitic Rocks

The Yale Intrusions (unit 20) are sills and small composite bodies that occur in a north-south trending belt mainly on the west side of the Fraser River north of Hope. They are of variable composition, ranging from quartz diorite to aplite granite, with granodiorite the most common variety, and are typically sheared. These rocks were described and named by McTaggart and Thompson (1967).

Lithology

A typical granodiorite in this group consists of 5 to 10 per cent orthoclase, 20 per cent quartz, 5 per cent biotite, with the remainder largely zoned plagioclase (An_{20}-An_{30}). K-feldspar makes up to 50 per cent of the rock in some places. It may contain abundant inclusions of Spuzzum quartz diorite and Custer Gneiss. Other varieties are fine-grained oligoclase porphyry, aplite granite, hornblende granodiorite and tonalite.

Evidence of shearing is common and ranges from mortar structure to mylonite, although a few rocks are unsheared. Cataclasis of small tabular intrusions has developed a planar structure that is parallel with the foliation or layering of the enclosing country rocks and discordant to the margins of the body. Thus the pre-existing structural grain of the country rock appears to have controlled the planar structure in the intrusion.

External relationships

The Yale Intrusions cut the Hozameen Group, Custer Gneiss and Spuzzum quartz diorite. They are particularly abundant along the contact between the Custer Gneiss and the Hozameen Group, where they are intensely sheared. They are intruded by rocks of the Chilliwack Batholith.

Age

The age of the Yale Intrusions is probably latest Cretaceous or Early Tertiary. They cut the Late Cretaceous (?) Spuzzum quartz diorite and are intruded by Oligocene or late Eocene rocks of the Chilliwack Batholith. Comparable rocks in the Cascade Mountains of northern Washington may be the Ruby Creek heterogeneous plutonic belt, believed by Misch (1966) to be possibly synchronous with the latest Cretaceous Black Peak Batholith.

Mid-Tertiary granitic rocks

Mid-Tertiary granitic rocks (unit 24) are the most extensive granitic rocks in the map-area and form three large, discordant masses, the Chilliwack, Scuzzy and Needle Peak plutons. The lithology of these plutons is variable, but the most common rock is granodiorite. In contrast to the older rocks they are massive and unsheared.

Lithology

The Chilliwack Batholith, named and described in some detail by Daly in 1912, is a composite batholith, with at least nine separate phases ranging from hypersthene tonalite to albite granite (T. Richards, pers. comm.). Hornblende-biotite quartz diorite and hornblende-biotite granodiorite are the predominant phases. The average mode of the commonest variety is quartz 19 per cent, K-feldspar 4 per cent, zoned plagioclase about 65 per cent, with inner zones as calcic as An_{60} and outer zone about An_{20}, biotite 7 per cent, hornblende 4 per cent and accessory minerals 10 per cent (McTaggart and Thompson, 1967). Related to the pluton are granophyre dykes and plugs. Just south of the International Boundary, these grade into subvolcanic breccia dykes that resemble some phases of the Skagit Formation (unit 23). The Slesse Diorite of Daly (1912) seems to be merely a marginal phase of the quartz diorite of the Chilliwack Batholith (T. Richards, pers. comm.).

The Scuzzy Pluton, named and described by Roddick and Hutchison (1969) consists largely of massive granodiorite, with coarse-grained quartz and feldspar and much finer grained biotite. The mafic mineral content is much lower than that of the contiguous Spuzzum Pluton, and averages 5 per cent or less. The biotite granodiorite at Hells Gate on the Fraser River, described by Morris in 1955, is finer grained than the main part of the Scuzzy Pluton but is believed to be related to it. A narrow zone of biotite-rich quartz diorite forms the western margin of the Scuzzy Pluton near Big Silver Creek.

The Needle Peak Pluton was described by Cairnes in 1924 under "complex of Cretaceous batholithic rocks". The name, proposed by the present writer, is taken from Needle Peak in the eastern part of the body. The pluton consists of massive, coarse-grained granite and granodiorite, with numerous widely spaced, nearly vertical joints. Glacial erosion of this rock has produced steep cliffs above cirques and sharp peaks, that contrast markedly with the relatively subdued topography of the area underlain by Eagle Granodiorite. According to Cairnes (1924) the greater part of this pluton consists of granite, but it grades into granodiorite. A pink variety consists of glassy quartz, prominent alkali feldspars, both sodic orthoclase and albite-oligoclase, hornblende and biotite. In contrast is a grey variety with phenocrystic plagioclase (albite-oligoclase).

All of these plutons have sharp discordant contacts. Their massive nature, common textural isotropy and widely spaced, well-developed joints are characteristic and contrast markedly with many of the granitic older rocks, which are commonly foliated. In addition, both Chilliwack and Needle Peak plutons are in proximity to volcanic rocks (units 22, 23) of apparently similar age, that may be the extrusive equivalents of some phase of the plutonic rocks.

Age

The age of emplacement of these bodies is mainly latest Eocene to Miocene. Structurally they can only be dated in part as post-Eocene as they intrude Eocene conglomerates southwest of Hope. Potassium-argon dating shows that the oldest bodies (Hells Gate body, Needle Peak Pluton, and parts of the Chilliwack Batholith) are of Oligocene and late Eocene age, although one Paleocene age has been obtained from granodiorite 5 miles southeast of Hope (Baadsgaard et al., 1961; Wanless et al., 1967 and T. Richards, pers. comm.). Middle Miocene ages are known from the northwestern part of the Chilliwack Pluton, east and northeast of Mount Cheam (Baadsgaard et al., 1961; T. Richards, pers. comm.). South of the International Boundary, Misch (1966) states that geological data place the main phase of the Chilliwack Pluton in the late Eocene or early Oligocene.

STRUCTURAL GEOLOGY

The Hope map-area is of regional significance as it contains the junction of the Coast and Cascade Mountain systems. The geology of these systems is somewhat different north and south of the map-area. In the map-area they merge, with a progression from the typical Cascade system geology in the south, composed of a granite, gneiss and schist core flanked by sedimentary and volcanic rocks, to the largely granitic and high-grade metamorphic belt in the north that is characteristic of the geology of the Coast Mountains. As there is no marked break between the two it seems probable that this difference merely reflects the greater uplift and erosion to a deeper level of the Coast Mountains, rather than any fundamental difference.

The basic structural pattern of the map-area appears to have been established in mid-Cretaceous to Early Tertiary time, when orogeny in both tectonic and geomorphic senses took place (Fig. 3). Pre-mid-Cretaceous rocks were strongly folded, thrust and reverse faulted and, at least locally, metamorphosed, migmatized and intruded by granitic rocks. Regional uplift took place at this time as well. All pre-mid-Cretaceous stratified rocks in the map-area are marine, with the exception of the latest Lower Cretaceous Kingsvale Group (unit 18) and possibly the Pasayten Group (unit 17) exposed on the eastern margin of the map-area, whereas all later rocks are non-marine. Following uplift there was an episode of normal and (?) strike-slip faulting in Early Tertiary time, that was concentrated along a north-south line passing through Hope. Intrusion of abundant granitic rocks (unit 24) in Oligocene-Miocene time apparently had little structural effect.

There is little evidence that orogeny (i.e. tectonism and mountain budding) took place in the map-area between mid-Devonian (?) and mid-Cretaceous time. Coarse clastic rocks of Permo-Pennsylvanian age and hiatuses between Lower Permian, Upper Triassic, Upper Jurassic and Lower Cretaceous rocks record crustal unrest presumably related to deep-seated tectonic processes. This stratigraphic evidence cannot be linked at present to any pre-mid-Cretaceous metamorphic or structural event recorded in originally deep-seated rocks. However, such events doubtless led up to orogeny in mid-Cretaceous time that involved both deep-seated and near surface rocks.

An earlier, pre-Middle Devonian orogeny may have occurred in the map-area, but the rocks in which such an event is recorded (unit Bd) form a minor part of the terrain and the evidence for this orogeny is outside the map-area.

Pre-Middle Devonian Deformation and Metamorphism

Pre-Middle Devonian deformation is probably recorded in foliated metamorphic rocks of unit Bb that form fault slices on the west side of the Cascade Mountains. These are correlated with deformed and metamorphosed rocks that are overlain with angular unconformity by Middle Devonian sedimentary and volcanic rocks 40 miles southwest of the map-area (Danner, 1967).

Permo-Pennsylvanian Uplift

Uplift in the region, although not necessarily in the map-area, took place in post-Early Pennsylvanian, pre-late-Early Permian time. Coarse sandstone and minor conglomerate in unit 2c of the Chilliwack Group overlie Lower Pennsylvanian limestone (unit 2b) and fine-grained clastic rocks (unit 2a). These coarse-grained rocks probably record an increased rate of uplift and erosion. Allochthonous plant fossils in unit 2c, which is marine, show that the source area was above sea level. As sandstone and conglomerate in unit 2c are derived from a volcanic rock, chert and limestone terrane, it seems probable that the erosion represented by unit 2c was shallow.

In the map-area no hiatus can be recognized between Lower Pennsylvanian limestone (unit 2b) the overlying clastic sequence (unit 2c) and Lower Permian limestone (unit 2d) so the southwestern part of the map-area may not have been uplifted at all. However, this may not be the case in adjacent areas, as Danner (1960) believed that a disconformity existed below the equivalent of unit 2c about 5 miles south of the map-area. Possibly one or more hiatuses may be included in unit 2c. Unfortunately fossils in unit 2c are insufficiently diagnostic to determine whether unit 2c is either Pennsylvanian or Permian or both.

Permo-Triassic Hiatus

No stratigraphic evidence for post-late Paleozoic, pre-Jurassic deformation and metamorphism is known from the map-area, although there was possibly uplift at this time. McTaggart and Thompson (1967) thought that there was northwest folding and faulting of the Hozameen Group (unit 1) together with the development of gneiss (unit C) in late Paleozoic or early Mesozoic time. This was based on the apparent gradational contact between gneiss and the Hozameen Group, the composition of the gneiss, which is compatible with it being derived from the Hozameen Group, and the seemingly more complex deformation of the late Paleozoic Hozameen Group in comparison to contiguous Lower Jurassic and later rocks. However, the last possibly could be due to the decreasing effects of deformation away from the core of the Cascade Mountains (McTaggart, pers. comm.). South of this part of

the map-area, Misch (pers. comm.) believes that the degree of deformation of the Mesozoic rocks is comparable to that of contiguous Paleozoic rocks.

Misch (1966) believed that there was pre-Jurassic deformation and metamorphism in the region that was later than the deformation producing the pre-Middle Devonian basement metamorphic rocks. The argument for pre-Jurassic deformation and metamorphism is based on the following. Gneiss and blueschist in the Cascade Mountains are cut and mylonitized by mid-Cretaceous faults. As there is no stratigraphic evidence of major orogeny in rocks of Late Triassic to Early Cretaceous age, the orogeny producing this metamorphism is assumed to be pre-Late Triassic. Exploratory K-Ar dates of 218 and 259 million years on crossite in the blueschist indicate a minimum age of Late Permian-Early Triassic for its formation. Furthermore, a pronounced angular unconformity exists between Upper Permian and Upper Jurassic-Lower Cretaceous rocks about 55 miles south of the map-area (Danner, 1966) and Upper Permian and Lower and Middle Triassic rocks are absent from much of the region. On this basis, Misch (1966) was inclined to assume an episode of intense deformation and metamorphism in permo-Triassic time, but stated that this episode conceivably pre-dates late Paleozoic deposition.

However, evidence from the map-area shows that no deformation of near-surface rocks took place in Permo-Triassic time, at least on the west side of the Cascade Mountains. Lower Permian rocks of the Chilliwack Group (unit 2) are overlain disconformably by Upper Triassic rocks of the Cultus Formation (unit 4) (Monger, 1966). Bedding in both units is conformable in outcrop and regionally within the map-area. South of Fraser River, for example, Permian volcanic rocks (unit 2e) are apparently everywhere in stratigraphic contact with Upper Triassic rocks. Although the thickness of the Permian volcanic rocks varies from 2,000 feet to 200 feet this variation could well be due to the nature of the sequence, and because it occupied a much greater area prior to mid-Cretaceous folding and thrusting. Contiguous Permian and Triassic rocks in this part of the map-area have undergone the same amount of deformation and metamorphism. Lawsonite, a characteristic mineral of the blueschist facies, occurs in feldspars in both Permian and Mesozoic rocks (units 2e and 4), although it could conceivably be detrital in the latter.

The Permo-Triassic hiatus could have been caused by gentle upwarping and nondeposition or alternatively could result from the volcanic rocks (unit 2e) accumulating more rapidly than they subsided so that they were above sea level (see Dott, 1961). Minor (?) erosion of Permian rocks in the region did take place because a thin breccia, which contains angular clasts of mainly volcanic rocks similar to the Permian volcanic rocks, forms the base of the Mesozoic section in the Chilliwack Valley area.

In conclusion the writer feels that either no deformation took place in the region in Permo-Triassic time or that it took place only at deeper levels. Near-surface rocks were essentially undeformed, although they may have been upwarped.

Jurassic and Cretaceous Hiatuses

Two roughly synchronous hiatuses in Middle Jurassic to Lower Cretaceous rocks on both sides of the Cascades, and abundant granitic detritus in Lower Cretaceous rocks, reflect crustal unrest and uplift that culminated in orogeny in mid and Late Cretaceous time. On the western side of the Cascades, the Oxfordian Kent Formation (unit 10), composed of conglomerate containing clasts of volcanic and sedimentary origin, overlies the Callovian Billhook Formation (unit 9) with slight angular unconformity (Crickmay, 1962). On the east side of the Cascades, in the southeast part of the map-area, Coates (in press) has shown that the Oxfordian to Portlandian Dewdney Creek Group (unit 12a) overlies the Toarcian-Bajocian Ladner Group (unit 5) with apparent disconformity or low angle unconformity. According to Coates the Dewdney Creek Group contains "a trace of granitic material". The Berriasian and lower Valanginian Peninsula Formation (unit 14) of the Harrison Lake area has a basal conglomerate and pebble-bearing arkose containing granitic clasts. It rests with slight angular unconformity on Oxfordian and Callovian rocks. On the eastern side of the Cascades the Hauterivian to Albian Jackass Mountain Group (unit 16b) disconformably overlies the Dewdney Creek Group. Granitic detritus is abundant in the Jackass Mountain Group and its nonmarine eastern partial equivalent, the Albian Pasayten Group. According to Coates, the uppermost Lower Cretaceous rocks have two source areas. A western one, consisting of Paleozoic and Mesozoic rocks, indicating that there was uplift of the Cascade axis at this time, and an eastern granitic source area.

Mid- and Late Cretaceous Orogeny

Deformation, metamorphism (?) and granitic intrusion (?) in mid- and Late Cretaceous time appears to have established the basic structural pattern of the map-area. Five northwest-trending belts were formed, each with a distinctive structural style. These belts correspond to the vertical divisions shown on the Table of Formations (Fig. 2), except that there the Paleozoic and Mesozoic rocks on the east side of the map-area have not been separated. Between these belts are mid-Cretaceous faults. Post-Cretaceous granitic intrusions (unit 24) have obscured the boundaries of the belts in some places. Characteristics of these belts are given below in Table IV.

1. Eastern plutonic belt

This structural unit differs from the others in that it appears to have been little involved internally in mid- to Late Cretaceous deformation but was merely uplifted. It consists mainly of the Eagle Granodiorite (unit 13) that has a pronounced foliation concordant with the regional structural trend and minor Upper Triassic, Cretaceous and Tertiary volcanic rocks (units 3, 18 and 23).

The Eagle Granodiorite may have been formed during metamorphism in Triassic-Jurassic time that affected a much wider area than the Coast Cascade orogen. In the southern extension of the belt in Princeton map-area Rice (1947) noted the conformity between structures in the Upper Triassic

Table IV

Structural belts formed in Cretaceous time, Hope map-area

	Name of belt	Composition	Structural Characteristics	Western Boundary
East	Eastern plutonic belt	mainly Eagle grano-diorite (unit 13)	pre-Cretaceous foliation, apparently only uplift in Cretaceous time	Pasayten Fault
	Eastern Mesozoic sedimentary belt	Mesozoic sedimentary rocks (units 5, 12, 16, 17)	mid-Cretaceous folding; west limbs of folds overturned to east, reverse and high angle thrust faulting	Hozameen Fault
	Eastern Paleozoic sedimentary and volcanic belt.	late Paleozoic sedimentary and volcanic rocks of Hozameen Group (unit 1)	complex folding and faulting; earliest folds possibly pre-date the Lower Jurassic. Minor Lower Cretaceous intrusions	movement zone marking the transition to gneiss (unit C)
	Axial belt	gneiss (unit C) schist (unit B) granitic rocks (units 19, 24)	complex folding; possibly in part pre-Lower Jurassic; faulting, metamorphism?, local anatexis?, granitic intrusion in mid- and Late Cretaceous time	reverse fault
West	Western belt	Paleozoic and Mesozoic sedimentary and volcanic rocks (units 2, 4, 6, 7, 8, 9, 10, 11, 14, 15, local granitic rocks (unit 19)	recumbent folding and thrusting in south, reverse faults (or tilted thrusts?) in north in mid, Late Cretaceous time	intrusive contact with Coast Mountains granitic rocks

Nicola Group and the Eagle Granodiorite (there a complex of gneissic and granitic rocks). He felt that granitic material had been introduced along the bedding of the Nicola Group after folding, as there was no evidence of crushing in the granitic rock. Working south of this in the Okanogan Range of northern Washington, Hawkins (1968) noted the resemblance of the Eagle Granodiorite of Rice and the Spanish Camp Gneiss of the Okanogan Range. The latter was felt to be the result of post-Paleozoic, pre-mid-Jurassic "Isochemical metamorphism of eugeosynclinal rocks". In the map-area an analogous rock is gneiss of unit C in the axial belt, believed to be of pre-Jurassic age and derived by metamorphism from rock of the Hozameen Group (McTaggart and Thompson, 1967). Unit C differs from gneiss to the east as it has been strongly involved in mid- to Late Cretaceous deformation and intruded by Late Cretaceous and Tertiary granitic rocks. Possibly there was deep-seated metamorphism and anatexis over a wide area in early Mesozoic time. By Cretaceous time this had become restricted to the axial belt of the Cascade and Coast mountains, and little else happened in the Eastern plutonic belt apart from uplift in Lower and mid-Cretaceous time.

The Pasayten Fault bounding this structural unit on the west is assumed in the map-area on the basis of the straightness of the contact between the granodiorite and Mesozoic rocks and mapped faults both north and east of the map-area. To the north Duffell and McTaggart (1952) showed a fault separating the Mount Lytton pluton (the continuation of the Eagle Granodiorite) from downdropped Mesozoic rocks to the west. East of the map-area Coates (in press) named and described this fault. He believed it was a normal fault with up to 20,000 feet dip-slip movement that was probably active in Early Cretaceous time as the uplifted eastern side was the source of some Cretaceous sandstones to the west. Slickensides on the fault surface show both oblique- and strike-slip movement. The latter is also indicated by the volume of Cretaceous arkose west of the fault, material that could only have been derived from a granitic terrane of considerable extent, such as the Okanogan batholithic complex.

2. Eastern Mesozoic belt

Little is known of the structure of the Mesozoic belt in the map-area, Cairnes (1924) reported a major syncline that crossed Coquihalla River just east of its confluence with Ladner Creek, minor folds and reverse faults, and southwest dipping bedding and slaty cleavage in the Ladner Group. He showed a fault separating the Pasayten Group (unit 17) from the Dewdney Creek Group (12b).

Detailed mapping by Coates (in press), mainly from east of the map-area, has shown structures that appear to conform to these. Coates described two major synclines with axial surfaces dipping west-southwest. The westernmost may be the southern extension of the syncline mapped by Cairnes. Large-scale reverse faulting, genetically related to the folding, has caused imbrication of the eastern limbs of these folds. One such fault, called the Chuwanten Fault by Coates, probably extends north-northwesterly into the map-area as the fault that separates the Dewdney Creek and Ladner groups. According to Coates the form and attitude of these folds and faults is compatible with a single episode of nearly horizontal compression.

The age of this deformation, which involves youngest Lower Cretaceous rocks, is best dated as early Late Cretaceous. Evidence for this comes from the Hozameen Fault, which separated Paleozoic rocks from Jurassic and (?) Lower Cretaceous rocks. Coates has shown it as a steep dipping reverse fault, similar to the reverse faults in the Mesozoic rocks, and believed that it formed during deformation of the Mesozoic rocks. A minimum age on this fault is 84 million years or mid-Late Cretaceous, obtained by radiometric dating on a small pluton that cuts it (Coates, in Wanless, et al., 1967).

The Hozameen Fault is assumed for most of its length in the map-area, on the basis of the straightness of the contact between Paleozoic and Mesozoic rocks and the presence of serpentinite (unit Aa) along it. At its northern end it appears to merge with the complex of faults along Fraser Valley, crosses the Fraser River just south of Boston Bar, recrosses it to the north, and juxtaposes metamorphic rocks (unit Ba) against Lower Cretaceous rocks (unit 16a).

3. Eastern Paleozoic sedimentary and volcanic belt

According to McTaggart and Thompson (1967) these rocks have undergone multiple deformation. Earliest deformation, possibly in pre-Jurassic time, produced northwest-trending folds and faults and the concomitant formation of the Custer Gneiss (part of unit C). This event is tentatively correlated by the writer with the early Mesozoic? formation of gneiss associated with Eagle Granodiorite east of the map-area. Following this, in mid-Cretaceous time, there was minor northeasterly folding and local deformation near the Hozameen Fault. In the south of the map-area the early northwest-trending folds were probably compressed in the same episode of deformation that produced the folds in Mesozoic rocks to the east. North of Hope the Hozameen Group was metamorphosed and intruded by partly concordant, possibly partly anatectic, quartz diorite (unit 19).

A zone of shearing, metamorphism and intrusion separates this belt from the central complex of schist, gneiss and granitic rock. This was presumably the limit of development of the gneissic rocks (unit C) from the Hozameen Group. In mid? and Late Cretaceous time it was a zone of intense shearing and mylonitization along which, north of Hope, small granodiorite bodies (unit 20) were intruded.

4. Axial belt

This belt is distinguished from the others as it is the principal site of high-grade metamorphism and granitic intrusion in the map-area, and merges with the typical Coast Mountains geology in the north. Metamorphism in this belt possibly started in pre-Early Jurassic time and continued into the Late Cretaceous, far longer than anywhere else in the map-area. Unfortunately most of the complex and long structural development of this belt took place at depth and cannot be linked to the stratigraphic record until Early Tertiary time, so its history is very uncertain. The abundance of Late Cretaceous and Tertiary granitic rocks in the belt obscures the record still more.

Folds in the belt trend mainly northwesterly. Well-documented major structures are rare because of the relative lack of marker horizons, although Roddick and Hutchison (1969) reported an elongate gneiss dome (unit C) surrounded by schists (units Bb, Bc) in the northwest part of the map-area.

A fault zone separating this belt from little metamorphosed rocks to the west is largely obscured by Cretaceous and Tertiary intrusions. On the west side of Harrison Lake, near Big Silver Creek, it appears to be a steeply northeast-dipping reverse fault that juxtaposes gneissic rocks with greenschist grade rocks probably belonging to the Chilliwack Group. South of this, near The Old Settler, it is possibly a complex zone rather than a single fault, that involves slices of possible pre-Devonian basement (unit Bd), Paleozoic rocks (unit 2) and ultramafic rocks. On one side of this zone are greenschist-grade volcanics and pelites mapped as Chilliwack Group (unit 2) and on the other quartzose schists and other schistose rocks (unit Bb). Farther south this fault appears to be obliterated by granitic rocks. The prominent north-south fault or fault zone extending from Ruby Creek to the International Boundary along which ultramafic rocks (units Aa, Ac) and basement slices (unit Bd) have been emplaced may not be the continuation of the fault zone to the north, as relatively little-metamorphosed Chilliwack Group rocks occur west of it in Chilliwack Valley.

5. Western Paleozoic and Mesozoic sedimentary and volcanic belt

Upper Paleozoic and Mesozoic rocks in this belt are separated by a disconformity and have been tightly folded and thrust, probably in mid-Cretaceous time. Subsequently, possibly in Eocene time, the rocks south of Fraser River at least, were folded, reverse faulted and warped.

Three major tectonic units are separated by thrust and reverse faults in the belt south of Fraser River (Fig. 4). The lowest unit is believed to be autochthonous and consists mainly of Mesozoic rocks with minor Paleozoic rocks. On the west it is bounded by a steep northeast-trending fault across which a narrow sliver of probable pre-Devonian basement (unit Bd) has been brought up, and on the south and east by a thrust fault. Minor folds in this unit are tight, overturned to the northwest and have axial planes that dip southeast at moderate angles. A penetrative fracture cleavage (or reticulate cleavage of Crook, 1964) is developed only in the pelitic rocks and not in the sandstones. Paleozoic rocks overlying the Mesozoic rocks on Church Mountain are believed to be part of this unit as the degree of alteration and development of planar structures is identical to that in the Mesozoic rock below. The Paleozoic rocks may comprise the lower limb of an overturned fold and as such should be called parauthochthonous, although Misch (pers. comm.) believes that they form a thrust slice. Above this unit are allochthonous rocks that overlie a major thrust correlated with the (American) Church Mountain thrust of Misch (1966). Within the allochthonous rocks a thick lower sequence of Permian volcanic rocks (unit 2e) is separated by an assumed thrust from overlying Pennsylvanian and Permian strata (units 2a, 2b, 2c, 2d, and 2e) and Mesozoic rocks (unit 4). Permian limestone (unit 2d) on Mount McGuire and the north side of Chilliwack Valley outlines a major recumbent fold overturned to the northwest (Fig. 4). This plunges gently to the northeast, probably as the result of later deformation. The lower limb

of the fold is replaced by a thrust, below which is the thick sequence of Permian volcanic rocks. The thrust appears to be genetically related to the recumbent folding. Minor folds in these rocks mirror the geometry of the major structure. Planar structures in the allochthonous rocks are far better developed than those in the autochthon. An axial-plane slaty or phyllitic cleavage is found in both Paleozoic and Mesozoic pelitic rocks and the grains in coarser clastic rocks are flattened, producing a crude foliation. Paleozoic rocks on Cheam Peak, and those that form a klippe to the south of it, appear to be a structurally higher thrust sheet as they overlie Mesozoic rocks. The easternmost tectonic unit includes Paleozoic rocks (unit 2), probable basement rocks (unit Bd) and minor ultramafic rocks (units Aa, Ac), and is separated from rocks to the west by a north-south trending fault zone that dips easterly at about 70 degrees where well-exposed near Mount Pierce. This fault appears to truncate structures to the west. Rocks east of the fault probably form the northerly continuation of the zone of imbricated Paleozoic rocks and basement slices below the main Shuksan Thrust of Misch (1966) that is well-exposed west of Slesse Creek just south of the International Boundary.

The structural pattern north of Fraser River is probably similar. Rocks west of the imbricate zone along Harrison Lake correspond to the autochthon. The probable Paleozoic rocks (unit 2) between this zone and the fault along Ruby Creek are analogous to the allochthonous Paleozoic and Mesozoic rocks in the Chilliwack Valley. Rocks east of the Ruby Creek fault are schists (unit Bb) as well as Chilliwack Group rocks. North of here the complex of ultramafic rocks (unit Aa), basement slices (unit Bd), Chilliwack rocks (unit 2), and schists (unit Bb), forming The Old Settler in many ways resembles the imbricated zone near where Slesse Creek crosses the International Boundary. The main difference between this are north of Fraser River and that south of Fraser River is that here all faults dip steeply eastward whereas south of the Fraser they are relatively flat lying. This difference is possibly due to differential uplift of the Coast Mountains west of Harrison Lake.

Metamorphism of most of these rocks is relatively slight. Exceptions are pre-Devonian basement rocks (unit Bd) and contact metamorphosed rocks near the granitic intrusions. South of Fraser River volcanic rocks are invariably saussuritized and belong to the lower part of the greenschist facies. Fine-grained lawsonite, characteristic of the glaucophane schist facies, occurs in Permian volcanic rocks and in feldspar grains in Lower (?) Jurassic sediments. This is perhaps a marginal development of that belt of greenschist and blueschist (Shuksan greenschist of Misch, 1966) on the west side of the gneissic and granitic core of the Cascade Mountains south of the International Boundary. The age of this metamorphism is not known. Exploratory K-Ar dates indicate that the minimum age of crossite in this blueschist is Permo-Triassic (Misch, 1966). If this is so then the lawsonite in Mesozoic rocks may be detrital.

Age of the deformation cannot be dated more precisely than post-Upper Jurassic, pre-Miocene. South of the map-area a maximum age is given by the involvement of Lower Cretaceous rocks and a minimum age by the latest Cretaceous-Paleocene Chuckanut Formation that has not been affected by this deformation.

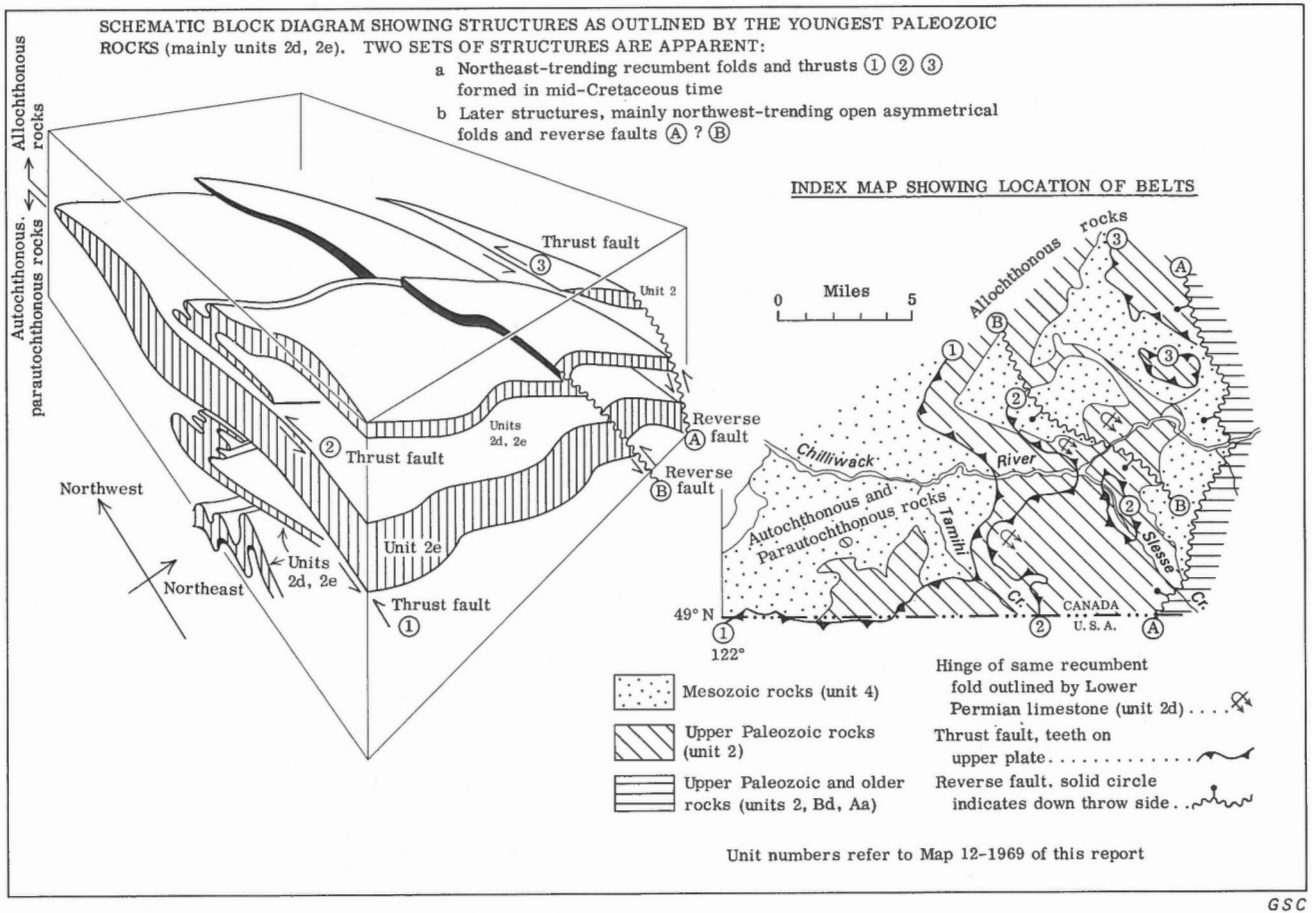

Figure 4. Interpretation of structures in southwestern part of Hope map-area.

Early Tertiary Deformation

The most noticeable effect of Early Tertiary deformation is the zone of north-south trending faults along the Fraser River above Hope. In addition, there was folding along the Fraser River partly synchronous with this faulting. Folding and reverse faulting in the westernmost of the mid- to Late Cretaceous structural belts may have taken place at this time.

The Fraser River fault zone contains two major, nearly parallel faults, the Hope Fault on the west and the Yale Fault on the east. The sense of movement on these faults suggests that prior to Tertiary folding and intrusion a graben existed north and south of Hope in which Eocene sedimentary rocks (unit 21) were deposited. In addition, there may have been considerable lateral movement on these faults. Northwest of Hope, Eocene sedimentary rocks (unit 21) have been downdropped along the east side of the Hope Fault and are in contact with Late Cretaceous granitic rocks (unit 19). South of Hope small patches of Eocene sedimentary rocks surrounded by granitic rock (units 19, 24) are aligned in a north-south direction as far as the International Boundary and may mark the trace of the Hope Fault. The parallel Yale Fault is delineated mainly by a zone of mylonitization and extends from just north of Chilliwack Lake to north of Spuzzum. In the southern part it is cut by mid-Tertiary intrusive rocks. In the north it probably merges with the Hope Fault north of Spuzzum and then with the older Hozameen Fault near China Bar. Small folds in the mylonite suggest that the west side of this fault has moved relatively down (McTaggart and Thompson, 1967). South of the International Boundary the Straight Creek Fault of Misch (1966) is aligned with the Yale Fault and shows the same sense of vertical movement. Possible right-lateral movement on the Fraser River fault zone is indicated in the map-area by the change of structural trend near the fault zone. Away from it structures trend north-northeasterly whereas near the fault they trend north. The fault zone continues into Ashcroft map-area to the north (Duffell and McTaggart, 1952) and from there apparently swings northwesterly and possibly connects with the numerous faults in Mount Waddington map-area (92N), about 150 miles north of the map-area. Considerable right lateral movement on some of these faults has been reported by Tipper (1968). The severe shearing of the granitic rocks (units 19, 21) near the Fraser River fault zone may be related to this strike-slip movement.

Early Tertiary folding can be well-documented along the Fraser River fault zone, where strong folding following deposition of Eocene rocks resulted in near vertical dips of bedding in many places. Folding and faulting in the southern part of the western sedimentary and volcanic belt can only be dated as post mid- to Late Cretaceous deformation, pre-Oligocene and Miocene granitic intrusions. It is tentatively correlated with well-documented early Eocene deformation just southwest of the map-area (Miller and Misch, 1963). The mid- to Late Cretaceous, northeast-trending, recumbent folds and thrusts are refolded into broad anticlinal structures on northwest-trending axes and cut by reverse faults that dip northeasterly (Fig. 4). Minor structures are conjugate and chevron folds, kink bands and crenulation cleavage.

Some movement on the Hope Fault took place in Eocene time but some may have been earlier. The patch of Eocene sedimentary rock on Isolillock Peak is probably faulted against Lake Cretaceous (?) granitic rock (unit 19) on the west and intruded by Tertiary granitic rock (unit 24) on the

east. As the latter has been dated at 35 million years (early Oligocene) latest movement on this fault was probably in late Eocene time.

Mid-Tertiary Intrusion

Extensive granitic rock (unit 24) intruded in Oligocene-Miocene time apparently had no large scale structural effect. Contacts are sharp and discordant and any metamorphism of country rock accompanying intrusion is restricted to a narrow band near the contact.

Pliocene-Pleistocene Upwarping

Pliocene-Pleistocene upwarping of the Coast and Cascade mountains is supported by both geomorphological and paleobotanical evidence from outside of the map-area. According to Tipper (in Roddick, 1967) Pliocene plateau basalts rise smoothly from elevations of 2,500 feet in the central interior of the province to elevations as high as 8,500 in the Coast Mountains. Mathews (1968) noted that small upland relicts of an apparently once extensive erosion surface occur in the Coast and Cascade mountains and are correlated with a post-Eocene, pre-Late Miocene erosion surface in the central interior. Plant fossils in upper Miocene or lower Pliocene rocks just east of the Coast Range indicate that the climate that this flora grew in was moister and milder than now. Therefore it seems probable that the Coast and Cascade mountains were lower in Miocene and early Pliocene time allowing moist, mid-Pacific air to penetrate the interior.

The Problem of the Age of High-Grade Metamorphic Rocks in the Map-area

A major problem in the map-area is the age of the high-grade metamorphic rocks and migmatites that comprise unit C and much of unit Bb. As is apparent from Figure 3, there is nothing in the stratigraphic record that can be positively linked with any episode of high-grade metamorphism in pre-mid-Cretaceous time, with the possible exceptions of pre-Middle Devonian rocks in the west and pre-Lower Jurassic? deformation of the Hozameen Group in the east.

There are three possible origins for these metamorphic rocks. Firstly, they could be part of an old, pre-Devonian, high-grade metamorphic basement that became involved in mid-Cretaceous deformation. Secondly, they could have formed during orogeny in mid-Cretaceous time. Finally, they could have been produced by a long continuing process that culminated in mid-Cretaceous orogeny. As there is no record of the latter in the surficial rocks, such a process could only be accounted for if there was a mobile, deep layer of high-grade metamorphic rock and migmatite (or infrastructure) overlain by a structurally competent cover of surficial rock (or suprastructure) that reflects events in the deeper layers only by vertical movement, if at all. Not until mid-Cretaceous time were both layers involved in the same deformation. Rocks of all three origins may be included in units C and Bb.

Some gneiss could be part of an old, pre-Middle Devonian basement, relicts of which (unit Bd) may be preserved in the western nonmetamorphic

belt. Misch (1966) has distinguished such rocks (e. g. Eldorado orthogneiss) within the axial belt of schist and gneiss in the Cascade Mountains of northern Washington. Such gneiss possibly occurs in the northwestern part of the map-area, 8 miles east-southeast of Mount Breakenridge, where it forms the core of a doubly plunging anticline and is apparently concordantly overlain by schist (Roddick and Hutchison, 1969). However even if the schist is of Mesozoic age, the gneiss cannot be dated as other than pre-Mesozoic. Lithologically this gneiss is far more homogeneous than gneiss exposed in the southern part of the map-area, and the two may be of different ages.

Gneiss, migmatite and schist possibly formed during a single episode during Cretaceous time. Indications that this may be so locally comes from near Yale, where the Spuzzum quartz diorite (unit 19) may have formed by metasomatism or anatexis of metamorphosed Hozameen rocks (McTaggart and Thompson, 1967). However, the Late Cretaceous radiometric age obtained from this pluton, which is the sole evidence here of its time of formation, probably only records the time of cooling below a certain temperature, and may be very different from its time of formation.

In addition, gneiss and high-grade metamorphic rocks were formed at some time between the development of pre-Middle Devonian metamorphic rocks and mid-Cretaceous orogeny, possibly in early Mesozoic time. A minimum age is indicated by gneiss of unit C in the Fraser Canyon north of Hope that was crushed and mylonitized during Cretaceous deformation (McTaggart and Thompson, 1967). The crushing indicates that the gneiss was deformed in a very different environment from that in which it was produced. Similar evidence is used by Misch (1966, and pers. comm.) to demonstrate that high-grade metamorphic rocks in the Cascade Mountains pre-date mid-Cretaceous orogeny. Two arguments suggest that the maximum age is latest Paleozoic. Firstly, on the basis of composition McTaggart and Thompson (1967) suggested that gneiss in the southern part of the map-area is derived from the Hozameen Group, and Misch (1966) noted that the overall lithology of his Skagit Gneiss (equivalent to unit C) is comparable to that of upper Paleozoic rocks in the area, although there are some differences. Secondly, the composition of volcanic rocks indicates that the gneiss is either post-latest Paleozoic or pre-Devonian (?). Paleozoic volcanic rocks are predominantly basic, whereas Mesozoic volcanic rocks are intermediate or acidic. It seems unlikely to the writer that basic magma would be extruded in the same area and at the same time as acidic gneiss was being formed at depth.

GEOLOGICAL HISTORY OF HOPE MAP-AREA

Pre-Middle Devonian Region

Deposition, intrusion and metamorphism took place in the map-area probably in pre-Middle Devonian time. Relicts of the terrane resulting from these processes are amphibolite and schist (unit Bd) that form slices along mid-Cretaceous faults in the western part of the map-area.

Late Paleozoic Record

In late Paleozoic time great thicknesses of basic volcanic rocks, chert and pelite with lesser amounts of limestone, sandstone and pyroclastic rocks were deposited. On the western side of the Cascade Mountains fine clastic rock and argillaceous limestone (units 2a, b) of Early Pennsylvanian age probably were laid down under quiescent conditions. These were succeeded by coarser clastic rock (unit 2c) derived from a volcanic and limestone terrain and containing allochthonous plant material that presumably records uplift and emergence of land in Permo-Pennsylvanian time. Then followed a thick sequence of Lower Permian volcanic rocks (unit 2e), mainly basic but locally as acidic as dacite, and partly stratigraphically equivalent Lower Permian limestone (unit 2d). The accumulated volcanic rocks may have formed highs on and about which limestone was deposited. Rocks on the eastern side of the Cascade Mountains (unit 1) cannot be dated precisely because of the absence of fossils, but their lithology suggests they are upper Paleozoic. They may represent a deeper water facies than Permo-Pennsylvanian rocks to the west as coarse clastic rocks are absent, chert is abundant and limestone only a minor part of the succession. In addition, the volcanic rocks are nearly all flows, whereas about one-third of the Permian volcanic succession to the west is pyroclastic material. These basic volcanic rocks are intimately associated with ultramafic rocks along the eastern margin of the Paleozoic rocks.

A regional hiatus between Lower Permian and Upper Triassic rocks may be due either to upwarping, possibly related to deep-seated formation of gneiss, or because volcanic accumulation in Early Permian time exceeded subsidence and the building up of high areas that were not covered until the Late Triassic.

Mesozoic Record

In contrast to upper Paleozoic rocks the Mesozoic succession is largely clastic rock, with volcanic rocks locally important in Late Triassic, Middle Jurassic and late Early Cretaceous time. In general the clastic succession becomes coarser upwards, with pelites and siltstones predominating in the oldest part and sandstones and conglomerates in the youngest. The composition changes upwards as well. Older rocks consist largely of volcanic detritus whereas the youngest contain much granitic material. All of these rocks are marine, with the exception of late Lower Cretaceous rocks in the eastern part of the map-area. These changes are compatible with an increase in local relief with time, concomitant erosion of deeper levels exposing granitic rocks, and late Lower Cretaceous regional uplift.

A trough appears to have occupied much of the map-area in early Mesozoic time. In this, Upper Triassic and Lower to Middle Jurassic pelites and fine-grained graded sandstones derived largely from volcanic rocks were deposited by turbidity currents. Bordering the trough on east and west were high areas that probably were the sources of these sediments. The high area to the east was composed of volcanic rocks (unit 3) and underlay the northeast part of the map-area and the adjoining Princeton and Nicola map-areas. That to the west consisted of volcanic rock and limestone and underlay Vancouver Island.

In Middle Jurassic time a thick sequence of intermediate to acidic flows and pyroclastic rocks (unit 6) was deposited locally (?) in the western part of the trough.

The trough apparently persisted through Jurassic time, but in Early Cretaceous time became divided into eastern and western parts by a geanticline located along the present axis of the Cascade Mountains. Pelites, sandstones and conglomerates, together with pyroclastic rocks were laid down in Late Jurassic and Early Cretaceous time. Partly synchronous hiatuses on both sides of the Cascade axis record crustal movements in early Late Jurassic and latest Jurassic - earliest Cretaceous time that may have been precursors of mid- and Late Cretaceous orogeny. By late Early Cretaceous time material was being eroded from uplifted upper Paleozoic and lower Mesozoic rocks of the axial geanticline and deposited in the eastern trough, along with granitic and gneissic detritus from uplifted rocks east of the Pasayten Fault.

In the upper Cretaceous the whole area underwent orogeny. All pre-mid-Cretaceous rocks were folded, faulted, metamorphosed (?), intruded and uplifted, with the apparent exception of rocks (mainly unit 13) on the east side of the Pasayten Fault which was only uplifted. This deformation may have initially started in the axial belt, where it was reflected in the axial geanticline in late Early Cretaceous time and progressed outwards. Granitic rocks and gneisses (units C, 19, 20) in the axial belt were sheared and mylonitized and some may have evolved at this time by anatexis or metasomatism. Sedimentary and volcanic rocks west of the axis were folded and thrust to the west and northwest; those to the east were folded and reverse faulted. Subsequent normal and strike-slip (?) faulting in Eocene time produced a prominent north-south graben along the Fraser River above Hope and to the south, in which nonmarine Eocene rocks were deposited.

Post-Eocene Record

Following this orogeny, Tertiary volcanic rocks (units 22, 23) were unconformably laid down on the older rocks, and related (?) mid-Tertiary granitic rock (unit 24) discordantly intruded. The Coast and Cascade mountains were then uplifted in Pliocene-Pleistocene time and extensively glaciated, to produce the present topography.

ECONOMIC GEOLOGY

Hope map-area has a long history of mineral discoveries, although relatively few of the many properties recorded from this area have been exploited with any major commercial success. In 1858 placer gold was found in gravel bars of the Fraser River near Yale. A lode silver deposit, discovered in 1868 on Silver Peak 6 miles south of Hope, was covered by the first crown-granted claims in British Columbia and was one of the earliest lode mine producers in the province. Exploration in the late 19th century and early years of this century led to the discovery and subsequent exploitation of (1) lode gold in the Siwash Creek-Ladner Slate belt - Coquihalla serpentine belt area, about 12 miles northeast of Hope, (2) silver-lead-zinc deposits in

Summit Camp, 18 miles east-northeast of Hope and (3) silver-copper-lead-zinc deposits in the Skagit River valley. The most important discovery to date was made in 1923, when a nickel-copper deposit was discovered at the head of Stulkawhits Creek, 7 miles northwest of Hope. This was subsequently developed into by far the most productive mine in the map-area. Numerous isolated occurrences are known from elsewhere in the map-area and are listed below, but few have been commercially exploited.

Location of properties is shown on the geological map. The number in brackets following the property corresponds with the property number shown on geological map.

METALLIFEROUS DEPOSITS

Placer Deposits

References: Cairnes, 1924, Geol. Surv. Can., Mem. 139, pp. 131-132.
Galloway, 1933, B.C. Dept. Mines, Bull. 1, p. 42.
Holland, 1950, B.C. Dept. Mines, Bull. 28, pp. 41-2.
Minister of Mines, B.C., Ann. Rept.

Production of placer gold in the map-area has come mainly from the Fraser River. Following the discovery of placer gold in 1858, gravel bars along the Fraser were rapidly mined and most of their wealth was recovered before the commencement of production records in 1874. Although mining continued in the following years, yields were relatively low.

Prospecting was intensive along Siwash and Hidden creeks as early as the 1870s, but only small yields were recorded. Colours were demonstrated in the Skagit River area and in tributaries of the Nahatlatch River, but there was no recorded production.

Placer activity, commencing around 1911, took place along the Coquihalla River and its tributaries including Ladner Creek, Fifteen Mile Creek, Sowaqua Creek, Peers Creek and Nine Mile Creek. There was little or no recorded production from these areas.

Platinum associated with placer gold is present in the map-area, but yields have been negligible.

Lode Deposits

1. Gold deposits of Siwash Creek, 'Ladner Slate belt' and 'Coquihalla serpentine belt'.

References: Cairnes, 1920, Geol. Surv. Can., Summ. Rept., Pt. A, pp. 23-41.
1924, Geol. Surv. Can., Mem. 139.
1929, Geol. Surv. Can., Summ. Rept., Pt. A, pp. 144-147.
Stevenson, 1944, B.C. Dept. Mines, Bull. 20, Pt. IV, pp. 20-23.

The main concentration of lode gold deposits in the map-area extends from near the bend in Siwash Creek in the northeast to just southeast of the Coquihalla River, between Jessica and Sowaqua Creek valley. The deposits occur in rocks of the Ladner Group (unit 5), serpentinite (unit Aa) and the Hozameen Group (unit 1).

Interest in the area began with the discovery in 1891-92 of gold-bearing quartz veins in Siwash Creek valley. Prospecting in subsequent years was directed at quartz veins and siliceous zones in the Ladner and Hozameen groups. Not until 1927, when high-grade gold ore was found associated with serpentine on the Aurum property, was prospecting of the 'Coquihalla Serpentine belt' actually started.

Although considerable exploration and development of small showings was undertaken only very few small and intermittent producers emerged. Between 1916 and 1942, five properties in this area produced some 3,102 tons of ore containing 3,117 ounces of gold, most of which was obtained from quartz veins in the Ladner Group.

(a) Emancipation property (1)

References: Minister of Mines, B.C., Ann. Rept., 1915, p. 257; 1916, p. 264, p. 518; 1917, p. 234, p. 450; 1918, p. 239; 1920, p. 169; 1921, p. 197; 1922, p. 141; 1923, p. 162; 1924, p. 137; 1925, p. 181; 1926, p. 196; 1927, p. 208; 1928, p. 227; 1929, p. 238; 1930, p. 204; 1931, p. 114; 1932, p. 78; 1933, p. 175; 1937, p. A40, p. F35; 1938, p. A38; 1940, p. 28; 1941, p. 28.

Free gold, arsenopyrite, pyrrhotite and minor chalcopyrite occur in large quartz veins running along the contact between slaty members of the Ladner Group and volcanic rock of the Hozameen Group.

(b) Pipestem property (2)

References: Minister of Mines, B.C., Ann. Rept. 1922, p. 143; 1927, p. 208; 1928, p. 227; 1929, p. 238; 1932, p. 156; 1933, p. 176, p. 307; 1934, p. A30; 1935, p. A29, p. F58; 1936, p. F33; 1937, p. A40, p. F35.

Pyrite and arsenopyrite with sporadic high values of gold is in silicified zones or quartz veins paralleling cleavage and bedding in the Ladner Group.

(c) Aurum property (3)

References: (under Idaho) Minister of Mines, B.C., Ann. Rept. 1919, p. 185; 1922, p. 143; 1925, p. 182; 1926, p. 196; (under Aurum) Minister of Mines, B.C. Ann. Rept. 1927, p. 208; 1928, p. 225; 1929, p. 440; 1930, p. 182, p. 445; 1931, p. 105, p. 115, p. 203; 1932, p. 156; 1935, p. F35; 1939, p. 41, 1942, p. 28.

Native gold, pyrrhotite, pyrite, chalcopyrite, arsenopyrite and possibly millerite commonly from polished films on slickensided surfaces in talcose rocks or serpentine.

(d) Other properties in this area

(1) Siwash Creek area

Emigrant (4) (Minister of Mines, B.C., Ann. Rept., 1917, p. 226, 1918, p. 240); Roddick (Minister of Mines, B.C., Ann. Rept., 1934, p. F19); British Gold Mining Syndicate (Minister of Mines, B.C., Ann. Rept., 1937, p. F33); Coronation (Minister of Mines, B.C., Ann. Rept., 1937, p. F33); Golden Eagle (Minister of Mines, B.C., Ann. Rept., 1937, p. F33); Jubilee (Minister of Mines, B.C., Ann. Rept., 1937, p. F33).

(2) Coquihalla River to divide between Siwash and Ladner Creeks, Fifteen Mile, South Fork, (5) Montana, Spider Peak, Spencer Holdings, Keystone, Mammoth Holdings and properties of Columbia Metals Ltd., Reward Mining Co., and Dalhousie Mining Co. (Cairnes, 1929, Geol. Surv. Can., Summ. Rept., pp. 165-173).

(3) Three miles southeast of Yale. Hillsbar Creek property (6) (Cairnes, 1923, Geol. Surv. Can., Summ. Rept., Pt. A, pp. 81-83; Minister of Mines, B.C., Ann. Rept., 1927, pp. 209-10).

2. Silver-lead-zinc deposits of Summit Camp.

Reference: Black, 1952, in Minister of Mines, B.C., Ann. Rept., Pt. A, 119-A134.

The first claim staked in this area, in 1894, was the Eureka Claim on the southern slopes of Treasure Mountain. Small galena-sphalerite finds were made in subsequent years, but little exploration work was undertaken until the discovery in 1906 of the Silver Chief lode near the earlier claim. Development work took place at various times on other properties in the area, and small shipments of silver-lead-zinc ore were made over the years from the Eureka and Silver Chief properties.

Reported ore minerals include sphalerite, galena, pyrite, arsenopyrite, tetrahedrite, stibnite, pyrrhotite and possibly some rarer silver-bearing minerals. Cadmium and manganese have been recorded. Together with quartz and carbonate gangue, the ore minerals form stringers, veins, pockets and disseminations within and near faults that cut sedimentary and volcanic rocks of the Dewdney Creek and Pasayten groups (units 12b, 17).

(a) Silver Chief property (7)

References: Minister of Mines, B.C., Ann. Rept., 1913, p. 230; 1917, p. 208; 1922, p. 166; 1923, p. 188; 1925, p. 210; 1926, p. 223; 1927, p. 254; 1929, p. 278; 1930, p. 214; 1931, p. 24, p. 129, p. 203; 1939, p. 37; 1950, p. 112; 1952, pp. 125-127; 1953, p. 103; 1954, p. 111; 1955, p. 39; 1956, p. 71; 1957, p. 32.

Coarse sphalerite, galena, pyrite and tetrahedrite and chalcopyrite occurs in stringers and veins in sandstones and argillites of the Pasayten Formation, near the Treasure Mountain (Chuwanten?) fault zone. A total of 39,558 ounces of silver, 379,532 pounds of lead and 88,455 pounds of zinc were shipped from the mine prior to 1952.

(b) Eureka property (7)

References: Minister of Mines, B. C., Ann. Rept., 1923, p. 189; 1924, p. 170; 1925, p. 211; 1926, p. 223; 1928, p. 267; 1931, p. 130; 1952, pp. 129-130.

Mineralization is of a similar type to that of the Silver Chief. Production up until 1952 was 873 ounces silver, 12,825 pounds lead and 13,624 pounds zinc.

(c) Other properties in Summit Camp

1. Indiana.

References: Minister of Mines, B. C., Ann. Rept., 1896, p. 573; 1898, p. 1112; 1899, p. 742; 1913, p. 228-229; 1917, p. 208; 1919, p. 172; 1926, p. 223; 1928, p. 266; 1952, p. 132-33.

2. Southern Fraction No. 8.

Reference: Minister of Mines, B. C., Ann. Rept., 1952, p. 130.

3. Bluebell.

References: Minister of Mines, B. C., Ann. Rept. 1920, pp. 160-162; 1921, p. 180; 1926, p. 224; 1927, p. 254; 1952, pp. 130-132.

4. Summit.

References: Minister of Mines, B. C., Ann. Rept., 1899, p. 742; 1904, p. 300; 1913, p. 229; 1921, p. 180; 1922, p. 126; 1952, p. 133.

5. Queen Bess.

References: Minister of Mines, B. C., Ann. Rept., 1927, p. 255; 1928, p. 266; 1929, p. 278; 1930, p. 215; 1952, p. 215.

6. Rook.

Reference: Minister of Mines, B. C., Ann. Rept., 1967, p. 66.

3. Skagit River area.

The reported discovery of gold on Shawatum (formerly Steamboat) Mountain in 1910 stimulated prospecting in the area. This resulted in a number of low grade silver, copper, lead and zinc discoveries in the areas around the junction of Sumallo and Skagit rivers and north of Shawatum Mountain. Small shipments of ore were made from some of these properties. Intermittent prospecting resulted in the discoveries of copper and silver-lead-zinc properties (the AM and Invermay) in the 1930s, and interest in the area has continued to the present day.

The orebodies are diverse in character and mineralogy. They are mainly in rocks of the Hozameen Group (unit 1) and to a lesser extent in adjacent Mesozoic rocks, near the trace of the Hozameen Fault and near small, post-faulting quartz diorite stocks (unit 19).

Up until 1944 the Skagit area produced 11,477 ounces of silver, 26,541 pounds of lead and 12,163 pounds of zinc.

(a) AM property (8)

Main references: Minister of Mines, B. C., Ann. Rept., 1938, pp. F10-F13, pp. F23-F27; 1949, pp. 210-213; 1954, pp. 152-159; 1959, pp. 122-124; 1964, p. 136; 1965, pp. 206-213; 1967, p. 66.

Mineralization occurs in a pipe-like breccia in fine-grained, tuffaceous pelite of the Ladner Group (5). These rocks are cut by ultramafic, mafic and quartz diorite sills and dykes and by a quartz diorite stock. The ore is in pockets in the matrix of the breccia and in lesser amounts in veinlets cutting both breccia fragments and matrix. It consists of pyrrhotite, chalcopyrite and smaller amounts of pyrite. A gouge zone cutting the breccia contains lenses of massive arsenopyrite, pyrite and chalcopyrite. Molybdenite, magnetite, uranite, scheelite and galena are also reported.

In 1961, Canam Copper Co. Ltd., estimated the reserve of potential ore as 2,069,500 tons, grading 1.4 per cent copper, 0.026 ounce per ton gold and 1.00 ounces per ton silver.

(b) Invermay property (originally Norwegian Group) (9)

References: Minister of Mines, B. C., Ann. Rept. 1938, p. F23-F26; 1965, pp. 206-213.

Mineralization is in a stock of quartz diorite and occurs as (1) lenses and bands of sphalerite and galena with quartz in shear zones and as (2) grains and pockets of pyrite and chalcopyrite in tourmaline-rich layers.

(c) Hope property (10)

References: Minister of Mines, B. C., Ann. Rept., 1929, pp. 242-243; 1938, pp. F14-F16; 1967, p. 66.

Contact metamorphosed impure limestone contains disseminated chalcopyrite, sphalerite, pyrite, magnetite, specular hematite and minor galena associated with actinolite, garnet, calcite, quartz, and epidote.

(d) Mammoth property (11)

References: Minister of Mines, B. C., Ann. Rept., 1920, p. 171; 1923, p. 164; 1927, p. 210; 1929, p. 241; 1955, p. 74; 1962, p. 89; 1964, p. 137; 1965, p. 213.

Disseminated pyrrhotite, sphalerite and chalcopyrite are in pyroxenite dykes which intrude cherty rocks of the Hozameen Group. Scheelite and molybdenite have also been reported from this property.

(e) D and J property (12)

References: Minister of Mines, B. C., Ann. Rept., 1915, p. 265; 1923, p. 164; 1938, p. F9, F11; 1948, p. 154; 1962, p. 90.

Geol. Surv. Can., Summ. Rept., 1911, p. 122; 1920, Pt. A, p. 39; 1922, Pt. A, p. 122.

Pyrrhotite, chalcopyrite and minor sphalerite with sporadic stringers of arsenopyrite and minor galena from fracture fillings in chert, volcanic rock and minor limestone of the Hozameen Group.

(f) Gold Coin property (13)

References: Minister of Mines, B. C., Ann. Rept., 1929, p. 241; 1938, pp. F16-F20; 1950, p. 167; 1958, p. 55; 1960, p. 87; 1961, p. 86.

Pyrrhotite, sphalerite, arsenopyrite, chalcopyrite and galena occur in numerous parallel veins in fine-grained greenstone of the Hozameen Group.

(g) Silver Daisy property (14)

References: Minister of Mines, B. C., Ann. Rept., 1938, pp. F27-F28; and various reports between 1913 and 1929.

Pyrrhotite, sphalerite, chalcopyrite and galena are in a sheared quartz vein in chert of the Hozameen Group. Small shipments of ore were made from the property between 1916 and 1929.

(h) Rainbow property (15)

References: Minister of Mines, B. C., Ann. Rept., 1914, p. 363; 1915, p. 264; 1927, p. 211.

Silver and zinc with minor copper and gold are reported from this property.

(i) International and Grandview (16)

References: Minister of Mines, B. C., Ann. Rept., 1915, p. 265; 1929, p. 241; 1938, pp. 22F-23F.

These are the oldest recorded claims in the Skagit area. Galena and minor pyrite and chalcopyrite occur in andesite breccia and tuff of the Skagit Formation (unit 22).

4. Pride of Emory property (17).

References: Cairnes, 1924, Geol. Surv. Can., Summ. Rept., Pt. A, pp. 100-106.
Cockfield and Walker, 1933, Geol. Surv. Can., Summ. Rept., Pt. A, pp. 62-68.
Horwood, 1936, Geol. Surv. Can., Mem. 190.
Aho, 1956, Econ. Geol., vol. 51, pp. 444-481.
Minister of Mines, B. C., Ann. Rept., Bacon, 1954, pp. 161-163.
James and Eastwood, 1964, pp. 139-142; Eastwood and Robinson, 1965, pp. 215-217, plus numerous progress reports.

This has been the most valuable property to date in the map-area. It was discovered in 1923 and subsequently developed by a number of different companies. First ore shipments were made between 1933 and 1937. From

1937 to 1959, no ore was shipped although exploration and development continued sporadically. Since 1958 there has been continuous production from the mine, with the shipment of bulk nickel-copper concentrate. Below are production figures for the years 1958-1967.

Year	Ore treated (tons)	Ni-Cu Concentrates (tons)	Nickel Content (lb)	Copper Content (lb)
1958	131, 133	8, 317	1, 776, 183	744, 657
1959	124, 500	6, 019	?	564, 063
1960	250, 261	19, 995	4, 295, 316	1, 578, 312
1961	260, 583	21, 293	?	1, 734, 123
1962	311, 443	19, 900	3, 950, 531	1, 806, 437
1963	313, 836	20, 107	4, 250, 000	2, 050, 000
1964	319, 801	19, 100	3, 862, 000	1, 952, 000
1965	330, 954	18, 800	3, 770, 000	2, 000, 000
1966	327, 164	18, 387	3, 622, 400	1, 822, 000
1967	338, 912	22, 777	4, 750, 957	1, 974, 527

Some seventeen orebodies have been outlined in an area of about 1 1/2 square miles underlain by ultramafic rock (peridotite, pyroxenite and hornblendite), norite, diorite and relic metasedimentary and metavolcanic rocks. The orebodies are pipe-like in form with steeply dipping long axes and occur in ultramafic rock close to contacts with the diorite. Mineralization consists mainly of nickeliferous pyrrhotite, chalcopyrite and pentlandite that forms disseminated grains, lenses, blocks, intergranular laceworks, veins and veinlets.

5. Isolated, relatively minor deposits.

Gold, silver, principal metals.

(a) Eureka Victoria property, located on Silver Peak, 6 miles west-southwest of Hope (18).

References: Minister of Mines, B. C., Ann. Rept., 1874, p. 15; 1875, p. 17; 1890, p. 378; 1902, p. 196; 1921, p. 197; 1924, p. 138; 1926, p. 198; 1962, p. 92; 1963, p. 90.
Cairnes, 1924, Geol. Surv. Can., Mem. 139, pp. 152-160.

Disseminated argentiferous tetrahedrite associated with siderite, pyrite and quartz is in veins filling fracture zones in massive Eocene conglomerate (unit 21).

(b) Camrock Mines Ltd. property, located 3 miles southwest of Hope (19).

References: Minister of Mines, B. C., Ann. Rept., 1911, p. 184; 1912 p. 187; 1913, p. 219, 1914, p. 363; 1915, p. 255; 1918, p. 240; 1924, p. 139; 1937, p. A40; 1938, p. A38; 1939, p. 86; 1940, p. 28; 1967, p. 65.

This was formerly owned by Aufeas Gold Mines Ltd., and also Northwest Ventures. Arsenopyrite with gold or silver values and some chalcopyrite is in fissure veins.

(c) Providence Group, located on west side of Harrison Lake, 28 miles north of Harrison Hot Springs (20).

Reference: B. C. Dept. Mines, Bull. 1, p. 145.

Quartz veins carry pyrite with gold and silver values.

(d) Harry, Murphy, Hope, MC, Jan groups, located 2 miles north of Hope (21).

References: Minister of Mines, B. C., Ann. Rept., 1902, p. 196; 1915, p. 259; 1964, p. 143; 1965, pp. 218-19; 1967, p. 65.

Oldest lode deposit known on mainland British Columbia. Quartz vein containing pyrite, chalcopyrite, pyrrhotite and sparse galena. Scheelite has been observed.

(e) Pierce Mt., Forest Ranger, Mountain Goat groups, located on Mount Pierce (22).

References: Minister of Mines, B. C., Ann. Rept., 1915, pp. 305-307.
B. C. Dept. Mines, Bull. 1, p. 145.
B. C. Dept. Mines, Bull. 20, Pt. IV, p. 19.

Minor gold and silver in quartz veins at contact between Mesozoic rocks (unit 4) and 'dioritic rocks' (unit Bd).

(f) Blue Chip property, located 1 mile west of Laidlaw near Trans-Canada Highway (23).

Reference: Minister of Mines, B. C., Ann. Rept., 1957, p. 66.

Narrow stringers with pyrrhotite, arsenopyrite and chalcopyrite in diorite.

Copper, principal metal.

(a) Empress property, located on Bear Mountain near south end of Harrison Lake (24).

References: Minister of Mines, B. C., Ann. Rept., 1895, p. 701; 1896, p. 572; 1898, p. 1103; 1917, p. 286; 1931, p. 176; 1965, p. 220.

Mineralization is in metamorphosed limestone at the contact with granodiorite on Bear Mountain and consists of chalcopyrite with some bornite, together with magnetite, pyrite and molybdenite. Ore was shipped from the property between 1915 and 1917.

(b) Anna Group (formerly Contact Group) located on Bear Mountain at south end of Harrison Lake (24).

References: Minister of Mines, B. C., Ann. Rept., 1918, p. 290; 1922, p. 253.

Chalcopyrite is in skarn at the contact between crystalline limestone and granodiorite on Bear Mountain. Ore was shipped in 1920.

(c) Mex, Andie, Pat, Dot, Lucky. Four groups, located at south end of Cheam Ridge, from Welch Peak to Foley Creek (25).

References: Minister of Mines, B. C., Ann. Rept., 1916, p. 264; 1917, p. 286, p. 300; 1918, p. 284; 1919, p. 234, p. 258; 1926, p. 324; 1949, pp. 214-216; 1950, p. 167; 1951, p. 194; 1952, p. 206; 1953, p. 158; 1954, p. 159; 1955, p. 74; 1956, p. 115; 1965, p. 219; 1967, p. 64.

Chalcopyrite with minor pyrrhotite, arsenopyrite, pyrite and molybdenite are in contact metamorphosed rock of the Chilliwack Group (unit 2) adjacent to granodiorite (unit 24).

(d) Bea Group, located 3 miles north of Hope (26)

References: Minister of Mines, B. C., Ann. Rept., 1934, p. F19; 1965, pp. 217-218; 1966, p. 60.

Pyrite and chalcopyrite are in crushed granitic rock along Hope Fault.

(e) PR, David, Skidoo groups, located near head of Jim Kelly Creek. Approximately 20 miles east-northeast of Hope.

References: Minister of Mines, B. C., Ann. Rept., 1965, p. 161; 1966, p. 174 (older reports for same area in Minister of Mines, B. C., Ann. Rept., 1913, pp. 232-3; 1937, pp. D21-D22.

Pyrrhotite and chalcopyrite occur sporadically in altered granitic rocks.

(f) PF, Midnight groups, located on south side of Mount Agassiz (28).

Reference: Minister of Mines, B. C., Ann. Rept., 1966, p. 62.

Coarse pyrite, chalcopyrite and minor quartz fill fractures in Mesozoic sedimentary rocks.

(g) Ascot, Jes, Gloria, J. groups (29), located on southwest end of Mount Agassiz.

Reference: Minister of Mines, B. C., Ann. Rept., 1966, pp. 62-3.

Chalcopyrite, pyrite and sphalerite occur in volcanic rock of the Harrison Lake Formation at southwest end of Mount Agassiz.

(h) Seneca, Lucky Jim, Harrison Group (30).

References: Minister of Mines, B.C., Ann. Rept., 1961, p. 88; 1962, p. A47, p. 93.

Pyrite, chalcopyrite and sphalerite are in volcanic rock of the Harrison Lake Formation in the lower Chehalis River valley. In 1962, crude ore containing 17 ounces gold, 959 ounces silver, 7,118 pounds copper and 40,657 pounds of zinc was shipped.

(i) C.M. property, located on north side of Peers Creek, immediately east of its junction with Coquihalla River (31).

Reference: Minister of Mines, B.C., Ann. Rept., 1967, p. 67.

(j) Mount Cheam No. 2 property, located on north side of Cheam Peak (32).

Reference: Minister of Mines, B.C., Ann. Rept., 1966, p. 61.

Quartz veins in limestone of the Chilliwack Group (unit 2) carry sparsely distributed chalcopyrite and pyrrhotite.

Lead, zinc, principal metals.

(k) Hope Group, located on the Coldwater River valley, midway between Coquihalla and Juliet (33).

References: Minister of Mines, B.C., Ann. Rept., 1936, pp. D31-D32; 1954, p. 113; 1965, p. 160; 1966, p. 171.

Pyrite, galena, sphalerite, tetrahedrite and rare chalcopyrite together with quartz and carbonate gangue form veins in the Eagle Granodiorite (unit 13).

(l) Mag and Ly, Ford, Snow, Dora etc. groups (34).

Reference: Minister of Mines, B.C., Ann. Rept., 1966, pp. 171-172.

Disseminated pyrite, sphalerite, galena and chalcopyrite are in altered porphyritic quartz monzonite or quartz diorite.

(m) Faith Group (formerly Dolly Varden), located at south end of Chilliwack Lake (35).

References: Minister of Mines, B.C., Ann. Rept., 1923, p. 262; 1926, p. 324; 1930, p. 315.

Minor sphalerite and galena are in quartz veins in shear zones in granodiorite.

(n) Elkhorn property, located at northeast end of Greendrop Lake (36).

Reference: Cairnes, C. E., Geol. Surv. Can., Summ. Rept. 1923, Pt. A, pp. 70-72.

Galena, sphalerite and pyrite, together with quartz and calcite form veins in a zone of fracture in gneiss (unit C).

Molybdenum, principal metal.

(n) Gem property, located near head of Clear Creek on east side of Harrison Lake (37).

References: Minister of Mines, B. C., Ann. Rept., 1963, pp. 91-92; 1964, pp. 143-144; 1965, pp. 219-220; 1966, p. 61; 1967, p. 67.

Young and Airds, 1969; Can. Inst. Mining Met. Bull., vol. 62, No. 681, pp. 41-45.

Molybdenite, locally associated with minor amounts of pyrrhotite, pyrite, scheelite, chalcopyrite and sphalerite occurs in quartz veins in a pipe-like breccia composed of metamorphic rocks, granite and quartz monzonite porphyry, cemented by quartz monzonite porphyry.

(o) Mary Jane and Annie Lou property, located on mountain about 2 1/2 miles southeasterly of Cheam View, on the south side of Fraser Valley (38).

Reference: Minister of Mines, B. C., Ann. Rept., 1918, pp. K286-287.

Molybdenite in quartz veins in shear zones in granodiorite.

Other metallic mineral occurrences in map-area, too improcisely located to show on map.

(a) APM, Bear, King, Calico, Len claims, located about 7 miles south by logging road from Hope-Princeton highway, from Allison Pass Saw Mills.

Reference: Minister of Mines, B. C., Ann. Rept., 1966, pp. 59-60; 1967, p. 65.

Galena, sphalerite, molybdenite, chalcopyrite, pyrrhotite and pyrite are in a zone of altered, brecciated, and silicified argillites of the Hozameen Group intruded by dioritic rocks and numerous basic dykes.

(b) Valley View property, located on east side of mountain 4 1/2 miles west of Agassiz.

Reference: Minister of Mines, B. C., Ann. Rept., 1961, p. A47, p. 88.

Chalcopyrite-bearing quartz ore.

(c) June, Tee Cee groups located at southern end of Harrison Lake south of Green Point Park.

Reference: Minister of Mines, B.C., Ann. Rept., 1967, p. 67.

(d) Iago, Mac, Max, Bar Groups, located about 15 miles northeast of Hope.

Reference: Minister of Mines, B.C., Ann. Rept., 1966, p. 61.

Dykes with molybdenum and chalcopyrite are in pegmatitic granite.

NON-METALLIC DEPOSITS

1. Mainly Talc, Silica, Asbestos

(a) Gisby Group, located on west bank of Fraser River immediately south of the confluence with the Nahatlatch River.

Reference: Minister of Mines, B.C., Ann. Rept., 1965, pp. 276-278.

Silica and talc in slaty argillite.

(b) Clover Leaf property, located at lower end of Ruby Creek, 8 miles west of Hope.

References: Minister of Mines, B.C., Ann. Rept., 1966, p. 276; 1967, p. 64.

Talc in shear zone in serpentinite.

(c) Wahleach Creek.

Reference: Minister of Mines, B.C., Ann. Rept., 1960, p. 133.

Actinolite in fractures in 'altered' diorite.

(d) Harrison Lake, east side.

Reference: Minister of Mines, B.C., Ann. Rept. 1960, p. 133.

Light to dark green fibrous tremolite.

2. Lime, Travertine

(a) Rosedale Marl Lime Products Ltd., located 1 1/2 miles southeast of Rosedale.

Reference: B.C. Dept. Mines, Bull. 40, p. 100.

Small travertine deposit.

(b) Marble Hill Travertine deposit, located 4.9 miles by road southwest of Rosedale.

Reference: B.C. Dept. Mines, Bull. 40, p. 100.

Travertine deposit.

(c) Fraser Valley Lime Supplies, located on east side of Trans-Canada Highway, 3/4 mile east of Popkum Station.

Reference: Minister of Mines, B. C., Ann. Rept., 1947 to 1967 (inclusive).
B. C. Dept. Mines, Bull. 40, p. 42.

Limestone quarried from the Chilliwack Group (unit 2).

(d) Agassiz Lime Quarry, deposit is 2 miles southwest of Agassiz.

Reference: Minister of Mines, B. C., Ann. Rept., 1947 to 1958 (inclusive).
B. C. Dept. Mines, Bull. 40, 1957, p. 43.

(e) Cheam Marl Products.

Reference: Minister of Mines, B. C., Ann. Rept., 1947-1967 (inclusive)

3. Construction Materials

(f) Valley Granite Products Ltd., quarry located on west side of Trans-Canada Highway about 10 miles west of Hope.

Reference : Minister of Mines, B. C., Ann. Rept., 1947-1967 (inclusive).

Granite is quarried; principal markets are sand blasting material, filler, roofing rock, stucco dash, concrete mix and poultry grit.

(g) Sand and gravel.

There are numerous small sand and gravel quarries in the area, mainly in the Fraser Valley, that are worked intermittently.

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ADDENDUM

The following comments and additional references were received from the author after the text of this report had been prepared for printing.

page 1: before final sentence add: "McTaggart (in press)[1] has recently described the development of the Cascade Mountains in Canada."

page 23: para. 2, after Alexandra Bridge delete period and add: "according to Roddick and Hutchison (1969) but possibly could come from the Mount Lytton batholith (K. C. McTaggart, pers. comm.)."

page 28: after para. 4 add: "A major landslide, the Hope slide of 9 January 1969, was described by Mathews and McTaggart (1969)[2]."

page 35: after para. 3 delete period and add: "and its continuation south of the International Boundary by Misch (1966, 1967[2])."

page 49: after para. 2 add: "Possibly a branch runs northwesterly from near the northern limit of the map-area and connects with the ultramafic belt in the southwestern part of the Ashcroft map-sheet."

page 51: after para. 1 add: "The cause of the northeast-trending folds is not known although Crickmay (1930a) suggested that they result from the buttressing effect during deformation of the Coast Range batholith to the northwest".

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[1] McTaggart, K. C.: Tectonic history of the northern Cascade region; Geol. Assoc. Can., Sp. Paper 6 (in press).

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[3] Misch, P.: Plagioclase compositions and non-anatectic origin of migmatitic gneisses in northern Cascade Mountains of Washington State; Cont. Mineral Petrol., vol. 17, pp. 1-70 (1967).