GEOLOGY AND GEOCHRONOLOGY
OF
PORPHYRY COPPER AND MOLYBDENUM DEPOSITS
IN
WEST-CENTRAL BRITISH COLUMBIA

by

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ABSTRACT

Porphyry copper and molybdenum deposits in west-central British Columbia are associated with plutons of Late Cretaceous and Tertiary age which intrude Mesozoic volcanic and sedimentary rocks of the Intermontane Tectonic Belt. The porphyry deposits are contained in an area bounded on the west by granitic rocks of the Coast Plutonic Complex, and on the east and southeast by a belt containing Mesozoic granitic stocks and an extensive area of Tertiary volcanic rocks.

The porphyry intrusions take the form of small stocks, plugs, dykes, and dyke swarms generally not exceeding 1 square mile in surface area. The intrusions are commonly multiple and range in composition from quartz diorite to granite. Copper and molybdenum sulphides occur as fracture fillings and as veinlet stockworks within and adjacent to the intrusive bodies. Sulphide and alteration minerals exhibit concentric zoning patterns. Volcanic and sedimentary rocks marginal to the intrusions are thermally metamorphosed to biotite hornfels.

Results of potassium-argon dating indicate four crudely parallel north to northwest-trending belts of porphyry intrusions, each being distinctive in age, rock composition, and contained metallic mineralization. From west to east these include: (1) Alice Arm intrusions - 50 m.y. molybdenum-bearing quartz monzonite and granite intrusions; (2) Bulkley intrusions - 70 to 84 m.y. copper-molybdenum and molybdenum-bearing porphyries of granodiorite to quartz monzonite composition; (3) Nanika intrusions - 50 m.y. copper-molybdenum and molybdenum-bearing intrusions of quartz monzonite composition; (4) Babine intrusions - 50 m.y. copper-bearing intrusions of quartz diorite and granodiorite composition.

Potassium-argon analyses were carried out mainly on biotite separates from the mineralized porphyry phases within the deposits. Dating of inter-mineral and post-mineral porphyry phases, common at many of the deposits, yielded ages equivalent to, or 2 to 3 m.y. younger than, the mineralized phases, indicating that the age of mineralization is essentially synchronous with the age of intrusion. Limits of analytical errors in these potassium-argon analyses are within 3 per cent of the calculated ages.

The distribution of potassium-argon ages for porphyry deposits in west-central British Columbia does not fit the plate tectonic theories proposed for the origin of similar deposits elsehwere in the Cordillera of North and South America, in which deposits are progressively younger in a given direction. Here, four crudely parallel belts of porphyry intrusions display a reversal in age from 50 m.y. to 70 - 84 m.y. to 50 m.y. in an eastward direction. This distribution of ages may have been caused by periodic movement from Late Jurassic to Tertiary time along a subduction zone beneath the Coast Plutonic Complex which forms the west border of the area containing the porphyry deposits.

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Dr. A. E. Soregaroli supervised the study in its later stages and contributed greatly to the organization of the manuscript. Dr. W. H. Mathews offered useful suggestions for improvement of the manuscript. J. E. Harakal supervised all of the argon analyses and assisted in the interpretation of the potassium-argon analytical data.

Much of the financial support for this study was provided by the Mineralogical Branch, now the Geological Division, Mineral Resources Branch, of the British Columbia Department of Mines and Petroleum Resources. Dr. Stuart S. Holland, current Chief of the Geological Division, and Drs. M. S. Hedley and H. Sargent offered encouragement for the study. Several of the author's colleagues in the Geological Division helped with useful discussion and advice , especially Drs. A. Sutherland Brown, P. A. Christopher, and A. Panteleyev.

Drs. H. W. Tipper, R. V. Kirkham, and T. Richards of the Geological Survey of Canada contributed information on the regional geology of the area.

Finally, this study would not have been possible without the cooperation of mining and exploration company personnel active in west-central British Columbia during the course of field work related to the study. Their assistance is gratefully acknowledged.

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1. INTRODUCTION

1.1 SCOPE OF STUDY

This study of porphyry-type copper and molybdenum deposits in west-central British Columbia was initiated in 1967 to establish, by the potassium-argon method, the age of intrusion and mineralization. An integral part of the project is a comparative geological study of these deposits plus an analysis of their regional distribution relative to the geological and tectonic framework of the area.

The area was selected for several reasons. First, the author had obtained first-hand knowledge of both molybdenum deposits in the Alice Arm area and the porphyry copper deposits of the Babine Lake area, while conducting geological studies for the British Columbia Department of Mines and Petroleum Resources. Second, other deposits with similar characteristics were known throughout west-central British Columbia, and the area appeared to comprise a metallogenic province. Further, the study is a continuation of previous investigations into the age of mineral deposits of British Columbia initiated by the late Dr. W. H. White.

Prior to the inception of this study, only one porphyry deposit in the area had been dated by isotopic methods. Two samples from the British Columbia Molybdenum deposit at Alice Arm indicated an apparent Eocene age of intrusion and mineralization (Woodcock, et al., 1966). Elsewhere in British Columbia, studies by White and others (White, et al., 1967; Sinclair and White, 1968) indicated a Late Triassic age for porphyry deposits, and thus it was apparent that at least several deposits in the central part of British Columbia represented a younger age.

Geological studies and sampling of porphyry deposits in west-central British Columbia (Figure 1), which began in the 1967 field season, were sponsored by the British Columbia Department of Mines and Petroleum Resources. Deposits sampled during that year included copper deposits in the Babine Lake area, copper and molybdenum deposits in the Hazelton-Smithers and Morice-Tahtsa Lake areas, and molybdenum deposits in the Alice Arm-Nass River area.

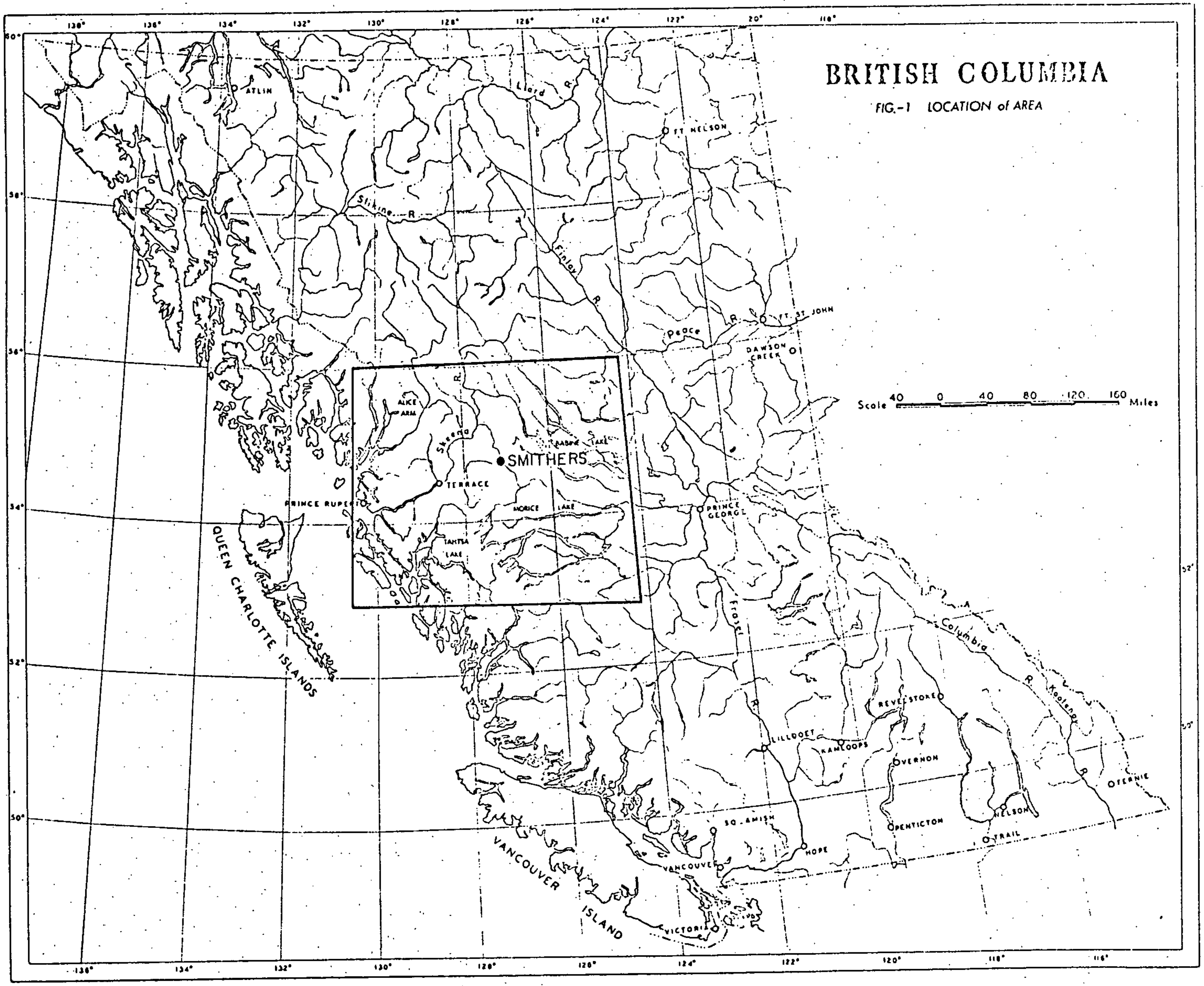
At deposits where the author had no first-hand knowledge, several days were spent studying geological relationships and style of mineralization before samples were collected. In addition to those collected by the author, a number of samples were provided by staff geologists of the British Columbia Department of Mines and Petroleum Resources and by mining exploration company personnel. Additional samples were collected in 1968, 1969, and 1970.

Samples were analysed at the geochronology laboratory operated jointly by the Department of Geological Sciences and Department of Geophysics, University of British Columbia. A total of 70 potassium-argon ages were obtained from samples collected at or near 27 porphyry deposits.

1.2 LOCATION OF AREA

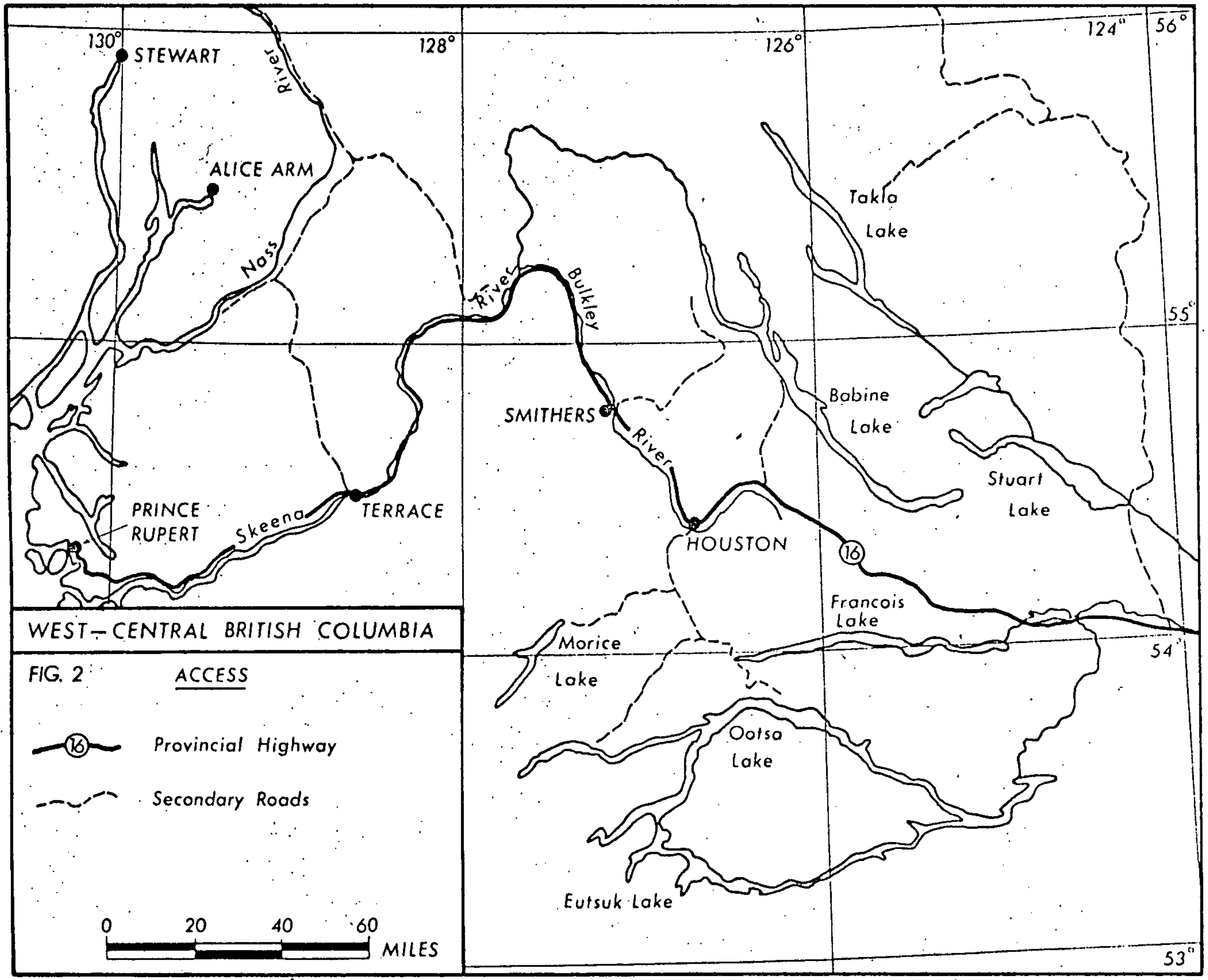
West-central British Columbia, for purposes of this study, is situated between latitudes 53 degrees and 56 degrees north and longitudes 124 degrees and 130 degrees west, as indicated on Figure 1. The town of Smithers is near the geographic centre of this area.

Access within the area is reasonbly good (Figure 2). Northern Trans-Provincial Highway 16 crosses the area in an east-west direction and is paralleled by the Canadian National Railway line linking Jasper, Alberta, and Prince Rupert.



BRITISH COLUMBIA

FIG.-1 LOCATION of AREA



WEST-CENTRAL BRITISH COLUMBIA

FIG. 2 ACCESS

Access to the north and south is provided by numerous secondary roads. Helicopter and/or fixed-wing aircraft transportation is necessary to reach the more remote parts of the area. A new extension of the British Columbia Railway extends northwesterly from Fort St. James along the eastern shore of Takla Lake.

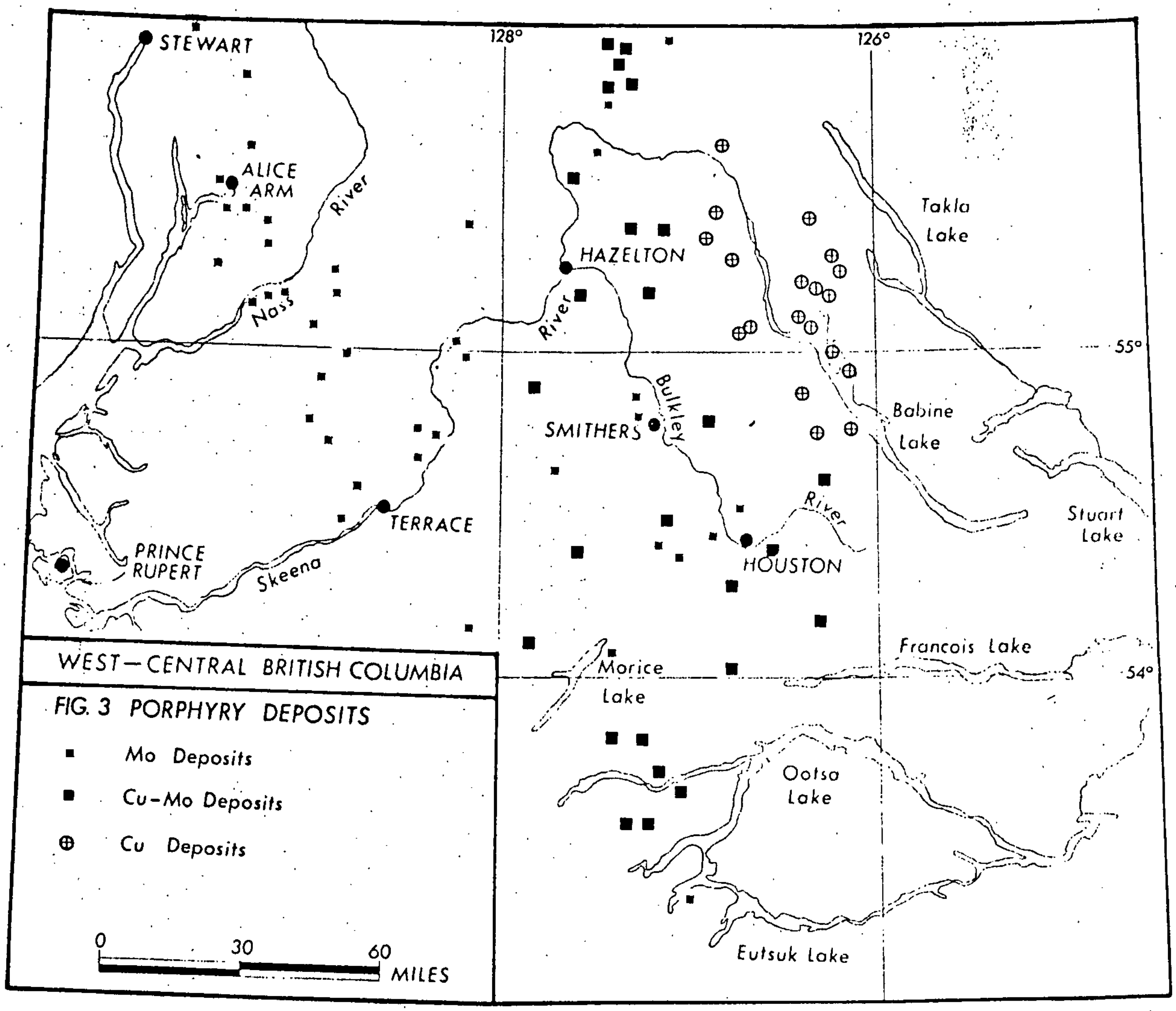
1.3 PORPHYRY MINERAL DEPOSITS STUDIED

Most of the known porphyry-type copper and molybdenum deposits in west-central British Columbia are indicated on Figure 3.

Porphyry deposits in the area exhibit features that conform to those outlined in the definition of porphyry deposits by Lowell and Guilbert (1970) and Sutherland Brown, et al. (1971). The deposits are intimately associated with small (1 kilometre diameter or less) porphyritic, felsic to intermediate intrusions which cut Mesozoic volcanic and sedimentary rocks. Extrusive equivalents of the porphyry intrusions have been recognized in several areas. Copper and molybdenum sulphides occur as fracture fillings and in veinlet stockworks both within and adjacent to the intrusive bodies. Sulphide and alteration minerals exhibit concentric zoning relative to the host intrusion at many of the deposits.

Unaltered primary and secondary biotite and lesser amounts of hornblende are common constituents of most deposits, rendering these minerals particularly useful for potassium-argon studies.

Porphyry deposits of this study are shown on Figure 4 (pocket). Only two of these deposits, both of which are at Babine Lake, are currently being mined. Granisle Copper Limited is in production at a daily milling rate of 14,000 tons and the Newman mine of Noranda Mines, Limited, Bell Copper Division, is milling



WEST–CENTRAL BRITISH COLUMBIA

FIG. 3 PORPHYRY DEPOSITS

▪ Mo Deposits
■ Cu–Mo Deposits
⊕ Cu Deposits

10,000 tons per day. Both mines have reserves in excess of 50 million tons of grades exceeding 0.5 per cent copper.

British Columbia Molybdenum mine at Alice Arm suspended operations in mid-1972 due in part to depressed molybdenum markets. The mine produced for nearly five years at a daily rate of 7,000 tons of rock grading close to 0.20 per cent MoS_2.

Other deposits, shown on Figure 4 and considered as potential producers, include: the Morrison deposit at Babine Lake; and the Berg and Huckleberry deposits near Tahtsa Lake.

1.4 SAMPLING METHODS FOR POTASSIUM-ARGON STUDIES

The primary objective of this study was to determine the age of intrusion and the age of mineralization in each porphyry deposit by the potassium-argon method.

Figure 5, a generalized sketch incorporating features common to many of the deposits, illustrates an ideal deposit for potassium-argon dating. In this ideal case, the following samples would be collected and analysed:

(1) A sample of mineralized porphyry intrusion, usually containing both primary and secondary biotite, to establish the age of mineralization.

(2) A sample of primary biotite from the intrusive rock outside the mineralized zone and away from the area of hydrothermal alteration, if possible, to determine the age of intrusion. Failing this, a whole-rock sample of biotite hornfels, a product of thermal meta-

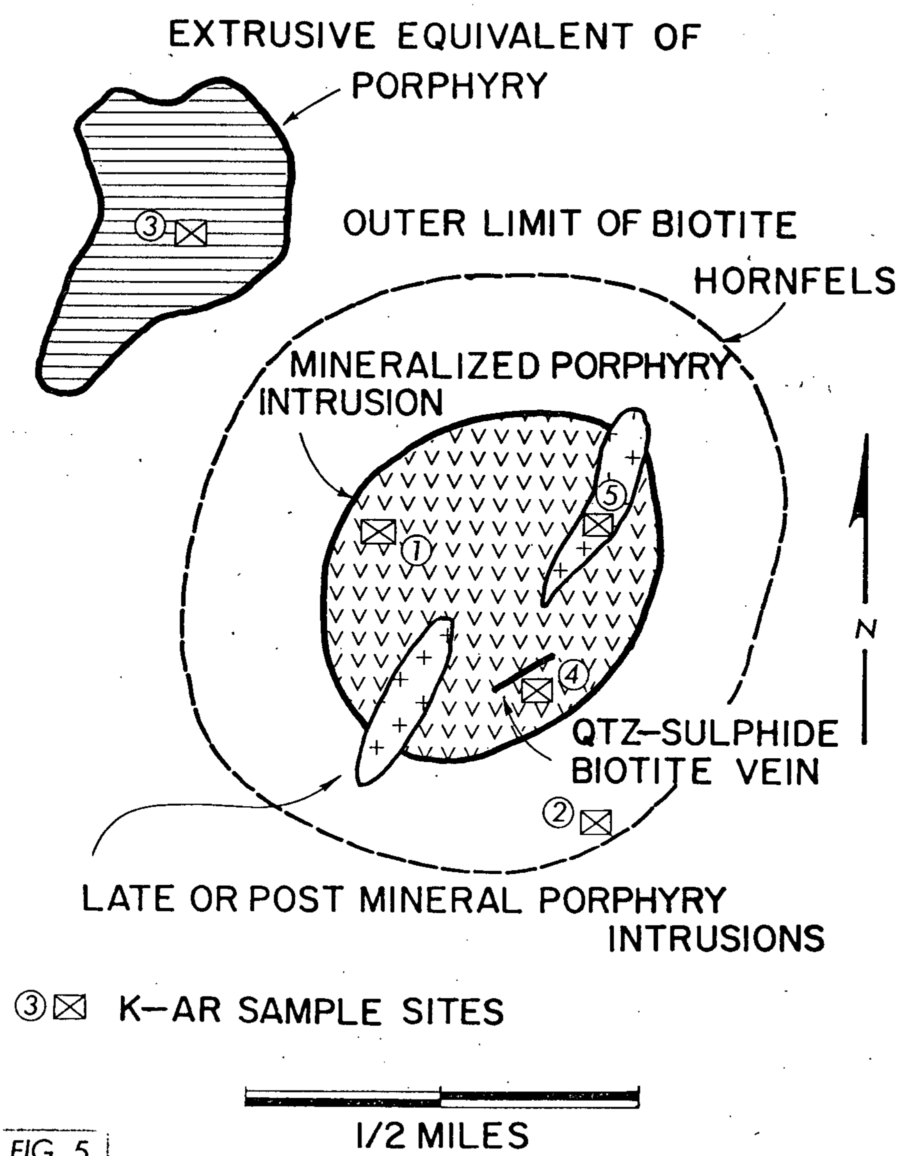


FIG. 5

IDEAL PORPHYRY DEPOSIT FOR K-AR DATING

morphism related to the intrusion, would be collected to give the same result.

(3) Samples of extrusive equivalents of porphyry intrusions to determine the age of intrusion and/or extrusion. Such extrusive equivalents have been recognized in the Babine Lake area.

(4) Samples of biotite from quartz-sulphide veins, collected from a few deposits, to yield the age of mineralization. Such a sample can be used to corroborate results obtained by the first sample type.

(5) Samples of inter- and post-mineral porphyry dykes and intrusive breccias; petrologically similar to the main mineralized porphyry phase, to more closely define an upper age limit for intrusive and hydrothermal activity.

Other samples that might be collected include basic dykes which are common in the molybdenum deposits of the Alice Arm area. Analyses of mineral separates or whole-rock samples from the dykes date the last igneous event at these deposits. Samples of nearby non-mineralized intrusive bodies, which apparently are unrelated to mineralization, were collected wherever possible.

2. GENERAL GEOLOGY OF WEST-CENTRAL BRITISH COLUMBIA

2.1 PHYSIOGRAPHY

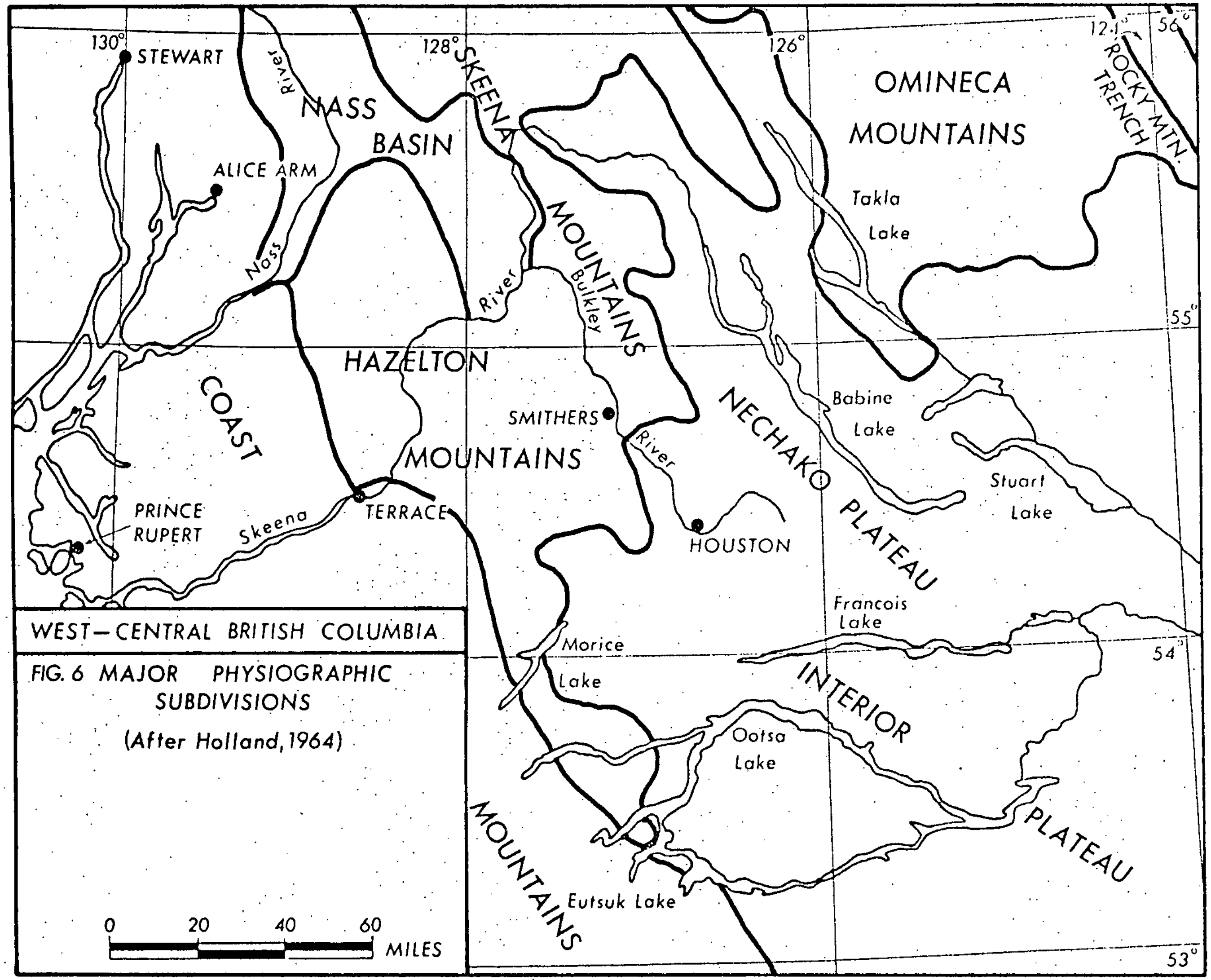
The major physiographic subdivisions of west-central British Columbia are shown on Figure 6. Most of the porphyry deposits included in this study are situated within the Interior Plateau, the Hazelton Mountains, and along the eastern flanks of the Coast Mountains.

Much of the area on Figure 6 is occupied by the Nechako Plateau, the northernmost subdivision of the Interior Plateau. This area is one of low relief, dominated by flat or gently rolling topography (Holland, 1964). Glacial drift obscures much of the bedrock and ubiquitous glacial features include glacial grooving and drumlin-like ridges, numerous lakes, eskers, and dry melt-water channels. The northern and western boundaries of the Nechako Plateau are fairly sharply defined by mountainous areas, which include the Omineca, Skeena, and Hazelton Mountains.

Omineca Mountains consist of both rounded and serrated peaks in excess of 6,000 feet which are separated by broad, drift-filled valleys. Skeena Mountains feature jagged peaks, products of alpine glaciation, and are divided into ranges by northwest-trending valleys. Hazelton Mountains comprise a number of mountain ranges separated by prominent river valleys.

Nass Basin, situated north of the Hazelton Mountains, is an area of low relief entirely encircled by mountains which rise abruptly from the basin floor dotted with numerous lakes of glacial origin.

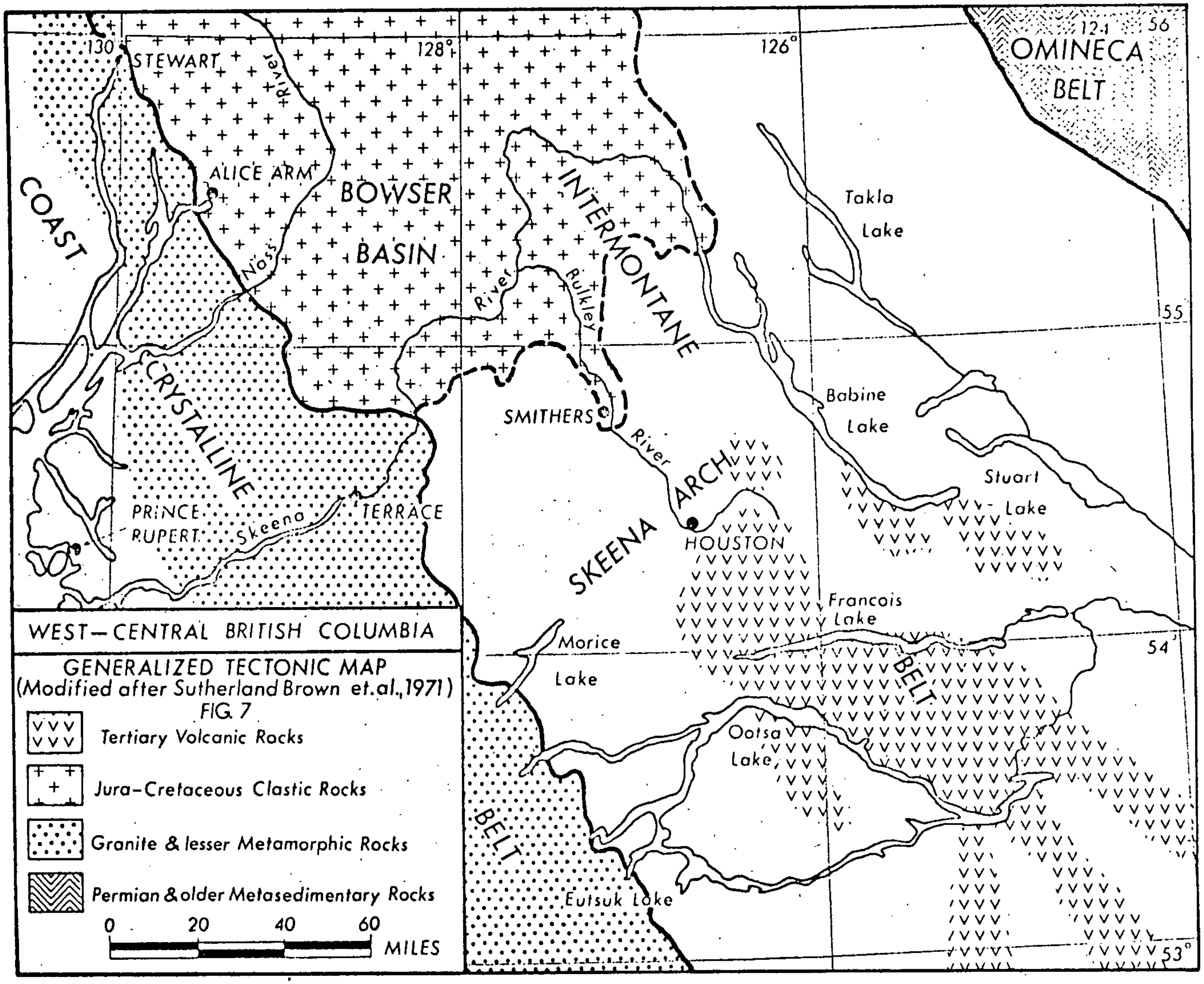
Coast Mountains are underlain predominantly by granitic rocks. Within the area shown on Figure 6, they include the Boundary and Kitimat Ranges which are



WEST–CENTRAL BRITISH COLUMBIA

FIG. 6 MAJOR PHYSIOGRAPHIC SUBDIVISIONS

(After Holland, 1964)


WEST—CENTRAL BRITISH COLUMBIA
GENERALIZED TECTONIC MAP
(Modified after Sutherland Brown et.al.,1971)
FIG. 7
Tertiary Volcanic Rocks
Jura-Cretaceous Clastic Rocks
Granite & lesser Metamorphic Rocks
Permian & older Metasedimentary Rocks
0 20 40 60 MILES
COAST
CRYSTALLINE
BELT
BOWSER BASIN
INTERMONTANE
BELT
SKEENA ARCH
OMINECA BELT
STEWART
ALICE ARM
PRINCE RUPERT
TERRACE
SMITHERS
HOUSTON
Nass River
Skeena River
Bulkley River
Takla Lake
Babine Lake
Stuart Lake
Francois Lake
Morice Lake
Ootsa Lake
Eutsuk Lake
130°
128°
126°
124
56
55
54
53°

separated by the Nass River valley. The ranges comprise rounded granitic peaks and serrated peaks underlain by sedimentary and volcanic rocks. Prominent U-shaped and hanging valleys are common as are extensive icefields. Steep topography is a dominant feature.

2.2 REGIONAL TECTONIC SETTING

The major tectonic features of west-central British Columbia are shown on Figure 7 (modified after Sutherland Brown, et al, 1971). Most porphyry copper and molybdenum deposits of this area lie within the Intermontane Belt which is bounded on the east by predominantly metamorphic rocks of the Omineca Belt and on the west by granitic and lesser metamorphic rocks of the Coast Crystalline Belt.

The Intermontane Belt is underlain principally by Mesozoic volcanic and sedimentary rocks. Skeena Arch, a prominent transverse structure during Early Mesozoic time, marks the approximate boundary between the Bowser successor basin to the north and a broad area to the southeast covered by a veneer of Early to Late Tertiary volcanic rocks.

Granitic intrusions of Late Cretaceous and Early Tertiary age, with which the porphyry copper and molybdenum deposits are associated, intrude Mesozoic volcanic and sedimentary rocks throughout the Intermontane Belt.

2.3 GENERAL GEOLOGY

The regional geology of west-central British Columbia is illustrated on Figure 8 (pocket) and is based mainly on compilation maps prepared by the British Columbia Department of Mines and Petroleum Resources (Carter and Kirkham, 1969;

Carter and Grove, 1972), and on work directly related to this study. Additional information was obtained from previous and current work by geologists of the British Columbia Department of Mines and Petroleum Resources and the Geological Survey of Canada, references to which are included in the following outline and in the bibliography.

The following outline follows the divisions as listed on the legend for Figure 8 and in the Table of Formations (Table 1).

2.3.1 Sedimentary and Volcanic Rocks

Sedimentary and volcanic rocks occupy much of the central and eastern parts of the area illustrated on Figure 8 and comprise units ranging in age from Permian to Recent.

Permian - Cache Creek Group

Cache Creek Group rocks of Late Paleozoic (mainly Permian) age are confined to the eastern margins of the area shown on Figure 8. The group is characterized by limestones and ribbon cherts with subordinate interbedded andesite flows and fragmental rocks (Armstrong, 1949).

Rocks of the Cache Creek Group are tightly folded about northwest-trending axes, and are mainly in fault contact with younger rocks.

Triassic - Takla Group

Takla Group rocks, predominantly of Late Triassic age, are most widespread near the east and west boundaries of the area. In the type area east of Takla Lake, andesitic and basaltic flows predominate and are accompanied by lesser amounts of clastic volcanic and sedimentary rocks (Armstrong, 1949).

TABLE 1

TABLE OF FORMATIONS

SEDIMENTARY AND VOLCANIC ROCKS

ERA	PERIOD	EPOCH	FORMATION	LITHOLOGY
Cenozoic	Quaternary	Pleistocene and Recent		Basalt flows and cinder cones.
	Tertiary	Eocene and Miocene	Endako Group, Goosly Lake and Buck Creek volcanic rocks	Basalt and andesite flows and breccias, some rhyolite and dacite.
	Unconformity			
Mesozoic and Cenozoic	Cretaceous and Tertiary	Upper Cretaceous and Paleocene	Ootsa Lake Group, Tip Top Hill volcanic rocks	Basalt, andesite, dacite and related tuffs and breccias, some rhyolite flows and breccias.
			Sustut Group	Sandstone, conglomerate, shale.
	Unconformity			
	Cretaceous	Lower Cretaceous	Skeena Group, Brian Boru and Red Rose formations	Siltstone, sandstone, shale, porphyritic andesite flows, breccias and tuffs.
	Unconformity			
Mesozoic	Jurassic and Cretaceous	Upper Jurassic and Lower Cretaceous	Hazelton Group (in part)	Siltstone, greywacke, sandstone, conglomerate, argillite, minor limestone and coal.
	Local Unconformity			
	Jurassic	Middle Jurassic	Hazelton Group	Andesite, basalt, dacite tuffs and breccias, volcanic sandstone and conglomerate, siltstone, and greywacke.
		Unconformity		
		Lower Jurassic	Hazelton Group	Green, red, and purple andesite and basalt tuffs and breccias, volcanic sandstone and conglomerate, argillite and greywacke.

TABLE 1 (Cont'd.)

ERA	PERIOD	EPOCH	FORMATION	LITHOLOGY
	Local Unconformity			
Mesozoic	**Triassic**	**Upper Triassic**	**Takla Group (in part)**	**Mafic volcanic rocks, volcanic sandstone, argillite, limestone, chert, some acid metavolcanic rocks, chlorite, sericite, and biotite schists.**
	Unconformity			
Paleozoic	Permian and older?		Cache Creek Group	Andesite flows and breccias, chert, limestone, quartzite, chlorite and hornblende schists.

METAMORPHIC ROCKS

Paleozoic				Gneiss Complex-almandine, amphibolite, facies, gneisses, and related migmatite gneiss, greenstone, amphibolite, and schist.

TABLE 1 (Cont'd.)

INTRUSIVE ROCKS

ERA	PERIOD	EPOCH	FORMATION	LITHOLOGY
Cenozoic	Tertiary	Oligocene		Lamprophyre dyke swarms.
		Eocene	Portland Canal dyke swarms	Granitic rocks.
			Goosly Lake intrusions	Gabbro syenomonzonite.
			Alice Arm intrusions	Quartz monzonite and granite porphyry.
			Nanika intrusions	Quartz monzonite, porphyry, feldspar porphyry and felsite.
			Babine intrusions	Quartz diorite and granodiorite porphyry.
Cenozoic and Mesozoic (?)	Tertiary and older (?)		Coast Plutonic Complex	Granitic rocks, quartz diorite, granodiorite, quartz monzonite, locally foliated and/or gneissic.
Mesozoic	Cretaceous	Upper Cretaceous	Bulkley intrusions	Porphyritic quartz monzonite and granodiorite.
	Jurassic and Cretaceous		Kitsault intrusions	Feldspar, porphyry, augite porphyry, hornblende, diorite.
	Jurassic	Upper Jurassic	Francois Lake intrusions	Porphyritic quartz monzonite; granodiorite, and quartz diorite.
		Lower and Middle Jurassic	Omineca intrusions	Granodiorite, quartz diorite, syenite, gabbro, monzonite, and diorite.
	Triassic and Jurassic	Upper Triassic - Lower Jurassic	Topley intrusions	Quartz monzonite, granodiorite, and quartz diorite, and porphyritic varieties.
	INTRUSIVE CONTACT			
Paleozoic	Permian		Trembleur intrusions	Ultramafic rocks.

Along the west shore of Babine Lake, rocks regarded as Takla age (Tipper, 1971) comprise a succession of maroon fragmental volcanic rocks and interbedded white to grey crystalline limestone and calcareous and graphitic black shales. Chlorite and sericite schists are also included in this sequence (Carter, 1973), but these may be in part Cache Creek Group equivalent.

In the Terrace area, rocks designated as part of the Takla Group (Figure 8) include some older rocks, perhaps of Permian age. These are comprised of fair thicknesses of white crystalline limestone underlain by mafic volcanic rocks. Metavolcanic rocks, which occur on the north side of the Skeena River, are considered as part of the Takla Group.

Takla Group rocks in the eastern part of the area are in fault contact with older Cache Creek rocks. In the Babine Lake area they are overlain with angular unconformity by Jurassic age rocks.

Jurassic – Hazelton Group

Volcanic and sedimentary rocks of Jurassic age, comprising the Hazelton Group, underlie much of west-central British Columbia. Recent work by Tipper (1971), Richards (1973, 1974), and Grove (1971) defines the Hazelton Group as a nearly continuous sequence ranging in age from Early to Late Jurassic. The Hazelton Group consists of volcanic flows and fragmental rocks as well as sedimentary rocks derived from older volcanic terranes and the reworking of contemporary volcanic material.

Lower Jurassic

Lower Jurassic rocks occur mainly in the central part of the map-area and consist principally of submarine and subaerial andesite and basalt flows and fragmental rocks with some intercalated clastic and sedimentary rocks. In the

Portland Canal area, Lower Jurassic rocks include epiclastic volcanic conglomerates and sandstones plus andesite flows and pillow lavas. Products of dynamic metamorphism, cataclasites, are also included in this unit.

Lower Jurassic rocks overlie Triassic and older rocks disconformably to unconformably.

Middle Jurassic

Middle Jurassic rocks of the Hazelton Group are distributed throughout the map-area and comprise a mainly marine sequence of tuffs, volcanic breccias, shales, and greywackes. The rocks are notably fossiliferous in a number of localities.

The Middle Jurassic sequence exhibits both conformable and unconformable contact relationships with older rocks. In parts of the Smithers map-area, they have been thrust over Lower Jurassic rocks (Tipper, 1971).

Upper Jurassic - Lower Cretaceous

Upper Jurassic and Lower Cretaceous rocks comprise a marine to continental sedimentary sequence which is restricted to the northern half of the map-area, mainly within the Bowser successor basin. The lower part of this succession includes the upper unit of the Hazelton Group which consists of well-bedded siltstone, greywacke, argillite, sandstone, conglomerate, and minor limestone and coal. The upper part of the sequence is a dominantly continental sedimentary sequence.

The Upper Jurassic - Lower Cretaceous succession features conformable contacts with Middle Jurassic rocks in the western part of the area and rests with angular unconformity on older rocks in the central part of the area.

Cretaceous

Lower Cretaceous

Lower Cretaceous rocks were first recognized in west-central British Columbia during the course of mapping by Sutherland Brown (1960) in the Hazelton area. These rocks include the Red Rose Formation, a marine sedimentary sequence, which is overlain conformably by the Brian Boru Formation, a volcanic unit consisting primarily of porphyritic andesite flows.

Recent work in the Smithers and Hazelton map-areas by Tipper (1971) and by Richards (1973) indicates that similar rocks, now known to be of Albian (Early to Middle Cretaceous) age, are more widespread than previously recognized. Further mapping probably will show that these rocks occupy a larger area of the Bowser Basin than indicated on Figure 8. This sequence of Lower Cretaceous rocks, informally called the Skeena Group, consists of black marine shales overlain by, and in part interbedded with, volcanic tuffs and breccias. North of Babine Lake, a slightly younger continental sequence of sedimentary rocks has been mapped by Richards (1973).

Lower Cretaceous rocks overlie older rocks with angular discordance or are in fault contact with them.

Cretaceous and Tertiary

Upper Cretaceous - Paleocene

Rocks of this age include continental sedimentary and volcanic rocks which are widespread in the central part of the area shown on Figure 8.

The Sustut Group, which consists of a continental clastic sequence of sandstone, conglomerate, shale, and mudstone, is restricted to the central part of the map-area, principally in the Babine and Takla Lake areas. These rocks occur mainly in northwest-trending fault-bounded basins. Sedimentary rocks of similar age were noted on Nadina Mountain by Lang (1940).

The Ootsa Lake Group is a dominantly volcanic sequence which occurs mainly in the eastern half of the map-area where it covers extensive areas south of Francois and Ootsa Lakes (Tipper, 1963; Duffel, 1959). The group includes rhyolite, dacite, andesite, and basalt flows as well as fragmental rocks and some sedimentary rocks.

Recent work by Church (1973) has disclosed the presence of these rocks in an area east of Morice Lake. Whole-rock potassium-argon ages indicate a Late Cretaceous age (76 m.y.) for both Tip Top Hill volcanic rocks of andesite and dacite composition, and for rhyolite flows and related quartz porphyry intrusions in the same area. Similar acid volcanic rocks and intrusive equivalents have been recognized in the Babine Lake area (Carter, 1973; Richards, 1973).

Rocks of the Ootsa Lake Group feature moderate dips and lie with angular discordance on older Mesozoic rocks.

Tertiary

Eocene – Miocene

Rocks of Early to Middle Tertiary age include extensive areas of flat-lying to gently dipping andesitic to basaltic flows and pyroclastic rocks in the east-central part of the map-area.

Armstrong (1949) referred to these rocks as the Endako Group, which he believed to be of Oligocene or younger age. Recent mapping and whole-rock potassium-argon dating by Church (1973) in the Buck Creek area south of Houston has shown the bulk of these rocks to be of Eocene age, corroborating earlier work by Mathews (1964). A two-fold division of this unit, separated by an angular discordance, has been recognized by Tipper (1971) and Church (1973). Many of the rocks mapped as Ootsa Lake Group south of Francois Lake also could be of this age.

Small, flat-lying olivine basalt outliers of definite Miocene age have been identified by Church (1973) in the Buck Creek area.

Quaternary

Pleistocene and Recent

Basaltic rocks of Quaternary age have been noted only in the northwest part of the map-area, in the Nass River-Alice Arm area.

Basalt outliers, ranging in thickness from tens to hundreds of feet, are best known in the Alice Arm area, where two whole-rock samples collected by the author indicated an age range of 0.29 $\pm$ 0.5 m.y. to 1.1 $\pm$ 0.8 m.y. The basalt outliers exhibit an east-northeast distribution from south of Alice Arm to the big bend of the Nass River, reflecting one of the dominant structural trends of the area.

Similar remnants of Pleistocene volcanic activity have been noted in the Nass River area, but the dominant young volcanic feature of this area is the Recent Aiyansh lava flow which erupted from a vent area some 14 miles south of the prominent lava plain bordering the Nass River. This flow and associated cinder cones represent one of the youngest volcanic features in British Columbia, yielding a ^{14}C age of 220 $\pm$ 130 years (Sutherland Brown, 1969).

2.3.2 Metamorphic Rocks

Metamorphic rocks are restricted to the core and eastern flank of the Coast Plutonic Complex near the west boundary of the area.

Paleozoic - Gneiss Complex

Gneissic rocks, probably the oldest rocks in the map-area, are within and marginal to the Coast Plutonic Complex near the western boundary of the area. In the Prince Rupert map-area, high-grade gneisses and migmatites are referred to by Hutchison (1967) as Late Paleozoic age or older. The gneiss complexes have indistinct boundaries and grade into homogeneous plutonic rocks. A tentative pre-Permian age has been assigned to these rocks by Hutchison (1967) because they apparently are older than relatively non-metamorphosed Permian rocks in the Terrace area. Similar gneissic rocks to the southeast apparently underlie metamrophic rocks containing fossils of Permian age.

2.3.3 Intrusive Rocks

Mesozoic volcanic and sedimentary rocks of west-central British Columbia have been intruded by plutonic and hypabyssal rocks of variable composition and age. A brief description of these rocks is included here, but a more detailed description of the age and distribution of the granitic rocks, an integral part of this study, will be contained in the following chapter.

Permian and/or Triassic Intrusions

Trembleur ultramafic intrusions, the oldest intrusive rocks recognized in the map-area, are confined to the eastern part of the area where they cut Permian and older rocks of the Cache Creek Group. The intrusions take the form of sills, stocks, and small batholiths of peridotite, dunite, pyroxenite, and minor gabbro and their serpentinized equivalents.

Triassic and Jurassic Intrusions

Granitic rocks of Late Triassic to Late Jurassic age include the Topley, Omineca, and Francois Lake intrusions. These intrusions occur as stocks and batholiths in the central and eastern parts of the area (Figure 8) where they cut volcanic and sedimentary rocks of similar age.

Kitsault intrusions, consisting of stocks and irregular intrusions of feldspar porphyry, augite porphyry, and hornblende diorite, occur north of Alice Arm and appear to represent volcanic centres of part of the Hazelton Group.

Cretaceous

Bulkley intrusions of Late Cretaceous age occur as a northerly trending belt of stocks and small batholiths extending through the central part of the map-area.

Tertiary

Intrusive rocks of Tertiary age include a wide variety of large and small intrusive bodies. The Coast Plutonic Complex, bordering the area on the west (Figure 8), constitutes the most extensive area of Tertiary plutonic rocks, although older granitic rocks are also included in the complex. Numerous small plugs, stocks, and dykes of Eocene age occur along the eastern margin of the Coast Plutonic Complex and throughout the central part of the area.

The Portland Canal dyke swarm, situated northeast of the head of Portland Canal, includes an extensive area of hundreds of granitic sills and dykes related to the Coast Plutonic Complex (Grove, 1971).

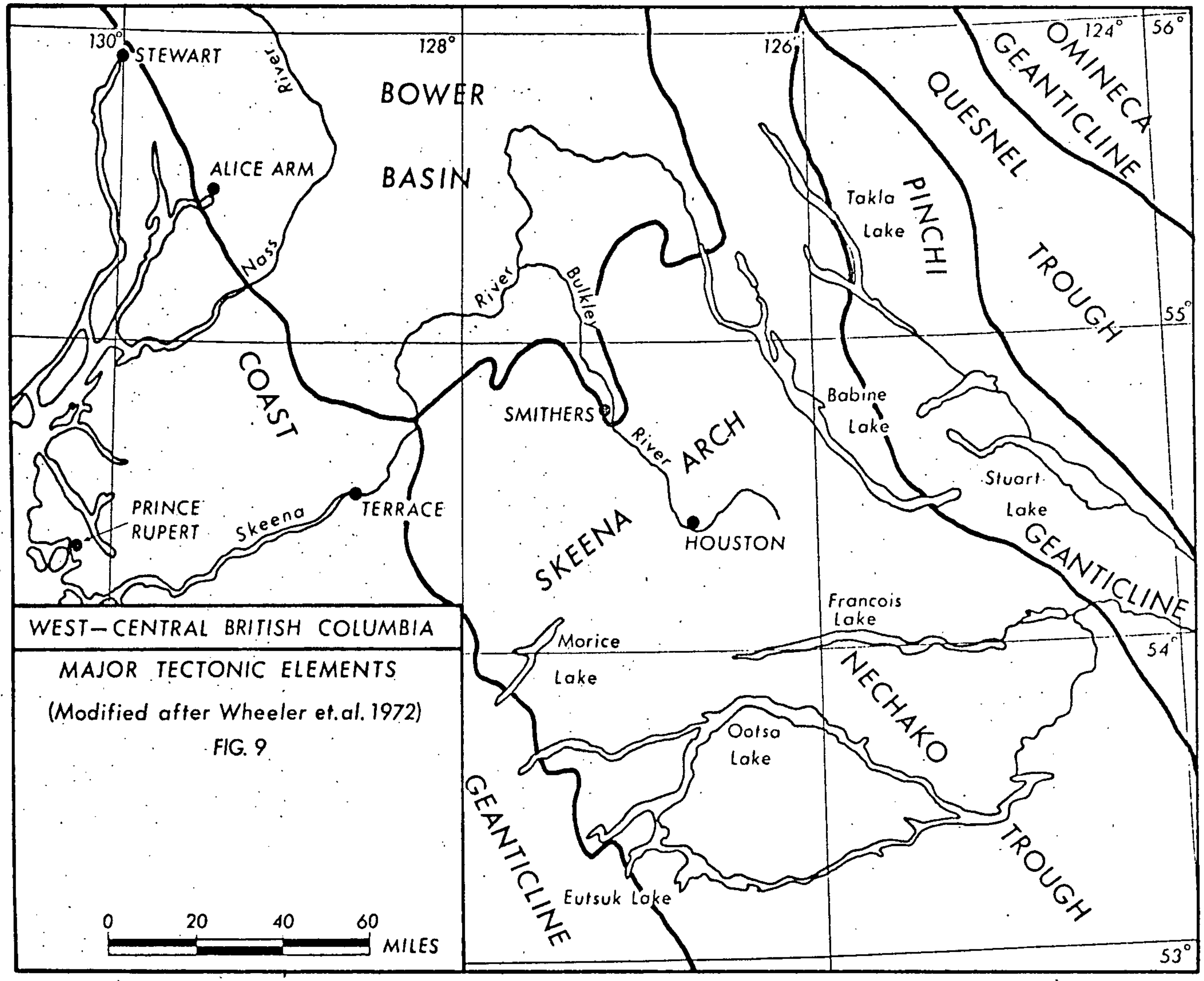
Lamprophyre dyke swarms with northeast trends are prominent in the Portland Canal and Alice Arm districts (Carter and Grove, 1972) and in neighbouring southeast Alaska (Smith, 1973), where they commonly transect the numerous vein-type mineral deposits of these areas. Two samples collected for potassium-argon analysis in the Alice Arm area yielded ages of 34.4 $\pm$ 1.5 m.y. and 36.5 $\pm$ 1.2 m.y.

2.4 TECTONIC HISTORY

The major tectonic elements of west-central British Columbia are shown on Figure 9 (modified after Wheeler, et al., 1972).

The northwest trend of the area is defined by troughs and basins of Mesozoic and younger layered rocks which are separated by geanticlinal areas of similar trend. The major part of the area is occupied by the Nechako Trough and Bowser Basin which are bounded on the east by the Pinchi geanticline and on the west by the Coast geanticline.

Significant thicknesses of carbonate rocks in Permian strata indicate stable shelf conditions in the eastern part of the map-area during that time. In the western part of the area, the Coast geanticline was in part an uplifted area by Permian time, as indicated by the gneiss complexes in this area, which are believed to be products of regional metamorphism which occurred in pre-Permian time.



WEST–CENTRAL BRITISH COLUMBIA

MAJOR TECTONIC ELEMENTS

(Modified after Wheeler et.al. 1972)

FIG. 9

Orogenic activity in Mid-Triassic time culminated in uplift and established the main tectonic elements including the Coast and embryonic Pinchi geanticlines, the Nechako and Quesnel Troughs, and marked the beginning of an eugeosynclinal regime. Late Triassic and Early Jurassic was a time of widespread volcanism and related sedimentation in numerous basins throughout the area. This period of tectonic activity also included the emplacement and unroofing of the Topley and Omineca intrusions and the total emergence of the Pinchi geanticline. During Early and Mid-Jurassic time, uplift along the northeast-trending Skeena Arch separated the Nechako Trough from the Bowser Basin, in which a thick succession of marine clastic sedimentary and volcanic rocks accumulated from Mid-Jurassic to Early Cretaceous time. Intrusion of the Francois Lake granitic rocks also took place during this time. In the Early Cretaceous, uplift occurred along the Coast geanticline and continental clastic rocks accumulated in marginal parts of the Bowser Basin in Mid-Cretaceous time.

Uplift, faulting, and intrusion occurred in Late Cretaceous and Early Tertiary time, principally along the Coast geanticline and in the central part of the area where high-level subvolcanic granitic plutons were emplaced and extensive sheets of rhyolitic to basaltic lavas were extruded. Continental clastic sedimentary rocks, represented by the Sustut Group, were deposited in fault-bounded basins in the central part of the area.

Pleistocene and younger volcanic rocks were erupted along northerly and northeasterly trending fault zones which developed late in Tertiary time in the western part of the area.

2.5 STRUCTURAL GEOLOGY

Structural features in west-central British Columbia are related to several recognizable episodes of tectonic activity.

Within the western gneiss complexes, tight, overturned, and recumbent folds trend east-northeast and northwesterly. In Mesozoic rocks marginal to the Coast Plutonic Complex, folds (simple to complex) were developed by repeated uplift and plutonism principally from Early Jurassic through Tertiary time. Broad, open folds predominate, except adjacent to the Coast intrusions and satellitic intrusive bodies, where overturned and isoclinal folds and thrust faulting occur in sedimentary rocks. Faults in the western part of the area trend northerly, northeasterly, and northwesterly. Many basic dykes follow northeast faults and fracture zones and are offset by later northwesterly faults. The trend of major fiords, Portland Canal and Observatory Inlet, probably owe their trend to basement structures.

The structure in the central part of the area displays only slight deformation of the Mesozoic rocks represented mainly by broad, open folds. Thrust faults and related folds are common along the west side of the Babine Range and north of Smithers where a Lower Jurassic sequence is thrust over Middle Jurassic rocks (Figure 8). The most persistent structures of the area are closely spaced block faults. Although important northeast-striking block faults exist, the dominant trend is northwest, as exemplified by major faults parallel to the Bulkley River and along the east side of the Babine Range. Northwest-trending horst and graben structures are prominent in the Babine Lake area.

In the eastern part of the area, Mesozoic volcanic and sedimentary rocks display northwest fold trends. Upper Paleozoic Cache Creek Group rocks are closely folded in a northwest direction.

Two faults of regional magnitude dominate the structure of the area. The Pinchi fault zone extends northwesterly through the area, marking the contact between the Cache Creek Group and plutonic rocks of the Hogem batholith. Movement has involved older Cache Creek rocks moving up relative to those on the east side of the fault, either by thrusting or reverse movement. Truncating the Pinchi fault north of the map-area is the north-trending Takla fault along which rocks on the west side moved down relative to those on the east side.

2.6 EVOLUTION AND SIGNIFICANCE OF THE SKEENA ARCH

The Skeena Arch is a transverse tectonic feature which segmented the Intermontane Tectonic Belt in west-central British Columbia during Mesozoic time (Figure 9).

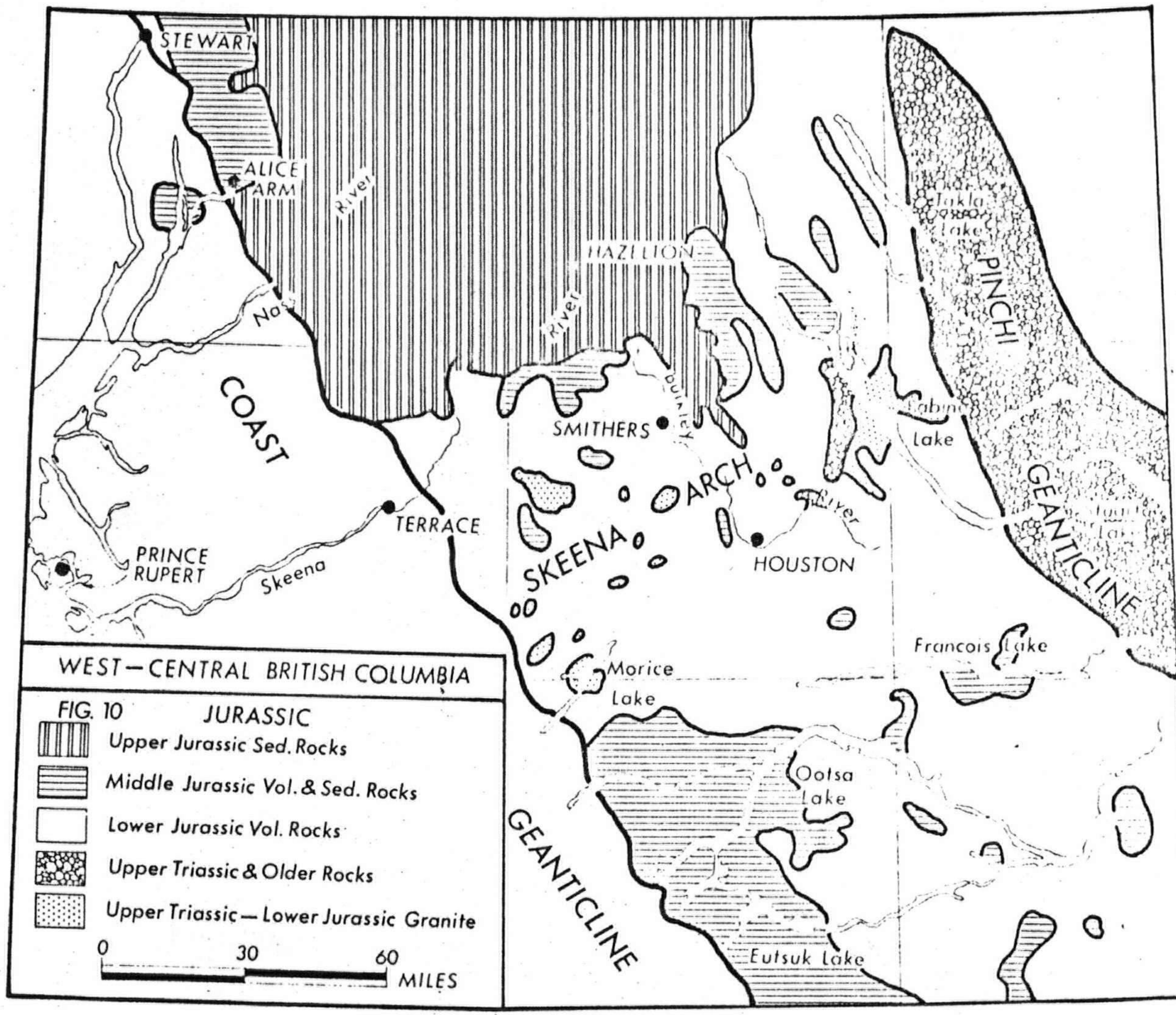
The Skeena Arch was first recognized (White, 1959) as a salient in fold trends which parallel the northwest Cordilleran trend. This salient is coincident with northeast-trending apophyses of granitic rock along the eastern margin of the Coast Crystalline Belt near Terrace. Lack of geologic mapping north of latitude 56 degrees in 1959 also suggested a concentration of small stocks and batholiths in a northeast zone between the Coast Plutonic Complex and the Pinchi geanticline. The greatest number of the smaller intrusions appeared to be contained in the axial region of the salient or arch, and suggested that this zone effected some control over the emplacement of the plutons.

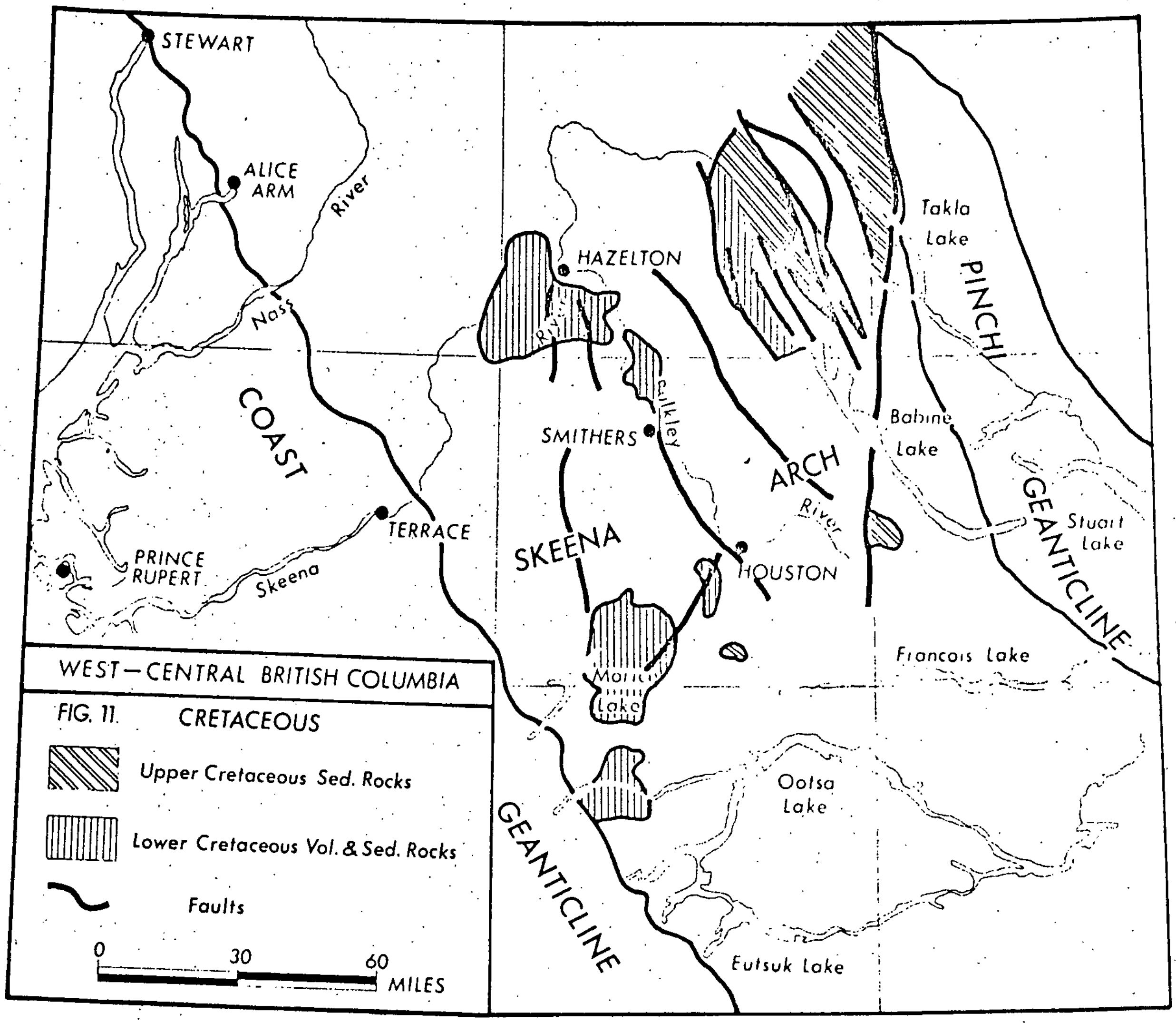
Recent geological mapping of the Mesozoic volcanic and sedimentary rocks and potassium-argon dating of many of the intrusions in west-central British

Columbia has further defined the position and relative tectonic importance of the Skeena Arch. As now defined, the axis of the Skeena Arch is south of that originally proposed and corresponds with a curved line projected northeasterly from the Coast geanticline north of Morice Lake, through the central part of Babine Lake to the Pinchi geanticline (Figure 10). This line is roughly coincident with the projection of a major magnetic discontinuity extending southeasterly from the Great Slave Lake fault (Morley, et al., 1967). Assuming that this part of the Intermontaine Belt is underlain by Precambrian basement, reactivation of this ancient zone of weakness in Early Mesozoic time may have played a role in the development of the Skeena Arch.

The Skeena Arch was a positive tectonic feature throughout Jurassic time. Shoreline facies have been recognized in intravolcanic sedimentary rocks of Middle Jurassic age which flank the arch on the north and south (Tipper, 1971, personal communication). The Lower Jurassic rocks, which occupy much of the axial region of the arch, are mainly products of subaerial volcanism. Rocks of Late Triassic and older age and gneissic rocks east of Babine Lake along the projection of the arch lend further proof that this represents a zone of uplift in which older rocks were preserved. A northeast-trending belt of Upper Triassic-Lower Jurassic granitic plutons, probably the roots of Triassic and Jurassic volcanoes, also coincides with the axial region of the arch (Figure 10). The restriction of Upper Jurassic sedimentary rocks to the north side of the arch indicates that it remained an uplifted area until at least the close of Jurassic time.

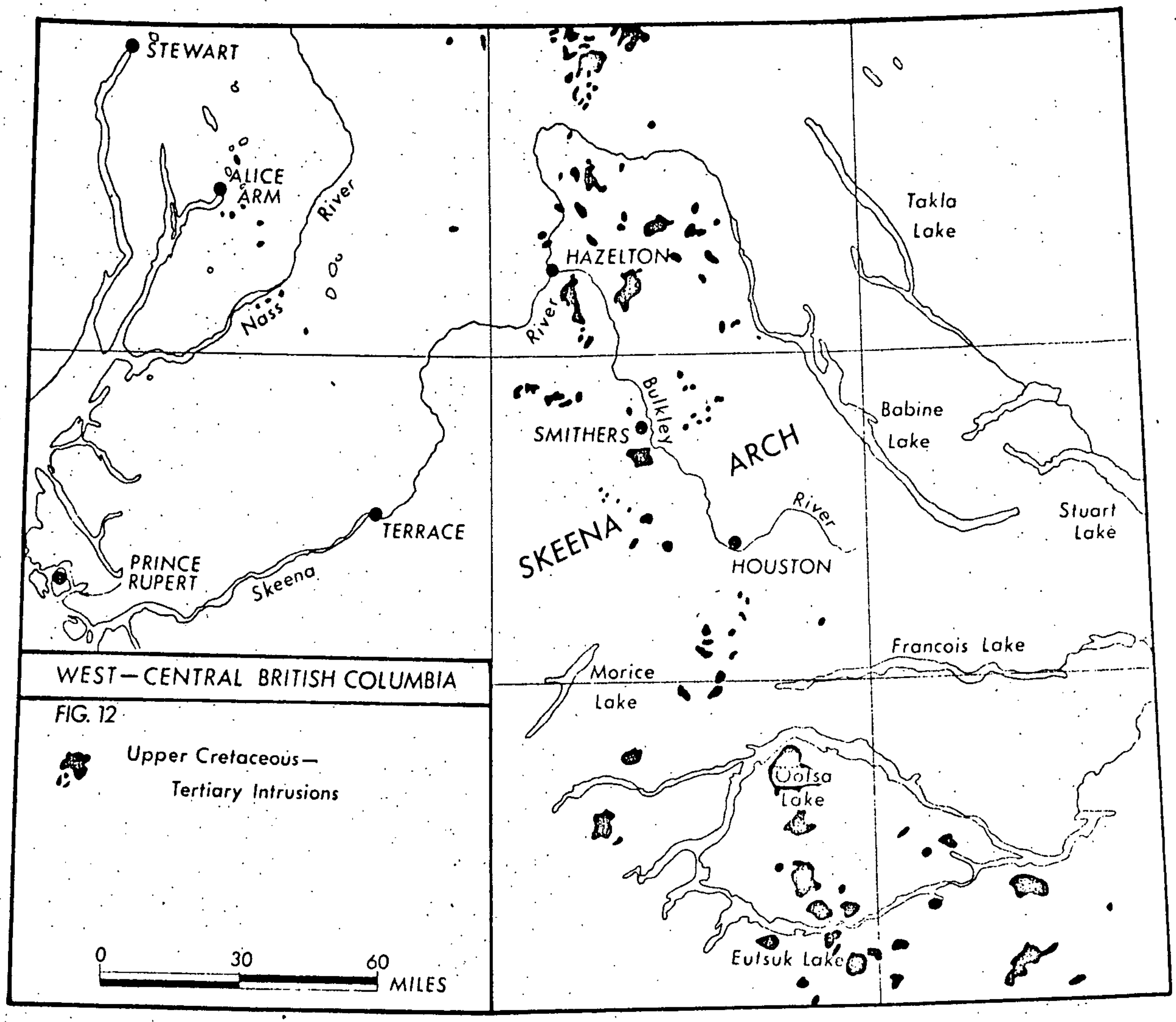
In Early Cretaceous time, the Skeena Arch was cut by north-northeast- and northwest-trending block faults. Clastic sedimentary rocks of Early to Late Cretaceous age are preserved in fault-bounded basins near the axial region of


WEST—CENTRAL BRITISH COLUMBIA
FIG. 10
JURASSIC
Upper Jurassic Sed. Rocks
Middle Jurassic Vol. & Sed. Rocks
Lower Jurassic Vol. Rocks
Upper Triassic & Older Rocks
Upper Triassic — Lower Jurassic Granite
0
30
60
MILES
STEWART
ALICE ARM
River
HAZELTON
River
Nass
COAST
GEANTICLINE
SMITHERS
SKEENA
ARCH
River
HOUSTON
TERRACE
PRINCE RUPERT
Skeena
Morice Lake
Takla Lake
PINCHI
GEANTICLINE
Lake
Francois Lake
Ootsa Lake
Eutsuk Lake



WEST—CENTRAL BRITISH COLUMBIA

FIG. 11. CRETACEOUS



WEST—CENTRAL BRITISH COLUMBIA

FIG. 12

the arch (Figure 11). Many of these faults localized the intrusion of numerous granitic plugs and stocks in Late Cretaceous and Early Tertiary time (Figure 12).

In summary, the Skeena Arch was a dominant tectonic feature in central British Columbia only during Jurassic time when, as a positive feature, it governed the distribution of volcanic and sedimentary rocks and provided one of the controls for the emplacement of Upper Triassic and Lower Jurassic granitic plutons. Most smaller intrusions of Late Cretaceous and Tertiary age show no apparent relationship to the Skeena Arch as now defined.

3. AGE AND DISTRIBUTION OF GRANITIC ROCKS

The granitic rocks of west-central British Columbia, shown on Figure 13, range in age from Early Mesozoic to Tertiary and occur in a number of forms. The Coast Plutonic Complex constitutes the western border of the area. Batholiths and large stocks of Late Triassic and Jurassic age occupy the central and eastern parts of the area, while small plugs and stocks of Late Cretaceous and Tertiary age occur in the central part of the area.

Potassium-argon age determinations were obtained for many of these plutons during the course of this study and these determinations, coupled with those obtained by previous and current workers in the area, have enabled a new definition of the granitic rocks in this part of British Columbia. These potassium-argon ages are listed in Appendix A and are shown on Figure 14 (pocket) and Figure 15.

Age and distribution of the granitic rocks are presented in two parts. The Late Triassic and Jurassic stocks and batholiths and the Tertiary and older Coast Plutonic Complex are described first. Although the granitic rocks of the Coast Plutonic Complex are generally of a much younger age, they are included in the first section because they form the western boundary of the area containing the Upper Cretaceous and Tertiary intrusions, the principal subject of this study. The second part includes a more detailed description of the Upper Cretaceous and Tertiary intrusions which are host to porphyry copper and molybdenum deposits.

The subdivision and nomenclature of granitic rocks used in this study is listed in Table II.

TABLE II. SUBDIVISION OF GRANITIC ROCKS

TERTIARY INTRUSIONS

TERTIARY

Middle Eocene

Goosly Lake intrusions (49 m.y.)

Alice Arm intrusions (48 - 54 m.y.)

Nanika intrusions (47 - 54 m.y.)

Babine intrusions (49- 55 m.y.)

TERTIARY AND OLDER INTRUSIONS

Coast Plutonic Complex (43 - 140 m.y.)

MESOZOIC INTRUSIONS

CRETACEOUS

Upper Cretaceous

Bulkley intrusions (70 - 84 m.y.)

JURASSIC AND CRETACEOUS

Kitsault intrusions

JURASSIC

Upper Jurassic

Francois Lake intrusions (133 - 155 m.y.)

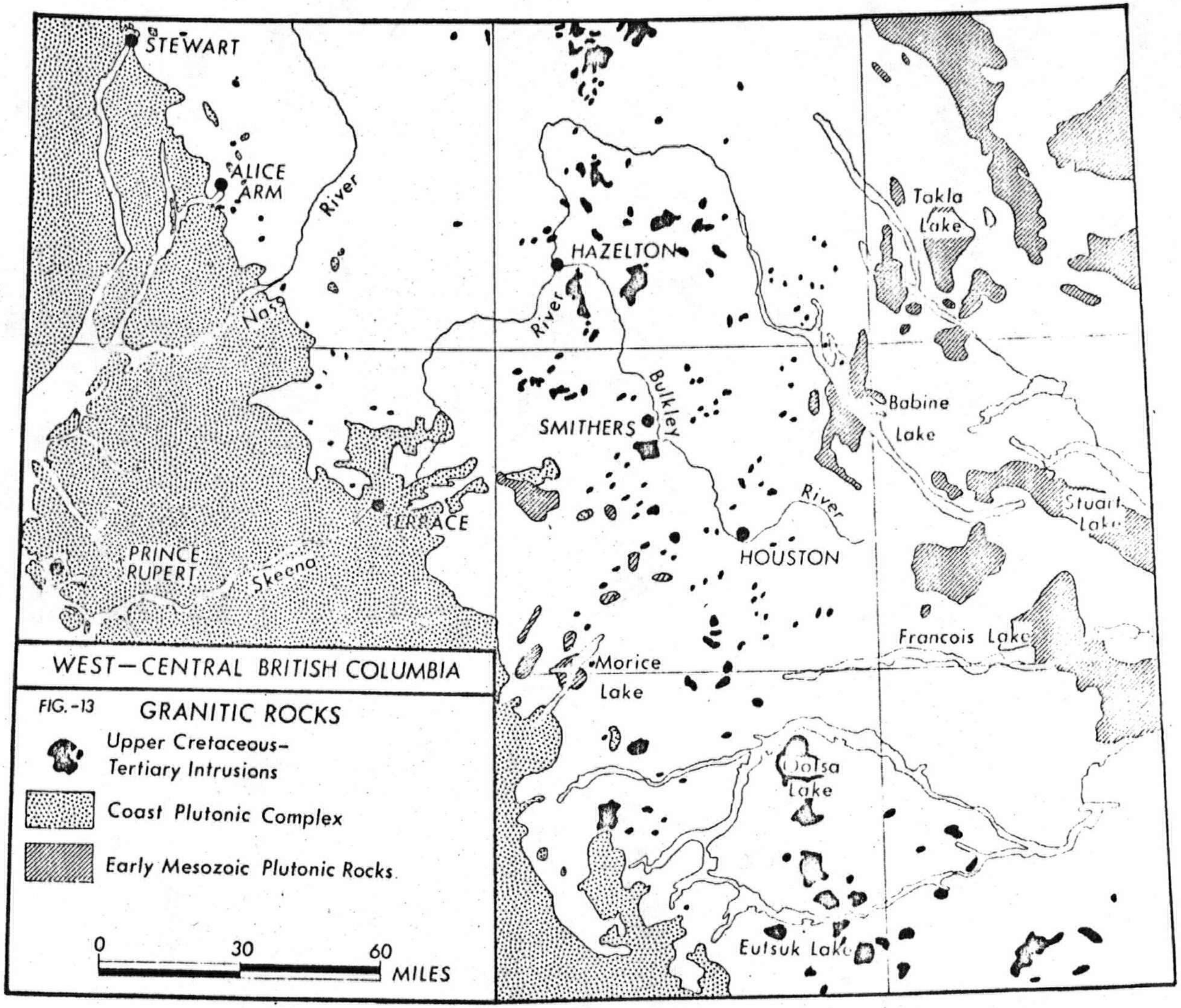
Lower and Middle Jurassic

Omineca intrusions (121 - 189 m.y.)

TRIASSIC AND JURASSIC

Upper Triassic - Lower Jurassic

Topley intrusions (173 - 206 m.y.)


STEWART
ALICE ARM
Nass River
HAZELTON
River
Bulkley
River
SMITHERS
HOUSTON
TERRACE
PRINCE RUPERT
Skeena
Takla Lake
Babine Lake
Stuart Lake
Francois Lake
Morice Lake
Ootsa Lake
Eutsuk Lake
WEST—CENTRAL BRITISH COLUMBIA
FIG.-13
GRANITIC ROCKS
Upper Cretaceous-Tertiary Intrusions
Coast Plutonic Complex
Early Mesozoic Plutonic Rocks
0
30
60
MILES

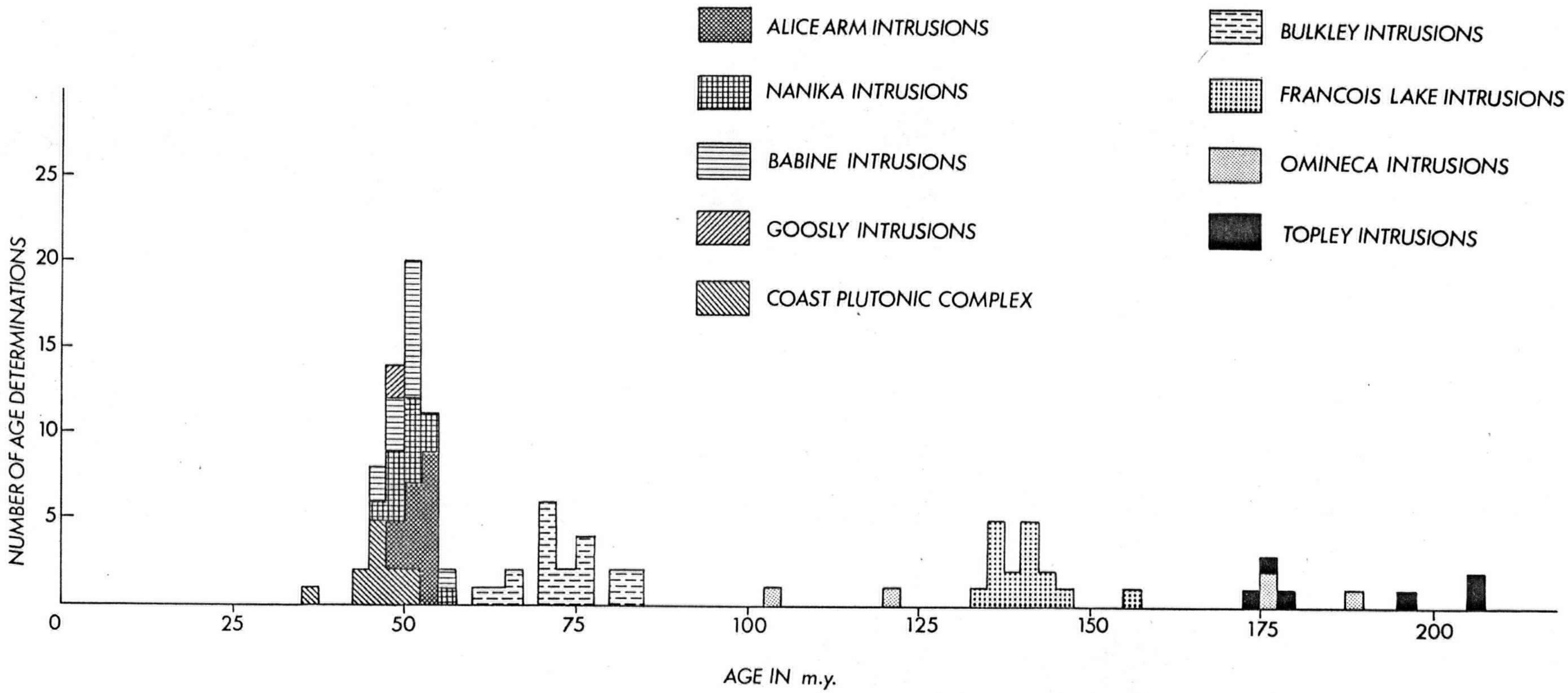


Fig.-15 K-Ar AGE DETERMINATIONS—WEST CENTRAL BRITISH COLUMBIA

3.1 UPPER TRIASSIC AND JURASSIC GRANITIC ROCKS

Granitic rocks of Late Triassic to Late Jurassic age occur as small stocks and batholiths in the central and eastern part of the area (Figure 13). From oldest to youngest, they include the Topley, Omineca, Francois Lake, and Kitsault intrusions.

3.1.1 Topley Intrusions

Topley intrusions of Late Triassic to Early Jurassic age (173 - 206 m.y.) are here defined as a northeast-trending belt of stocks and small batholiths extending from the margins of the Coast Plutonic Complex near Morice Lake to Babine Lake (Figure 14). These rocks range in composition from quartz diorite to quartz monzonite and occupy the core of the Skeena Arch. They probably represent centres of eruption of Lower Jurassic volcanic rocks.

In recent years, the term Topley intrusions has been used to refer to a northwest-trending belt of stocks and batholiths extending from south of Vanderhoof to the central part of Babine Lake (Armstrong, 1949; White, et al., 1969). However, previous work (White, et al., 1970) coupled with results from this study demonstrates that the bulk of granitic intrusions previously included with the Topley intrusions are of a different age and character. These rocks are called the Francois Lake intrusions and are discussed in a subsequent section. The term Topley intrusions is retained for the granitic intrusions in the Skeena Arch area because it was originally used by Hanson and Phemister (1928) to describe the granitic rocks north of Topley which are known to be definitely part of the newly defined Topley intrusions.

The significance of this northeast-trending belt of Upper Triassic-Lower Jurassic was not realized prior to age determinations made on granitic rocks at Morice Lake and south of Babine Lake during the course of this study (Figure 14). Subsequent potassium-argon dating along this belt by the Geological Survey of Canada yielded ages ranging from 173 to 206 m.y. (Tipper, personal communication) corroborating the earlier dates.

The Topley intrusions of the Skeena Arch area are not known to contain significant economic mineral deposits. South of the central part of Babine Lake, low-grade copper and molybdenum mineralization is associated with 176 m.y. hornblende-biotite-quartz-feldspar porphyry dykes which cut somewhat older (ca. 205 m.y.) granitic rocks (Carter, 1969).

3.1.2 Omineca Intrusions

Omineca intrusions, originally described by Armstrong (1949), are chiefly of Early Jurassic age and occur in the northeast part of the area (Figure 14). The largest intrusive mass, the Hogem batholith, is a complex, composite intrusion in which diorites and quartz monzonites are cut by syenites of Early Jurassic age and by later, possibly Early Cretaceous, granitic rocks (Garnett, 1971, 1973). Potassium-argon ages obtained from the Hogem batholith by Garnett (1973) range in age from 189 to 121 m.y.

Smaller batholiths and stocks included with the Omineca intrusions consist of quartz diorites, quartz monzonites, granodiorites, diorites, and some monzonite and syenite. Northeast of Babine Lake, stocks and sills of diorite and monzonite are included with the Omineca intrusions, although they may in part be of a younger, possibly Cretaceous age.

Porphyry-type copper mineralization is associated with syenitic phases of the Omineca intrusions in the central and southern parts of the Hogem batholith. Copper and molybdenum mineralization also occurs in fractured granitic rocks of Early Cretaceous age near the west margin of the Hogem batholith.

3.1.3 Francois Lake Intrusions

Francois Lake intrusions refers to a number of granitic intrusions of batholithic size, which extend in a southeasterly direction from the south end of Babine Lake for approximately 100 miles (Figure 14). They were originally grouped by Armstrong (1949) with the Topley intrusions and this terminology has continued to the present. Potassium-argon age determination studies, however, indicate a Middle to Late Jurassic age for these intrusions, in contrast to the Late Triassic-Early Jurassic age for the Topley intrusions.

Potassium-argon dating of the granitic rocks in the Endako area by White, et al. (1970) indicate a Middle Jurassic age (133 - 155 m.y.) for the bulk of the intrusive phases. Because of the proximity of this batholith to Francois Lake, a prominent geographic feature of this area, these intrusions are here called the Francois Lake intrusions. Similar rocks east of the south end of Babine Lake yielded one age determination of 178 m.y. (Tipper, 1962), but this has since been recalculated to 144 m.y. (Tipper, personal communication) which is consistent with potassium-argon ages obtained by White, et al. (1970).

Further evidence supporting a division between Topley intrusions and Francois Lake intrusions is a gravity survey conducted by the Earth Physics Branch of the Department of Energy, Mines, and Resources. This study indicates the northwest boundary of the Francois Lake intrusions as being near the south end of Babine Lake as shown on Figure 14 (Stacey, personal communication).

Porphyritic quartz monzonite is the dominant rock type of the Francois Lake intrusions in the Endako area, but lesser amounts of diorite, granite, and alaskite are present. The quartz monzonites in the Endako area are subdivided by Carr (1965) and Dawson and Kimura (1972) into numerous mappable phases.

Francois Lake intrusions are host to numerous molybdenum prospects and one major molybdenum mine, the Endako mine, the largest molybdenum producer in Canada. This deposit is an elongate stockwork of quartz-molybdenum veins developed in porphyritic quartz monzonite and in dyke swarms of fine-grained felsic porphyries (Dawson, 1972).

3.1.4 Kitsault Intrusions

Quartz diorites, augite porphyries, and feldspar porphyries of the Kitsault intrusions have been recognized only in the northwest part of the area (Figure 14) and are so named because of their distribution near the Kitsault River which flows into the head of Alice Arm (Carter and Grove, 1972).

Because of the highly altered nature of these intrusions, samples suitable for potassium-argon determinations were not collected. Geological relationships, however, indicate that they probably represent volcanic centres of Middle Jurassic and younger fragmental volcanic rocks of the Hazelton Group in this area.

The Kitsault intrusions are host to numerous copper deposits of limited or unknown potential in the Alice Arm area (Carter, 1970).

3.2 TERTIARY AND OLDER COAST PLUTONIC COMPLEX

Granitic rocks of the Coast Plutonic Complex lie along the west boundary of the area (Figure 13) and are part of a continuous granitic terrane, 1,100 miles long and 80 to 100 miles wide, which extends along the coast of British Columbia and Alaska. Originally referred to as the Coast intrusions (Rice, 1947; Duffell and Souther, 1964), the term Coast Plutonic Complex more accurately describes the varied nature of this belt of granitic rocks.

Coast Plutonic Complex comprises a number of coalescing, northwesterly elongate granitic plutons and narrow belts of metamorphic rocks. The complex consists of three zones which are younger and more potassic eastward (Wheeler and Gabrielse, 1973). These are: (1) a western zone of quartz diorite and diorite with potassium-argon ages of 84 to 140 m.y. in the western part and 64 to 79 m.y. ages in the eastern part; (2) a central core zone of migmatitic gneiss, quartz diorite, and granodiorite, yielding potassium-argon ages averaging 45 m.y.; and (3) an eastern zone of post-tectonic quartz diorite and quartz monzonite (43 - 51 m.y.) intrusive into Mesozoic rocks.

The western and central zones of the Coast Plutonic Complex are to the west of the area (Figure 14) studied. The oldest potassium-argon age (140 m.y.) was obtained from an island south of Douglas Channel (Hutchison, 1970), 80 miles west of Eutsuk Lake. The eastern zone forms the western boundary of the area shown on Figure 14. Several large, easterly trending apophyses extend from the main mass in the Terrace area and numerous small satellitic stocks are present along the eastern flank of the complex throughout the map-area. Quartz diorite, granodiorite, and quartz monzonite are the dominant rock types found in the eastern zone although a wider diversity of granitic rocks are present in the apophyses in the Terrace area (Duffell and Souther, 1964). In general, the rocks are equigranular and foliated only near contacts with older rocks. Contacts between the granitic rocks and Mesozoic layered rocks generally are sharp. Evidence of forceful emplacement is common, especially adjacent to small satellitic stocks.

Hutchison (1970) describes the granitic rocks of the eastern zone as being marginal to and generated from a central migmatitic gneiss complex. Potassium-argon dates obtained by both the Geological Survey of Canada and this study indicate a Middle Eocene (43 - 51 m.y.) age for the emplacement of the granitic rocks of the eastern zone (Figure 14).

3.3 UPPER CRETACEOUS AND TERTIARY INTRUSIONS

Granitic rocks of Late Cretaceous and Tertiary age occur in an area bounded on the west by the Coast Plutonic Complex and on the east by a belt of Mesozoic stocks and batholiths (Figures 13 and 14).

A five-fold division of these intrusions is proposed, based on areal distribution, age, whole-rock chemistry, major and trace elements in biotite, and on associated metal content. The distribution of these intrusions (Figure 16) can be described in a general way as consisting of a central north to northwest-trending belt of stocks and small batholiths of Late Cretaceous age, flanked on the east and west by small intrusions of Tertiary (Eocene) age. The intrusive rocks are discussed in order, from oldest to youngest.

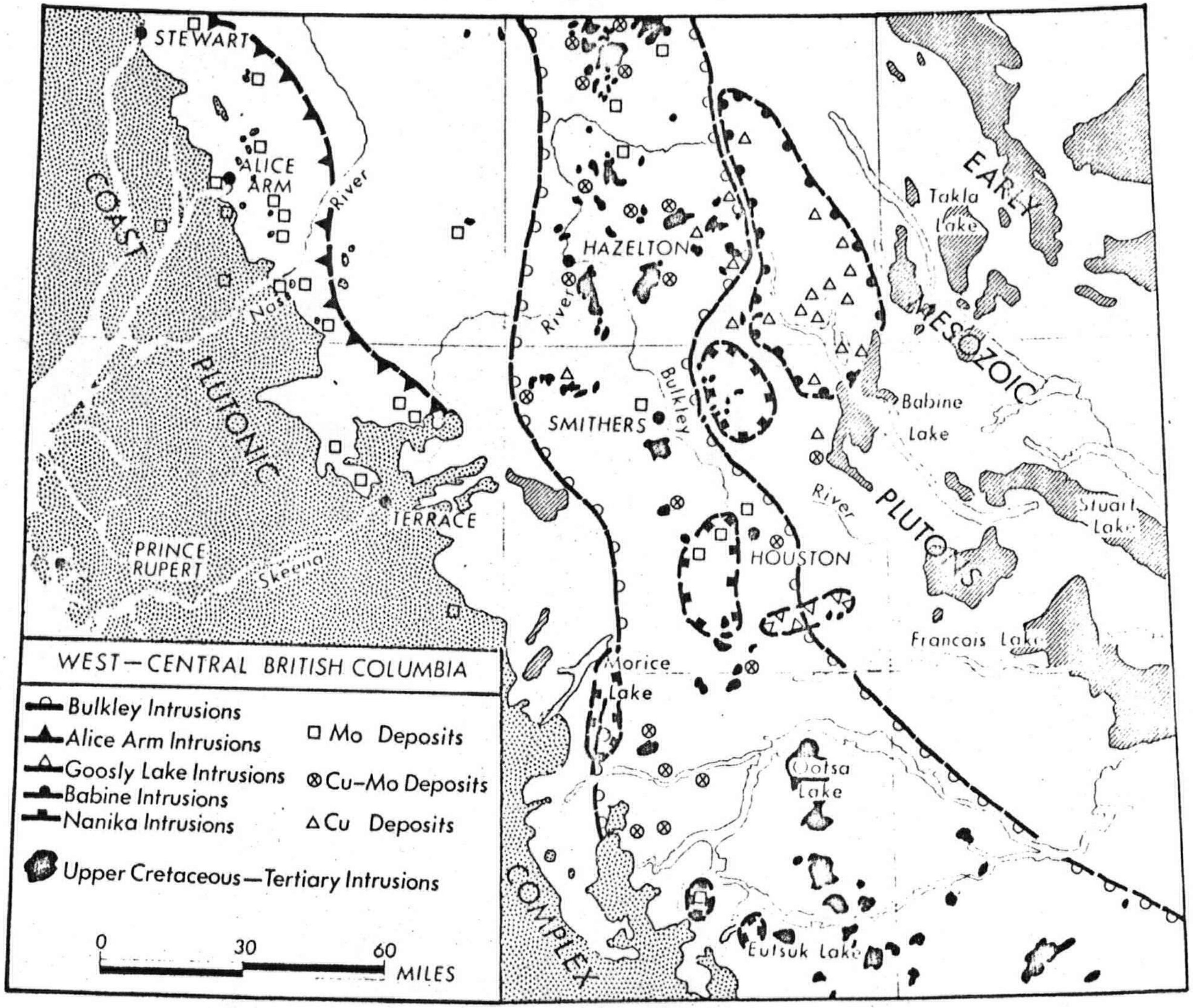


Fig.-16 AGE AND DISTRIBUTION OF UPPER CRETACEOUS AND TERTIARY INTRUSIONS—WEST CENTRAL B.C.

3.3.1 Upper Cretaceous

Bulkley Intrusions

The term Bulkley intrusions was first proposed by Kindle (1954) to describe the granitic rocks in the Hazelton area. The name has been retained for intrusive rocks of similar age and composition which occur in the central part of the Intermontane Belt, extending from north of Hazelton to the south boundary of the area shown on Figure 14.

Bulkley intrusions occur as stocks and small batholiths of porphyritic granodiorite and quartz monzonite. Potassium-argon ages obtained from a number of intrusions (Figure 14) yielded ages ranging from 70 to 84 m.y. A number of intrusions which were not sampled for potassium-argon dating are grouped with the Bulkley intrusions on the basis of their description, associated metallic mineralization, and their tectonic setting. These include granite plutons north of Hazelton in the Sicintine and Atna Ranges and the Quanchus intrusions in the Whitesail Lake area (Duffell, 1959).

The Bulkley intrusions are host to important copper-molybdenum and molybdenum-tungsten deposits.

3.3.2 Tertiary (Eocene) Intrusions

Goosly Lake Intrusions

The Goosly Lake intrusions, named by Church (1970), refer to a number of small plugs of porphyritic gabbro and syenomonzonite south of Houston. They occur in a northeast-trending belt of apparent limited extent (Figure 14), and are regarded by Church (1970) as centres of Eocene volcanism.

Intrusive rocks of similar composition and texture have been recognized only in a few other localities, including the Grouse Mountain area north of Houston (Church, 1972) and in an area south of Francois Lake as shown on Figure 14. Two potassium-argon samples, both biotite separates, analysed at the University of British Columbia, yielded identical ages of 49 m.y. A replicate sample analysed at Geochron Laboratories, Ltd. returned a potassium-argon age of 53 m.y. This analysis was carried out on a mafic (biotite + hornblende) concentrate, which may in part explain the disparity in age obtained by the two laboratories.

The relationship between the Goosly Lake intrusions and sulphide mineralization is not clear. Church (1970) considers the intrusions as the source of the copper and silver mineralization at the Sam Goosly deposit, while Ney, et al. (1972) believe the deposit to be of the volcanogenic type, contemporaneous with the enclosing Hazelton volcanic rocks. The syenomonzonite stock and related dykes are regarded as post-mineral age, perhaps causing some remobilization of pre-existing sulphide mineralization.

Alice Arm Intrusions

The Alice Arm intrusions are so named because of their distribution along the east margin of the Coast Plutonic Complex north and south of the village of Alice Arm (Figure 14). The intrusions take the form of small stocks of one-half mile in diameter or less. Quartz monzonite porphyry is the dominant rock type. Potassium-argon ages from a number of these intrusions range from 48 to 54 m.y. Plutons grouped with the Alice Arm intrusions extend from the Terrace area to Stewart.

Molybdenite is the major economic mineral associated with the Alice Arm intrusions.

Nanika Intrusions

Nanika intrusions are here named to include a number of small plutons of quartz monzonite to granite composition which are distributed within and marginal to the central belt containing the Bulkley intrusions (Figures 14 and 15). The name Nanika intrusions is used because of the proximity of two important porphyry deposits, Lucky Ship and Berg, to Nanika Lake.

Plutons of this group extend from Mount Thomlinson, north of Hazelton, to the Red Bird molybdenum deposit, west of Eutsuk Lake. Potassium-argon ages of these intrusions range from 47 to 56 m.y.

Several of the Nanika intrusions contain major deposits of copper and molybdenum. Many, however, are apparently barren of economic mineralization. Examples of barren plutons are the small stocks in the Babine Range east of Smithers, and a stock that forms the core of Nadina Mountain.

Babine Intrusions

Babine intrusions include a number of small plugs, dykes, and dyke swarms of fine-grained biotite feldspar porphyry of granodiorite and quartz diorite composition which occur near Babine Lake. Potassium-argon ages range from 49 to 55 m.y. for this unique suite of intrusions which have been recognized only in the Babine area. The intrusions are regarded as volcanic centres and extrusive equivalents are preserved in several localities. The Babine biotite feldspar porphyries invariably contain chalcopyrite mineralization and several intrusions host major deposits.

3.4 CHEMISTRY OF UPPER CRETACEOUS AND TERTIARY INTRUSIONS

Chemical analyses of samples from a number of Upper Cretaceous and Tertiary intrusions were made by the Analytical Branch of the British Columbia Department of Mines and Petroleum Resources (see Appendix B). CIPW (water free) weight per cent norms were calculated and ternary quartz-alkali feldspar-plagioclase normative diagrams (Figures 17a and 17b) were plotted to illustrate the range in composition of the five intrusive divisions. The classification scheme on Figure 17a will be used throughout this thesis. Figure 17b is for comparative purposes, being the classification and nomenclature recommended in 1973 by the I.U.G.S. Subcommission on the Systematics of Igneous Rocks.

Bulkley intrusions, with the exception of one pluton, are predominantly within the granodiorite field as illustrated on Figure 17a. Several samples fall just within the quartz monzonite field.

Babine intrusions of Early Tertiary age are clustered in the granodiorite field. Other Tertiary intrusions, the Alice Arm and Nanika intrusions, are predominantly of quartz monzonite or granite composition.

The basic Goosly Lake intrusions are well within the monzodiorite field according to the classification on Figure 17a.

3.4.1 Major and Trace Element Analyses

Major and trace element contents were dtermined on 39 biotite separates from a number of intrusions in west-central British Columbia. Analyses were conducted by Cominco Research, Trail, under the supervision of M. Osatenko. Detailed results of these analyses are contained in Appendix B.

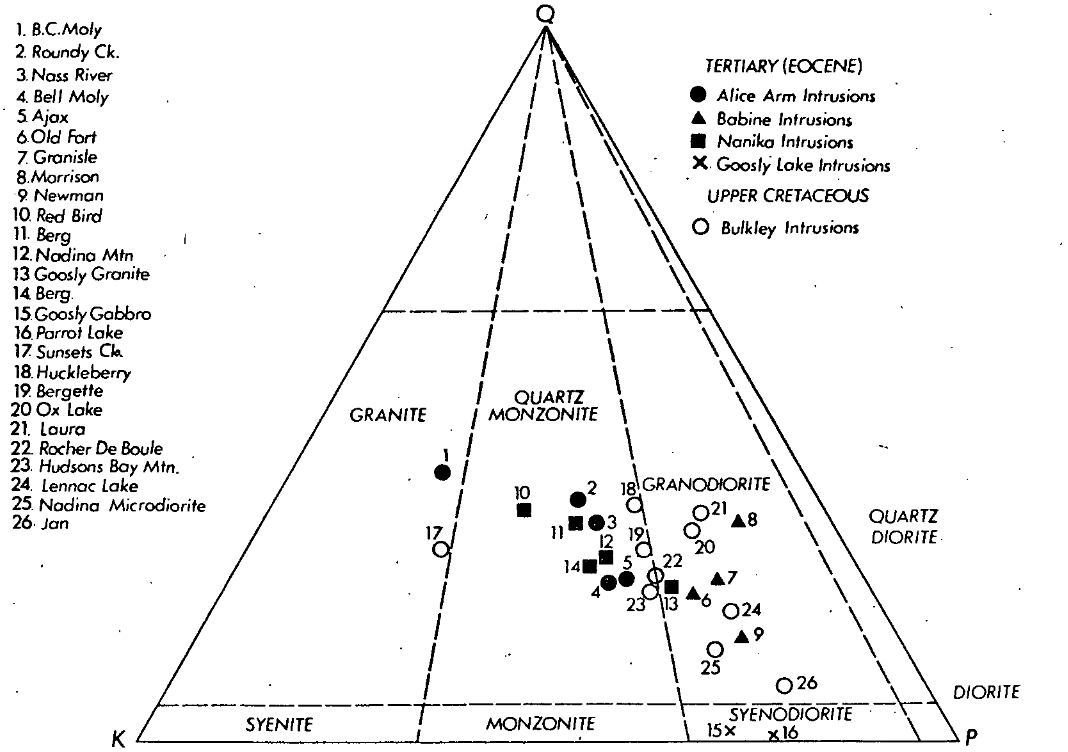


FIG. 17a DISTRIBUTION OF NORMATIVE QUARTZ (Q), PLAGIOCLASE (Ab + An) & ORTHOCLASE (K) IN CHEMICALLY ANALYZED SAMPLES (Rock Classification After Hutchison 1970).

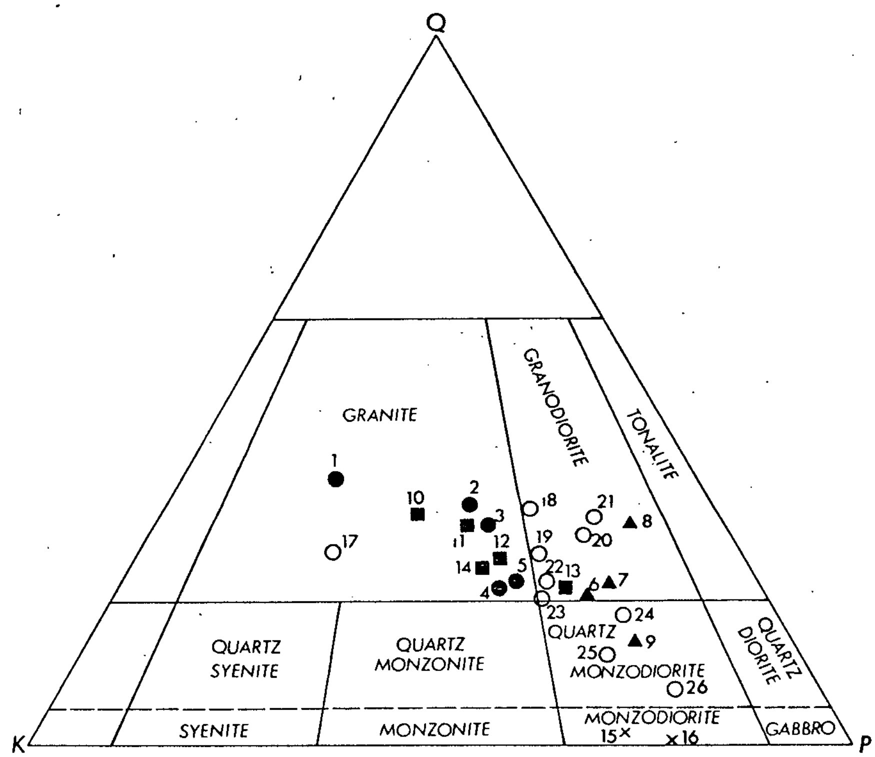


FIG. 17b AS ABOVE. (Rock Classification As Proposed By Subcommission on Systematics Of Igneous Rocks, International Union Of Geological Sciences 1973).

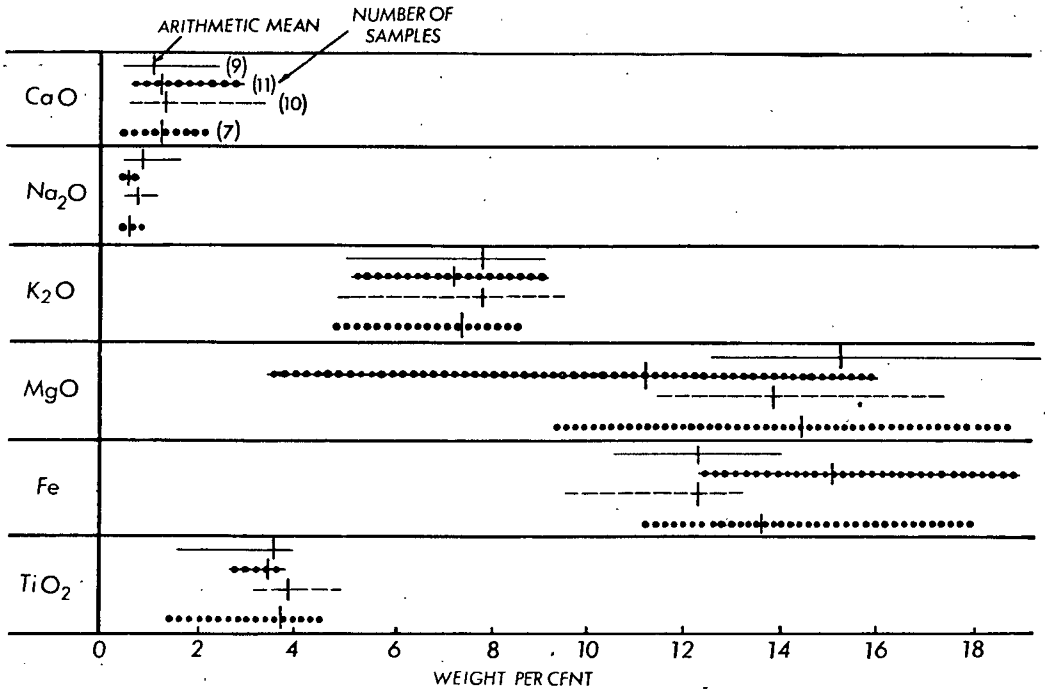
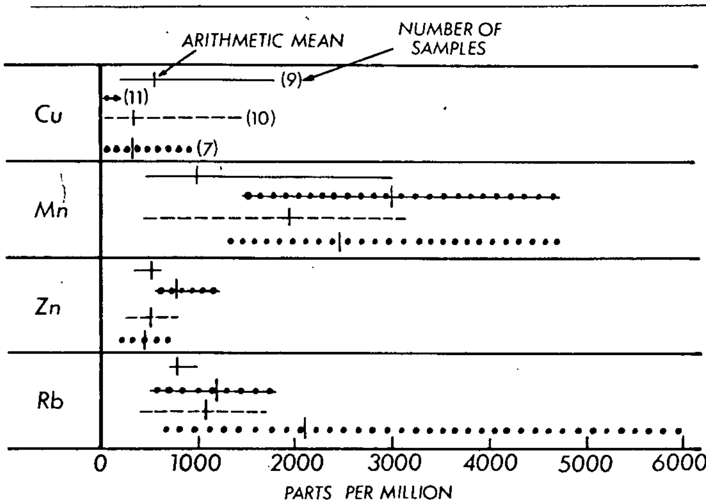
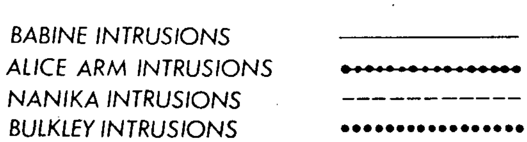


Figure 18a — MAJOR ELEMENTS IN BIOTITES



TRACE ELEMENTS IN BIOTITES

Figure 18b



A tabular summary of some of these analyses are presented on Figures 18a and 18b. The various intrusive types are indistinguishable on the basis of their CaO, Na_2O, and K_2O contents in biotites (Figure 18a). MgO results occupy a wider range with biotites from the Babine intrusions having a higher MgO content, possibly because of the presence of abundant secondary biotite in these samples. Iron and titanium contents are roughly similar for the various intrusive types.

Copper content in biotites varies for different intrusive types. As might be expected, copper values are very low in Alice Arm intrusions which are predominantly molybdenum-bearing plutons. The copper-bearing Babine intrusions contain the highest trace copper values, whereas copper-bearing and molybdenum-bearing Nanika and Bulkley intrusions fall in the middle range. An interesting feature of the Babine intrusions is that copper contents in biotites of late or post-mineral porphyry phases are two to three times higher than the copper contents in biotites of mineralized porphyry phases. Manganese values are highest for the Alice Arm intrusions. Trace zinc contents are roughly similar for the four intrusive types, while rubidium exhibits the highest range in the biotites from the Bulkley intrusions.

3.4.2 Metal Content

Figure 16 shows the five-fold subdivision of Upper Cretaceous and Tertiary intrusions and their type of associated metallic mineralization. In a general way, there is a crude metal zonation from west to east consisting of the following: molybdenum-bearing Alice Arm intrusions of Eocene age; copper-bearing and molybdenum-bearing Upper Cretaceous Bulkley intrusions and Eocene Nanika intrusions; and copper-bearing Babine intrusions. Notable exceptions to this westward pattern of copper, copper-molybdenum, and molybdenum mineralization are found in the central belt where several deposits related to the Bulkley intrusions contain only molybdenum. An example is the Hudson Bay Mountain molybdenum-tungsten deposit at Smithers.

4. GEOLOGICAL RELATIONSHIPS AND GEOCHRONOLOGY OF PORPHYRY COPPER AND MOLYBDENUM DEPOSITS

The majority of known porphyry copper and molybdenum deposits in west-central British Columbia are spatially and genetically associated with Upper Cretaceous and Tertiary intrusions. From west to east, these include the Alice Arm intrusions, the Bulkley intrusions, the Nanika intrusions, and the Babine intrusions. Each group is discussed as a unit.

Each section includes a description of the geological setting of the porphyry deposits, detailed geology and style of mineralization, potassium-argon results, and a discussion of the results.

4.1 PORPHYRY MOLYBDENUM DEPOSITS ASSOCIATED WITH THE ALICE ARM INTRUSIONS

A number of molybdenum deposits are related to the Alice Arm intrusions in the area between Stewart and Terrace (Figure 19, in pocket). These deposits exhibit features typical of porphyry deposits although they have been referred to by some writers as stockwork molybdenum deposits (Clark, 1972) because the bulk of molybdenum mineralization is contained in a stockwork of quartz veinlets.

4.1.1 Geologic Setting

Most of the known molybdenum-bearing stocks occur near the western edge of the Bowser successor basin, marginal to the Coast Plutonic Complex (Figure 19). The intrusions occur in the form of small stocks, generally not exceeding one-half mile in diameter. Porphyritic quartz monzonite is the dominant rock type, and this distinguishes the molybdenum-bearing stocks from the equigranular, satellitic stocks related to the Coast Plutonic Complex. Molybdenum-bearing stocks generally intrude argillaceous siltstones, greywackes, and shales of Late Jurassic and Early Cretaceous age, although some occur within the Coast Plutonic Complex.

Evidence for both forceful and passive emplacement of the intrusions is well documented. In the Alice Arm area, sedimentary rocks have been arched and domed around the stocks. Elsewhere, little disturbance of the country rock is seen and the elongate nature of some of the intrusions indicates that they probably were emplaced along major fault zones.

South of Alice Arm, several molybdenum-bearing stocks are clustered near remnants of flat-lying Quaternary basalt which probably overlie their feeders. In the Nass River area, small stocks occur south and west of the Recent lava flow (Figure 19). These features suggest that the extrusion of lava may have been related, in part, to deep-seated structures that previously controlled the intrusion of the granitic stocks.

Many of the stocks apparently have been localized at or near intersections of east-northeast and north-northwest faults. The east-northeast trend is reflected by the elongation of several of the stocks (Bell Molybdenum, Roundy Creek, Kay) in the Alice Arm-Nass River areas which may also represent some control of the attitude of the sedimentary rocks. Also a crude east-northeast distribution of the stocks is evident in the cluster south of Alice Arm and south of the Nass River (Figure 19). Some stock contacts are rectilinear in plan, again reflecting the dominant fault and fracture patterns. A good example of this is seen at the Ajax molybdenum deposit northeast of Alice Arm (Figure 20).

4.1.2 Geology and Style of Mineralization

Molybdenum deposits are associated with the Alice Arm intrusions, which occur as small oval or elongate stocks. Some intrusions, most notably the Roundy Creek intrusion south of Alice Arm, are sheet- or sill-like in form and are related to small feeder pipes. Intrusions at Alder Creek, near Lava Lake (Figure 19) and Molybdenum Creek, north of Terrace, are northwest-striking dyke swarms intruding sedimentary rocks.

Quartz monzonite porphyry is the most common host rock at most deposits. Phenocrysts range in size from 2 millimetres to 1 centimetre and include, in decreasing order of abundance, euhedral plagioclase, K-feldspar, and both euhedral and anhedral quartz eyes. Quartz monzonite porphyry is characteristically mesocratic with both biotite and hornblende as primary mafic minerals. Leucocratic quartz feldspar porphyry phases of quartz monzonite to granite composition also are prominent at most of the deposits and at some they constitute the bulk of the intrusive rocks. Muscovite is the mica mineral of this phase.

Some intrusions are zoned, most notably the intrusion that is host to the British Columbia Molybdenum deposit. Here, a core of quartz monzonite porphyry is bordered by more basic granodiorite and quartz diorite which possibly formed by contamination from the argillaceous siltstone and greywacke country rocks.

Most molybdenum-bearing stocks exhibit several stages of intrusion. The first stage is represented by quartz monzonite and/or quartz feldspar porphyry and constitutes the bulk of the stock. This main phase may be intruded by fine-grained, equigranular alaskite that consists essentially of quartz, K-feldspar,

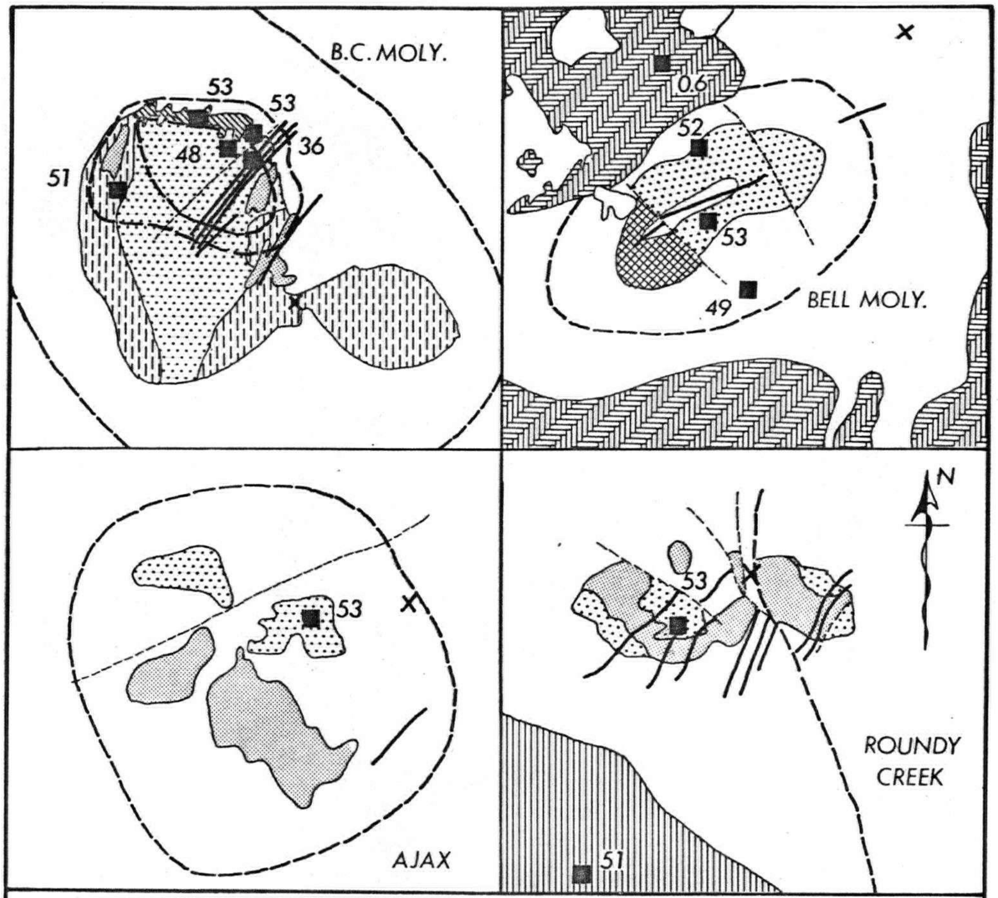


FIG.-20 **MOLYBDENUM DEPOSITS, ALICE ARM**

QUATERNARY
BASALT
TERTIARY—OLIGOCENE
LAMPROPHYRE DYKES
INTRUSIVE ROCKS—EOCENE
COAST COMPLEX—GRANODIORITE
LATE QUARTZ MONZONITE PORPHYRY
INTRUSIVE BRECCIA
× Ag-Pb-Zn Showing
■ K-Ar Sample

ALASKITE, LEUCOCRATIC QUARTZ FELDSPAR PORPHYRY
QUARTZ DIORITE
QUARTZ MONZONITE—GRANODIORITE PORPHYRY
JURASSIC—CRETACEOUS
BIOTITE HORNFELS
— — LIMIT OF BIOTITE HORNFELS

0 FEET 3000

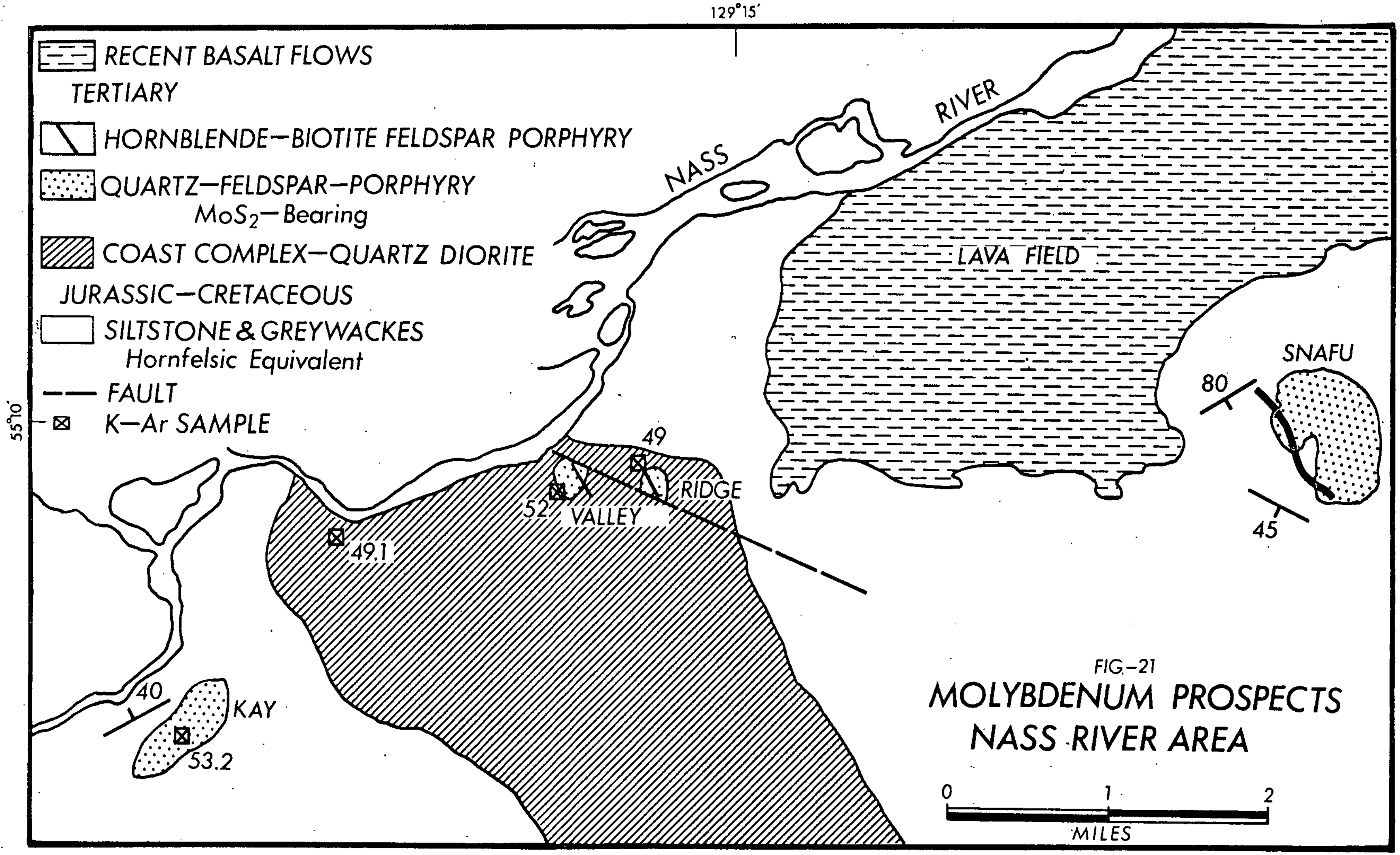


FIG.–21
MOLYBDENUM PROSPECTS
NASS RIVER AREA

and myrmekite. Alaskites, which are very common at the British Columbia Molybdenum and Roundy Creek properties (Figure 20), occur as dykes and irregular masses and are host to better grades of disseminated and replacement molybdenite mineralization. Other inter-mineral intrusions include dykes and irregular lenses of intrusive breccia, best developed along the northern stock contact at the British Columbia Molybdenum deposit (Figure 20). Angular fragments 1 to 2 centimetres in size, of both intrusive and country rock, are contained in a granulated matrix of quartz, plagioclase, and K-feldspar. Several deposits feature intrusive phases that are very late in the intrusive-mineralization sequence. These also are quartz monzonite in composition. Examples include an unexposed plug at the British Columbia Molybdenum deposit, the southwest portion of the Bell Molybdenum stock (Figure 20), and post-mineral dykes at some of the Nass River deposits (Figure 21).

Post-mineral lamprophyre and basalt dykes cut virtually all of the molybdenum-bearing stocks. These usually strike northeasterly, dip vertically, and truncate all pre-existing rocks and structures, including mineralized fractures. Northwest-striking, post-intrusive, and post-lamprophyre dyke faults are found at the Bell Molybdenum, Roundy Creek, and Nass River deposits (Figures 20 and 21).

Sedimentary rocks adjacent to the Alice Arm intrusions have been thermally metamorphosed to biotite hornfels in an aureole which may extend outward from the stock contact for several hundred feet (see property descriptions, Appendix C). Biotite hornfels is a brown, indurated, fine-grained rock with a grano-blastic texture that consists of quartz, minor feldspar, and abundant felted, brown biotite. Some cordierite and andalusite are developed in the hornfels adjacent to intrusive contacts.

Alteration patterns within and marginal to the molybdenum-bearing stocks are typical of porphyry deposits. At many of the deposits, a central zone of potassic alteration is coincident with molybdenite mineralization. At the British Columbia Molybdenum deposit, the most intense potassic alteration is contained within an annular ore zone (Figure 20). Rock within this core of intense alteration is laced with barren quartz veinlets rimmed by secondary K-feldspar, such that the original quartz monzonite porphyry has been converted to a rock consisting mainly of quartz and K-feldspar. Within the annular zone of mineralization, secondary K-feldspar is restricted to the margins of quartz-molybdenite veinlets. Other deposits also feature secondary K-feldspar but not to the same degree as at British Columbia Molybdenum. Secondary biotite, an alteration of primary hornblende, is present to a limited degree in several of the deposits. At Roundy Creek, quartz-muscovite veins constitute the potassic alteration zone.

The potassic zone at most deposits is gradational outward to a phyllic (quartz-sericite-pyrite) zone which is marginal to the plutons and involves an overprinting on the effects of thermal metamorphism. The phyllic zone is represented at many deposits by a bleaching of the biotite hornfels to a cream or light green colour marginal to fractures and quartz veinlets and is due to the development of very fine-grained quartz, sericite, albite, and epidote. This type of alteration may be weakly developed, as at many of the deposits, or so intense that the original biotite hornfels has been largely transformed to a buff or light green-coloured rock within a zone a few hundred feet outward from the stock contact as at the British Columbia Molybdenum and Ajax deposits. Pyrite is a common constituent in this alteration zone, occurring both in quartz veinlets and as disseminations. The intensity of pyritization may be related in part to thermal metamorphism, which involves a concentration of syngenetic pyrite and pyrrhotite in the sedimentary country rocks.

Better grades of molybdenite mineralization in the Alice Arm intrusions are dependent on structural and lithologic controls. Fracturing and attendant quartz-molybdenite veining are best developed near stock contacts. Later alaskite intrusive phases contain disseminated to near-massive molybdenite. An example is the ore zone at British Columbia Molybdenum which is annular or ring-shaped in plan, occurring near the contacts of the northern half of the stock (Figure 20) with molybdenite occurring as selvages in a network of east-northeast and west-northwest quartz veinelts. A similar style of mineralization occurs at most of the other deposits. Disseminated rosettes of molybdenite occur in leucocratic quartz-feldspar porphyry phases at the Tidewater and Kay properties.

Disseminated molybdenite is contained in the alaskite intrusive phase at the British Columbia Molybdenum deposit. At Roundy Creek, the alaskite contains near-massive lenses, pods, and parallel bands of molybdenite.

At least three stages of quartz-molybdenite veining are present in the British Columbia Molybdenum deposit. Virtually all of the Alice Arm molybdenite deposits feature late-stage quartz-carbonate veins which contain pyrite, galena, sphalerite, tetrahedrite, chalcopyrite, minor molybdenite, and at British Columbia Molybdenum, a silver-lead-bismuth sulphosalt, neyite (Drummond, et al., 1969). These silver-lead-zinc veins which are best developed peripheral to the stocks were explored many years before the molybdenite mineralization attained economic significance.

A pyrite halo may extend outward from the molybdenite zone for several hundred to a thousand feet. Where exposed, the pyrite zone is weathered to a prominent gossan, particularly at the Ajax and Snafu properties.

Other molybdenite deposits studied in the Alice Arm area include the Molly Mack prospect near Anyox and the Penny Creek showing south of Alice Arm (Figure 19). At the Molly Mack property, coarse-grained molybdenite is abundantly disseminated in a small zone of biotite granite contained within a stock-like body of leucocratic quartz monzonite porphyry which is similar in appearance to some phases of the Alice Arm intrusions. The Penny Creek occurrence consists of rosettes of molybdenite in a biotite quartz monzonite, a late phase of the Coast Plutonic Complex.

Numerous showings of molybdenite occur near the eastern margin of the Coast Plutonic Complex and in the satellite stocks related to the complex.

4.1.3 Potassium-argon Dating of the Alice Arm Porphyry Molybdenum Deposits

Potassium-argon ages obtained from samples collected in the Alice Arm-Nass River area are shown on Figures 19, 20, and 21. Analytical data, sample descriptions, and precise locations are contained in Appendices A and C.

Most samples were collected to date the age of intrusion and mineralization. Several, however, were collected to date other geologic units and to assess their relationship to the molybdenum deposits. These include samples collected from the Coast Plutonic Complex and from the basalt outliers south of Alice Arm.

Potassium-argon results for all samples collected are listed in Table III. Unless otherwise indicated, all analyses were carried out on biotite separates.

TABLE III. POTASSIUM-ARGON AGES OF ALICE ARM INTRUSIONS

Sample No.	Location	Rock Unit	Age (m.y.)
NC-67-38	British Columbia Molybdenum	Quartz monzonite porphyry	53.2 ± 3
NC-69- 2	British Columbia Molybdenum	Intrusive breccia	53.7 ± 1.7
NC-70- 1	British Columbia Molybdenum	Lamprophyre dyke (W.R.)	36.5 ± 1.2
NC-70- 2	British Columbia Molybdenum	Quartz diorite	51.4 ± 1.5
NC-70- 3	British Columbia Molybdenum	'Late' quartz monzonite porphyry	48.3 ± 1.6
NC-67-30	Bell Molybdenum	Quartz monzonite porphyry	52.9 ± 2
NC-67-31	Bell Molybdenum	Biotite hornfels (W.R.)	48.7 ± 1.5
NC-68- 2	Bell Molybdenum	Quartz diorite - border phase	51.7 ± 2.2
NC-67-33	Ajax	Granodiorite	53.5 ± 3
NC-67-35	Roundy Creek	Quartz monzonite porphyry	52.5 ± 2*
NC-67-25	Ridge	'Late' porphyry	49.0 ± 2
NC-67-26	Valley	Quartz monzonite porphyry	52.0 ± 3
NC-67-27	Kay	Quartz feldspar porphyry	53.2 ± 2.3
NC-67-45	Penny Creek	Biotite quartz monzonite	36.1 ± 1.6
NC-68-11	Molly Mack	Biotite granite	48.3 ± 1.9
NC-67-24	Mount Priestly	Coast Plutonic Complex	48.4 ± 1.5*
NC-67-28	Nass River	Coast Plutonic Complex	49.1 ± 2
NC-67-29	Alice Arm	Coast Plutonic Complex	50.5 ± 3
NC-69- 3	Lava Lake	Coast Plutonic Complex	50.7 ± 2.1
NC-68- 3	Bonanza Creek - Anyox	Biotite schist	33.3 ± 1.4
NC-68- 4	Illiance River	Lamprophyre dyke	34.4 ± 1.5
NC-67-32	Alice Arm	Basalt	0.62 ± 0.6*
NC-70- 4	Alice Arm	Basalt	1.6 ± 0.8

*Average of two or more analyses.
(W.R.) – Whole Rock Sample.

Note: Calculation of analytical error is outlined in Appendix A.2.

Molybdenum-bearing Stocks

Samples for dating were collected from molybdenum-bearing quartz monzonite porphyries and related intrusive phases at six of the deposits. Potassium-argon results from the main mineralized phase at these deposits fall within the range of 52.0 ± 3 m.y. to 53.3 ± 3 m.y. (Table III and Figures 20 and 21). Quartz diorite border phases at British Columbia Molybdenum and Bell Molybdenum are 51.4 ± 1.5 m.y. and 51.7 ± 2.2 m.y. respectively, within the limits of analytical error of the main phase.

Late intrusive phases, which exhibit definite crosscutting relationships with the first phase, were sampled at British Columbia Molybdenum. A dyke of intrusive breccia near the northern contact of the stock has an age of 53.7 ± 1.7 m.y., almost identical to the age obtained from the geologically older quartz monzonite porphyry phase (53.2 ± 3 m.y.). An age of 48.3 ± 1.6 m.y. was obtained for a sample of a later, nearly barren phase of quartz monzonite occurring at a depth some 1,000 feet vertically below the northeast section of the stock. This age determination corroborates the geological evidence that this is a younger porphyry phase which post-dates the main period of molybdenite mineralization and provides an upper limit for the age of mineralization. A similar post-mineral porphyry dyke that cuts the quartz monzonite porphyry host rock at one of the Nass River deposits (Figure 21) yields a potassium-argon age of 49.0 ± 2 m.y.

A whole-rock sample of biotite hornfels from outside the mineralized zone at Bell Molybdenum was dated at 48.7 ± 1.5 m.y. Although such a sample should reflect the age of intrusion, the somewhat younger age could be explained by partial argon loss inherent in a whole-rock sample.

Two molybdenum deposits returned somewhat anomalous ages. The 48.3 ± 1.9 m.y. age determined for the Molly Mack occurrence south of Anyox might be explained by partial resetting of a slightly older age by the emplacement of the adjacent Coast Plutonic Complex granitic rocks. The 36.1 ± 1.6 m.y. age for the Penny Creek occurrence southwest of Alice Arm (Figure 19) possibly could be due to a complete resetting of the original age by a younger lamprophyre dyke not seen during field examination. However, it should be noted that similar Oligocene ages for granitic rocks have been reported in the Prince William Sound area of southern Alaska by Lanphere (1966) and on Vancouver Island by Carson (1969).

Coast Plutonic Complex

Potassium-argon ages for four samples collected from granitic rocks of the Coast Plutonic Complex between Alice Arm and Lava Lake (Figure 19) range from 48.8 ± 1.5 to 50.7 ± 2.1 m.y. These are in agreement with ages obtained by the Geological Survey of Canada in the same area and are somewhat younger than the mean age of 53 m.y. determined for the molybdenum-bearing porphyry stocks. Although with the limits of analytical error, these consistently younger ages found along the eastern margin of the Coast Plutonic Complex over a relatively large geographic area (Figure 19) suggest that the molybdenum-bearing stocks were intruded a measurable amount of time prior to the emplacement of the Coast granitic rocks.

Basalt Outliers

Prior to this study, the flat-lying basalts south of Alice Arm were regarded as being of Early to Mid-Tertiary age. A sample collected from north of the Bell Molybdenum stock has an age of 0.62 $\pm$ 0.6 m.y. which is an average of three determinations. A similar sample from a basalt remnant east of British Columbia Molybdenum has an age of 1.6 $\pm$ 0.8 m.y. This apparent disparity in age can be attributed to a lower level of accuracy in the conventional potassium-argon method in this young age range.

Potassium-argon Results from Other Studies

Potassium-argon results obtained from previous and contemporary studies in the Alice Arm area are in good agreement with those determined in this investigation.

Woodcock, et al. (1966) reported a potassium-argon age of 53.3 m.y. for a sample collected near the south contact of the British Columbia Molybdenum stock. Later work on the same deposit in 1971 by D. L. Giles (personal communication), formerly of Kennecott Research, indicated ages of 53.7 m.y. for secondary biotite from the alaskite phase and 63.2 m.y. for a biotite from fresh intrusive rock in a drill hole at a depth of 2,400 feet below the open pit. The latter date is at variance with the ages obtained from this study and could be due to accumulation of excess argon in this sample. Giles also obtained a date of 52.4 m.y. for a secondary sericite sample from the Roundy Creek deposit, in good agreement with the result obtained from this study.

4.1.4 Summary

The following conclusions can be drawn based on potassium-argon results obtained in the Alice Arm-Nass River area:

(1) Age of intrusion of the molybdenite-bearing quartz-monzonite porphyry

stocks is in the range of 50 to 54 m.y., based on results of samples from the main intrusive phase and biotite hornfels from outside the zone of mineralization.

(2) The age of mineralization is synchronous, or nearly so, with the age of intrusion. This is borne out by the 48 and 49 m.y. ages obtained from later, nearly post-mineral porphyry phases which provide an upper limit for the age of mineralization.

(3) Molybdenite-bearing Alice Arm intrusions were emplaced an average of 3 million years prior to the granitic rocks in the east margin of the Coast Plutonic Complex.

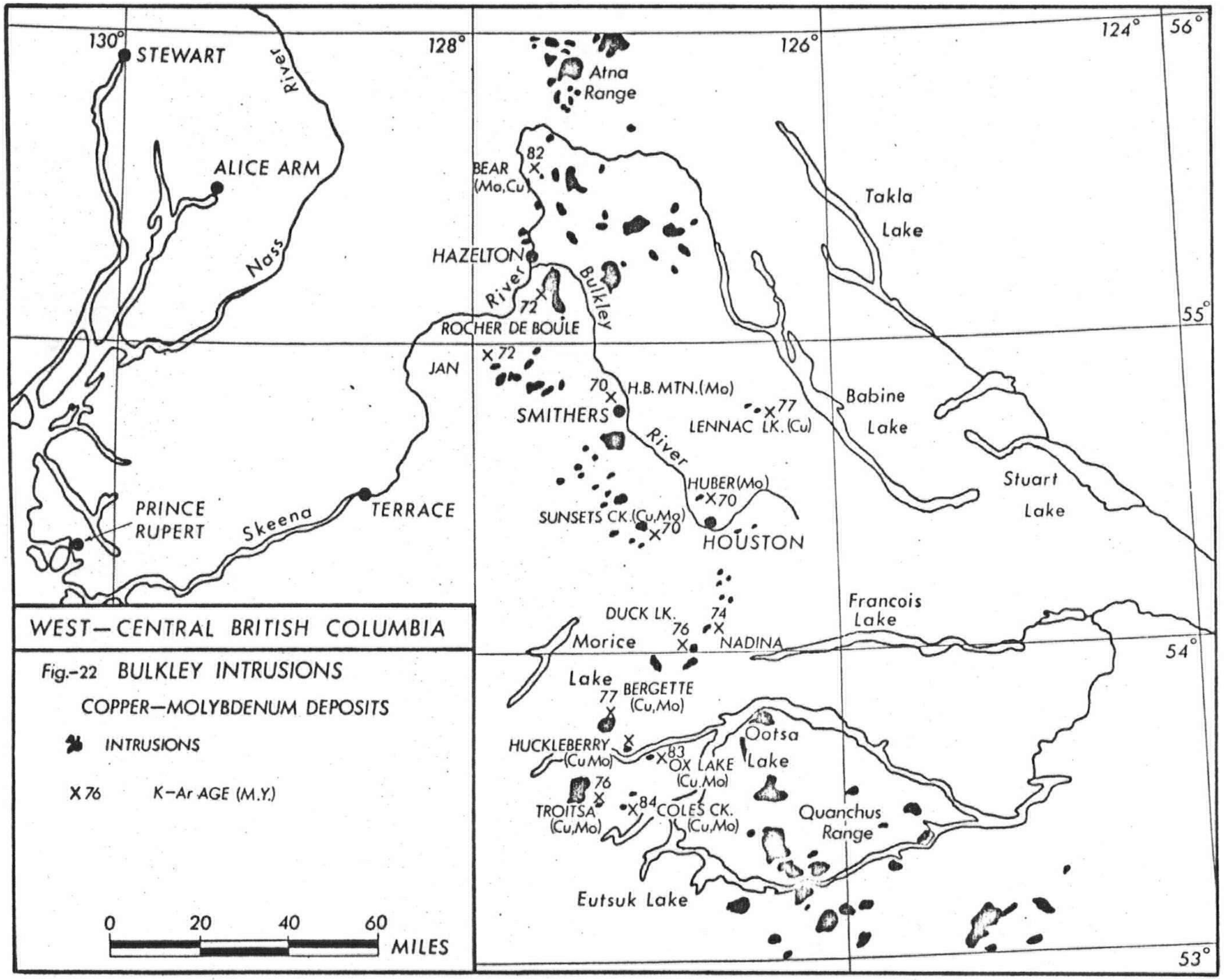
(4) Lamprophyre dykes, prominent in this area, were intruded in Oligocene time (33.3 - 36.5 m.y.).

(5) The youngest igneous events of the region are represented by the Quaternary basalt outliers south of Alice Arm and the Recent lava flow south of the Nass River.

4.2 PORPHYRY COPPER AND MOLYBDENUM DEPOSITS ASSOCIATED WITH THE BULKLEY INTRUSIONS

Bulkley intrusions of Late Cretaceous age, which occur in the central part of the area (Figure 22), extend from north of Hazelton to Eutsuk Lake. A number of intrusive bodies are grouped with the Bulkley intrusions on the basis of their geologic setting and their geological descriptions. These include granitic stocks in the Atna and Sicintine Ranges north of Hazelton and the Quanchus intrusions north of Eutsuk Lake.

Bulkley intrusions host a number of important copper-molybdenum deposits, principally in the southern part of the area (Figure 22). One important



WEST—CENTRAL BRITISH COLUMBIA

Fig.-22 BULKLEY INTRUSIONS

COPPER—MOLYBDENUM DEPOSITS

INTRUSIONS

X 76 K–Ar AGE (M.Y.)

molybdenum-tungsten deposit, Glacier Gulch, is also related to an intrusion of this age.

4.2.1 Geologic Setting

Bulkley intrusions cut sedimentary and volcanic rocks ranging in age from Early Jurassic to Early Cretaceous. They occur as oval and elongate stocks which range from one-half to more than 2 miles in diameter. The largest known of these intrusions is the Rocher Deboule stock south of Hazelton which occupies an area of 27 square miles (Sutherland Brown, 1960). The more important copper-molybdenum deposits are associated with stocks of less than 1 square mile surface area or with offshoot dykes related to them.

Most available evidence favours forceful emplacement of the Bulkley intrusions. Country rocks are domed around the relatively large Sunsets Creek pluton and around the buried stock related to the Glacier Gulch molybdenum deposit (Kirkham, 1966). Passive emplacement is postulated for the Rocher Deboule stock (Sutherland Brown, 1960).

The Bulkley intrusions have been localized, at least in part, by north to northwest-striking faults.

4.2.2 Geology and Style of Mineralization

Bulkley intrusions are of granodiorite and quartz monzonite composition. The hypabyssal rocks invariably are porphyritic with phenocrysts of plagioclase and quartz ranging in size from 2 millimetres to 1 centimetre. Most intrusions contain both biotite and hornblende, which in many intrusions occur as phenocrysts.

Multiple intrusion is a feature of several porphyry deposits associated with the Bulkley intrusions. Perhaps the best example is the Glacier Gulch molybdenum deposit at Smithers. Here a sheet of intensely altered granodiorite is intruded by a small (1,100 feet in diameter) quartz porphyry plug which was emplaced in three pulses (Kirkham, 1966; Jonson, et al., 1968). The bulk of the molybdenum mineralization in the older granodiorite sheet is related to the first pulse, and a lesser amount is related to inter-mineral quartz porphyry breccias and dykes. The quartz porphyry plug is truncated by a large (at least 2 miles in diameter) weakly mineralized quartz monzonite porphyry stock, indicating that it occurred very late in the mineralization-intrusive sequence.

Other examples of multiple intrusion which have been documented are the Coles Creek deposit (MacIntyre, 1974) and the Huber molybdenum prospect (Sutherland Brown, 1965). At the latter deposit (Figure 23), the sequence has been fine-grained alaskite, porphyritic quartz monzonite, and a post-mineral monzonite dyke. At the Ox Lake property (Figure 23), mineralized granodiorite porphyry is preceded by the intrusion of porphyritic quartz monzonite and related feldspar porphyry dykes. Late post-mineral diabase and lamprophyre dykes are a common feature of most of the deposits.

Mesozoic volcanic and sedimentary rocks adjacent to the Bulkley intrusions have been thermally metamorphosed to biotite hornfels. The metamorphic aureole may extend outward from the stock contacts for 15 hundred to several thousand feet. Locally, higher grade metamorphic minerals, such as garnet, epidote, and actinolite, are noted in the innermost contact zones.

Fairly well-developed alteration zones are present at most of the better mineralized deposits. At the Glacier Gulch deposit, an inner zone of silicification overlies the quartz porphyry plug and a K-feldspar-sericite-carbonate

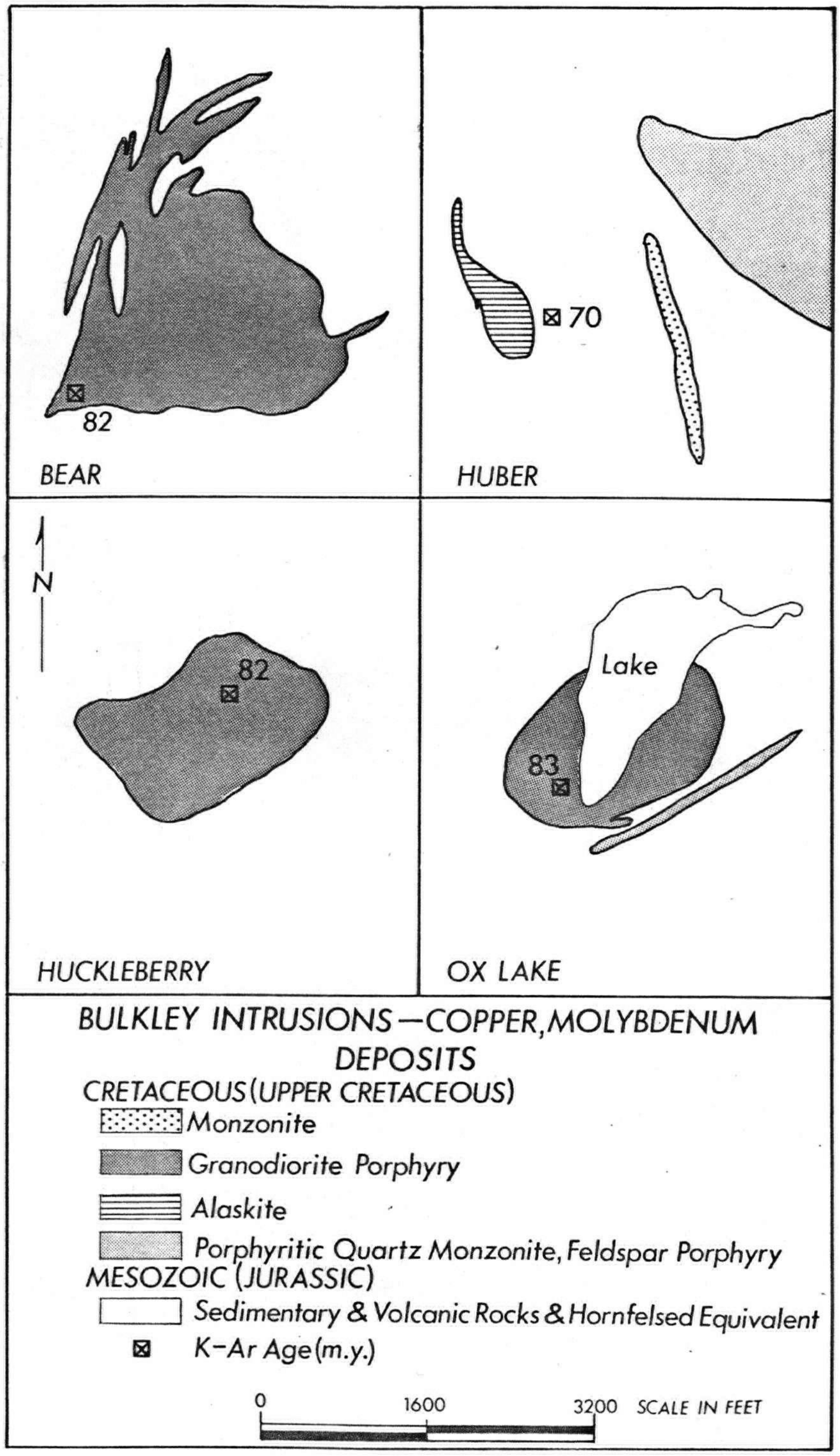

BEAR
82
HUBER
70
N
HUCKLEBERRY
82
OX LAKE
Lake
83
BULKLEY INTRUSIONS—COPPER, MOLYBDENUM DEPOSITS
CRETACEOUS (UPPER CRETACEOUS)
Monzonite
Granodiorite Porphyry
Alaskite
Porphyritic Quartz Monzonite, Feldspar Porphyry
MESOZOIC (JURASSIC)
Sedimentary & Volcanic Rocks & Hornfelsed Equivalent
K–Ar Age (m.y.)
0
1600
3200
SCALE IN FEET

FIG.–23

alteration is spatially related to the zone of molybdenite mineralization (Jonson, et al, 1968). This zone is partly expressed by bleaching of the hornfelsed volcanic and sedimentary rocks, principally marginal to quartz veinlets. Similar bleaching of biotite hornfels adjacent to quartz veinlets has been noted at Huckleberry (Carter, 1970) and at Ox Lake (Sutherland Brown, 1969; Richards, 1974). Most deposits exhibit an outer phyllic (quartz-sericite-pyrite) zone of alteration.

Copper and molybdenum mineralization is contained in a stockwork of quartz veinlets and fractures best developed near stock contacts in both the intrusive and country rocks. Good examples of this style of mineralization are the Huckleberry and Ox Lake deposits where better grades of mineralization occur around one end of the stock. At Huckleberry, most mineralization is restricted to hornfelsed country rocks and extends for hundreds of feet from the northeast stock contact. Where both chalcopyrite and molybdenite occur, molybdenum grades are better in that part of the ore zone which is within the stock.

At Glacier Gulch, molybdenite and scheelite-powellite are contained in a stockwork of veins best developed in the granodiorite sheet between the quartz porphyry plug and the quartz monzonite porphyry stock. At least two periods of molybdenite mineralization are recognized (Kirkham, 1966; Jonson, et al., 1968). Molybdenite mineralization at the Huber property is best developed in veinlets in the alaskite tongue and in adjacent hornfelsed rocks. At the Bear property, four stages of fracturing, veining, and attendant molybdenite-chalcopyrite mineralization are recognized, with better grades occurring near the periphery of the stock.

Pyrite haloes, often weathered to prominent gossans, envelop most deposits related to the Bulkley intrusions. This pyrite zone most often is restricted to the hornfelsed zone. Vein deposits of silver-lead-zinc, peripheral to the main zone of copper-molybdenum mineralization, are known at Glacier Gulch, Huber, Sunsets Creek, Coles Creek, and Ox Lake properties.

4.2.3 Potassium-argon Dating of the Bulkley Intrusions

Potassium-argon ages from the Bulkley intrusions are shown on Figures 22 and 23. Results obtained from this study are listed in Table IV. Analytical data is presented in Appendix A, with sample locations in Appendix C. Only one sample was collected at most deposits because only one intrusive phase was recognized or deemed suitable for dating. Two samples from the Glacier Gulch deposit were analysed.

Copper-molybdenum-bearing Stocks

Most samples collected and analysed for the Bulkley intrusions are from the mineralized intrusive phase. Potassium-argon results from these samples range in age from 70 $\pm$ 3 m.y. to 83.8 $\pm$ 2.8 m.y. (Table IV). Results from this study, coupled with those obtained from other sources, suggest that the Bulkley intrusions were emplaced over a span of 13 to 14 million years, in three main pulses. These are: 70, 76, and 82 million years.

A biotite sample from a quartz-biotite-molybdenite vein at Glacier Gulch yields a potassium-argon age of 69.5 $\pm$ 3 m.y., which is interpreted as the age of mineralization. A sample from the buried quartz monzonite porphyry stock, interpreted by Jonson, et al. (1968) and Kirkham (1966) as being late in the intrusive-mineralization sequence, gave a potassium-argon age of

TABLE IV. POTASSIUM-ARGON AGES OF BULKLEY INTRUSIONS

Sample No.	Location	Rock Unit	Age (m.y.)
NC-67-16	Huber	Biotite hornfels (W.R.)	69.5 ± 2
NC-67-41	Glacier Gulch	Quartz-biotite-sulphide vein	69.5 ± 3*
NC-68- 6	Glacier Gulch	Quartz monzonite porphyry	73.3 ± 3.4
NC-67-39	Sunsets Creek	Granodiorite	70.0 ± 3
NC-67-46	Rocher Deboule	Granodiorite	71.9 ± 3.1
NC-68-12	Bear	Quartz monzonite porphyry	82.4 ± 3.1
NC-67-44	Huckleberry	Granodiorite porphyry	82.0 ± 3
NC-69- 5	Ox Lake	Granodiorite porphyry	83.4 ± 3.2
MC-9	Coles Creek	Quartz monzonite porphyry	83.8 ± 2.8

*Average of two analyses.

(W.R.) – Whole Rock sample.

Note: Calculation of analytical error is outlined in Appendix A.2.

73.3 ± 3.4 m.y., somewhat older than the geological relationships suggest, but still within the limits of analytical error.

A number of samples from Glacier Gulch were collected by Kirkham (1969) and analysed at the geochemistry laboratories of the Geological Survey of Canada. Biotite from a quartz latite porphyry dyke, interpreted by Kirkham as post-dating the molybdenite mineralization, yielded an age of 60 ± 5 m.y. A sample of quartz-biotite-molybdenite vein, the duplicate of which was analysed during this study (NC-67-41), gave an age of 63 ± 4 m.y., and a hornblende sample, also from a quartz vein, was analysed as being 65 ± 6 m.y. Biotite from the buried quartz monzonite porphyry stock returned an age of 67 ± 5 m.y.

Four Bulkley intrusions are illustrated on Figure 23. Biotite samples from the main mineralized phase at three of these (Bear, Huckleberry, and Ox Lake) yielded potassium-argon ages in the narrow range of 82.0 to 83.4 m.y. Lack of suitable biotite in the intrusive rocks at the Huber property necessitated analysis of a whole-rock biotite hornfels sample which gave a potassium-argon age of 69.5 ± 2.0 m.y.

Other ages obtained from mineralized Bulkley intrusions include 70 ± 3 m.y. for the Sunsets Creek pluton and 83.8 ± 2.8 m.y. for part of the Coles Creek intrusion (Figure 22). A sample of porphyritic granodiorite from the Rocher Deboule stock in the vicinity of Rocher Deboule mine, which contains veins of chalcopyrite with lesser molybdenite, arsenopyrite, and pyrrhotite (Sutherland Brown, 1960) gave a potassium-argon age of 71.9 ± 3.1 m.y.

Potassium-argon Results from Other Studies

Three samples from Bulkley intrusions were analysed during geological studies in the Owen Lake-Tahtsa Lake area by Church (1971, 1972). The results are shown on Figure 22. The Nadina microdiorite sill yielded an age of 74 ± 2 m.y. This unit is cut by vein deposits of the Bradina mine which are related to a younger intrusive event. The Duck Lake granitic stock to the southwest, apparently devoid of mineralization, gives a potassium-argon age of 76 ± 2 m.y. The Bergette sample (76.7 ± 2.5 m.y.) is from a feldspar porphyry phase of the Sibola stock which is host to copper and molybdenum mineralization. The Troitsa Lake copper-molybdenum-bearing intrusion was dated by Cawthorne (1973) as being 76 ± 2 m.y. and the Jan porphyry was dated by Kirkham as 72 ± 3 m.y. (Wanless, et al., 1974).

All of these ages fall within the time interval determined for the Bulkley intrusions.

4.2.4 Summary

(1) The Bulkley copper-molybdenum-bearing intrusions were emplaced over a span of ages between 70 and 84 m.y., with the major pulses of intrusion occurring in the three time periods of 70 m.y., 76 m.y., and 83 m.y.

(2) Potassium-argon results from the Glacier Gulch deposit suggest that the age of mineralization, within the limits of analytical error, is synchronous with the age of intrusion of the Bulkley intrusions. Ages obtained from other Bulkley intrusions also suggest this.

4.3 PORPHYRY COPPER-MOLYBDENUM DEPOSITS ASSOCIATED WITH THE NANIKA INTRUSIONS

The Nanika intrusions of Early Tertiary age occur in the central part of west-central British Columbia. Their distribution ranges from north of Hazelton to the south boundary of the area shown on Figure 24. They apparently occur in four discrete areas with the same geographic setting as the previously described Bulkley intrusions.

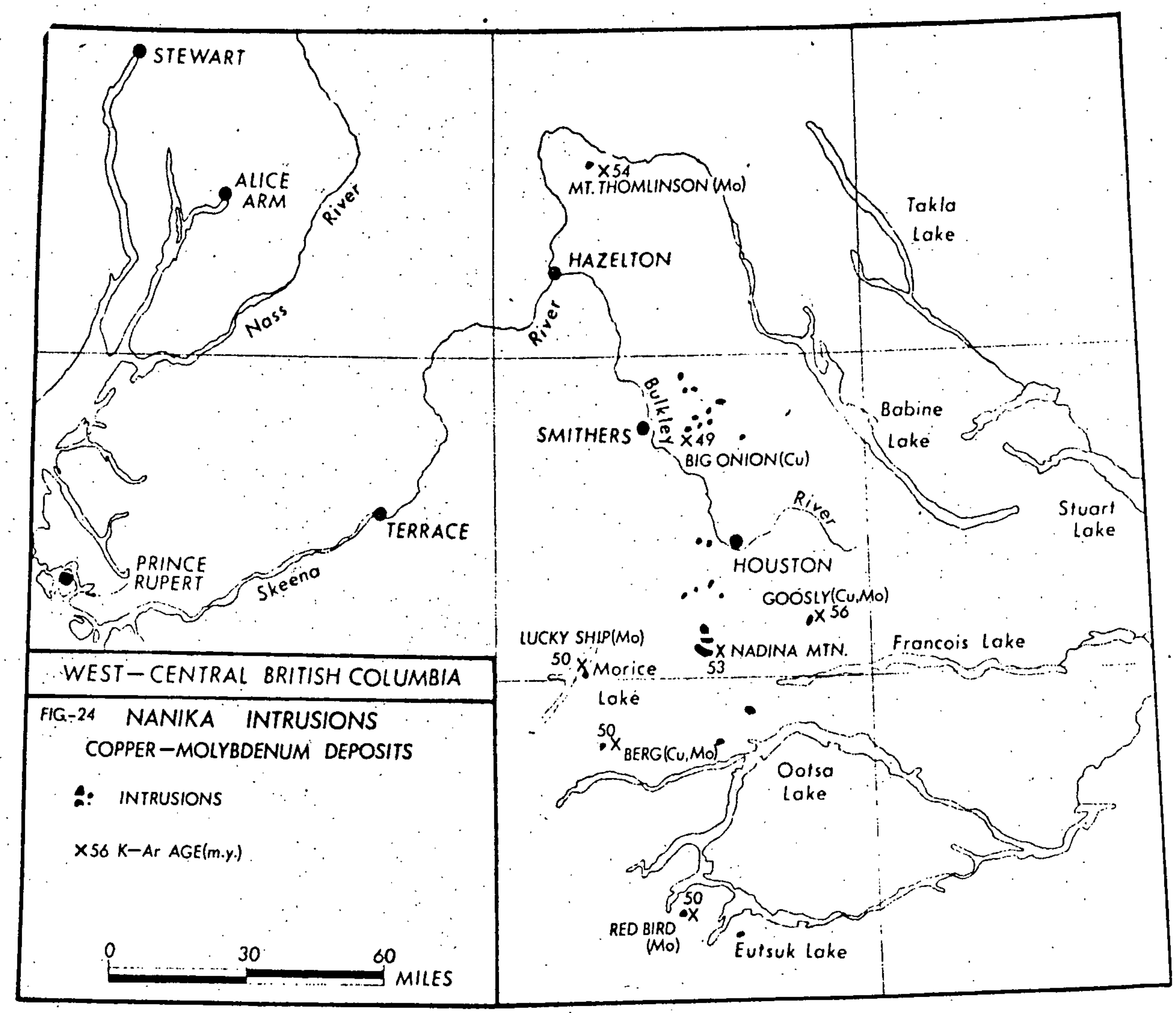
The Nanika intrusions are so named because of the proximity to Nanika Lake of several important copper-molybdenum deposits associated with intrusions of this age.

4.3.1 Geologic Setting

Nanika intrusions cut Mesozoic volcanic and sedimentary rocks as small stocks and plugs. Many intrusions have northeast-striking dykes projecting from them and a few, such as the Red Bird deposit, are bordered by partial ring dykes.

Many Nanika intrusions were emplaced forcefully causing doming and arching of surrounding sedimentary rocks such as at Mount Thomlinson and Nadina Mountain (Figure 24). Some examples of passive emplacement, wherein the intrusions have occupied pre-existing fractures and fault zones, are seen at the Lucky Ship, Berg, and Big Onion properties.

Structural controls for emplacement of the Nanika intrusions include intersections of regional northeast and northwest-striking faults and the cores of anticlinal structures. Northeast-striking dykes projecting from many of the plutons indicate this direction as a dominant structural trend.



WEST—CENTRAL BRITISH COLUMBIA

FIG.-24 NANIKA INTRUSIONS COPPER—MOLYBDENUM DEPOSITS

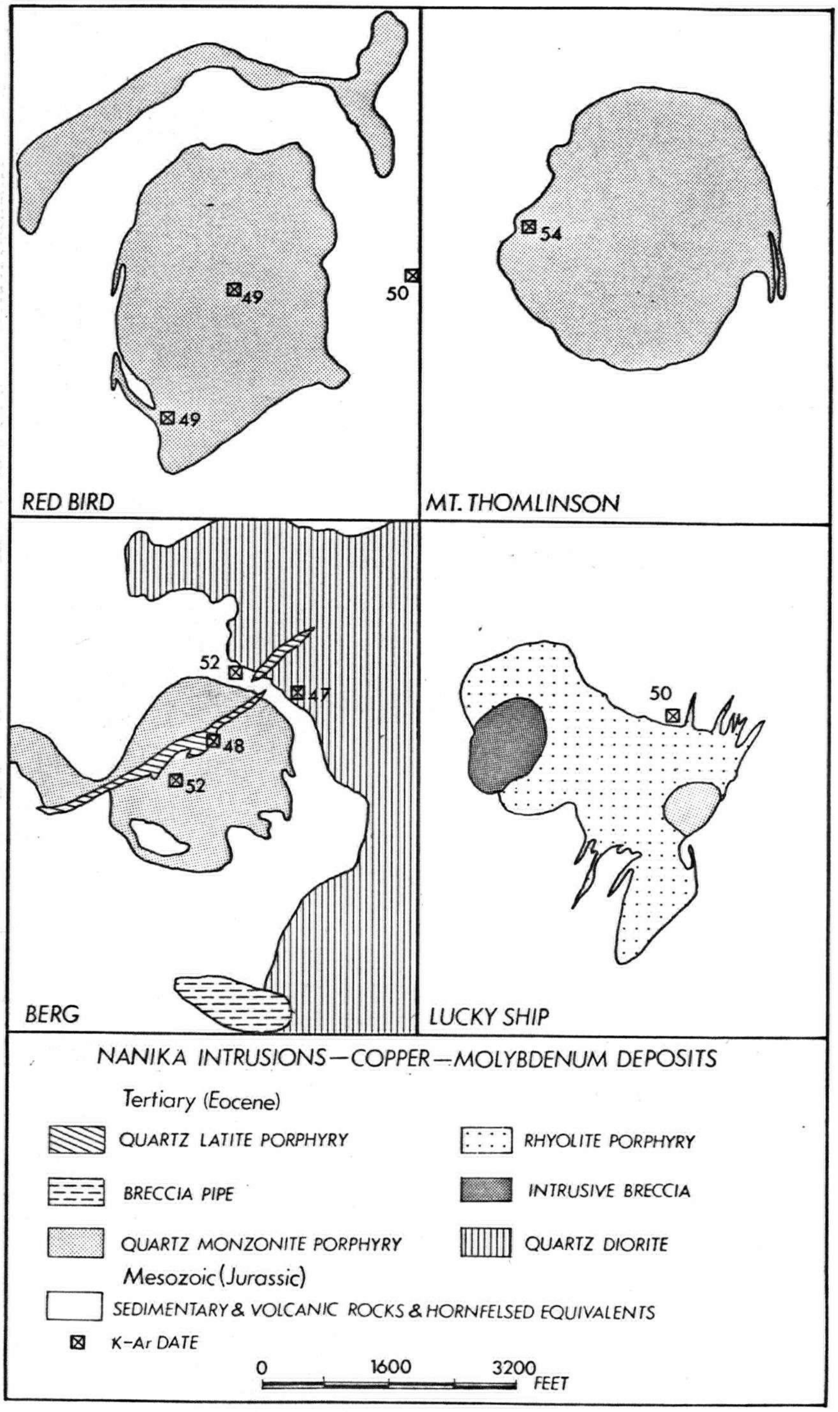
4.3.2 Geology and Style of Mineralization

Nanika intrusions occur in a variety of forms. They may be oval or circular as at the Berg and Red Bird deposits (Figure 25), elongate as at Big Onion and Lucky Ship, or as dyke swarms as at Serb Creek. Oval stocks or plugs generally do not exceed 0.5 mile in diameter, but elongate intrusions may extend for thousands of feet in their long direction. Some non-mineralized Nanika intrusions, most notably that at Nadina Mountain, may be several square miles in area.

The major rock type of Nanika intrusions is quartz monzonite porphyry in which 2- to 4-millimetre phenocrysts of quartz, plagioclase, and K-feldspar are set in a fine-grained matrix. Biotite occurs as prominent phenocrysts and books in many of these intrusions. The main intrusive phase at some deposits, including Lucky Ship and Big Onion, is represented by fine-grained quartz feldspar porphyry of rhyolitic composition.

Examples of multiple intrusion are evident at most deposits related to the Nanika intrusions. One of the better examples of this is the Berg deposit, where the mineralized quartz monzonite porphyry stock is intruded by a number of younger, post-mineral quartz latite porphyry dykes, similar in texture and composition to the main phase (Figure 25). A breccia pipe occurs south of the quartz monzonite porphyry stock and is believed to be intermediate in age between the quartz monzonite porphyry and the post-mineral dykes (Sutherland Brown, 1966). A similar situation exists at Red Bird, where small post-mineral monzonite porphyry dykes cut mineralized quartz monzonite porphyry.

At Lucky Ship, a circular breccia pipe containing some molybdenite represents an initial intrusive phase (Figure 25). This is intruded by the



RED BIRD
49
49
50
MT. THOMLINSON
54
BERG
52
47
48
52
LUCKY SHIP
50
NANIKA INTRUSIONS—COPPER—MOLYBDENUM DEPOSITS
Tertiary (Eocene)
QUARTZ LATITE PORPHYRY
BRECCIA PIPE
QUARTZ MONZONITE PORPHYRY
RHYOLITE PORPHYRY
INTRUSIVE BRECCIA
QUARTZ DIORITE
Mesozoic (Jurassic)
SEDIMENTARY & VOLCANIC ROCKS & HORNFELSED EQUIVALENTS
K-Ar DATE
0
1600
3200
FEET

FIG.–25

elongate 'wipeout' rhyolite porphyry phase which itself is essentially non-mineralized and obliterates some pre-existing mineralization in the breccia pipe. This in turn is intruded by a small granitic plug containing molybdenite. At Big Onion, the initial quartz porphyry phase is intruded by a quartz diorite and finally by a post-mineral, fine-grained quartz monzonite dyke.

Basic dykes of post-mineral age and principally of andesitic composition transect several of the Nanika intrusions.

Sedimentary and volcanic rocks adjacent to the Nanika intrusions are thermally metamorphosed to biotite hornfels. Hydrothermal alteration patterns include a central potassic alteration zone which grades outward to a quartz-sericite-pyrite (phyllic) zone. This latter zone may or may not be well developed. Potassic zone alteration generally occurs as secondary K-feldspar within and marginal to quartz veinlets and as replacement of original plagioclase in the rock matrix. Development of secondary muscovite is a feature of some potassic alteration zones. At some deposits such as Lucky Ship, the central alteration zone is extensively silicified. The phyllic zone is represented by an addition of quartz, sericite, and pyrite in hornfelsed country rocks marginal to the plutons.

Better grades of copper and molybdenum are restricted to contacts of the Nanika intrusions. Chalcopyrite and molybdenite occur in stockworks of quartz veinlets, with molybdenum mineralization occupying an inner zone almost entirely within the intrusion and copper mineralization best developed in hornfelsed rocks marginal to the stock contacts. An example of this is the Berg deposit (Sutherland Brown, 1966). At Red Bird, molybdenite occurs in a stockwork of quartz veinlets within a crescent-shaped zone developed around the north half of the stock contact area. Several stages of quartz veining and attendant mineralization are recognized at both deposits.

At Lucky Ship, best grades of molybdenite mineralization are contained in an annular zone around the later stage quartz monzonite porphyry plug (Figure 25), coincident with a zone of intense silicification and quartz veining. Molybdenite mineralization at Mount Thomlinson is confined to a stockwork of quartz veinlets within the intrusion near the northwest contact. At the Big Onion property, chalcopyrite and molybdenite occur near the contacts between the quartz diorite and quartz feldspar porphyry, with chalcopyrite principally within the quartz diorite and molybdenite in the quartz feldspar porphyry.

Pyrite haloes envelope deposits associated with the Nanika intrusions extending outward from them a distance of several hundred to thousands of feet. Extensive gossans are visible at the Berg and Red Bird deposits where they are not obscured by vegetation.

Mineralized zones at Red Bird, Berg, and Mount Thomlinson have been subjected to intense oxidation and leaching, which may extend 200 feet below the surface and which is accompanied by the development of limonite and ferrimolybdite. At Berg an enriched zone in which secondary chalcocite appears as coatings on disseminated pyrite is developed beneath a leached zone. The enriched zone may be up to 400 feet thick (Sutherland Brown, 1966).

Vein deposits of silver-lead-zinc occur in the outer part of the pyrite halo surrounding the Berg deposit.

4.3.3 Potassium-argon Dating of the Nanika Intrusions

Potassium-argon ages obtained from samples collected from the Nanika intrusions are shown on Figures 24 and 25, and listed on Table V. Analytical data and sample descriptions and locations are contained in Appendices A and C.

Where possible, more than one sample was collected from each deposit studied to establish the ages of both intrusion and mineralization. One sample was collected from a stock at Morice Lake to determine its possible relationship to the Lucky Ship deposit immediately to the north. A sample also was collected from an apparently barren granitic stock at Nadina Mountain.

Potassium-argon results for all samples are listed in Table V. Most analyses were made on biotite separates although a few whole-rock samples were analysed.

Copper-molybdenum-bearing Intrusions

The bulk of samples for dating were collected from mineralized intrusive phases at the various deposits. Potassium-argon results from these samples range in age from 49.5 ± 3 m.y. to 56.2 ± 2.3 m.y.

Later intrusive phases were dated at three of the deposits. At Red Bird, a geologically younger, post-mineral monzonite porphyry was dated at 49.0 ± 2 m.y., slightly younger than the 49.5 ± 3 m.y. age obtained for the mineralized quartz monzonite porphyry. Two samples from nearly barren quartz latite porphyry at Berg gave an average age of 47.5 ± 3 m.y., or 4 million years younger than the mineralized quartz monzonite porphyry phase. A post-mineral quartz monzonite

TABLE V. POTASSIUM-ARGON AGES OF NANIKA INTRUSIONS

Sample No.	Location	Rock Unit	Age (m.y.)
NC-68-13	Mount Thomlinson	Quartz monzonite porphyry	53.8 ± 2.2
NC-67- 7	Big Onion	Quartz monzonite	48.7 ± 1.9
NC-67-42	Lucky Ship	Biotite hornfels (W.R.)	49.9 ± 2.3
NC-69- 6	Goosly	Quartz monzonite porphyry	56.2 ± 2.3
NC-68- 7	Nadina Mountain	Quartz monzonite	52.9 ± 2.2
NC-67- 8	Berg	Quartz diorite	46.8 ± 1.5
NC-67- 9	Berg	Quartz latite porphyry	48.0 ± 3
NC-67-10	Berg	Quartz latite porphyry	47.0 ± 3
NC-67-11	Berg	Quartz monzonite porphyry	52.0 ± 2
NC-67-12	Berg	Biotite hornfels (W.R.)	52.0 ± 3
NC-67-13	Berg	Metamorphosed quartz diorite	49.9 ± 2.1
NC-67-17	Red Bird	Biotite hornfels (W.R.)	50.0 ± 1.7
NC-67-19	Red Bird	Quartz monzonite porphyry	49.5 ± 3*
NC-67-20	Red Bird	Quartz monzonite porphyry	49.0 ± 2

*Average of two analyses.

(W.R.) – Whole Rock Sample.

Note: Calculation of analytical error outlined in Appendix A.2.

dyke at Big Onion was dated at 48.7 ± 1.9 m.y. All of these ages provide an upper limit for the age of mineralizaton of these deposits.

Biotite Hornfels

Whole-rock biotite hornfels samples from the Berg and Red Bird deposits and the results (52 ± 3 and 50.0 ± 1.7 m.y. respectively) are in good agreement with those obtained for the initial porphyry phases (Table V and Figure 25). Comparing these results with that obtained from a biotite hornfels sample at the Lucky Ship deposit, the age of intrusion of the Lucky Ship pluton may be inferred as being 49.9 ± 2.3 m.y.

Similarly, a sample of quartz diorite from within the metamorphic aureole at Berg, which contains secondary biotite after hornblende, yields an age of 49.9 ± 2.1 m.y., very close to the age determined for the main quartz monzonite porphyry intrusion.

Other Intrusions

Three samples were collected from intrusive bodies apparently barren of copper or molybdenum mineralization, but spatially related to mineralized Nanika intrusions.

The quartz monzonite stock at Nadina Mountain has a potassium-argon age of 52.9 ± 2.2 m.y., similar to ages obtained for copper-molybdenum-bearing Nanika intrusions, although it apparently is lacking in sulphide mineralization.

The large elongate quartz diorite pluton bordering the Berg deposit on the east (Figure 25) is believed to be a stock satellitic to the Coast Plutonic

Complex or a pluton related to the Bulkley intrusions. The 46.8 $\pm$ 1.5 m.y. age is anomalously young compared to the metamorphosed sample dated at 49.9 $\pm$ 2.1 m.y., and may be explained by the chloritized nature of the biotite sample. The low potassium content of 2.64 per cent signifies probable argon loss.

The quartz monzonite stock at Morice Lake yielded a potassium-argon age of 178 $\pm$ 8 m.y. indicating that it is unrelated to the molybdenum-bearing Lucky Ship pluton. Instead, it is part of the much older Topley intrusions.

4.3.4 Summary

(1) The age of intrusion of the copper-molybdenum-bearing Nanika intrusions is in the range of 49.5 to 56 million years, based on results obtained from samples of the initial intrusive phase and of biotite hornfels samples peripheral to several of the intrusions.

(2) The age of mineralization is congruent or slightly younger than the age of intrusion as indicated by the slightly younger ages obtained from post-mineral porphyry phases which are petrologically similar to the initial porphyry phases at the Berg and Red Bird deposits.

(3) Where suitable biotite cannot be collected from plutons (e.g., Lucky Ship) the age of intrusion and/or mineralization can be obtained by analysing whole-rock samples of biotite hornfels.

4.4 PORPHYRY COPPER DEPOSITS ASSOCIATED WITH THE BABINE INTRUSIONS

Babine intrusions occur in a northwest-trending belt, not more than 25 miles wide, near the east boundary of the area shown on Figures 14 and 16.

They extend from the northern part of Babine Lake northward almost to latitude 56 degrees. Babine intrusions comprise a number of small stocks, plugs, and dyke swarms of equigranular quartz diorite and quartz monzonite and a distinctive biotite feldspar porphyry which is host to important porphyry copper deposits.

4.4.1 Geologic Setting

The porphyry copper deposits of the Babine Lake area are associated with small intrusions of Tertiary (Eocene) age which intrude Mesozoic volcanic and sedimentary rocks.

The Mesozoic rocks range in age from Late Triassic to Late Cretaceous or Early Tertiary age. Upper Triassic limestones, siltstones, and volcanic rocks are confined to a relatively small area west of Babine Lake. The most widespread rocks of the area are the clastic volcanic and sedimentary rocks of the Jurassic Hazelton Group (Figure 8, pocket). Sedimentary and volcanic rocks of Early to Mid-Cretaceous age are widespread north of Babine Lake, and younger clastic sedimentary rocks, part of the Sustut Group, are found as small outliers adjacent to northwest-trending faults of regional magnitude. Small remnants of young (post-Eocene ?) basaltic and andesitic volcanic rocks occur throughout the area shown on Figure 26 (pocket).

Plutonic rocks of various ages intrude the Mesozoic rocks of the Babine Lake area (Figure 26). The oldest of these include Lower Jurassic porphyritic quartz monzonites and granodiorites of the Topley intrusions and small stocks of diorite, monzonite, and quartz diorite of Cretaceous age, possibly a part of the Omineca intrusions. Upper Cretaceous intrusions include rhyolite porphyry stocks and dykes and granodiorite porphyries of similar age to the Bulkley intrusions.

Babine intrusions of Eocene age are widespread and include equigranular quartz diorite, quartz monzonite, and related biotite feldspar porphyries. These occur as small stocks, dykes, dyke swarms, and plugs. Extrusive equivalents of these subvolcanic intrusions occur as flat-lying sheets which exhibit columnar jointing near the south end of Newman Peninsula and west of Babine Lake (Figure 26). Although these rocks are similar in appearance to the intrusive biotite feldspar porphyries, they differ by having hornblende as the chief mafic mineral. The hornblende imparts a flow texture to these rocks. Extrusive equivalents also include crystal tuffs and flow breccias.

The major structural trend of the area is northwest, as reflected by the trend of numerous parallel block faults. Important northeast faults are also known, most notably that which separates older bedded rocks and the Topley intrusions on the south from younger rocks to the north (Figure 8, pocket).

The Tertiary Babine intrusions and related porphyry copper deposits have been localized at or near intersections of northeast and northwest faults (Carter, 1972). The bulk of porphyry copper deposits are contained in three parallel northwest-trending graben structures which include, from west to east: (1) Granisle-Newman (Bell Copper) - Old Fort; (2) Morrison-Hearne Hill; (3) Dorothy-Nak Lake-Trail Peak (Figure 26).

4.4.2 Geology and Style of Mineralization

Porphyry copper deposits are associated with the Babine intrusions which occur as irregular dykes, dyke swarms, and plugs of one-half to 1 square mile in surface area. Copper mineralization invariably is related to the biotite feldspar porphyry phase of the Babine intrusions. This distinctive rock type is a crowded porphyry in which 2-millimetre to 3-millimetre phenocrysts of euhedral plagioclase and biotite are set in a fine-grained matrix of plagioclase, quartz, biotite, and minor K-feldspar. The rocks range in composition from quartz diorite to granodiorite.

Multiple intrusion is evident at most copper mines and prospects associated with the Babine intrusions. At the Granisle and Old Fort properties (Figure 26), the first intrusive phase is represented by oval plugs of fine-grained, equigranular quartz diorite and/or quartz monzonite. These quartz diorites are intruded by somewhat younger biotite feldspar porphyries.

At Granisle, the small, elliptical quartz diorite plug is invaded by a large northeast-striking dyke of biotite feldspar porphyry in which several pre- and intermineral phases are recognized (Kirkham, 1971; Carter, 1972). These are grossly similar in appearance and composition, but can be distinguished by slight differences in the colour of the matrix resulting mainly from variations in grain size, by crosscutting relationships, and by the presence of inclusions of earlier phases contained in later ones. The later phases are progressively less well fractured and mineralized. Within the ore zone, a narrow zone consisting of dykes and stringers of intrusive breccia occurs along the contact between biotite feldspar porphyry and the quartz diorite. These breccias commonly contain 1-centimetre to 2-centimetre rounded fragments of both the quartz diorite and biotite feldspar porphyry in a fine-grained, light to dark grey granulated matrix of strained and fractured quartz, broken plagioclase grains, and locally abundant, very fine-grained biotite. The quartz diorite and biotite feldspar porphyry fragments commonly contain quartz-filled

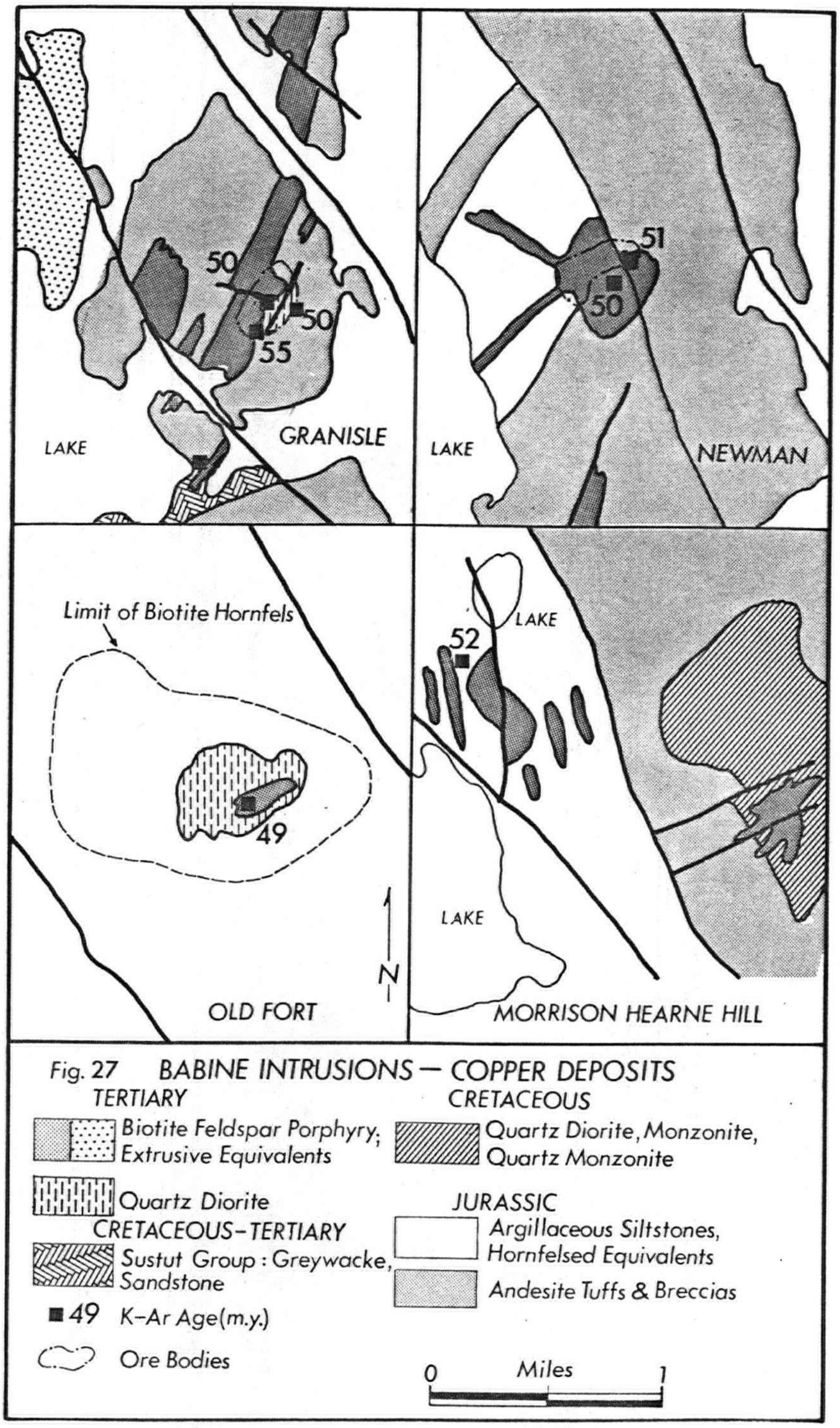


Fig. 27 BABINE INTRUSIONS — COPPER DEPOSITS

fractures mineralized with chalcopyrite. Breccias are obviously intermineral intrusions inasmuch as they contain disseminated chalcopyrite in the matrix.

The latest porphyry phase at Granisle contains only sparse chalcopyrite and is interpreted as being nearly of post-mineral age. This phase occurs as small dykes of dark grey biotite feldspar porphyry which intrude quartz diorite near the eastern edge of the ore zone.

Multiple intrusion, in the form of intermineral dykes and stringers of porphyry and intrusive breccia, is also a feature of the Morrison, Nak Lake, and Dorothy properties. At Bell Copper, a northerly striking dyke of late, possibly post-mineral, biotite feldspar porphyry, up to 400 feet wide, truncates the eastern part of the ore zone. Stringers of intrusive breccia occur near the contact between this intrusive phase and the mineralized phase.

A characteristic of the Babine intrusions as contrasted with others in west-central British Columbia is the relative lack of post-mineral basic dykes. One basic dyke was noted in diamond-drill core at the Morrison deposit. Hornfelsing of sedimentary and volcanic rocks adjacent to the Babine intrusions is not a prominent feature, due to the composition of the country rocks. Well-developed biotite hornfels aureoles were noted only at the Old Fort, Morrison, and Trail Peak properties.

Hydrothermal alteration at porphyry copper deposits related to Babine intrusions has been well documented in a recent paper by Carson and Jambor (1974). Essentially, hydrothermal alteration zones consist of a central potassic zone, represented by abundant secondary biotite, gradational outward to a quartz-sericite-pyrite zone which in turn is enveloped by a propylitic zone.

At Granisle, the potassic zone is roughly coincident with the zone of copper mineralization. Within this zone, the intrusive rocks appear relatively fresh in hand specimen and plagioclase phenocrysts are essentially unaltered. The main alteration product is secondary biotite which occurs as very fine-grained, dark brown aggregates which retain original amphibole outlines in both the porphyries and quartz diorites. Fine-grained secondary biotite also is uniformly distributed in the matrix of the intrusive rocks. Minor secondary K-feldspar also occurs in the potassic zone, usually as fine grains in the intrusive rock matrix and in thin envelopes enclosing quartz veinlets and fractures in the deeper sections of the ore zone.

At the Newman deposit (Bell Copper), the potassic zone also coincides with the zone of copper mineralization, but is difficult to recognize in the upper parts of the ore zone because supergene alteration has destroyed the biotite. The biotite or potassic zone at the Morrison deposit extends somewhat beyond the copper zone and consists of sugary textured, brown hydrothermal biotite that has replaced hornblende phenocrysts and locally has flooded the matrix of the host biotite feldspar porphyry.

Carson and Jambor (1974) indicate that dark brown, coarse-grained, sugary textured hydrothermal biotites are associated with relatively strong copper mineralization, whereas greenish and/or fine-grained hydrothermal biotites are indicative of weak copper mineralization. The latter point would appear to apply to such deposits as Old Fort, Nak Lake, Dorothy, and Trail Peak where secondary biotite alteration is only weakly developed and copper mineralization is of low grade and/or sporadic distribution.

However, it should be pointed out that late or post-mineral biotite feldspar porphyry dykes, which occur within the biotite zones at Granisle and

Newman, contain little, if any, secondary biotite. This would indicate that alteration is an integral part of an earlier intrusive-mineralization time period.

The quartz-sericite-pyrite alteration zone also is best developed at the better mineralized properties. Intrusive and adjacent volcanic and sedimentary rocks within this zone are weathered to a uniform buff colour. Abundant fine-grained quartz and pyrite have been introduced, mafic minerals have been altered to a mixture of sericite and carbonate, and plagioclase is clouded by sericite. Enveloping this zone is the propylitic zone which is represented by chlorite, carbonate, and epidote alteration of volcanic and sedimentary rocks.

Chalcopyrite is the dominant ore mineral at all Babine porphyry copper deposits. It occurs primarily in northeast and northwest-striking, vertically dipping, quartz-filled fractures which vary in width from 1 to 5 millimetres. Chalcopyrite also is disseminated in the fine-grained quartz diorite and intrusive breccia at Granisle. Also at Granisle, bornite occurs with chalcopyrite in the central part of the ore zone. Irregular veins up to 1 foot wide, which consist of coarse-grained chalcopyrite, bornite, quartz, biotite, and apatite have been uncovered in the southern half of the ore zone at Granisle.

The Granisle orebody is localized along the contact between biotite feldspar porphyry and quartz diorite (Figure 27). Most other deposits, most notably Newman (Bell Copper), also exhibit better grades of copper mineralization at or near contacts between the porphyries and marginal sedimentary and volcanic rocks.

The Newman orebody is unique in that it is one of the few porphyry deposits in British Columbia with a substantial zone of supergene mineralization. This zone extends to depths of as much as 400 feet and consists of chalcocite coating pyrite and chalcopyrite in fractures and quartz veinlets in porphyry and adjacent siltstones. The best-developed zone of supergene mineralization is centred over best grades of primary chalcopyrite mineralization which are contained in a vertical pipe-like zone approximately 400 feet in diameter and extending to a depth of at least 2,500 feet. Within this zone, fine-grained chalcopyrite occurs in a stockwork of quartz veinlets and in irregular silicified areas in the porphyry and bordering siltstones. Lower grade, primary and secondary copper mineralization is peripheral to a higher grade zone on its eastern side.

Better grades of copper mineralization at the Morrison deposit consist of chalcopyrite and minor bornite in quartz-filled fractures, and are best developed in, and marginal to, northerly trending dyke swarms of biotite feldspar porphyry which occur west and east of a small pluton of similar composition.

Pyrite haloes are well developed around the Granisle, Newman, and Morrison deposits and these may extend outward at least 1,000 feet from the copper orebodies. Carson and Jambor (1974) suggest that large pyrite haloes, containing 5 to 10 per cent pyrite, are developed only around economic copper deposits in the Babine Lake area.

Both the Granisle and Newman deposits have peripheral quartz-carbonate vein deposits which contain varying amounts of pyrite, galena, sphalerite, and chalcopyrite. These were explored 40 years before the copper deposits attained economic significance.

4.4.3 Potassium-argon Dating of the Babine Porphyry Copper Deposits

Potassium-argon ages obtained from samples collected in the Babine Lake area are shown on Figures 26 and 27. Analytical data, deposit and sample descriptions, and precise locations are contained in Appendices A and C. Most samples were collected at or near porphyry deposits related to the Babine intrusions. Several samples were collected from other intrusive and extrusive bodies to determine their geologic sigificance.

Potassium-argon results for all samples collected are listed in Table VI. Analyses were made on biotite separates from all but one sample.

Copper-bearing Intrusions

Samples from the mineralized biotite feldspar porphyry phase were collected from five deposits (Table VI) and potassium-argon ages obtained from these samples range from 49.0 $\pm$ 2 to 55.0 $\pm$ 3 m.y. Because these samples contain hydrothermal biotite in addition to primary biotite phenocrysts, these results can be interpreted as reflecting the apparent age of mineralization at these deposits. The age of mineralization at Granisle is indicated by the 50.2 $\pm$ 2.1 m.y. age obtained from a coarse-grained quartz-biotite-apatite-chalcopyrite-bornite vein.

Late, nearly post-mineral, biotite feldspar porphyry phases at Granisle and Newman give ages of 51.0 $\pm$ 2 and 48.9 $\pm$ 2.1 m.y. respectively. While within the limits of analytical error, these are younger than the ages obtained for the mineralized porphyry phases at these deposits and provide an upper limit for the age of mineralization.

TABLE VI. POTASSIUM-ARGON AGES OF BABINE INTRUSIONS

Sample No.	Location	Rock Unit	Age (m.y.)
NC-67- 1	Old Fort	Biotite feldspar porphyry	49.0 + 2
NC-67- 2	Old Fort	Biotite quartz monzonite	52.0 + 2
NC-67- 4	Granisle	Biotite feldspar porphyry	55.0 + 3
NC-67- 5	Granisle	Biotite feldspar porphyry	51.0 + 2
NC-68- 1	Granisle	Biotite feldspar porphyry	51.0 + 2
NC-69- 8	Granisle	Quartz-biotite-sulphide vein	50.2 + 2.1
NC-67-22	Newman	Biotite feldspar porphyry	49.8 + 2.1
NC-67-23	Newman	Biotite feldspar porphyry	51.0 + 3
NC-67-40	Morrison	Biotite feldspar porphyry	52.1 + 2.1
NC-68-10	Trail Peak	Biotite feldspar porphyry	48.9 + 1.5
NC-69- 1	Trail Peak	Quartz diorite	104 + 4
NC-67-43	Newman Peninsula	Hornblende feldspar porphyry	51.5 + 1.9
NC-69- 4	Tachek Creek	Hornblende-biotite-quartz porphyry	176 + 7
NC-72- 1	Lennac Lake	Quartz-hornblende-biotite feldspar porphyry	77.0 + 2.5

The age of intrusion of the Babine porphyries is congruent, or nearly so, with the age of mineralization as indicated by three of the samples analysed. An age of 52.0 $\pm$ 2 m.y. was obtained for a biotite sample collected from a non-mineralized biotite-quartz-monzonite sill south of the Old Fort property (Figure 26). Biotite from a biotite feldspar porphyry dyke south of the Granisle deposit (Figure 27), and devoid of secondary biotite and sulphide minerals, yielded an age of 51.0 $\pm$ 2 m.y.

A hornblende sample (NC-67-43) from a hornblende feldspar porphyry extrusive on the south end of Newman Peninsula (Figure 26) returned an age of 51.5 $\pm$ 1.9 m.y. Because this porphyry is an extrusive equivalent of biotite feldspar porphyry, the age obtained can be interpreted as being that of extrusion and intrusion.

Other Intrusions

Stocks of medium-grained to coarse-grained equigranular diorite, quartz diorite, and monzonite occur throughout the northern Babine Lake area (Figure 26). These are believed to be related to the Omineca intrusions and are non-mineralized in this area. Several of these stocks, including those at Hearne Hill and Trail Peak (Figures 26 and 27) are cut by dykes and irregular bodies of biotite feldspar porphyry which contain some copper mineralization.

A sample from the quartz diorite stock at Trail Peak yielded a potassium-argon age of 104 $\pm$ 4 m.y., somewhat younger than the Early Cretaceous ages obtained for some phases of the Omineca intrusions in the Hogem batholith to the northeast (Garnett, 1972). This younger age would be due to partial radiogenic argon loss in the biotites of the quartz diorite due to the intrusion of younger biotite feldspar porphyry dykes.

Porphyry-type copper and molybdenum mineralization in Tachek Creek south of Topley Landing (Figure 26) is associated with hornblende-biotite-quartz-feldspar porphyry dykes which cut porphyritic quartz monzonite of the Topley intrusions. A sample from one of these dykes (NC-69-4) returned a potassium-argon age of 176 + 7 m.y., indicating that these dykes represent a late phase of the Topley intrusions of Late Triassic-Early Jurassic age.

A relatively coarse-grained quartz-hornblende-biotite feldspar porphyry from the Lennac Lake porphyry copper prospect (Figure 26), similar in appearance to some of the typical Babine porphyries, was analysed as 77.0 + 2.5 m.y. Similar intrusions with associated copper-molybdenum mineralization are known in the French Peak-Mount Thoen area to the northwest and these constitute a third age of mineralization in the Babine Lake area.

4.4.4 Summary

(1) Babine intrusions were emplaced at about 52.0 m.y. as indicated by results from samples collected away from mineralized and hydrothermally altered zones.

(2) The age of mineralization in Babine intrusions is synchronous, or nearly so, with the age of intrusion. This is borne out by a number of potassium-argon ages obtained from (a) mineralized porphyry phases containing abundant hydrothermal biotite; (b) from late porphyry phases which provide an upper limit for the age of mineralization; and (c) from a quartz-biotite-sulphide vein.

(3) At least four ages of intrusive activity are known in the northern Babine Lake area including: 176 to 200 m.y. (Topley intrusions); 104 m.y. (Omineca intrusions); 77 m.y. (Bulkley intrusions); and 50 m.y. (Babine intrusions).

(4) Three ages of porphyry copper mineralization have been defined in the Babine area. Babine intrusions of Middle Eocene (50 m.y.) age are known to be the most significant. The other two ages include copper-molybdenum mineralization related to a late porphyry phase of the Topley intrusions and porphyry stocks of Late Cretaceous age, equivalent to the Bulkley intrusions and hosting copper-molybdenum mineralization.

5. COMPARISON OF PORPHYRY DEPOSIT POTASSIUM-ARGON AGES TO OTHER AREAS AND THEIR TECTONIC EVOLUTION

5.1 INTRODUCTION

Two metallogenic epochs have been defined in this study. These include the 50 m.y. ages obtained for copper and molybdenum deposits related to the Alice Arm, Nanika, and Babine intrusions and the 70 to 84 m.y. ages for the copper-molybdenum deposits associated with the Bulkley intrusions. All of these deposits are situated within or marginal to the Intermontane Tectonic Belt.

Similar ages for porphyry deposits have been reported in the Intermontane, Coast Crystalline, and Insular Tectonic Belts of British Columbia, Yukon, southern Alaska, and Washington State. The classic porphyry copper province of southwest Arizona and northern Mexico is of similar age being in the 50 to 70 m.y. range.

5.2 POTASSIUM-ARGON AGES OF PORPHYRY DEPOSITS IN NORTH AMERICA

Most porphyry copper and molybdenum deposits in western North America are of Cretaceous or Tertiary age. The major exceptions are the important porphyry copper deposits in British Columbia, principally those in the Princeton, Highland Valley, Cariboo, Omineca, and Stikine areas, which are of Late Triassic and Jurassic age.

Porphyry deposits of Late Cretaceous and Tertiary age, outside the study area, are briefly described on the following pages.

5.2.1 British Columbia

Late Cretaceous and Tertiary ages for many porphyry deposits outside the study area are shown on Figure 28.

In northern British Columbia, the Eocene (50 m.y.) and Late Cretaceous (70 m.y.) metallogenic epochs have been documented by Christopher (1972, 1973). Ages ranging from 48.7 ± 1.9 to 50.5 ± 1.5 m.y. were obtained for samples from the Mount Haskin and Mount Reed molybdenum properties east of Cassiar (Figure 28). The Cassiar molybdenum property south of Cassiar is of Late Cretaceous or Early Tertiary age (68 to 72 m.y.) and the Adanac molybdenum property east of Atlin is of similar (62 m.y.) age.

Late Cretaceous and Early Tertiary ages have also been reported for porphyry deposits in south-central British Columbia. The Maggie porphyry copper-molybdenum deposit 10 miles north of Cache Creek has a potassium-argon age of 61.2 ± 2 m.y. (McMillan, 1970). An age of 67 m.y. was obtained for the Rey Lake porphyry copper prospect east of the Guichon batholith (McMillan, personal communication).

Several other porphyry prospects situated in the Intermontane Tectonic Belt of southwestern British Columbia are believed to be of Late Cretaceous or Early Tertiary age although no radiometric ages have as yet been determined for them. These include the Fish Lake copper-gold porphyry deposit east of Taseko Lakes, the Poison Mountain copper-molybdenum deposit northwest of Lillooet, and the Whipsaw Creek and Ashnola River porphyry prospects south of Princeton.

The Red Mountain molybdenum deposit at Rossland is believed to be related to an igneous event dated at 48 m.y. (Fyles, et al., 1973).

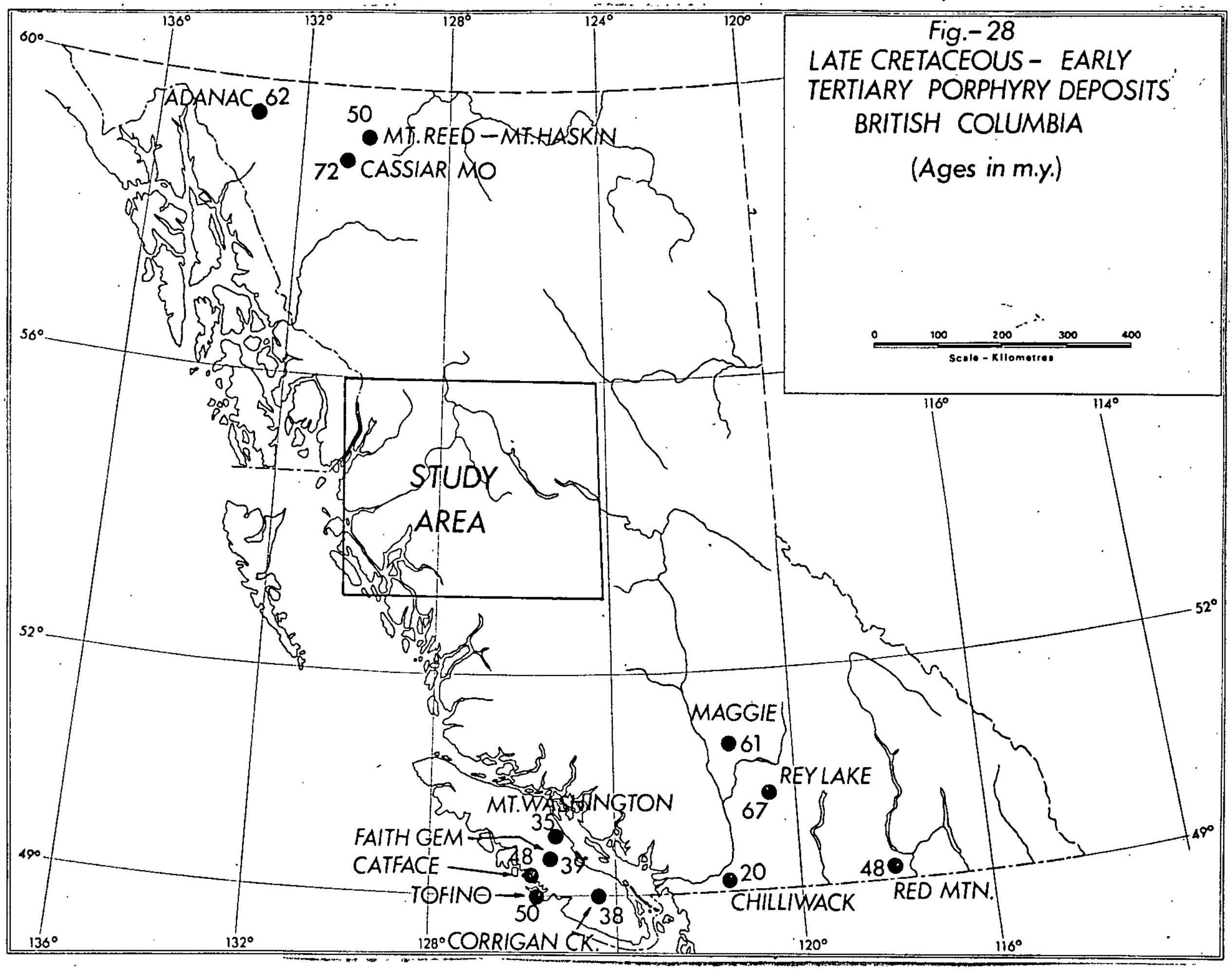


Fig.– 28
LATE CRETACEOUS – EARLY TERTIARY PORPHYRY DEPOSITS BRITISH COLUMBIA
(Ages in m.y.)

Granitic rocks of the Chilliwack batholith range in age from 16 to 32 m.y., with the majority of ages being about 20 m.y. (Richards and White, 1970). Minor copper occurrences have been reported in these rocks.

Two discrete age groups of Tertiary porphyry-type mineralization are known on Vancouver Island (Carson, 1969). These include 48 and 50 m.y. ages for the Catface copper and Tofino molybdenum properties on the west coast of the Island, and the 30 to 39 m.y. ages for the Mount Washington, Faith copper, and Gem Lake deposits west of Courtenay, and the Corrigan Creek prospect south of Alberni (Figure 28).

In summary, the Late Cretaceous and Tertiary mineralizing epochs can be extended north and south of the study area, although definition of these awaits further study.

5.2.2 Washington State

Numerous copper deposits of vein and porphyry type in the Cascade Range of Washington are temporally and spatially related to high-level calc-alkaline intrusive rocks ranging in age from Oligocene to Miocene (15 to 30 m.y.) (Grant, 1969). These ages correspond to those obtained for the Chilliwack batholith immediately to the north in British Columbia (Richards and White, 1970).

5.2.3 Southern Alaska

Most known mineral deposits and areas of hydrothermal alteration in southern Alaska are associated with hypabyssal intrusions of Late Cretaceous and Tertiary age, ranging from 58 to 75 m.y. (Reed and Lanphere, 1969;

Hollister, et al., 1974). These ages are in good agreement with those obtained in west-central British Columbia.

5.2.4 Yukon

Potassium-argon ages have been determined for two porphyry deposits in the Yukon.

The Casino copper-molybdenum deposit at Canadian Creek has a mean age of 70 ± 3 m.y. (Phillips and Godwin, 1970), in good agreement with ages obtained for similar deposits in central British Columbia.

The Burwash Creek copper-molybdenum deposit west of Kluane Lake has a mean age of 26.0 ± 0.3 m.y. (Christopher, 1972), much younger than the 50 m.y. epoch in central British Columbia but similar to ages of deposits in the Cascade Range of Washington.

5.2.5 Southern Basin and Range Province, U.S.A.

No comparison of potassium-argon ages obtained during this study would be complete without relating them to potassium-argon ages for the extremely important porphyry copper deposits of Arizona, New Mexico, and Sonora state of Mexico. The deposits of this area are regarded as the typical porphyry copper. The porphyry deposits of west-central British Columbia have many features in common with them, including size, form, composition of host intrusive, style of mineralization, and hydrothermal alteration.

A similarity of potassium-argon ages is also apparent. Potassium-argon ages for 27 porphyry deposits in the southern Basin and Range province range in age from 52 m.y. to 72 m.y., referred to as Laramide age (Livingston, 1973).

The greater number of deposits have an age of about 65 m.y. Where determined, the age of mineralization is indistinguishable from the age of the host pluton (Livingston, et al., 1968), again in agreement with results obtained from this study.

The potassium-argon ages in the southern Basin and Range province have a trend from oldest to youngest in a southeast direction from northwestern Arizona to Sonora state in Mexico (Livingston, 1973).

5.3 EVOLUTION OF PORPHYRY DEPOSITS OF WEST-CENTRAL BRITISH COLUMBIA

Several authors have attempted to relate the distribution of porphyry copper deposits in North and South America to the plate tectonic theory (Farrar, et al., 1970; Hodder and Hollister, 1972; Sillitoe, 1972; Livingston, 1973).

This theory postulates that calc-alkaline igneous rocks and related porphyry mineral deposits are generated by partial melting of oceanic crustal rocks in subduction zones beneath the continental margins. These subduction zones are believed to have migrated with time.

Farrar, et al. (1970) and Sillitoe (1972) give good evidence for migration of subduction zones resulting in varying ages of intrusive activity. An example of this is shown by the potassium-argon ages obtained in Peru and northern Chile (Farrar, et al., 1970). Magmatism began in Permian time as represented by intrusion of this age near the present coastline, and was followed by four major intrusive episodes in the Lower Jurassic, Middle Cretaceous, Lower Paleocene, and Upper Eocene. Intrusive rocks of these ages are arranged in linear belts crudely parallel to the present coastline, and these belts decrease in age eastward.

Clark and Zentilli (1972) indicate that porphyry copper deposits in northern Chile and northwestern Argentina are related to felsic stocks of Upper Jurassic, Middle Cretaceous, Lower Paleocene, Upper Eocene, Oligocene-Miocene, and Miocene-Pliocene age. They postulate that from Triassic-Jurassic time to Middle Tertiary, the loci of epizonal magmatism has migrated in an east-southeast direction to form a series of discrete longitudinal metallogenic sub-provinces.

The trend in ages of porphyry copper deposits in the southern Basin and Range province, from 70 m.y. in Arizona to 50 m.y. in northern Mexico, is explained by Livingston (1973) as being due to the migration of the North American plate in a northwesterly direction over a mantle hot spot.

The potassium-argon ages for porphyry deposits in west-central British Columbia show no simple trend as in South America or the southern Basin and Range province. Four crudely parallel belts are evident, including from west to east: 50 m.y. Alice Arm molybdenum deposits; 70 to 84 m.y. Bulkley copper-molybdenum deposits; 50 m.y. Nanika copper-molybdenum deposits; and the 50 m.y. Babine copper deposits. Thus, there is no simple eastward migration of intrusive centres, rather there appears to be a reversal from 50 m.y. to 70-84 m.y., and back to 50 m.y.

This more complicated pattern of intrusive ages may be a reflection of the complex tectonic history of the northwestern Cordillera of North America. The study area is bordered on the west by the Coast Plutonic Complex, a tectonic belt unique in the Cordillera of North and South America. It is possible that the numerous copper and molybdenum-bearing intrusions in west-central British Columbia were related to the evolution of the Coast Plutonic Complex.

Wheeler, et al., (1972) postulate that the Coast Plutonic Complex evolved independently of the rest of the Cordillera until Mid-Mesozoic time. After this time, it is impinged on the remainder of the Cordillera and a subduction zone beneath the Complex affected the tectonic evolution of the entire Cordilleran region.

Potassium-argon ages obtained from granitic rocks of the Coast Plutonic Complex indicate three parallel belts which are younger and more potassic in an eastward direction. These belts include a western zone, predominantly of quartz diorite composition (84 - 140 m.y. on the west and 79 - 64 m.y. on the east part of the zone), a central core zone of migmatitic gneiss, quartz diorite, and granodiorite (45 m.y.), and an eastern zone of granodiorite and quartz monzonite (40 - 50 m.y.) which is intrusive into Mesozoic layered rocks. This trend in ages is in agreement with the concept of an eastward migrating subduction zone beneath the Coast Plutonic Complex from Late Jurassic to Early Tertiary time.

The Bulkley copper and molybdenum-bearing intrusions (70 - 84 m.y.) correspond in age and composition to the quartz diorites and granodiorites of the eastern part of the west zone of the Coast Plutonic Complex (64 - 79 m.y.). Although situated a fair distance to the east, the Bulkley intrusions may have been generated by the same period of underthrusting along the subduction zone that resulted in the emplacement of the east part of the western zone of the Coast Plutonic Complex. The hypabyssal nature of the Bulkley intrusions, in contrast to the plutonic nature of the granitic rocks of the Coast Complex, and their localization at or near fault intersections, reflects their greater vertical distance above the east-dipping subduction zone.

Renewed underthrusting of the oceanic plate beneath the continental crust in Eocene time (40 - 50 m.y.) culminated in the emplacement of the core and eastern zones of the Coast Plutonic Complex. Related to this igneous event are the Alice Arm molybdenum-bearing intrusions (50 m.y.) which occur along the eastern flank of the Coast Complex. These are of quartz monzonite or granite composition and were intruded a measureable amount of time (2 - 5 m.y.) prior to the emplacement of the eastern zone of the Coast Plutonic Complex.

The Nanika and Babine intrusions, also of 50 m.y. age, may be related to this period of movement along the subduction zone. Most Nanika intrusions are similar in chemical composition to the Alice Arm intrusions and similarly several of them are not far removed from the east flank of the Coast Plutonic Complex. Those Nanika intrusions further to the east appear to have been localized by the same fault systems governing the emplacement of the Bulkley intrusions in Late Cretaceous time.

The Babine intrusions are also of 50 m.y. age but are markedly different from the Alice Arm and Nanika intrusions in form and composition. They are of granodiorite and quartz diorite composition and exhibit features typical of subvolcanic intrusions, occurring as dykes, dyke swarms, necks, and plugs. Volcanic features include the presence of intrusive breccias and extrusive sheets and flows preserved nearby several of the intrusive centres. They, like the Bulkley intrusions of earlier age, occur a fair distance to the east of the youngest zone of the Coast Plutonic Complex and were localized at intersections of major faults. The volcanic nature of the Babine intrusions may be a reflection of their emplacement a great vertical distance above an active subduction zone.

The crude zonation of contained metallic mineralization in the porphyry deposits of west-central British Columbia include from west to east: Alice Arm molybdenum deposits, Bulkley and Nanika copper-molybdenum deposits, and Babine copper deposits. Notable exceptions to this pattern include the several deposits associated with the Nanika and Bulkley intrusions which contain only molybdenum. As might be expected, molybdenum-bearing plutons such as the Alice Arm intrusions are more acidic than those containing copper-molybdenum or copper. Alice Arm molybdenum-bearing plutons also intrude a sedimentary sequence while the copper-molybdenum and copper-bearing Bulkley, Nanika, and Babine intrusions occur in predominantly volcanic sequences.

6. CONCLUSIONS

(1) Porphyry copper and molybdenum deposits in west-central British Columbia are associated with the Alice Arm, Bulkley, Nanika, and Babine intrusions which occur in four subparallel belts and are distinguished on the basis of age, chemical composition, and contained metal content. These intrusions cut Mesozoic volcanic and sedimentary rocks of the Intermontane Tectonic Belt. Copper and molybdenum sulphides occur as fracture fillings and in veinlet stockworks within and adjacent to the intrusive bodies. Sulphide and alteration minerals exhibit concentric zoning relative to the host intrusions.

(a) The 50 m.y. Alice Arm molybdenum-bearing intrusions make up the westernmost belt, occurring as small stocks which intrude Mesozoic sedimentary rocks along the east flank of the Coast Plutonic Complex. Multiple intrusion is a common feature of the deposits and potassium-argon dating of two or more inter-mineral and post-mineral intrusive phases indicates that the age of mineralization is synchronous with the age of intrusion. Coast Plutonic Complex granitic rocks nearby the Alice Arm intrusions were emplaced a few million years later than the molybdenum-bearing stocks.

(b) Bulkley intrusions of 70 - 84 m.y. age occur in the central part of the area studied and are in the form of stocks of granodiorite composition which contain copper and molybdenum mineralization. Mesozoic sedimentary and volcanic rocks adjacent to the intrusions are hornfelsed and whole-rock potassium-argon dating of these rocks were found to give reliable ages of intrusion of stocks which contained no suitable mafic minerals. Multiple intrusion is a common feature and potassium-argon dating of various intrusive phases indicates congruent ages for mineralization and intrusion.

(c) Nanika intrusions have the same geographic setting as the Bulkley intrusions but are of 50 m.y. age. They also host copper and molybdenum mineralization and occur as small stocks or plugs of quartz monzonite porphyry. Sedimentary rocks marginal to the intrusions are converted to biotite hornfels and in some instances whole-rock samples of hornfels were used to date the age of intrusion. Potassium-argon dating of mineralized and inter-mineral porphyry phases indicates congruent ages for intrusion and mineralization.

(d) Babine intrusions and associated copper deposits occur in the eastern part of the area studied and are of 50 m.y. age. They differ in form, composition, and texture from the other plutons of similar age. They are subvolcanic intrusions and occur as dykes, dyke swarms, necks, and plugs emplaced into Mesozoic porphyries of quartz diorite-granodiorite composition and extrusive equivalents of these are present in the area. Multiple intrusion is a common feature and potassium-argon dating of two or more phases at several deposits demonstrates congruent ages for mineralization and intrusion.

(2) This study proposes a new subdivision of granitic rocks in central British Columbia. These range in age from Early Mesozoic to Tertiary. Mesozoic granitic intrusions occur as batholiths and stocks and include the Upper Triassic-Lower Jurassic Topley intrusions (176 - 206 m.y.), the Lower to Upper Jurassic Omineca intrusions (121 - 177 m.y.), and

the Upper Jurassic Francois Lake intrusions (133 - 155 m.y.). The Kitsault intrusions of Jurassic and Cretaceous age occur as stocks in the northwest part of the area. Granitic rocks of the Coast Plutonic Complex border the area on the west and range in age from 43 to 140 m.y. The great number of Late Cretaceous and Tertiary intrusions in the central part of the area include the Bulkley intrusions (70 - 84 m.y.), Babine intrusions (49 - 55 m.y.), Nanika intrusions (47 - 54 m.y.), Alice Arm intrusions (48 - 54 m.y.), and Goosly Lake intrusions (49 m.y.).

(3) Porphyry deposits of Late Cretaceous and Early Tertiary age, similar to those in west-central British Columbia, are known throughout the North American Cordillera. These include the porphyry deposits of the southern Basin and Range province, U.S.A., southern and northern British Columbia, Yukon, and southeast Alaska.

(4) The distribution of potassium-argon ages of porphyry deposits in west-central British Columbia does not fit the relatively simple plate tectonic theory advanced for deposits of similar type and age in the Andes of South America and the southern Basin and Range province, where deposits become progressively younger in a given direction. Here instead two widely separated belts of plutons, the Alice Arm and Babine intrusions, of the same 50 m.y. age but of different character, are separated by a belt of older (70 - 84 m.y.) Bulkley intrusions. Also occurring within this central belt are the Nanika intrusions, of similar 50 m.y. age to the Alice Arm and Babine intrusions.

(5) These intrusions may have been related to periodic movement along a subduction zone from which the granitic rocks of the Coast Plutonic Complex evolved in three distinct episodes. Potassium-argon ages in

the Coast Plutonic Complex range from 140 to 40 m.y. and are contained in three parallel belts which are progressively younger in an eastward direction. The hypabyssal Bulkley intrusions of 70 to 84 m.y. age range may have been related to a period of underthrusting along the subduction zone that gave rise to part of the western zone of the Coast Plutonic Complex which ranges in age from 64 to 79 m.y. Repeated movement along the subduction zone in Eocene (50 m.y.) time culminated in the emplacement of the eastern zone of the Coast Plutonic Complex, and from west to east, the Alice Arm, Nanika, and Babine intrusions. These intrusions become more volcanic in nature in an eastward direction, reflecting increased depth of generation along the subduction zone.

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APPENDIX A. POTASSIUM-ARGON METHOD

A.1 PROCEDURE

Biotite, whole rock, and hornblende potassium-argon ages were determined in laboratories of the Department of Geology, University of British Columbia, using procedures and equipment previously described (White, et al., 1967; Northcote, 1969). The potassium analyses were performed on quadruplicate splits and the solutions atomized in Baird-Atomic KY and KY-3 series flame photometers. The argon data was recorded with an AEI MS-10 mass spectrometer modified to permit rapid, static isotopic ratio measurements on a small quantity of gas, approximately 5 per cent by volume.

Argon analyses carried out after late 1970 also involved the baking out of the fusion system and sample at 130 degrees centigrade for approximately 18 hours to eliminate or reduce atmospheric argon contamination.

Analytical data and potassium-argon isotopic ages are given in Table A.2.

A.2 PRECISION AND ACCURACY

The precision and accuracy of the potassium-argon age determination must be continually monitored to determine reliability of potassium-argon model ages. Interlaboratory standard mineral and rock samples are analysed in the University of British Columbia potassium-argon laboratory to establish the accuracy of the equipment and replicate analyses of minerals are used to determine the precision of the equipment (see White, et al., 1967; Northcote, 1969).

J. E. Harakal runs periodic checks on the Ar^{40}/Ar^{36} ratio of atmospheric argon and on the argon isotope ratios in the spike system as measured on the Unversity of British Columbia MS-10 mass spectrometer. For samples containing less than 50 per cent atmospheric argon contamination, University of British Columbia results are internally consistent within 1 per cent and a limit of error in an age determination (accuracy) is within 3 per cent of the calculated age (J. E. Harakal, personal communication).

A.3 APPLICATION OF INITIAL ARGON AND POTASSIUM-ARGON ISOCHRON DIAGRAMS

Initial argon and potassium-argon isochron diagrams provide a graphical means for checking values of initial argon and initial Ar^{40}/Ar^{36} ratios.

Investigation of argon content of biotite (Giletti, 1971) and hornblende (Roddick and Farrar, 1971) shows that excess initial Ar^{40} can occur in most datable minerals. Samples should be treated in a manner that does not assume that initial argon has the present atmospheric ratio ($Ar^{40}/Ar^{36} = 295.5$). The potassium-argon isochron method (Roddick and Farrar, 1971; Hayatsu and Carmichael, 1970) provides a method of determining the initial argon ratio.

The data necessary for determining isochron ages is the same as the data required for the conventional potassium-argon calculation. The isochron method requires that for each rock unit dated, preferably three analyses are available from phases of minerals differing by at least 50 per cent in potassium content. In addition, the entire fusion system must be baked at 130 degrees centigrade for about 18 hours to remove loosely held atmospheric argon.

Ar^{40}/Ar^{36} versus K^{40}/Ar^{36} and Ar^{40} (radiogenic) versus %K diagrams can be plotted and the method least squares (York, 1966) is used to fit the best straight line to the points. The lines produced are called isochrons and the slope of the line is used to calculate an isochron age.

The baking-out procedure of the sample and fusion system was applied to only 12 samples analysed during this study. Since no more than two of these analyses were from the same intrusive body, the plotting of Ar^{40}/Ar^{36} versus K^{40}/Ar^{36} diagrams was not attempted.

Potassium-argon data for each of the intrusive types (Alice Arm, Bulkley, Nanika, and Babine intrusions) was evaluated using Ar^{40} (radiogenic) versus %K diagrams. These isochron plots supported the conventional age determinations. For the four intrusive types the mean age of conventional determinations was consistent with the isochron age. For all types, the initial argon ratio is essentially the same as the present-day value (Ar^{40}/Ar^{36} = 295.5).

A.4 GEOLOGICAL TIME SCALE

The geological time scale used throughout this study is that proposed by Holmes (1959). Divisions of the Mesozoic and Cenozoic eras are shown on Table A.1.

TABLE A.1. GEOLOGICAL TIME SCALE (Holmes, 1959)

ERA	PERIOD	EPOCH	APPROXIMATE TIME (m.y.)
	Quaternary	Pleistocene	1
	Tertiary	Pliocene	11
		Miocene	25
		Oligocene	40
Cenozoic		Eocene	60
		Paleocene	70
	Cretaceous	Upper	
		Lower	136
		Upper	
	Jurassic	Middle	
		Lower	180
Mesozoic			
		Upper	
	Triassic	Middle	
		Lower	225

TABLE A.2

POTASSIUM-ARGON ANALYTICAL DATA

ALICE ARM INTRUSIONS

Specimen No.	Location	Rock Type	Mineral or Concentrate	% K±S*	A^{40}rad.** / A^{40}total	A^{40}rad. (10^{-5}cc STP/g)	A^{40}rad. / K^{40} x 10^{-3}	Apparent Age (m.y.)
NC-67-38	British Columbia Molybdenum	Quartz monzonite porphyry	Biotite	7.59±.02	0.77	1.623	3.159	53.0±3
NC-69-2	British Columbia Molybdenum	Intrusive breccia	Biotite	6.62±.03	0.23	1.429	3.189	53.7±1.7
NC-70-1	British Columbia Molybdenum	Lamprophyre dyke	Whole Rock	2.30±.01	0.66	3.353×10^{-1}	2.154	36.5±1.2
NC-70-2	British Columbia Molybdenum	Quartz diorite	Biotite	6.47±.01	0.90	1.334	3.046	51.4±1.5
NC-70-3	British Columbia Molybdenum	Quartz monzonite porphyry "Late phase"	Biotite	4.40±.03	0.85	8.530×10^{-1}	2.864	48.3±1.6
NC-67-35 Run 1	Roundy Creek	Quartz monzonite porphyry	Biotite	6.09±.06	0.60	1.280	3.106	52.0±3
NC-67-35 Run 2	Roundy Creek	Quartz monzonite porphyry	Biotite	6.09±.06	0.65	1.289	3.126	53.0±2
NC-67-30	Bell Molybdenum	Quartz monzonite porphyry	Biotite	5.72±.05	0.33	1.217	3.143	53.0±2
NC-67-31	Bell Molybdenum	Biotite hornfels	Whole Rock	1.66±.01	0.19	3.241×10^{-1}	2.884	48.7±1.5
NC-68-2	Bell Molybdenum	Quartz diorite	Biotite	4.75±.04	0.58	9.857×10^{-1}	3.066	51.7±2.2
NC-67-33	Ajax	Quartz monzonite porphyry	Biotite	6.47±.04	0.67	1.390	3.175	54.0±3
NC-67-25	Ridge-Nass River	Quartz monzonite porphyry "Late phase"	Biotite	5.13±.03	0.75	1.010	2.909	49.0±2
NC-67-26	Valley-Nass River	Quartz monzonite porphyry	Biotite	7.08±.08	0.56	1.478	3.085	52.0±3
NC-67-27	Kay-Nass River	Quartz feldspar porphyry	Biotite	6.07±.04	0.71	1.297	3.158	53.2±2.3

ALICE ARM - NASS RIVER AREA

Specimen No.	Location	Rock Type	Mineral or Concentrate	% K±S*	A^{40}rad.** / A^{40}total	A^{40}rad. (10^{-5}cc STP/g)	A^{40}rad. / K^{40} x 10^{-3}	Apparent Age (m.y.)
NC-67-32 Run 1	Alice Arm	Basalt	Whole Rock	1.99±.015	0.01	8.418×10^{-3}	6.434×10^{-2}	1.1±0.8
NC-67-32 Run 2	Alice Arm	Basalt	Whole Rock	1.99±.015	0.04	2.255×10^{-3}	1.724×10^{-2}	0.293±0.5
NC-67-32 Run 3	Alice Arm	Basalt	Whole Rock	1.99±.015	0.04	3.468×10^{-3}	2.651×10^{-2}	0.453±0.5
NC-70-4	Alice Arm	Basalt	Whole Rock	1.30±.01	0.11	8.362×10^{-3}	9.503×10^{-2}	1.6±0.8
NC-67-45	Penny Creek	Biotite quartz monzonite	Biotite	6.11±.05	0.25	8.805×10^{-1}	2.129	36.1±1.6
NC-68-11	Molly Mack	Biotite granite	Biotite	6.54±.02	0.68	1.266	2.360	48.3±1.9
NC-68-3	Bonanza Creek Anyox	Quartz biotite schist	Biotite	5.73±.04	0.20	7.621×10^{-1}	1.965	33.3±1.4
NC-68-4	Illiance River Alice Arm	Biotite lamprophyre	Biotite	6.55±.06	0.73	9.013×10^{-1}	2.033	34.4±1.5
NC-67-24 Run 1	Mt. Priestly Coast Plutonic Complex	Quartz monzonite	Biotite	4.91±.02	0.45	9.114×10^{-1}	2.742	46.3±1.4
NC-67-24 Run 2	Mt. Priestly Coast Plutonic Complex	Quartz monzonite	Biotite	4.91±.02	0.82	1.011	3.043	51.3±1.6
NC-67-29	Alice Arm Coast Plutonic Complex	Quartz monzonite	Biotite	6.68±.05	0.55	1.355	2.997	51.0±3
NC-69-3	Lava Lake Coast Plutonic Complex	Quartz monzonite	Biotite	7.30±.05	0.85	1.485	3.006	50.7±2.1
NC-67-28	Nass River	Quartz diorite	Biotite	6.95±.02	0.90	1.369	2.911	49.0±2.0

TABLE A.2 (cont.)

BULKLEY INTRUSIONS

Specimen No.	Location	Rock Type	Mineral or Concentrate	% K±S*	A^{40}rad.** / A^{40}total	A^{40}rad. (10^{-5}cc STP/g)	A^{40}rad. / K^{40} x 10^{-3}	Apparent Age (m.y.)
NC-68-12	Bear	Quartz monzonite porphyry	Biotite	6.23±.01	0.81	2.078	4.929	82.4±3.1
NC-67-46	Rocher de Boule	Granodiorite	Biotite	6.64±.05	0.86	1.936	4.289	71.9±3.1
NC-67-41 Run 1	Glacier Gulch	Quartz-biotite-sulfide vein	Biotite	7.27±.02	0.65	2.024	4.113	69.0±3
NC-67-41 Run 2	Glacier Gulch	Quartz-biotite-sulfide vein	Biotite	7.27±.02	0.68	2.064	4.195	70.0±3
NC-68-6	Glacier Gulch	Quartz monzonite porphyry	Biotite	5.78±.06	0.79	1.711	4.373	73.3±3.4
NC-67-16	Huber	Biotite hornfels	Whole Rock	1.07±.002	0.82	3.001x10^{-1}	4.144	69.5±2.0
NC-67-39	Sunsets Creek	Granodiorite	Biotite	6.92±.06	0.80	1.956	4.175	70.0±3
NC-67-44	Huckleberry	Granodiorite porphyry	Biotite	6.29±.05	0.89	2.079	4.884	82.0±3
NC-69-5	Ox Lake	Granodiorite porphyry	Biotite	4.25±.01	0.78	1.435	4.987	83.4±3.2
MC-9	Coles Creek	Quartz monzonite porphyry	Biotite	6.89±.04	0.89	2.337	5.012	83.8±2.8

NANIKA INTRUSIONS

Specimen No.	Location	Rock Type	Mineral or Concentrate	% K±S*	A^{40}rad.** / A^{40}total	A^{40}rad. (10^{-5}cc STP/g)	A^{40}rad. / K^{40} x 10^{-3}	Apparent Age (m.y.)
NC-68-13	Mt. Thomlinson	Quartz monzonite porphyry	Biotite	7.50±.03	0.77	1.620	3.191	53.8±2.2
NC-67-7	Big Onion	Quartz monzonite "Late phase"	Biotite	4.50±.01	0.77	8.782x10^{-1}	2.883	48.7±1.9
NC-69-6	Goosly	Quartz monzonite porphyry	Biotite	7.09±.04	0.77	1.601	3.336	56.2±2.3
NC-68-7	Nadina Mountain	Quartz monzonite	Biotite	6.55±.03	0.63	1.392	3.139	52.9±2.2
NC-67-42	Lucky Ship	Biotite hornfels	Whole Rock	1.56±.05	0.29	3.131x10^{-1}	2.959	49.9±2.3
NC-67-8	Berg	Quartz diorite (Coast Plutonic Complex)	Biotite	2.64±.01	0.23	4.955x10^{-1}	2.773	46.8±1.5
NC-67-9	Berg	Quartz latite porphyry "Late phase"	Biotite	6.69±.05	0.42	1.283	2.834	48.0±3
NC-67-10	Berg	Quartz latite porphyry "Late phase"	Biotite	6.56±.06	0.38	1.249	2.813	47.0±3
NC-67-11	Berg	Quartz monzonite porphyry	Biotite	6.76±.05	0.34	1.413	3.088	52.0±2
NC-67-12	Berg	Biotite hornfels	Whole Rock	2.92±.05	0.29	6.175x10^{-1}	3.124	52.0±3
NC-67-13	Berg	Quartz diorite (Metamorphosed)	Biotite	6.97±.05	0.75	1.396	2.960	49.9±2.1
NC-67-17	Red Bird	Biotite hornfels	Whole Rock	4.09±.03	0.23	8.201x10^{-1}	2.962	50.0±1.7
NC-67-19 Run 1	Red Bird	Quartz monzonite porphyry	Biotite	7.94±.07	0.65	1.572	2.925	49.0±3
NC-67-19 Run 2	Red Bird	Quartz monzonite porphyry	Biotite	7.94±.07	0.59	1.603	2.982	50.0±2
NC-67-20	Red Bird	Quartz monzonite porphyry "Late phase"	Biotite	7.24±.03	0.74	1.433	2.924	49.0±2
NC-67-15	Morice Lake	Quartz monzonite (Topley Intrusions)	Biotite	6.50±.07	0.70	4.821	10.957	178±8
NC-69-7	Goosly	Syenomonzonite (Goosly Lake Intrusions)	Biotite	7.53±.02	0.69	1.473	2.891	48.8±1.9

TABLE A.2 (cont.)

BABINE INTRUSIONS

Specimen No.	Location	Rock Type	Mineral or Concentrate	% K+S*	$\frac{A^{40}rad.}{A^{40}total}$ **	A^{40}rad. (10^{-5}cc STP/g)	$\frac{A^{40}rad.}{K^{40}} \times 10^{-3}$	Apparent Age (m.y.)
NC-67-1	Old Fort	Biotite feldspar porphyry	Biotite	7.59±.06	0.53	1.497	2.914	49.0±2
NC-67-2	Old Fort	Biotite quartz monzonite	Biotite	5.89±.04	0.76	1.232	3.089	52.0±2
NC-67-4	Granisle	Biotite feldspar porphyry	Biotite	7.63±.03	0.67	1.682	3.256	55.0±3
NC-67-5	Granisle	Biotite feldspar porphyry	Biotite	7.06±.03	0.87	1.436	3.005	51.0±2
NC-68-1	Granisle	Biotite feldspar porphyry "Late phase"	Biotite	6.67±.01	0.54	1.354	2.999	51.0±2
NC-69-8	Granisle	Quartz-biotite-sulfide vein	Biotite	4.42±.02	0.69	8.894×10^{-1}	2.973	50.2±2.1
NC-67-22	Newman-Bell Copper	Biotite feldspar porphyry "Late phase"	Biotite	6.45±.04	0.63	1.288	2.951	49.8±2.1
NC-67-23	Newman-Bell Copper	Biotite feldspar porphyry "Late phase"	Biotite	6.90±.02	0.73	1.402	3.002	51.0±3
NC-67-40	Morrison	Biotite feldspar porphyry	Biotite	6.66±.04	0.57	1.393	3.091	52.1±2.1
NC-68-10	Trail Peak	Biotite feldspar porphyry	Biotite	6.61±.01	0.71	1.297	2.900	48.9±1.5
NC-69-1	Trail Peak	Quartz diorite (Omineca Intrusions)	Biotite	6.80±.03	0.92	2.871	6.238	104±4
NC-67-43	Newman Peninsula	Hornblende feldspar porphyry (Extrusive equivalent)	Hornblende	.672±.002	0.62	1.390×10^{-1}	3.056	51.5±1.9
NC-69-4	Tachek Creek	Hornblende-biotite-quartz porphyry (Topley Intrusions)	Biotite	6.54±.03	0.93	4.763	10.760	176±7
NC-72-1	Lennac Lake	Quartz-hornblende-biotite feldspar porphyry (Bulkley Intrusions)	Biotite	6.71±.03	0.95	2.088	4.597	77.0±2.5

* Potassium analyses by V. Bobik and N. C. Carter, using KY and KY-3 flame photometers; S-standard deviation of quadruplicate analyses

**Argon analyses by J. E. Harakal and N. C. Carter, using MS-10 mass spectometer. Constants used in model age calculations

$\lambda_e = 0.585 \times 10^{-10}\ y^{-1}$

$\lambda_\beta = 4.72 \times 10^{-10}\ y^{-1}$

$^{40}K/K = 1.181 \times 10^{-4}$

APPENDIX B. CHEMISTRY OF INTRUSIVE ROCKS

B.1 CHEMICAL ANALYSES OF INTRUSIVE ROCKS

Twenty-three samples collected for potassium-argon dating were submitted to the Analytical Laboratory of the Department of Mines and Petroleum Resources for chemical analysis. These were analysed by S. Metcalfe using classical wet chemical techniques.

Analyses are presented in Table B.1.

B.2 MAJOR AND TRACE ELEMENT ANALYSES OF BIOTITES

Most of the biotite separates used for potassium-argon dating were analysed for major and trace elements. Analyses were carried out at the Cominco Research Laboratories, Trail, under the supervision of M. Osatenko.

Major and minor elements were analysed by atomic absorption methods with the exception of TiO_2 which was determined by colorimetric methods. Results were calibrated against known U.S.G.S. rock standards.

Analyses of biotites are given in Table B.2.

TABLE B.1: CHEMICAL ANALYSES OF INTRUSIVE ROCKS

ALICE ARM INTRUSIONS					
	NC-67-38 B.C. MOLY	NC-67-30 BELL MOLY	NC-67-33 AJAX	NC-67-35 ROUNDY CREEK	NC-67-26 VALLEY
SiO_2	71.38	66.98	65.78	71.16	68.92
Al_2O_3	12.01	14.64	13.56	14.23	15.20
Fe_2O_3	0.99	0.69	1.29	0.36	1.02
FeO	0.62	2.02	2.22	1.86	0.87
P_2O_5	0.19	0.20	0.38	0.15	0.38
CaO	1.90	3.08	3.53	1.40	2.23
MgO	0.78	1.00	1.32	0.29	0.64
TiO_2	0.33	0.54	0.52	0.31	0.57
SO_3	1.87	0.75	1.50	0.72	1.84
MnO	0.03	0.04	0.03	0.04	0.01
Na_2O	1.07	3.76	3.97	3.22	3.32
K_2O	6.72	4.65	4.25	4.58	4.43
H_2O below 105°C	0.08	0.14	0.01	0.02	0.01
H_2O above 105°C	1.42	1.04	1.26	1.37	0.22
CO_2	0.09	0.06	0.01	0.01	0.01
BaO	0.26	0.28	0.25	0.13	0.30
CuO	-	-	-	-	0.01
MoO_3	0.11	-	-	-	0.02
PbO	0.01	-	-	0.01	0.01

BULKLEY INTRUSIONS								
	NC-67-39 SUNSETS CREEK	NC-68-6 GLACIER GULCH	NC-67-44 HUCKLEBERRY	NC-68-12 BEAR	NC-69-5 OX LAKE	JAN	ROCHER DE BOULE (average)	NADINA Microdiorit
SiO_2	65.44	70.98	66.98	63.52	64.22	60.86	64.58	57.92
Al_2O_3	16.39	13.58	15.37	15.74	16.36	17.53	15.74	17.74
Fe_2O_3	2.11	1.06	1.93	1.50	2.02	1.99	1.67	3.10
FeO	2.11	1.43	2.19	2.70	2.66	2.60	2.43	2.84
P_2O_5	0.35	0.20	0.33	0.26	0.19	0.19	0.20	0.22
CaO	3.59	1.87	2.12	3.15	2.53	4.72	4.48	-
MgO	1.31	0.43	1.53	1.66	1.97	1.86	1.97	6.13
TiO_2	0.60	0.32	0.49	0.53	0.58	0.47	0.57	1.40
SO_3	0.07	0.16	0.30	3.35	0.02	0.01	-	0.74
MnO	0.04	0.04	0.03	0.04	0.07	0.06	0.06	0.07
Na_2O	3.32	5.55	3.48	3.51	3.75	5.80	3.73	0.18
K_2O	3.53	4.08	3.30	1.98	2.45	2.44	2.81	3.61
H_2O below 105°C	0.01	0.03	0.12	0.04	0.27	0.28	0.10	3.25
H_2O above 105°C	0.85	0.20	1.36	2.15	2.78	0.65	1.49	0.11
CO_2	0.01	0.01	0.01	0.01	0.01	0.46	-	2.28
BaO	0.16	0.09	0.16	-	-	-	0.10	0.11
CuO	-	-	0.16	-	-	-	-	0.18
MoO_3	-	-	-	-	-	-	-	-
PbO	-	-	-	-	-	-	-	-

TABLE B.I (cont.)

	NANIKA INTRUSIONS				
	NC-67-10 BERG	NC-67-11 BERG	NC-67-14 RED BIRD	NC-68-7 NADINA MOUNTAIN	NC-69-6 GOOSLY
SiO_2	67.54	62.50	73.42	66.70	65.02
Al_2O_3	15.62	15.12	13.25	15.46	15.76
Fe_2O_3	1.16	1.64	0.29	1.74	2.12
FeO	0.76	0.85	0.32	1.71	1.54
P_2O_5	0.30	0.18	0.17	0.21	0.28
CaO	1.02	2.39	1.14	1.96	-
MgO	1.04	1.49	0.35	1.14	3.21
TiO_2	0.51	0.51	0.36	0.62	1.27
SO_3	1.92	4.53	0.08	0.01	0.65
MnO	0.02	0.06	0.01	0.09	0.01
Na_2O	2.76	3.13	2.97	3.69	0.04
K_2O	5.06	4.55	6.02	4.55	4.21
H_2O below 105°C	0.31	0.95	0.09	0.21	3.59
H_2O above 105°C	1.32	2.18	1.18	2.10	0.21
CO_2	0.02	0.01	0.01	0.02	1.69
BaO	0.12	-	0.13	-	0.08
CuO	0.38	-	0.03	-	0.18
MoO_3	-	-	0.04	-	-
PbO	-	-	0.01	-	-

	BABINE INTRUSIONS				GOOSLY INTRUSIONS	
	NC-67-1 OLD FORT	NC-67-4 GRANISLE	NC-67-23 NEWMAN	NC-67-40 MORRISON	NC-69-7 GOOSLY	PARROT LAKE
SiO_2	63.90	64.34	59.76	63.18	52.80	50.80
Al_2O_3	15.22	15.14	15.16	15.40	16.95	16.25
Fe_2O_3	2.60	2.43	2.23	1.97	3.97	5.00
FeO	1.97	2.74	2.60	3.02	3.63	2.28
P_2O_5	0.30	0.34	0.36	0.27	0.91	0.59
CaO	3.44	2.97	3.36	2.45	-	7.32
MgO	1.49	1.51	2.54	2.17	6.03	3.63
TiO_2	0.54	0.61	0.56	0.66	3.85	1.42
SO_3	0.82	0.35	3.13	1.78	1.82	1.55
MnO	0.03	0.02	0.01	0.04	0.01	0.10
Na_2O	4.32	4.59	4.88	3.91	0.14	4.79
K_2O	3.20	2.66	2.66	1.39	4.10	2.64
H_2O below 105°C	0.29	0.06	0.66	0.26	3.30	0.89
H_2O above 105°C	0.99	1.35	1.32	2.39	0.18	1.10
CO_2	0.02	0.01	0.08	0.01	1.90	1.15
BaO	0.28	0.18	0.18	1.08	0.02	0.28
CuO	0.23	0.29	0.39	-	0.27	0.12
MoO_3	0.23	-	-	-	-	-
PbO	0.01	0.02	-	-	-	-

TABLE B.2

MAJOR AND TRACE ELEMENT ANALYSES OF BIOTITES *

ALICE ARM INTRUSIONS

SPECIMEN NUMBER	LOCATION	MAJOR ELEMENTS (wt. per cent) CaO	Na_2O	K_2O	MgO	Fe	TiO_2	TRACE ELEMENTS (ppm) Cu	Mn	Zn	Rb
NC-67-38	British Columbia Molybdenum	.9	.5	9.2	14.7	12.8	3.7	60	2800	900	1350
NC-69-2	British Columbia Molybdenum	.8	.5	8.1	15.4	12.6	3.5	50	1450	540	1200
NC-67-33	Ajax	1.5	.6	8.0	12.1	15.2	3.9	60	2400	800	1000
NC-67-35	Roundy Creek	1.1	.5	7.1	6.1	19.0	3.2	10	5100	940	1200
NC-67-30	Bell Molybdenum	1.1	.5	7.0	12.3	15.3	3.5	20	2800	920	1000
NC-68-2	Bell Molybdenum	3.0	.6	5.2	12.7	14.6	3.5	30	2900	750	500
NC-67-45	Penny Creek	1.0	.7	7.4	8.4	17.0	3.5	55	4600	930	1500
NC-67-25	Ridge-Nass River	.9	.6	6.0	13.4	14.8	3.9	40	2190	700	700
NC-67-26	Valley-Nass River	1.2	.5	8.1	16.0	12.3	2.7	140	4100	1080	1500
NC-67-27	Kay-Nass River	1.8	.7	7.5	10.1	13.8	3.9	80	3450	1050	1200
COAST PLUTONIC COMPLEX											
NC-67-24	Mt. Priestly	4.3	.9	5.7	11.5	13.6	3.3	30	1930	620	850
NC-67-28	Nass River	1.1	.6	8.3	10.2	15.6	3.5	80	2160	690	950
NC-67-29	Alice Arm	1.2	.5	8.3	12.2	14.3	3.7	100	2950	750	1550
NC-69-3	Lava Lake	.8	.5	8.6	12.4	15.4	3.9	10	2640	700	1300

BULKLEY INTRUSIONS

SPECIMEN NUMBER	LOCATION	MAJOR ELEMENTS (wt. per cent) CaO	Na_2O	K_2O	MgO	Fe	TiO_2	TRACE ELEMENTS (ppm) Cu	Mn	Zn	Rb
NC-68-12	Laura	1.3	.7	7.6	13.6	13.2	4.0	650	1375	220	1250
NC-67-46	Rocher Deboule	1.4	.5	7.9	9.4	18.0	3.8	35	1730	680	1900
NC-67-41	Glacier Gulch	.4	.5	8.7	18.8	11.2	1.4	60	4650	460	6000
NC-68-6	Glacier Gulch	1.6	.5	6.9	13.8	13.4	4.0	70	3100	540	1950
NC-67-39	Sunsets Creek	1.2	.5	8.0	13.3	13.6	4.5	100	2750	600	1650
NC-67-44	Huckleberry	.6	.6	7.2	15.4	12.3	4.0	975	1450	430	1150
NC-69-5	Ox Lake	2.1	.5	4.8	15.6	13.6	4.6	900	2080	400	650

NANIKA INTRUSIONS

SPECIMEN NUMBER	LOCATION	MAJOR ELEMENTS (wt. per cent) CaO	Na_2O	K_2O^*	MgO	Fe	TiO_2	TRACE ELEMENTS (ppm) Cu	Mn	Zn	Rb
NC-67-8	Berg	3.8	.6	2.8	16.0	13.5	3.9	90	3020	580	200
NC-67-9	Berg	.6	.7	7.9	14.1	12.6	3.9	850	1000	610	800
NC-67-10	Berg	.7	.6	8.2	16.6	8.8	3.9	1410	610	450	750
NC-67-11	Berg	1.0	.9	8.4	17.0	8.9	4.4	425	550	250	1000
NC-67-13	Berg	1.4	.8	8.5	16.8	9.8	4.0	590	450	300	950
NC-67-7	Big Onion	3.3	1.1	4.9	13.6	11.3	5.0	900	1680	500	400
NC-67-19	Red Bird	.6	.7	9.5	17.4	9.6	3.2	320	890	500	1550
NC-67-20	Red Bird	1.1	.7	8.6	12.3	14.6	3.2	480	1900	600	750
NC-68-13	Mt. Thomlinson	1.0	.6	8.6	11.5	12.8	3.2	90	3000	450	1650
NC-68-7	Nadina Mountain	1.5	.7	7.5	14.3	13.1	4.3	25	3100	680	1350
NC-69-6	Goosly	.6	.5	8.3	14.4	12.8	4.5	10	1200	400	1300
NC-69-7	Goosly	1.1	.7	8.9	19.6	9.1	5.0	25	1000	400	1950

TABLE B.2 (cont.)

BABINE INTRUSIONS

SPECIMEN NUMBER	LOCATION	MAJOR ELEMENTS (wt. per cent) CaO	Na_2O	K_2O*	MgO	Fe	TiO_2	TRACE ELEMENTS (ppm) Cu	Mn	Zn	Rb
NC-67-4	Granisle	.5	.7	8.9	16.0	11.9	4.0	300	550	375	800
NC-67-5	Granisle	.9	.8	8.4	12.9	14.0	3.8	200	1060	735	700
NC-68-1	Granisle	1.2	.7	7.5	13.4	13.7	3.8	680	440	450	700
NC-69-8	Granisle	.9	.5	5.1	20.3	10.6	1.6	1860	590	590	600
NC-67-22	Newman	.9	.8	8.1	16.2	10.8	4.0	370	1080	560	850
NC-67-23	Newman	1.2	.8	8.4	16.6	10.7	4.0	1630	640	530	900
NC-67-40	Morrison	.9	.8	7.5	15.1	13.6	3.6	1300	730	430	1000
NC-67-1	Old Fort Mountain	1.1	.8	9.1	15.0	12.2	3.9	600	920	465	950
NC-67-2	Old Fort Mountain	2.4	1.6	7.4	12.6	13.9	3.8	300	3000	580	700

* Analyses carried out under the supervision of M. Osatenko, Cominco Research, Trail.

APPENDIX C. PORPHYRY COPPER AND/OR MOLYBDENUM DEPOSIT DESCRIPTIONS (INCLUDING POTASSIUM-ARGON SAMPLE LOCATIONS AND DESCRIPTIONS)

C.1 ALICE ARM INTRUSIONS AND ASSOCIATED MOLYBDENUM DEPOSITS

C.1.1 British Columbia Molybdenum (after Carter, 1964)

This property is situated on the southeast fork of Lime Creek, approximately 5 miles south of Alice Arm. Molybdenum mineralization was first identified in 1911 and several adits were driven in molybdenum mineralization and in marginal quartz veins containing lead, zinc, and silver prior to 1916.

In 1959, the property was acquired by Kennco Explorations, (Western) Limited who conducted some 45,000 feet of diamond drilling. Decision to equip the property for production was made in late 1964. Mining and milling began in late 1967. When the operation was suspended in mid-1972, some 10 million tons of material grading 0.15 to 0.20 per cent MoS_2 had been mined.

Molybdenite mineralization is associated with a small elliptical stock of quartz monzonite-quartz diorite composition which intrudes siltstones and greywackes of Late Jurassic-Early Cretaceous age (Fig. C.1). An appendage or extension is connected to the main stock on the eastern side. The main stock is composed of granitoid rocks of several types and ages, with a central zone of quartz monzonite porphyry grading to a quartz diorite on the western and southeastern sides. These rocks appear to have formed contemporaneously and are cut by later inter-mineral and post-mineral dykes and irregular bodies.

At least three types of quartz monzonite porphyry can be distinguished in the central part of the stock on the basis of degree of alteration. The

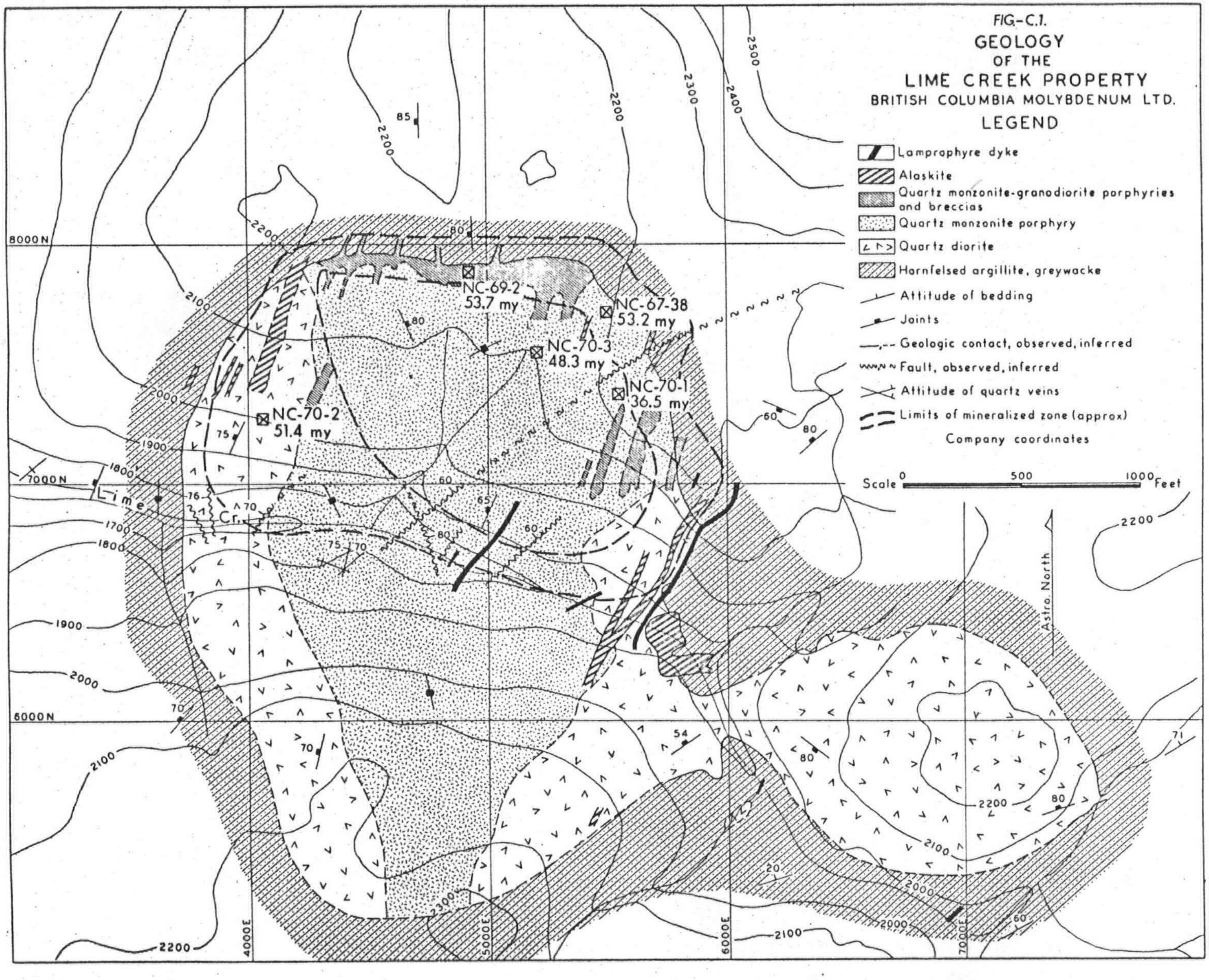

FIG.-C.1.
GEOLOGY
OF THE
LIME CREEK PROPERTY
BRITISH COLUMBIA MOLYBDENUM LTD.
LEGEND
Lamprophyre dyke
Alaskite
Quartz monzonite-granodiorite porphyries and breccias
Quartz monzonite porphyry
Quartz diorite
Hornfelsed argillite, greywacke
Attitude of bedding
Joints
Geologic contact, observed, inferred
Fault, observed, inferred
Attitude of quartz veins
Limits of mineralized zone (approx)
Company coordinates
Scale 0 500 1000 Feet
NC-69-2 53.7 my
NC-67-38 53.2 my
NC-70-3 48.3 my
NC-70-1 36.5 my
NC-70-2 51.4 my
Lime Cr.
Astro North
8000 N
7000 N
6000 N
4000 E
5000 E
6000 E
7000 E

rock is essentially a medium-grained leucocratic rock with euhedral to subhedral 4-millimetre phenocrysts of normally zoned plagioclase (An_{25-30}) and poikilitic K-feldspar making up the major portion of the rock volume. Hornblende and biotite are the chief mafic minerals.

The quartz monzonite grades through granodiorite to quartz diorite on the western and eastern sides of the stock. These are medium-grained white to grey massive rocks with only sparse phenocrysts of plagioclase. Abundant secondary biotite is a feature of these rocks.

Intrusive into both the quartz monzonite porphyries and quartz diorites and apparently confined to the northern half of the stock are irregular lenses and dykes of finer grained quartz monzonite and granodiorite porphyries and intrusive breccias. These are of inter-mineral age and commonly contain angular fragments of biotite hornfels, quartz monzonite porphyry, and quartz diorite in a fine-grained granulated matrix.

Fine-grained, white to pink equigranular alaskites are intrusive into all of the above-mentioned rock types. They consist essentially of anhedral quartz and K-feldspar and occur most commonly as dykes and irregular masses near the contact areas of the stock.

The latest granitic intrusive phase is represented in a nearly post-mineral quartz feldspar porphyry situated beneath the northern half of the stock. This rock type was intersected only in drilling several hundred feet below the original surface level, and it apparently terminates the ore-grade mineralization of the northeastern part of the ore zone.

Lamprophyre dykes which vary in width from 2 to 30 feet cut all rocks in the stock. These include both biotite and pyroxene varieties and have sharp, chilled contacts. The lamprophyre dykes occur in northeasterly trending swarms near the eastern contact.

Siltstones and greywackes adjacent to the stock have been thermally metamorphosed to biotite hornfels in a roughly circular zone 200 to 500 feet in width. The inner part of the hornfels aureole features a quartz-sericite bleaching of the biotite hornfels adjacent to quartz veinlets. Minor amounts of secondary contact metamorphic biotite are present within the sedimentary rocks in a zone 1,000 to 4,000 feet outward from the stock.

Alteration of granitic rocks includes secondary K-feldspar which rims mineralized quartz veinlets and occurs as 5-millimetre grains replacing plagioclase in the rock matrix. Secondary K-feldspar alteration in the central barren zone of the northern half of the stock has been so intense as to obliterate all traces of the original rock, converting it to an equigranular rock composed of quartz and pink orthoclase. Argillic and sericitic alteration of plagioclase feldspar is common in and adjacent to northeast-striking faults and shear zones.

The zone of molybdenum mineralization is a ring structure, elliptical in outline and elongated in an east-west direction (Figure C.1). The annular mineralized zone conforms roughly to the north, east, and west contacts of the stock, while the southern part of the zone cuts across the stock at its mid-point. Molybdenite content fades out toward the centre of the zone, with a central barren core containing little or no molybdenite.

Molybdenum mineralization occurs along the boundaries of one-eighth to one-quarter-inch quartz veinlets, and in hairline fractures. Disseminated molybdenite is found only in the alaskites. Quartz veinlets are closely spaced and appear randomly oriented in a stockwork pattern, but as a general rule, the majority of the veins are vertical and strike north-northeast. A second stage of molybdenite-bearing quartz veinlets strikes west-northwest. The quartz-molybdenite veinlets are cut by drusy, white quartz veins ranging up to 3 feet wide and containing pyrite, galena, sphalerite, neyite, scheelite, chalcopyrite, tetrahedrite, and pyrrhotite. Some fluorite and gypsum were also noted in these veins.

Higher grades of molybdenum mineralization occur in areas of intense fracturing and faulting particularly in the northeast contact area of the stock where the intensity of fracturing has also provided channelways for the later lamprophyre dyke swarms. Fractures and faults trend predominantly northeasterly with a subsidiary northwest fracture set.

Disseminated pyrite is widespread in quartz veins and rock matrices particularly marginal to the annular zone of molybdenum mineralization.

Locations of potassium-argon samples collected from the British Columbia Molybdenum deposit are shown on Figure C.1 and include the following:

NC-67-38 – Quartz Monzonite Porphyry

Sample is from the northeast part of the orebody. The sample is a leucocratic, medium-grained porphyritic rock cut by numerous quartz veinlets containing molybdenite and some pyrite. Making up 15 per cent of the rock are 1 to 2-millimetre phenocrysts or porphyroblasts of K-feldspar which occur marginal to quartz veinlets and replace plagioclase. The matrix contains abundant secondary quartz.

Biotite constitutes 7 per cent of the rock and occurs both as primary 0.5 to 1.0-millimetre plates and as finer grained aggregates on fractures which may be secondary. The biotite exhibits 10 to 15 per cent alteration to chlorite, principally along cleavage planes.

NC-69-2 – Quartz Monzonite Porphyry Intrusive Breccia

Sample is from a dyke cutting quartz monzonite porphyry in the northern part of the ore zone. The rock is leucocratic and contains 1-inch angular fragments of biotite hornfels in a porphyritic matrix. One to 2-millimetre subhedral phenocrysts of sericitized plagioclase (An_{25}) and K-feldspar make up 25 per cent of the rock. In thin section, these were seen to be broken crystals set in a very fine-grained granulated matrix of abundant quartz and subsidiary feldspar and biotite. Accessory minerals include epidote, apatite, sphene, and carbonate.

Biotite equals 5 per cent of the rock and occurs as 0.5 to 1.0-millimetre broken plates with up to 20 per cent chlorite alteration, and as very fine-grained aggregates which may be up to 50 per cent chloritized.

NC-70-2 – Quartz Diorite

Sample is from the west part of the ore zone. The quartz diorite is medium grey, equigranular, and contains coarse pyrite in fractures with quartz. The rock has a hypidiomorphic granular texture and consists of 1 to 2-millimetre euhedral, zoned plagioclase, 70 per cent; quartz, 15 per cent; K-feldspar, 5 per cent; biotite, 10 per cent; and metallics, 5 per cent.

Biotite occurs as 0.5 to 1.0-millimetre plates and as fine-grained aggregates which replace original hornblende. Biotite is essentially unaltered.

NC-70-3 – Quartz Monzonite Porphyry

Sample of this late porphyry phase was collected from drill core from a vertical depth 900 feet below the original surface level in the northeast section of the ore zone.

The rock is a fine to medium-grained porphyry with 2 to 4-millimetre phenocrysts of euhedral plagioclase (An_{25}), K-feldspar, and anhedral quartz which make up 25 per cent of the rock by volume. These are set in a fine-grained matrix of quartz, feldspar, carbonate, pyrite, and sphene.

Biotite constitutes 7 per cent of the rock and occurs primarily as 1-millimetre plates and books which are up to 30 per cent chloritized.

C.1.2 Bell Molybdenum (after Carter, 1967)

The Bell Molybdenum property is situated 6 miles southeast of Alice Arm. Molybdenum mineralization is associated with an elliptical stock of quartz monzonite porphyry which is elongate in an east-northeast direction and measures 2,200 by 1,100 feet (Fig. C.2). The stock intrudes a sequence of dark grey to black siltstones and greywackes which are thermally metamorphosed to biotite hornfels adjacent to the stock. Flat-lying olivine basalts of Pleistocene age and of variable thickness overlie the sedimentary rocks north and south of the stock.

Quartz monzonite porphyries of the stock include three major types. The main type, leucocratic quartz monzonite porphyry, occupies the central part of the stock. Two to 4-millimetre phenocrysts of quartz, plagioclase (An_{20-28}), and perthitic orthoclase make up 30 per cent of the rock, and are set in a fine-grained matrix of quartz and feldspar. Original biotite is bleached to

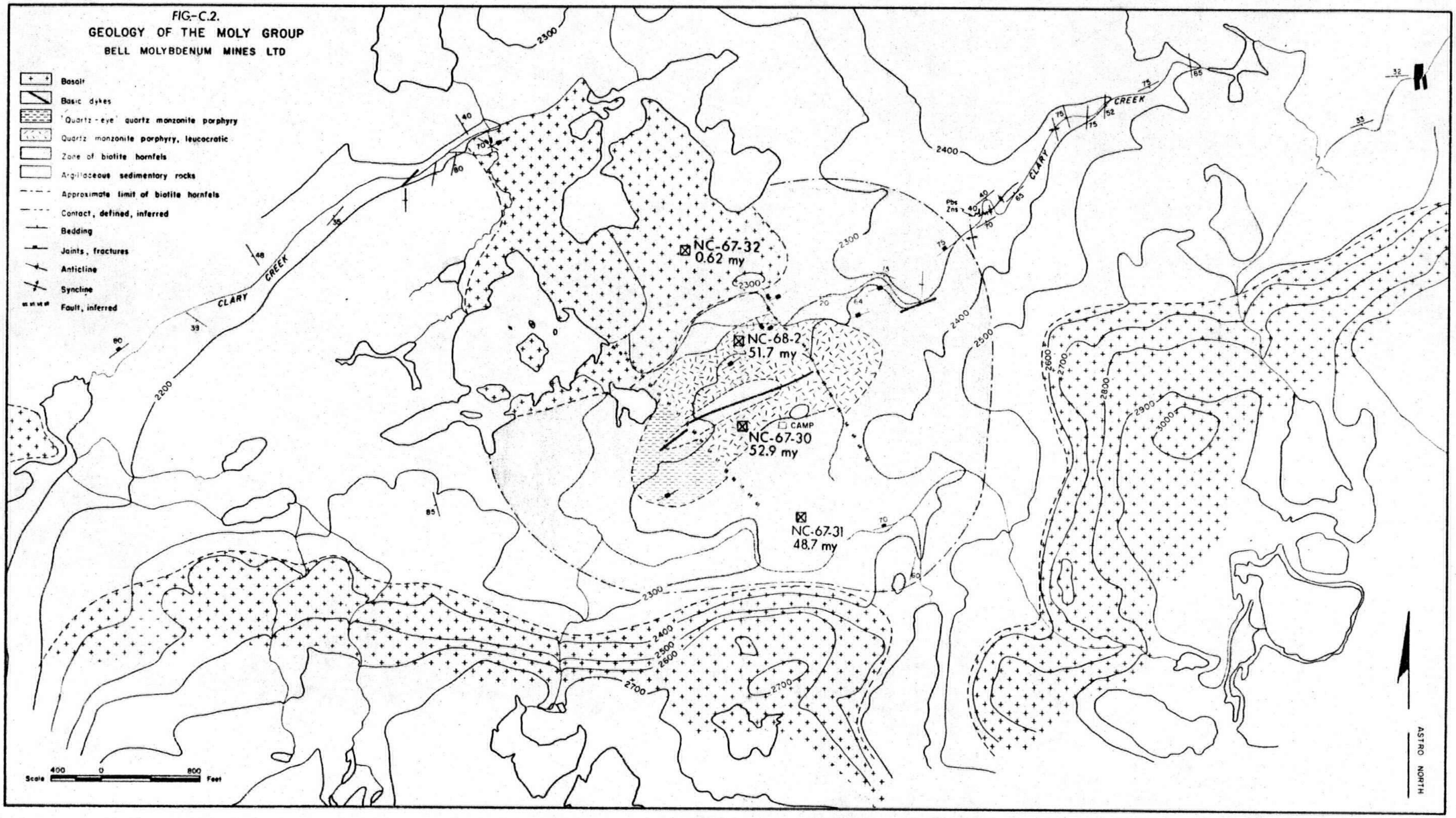

FIG.-C.2.
GEOLOGY OF THE MOLY GROUP
BELL MOLYBDENUM MINES LTD

a mixture of chlorite and sericite. Phenocrysts of euhedral orthoclase range up to 1 centimetre in size. Accessory minerals include sericite, carbonate, apatite, sphene, and pyrite.

Near the stock contacts and in dykes peripheral to the stock, the leucocratic quartz monzonite porphyry is gradational to a quartz monzonite or granodiorite porphyry. This rock contains a more calcic plagioclase, a lesser amount of orthoclase, and fresh biotite and hornblende.

The southwestern part of the stock is composed of a crowded 'quartz-eye' porphyry of distinctive appearance. Phenocrysts which make up 50 per cent of the rock by volume, include 4-millimetre quartz anhedra, 2 to 4-millimetre euhedral crystals of plagioclase, and randomly distributed 1 to 2-centimetre euhedral crystals of perthitic orthoclase. Average rock composition, which is similar to the leucocratic quartz monzonite porphyry, is: quartz, 27 per cent; plagioclase (An_{20-28}), 35 per cent; orthoclase, 25 per cent; biotite, 5 per cent; hornblende, 5 per cent; sphene, apatite, and opaques, 3 per cent. The distinguishing feature of this phase is its relative lack of alteration. A similar porphyry was encountered at depth in a drill hole near the central part of the stock where it appeared to have a gradational contact with the leucocratic quartz monzonite porphyry. The relative lack of quartz veinlets and fractures and attendant mineralization suggests that the 'quartz-eye' quartz monzonite porphyry represents a late, possibly post-mineral intrusive phase.

Narrow granitic dykes cut the leucocratic quartz monzonites in the central part of the stock. One drill-hole intersected 1-foot-wide dykes of fine-grained alaskite, consisting of interlocking grains of quartz, perthitic orthoclase, sericite, and some granophyre. Near the stock contacts, short sections of grey-green, fine-grained quartz monzonite porphyry breccias were noted. These cut the quartz monzonites and are distinguished by the presence of one-half-inch angular hornfels fragments in a granulated matrix. Narrow dykes of fine-grained light green quartz feldspar porphyry were noted in several drill holes.

Two varieties of basic dykes cut the granitic rocks of the stock. These include a fine to medium-grained porphyritic lamprophyre consisting of plagioclase, hornblende, and clinopyroxene, and fine-grained basalt and andesite dykes which are locally vesicular and may be related to the young lava flows nearby. Both varieties generally have a northeasterly strike and are 1 to 2 feet wide.

Sedimentary rocks have been contact metamorphosed to brown biotite hornfels a distance of between 1,200 and 1,500 feet outward from the stock contact. Near the contact, the hornfels is a dense fine-grained rock exhibiting a granoblastic texture and consisting of interlocking grains of quartz and biotite. Alteration of the biotite hornfels includes pale green chlorite-sericite bleaching marginal to fractures and quartz veinlets. Intensity of metamorphism decreases outward from the stock contact to colour-banded argillaceous sediments in which only certain beds contain secondary biotite.

Within the stock, the central leucocratic quartz monzonite porphyry exhibits the greatest degree of alteration. Most prevalent is sericite-carbonate alteration of plagioclase. In addition, plagioclase locally is altered to K-feldspar, particularly along the margins of quartz veinlets. Secondary reddish brown biotite was noted in both the 'quartz-eye' quartz monzonite porphyry and the quartz monzonite-granodiorite porphyry in the marginal areas of the stock. In both rock types, the original biotite has been altered to a mixture of chlorite and sericite. Intense argillic and sericite alteration is common in fault zones, as are chlorite-coated slip surfaces.

The major structural trends in the area of the porphyry stock are east-northeast and north-northwest, as reflected by the elongation of the stock itself, the strike of fractures, joints, faults, and basic dykes, and by the trend of creeks and airphoto lineaments. The stock contact, which dips steeply outward, is not well defined, rather it consists of a transitional zone of hornfels cut by numerous porphyry dykes. A large horse of hornfelsed sedimentary rocks within the stock, measuring 1,000 by 200 feet, parallels the long direction of the stock (Figure C.2) and is cut by numerous porphyry dykes. Drilling information suggests that this block of country rock decreases in size with depth.

Major faults preceded the period of intrusion and intersections of east-northeast and north-northwest faults and fractures were undoubtedly important in the localization of the stock. Later movement along these faults, particularly the north-northwest set, is documented by the apparent offsetting of the stock contacts along two major faults and by the presence of numerous post-mineral shears noted in drill cores (Figure C.2).

Molybdenum mineralization occurs in both the quartz monzonite porphyry and biotite hornfels adjacent to the central and eastern parts of the stock. The company has stated that drilling has indicated 35.8 million tons having an average grade of 0.11 per cent molybdenite (Carter, 1967a).

Molybdenite occurs mainly as selvages in one-eighth to one-quarter-inch steeply dipping quartz veinlets which follow major fracture directions. Three stages of quartz veining and mineralization have been noted. A first stage of barren quartz veinlets is followed by the second, the most important stage, consisting of quartz-molybdenite-pyrite veinlets which are steeply inclined. These are offset locally by flat quartz-molybdenite veins and hairline fractures. The third stage consists of 1-inch-wide and larger veins of quartz and carbonate which contain variable amounts of pyrite, pyrrhotite, galena, and sphalerite. In Clary Creek, 1,500 feet east of the stock, a 10-inch-wide quartz-carbonate vein containing pyrite, pyrrhotite, galena, and sphalerite was noted in a shear zone in argillaceous sediments. The quartz monzonite porphyries and biotite hornfels contain abundant disseminated pyrite and pyrrhotite.

Three samples for potassium-argon dating were collected from and adjacent to the Bell Molybdenum stock. Locations are shown on Figure C.2.

NC-67-30 – 'Quartz-eye' Quartz Monzonite Porphyry

Sample is from the late, possibly post-mineral porphyry phase and was collected from drill core from a hole in the central part of the stock.

Fifty per cent of the rock consists of 4-millimetre phenocrysts of euhedral plagioclase (An_{20-26}), anhedral quartz, and occasional 1-centimetre K-feldspar crystals. The rock contains both hornblende and biotite. Hornblende exhibits incipient alteration to biotite.

Primary biotite occurs as 1-millimetre plates and books which contain up to 15 per cent chlorite alteration.

NC-67-32 – Biotite Hornfels

Sample was collected from drill core recovered from a hole south of the stock but within the contact metamorphic aureole. The hornfels is fine grained and is a uniform brown colour. Numerous one-sixteenth-inch quartz veinlets cut the rock.

In thin section, the rock has a granoblastic texture and consists of a very fine-grained mosaic of quartz and subhedral biotite. The original rock was probably an argillaceous microgreywacke. Biotite constitutes 15 per cent of the rock and is unaltered.

NC-68-2 – Granodiorite Porphyry

Sample is from the border phase of the stock and is a core sample collected from a drill hole near the northern contact.

The rock is cut by one-eighth-inch quartz-molybdenite veinlets and is a medium grey colour. Phenocrysts of euhedral plagioclase (An_{32-40}), 1 to 2 millimetres in size, constitute 20 per cent of the rock by volume. These are set in a finer grained matrix of quartz, plagioclase, K-feldspar, biotite, hornblende, and chlorite.

Biotite occurs as 0.5 to 1.0-millimetre shredded plates which feature only incipient chlorite alteration. Very fine-grained shredded biotite in the matrix appears secondary after hornblende.

C.1.3 Ajax (after Carter, 1966)

The Ajax property is on the east slope of Mount McGuire, 8 miles northeast of Alice Arm.

Argillaceous sedimentary rocks and some interbedded volcanics are intruded by four small closely spaced stocks of quartz monzonite porphyry in the central part of the claim group (Fig. C.3). Molybdenum mineralization occurs both in the intrusive rocks and adjacent hornfelsed sedimentary rocks.

Black argillites, siltstones, and microgreywackes, which strike north-northwest and dip steeply east, underlie most of the eastern half of Mount McGuire. At lower elevations, calcareous argillites and buff-coloured limy siltstones were noted. Dark grey to black argillaceous sedimentary rocks in all parts of the area contain 2 per cent 0.05-millimetre plates of brown biotite and up to 5 per cent pyrite and pyrthotite as fine disseminations and as coatings on fracture planes. With increasing proximity to the quartz monzonite porphyry stocks, the sediments grade to biotite hornfels.

Augite andesites, weathering a reddish brown colour, occur as 3-foot-thick interbeds within the sedimentary rocks. A larger area of volcanic rocks, on the west slope of Mount McGuire, consists of purple tuffs and breccias.

Intrusive rocks, in the form of four small stocks of quartz monzonite porphyry, are grouped close together in a 2,500-foot-square area in the central part of the claim group between 3,000 and 4,200 feet elevation. The stocks are roughly rectilinear in plan, and the largest, the most southerly one, is elongate in a north-northwesterly direction, measuring 1,500 to 1,000 feet. The remaining three measure 1,000 by 500 feet and are elongate in an east-northeast direction. The area between the stocks features an abundance of dykes of similar composition. The largest stock and the one immediately northwest of it are composed of leucocratic white to pink quartz feldspar porphyry. Twenty-five to 30 per cent of the rock consists of 3 to 6-millimetre phenocrysts of anhedral quartz, subhedral sericitized plagioclase, and ragged perthitic orthoclase in a fine-grained matrix of quartz, feldspar, and sericite.

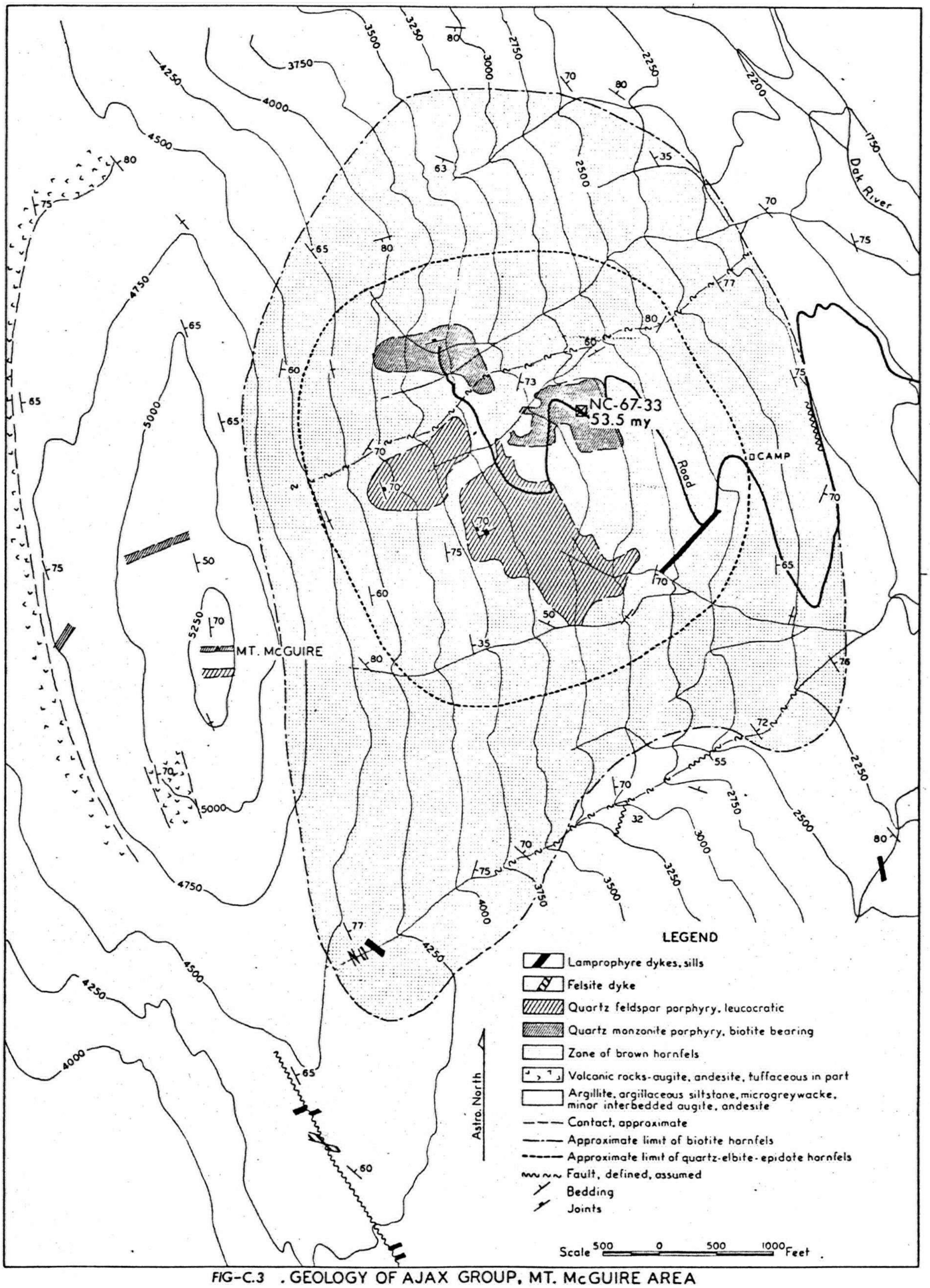

FIG-C.3 . GEOLOGY OF AJAX GROUP, MT. McGUIRE AREA

Sericite, in part an alteration of original biotite, is the major mafic mineral. One-eighth to one-quarter-inch quartz veinlets are common.

The other two intrusive bodies, which are essentially a network of closely spaced east-northeast and north-northwest dykes, are of similar composition, but differ from the quartz feldspar porphyries by being medium grey in colour and by having a biotite content of between 7 and 10 per cent, and some chlorite and hornblende. Two to 4-millimetre phenocrysts of quartz and normally zoned oligoclase-andesine make up 25 per cent of the rock. In contrast to the quartz feldspar porphyries, plagioclase is essentially fresh and K-feldspar is largely restricted to the matrix. Some of the narrow dykes have a seriate texture.

Dykes of quartz feldspar porphyry and biotite-bearing quartz monzonite porphyry, striking east to east-northeast and not exceeding 25 feet in width, cut sedimentary rocks on top of Mount McGuire. Felsite dykes, porphyritic in part and containing some disseminated pyrite, were noted south of the main area of intrusive rocks.

Northeast-striking 6-foot-wide dykes of fine-grained hornblende and biotite lamprophyres were noted south and east of the quartz monzonite porphyry stocks. These weather a brown colour, have chilled contacts, and are of post-mineral age.

Contact metamorphism associated with the intrusion of the porphyry stocks has converted a large area of sedimentary rocks in the central part of the property to brown and purple-coloured biotite hornfels. The hornfels zone surrounding the stocks, elongate in a north-northwest direction and measuring 7,000 to 5,000 feet, is gradational outward from a fine-grained granoblastic textured rock consisting of anhedral quartz and biotite to an alternating sequence of banded black argillite and brown hornfels. The biotite hornfels is featured by closely spaced fracturing and widespread limonite stain due to abundant disseminated pyrrhotite and pyrite. The inner zone of hornfels, extending outward from the stocks a distance of between 500 and 1,000 feet, has been affected by a more intense alteration, resulting in the transformation of biotite hornfels to a pale green fine-grained quartz-albite-epidote hornfels. In the outer part of this zone, hairline fractures in biotite hornfels containing quartz and actinolite and lesser amounts of clinopyroxene and pyrrhotite are rimmed by 4-millimetre-wide zones of quartz-albite-epidote hornfels. Adjacent to and between the four stocks, where fracturing is most intense, quartz-albite-epidote hornfels has almost completely replaced biotite hornfels, and is probably a reflection of the degree of quartz veining and silicification within and adjacent to the intrusive rocks coupled with higher temperatures prevailing near the contacts. East of the stocks, near the outer limits of the zone of quartz-albite-epidote hornfels, a narrow band of limestone contains 4-millimetre porphyroblasts of pink garnet.

The effects of contact metamorphism on interbedded augite andesites includes partial to complete alteration of original clinopyroxene to fibrous actinolitic hornblende and sericitization of plagioclase.

Alteration of the intrusive rocks, which is most widespread in leucocratic quartz feldspar porphyries, includes sericitization of plagioclase phenocrysts, alteration of biotite to muscovite, and development of ragged porphyroblasts of K-feldspar. Flakes of biotite in the quartz monzonite porphyries may be of secondary origin. Drilling information indicates light grey prevasive silicification adjacent to quartz veinlets in deeper parts of the intrusive bodies.

Sedimentary and volcanic rocks underlying Mount McGuire are part of the steep east limb of a regional anticlinal structure. East and west of the porphyry stocks, strikes are uniformly north-northwest, while attitudes north and south of the stocks indicate contortion of the sediments along strike. Attitudes adjacent to the stocks suggest the presence of a large dragfold modified by doming associated with the intrusion of the stocks.

Most creeks on Mount McGuire follow faults which strike north-northwest and east-northeast. The rectilinear nature of the porphyry stock contacts, which follow steep fractures, and the trends of smaller dykes reflect the north-northwest and east-northeast fault and fracture pattern and indicate the importance of major faults in the localization of the stocks.

Pyrrhotite and lesser amounts of pyrite coat fracture planes and occur as fine disseminations in the sedimentary rocks on the east slope of Mount McGuire. Pyrrhotite is particularly widespread in the intrusive rocks and adjacent altered sedimentary and volcanic rocks. Limonite staining is prominent.

Molybdenum mineralization occurs in both the intrusive rocks and in the marginal zone of hornfels affected by quartz-albite-epidote alteration. The most common form of occurrence is that of fine-grained quartz and molybdenite coating randomly oriented, hairline fractures. Disseminated molybdenite also occurs in a stockwork of one-eighth to one-quarter-inch quartz veinlets and in the silicified zones in the deeper parts of the stocks. At least two stages of quartz-molybdenum mineralization follow an initial stage of quartz-pyrrhotite mineralization. The latest stage of mineralization is represented by coarse-grained quartz veins several inches wide, containing sphalerite and lesser amounts of pyrite, galena, and chalcopyrite. On surface these veins strike north-northeast and dip to the west at shallow angles.

One sample for potassium-argon dating was collected from the Ajax property and the location is shown on Figure C.3.

NC-67-33 – Granodiorite Porphyry

Sample was collected from a roadcut in the easternmost of the four small stocks.

The granodiorite is a mesocratic porphyritic rock in which fresh, euhedral, zoned plagioclase (An_{25-30}) phenocrysts constitute 30 per cent. These are set in a fine-grained matrix of quartz and feldspar. Hornblende is uniformly distributed through the matrix and displays partial alteration to biotite.

Primary biotite books, 1 to 2 millimetres in size, amount to 7 per cent of the rock and are poikilitic, displaying only incipient chlorite alteration.

C.1.4 Roundy Creek (after Carter, 1964, 1968, 1970, 1971)

This property is south of Alice Arm Inlet on Roundy Creek, 1.5 miles from tidewater.

Molybdenum mineralization is associated with a small, elongate composite intrusion of quartz monzonite porphyry. The intrusion is stock-like in part and has been segmented by northwest faults along and adjacent to Roundy Creek (Figure C.4).

The intrusion consists of a number of recognizable phases, which are of similar compostion. The most widespread of these is a leucocratic 'quartz-eye'

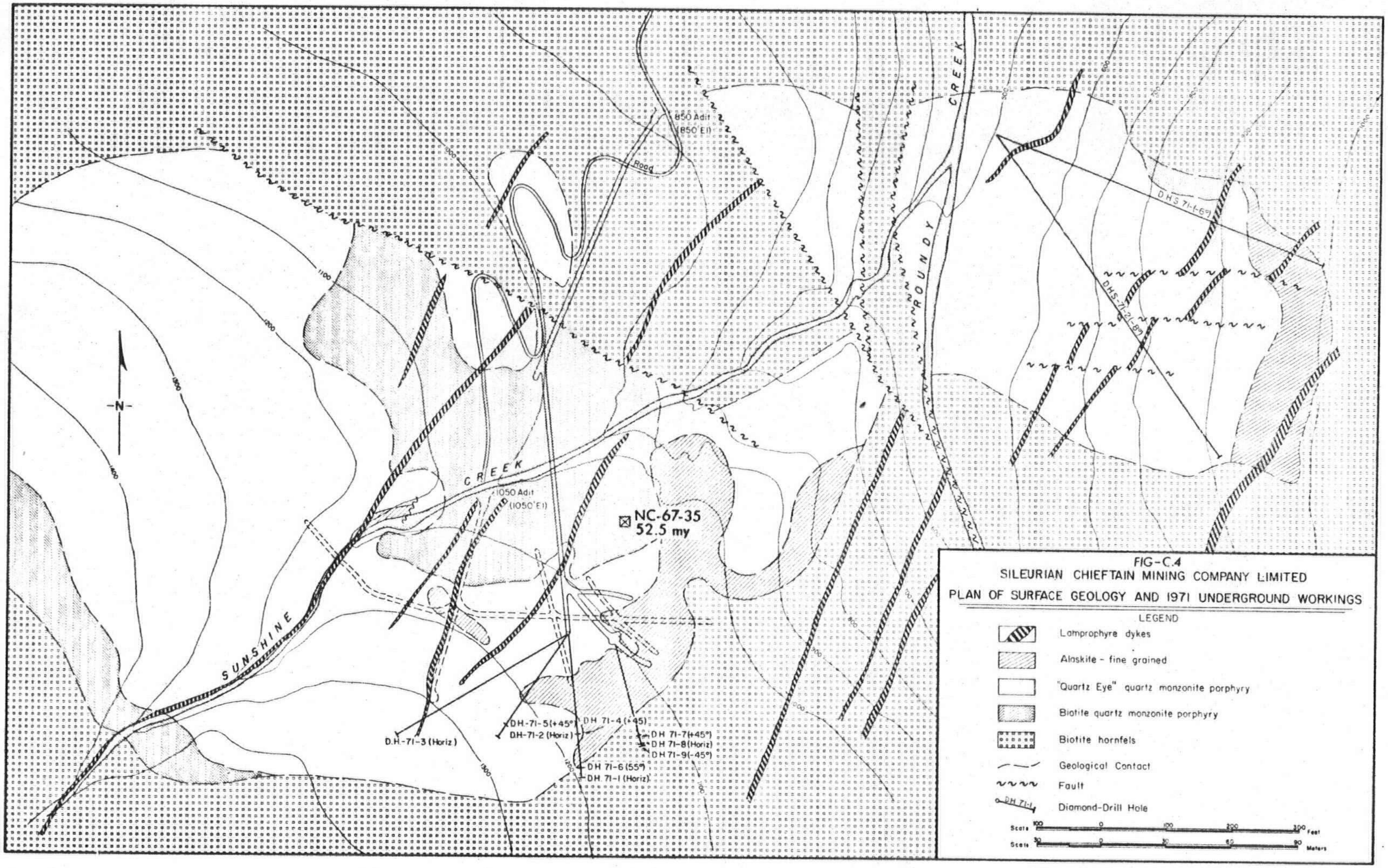

FIG-C.4
SILEURIAN CHIEFTAIN MINING COMPANY LIMITED
PLAN OF SURFACE GEOLOGY AND 1971 UNDERGROUND WORKINGS

quartz monzonite porphyry which forms the core of the intrusion. Twenty-five per cent of the rock is composed of 2 to 4-millimetre phenocrysts of subhedral quartz, perthitic K-feldspar, and euhedral plagioclase (An_{28-32}), which are set in a very fine-grained matrix of quartz and feldspar. The rock contains only minor biotite, with sericite being the chief mafic mineral. Where intensely sheared and fractured, the 'quartz-eye' quartz monzonite porphyry grades into brecciated quartz monzonite in which feldspar phenocrysts are partially broken down and the many randomly oriented fractures are coated with chlorite, sericite, carbonate, and molybdenite.

The 'quartz-eye' quartz monzonite porphyry is apparently gradational to biotite-quartz monzonite and is most abundant in the central and border areas of the intrusion. This rock type has a seriate texture and consists essentially of 2 to 4-millimetre grains of quartz, fresh euhedral plagioclase (An_{28}), and perthitic orthoclase, plus scattered flakes of biotite which are partially altered to chlorite and sericite.

Dykes and irregular masses of fine-grained white alaskite cut all of the aforementioned rock types. Alaskites consist of a fine-grained mosaic of quartz, sodic plagioclase, granophyre, and some sericite. In some areas the alaskite is gradational to a quartz feldspar porphyry.

A late intrusive phase is represented by narrow dykes of fine-grained, light grey biotite-quartz monzonite which were seen in one of the underground levels and in a few drill holes. The last phase contains only trace amounts of molybdenite.

Narrow, northeast-striking and steeply dipping hornblende and biotite lamprophyre dykes cut all granitic rocks and mineralized veinlets and fractures. Many terminate at, or are offset by, northwesterly trending faults (Figure C.4).

Sedimentary rocks have been contact metamorphosed to biotite hornfels in a zone roughly 200 feet wide surrounding the intrusion. Structural relationships of the intrusion are complex. In addition to the faulted segments in plan, drilling evidence indicates inward dipping intrusive contacts suggesting that parts of the intrusive may be sheet-like in form about a central feeder pipe. The eastern segment is apparently tabular in section.

Alteration of the intrusive rocks includes a potassic zone, which is best developed within and marginal to better grades of molybenum mineralization. Potassic alteration occurs as abundant sericite and lesser biotite-coated fracture planes particularly in the leucocratic quartz monzonite porphyry. Secondary biotite, principally on fractures, is best developed in the biotite-quartz monzonite peripheral to the main zones of mineralization.

Two zones of molybdenum mineralization are known within the intrusive. The eastern segment is host to uniform grades of molybdenite occurring as selvages in numerous randomly oriented quartz veinlets and as fracture fillings. Drilling has indicated the presence of 7 to 8 million tons of 0.11 per cent molybdenite in this zone.

High-grade molybdenum mineralization occurs along and south of Sunshine Creek (Figure C.4) where drilling and underground work has indicated 1.5 million tons of 0.347 per cent molybdenite in the southern zone and some 39,000 tons grading 0.668 per cent in a small zone explored on the north side of Sunshine Creek.

In both zones, higher grades of molybdenum mineralization are contained in alaskites. On the 1050 level (Figure C.4), closely spaced parallel one-quarter to one-half-inch bands of molybdenite are crudely parallel to the trend of the enclosing alaskite body. One-quarter-inch rosettes of molybdenite also are uniformly distributed in the alaskite. Molybdenite also occurs in numerous randomly oriented hairline fractures with chlorite in brecciated quartz monzonite and in closely spaced one-eighth to one-quarter-inch quartz veinlets in alaskites and leucocratic 'quartz-eye' quartz monzonite porphyries.

Drilling and underground exploratton indicate that the zones of molybdenum mineralization are lens-like in form and extremely erratic in lateral and vertical extent. The distribution of the higher grade zones suggests they are spatially related to the intrusive centre or feeder pipe.

One sample was collected from the Roundy Creek intrusion, the location of which is shown on Figure C.4.

NC-67-35 - Biotite Quartz Monzonite

Sample was collected from a drill hole in the central part of the intrusion. The rock is leucocratic, has a seriate texture, and is featured by flakes of reddish brown biotite which make up 10 per cent of the rock. Feldspars are equally divided between perthitic K-feldspar and plagioclase (An_{25}) and are essentially unaltered.

Biotite occurs as 0.5 to 1.0-millimetre shredded plates which display only incipient chlorite alteration along cleavage planes.

C.1.5 Molly Mack (after Carter, 1965)

The Molly Mack property is situated on the west shore of Observatory Inlet near the south end of Granby Point, 15 miles west of Alice Arm (Figure 19).

The main mineralized showing is at sea level immediately south of the contact between granitic rocks and sedimentary rocks to the north. South and west of the showing, leucocratic quartz monzonite porphyries form low ridges and weather to a uniform near white colour. Two-millimetre phenocrysts of anhedral glassy quartz and euhedral feldspars make up most of the rock, with muscovite as the dominant mafic mineral. Sedimentary rocks in the area have been metamorphosed to a biotite-quartz hornfels and are cut by numerous 1-foot-wide sills of fine-grained quartz monzonite near their contact with the quartz monzonite porphyry.

The main zone of molybdenum mineralization is confined to a small area of biotite-rich granite within the quartz monzonite porphyries. The granite, which consists essentially of anhedral quartz, subhedral perthitic K-feldspar, and coarse flakes of biotite, contains irregular inclusions of hornfelsed sediments and is cut by lenses of quartz monzonite porphyry and fine-grained felsite dykes. Coarse-grained molybdenum mineralization within this zone occurs along the biotite cleavages and near the margins of 1-foot-wide quartz veins and lenses. The zone is oriented in a north-south direction and measures 4 by 10 feet. A chip sample from the zone assayed 12.7 per cent MoS_2 with trace amounts of copper and lead. A few specks of molybdenite were noted in the intrusive rocks to the north and south of the main showing.

NC-68-11 – Biotite Granite

Sample is from a test pit near tide line and is a medium-grained, foliated granitic rock in which coarse grains of molybdenite are interleaved with biotite. The rock has a hypidiomorphic granular texture and consists of subhedral, perthitic K-feldpsar and microcline, 60 per cent; anhedral quartz, 10 per cent; finer grained interstitial sodic plagioclase, 5 per cent; biotite, 20 per cent; and epidote and apatite, 2 per cent.

The biotite is acicular, occurring as 1 to 2-millimetre plates and appears to have been introduced along fractures. Only minor chlorite alteration was noted.

C.1.6 Nass River Molybdenum Deposits (after Carter, 1967)

Four small molybdenite-bearing quartz feldspar porphyry stocks intrude argillaceous sedimentary rocks near their contact with the Coast Plutonic rocks along the south side of the Nass River. The stocks are clustered around the western edge of a thin, Recent lava flow (Figure C.5).

The Snafu property is situated directly south of the lava field. In the central part of the claim group, a subcircular stock of quartz feldspar porphyry, roughly 3,500 feet in diameter, intrudes northeast-striking, banded argillaceous sediments. A smaller mass of similar intrusive rock outcrops northwest of the main stock. The porphyry is typically leucocratic and is of quartz monzonite composition. Phenocrysts constitute 40 per cent of the rock and include 1 to 2-centimetre euhedral crystals of perthitic orthoclase and 4-millimetre euhedral grains of plagioclase (oligoclase) and subhedral quartz crystals which are set in a very fine-grained matrix of quartz, feldspar, and biotite. The rock is essentially fresh, with only minor silicification and secondary K-feldspar occurring adjacent to some quartz veinlets. Iron oxide staining is widespread, due to the presence of finely disseminated pyrite and pyrrhotite. Fine-grained dykes of alaskite, consisting of interlocking anhedral

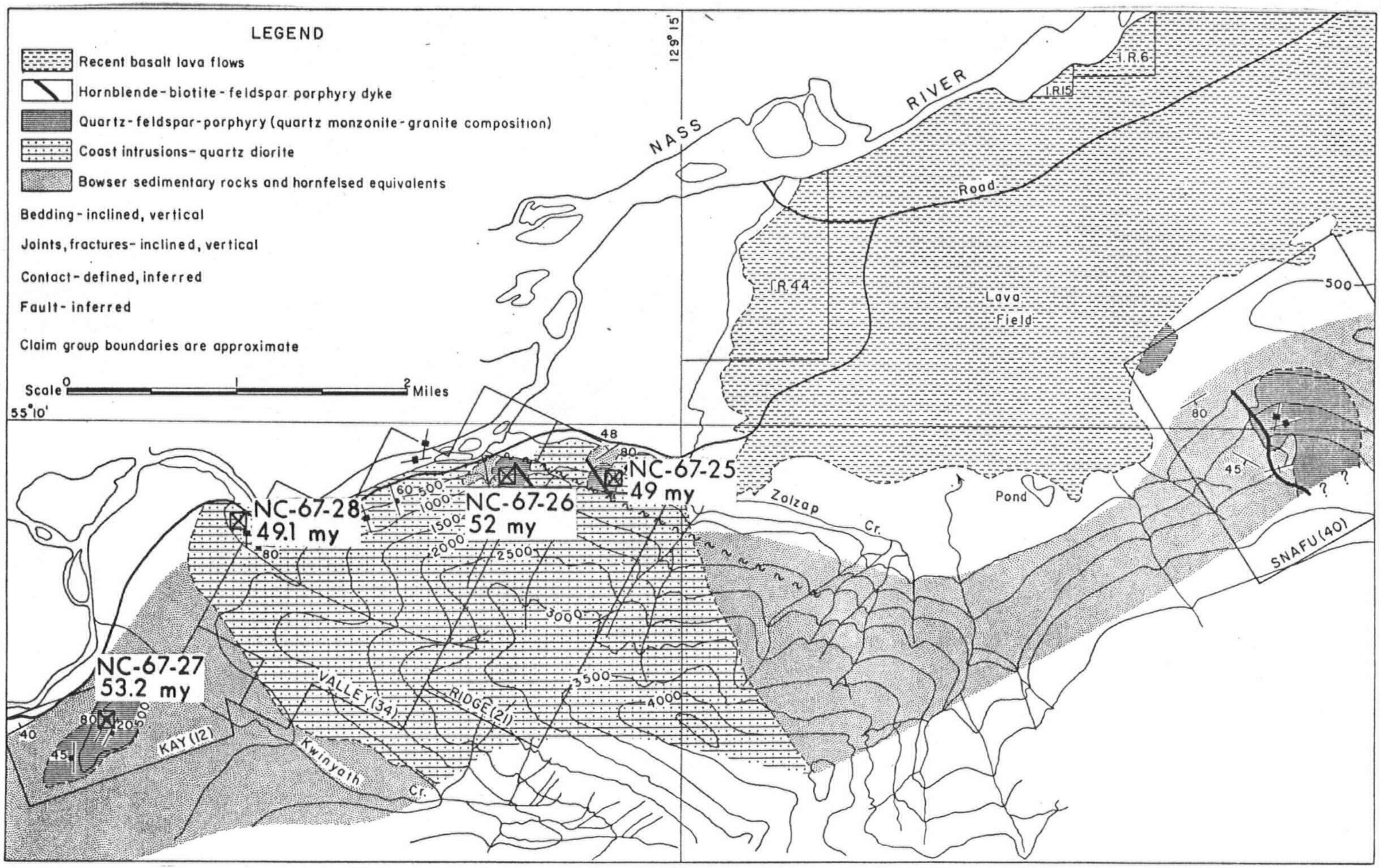

FIG-C.5 Nass River Mines Limited. Geology of the Kay, Valley, Ridge, and Snafu groups.

grains of quartz and microgranophyre, follow northeast and northwest fractures in the porphyry near the west contact of the stock. In the same area a 100-foot-wide northwest-striking dyke of grey hornblende-biotite feldspar porphyry of quartz-diorite composition cuts both the quartz feldspar porphyry and adjacent hornfelsed sediments. Numerous small screens of hornfels were noted within the stock near the irregular west-central contact, and peripheral dykes of porphyry are locally abundant. Molybdenite occurs in northeast and northwest fractures and quartz veinlets in quartz feldspar porphyry, alaskite, and hornfelsed sediments along the western stock contact.

The Valley and Ridge properties are situated 4 miles west of the Snafu showing (Figure C.5). Two small circular stocks of porphyritic granite 1,000 feet in diameter occur 2,000 feet apart on opposite sides of a west-northwest-trending topographic lineament which is probably a fault. The stocks, while partially enclosed in quartz diorite of the Coast Plutonic Complex, also are in contact with hornfelsed sedimentary rocks along their northern contact. The granites have a seriate to porphyritic texture and consist essentially of quartz and microcline perthite with only minor plagioclase (oligoclase) and scattered flakes of biotite. Near the northwest contact of the stock on the Ridge group, the granite is gradational to quartz monzonite. Narrow dykes of fine-grained alaskite cut the Valley stock near its western contact. Dykes of hornblende-biotite feldspar porphyry, 100 feet wide and striking northwest, cut the granites in both the Valley and Ridge stocks. These are post-mineral in age and are similar to the late dyke on the Snafu group. The Coast quartz diorite is typically a grey medium-grained equigranular rock consisting mainly of fresh, zoned plagioclase (oligoclase-andesine) with lesser amounts of quartz, hornblende, and biotite.

Molybdenum mineralization is exposed in trenches near the central part of the Valley stock, where it occurs as fine disseminations, irregular coarse replacements, and in northwest fractures in porphyritic granites and alaskite dykes. Iron oxide staining is widespread.

The Kay property is 3 miles southwest of the Valley and Ridge prospects on the Greenville road (Figure C.5). The claims cover an elliptical stock of quartz feldspar porphyry, elongate in a northeasterly direction and measuring 4,000 by 1,200 feet. The stock underlies a prominent ridge which is bounded by steep cliffs at its northern end. The leucocratic quartz feldspar porphyry is of quartz monzonite composition, and 0.4 to 2-centimetre phenocrysts make up between 20 and 50 per cent of the rock. These include euhedral perthitic orthoclase and microcline plus quartz and plagioclase (oligoclase) which are set in a fine-grained quartzofeldspathic matrix containing some biotite. Prominent sheeting in the intrusive strikes north and dips moderately to the west. Contacts between the intrusive and adjacent biotite hornfels were observed only at the base of the steep cliff at the northeast end of the stock. Quartz feldspar porphyry containing coarse rosettes of molybdenite was observed in several trenches near the central part of the stock. Diamond drilling in 1969 indicated the presence of late, possible post-mineral, fine-grained grey porphyry dykes which cut the leucocratic quartz feldspar porphyry.

The following potassium-argon samples were collected from the Nass River molybdenum prospects. Locations are shown on Figure C.5.

NC-67-25 – Hornblende-biotite Feldspar Porphyry

Sample is from a post-mineral porphyry dyke which cuts quartz monzonite porphyry at the Ridge prospect.

The rock, of quartz diorite composition, is a light grey porphyry with 25 per cent of the rock consisting of 4-millimetre phenocrysts of plagioclase (An_{20-35}), biotite books, and hornblende needles set in a very fine-grained matrix of quartz and feldspar. Corroded quartz phenocrysts are also present.

Hornblende is completely altered to chlorite and biotite, and biotite displays incipient to 50 per cent alteration to chlorite, principally along cleavage planes.

NC-67-26 – Porphyritic Granite

Sample was collected from a test pit on the Valley prospect. The granite is a pink colour and has occasional resorbed quartz eyes as phenocrysts. Major constituents are subhedral microcline and perthitic K-feldspar.

Biotite amounts to 7 per cent of the rock and occurs as fresh 0.5-millimetre discrete grains scattered through the matrix. Molybdenite occurs in close association with biotite, principally along cleavage planes.

NC-67-27 – Quartz Monzonite Porphyry

Sample is from a test pit near the central part of the Kay prospect. The rock is pink to white and has a porphyritic texture with 1-centimetre phenocrysts of poikilitic and perthitic K-feldspar contained in a medium-grained matrix of microcline, plagioclase, and quartz. Molybdenite is disseminated in the matrix.

Biotite displays only incipient alteration to sericite and epidote and occurs as 1-millimetre shredded flakes throughout the rock matrix.

C.1.7 Coast Plutonic Complex - Alice Arm-Nass River

Penny Creek

The Penny Creek prospect is situated within the Coast Plutonic Complex, 16 miles south of Alice Arm (Figure 19).

The principal showings are in a cirque near the headwaters of Penny Creek. Medium-grained quartz diorites of the Coast Plutonic Complex are cut by drusy quartz veinlets containing rosettes of molybdenite. The sparse mineralization is apparently marginal to a younger, equigranular, pink granite exposed near the head of the cirque.

NC-67-45 - Granite

Sample was collected from near the head of the cirque and is a leucocratic medium-grained pink rock which consists of quartz, 20 per cent; perthitic K-feldspar, 72 per cent; biotite, 3 per cent; opaque minerals, 2 per cent; and epidote and sphene, 3 per cent.

Biotite occurs as 1-millimetre plates and exhibits only incipient alteration to chlorite.

Dawson Ridge

Sparse amounts of molybdenum mineralization are associated with veins and dyke-like masses of alaskite and pegmatite, which cut equigranular quartz monzonites and quartz diorites near the summit of Dawson Ridge, near the headwaters of Roundy Creek (Figure 19).

NC-67-29 – Quartz Monzonite

Sample is a leucocratic medium-grained rock in which plagioclase (An_{28-32}) makes up 40 per cent; K-feldspar, 28 per cent; biotite, 8 per cent; hornblende, 5 per cent; and accessories, including sphene and magnetite, 5 per cent.

Biotite plates are 1-millimetre size and exhibit some alteration (10 to 20 per cent) to chlorite.

Mount Priestly

Mount Priestly, 8 miles east of Aiyansh on the Nass River (Figure 19), is underlain by a granitic stock related to the Coast Plutonic Complex. Light grey, medium-grained, equigranular quartz diorites near the peak of the mountain contain some disseminated molybdenite in fractures.

NC-67-24 – Granodiorite

The sample is a mesocratic, medium-grained, equigranular rock, having a hypidiomorphic granular texture and consisting of euhedral, fresh, zoned plagioclase (An_{20-28}), 57 per cent; interstitial quartz, 15 per cent; green hornblende, 10 per cent; biotite, 7 per cent; K-feldspar, 5 per cent; and apatite, sphene, and opaques, 5 per cent.

Biotite occurs as 1-millimetre plates which show only incipient chlorite alteration. Some biotite also occurs as a deuteric alteration of hornblende.

Nass River

Granitic rocks of the Coast Plutonic Complex are well exposed in roadcuts between the Valley and Kay molybdenite prospects on the south side of the Nass River (Figure 21).

NC-67-28 – Quartz Diorite

The sample is a mesocratic, medium-grained rock with hornblende and biotite as mafic minerals. The rock is of quartz diorite composition, has a hypidiomorphic granular texture, and consists essentially of euhedral, fresh, zoned plagioclase (An_{28-35}) with interstitial quartz and 1 to 2-millimetre grains of fresh hornblende and biotite.

Biotite makes up 10 per cent of the rock and exhibits only very minor chlorite alteration.

Lava Lake

Coat Plutonic Complex rocks are exposed in a roadcut near the southeast side of Lava Lake, 15 miles south of the Nass River (Figure 19).

NC-69-3 – Quartz Monzonite

Sample is leucocratic and contains abundant 2-millimetre plates of biotite. Fresh plagioclase (An_{25}) and K-feldspar occur in nearly equal proportions and quartz is interstitial. Green hornblende is partially altered to chlorite.

Biotite makes up 10 per cent of the rock and is only weakly altered to chlorite.

C.1.8 Lamprophyre Dykes

NC-70-1 – Biotite Lamprophyre

Sample is from a 1-foot-wide, northeast-striking, steeply dipping dyke which intrudes quartz monzonite porphyry in the northeast part of the British Columbia Molybdenum ore zone.

The rock is fine grained, dark grey, and slightly magnetic with 1 to 2-millimetre carbonate amygdules. Forty per cent of the rock is made up of fresh brown hornblende needles 1 to 2-millimetres long, and equant 1-millimetre grains of chlorite (originally pyroxene). The remainder consists of unaltered plagioclase and minor carbonate and magnetite.

NC-68-3 – Quartz Biotite Schist

Sample is from the dump at the portal of the old Bonanza copper mine south of Anyox (Figure 19).

Quartz and biotite are the major constituents of the rock, along with chalcopyrite which is intimately associated with biotite. Biotite is unaltered and may be the product of contact metamorphism related to the lamprophyre dyke swarm which cuts the ore zone.

NC-68-4 – Biotite Lamprophyre

Sample is from a 1-foot-wide dyke which parallels a silver-bearing quartz vein near the headwaters of the Illiance River, 10 miles northeast of Alice Arm (Figure 19).

The rock is a dark green colour and is fine-grained with 1-millimetre plates of biotite distributed through the matrix. The biotite is essentially unaltered and imparts a flow texture to the rock. The very fine-grained matrix consists of biotite, clinopyroxene (altered to carbonate), and plagioclase.

C.1.9 Basalt Lava Flows

NC-67-32 – Olivine Basalt

Sample was collected from drill core recovered from a hole through a basalt outlier north of the Bell Molybdenum stock (Figure C.2).

The lava flow is fine grained, light grey, vesicular, and has chilled contacts with underlying rocks. The rock has a trachytic texture as imparted by plagioclase (An_{36-40}) laths which make up 70 per cent of the rock. Interstitial areas are made up of olivine, clinopyroxene, and magnetite. The basalt is essentially unaltered.

NC-70-4 – Olivine Basalt

Sample was collected from the south side of Widdzech or Table Mountain, a basalt outlier one-half mile northeast of the British Columbia Molybdenum open pit (Figure 19).

The rock is a fine-grained, dark grey porphyry with scattered 1 to 2-millimetre euhedral phenocrysts of unzoned plagioclase (An_{36-40}), set in a fine-grained matrix, featuring a trachytic texture as imparted by plagioclase laths. Interstitial areas are occupied by olivine, clinopyroxene, and magnetite. The rock is fresh.

C.2 BULKLEY INTRUSIONS AND ASSOCIATED COPPER AND MOLYBDENUM DEPOSITS

C.2.1 Glacier Gulch-Hudson Bay Mountain (after Kirkham, 1966 and Jonson, et al., 1968)

The property is centred on Glacier Gulch on the east side of Hudson Bay Mountain, a few miles northwest of the town of Smithers.

On surface, molybdenum mineralization occurs over an area of about 1 by 1.5 miles in Glacier Gulch, and is known to extend to depths greater than 3,000 feet. Most of this area is underlain by an altered and metamorphosed bedded pyroclastic sequence and some clastic sedimentary rocks, both of Jurassic age. Aphanitic felsitic intrusions cut the pyroclastic sequence.

A concealed discordant and differentiated granodiorite sheet which intrudes the pyroclastic rocks is host to much of the higher grade molybdenum mineralization (Figure C.6). The granodiorite is intensely altered and original mafic minerals have been obliterated. Numerous basic dykes cut the granodiorite sheet and the volcanic rocks. Also intruding the volcanic rocks and the lower portion of the granodiorite sheet is an oval quartz porphyry plug 1,100 feet in diameter. Occurring above the porphyry plug are dykes and breccias of similar composition which both truncate, and are veined by, quartz-molybdenite mineralization and are therefore inter-mineral in age.

A stock of quartz monzonite porphyry truncates the mineralized quartz porphyry plug at depth, and is itself only weakly mineralized (Figure C.6). It is therefore a late phase in the intrusion-mineralization sequence. The stock is the apparent source of a subradial swarm of dykes which extends for at least 2 miles north and south of the glacier.

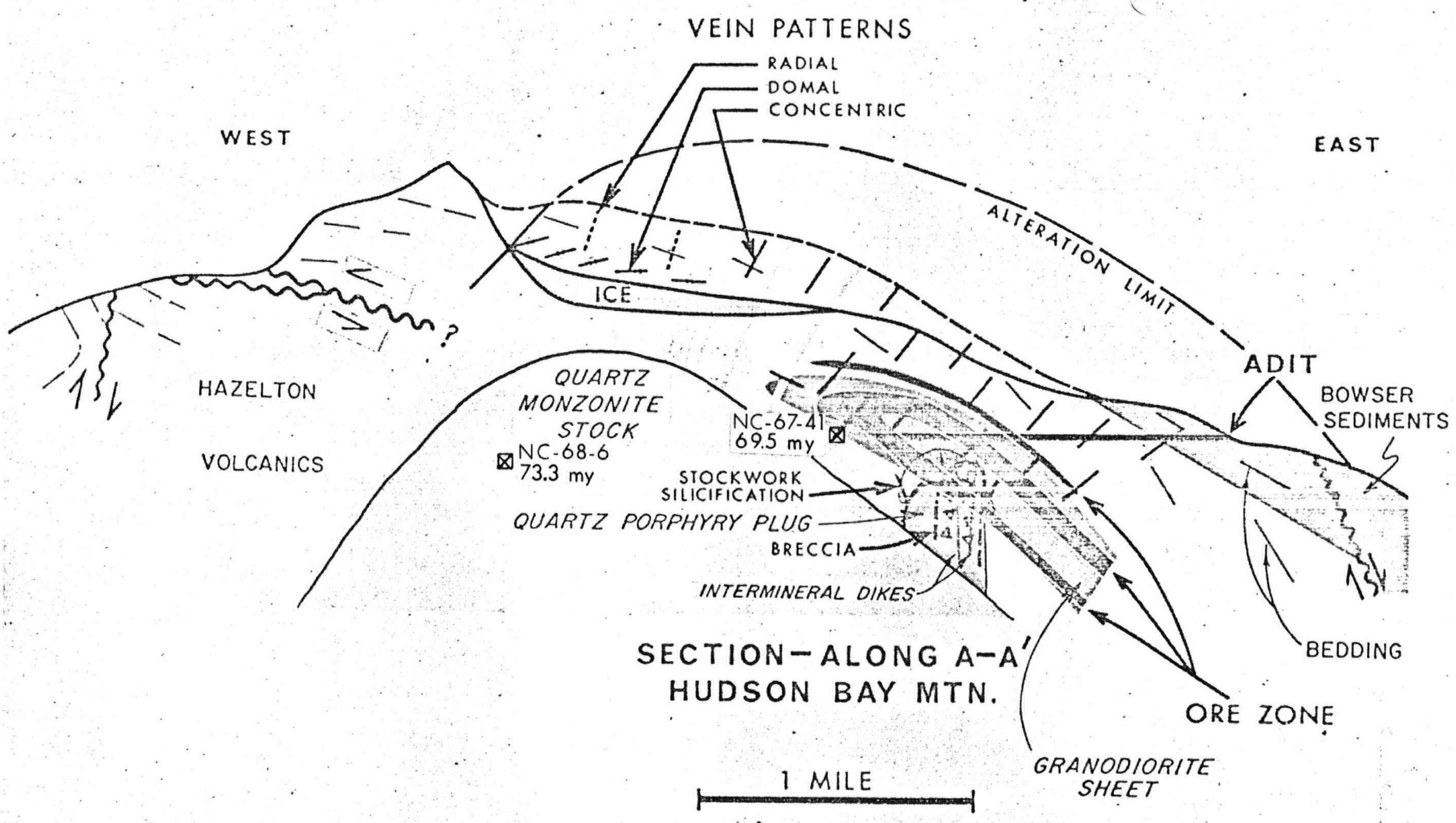

FIG.-C.6 GLACIER GULCH

The volcanic and sedimentary rocks in the Glacier Gulch area and the granodiorite sheet have been thermally metamorphosed by the intrusion of the quartz porphyry plug and the quartz monzonite porphyry stock. Hydrothermal alteration and bleaching are common both inside and outside the area of molybdenum mineralization. The quartz porphyry plug is overlain by a zone of intense silicification. In the vicinity of the molybdenum deposit, hydrothermal alteration is superimposed on products of thermal metamorphism, involving bleaching of the wallrocks, particularly adjacent to quartz veinlets.

Molybdenite occurs almost entirely in a stockwork of quartz veinlets. Lesser amounts of scheelite-powellite and chalcopyrite also occur in the veinlets. Most quartz veins are one-half inch wide, but locally they may be up to 2 feet in width. At least two main periods of molybdenite have been distinguished. An area of quartz veining extends beyond the molybdenum zone and is gradational to a pyrite halo 2.5 by 4 miles in area.

The molybdenum deposit is central to a great number of small, complex sulphide-sulphosalt veins rich in lead and zinc. These have a zonal arrangement and include a zone of zinc-gold-copper-arsenic mineralization surrounded by a zone of lead-silver-copper-arsenic mineralization. All of the mineral deposits on Hudson Bay Mountain appear to be genetically related, but the zonal arrangement is complicated by several stages of mineralization.

Two potassium-argon samples were collected from the molybdenum deposit, duplicates of which were also analysed at the Geochronology Laboratories of the Geological Survey of Canada (Wanless, et al., 1970).

NC-67-41 – Quartz-biotite Veinlets in Granodiorite

Sample was collected from the 3,500-foot level adit (Figure C.6).

Biotite is contained in one-eighth-inch quartz-molybdenite veinlets which cut intensely altered granodiorite. The biotite occurs as medium to coarse-grained reddish brown flakes. Minor chlorite alteration occurs on the edges of some biotite grains.

NC-68-6 – Quartz Monzonite Porphyry

Sample is from drill core from a hole collared on the north side of Hudson Bay Mountain and drilled into the concealed quartz monzonite porphyry stock.

The rock is a pink to grey porphyry with scattered 1-centimetre phenocrysts of K-feldspar and 3 to 4-millimetre phenocrysts of euhedral plagioclase (An_{25}) set in a finer grained matrix of quartz, plagioclase, hornblende, and biotite. Some quartz phenocrysts are also present. Hornblende exhibits deuteric alteration to biotite.

Biotite constitutes 3 to 5 per cent of the rock and occurs primarily as 1-millimetre plates which exhibit up to 10 per cent chlorite alteration along cleavages. Fine-grained, shredded biotite is up to 50 per cent chloritized.

C.2.2 Huber (after Sutherland Brown, 1965)

This property is about 8 miles north of Houston and the showings are about a mile east of Highway 16. The property was formerly known as Mineral Hill and was explored for copper, lead, and zinc in 1926 to 1928 by means of a shaft, an adit, and some trenching.

The geology of the Huber group is shown on Figure C.7. Hornfelsic sandstones, siltstones, and crystal tuffs of Jurassic age are intruded by three

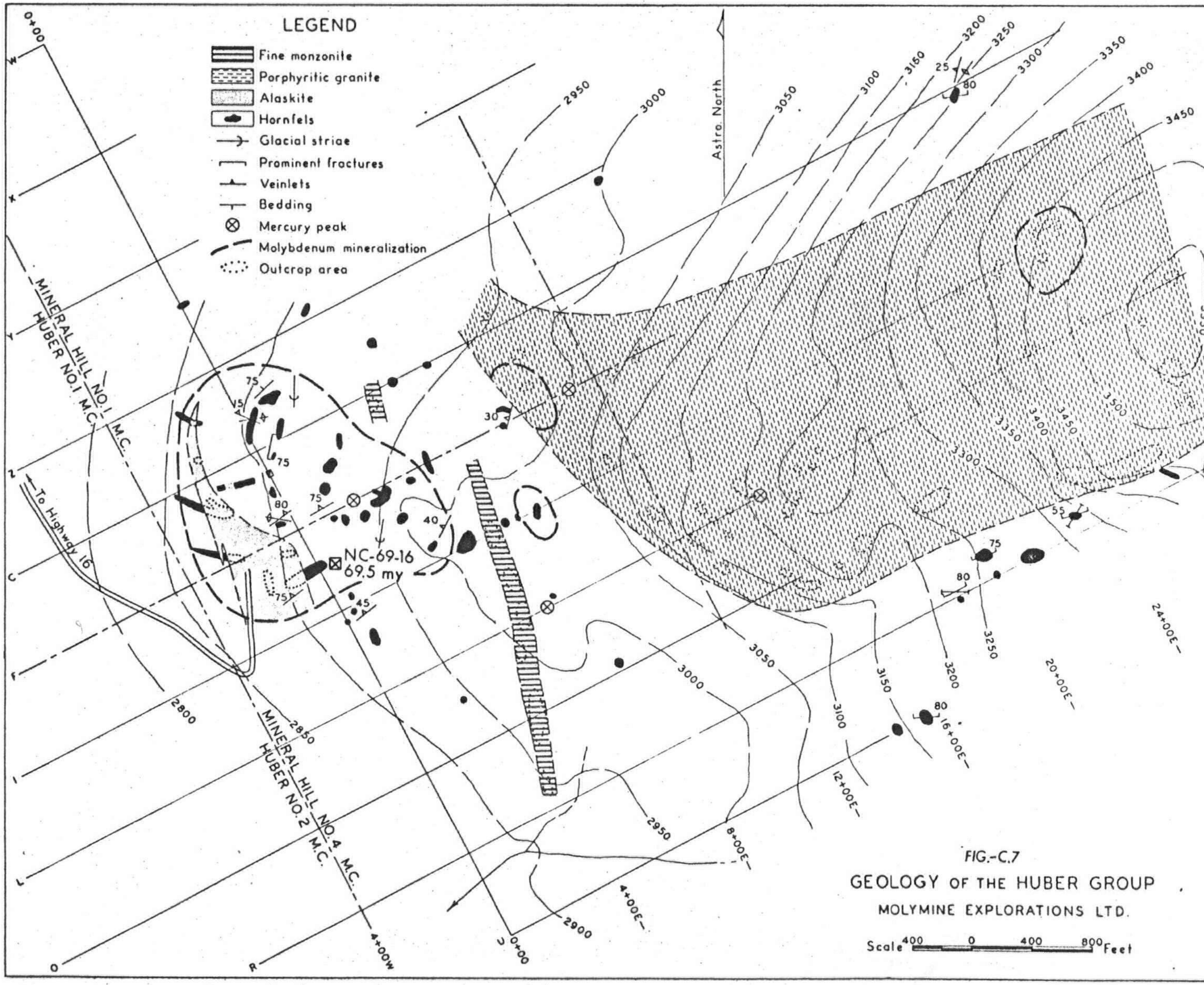

FIG.-C.7

GEOLOGY OF THE HUBER GROUP

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bodies. At the west is a tongue-like body of coarse alaskite, whereas the main mass of the hill is underlain by porphyritic granite that has aplitic border facies. A large dyke of fine-grained monzonite is unmineralized and unmetamorphosed.

The hornfelses are dense, dark purplish to brownish rocks that weather a light grey where leached or rusty colour where oxidized. The degree of metamorphism is fairly uniform, with an overlay of fine-felted brown biotite throughout. The alaskite is a relatively coarse-grained rock in which quartz is rounded, the plagioclase (An_{38}) lathy, perthite lathy to irregular, and the muscovite and opaque minerals are interleaved. The porphyritic granite is composed of about 65 per cent phenocrysts of perthite, quartz, and plagioclase (An_{20}) and minor mica in an aplitic fine-grained matrix of quartz, perthite, and micrographic granite and lesser small laths of plagioclase (An_{33}) with angular hornblende and interstices of quartz and micrographic granite. Alteration is moderately intense, with plagioclase partly altered to clinozoisite and sericite, and hornblende is altered to clinozoisite and chlorite.

Most of the hornfels is shattered and contains numerous closely spaced one-eighth-inch quartz veinlets in a stockwork pattern. The alaskite is cut by larger veins. Pyrite and some molybdenite occur in veinlets and fractures. Lead, zinc, and silver minerals occur in larger veins peripheral to the molybdenum mineralization, principally near the old shaft and in a breccia zone to the north.

One sample for potassium-argon dating was analysed, that being a whole-rock biotite hornfels. A sample collected from the monzonite dyke was considered to be unsuitable due to intense alteration of hornblende.

NC-67-16 – Biotite Hornfels

Sample was collected from a trench within the zone of molybdenum mineralization (Figure C.6).

Rock is fine grained, dense, and brown in colour. Quartz-carbonate veinlets have bleached borders. In thin section, very fine-grained unaltered biotite occurs in a matrix of quartz. The rock was originally a crystal tuff. Epidote occurs in the quartz-carbonate veinlets.

C.2.3 Sunsets Creek (Fog, Fly) (after Sutherland Brown, 1967)

This prospect is situated at the head of Sunsets Creek in the Telkwa Range, 19 miles south of Smithers.

The Telkwa Range is underlain by maroon pyroclastic rocks of the Hazelton Group. The Sunsets Creek pluton occurs in the centre of the range and has domed the surrounding pyroclastic rocks. Volcanic rocks in close proximity to the pluton have been hornfelsed.

The Sunsets Creek pluton is a steep-sided plug, approximately 6,000 feet in diameter (Figure C.8). It is composed entirely of quartz monzonite of nearly constant composition and texture. The rock is light grey and has a porphyritic texture with scattered 1 to 2-centimetre phenocrysts of feldspar in addition to numerous 1-millimetre plagioclase (An_{20-30}) phenocrysts which are set in a fine-grained matrix. The ratio of K-feldspar to total feldspar is 1:3. Other phenocrysts include resorbed quartz grains and hornblende and biotite.

Phenocrysts form 50 per cent of the rock. The matrix consists of very fine-grained quartz, K-feldspar, and minor plagioclase.

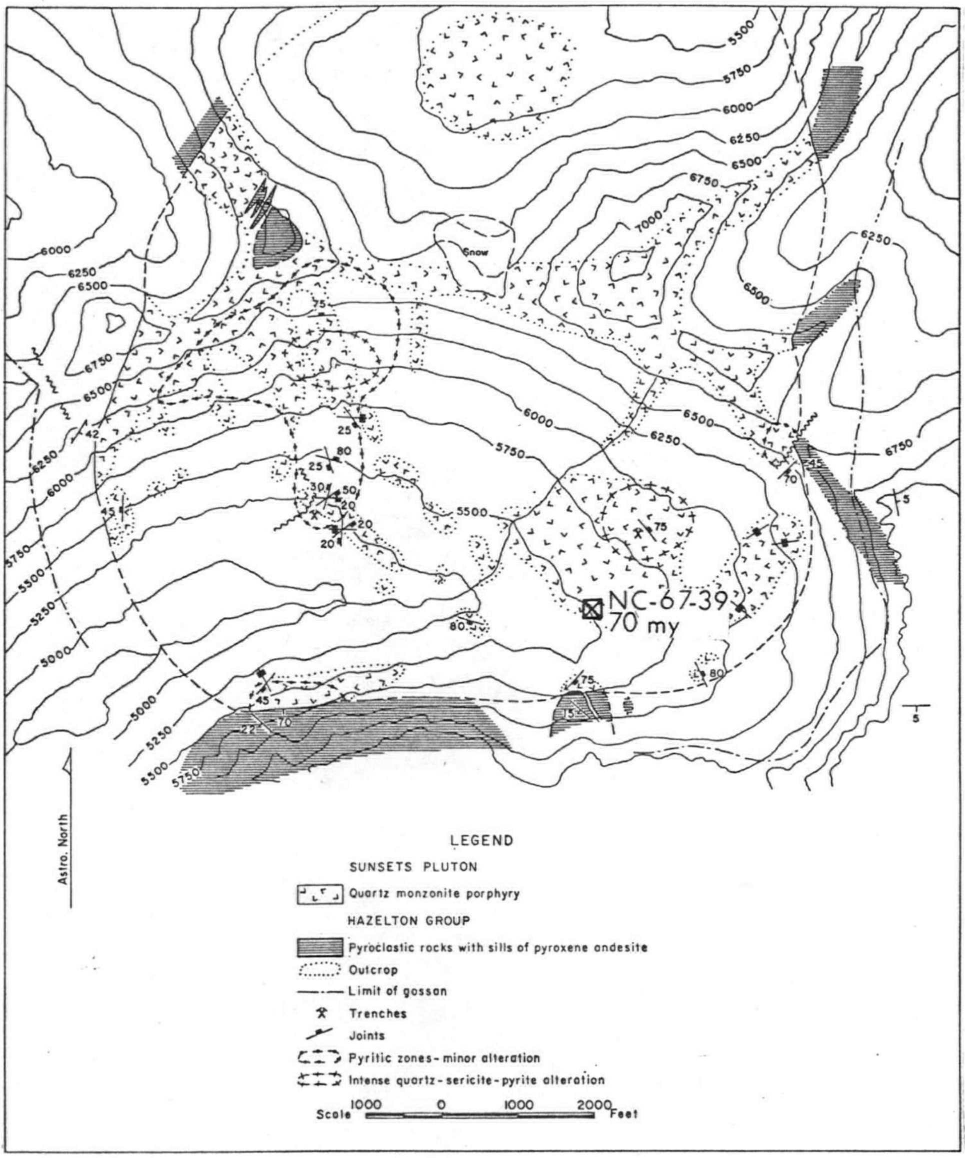


FIG.-C.8 SUNSETS CK.

A gossan zone surrounds the stock and roughly corresponds to the area of intense hornfelsing. Widely spaced 1-inch quartz veins containing pyrite, chalcopyrite, and minor molybdenite occur at many places along the periphery of the stock. Two altered zones with associated sulphide mineralization occur in the interior of the stock. A broad area 2,000 by 3,000 feet in the west part of the stock contains abundant pyrite as disseminations and as coatings on fracture planes. In the southern part of this zone, molybdenite occurs with pyrite in a wide-spaced stockwork of quartz veins, veinlets, and dry fractures. A smaller area of quartz-sericite-pyrite alteration to the east contains minor disseminated chalcopyrite.

One sample for potassium-argon dating was collected by A. Sutherland Brown from quartz monzonite in the southeastern part of the stock, south of the zone of quartz-sericite-pyrite alteration.

NC-67-39 – Porphyritic Quartz Monzonite

The sample is a leucocratic porphyritic rock with scattered 1 to 2-centimetre phenocrysts of K-feldspar plus 4-millimetre phenocrysts of plagioclase (An_{20-30}) which are set in a finer grained matrix of quartz, plagioclase, K-feldspar, hornblende, and biotite.

Biotite occurs as 1 to 2-millimetre plates and books which are only partly (less than 10 per cent) altered to chlorite. Biotite equals 3 to 5 per cent of the rock volume.

C.2.4 Rocher Deboule

A sample for potassium-argon dating was collected by R. V. Kirkham from near the 1200 level portal of the Rocher Deboule mine, 5 miles south of Hazelton.

This dormant copper-gold-silver vein deposit is situated on the western periphery of the northern dome of the Rocher Deboule stock (Sutherland Brown, 1960). Siltstones of the Middle Cretaceous Red Rose Formation have been hornfelsed marginal to the stock contact.

The main country rock of the mine is typical porphyritic granodiorite of the Rocher Deboule stock. The rock is formed of 20 to 35 per cent of 4-millimetre plagioclase (An_{20-40}) phenocrysts and hornblende and biotite total 15 per cent of the rock volume. The matrix is formed of plagioclase, perthitic K-feldspar, and quartz, and the accessory minerals sphene, apatite, zircon, and metallic minerals.

NC-67-46 – Porphyritic Granodiorite

Sample is a mesocratic porphyritic rock with crowded phenocrysts of plagioclase (An_{20-40}) set in a medium-grained matrix of quartz, K-feldspar, and hornblende and biotite.

Biotite occurs as 1-millimetre plates exhibiting only minor chlorite alteration and as a deuteric alteration of green hornblende.

C.2.5 Bear (Laura) (after Sutherland Brown, 1968)

This property is situated on the western flank of Mount Thomlinson between McCutcheon and Sterrett Creeks, 20 miles north of Hazelton.

Molybdenum and copper mineralization is associated with a subcircular porphyry plug of roughly one-half mile diameter. The plug occurs in the western flank of a major anticline in Bowser Group volcanic sandstones, which have been thermally metamorphosed to biotite hornfels in an irregular halo up to 1,500 feet wide.

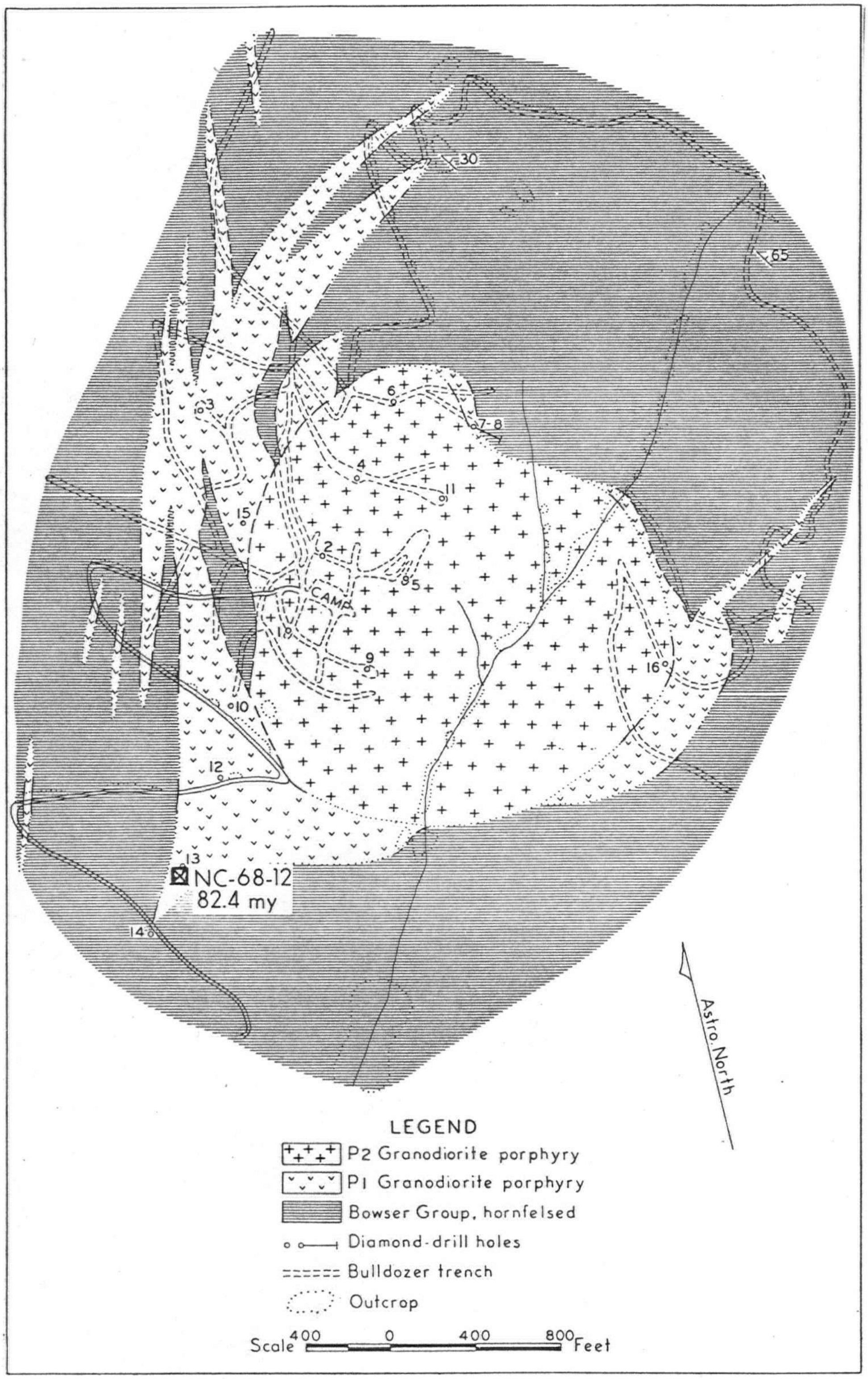

30
65
6
7-8
3
4
11
15
2
CAMP
85
1
9
16
10
12
13
NC-68-12
82.4 my
14
Astro. North
LEGEND
P2 Granodiorite porphyry
P1 Granodiorite porphyry
Bowser Group, hornfelsed
Diamond-drill holes
Bulldozer trench
Outcrop
Scale 400 0 400 800 Feet

FIG.- C.9 BEAR

The pluton consists of two nearly identical phases. The earlier phase is porphyritic, irregular in plan, and occupies the peripheral areas of the plug (Figure C.9). The later phase, a crowded porphyry bordering on a granitic texture, is concentric with the first and makes up the bulk of the pluton.

Both phases are rusty weathering, medium grey rocks with prominent plagioclase, hornblende, and scattered biotite books. Both are of granodiorite composition. The major difference between the two phases is the greater abundance of 1 to 4-millimetre zoned plagioclase (An_{20-45}) phenocrysts and the coarser grain size of the matrix. Hornblende prisms and biotite books occur as phenocrysts and apatite and sphene are accessory minerals.

Hydrothermal ateration is erratic in distribution and consists of clay minerals, or sericite with pyrite and quartz. Disseminated pyrite and pyrrhotite are also erratically distributed.

Molybdenum and copper mineralization is widely distributed in the pluton, with better grades most common near the periphery. Molybdenite and chalcopyrite occur in quartz veinlets and in dry fractures in a stockwork. Late-stage quartz-carbonate veins contain minor pyrite, sphalerite, specularite, arsenopyrite, and stibnite or bismuthinite.

A sample for potassium-argon dating was collected by A. Sutherland Brown from a hole drilled near the south end of the plug (Figure C.9).

NC-68-12 – Granodiorite Porphyry

Sample is a crowded porphyry, with abundant 2 to 4-millimetre phenocrysts of euhedral plagioclase (An_{20-30}) and 2-millimetre poikilitic biotite books set in a finer grained matrix consisting essentially of quartz and hornblende.

Biotite displays up to 15 per cent alteration to chlorite, principally along cleavages. Secondary, fine-grained biotite occurs as an alteration of primary hornblende.

C.2.6 Huckleberry (after Carter, 1970)

The Huckleberry copper-molybdenum deposit is situated between Tahtsa Reach and Sweeney Lake, 50 miles southwest of Houston.

Copper and molybdenum mineralization is associated with an elliptical plug of granodiorite porphyry, oriented with its long axis in a northeast direction and measuring 2,200 by 1,400 feet. The plug intrudes fine-grained crystal tuffs of the Hazelton Group (Figure C.10).

As exposed in the trenches in the central part of the plug, the intrusive is a light grey crowded porphyry with phenocrysts constituting 50 per cent of the rock. These include 2 to 4-millimetre phenocrysts of euhedral, fresh, zoned plagioclase (An_{30-40}), and subsidiary 2-millimetre plates and books of fresh biotite and 2-millimetre anhedral quartz phenocrysts, all set in a fine-grained matrix of quartz, feldspar, and biotite. Locally the rock has a pinkish cast due to the presence of K-feldspar in the matrix and marginal to narrow quartz veinlets.

Biotite may constitute 10 to 15 per cent of the rock by volume, occurring both as primary, fresh 1 to 2-millimetre plates and books and as fine-grained clusters of secondary biotite, partly chloritized, altering from original hornblende.

Porphyry dykes cut the volcanic rocks marginal to the plug as seen in drill core from holes east of the intrusive. These biotite feldspar porphyries,

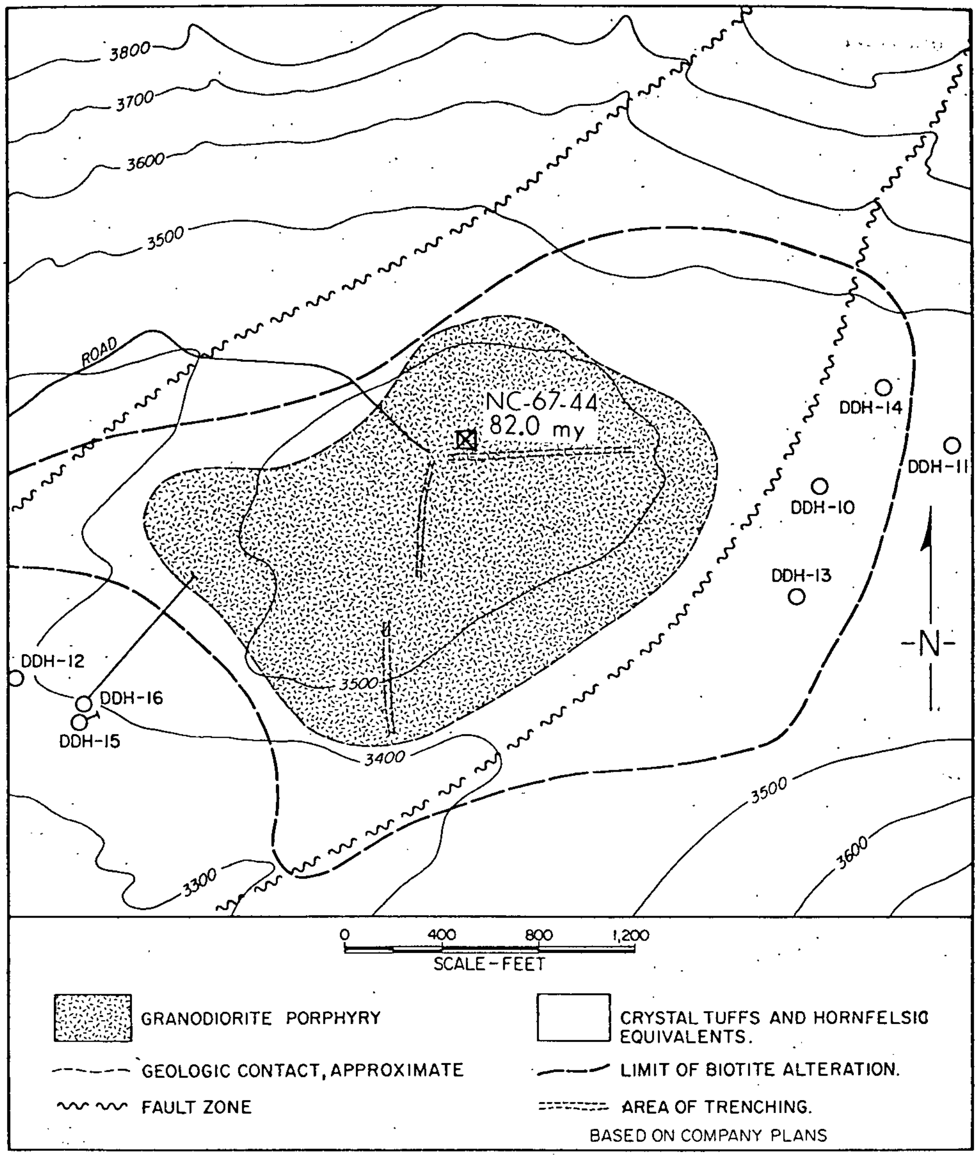


FIG. - C.10 HUCKLEBERRY

while of similar composition, are finer grained than the main intrusive, consisting mainly of crowded 2-millimetre phenocrysts of unzoned plagioclase (An_{30}) and 1-millimetre biotite plates set in a fine-grained quartz-rich matrix. Little K-feldspar was seen except marginal to quartz-filled fractures. Plagioclase exhibits a fair degree of sericite and argillic alteration and biotite is mostly altered to chlorite.

Intrusion of the granodiorite porphyry has caused hornfelsing of the adjacent fine-grained crystal tuffs. These rocks are mainly light to dark grey, but are locally tinged brown due to the selective development of secondary biotite within an oval zone extending outward from a plug a distance of up to 600 feet. Typically, the hornfelses contain 2-millimetre crystal fragments of plagioclase in a very fine-grained mosaic of quartz, plagioclase, and biotite. Abundant fine-grained biotite and actinolite were noted filling fractures in a few drill sections. Light grey hornfelsed volcanic rocks consist mainly of quartz, sericite, and carbonate and contain abundant disseminated pyrite. The hornfelses are well fractured, with many of the fractures filled with quartz and rimmed by bleached zones up to one-quarter-inch wide. These bleached haloes are made up of very fine-grained quartz, sericite, carbonate, and some K-feldspar or granophyre.

Lamprophyre dykes, fine grained and dark green, intrude all rocks in the area.

Northeast and northwest linear features, often marking the course of creeks, are common on airphotos covering the Huckleberry Mountain area, and some of these represent faults. The northwest faults appear to be terminated by the northeasterly ones. As suggested by Carr (1964), the porphyry plug was apparently localized by the two northeast faults which bound it closely on the north and south (Figure C.10). These faults also caused fracturing of the volcanic rocks which was intensified by the intrusion of the porphyry plug. The major fracture directions in the volcanic rocks and the porphyry plug also trend northeast and northwest.

Copper and molybdenum mineralization is associated with the granodiorite porphyry plug and, in particular, the hornfelsed rocks peripheral to the intrusive. The best mineralized sections occur in the hornfelsed rocks east and north of the granodiorite porphyry plug. Typically, these hornfelses are cut by closely spaced hairline fractures which are coated with chalcopyrite and lesser amounts of quartz and magnetite. Magnetite may also be disseminated in the matrix of the rock with pyrite. Chalcopyrite and lesser molybdenite also occur in vertical one-eighth-inch quartz veinlets which may also contain some K-feldspar. These fractures are commonly bordered by bleached zones up to one-quarter-inch wide.

Biotite feldspar porphyry dykes seen cutting hornfels in this area east of the main intrusive also contain one-eighth-inch vertical quartz-chalcopyrite-molybdenite veinlets. These veinlets, which may be rimmed by K-feldspar, are cut by horizontal gypsum-healed fractures. Some fluorite was also seen in fractures and chalcopyrite was noted replacing mafic minerals in one section.

In the trench area within the main intrusive, chalcopyrite occurs in 1 to 2-inch-spaced hairline fractures with quartz and minor K-feldspar and also in one-eighth to one-half-inch quartz veinlets. Magnetite is also common in fractures. Chalcopyrite also occurs as disseminations in the granodiorite porphyry.

A pyrite halo extends outward from the granodiorite porphyry a distance of up to 2,000 feet, and is marked by a gossan on the south slope of Huckleberry Mountain. This gossan occurs in an east-trending zone some 2 miles long, with the porphyry plug situated near the western end of the zone.

A sample for potassium-argon dating from the east-west trench in the central part of the plug (Figure C.10) was provided by P. T. Black, formerly of Kennco Explorations, (Western) Limited.

NC-67-44 – Granodiorite Porphyry

Sample is a medium grey crowded porphyry. Fifty per cent of the sample is composed of 2 to 4-millimetre phenocrysts of euhedral, zoned plagioclase (An_{30-40}), 2-millimetre books of biotite, and anhedral quartz phenocrysts. These are set in a fine-grained matrix of quartz, feldspar, and biotite. K-feldspar occurs in the matrix and adjacent to quartz veinlets and fractures which contain chalcopyrite. The rock is essentially fresh.

Biotite makes up between 5 and 10 per cent of the sample and occurs both as primary, fresh, 1 to 2-millimetre plates and books, and as very fine-grained aggregates secondary after hornblende. The edges of some biotite plates are chloritized.

C.2.7 Ox Lake (after Sutherland Brown, 1969)

The Ox Lake deposit is peripheral to a small granodiorite porphyry plug that intrudes a mixed pyroclastic and sedimentary sequence of the Hazelton Group (Figure C.11). The plutonic rocks of the plug are nearly identical to those of the Huckleberry deposit 5 miles west.

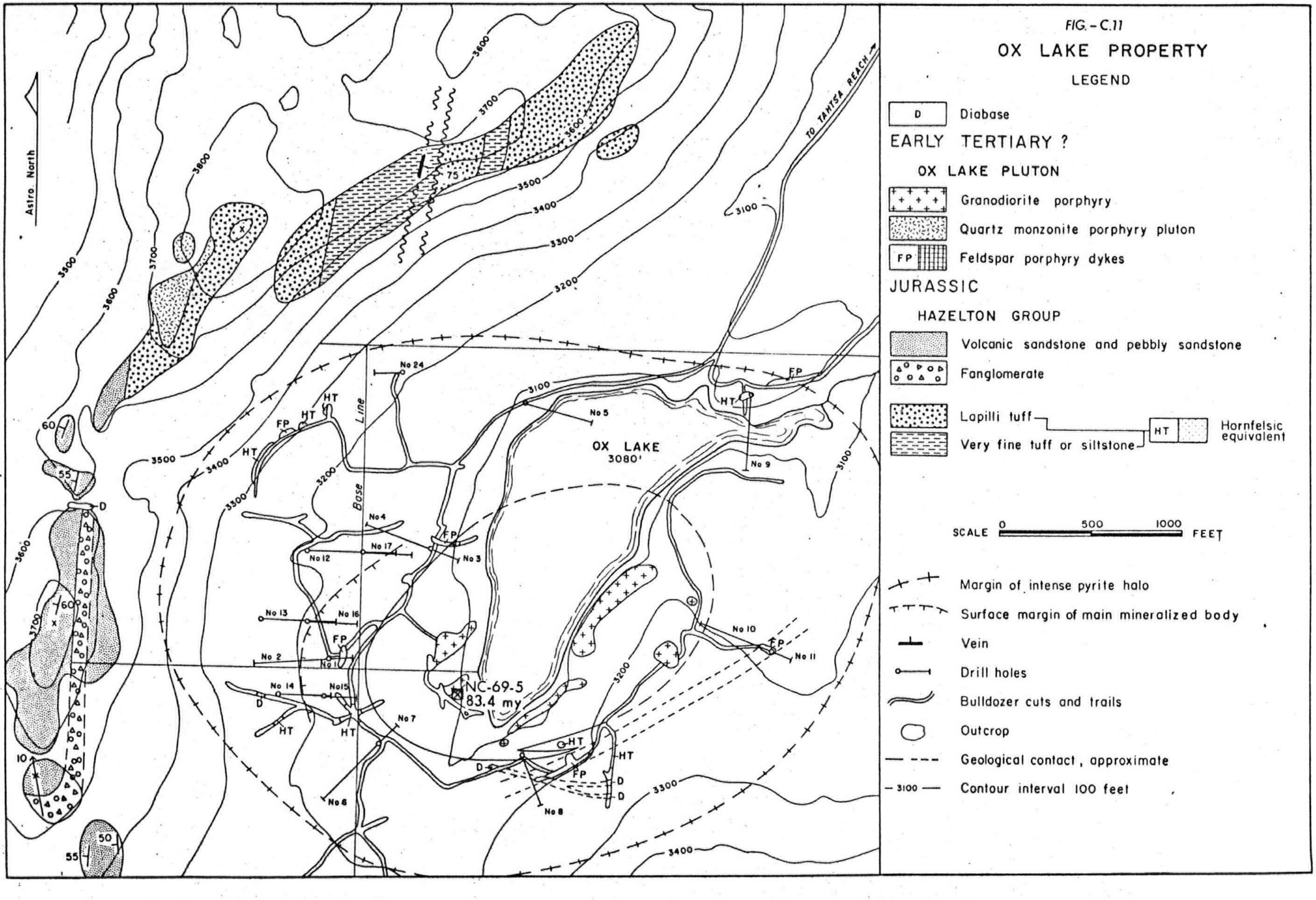


FIG. - C.11
OX LAKE PROPERTY
LEGEND
D Diabase
EARLY TERTIARY ?
OX LAKE PLUTON
Granodiorite porphyry
Quartz monzonite porphyry pluton
FP Feldspar porphyry dykes
JURASSIC
HAZELTON GROUP
Volcanic sandstone and pebbly sandstone
Fanglomerate
Lapilli tuff
Very fine tuff or siltstone
HT Hornfelsic equivalent
SCALE 0 500 1000 FEET
Margin of intense pyrite halo
Surface margin of main mineralized body
Vein
Drill holes
Bulldozer cuts and trails
Outcrop
Geological contact, approximate
3100 Contour interval 100 feet
Astro. North
TO TAHTSA REACH
OX LAKE
3080'
Base Line
NC-69-5
83.4 my

Volcanic tuffs marginal to the porphyry plug are hornfelsed and pyritized in a halo up to 1,000 feet wide. The stratified sequence outside this zone is cut by northerly trending feldspar porphyry dykes and sills which are older than the main porphyry plug. These occur mainly to the northeast of the plug and may be related to a quartz monzonite porphyry to the northwest (Figure C.11).

The porphyry plug is elliptical in outline and measures 2,000 feet by 1,300 feet. It is a distinctive crowded porphyry with prominent plagioclase (An_{24-40}) laths 3 to 10 millimetres long and books of biotite and long hornblende needles in a finely speckled pink and black matrix.

The most intense alteration within the plug is adjacent to the mineralized zone where plagioclase is altered to sericite and carbonate, mafic minerals to chlorite and muscovite, and K-feldspar partly to zeolite. In the hornfelsed rocks, metamorphic biotite has been completely obliterated by sericite in a zone 300 feet wide bordering the plug. This decreases in intensity outward to a point where secondary bleaching is only present marginal to quartz veinlets and fractures.

The main mineralized zone of copper and molybdenum is contained in a crescent-shaped body west of the plug. Chalcopyrite and molybdenite occur in a stockwork of dry fractures and quartz veinlets best developed adjacent to the plug. In general, copper mineralization is dominant in the hornfels while molybdenum is concentrated in porphyry dykes and near the granodiorite porphyry contact. Pyrite, up to 5 or 10 per cent, occurs in a halo extending beyond the ore zone. Minor late veins occur, formed of sphalerite, pyrite, quartz, and carbonate.

A sample for potassium-argon dating was collected by A. Sutherland Brown from a trench near the southwest end of Ox Lake (Figure C.11).

NC-69-5 – Granodiorite Porphyry

Sample is a crowded porphyry with up to 50 per cent of the rock consisting of 2 to 5-millimetre phenocrysts of euhedral plagioclase (An_{25-30}), and 2-millimetre phenocrysts of biotite, hornblende, and quartz. These are contained in a fine-grained matrix of quartz, K-feldspar, chlorite, and opaque minerals.

Biotite occurs principally as 1-millimetre, ragged, poikilitic plates, some of which exhibit up to 20 per cent chlorite alteration. Hornblende is mainly altered to chlorite although some biotite alteration was also noted.

C.2.8 Coles Creek

A biotite separate from the Coles Creek porphyry copper-molybdenum prospect was supplied by D. G. MacIntyre and the analytical results are included in this study.

The property is situated south of Troitsa Lake on a tributary of Coles Creek 80 miles north of Houston. A stock of quartz monzonite porphyry, 2,500 feet in diameter, intrudes Jurassic volcanic and sedimentary rocks. Possible extrusive equivalents of the stock include rhyolite tuffs and breccias. An inner phase of the quartz monzonite porphyry is a feldspar biotite porphyry of granodiorite composition which is host to chalcopyrite and molybdenite mineralization. A pyrite halo 4,000 feet wide surrounds the stock and galena and sphalerite mineralization occurs in fractures south of the stock.

MC-9 – Feldspar Biotite Porphyry

Sample is from a tributary of Coles Creek. The rock is of granodiorite composition and is texturally similar to the granodiorite porphyry at the Ox

Lake and Huckleberry deposits (MacIntyre, personal communication).

Both primary and secondary biotite are contained in the sample.

C.3 NANIKA INTRUSIONS AND ASSOCIATED COPPER AND MOLYBDENUM DEPOSITS

C.3.1 Mount Thomlinson (after Kirkham, 1964)

This molybdenum prospect is situated 24 miles north of Hazelton on a northerly trending ridge of Mount Thomlinson.

Massive black argillaceous siltstones of Jurassic-Cretaceous age have been intruded by a circular stock of leucocratic quartz monzonite poprhyry (Figure C.12). Near the contact, the sedimentary rocks have been deformed and metamorphosed to medium or dark grey schists in a zone 300 to 500 feet wide. Biotite, muscovite, cordierite, and andalusite have been formed in the contact aureole. Stock contacts are sharp. The margins of the stock are foliated parallel to the contact and to the schistosity in the intruded rocks.

Much of the stock is a coarse-grained porphyry with K-feldspar phenocrysts up to 5 centimetres long and quartz and plagioclase (An_{20-30}) phenocrysts up to 1 centimetre in size. In many areas, the stock is cut by narrow aplite dykes which occur in swarms.

Molybdenite, chalcopyrite, and pyrite occur in a stockwork of quartz veinlets with minor amounts of magnetite and scheelite. The quartz stockwork is best developed along the northwest stock contact.

A sample for potassium-argon dating from the mineralized zone was supplied by R. V. Kirkham.

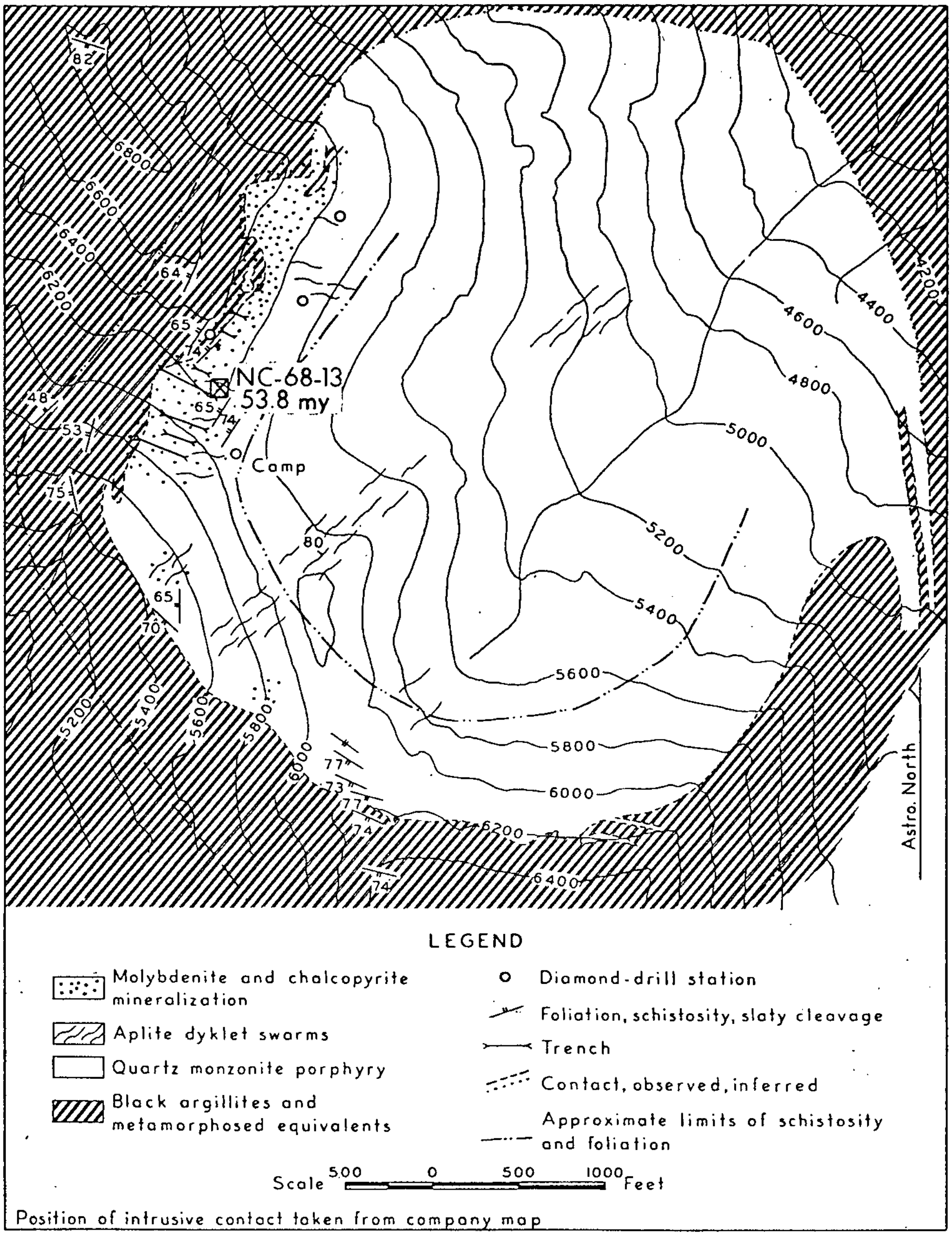


FIG.-C.12 MT. THOMLINSON

NC-68-13 – Quartz Monzonite Porphyry

Sample is a pink leucocratic porphyry with 5-centimetre euhedral phenocrysts of K-feldspar, 4-millimetre anhedral quartz eyes, and 2-millimetre biotite plates set in a medium-grained matrix of quartz, K-feldspar, and plagioclase (An_{20}). Accessory minerals include muscovite, apatite, and opaque minerals.

Biotite plates are poikilitic and are unaltered.

C.3.2 Big Onion (after Sutherland Brown, 1966)

The property is on the south side of Astlais Mountain, 12 miles east of Smithers.

The Big Onion property is underlain by Hazelton andesitic volcanic rocks that are intruded by an elongate complex pluton (Figure C.13). The pluton is formed of two phases: an early quartz feldspar porphyry which forms a sheath around a later quartz diorite porphyry. The quartz feldspar porphyry is a white aphanitic rock with a few scattered quartz phenocrysts 1 to 4 millimetres in size. Pyrite may form up to 3 per cent of the rock and exposures are commonly iron stained. The quartz diorite porphyry is a medium-grained grey rock with sericitized plagioclase and chloritized hornblende and biotite phenocrysts 3 to 7 millimetres in size.

Copper and molybdenum mineralization is widely distributed near the contacts of the two intrusive phases and in the peripheral volcanic rocks. Chalcopyrite, molybdenite, and minor bornite occur in a stockwork of quartz-filled fractures and as disseminations. The best copper mineralization occurs

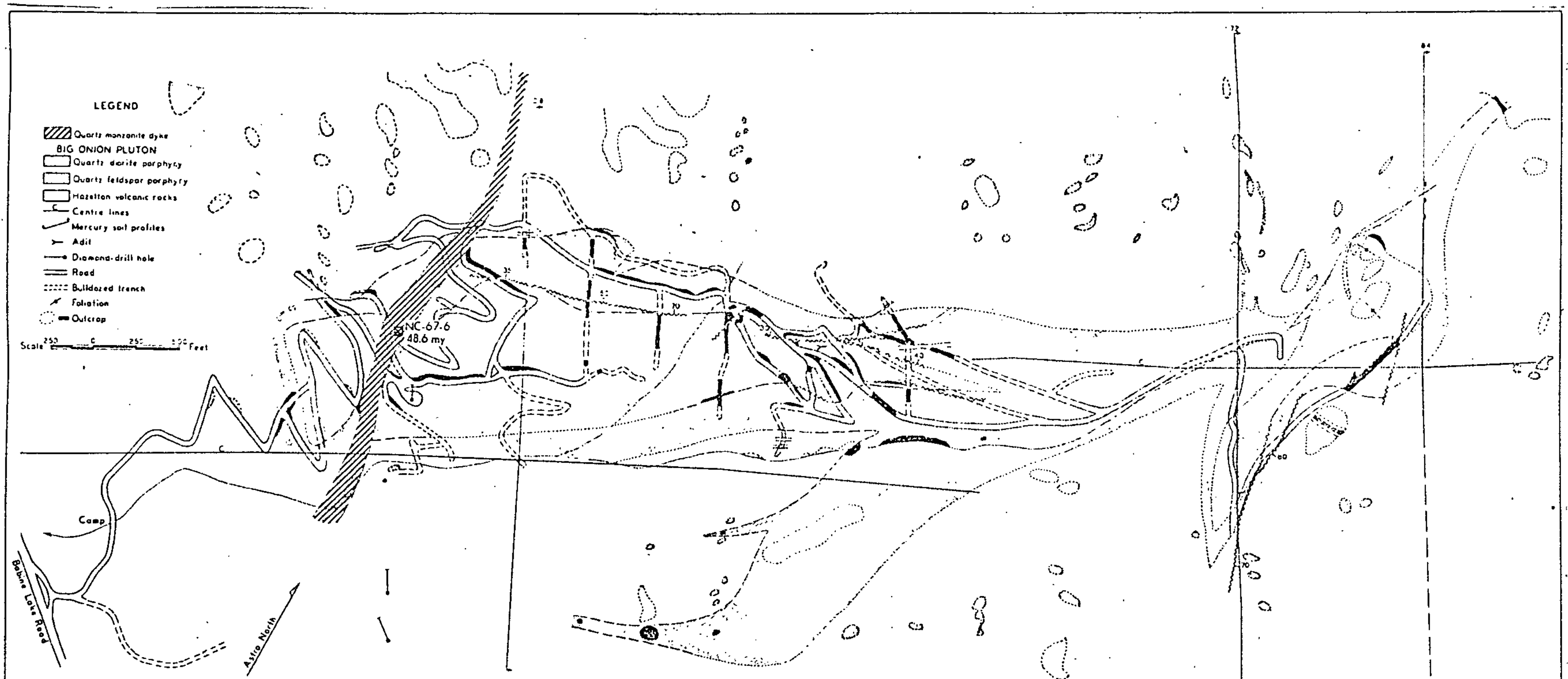


FIG- C.13
GEOLOGY OF THE BIG ONION

within the quartz diorite porphyry and molybdenite is mainly restricted to the quartz feldspar porphyry. Pyrite is best developed in volcanic rocks near the intrusive contact.

Post-mineralization dykes include a northerly striking quartz monzonite dyke and several varieties of late hornblende andesite dykes.

NC-67-7 – Quartz Monzonite

Sample is from a roadcut in the post-mineral quartz monzonite dyke (Figure C.13).

The rock is dark grey, medium grained, and is slightly magnetic. It is formed of 33 per cent plagioclase, 25 per cent orthoclase, 10 per cent quartz, 20 per cent biotite, 5 per cent granophyre, with the remainder consisting of magnetite and minor hornblende. Biotite plates are 1 to 2 millimetres in length and exhibit up to 10 per cent chlorite alteration, mainly along cleavage planes.

C.3.3 Lucky Ship (after Sutherland Brown, 1965)

The Lucky Ship molybdenum deposit is on a ridge between Morice Lake and the Nanika River, 50 miles south of Houston.

Molybdenum mineralization is associated with a rhyolite plug, 2,000 by 3,000 feet in diameter, that cuts Hazelton Group volcanic, pyroclastic, and sedimentary rocks (Figure C.14). The rhyolite porphyry plug consists of four phases including two porphyries and two breccias. The porphyry forming the major part of the plug is a white aphanitic rock with sparse phenocrysts of

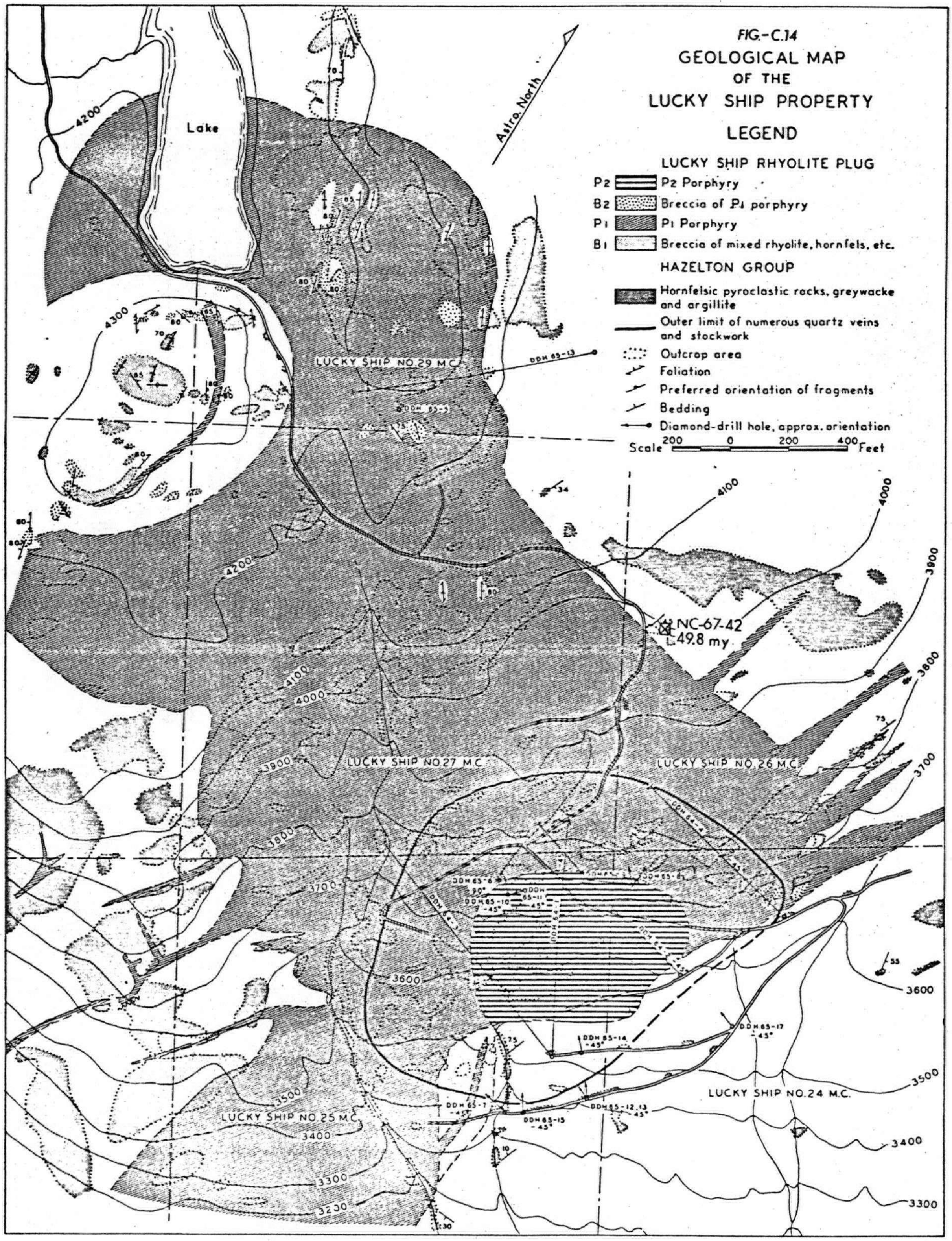


FIG.-C.14
GEOLOGICAL MAP
OF THE
LUCKY SHIP PROPERTY
LEGEND
LUCKY SHIP RHYOLITE PLUG
P2 Pz Porphyry
B2 Breccia of P1 porphyry
P1 P1 Porphyry
B1 Breccia of mixed rhyolite, hornfels, etc.
HAZELTON GROUP
Hornfelsic pyroclastic rocks, greywacke and argillite
Outer limit of numerous quartz veins and stockwork
Outcrop area
Foliation
Preferred orientation of fragments
Bedding
Diamond-drill hole, approx. orientation
Scale 200 0 200 400 Feet
Astro. North
Lake
LUCKY SHIP NO.29 M.C.
LUCKY SHIP NO.27 M.C.
LUCKY SHIP NO.26 M.C.
LUCKY SHIP NO.25 M.C.
LUCKY SHIP NO.24 M.C.
NC-67-42
49.8 my
4300
4200
4100
4000
3900
3800
3700
3600
3500
3400
3300
3200

quartz and feldspar. This phase intrudes an earlier breccia in which fragments of the porphyry occur along with fragments of country rock. The porphyry is intruded by a second breccia composed mainly of porphyry fragments and a small (800 feet in diameter) plug of quartz monzonite porphyry.

Argillites and lapilli tuffs marginal to the intrusion are hornfelsed and contain biotite and actinolite throughout the matrix.

Silicification is the most intense alteration and is developed in an annular zone around the periphery of the younger porphyry plug, where a stockwork of quartz veins and fractures is developed (Figure C.14).

Molybdenum mineralization is contained within the silicified zone and better grades occur in a zone immediately peripheral to the contact of the younger porphyry plug. A pyrite halo is developed in the earlier porphyry phase, the breccias, and the hornfels, surrounding the silicified zone.

NC-67-42 – Biotite Hornfels

Sample was collected from an outcrop immediately adjacent to the east contact of the intrusion (Figure C.14).

The rock is iron stained on weathered surface and is transected by parallel hairline fractures. On a fresh surface, the dark grey to dark brown rock exhibits a conchoidal fracture. In thin section, the rock is seen to be a fine-grained crystal tuff. Very fine-grained metamorphic biotite is best developed adjacent to fractures.

C.3.4 Goosly (after Church, 1969 and Ney, et al., 1972)

The Goosly property is northeast of Goosly Lake, 33 miles by road southeast of Houston.

The property is underlain principally by Hazelton Group sedimentary and pyroclastic rocks. Gently inclined Tertiary volcanic rocks unconformably overlie the Mesozoic rocks. Hazelton Group rocks are intruded by a granitic stock and a syenodiorite stock about a mile apart (Figure C.15). Both are of Tertiary age, with the granitic stock emplaced about 7 m.y. prior to the intrusion of the syenodiorite. Major economic mineralization at the Goosly property is a northerly trending slab of copper-silver mineralization which is roughly conformable with the enclosing volcanic and sedimentary rocks. The mineralized zone is between the two intrusive bodies.

Weak copper-molybdenum mineralization in fractures occurs near the northern contact of the granitic stock. The leucocratic, medium-grained quartz monzonite porphyry contains 2 to 4-millimetre phenocrysts of subhedral plagioclase and biotite set in a matrix of quartz and K-feldspar.

A sample for potassium-argon dating was collected by B. N. Church from a trench near the centre of the intrusion.

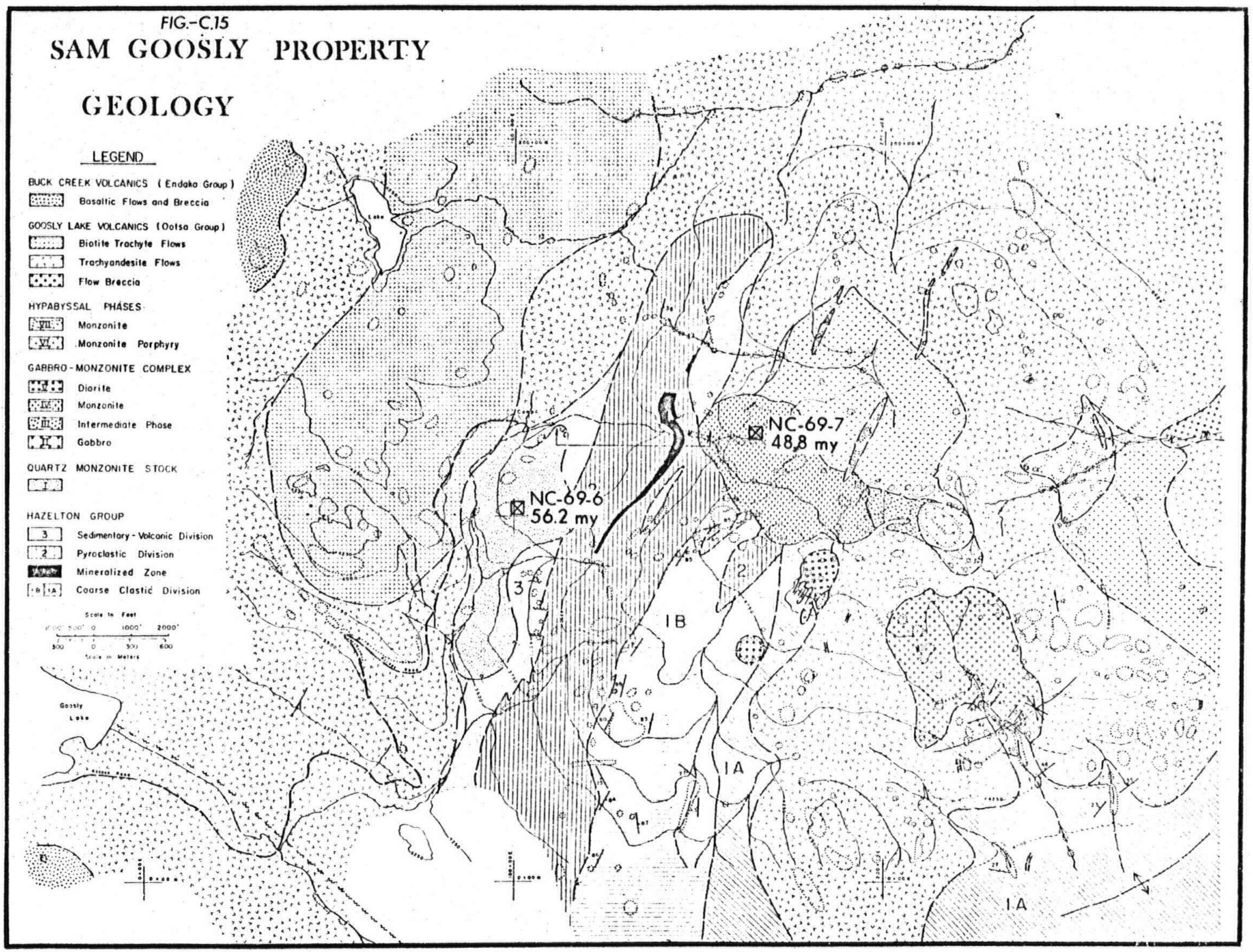
NC-69-6 – Quartz Monzonite Porphyry

The sample is a medium grey, crowded porphyry with 50 per cent euhedral, zoned plagioclase (An_{25-30}) as 1 to 2-millimetre phenocrysts. Biotite phenocrysts of similar size are scattered through the rock. The fine-grained matrix consists mainly of quartz, plagioclase, K-feldspar, and hornblende, which is

FIG.-C.15

SAM GOOSLY PROPERTY

GEOLOGY



altered to chlorite and some biotite. Biotite plates are poikilitic and exhibit up to 15 per cent chlorite alteration.

C.3.5 Berg (after Sutherland Brown, 1966 and Ney, 1972)

The property is in the Tahtsa Range about 70 miles south of Smithers.

The area is underlain by massive and clastic volcanic and sedimentary rocks of the Hazelton Group. These rocks have been intruded by an elongate quartz diorite stock several square miles in area and by a circular, composite porphyry stock of one-half-mile diameter. The porphyry stock is host to copper and molybdenum mineralization (Figure C.16).

The quartz diorite is a fine to medium-grained equigranular rock of uniform appearance. Scattered hornblende phenocrysts up to 8 millimetres long occur throughout the rock. The quartz monzonite porphyry which constitutes the bulk of the stock is a light grey to buff rock in which 4 to 6-millimetre phenocrysts of plagioclase, biotite, and quartz are prominent. These are set in a very fine-grained matrix of quartz, plagioclase, and perthitic K-feldspar. Post-dating the quartz monzonite porphyry are a breccia pipe and dykes of quartz latite porphyry. The breccia occurs south of the stock and partly intrudes the earlier quartz diorite (Figure C.16). It is a cream-coloured rock composed mainly of subangular, 15-millimetre fragments of quartz monzonite porphyry, siltstone, and andesite in a finely communited matrix. Pyrite is widely disseminated throughout the breccia. The quartz latite porphyry dykes occur both within and marginal to the quartz monzonite porphyry stock. One such dyke outcrops as a conspicuous northeast-trending spine through the central

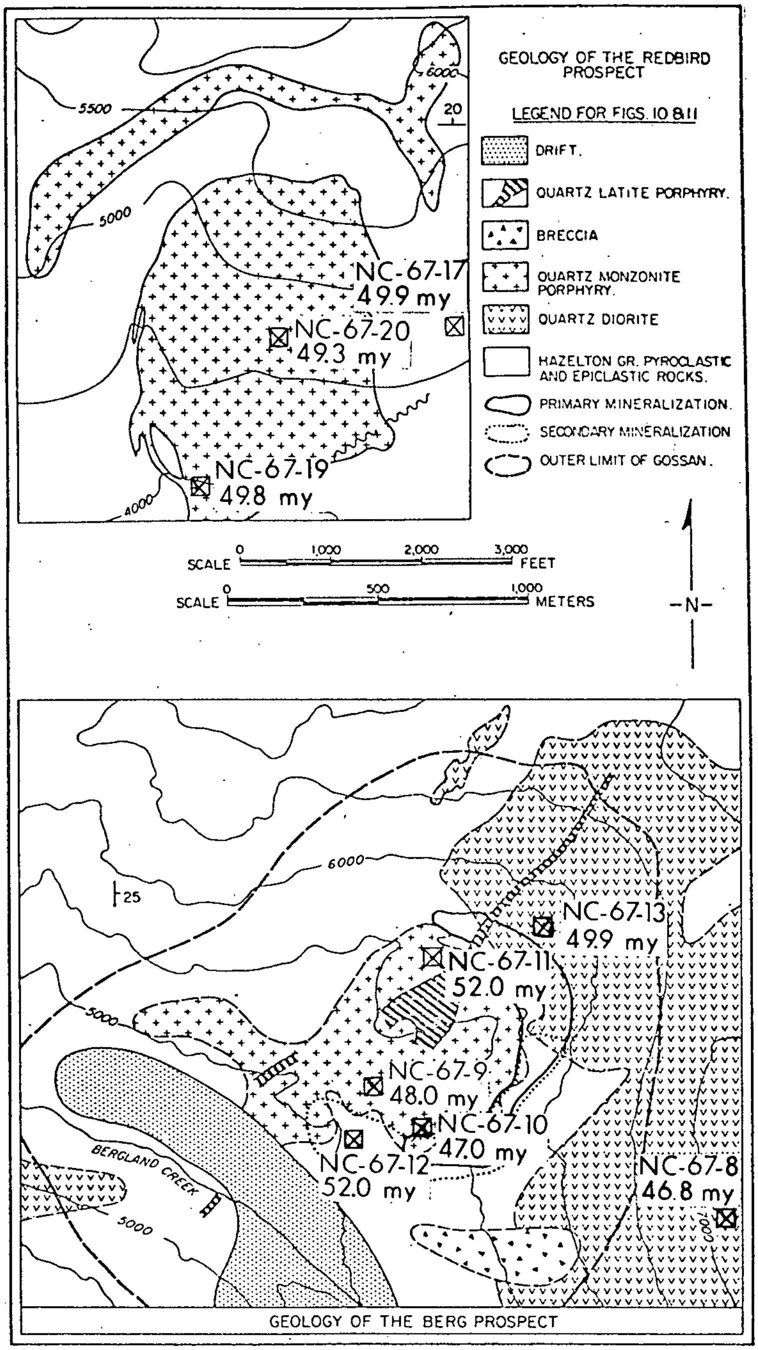

GEOLOGY OF THE REDBIRD PROSPECT
LEGEND FOR FIGS. 10 & 11
DRIFT.
QUARTZ LATITE PORPHYRY.
BRECCIA
QUARTZ MONZONITE PORPHYRY.
QUARTZ DIORITE
HAZELTON GR. PYROCLASTIC AND EPICLASTIC ROCKS.
PRIMARY MINERALIZATION.
SECONDARY MINERALIZATION
OUTER LIMIT OF GOSSAN.
5500
6000
5000
4000
20
NC-67-17
49.9 my
NC-67-20
49.3 my
NC-67-19
49.8 my
SCALE 0 1,000 2,000 3,000 FEET
SCALE 0 500 1,000 METERS
N
6000
25
5000
NC-67-13
49.9 my
NC-67-11
52.0 my
NC-67-9
48.0 my
NC-67-10
47.0 my
NC-67-12
52.0 my
NC-67-8
46.8 my
BERGLAND CREEK
5000
GEOLOGY OF THE BERG PROSPECT

FIG.–C.16.

part of the stock (Figure C.16). In hand specimen, the quartz latite greatly resembles the quartz monzonite, but crosscutting relationships and lack of mineralization indicate that it is of post-mineral age. Also of post-mineral age are narrow andesite dykes.

Volcanic and sedimentary rocks marginal to the quartz monzonite porphyry stock have been thermally metamorphosed to biotite hornfels. The earlier quartz diorite within the zone of thermal metamorphism features abundant secondary biotite, an alteration of magmatic hornblende. Superimposed on the metamorphic zone are alteration minerals related to mineralization, including K-feldspar, topaz, and silica.

Molybdenum and copper mineralization is contained in an annular zone co-axial with the quartz monzonite porphyry stock. The mineralized zone is best developed around the eastern contacts of the stock where chalcopyrite and molybdenite are contained in a stockwork of quartz veinlets. In general, best molybdenum mineralization is within and adjacent to the stock whereas copper has its greatest concentrations 200 feet or more beyond the contact. A pyrite halo extends outward 1,000 to 2,000 feet from the stock contact. Primary mineralization has been subjected to oxidation, leaching, and enrichment. The depth of leaching may extend to 300 feet, below which supergene chalcocite appears as coatings on pyrite in an irregular blanket.

NC-67-8 – Quartz Diorite

Sample is from an elevation of 7,200 feet at the head of the cirque, to the east of the Berg stock (Figure C.16).

The quartz diorite is a fine-grained, grey, equigranular rock with scattered 4-millimetre phenocrysts of hornblende. The rock has a hypidiomorphic granular texture and is composed essentially of plagioclase (An_{50}) with subordinate hornblende, biotite, and quartz. Plagioclase is fairly fresh, while hornblende shows partial alteration to chlorite. Biotite occurs as one-half to 1-millimetre plates which are up to 50 per cent altered to chlorite.

NC-67-4 – Quartz Latite Porphyry

Sample is from drill core from a hole drilled in the south-central part of the stock (Figure C.16).

The quartz latite porphyry is composed mainly of 2 to 4-millimetre phenocrysts of euhedral plagioclase (An_{20}), 2 to 4-millimetre biotite books, and 1 to 2-millimetre quartz phenocrysts, all set in a very fine-grained matrix of quartz, feldspar, and chloritized hornblende. Biotite is poikilitic and is relatively unaltered except for minor chlorite alteration along the edges of some grains.

NC-67-10 – Quartz Latite Porphyry

Sample is from drill core from a hole drilled near the southern contact of the Berg stock (Figure C.16).

Sample is similar to NC-67-9, except for a greater number of larger (4-millimetre) quartz phenocrysts and some hairline fractures containing quartz. Original hornblende is altered to a mixture of chlorite and biotite. Biotite occurs as 4-millimetre shredded, poikilitic plates exhibiting only minor chlorite alteration.

NC-67-11 – Quartz Monzonite Porphyry

Sample is from drill core from a hole drilled into the north part of the stock (Figure C.16).

Phenocrysts make up 35 to 50 per cent of the rock and include 4-millimetre euhedral plagioclase (An_{30}), biotite books, and anhedral quartz. Matrix is a very fine-grained mosaic of quartz and feldspar. Feldspars exhibit sericite alteration and hairline fractures cut through some phenocrysts. Biotite is poikilitic and minor chlorite and carbonate alteration (10 per cent) occurs along the edges of some grains.

NC-67-12 – Biotite Hornblende

Sample is from a drill hole collared near the southern contact of the stock (Figure C.16).

The hornfels is a dense, aphanitic, dark brown rock, transected by numerous hairline fractures filled with quartz. It consists principally of a mosaic of quartz grains and extremely fine-grained, unaltered biotite plates.

NC-67-13 – Quartz Diorite

Sample is from a drill hole which intersected quartz diorite in the contact metamorphic aureole northeast of the stock (Figure C.16).

The rock is fine grained, equigranular, and dark grey in colour. Quartz and biotite have been introduced. Biotite occurs as 1-millimetre plates which make up to 10 per cent of the rock. Biotite plates are poikilitic and are up to 10 per cent chloritized.

C.3.6 Red Bird (after Sutherland Brown, 1966, 1972)

This property is several miles west of Eutsuk Lake, 100 miles south of Smithers.

Middle Jurassic Hazelton Group pyroclastic rocks are intruded by an elliptical stock of quartz monzonite porphyry, 3,000 feet in diameter. A semicircular ring dyke occurs around the northern circumference of the stock (Figure C.16).

The stock consists largely of a single-phase, quartz monzonite porphyry. Where fresh, the rock is light grey to pink and contains phenocrysts of slightly corroded quartz, plagioclase, K-feldspar, and biotite, set in a matrix of quartz and feldspar. Grey monzonite porphyry, of post-mineral age, occurs as small crosscutting dykes and larger masses within the stock. Four-millimetre phenocrysts of plagioclase, quartz, and biotite are contained in a very fine-grained matrix of feldspar.

Fine-grained volcanic rocks adjacent to the stock have been converted to biotite hornfels. Hydrothermal alteration, involving the development of secondary K-feldspar, has affected some of the hornfelsed country rocks and the core of the stock where half the plagioclase phenocrysts have been converted to K-feldspar.

The quartz monzonite porphyry stock is host to a concentric zone of molybdenum mineralization contained mainly within a peripheral ring of the main mass of the stock. Molybdenite is contained in a stockwork of quartz veinlets, best develped near the stock contact. A prominent gossan developed in the volcanic rocks is about 2 miles in maximum diameter.

NC-67-17 – Biotite Hornfels

Sample is from a roadcut to the east of the Red Bird stock (Figure C.16).

The rock is dense, fine grained, dark brown, and is cut by numerous one-eighth-inch quartz-pyrite veinlets. Biotite and quartz constitute the bulk of the rock. Biotite occurs as unaltered one-half millimetre plates which are uniformly distributed throughout the rock.

NC-67-19 – Quartz Monzonite Porphyry

Sample was collected from near the south end of the stock (Figure C.16).

The quartz monzonite is a pink, leucocratic, crowded porphyry with 4-millimetre phenocrysts of quartz, plagioclase (An_{25-30}), and K-feldspar making up 50 per cent of the rock. Matrix is composed of a mosaic of quartz, feldspar, and biotite. One-millimetre poikilitic biotite plates are weakly altered to chlorite.

NC-67-20 – Monzonite Porphyry

Sample is from a roadcut in the central part of the stock (Figure C.16).

The monzonite is a medium grey rock containing scattered 2 to 6-millimetre phenocrysts of euhedral plagioclase and partly resorbed quartz. Quartz-pyrite one-eighth-inch veinlets cut the rock. The fine-grained matrix is composed mainly of quartz and sericitized feldspar.

Biotite occurs as 1 to 2-millimetre plates and books, and is poikilitic. Chlorite alteration amounts to 10 per cent and is principally along cleavages. Original hornblende is completely altered to a mosaic of fine biotite.

C.3.7 Nadina Mountain

A granitic stock underlies most of Nadina Mountain and is exposed on the eastern and western flanks of the mountain. The stock intrudes a sedimentary sequence blieved to be equivalent to the Sustut Group of Late Cretaceous-Early Tertiary age (Figure 14). The intrusive is not known to contain sulphide mineralization. A sample from near the top of the mountain was collected by A. Sutherland Brown.

NC-68-7 – Quartz Monzonite

The quartz monzonite is a pink to grey, medium-grained, equigranular rock containing abundant biotite plates.

The rock has a hypidiomorphic granular texture and consists of quartz, 15 per cent; plagioclase (An_{25-30}), 30 per cent; perthitic K-feldspar, 25 per cent; biotite, 7 per cent; chlorite, 10 per cent; and sphene, apatite, and opaque minerals, 12 per cent. Feldspars are slightly sericitized and original hornblende is entirely altered to chlorite. Biotite occurs as 1-millimetre plates with only incipient chlorite alteration.

C.3.8 Goosly

A sample from the syenodiorite stock at the Goosly property was collected by B. N. Church (Figure C.15). The stock is interpreted by Church (1969) as being a feeder for the extensive Tertiary volcanic rocks which occur nearby.

NC-69-7 – Syenodiorite

Sample is a medium-grained grey rock consisting essentially of feldspar and mafic minerals.

Laths of plagioclase (An_{45}), up to 2 centimetres long, make up most of the rock. Interstitial areas contain K-feldspar, clinopyroxene, and biotite. The rock is unaltered. Shredded, poikilitic unaltered biotite plates are intimately associated with clinopyroxene.

C.3.9 Morice Lake

A sample from the granitic stock at Morice Lake was collected to determine its possible relationship to the Lucky Ship molybdenum-bearing pluton (Figure 14). Sulphide mineralization is not known within the Morice Lake stock.

NC-67-15 – Quartz Monzonite

Sample was collected from the east shore of Morice Lake, 12 miles from the north end of the lake.

The quartz monzonite is a pink, leucocratic, medium-grained, equigranular rock, which consists mainly of quartz, plagioclase (An_{20}) and perthitic K-feldspar plus biotite. Biotite occurs as 1-millimetre poikilitic plates which are up to 15 per cent chloritized.

C.4 BABINE INTRUSIONS AND ASSOCIATED COPPER DEPOSITS

C.4.1 Granisle (after Carter, 1972b)

The Granisle mine is on McDonald Island near the north end of Babine Lake, 40 miles northeast of Smithers.

The property was originally worked on in the early 1900's and drilled in 1929. The Granby Mining Company Limited acquired the property in 1955 and mining began in 1966. The mill capacity is 14,000 tons per day and published reserves are 80 million tons of 0.43 per cent copper.

The Granisle mine is in the central part of McDonald Island, which is triangular shaped, each side being about 1 mile long.

The island is underlain chiefly by volcanic and sedimentary rocks of the Lower Jurassic Hazelton Group which are divisible into two distinct members. Green to purple waterlain andesite tuffs and breccias with intercalated chert pebble conglomerates and shales underlie the central and eastern part of the island. These rocks, which strike northerly and dip at moderate angles to the west are apparently overlain in the western part of the island by massive and amygdaloidal andesitic flow rocks (Figure C.17).

Copper mineralization is associated with a series of porphyry intrusions which occur in the central part of the island. The oldest of these is an elliptical plug of quartz diorite, however the largest and most prominent is a 400 to 600-foot-wide dyke of biotite feldspar porphyry which strikes north-easterly across the island. This wide dyke is evident as a ridge which before mining culminated as a 300-foot hill above lake level. There are small dykes very similar in composition that post-date mineralization. The multiple intrusions are well displayed in the present open pit.

The first intrusive stage is represented by a northeast-oriented ovaloid cylindrical pluton of fine-grained dark grey quartz diorite, the original dimensions of which were approximately 1,000 by 1,500 feet in plan. The quartz diorite is commonly a microporphyry with 1-millimetre phenocrysts of

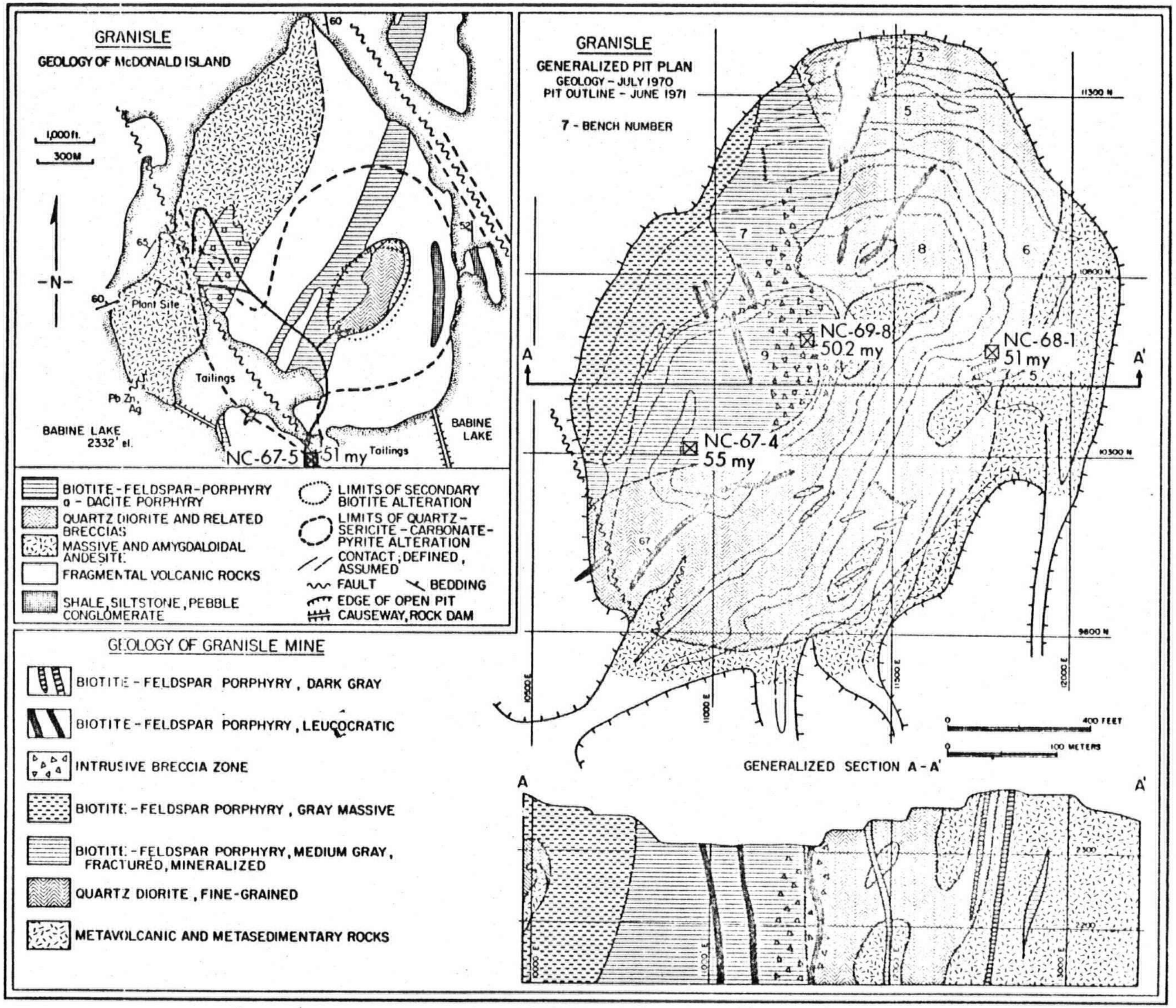

GRANISLE
GEOLOGY OF McDONALD ISLAND
1,000 ft.
300 M
Plant Site
Tailings
Pb Zn, Ag
BABINE LAKE
2332' el.
BABINE LAKE
NC-67-5
51 my
Tailings
BIOTITE-FELDSPAR-PORPHYRY
a - DACITE PORPHYRY
QUARTZ DIORITE AND RELATED BRECCIAS
MASSIVE AND AMYGDALOIDAL ANDESITE
FRAGMENTAL VOLCANIC ROCKS
SHALE, SILTSTONE, PEBBLE CONGLOMERATE
LIMITS OF SECONDARY BIOTITE ALTERATION
LIMITS OF QUARTZ-SERICITE-CARBONATE-PYRITE ALTERATION
CONTACT; DEFINED, ASSUMED
FAULT
BEDDING
EDGE OF OPEN PIT
CAUSEWAY, ROCK DAM
GEOLOGY OF GRANISLE MINE
BIOTITE-FELDSPAR PORPHYRY, DARK GRAY
BIOTITE-FELDSPAR PORPHYRY, LEUCOCRATIC
INTRUSIVE BRECCIA ZONE
BIOTITE-FELDSPAR PORPHYRY, GRAY MASSIVE
BIOTITE-FELDSPAR PORPHYRY, MEDIUM GRAY, FRACTURED, MINERALIZED
QUARTZ DIORITE, FINE-GRAINED
METAVOLCANIC AND METASEDIMENTARY ROCKS
GRANISLE
GENERALIZED PIT PLAN
GEOLOGY - JULY 1970
PIT OUTLINE - JUNE 1971
7 - BENCH NUMBER
11300 N
10300 N
9800 N
NC-69-8
50.2 my
NC-68-1
51 my
NC-67-4
55 my
A
A'
400 FEET
100 METERS
GENERALIZED SECTION A - A'

FIG.-C.17

207.

zoned andesine set in a fine-grained quartz-plagioclase-biotite matrix. Original amphibole grains, now completely altered to fine masses of biotite, locally impart a foliation to the rock.

Within the quartz diorite, particularly along its eastern edge, are irregular inclusions of metavolcanic and metasedimentary rocks which had a wider distribution in the original outcrop. Three varieties occur, two of which are breccias believed to be the product of recrystallization and metasomatism of the fragmental volcanic and sedimetnary rocks marginal to the intrusive. One variety of breccia includes 1 to 3-centimetre rounded chert and volcanic fragments in a fine-grained diorite matrix, while another consists of chert fragments in a white felsic matrix which also contains 4-millimetre clots of very fine-grained quartz and chloritized biotite. The third variety of inclusions consists of fine-grained, light to dark grey, hornfelsed volcanic and sedimentary rocks.

The most important intrusions are biotite feldspar porphyries of several distinct but very similar phases that overlap the period of mineralization. The largest and oldest is the wide northeasterly trending dyke which is intrusive into the western edge of the quartz diorite pluton. In plan, a salient of this porphyry projects into the quartz diorite in the pit area and the contact between the two is nearly vertical. Small dykes of porphyry radiate outward from the main dyke. The main porphyry is light to dark grey and ranges in composition from quartz diorite to granodiorite depending on the amount of K-feldspar present, most of which is of secondary origin. Characteristically the rock is a crowded porphyry with between 35 and 50 per cent by volume consisting of 2-millimetre euhedral, fresh, zoned plagioclase (oligoclase-andesine) phenocrysts and 1-millimetre flakes and books of fresh brown biotite.

These phenocrysts are set in a fine-grained matrix consisting essentially of quartz, plagioclase, patches of fine-grained biotite, some of which is pseudomorphic after amphibole, K-feldspar, and apatite. Outside of the pit area, the porphyry is a uniform grey colour and contains hornblende phenocrysts as well as biotite and plagioclase.

Several of the phases of porphyry intrusions can be recognized within the pit area. While these are all grossly similar in appearance and composition as described above, they can be distinguished by slight differences in the colour of the matrix, resulting mainly from variations in grain size, by crosscutting relationships, and by the presence of inclusions of earlier phases contained in later ones.

The earliest and most widespread porphyry phase is the medium-grained, well-fractured, and mineralized biotite feldspar porphyry exposed in the central part of the pit. Small dykes of similar material were noted cutting the quartz diorite. Bordering this type on the west is a massive grey porphyry of uniform appearance, differing mainly by having a slightly coarser matrix and by a relative absence of fracturing and mineralization. These two varieties of biotite feldspar porphyry are probably products of the initial stage of porphyry intrusion with fracturing being best developed in the contact area between the porphyry and the quartz diorite.

Occurring along the contact between the biotite feldspar porphyry and the quartz diorite are narrow discontinuous dykes and stringers of intrusive breccia which range in width from several inches to several feet and follow the principal fracture directions. The dykes and stringers are contained in a northerly trending, vertical zone which is up to 200 feet wide. The intrusive breccias commonly contain 1 to 2-centimetre rounded fragments of both the medium grey mineralized porphyry and the quartz diorite in a fine-grained light to dark grey granulated matrix of strained and fractured quartz, broken plagioclase grains, and locally abundant very fine-grained biotite. The breccias are also mineralized, with some disseminated chalcopyrite occurring in the matrix.

Dykes of light grey, relatively leucocratic biotite feldspar porphyry up to 10 feet wide, that also parallel the dominant fracture pattern, occur as northwest-trending, vertical dykes in the main porphyry mass and northeast-trending vertical to steeply dipping dykes in the marginal quartz diorites. These dykes have a coarse matrix which has a lower biotite content. Rounded inclusions of mineralized porphyry are common in the leucocratic type which are only locally mineralized themselves by minor disseminated pyrite and chalcopyrite.

The latest porphyry phase, post-mineral in age, occurs as dykes of dark grey biotite feldspar porphyry which intrude diorite rocks in the eastern part of the pit. The plagioclase phenocrysts are sparser than in earlier phases and the dark grey matrix is due to the presence of very fine-grained biotite and uniformly disseminated magnetite. Only minor disseminated pyrite and chalcopyrite were noted in this phase.

The porphyry dyke on McDonald Island is bounded by two parallel northwest block faults. The westernmost of these is marked by a topographic lineament which crosses the island to the south of the mine and extends through the western part of McDonald Island in the vicinity of the plant site. The eastern fault extends along the channel separating McDonald Island from the east shore of Babine Lake.

Within the pit area, the main fractures are vertical to steeply dipping and include the following sets: north 20 degrees to 40 degrees east; north 70 degrees to 85 degrees east; and north 30 degrees to 60 degrees west. Horizontal to slightly inclined fractures are also common. In general the resulting fracture spacing may vary from 0.1 to 1 metre.

Movement has occurred along many of the fractures; the most common faulting directions being north 20 degrees east and north 30 degrees to 60 degrees west.

An oval zone of potassic alteration is roughly coincident with the ore zone or the pit outline (Figure C.17). Within this zone, the intrusive rocks appear fresh in hand specimen and plagioclase phenocrysts are essentially unaltered. The main alteration product is secondary biotite which occurs as very fine-grained aggregates which retain original amphibole outlines in both the porphyries and the quartz diorites. Fine-grained biotite is also uniformly distributed in the matrix of the intrusive rocks. However secondary K-feldspar is also present within the ore zone, occurring most commonly as fine grains in the matrix of the biotite feldspar porphyry, and only detectable by staining. Pink K-feldspar also forms thin envelopes enclosing veinlets and fractures in the lower benches of the pit. Similar alteration was noted at depth in cores of holes drilled in the centre of the orebody.

The potassic alteration zone is gradational outward to a quartz-sericite-carbonate-pyrite zone. This zone, apparent by iron staining on weathered surfaces, is visible on the higher benches at the north end of the pit, and along roads south of the pit. This pyrite halo is elliptical in plan and is roughly coaxial with the ore zone, extending 500 to 800 feet beyond. It merges with a similar alteration along the regional fault southwest of the pit. The entire quartz-sericite-carbonate-pyrite zone measures 3,000 to 4,000 feet. Within this zone, the intrusive rocks and most of the volcanic rocks are weathered to a uniform buff colour. Abundant fine-grained quartz has been introduced, mafic minerals have been altered to a mixture of sericite and carbonate, and plagioclase is clouded by sericite. Pyrite occurs both as disseminations and as fracture fillings.

Outside the pyrite halo, most of the rocks on McDonald Island display varying degrees of propylitic alteration; chlorite, carbonate, and epidote are common constituents in the matrix of volcanic rocks and carbonate-filled fractures are widespread. Pyrite also occurs in fractured zones. Clay mineral alteration is confined to narrow gouge and fault zones.

The principal minerals within the ore zone are chalcopyrite, bornite, and some pyrite. Medium to coarse-grained chalcopyrite is most widespread, occurring principally in quartz-filled fractures which vary from 1 to 5 millimetres in width. The mineralized fractures have preferred orientations of north 35 degrees to 60 degrees east and north 30 degrees to 60 degrees west, and dip steeply. A horizontal fracture set in the pit is only weakly mineralized. Chalcopyrite is also disseminated in the quartz diorite and associated metasedimentary and metavolcanic rocks.

Bornite is most widespread in the southern half of the ore zone where it occurs with chalcopyrite and quartz in fractures. The greatest concentrations of bornite were confined to the upper 250 feet of the south end of the orebody. During the first few years of mining operations, a number of veins up to 0.3 metre wide and composed of coarse-grained bornite, chalcopyrite, quartz, biotite, and apatite were uncovered. They were vertical and had a strike of north 50 degrees east but were discontinuous.

Gold and silver are recovered from the copper concentrates. Molybdenite occurs locally within the ore zone, most commonly in drusy quartz veinlets which appear to be later than the main mineralizing stage. Magnetite and specularite are common in the north half of the ore zone where they occur in fractures with chalcopyrite and pyrite.

The greatest concentration of pyrite is peripheral to the copper orebody where it occurs as blebs, stringers, and disseminations.

Near the southwest end of the island, approximately 4,000 feet southwest of the pit, a narrow quartz-carbonate-pyrite-galena-sphalerite-chalcopyrite vein containing silver values follows a northeast-striking fault for a limited distance.

NC-67-4 – Biotite Feldspar Porphyry

Sample was collected from the open pit in the southwestern part of the orebody (Figure C.17).

The rock is a medium grey, fine to medium-grained crowded porphyry of granodiorite composition. The porphyry is cut by numerous hairline fractures and one-eighth to one-quarter-inch quartz veinlets containing chalcopyrite and a little bornite. Minor chalcopyrite is also contained in the matrix. Forty per cent of the rock is composed of 1 to 2-millimetre phenocrysts of fresh, euhedral, zoned plagioclase (An_{25-35}) and plates and books of biotite. These are contained in a very fine-grained matrix of quartz, plagioclase, Biotite, and minor K-feldspar. Accessory minerals include apatite and magnetite.

Biotite occurs as primary books and plates and as an alteration of original hornblende, and makes up 10 per cent of the rock by volume. Both varieties are free of chlorite alteration.

NC-67-5 – Biotite Feldspar Porphyry

Samples were collected from a 10-foot-wide dyke outside the quartz-sericite-pyrite zone on the north end of Sterrett Island (Figure C.17).

The porphyry is a light grey, fine-grained rock containing minor amounts of pyrite on hairline fractures. One to 2-millimetre phenocrysts of plagioclase (An_{25}) and biotite constitute 25 per cent of the rock. These are contained in a fine-grained matrix of quartz, sericitized feldspar, and hornblende which is completely altered to chlorite and carbonate. Biotite plates are primary and are fresh.

NC-68-1 – Biotite Feldspar Porphyry

Sample is from a late porphyry dyke in the eastern part of the pit area and contains only minor disseminated sulphide minerals (Figure C.17).

Thirty per cent of the rock consists of 2-millimetre phenocrysts of plagioclase (An_{25-35}) and 2-millimetre plates of biotite and chloritized hornblende. The matrix features abundant carbonate alteration. Poikilitic biotite plates exhibit no chlorite alteration.

NC-69-8 – Quartz-bornite-chalcopyrite-biotite-apatite Vein

Sample was collected from a 1-foot-wide vein in the central part of the open pit.

The vein contains abundant coarse-grained bornite and chalcopyrite in a quartz, apatite, and biotite gangue. Apatite occurs as one-half to 1-centimetre crystals. Biotite is in the form of one-half to 1-centimetre plates and books and is 20 to 50 per cent altered to chlorite.

C.4.2 Newman (Bell Copper) (after Carter, 1965 and Carson and Jambor, 1974)

The Newman mine of Noranda Mines, Limited, Bell Copper Division, is on Newman Peninsula, 4 miles northwest of the Granisle mine.

Initial work on the property, dating back to 1913, was directed to mineralized showings on the west shore of the peninsula opposite Newman Island. By 1927 three adits had been driven along small shear zones containing pyrite, pyrrhotite, and some chalcopyrite and sphalerite. The property was located by Noranda Exploration Company, Limited in 1962. Production began in 1972 at a daily milling rate of 10,000 tons. Reserves are in the order of 50 to 100 million tons of 0.5 per cent copper.

Copper mineralization is associated with a plug-like intrusion of biotite feldspar porphyry 2,600 feet in diameter. Radial dykes projecting from the west side of the plug suggest it is probably a volcanic neck which has come up along the fault contact between siltstones on the west and fragmental rocks on the east (Figure C.18).

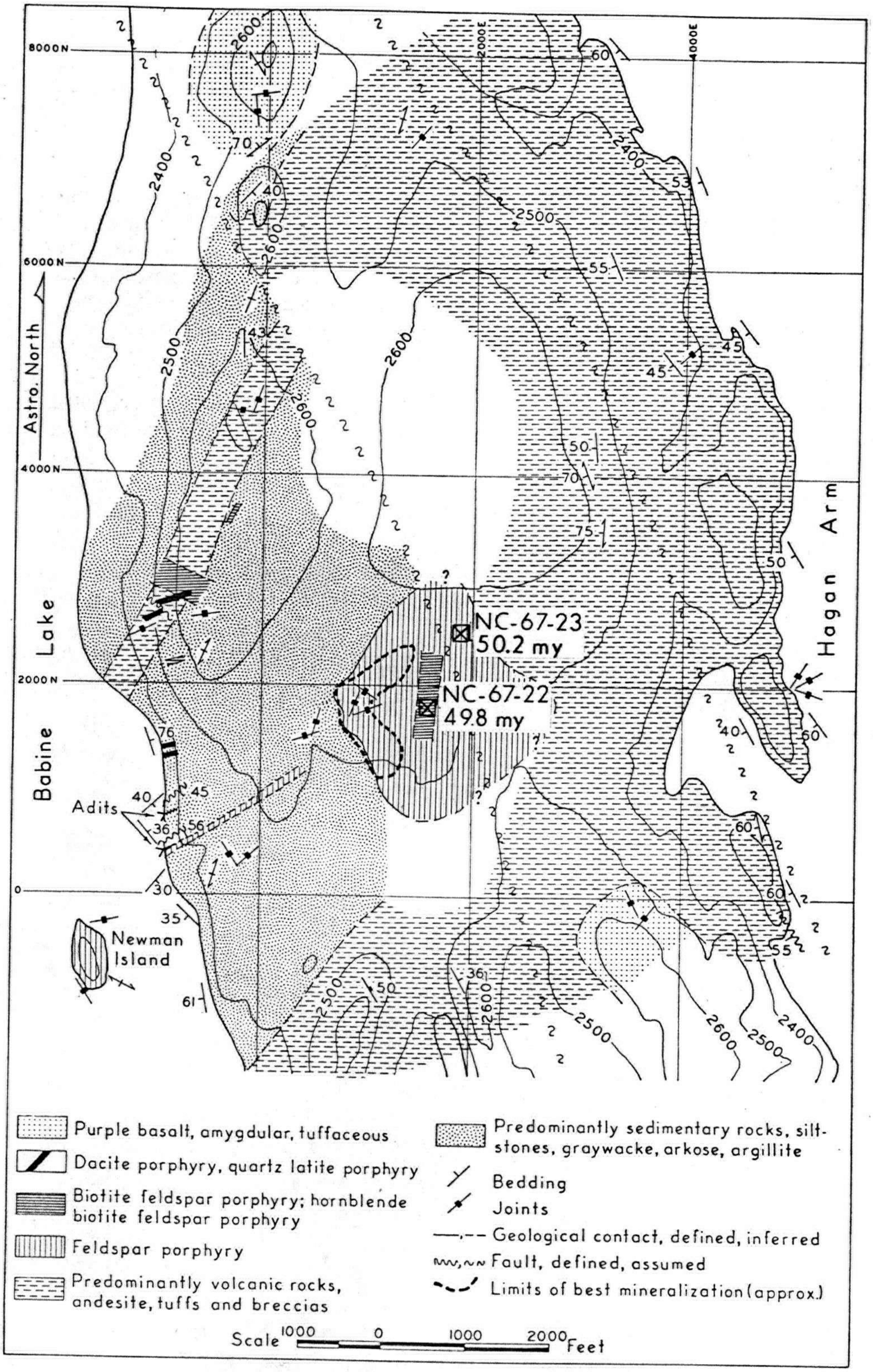


FIG.- C.18 NEWMAN (BELL COPPER)

Supergene weathering has transformed the biotite feldspar porphyry to a feldspar porphyry in the upper several hundred feet of the intrusive. This is a porous white rock composed of numerous 1 to 2-millimetre chalky white feldspar phenocrysts set in a quartz-rich matrix.

Along the western contact, sericite and carbonate alteration of feldspar is extreme, in some cases obliterating the original texture. The rock is cut by numerous randomly oriented quartz and carbonate veinlets. Original biotite has been leached out, leaving golden-brown-stained areas in the matrix. Metallic minerals, including pyrite and chalcopyrite, are finely disseminated throughout the rock matrix and the quartz veinlets. Quartz veining and silicification of the feldspar porphyry is most extensive throughout the northern part of the western contact of the plug, where irregular areas of light purple and grey quartz contain ragged inclusions of the feldspar porphyry. The degree of quartz veining and silicificiation has not been as extreme in the southern part of the western contact area, where larger 2-millimetre phenocrysts of sericite and carbonate, pseudomorphic after plagioclase, are contained in an altered quartz feldspar matrix. Irregular siltstone inclusions, having both sharp and gradational contacts, are common within the feldspar porphyry along the western contact.

A northerly trending dyke-like body of relatively unaltered biotite feldspar porphyry occurs in the central part of the intrusive (Figure C.18) and also forms a 500-foot capping over mineralized porphyry in the northeast part of the plug. It is interpreted as being a later, possibly post-mineral intrusive phase. The rock contains fairly fresh 2-millimetre phenocrysts of oligoclase-andesine and brown biotite with some hornblende.

Hydrothermal alteration patterns are similar to those developed at Granisle, but are masked in the upper part of the intrusion by supergene quartz-sericite alteration (Carson and Jambor, 1974). The potassic zone is best developed coincident with the zone of copper mineralization and consists almost entirely of secondary biotite alteration in the porphyry. The quartz-sericite-pyrite zone is best developed in the sedimentary and volcanic rocks marginal to the intrusive and extends to the western shore of Newman Peninsula. Enveloping this is a chlorite-carbonate zone of several thousand feet diameter.

Copper mineralization occurs in a crescent-shaped zone along the western contact of the porphyry plug. Better grades of copper mineralization are contained in a 200 to 300-foot-thick flat-lying, blanket-type deposit which is connected to a central pipe-like zone, centred on the western contact of the intrusive. The pipe-like zone of copper mineralization is 500 feet in diameter and extends to a depth of at least 2,500 feet.

Primary mineralization, consisting of pyrite, chalcopyrite, and some bornite, occurs as fine disseminations in the rock matrix, and in irregular quartz lenses and a stockwork of one-eighth to one-quarter-inch quartz veinlets which cut the feldspar porphyries and the siltstones. Quartz veinlets and hairline fractures containing specularite and magnetite are also common. Disseminations of molybdenite occur locally in the feldspar porphyry in the northern part of the zone. A zone of secondary enrichment, in the form of chalcocite coating chalcopyrite, is present over the entire mineralized body, extending to a depth of 500 feet over the central pipe-like zone. Elsewhere the depth of enrichment corresponds to the limits of the better grade mineralization in the northeast and southeast extensions of the zone of mineralization.

Relationships in the drill cores suggest several ages of fracturing and quartz veining, including at least two stages of primary copper mineralization. Hairline fractures and one-quarter-inch quartz veinlets containing specularite and magnetite represent the initial stage of mineralization, and these are cut by nearly flat-lying light grey quartz-pyrite veinlets containing some chalcopyrite. Offsetting these are chalcopyrite-bearing hairline fractures and veinlets of purple quartz oriented at angles of 40 degrees with respect to core surfaces in vertical drill holes. Associated with this stage is pervasive purple quartz silicification. Milky white quartz veins, several inches wide, and 2-foot lenses of pink calcite cut all other veinlets. Secondary enrichment, consisting of sooty chalcocite coating chalcopyrite, represents the final stage of copper mineralization.

Controls for the zone of copper mineralization are incompletely known. The crescent-shaped form of the zone accentuates the regional pattern of northeast and northwest fractures and the plug contact acted as a locus for intense fracturing and brecciation of the siltstones and feldspar porphyry. In general, areas of better grade primary copper mineralization are situated in the central and northeast parts of the zone, where silicification is more extensive and the quartz veinlets are more numerous than in the southern part of the zone.

Pyrite, with some chalcopyrite and sphalerite, occurs in narrow northeasterly trending shear zones in the adits on the lakeshore. A well-developed pyrite halo surrounds the orebody and is approximately 6,500 feet in diameter.

NC-67-22 - Biotite Feldspar Porphyry

Sample is from a drill hole collared in late phase, weakly mineralized porphyry in the south-central part of the plug (Figure C.18).

The rock is light grey to buff in colour and is composed of 2-millimetre phenocrysts of plagioclase almost totally altered to carbonate, and 1-millimetre plates of biotite in a fine-grained, quartz-rich matrix. Original hornblende is altered to biotite and carbonate. Biotite occurs both as 1-millimetre plates and as very fine-shredded grains in the rock matrix. Both varieties are unaltered.

NC-67-23 – Biotite Feldspar Porphyry

Sample is from drill core from a hole collared in the northeast part of the intrusion (Figure C.18). The porphyry is cut by numerous quartz veinlets containing chalcopyrite. The section sampled is well below the zone of supergene alteration and mineralization.

The rock is a dark grey crowded porphyry with 2 to 4-millimetre phenocrysts of plagioclase (An_{30}) and 1-millimetre biotite plates and books constituting 35 per cent of the rock. The matrix is composed essentially of quartz. Biotite occurs as primary plates and books and as secondary fine-grained aggregates after hornblende. Both varieties are fresh.

C.4.3 Morrison (after Carter, 1966 and Carson and Jambor, 1974)

The Morrison copper deposit, owned by Noranda Exploration Company, Limited, is on the southeast side of Morrison Lake about 14 miles north of the Newman mine. Copper mineralization was discovered in 1962 and drilling since that time has indicated a copper zone containing 70 million tons averaging 0.4 to 0.45 per cent copper.

Chalcopyrite mineralization is associated with a small plug and peripheral dykes and sills of biotite feldspar porphyry which intrude a northerly trending sedimentary sequence (Figure C.19). Post-intrusive faulting has horizontally offset the central plug 1,000 feet.

Argillaceous siltstones adjacent to the plug and peripheral dykes have been thermally metamorphosed to biotite hornfels. Best exposures are in trenched areas east and west of the central plug, where dykes of porphyry are closely spaced and vary from 10 to 20 feet in width. Contacts between the dykes and the hornfelsed siltstones are sharp. The biotite feldspar porphyries are dark grey and of quartz diorite composition. One-quarter to one-third of the rock consists of 2 to 3-millimetre phenocrysts of fresh, euhedral, normally zoned oligoclase-andesine. Abundant one-half to 1-millimetre plates and books of fresh brown biotite, partly an alteration of hornblende, are also a characteristic feature of these rocks. The biotite feldspar porphyries are gradational to an altered variety in which plagioclase is altered to sericite and biotite is mainly converted to sericite.

A biotite alteration zone envelops the zone of copper mineralization and extends several hundred feet outward from it. Within this zone, sugary textured brown hydrothermal biotite has replaced hornblende phenocrysts and invaded the matrix of the porphyry. Some K-feldspar alteration adjacent to fractures was also noted. The biotite zone is gradational outward to a chlorite-carbonate zone several thousand feet in diameter.

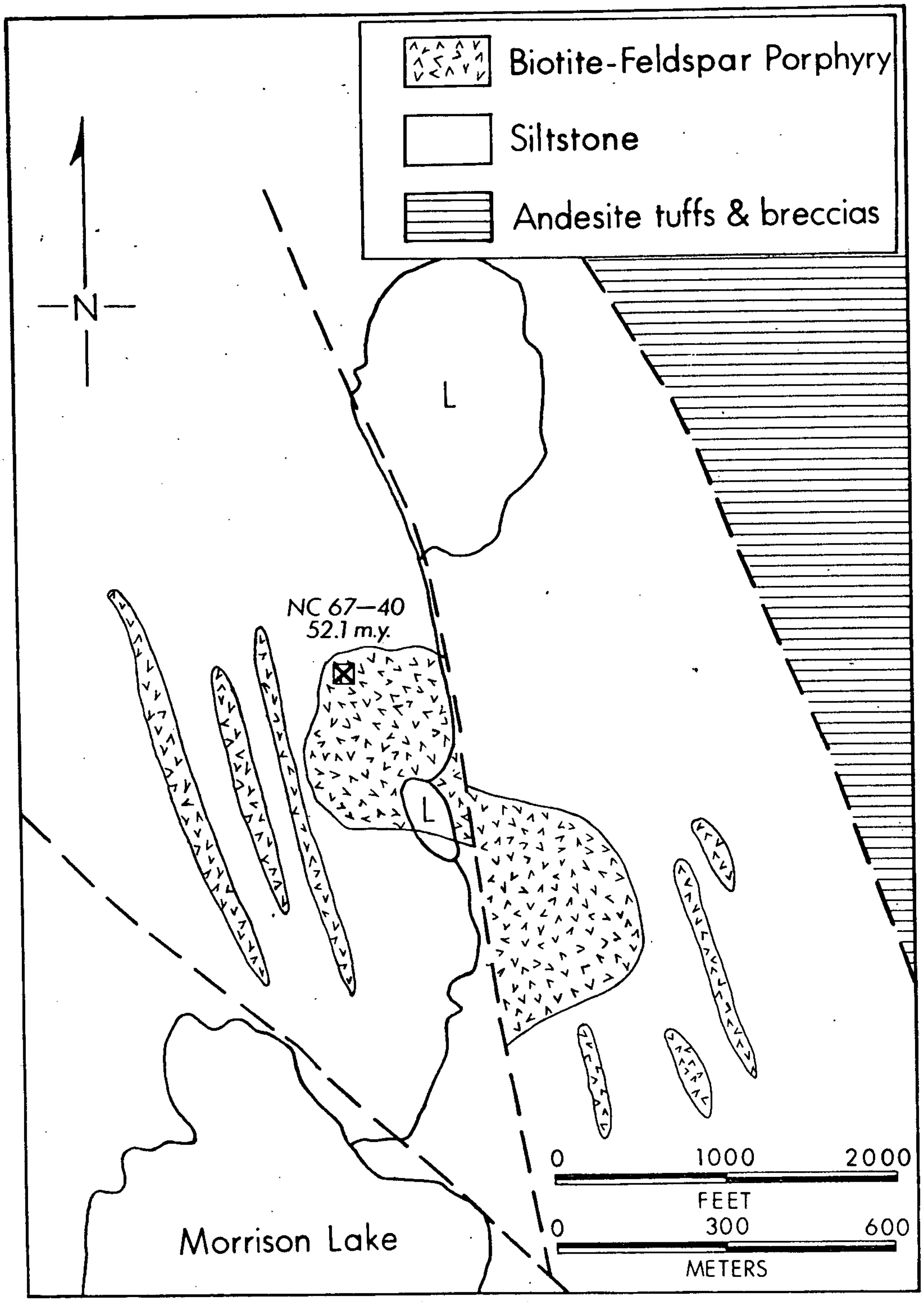


FIG.-C.19 MORRISON

Chalcopyrite occurs in closely spaced fractures and narrow quartz veinlets in the contact areas of the central plug and in the peripheral porphyry dykes and hornfelsed siltstones. Some bornite is contained in the central part of the deposit. A pyrite halo overlaps part of the copper zone and extends outward 1,000 feet from it.

NC-67-40 - Biotite Feldspar Porphyry

Sample was collected from a trench in the northwest part of the deposit.

The porphyry is dark grey and is featured by the presence of abundant biotite. Quartz-filled fractures cut the rock and contain chalcopyrite and a little bornite. One to 2-millimetre phenocrysts of euhedral plagiocoase make up 25 per cent of the rock. Biotite occurs mainly in fine-grained aggregates as an alteration of primary hornblende. The matrix consists of quartz, plagioclase, and some chlorite.

Biotite aggregates show little, if any, alteration to chlorite.

C.4.4 Old Fort (after Carter, 1966)

The property is on the southeast slope of Old Fort Mountain at the north end of the main part of Babine Lake (Figure C.20).

An elliptical stock of quartz diorite, elongated in an easterly direction and measuring 3,000 to 2,000 feet, intrudes argillaceous siltstones and interbedded andesite tuffs in the central part of the property (Figure C.20). Within the stock, quartz diorites have been intruded by a small elongate mass of quartz monzonite and related hornblende-biotite-feldspar porphyry dykes.

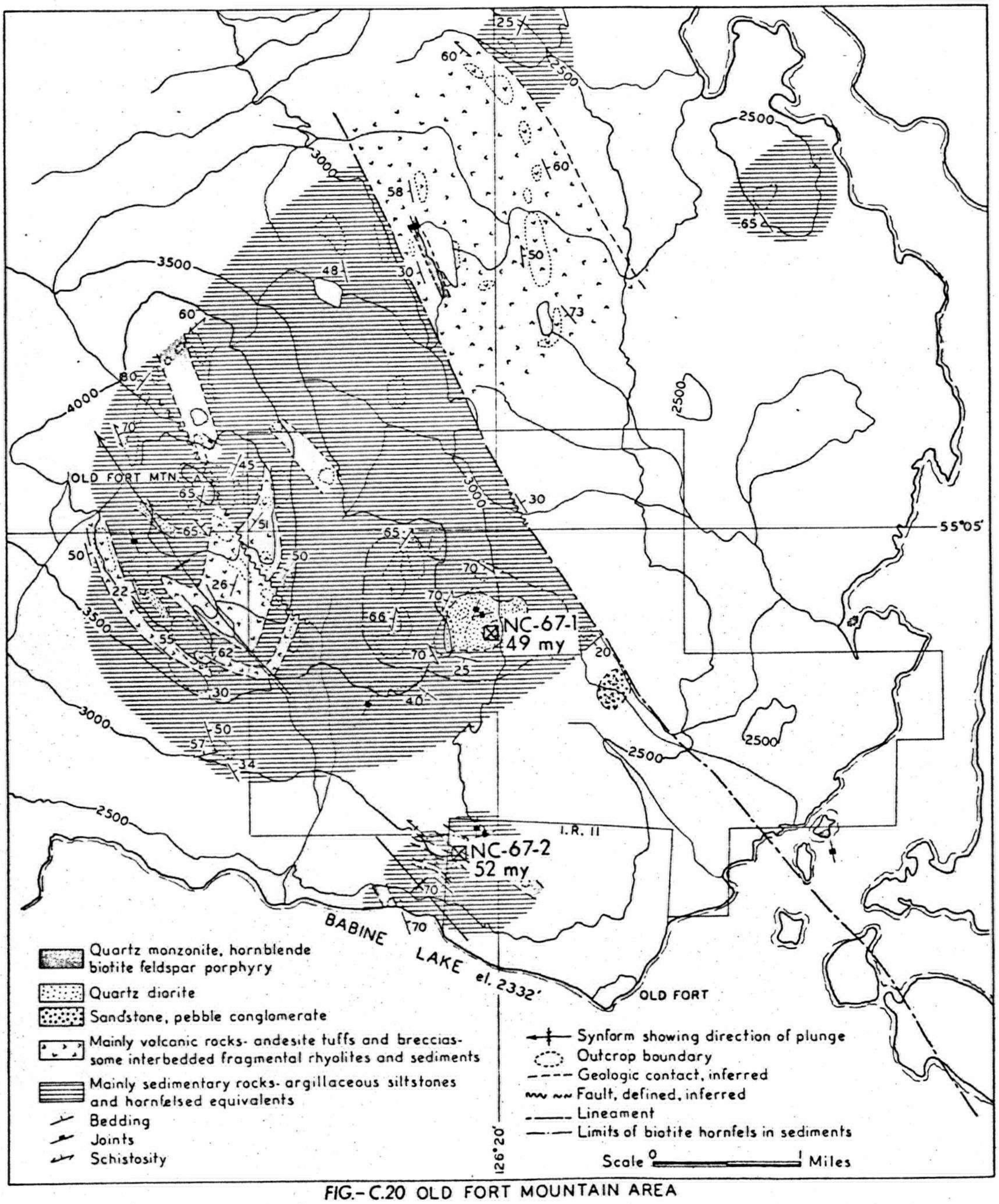


FIG.- C.20 OLD FORT MOUNTAIN AREA

Chalcopyrite and lesser amounts of molybdenite occur as disseminations and in fractures in both the quartz diorite and porphyry dykes adjacent to the western margin of the inner quartz monzonite body.

The quartz diorite which constitutes the greater part of the stock is a fine to medium-grained light grey equigranular rock having an average composition of 67 per cent euhedral, normally zoned oligoclase-andesine, 15 per cent quartz, 10 per cent hornblende, and 5 per cent biotite, with the remainder consisting of apatite, epidote, and opaque minerals. Alignment of 3-millimetre hornblende needles was noted near the margins of the stock. The quartz diorite is an essentially fresh rock, with only local sericitization of feldspar and chloritization of mafic minerals.

Contacts between the quartz diorite and later quartz monzonite are sharp to gradational. The quartz monzonite is distinguished by a slightly coarser equigranular to seriate texture, and a lighter grey colour with pinkish cast due to the presence of ragged, poikilitic K-feldspar. Biotite is the dominant mafic mineral, and occurs both as 1 to 2-millimetre books and flakes and as a fine alteration of hornblende. A typical specimen is composed of 45 per cent euhedral, normally zoned oligoclase-andesine, 20 per cent orthoclase, 15 per cent quartz, 10 per cent biotite, 5 per cent horbnlende, and 5 per cent accessory minerals including apatite, epidote, and opaque minerals. Varying degrees of argillic alteration of feldspar and bleaching of mafic minerals were noted in some sections of drill core. A porphyritic texture is developed along the western margin of the quartz monzonite body, and dykes of hornblende-biotite-feldspar porphyry, not exceeding 100 feet in width, radiate outward from this zone into the quartz diorites. Two-millimetre phenocrysts of euhedral oligoclase-andesine and plates and books of fresh brown biotite constitute 30 per cent of the rock, the remainder being composed of finer grained quartz, plagioclase, and amphibole, largely altered to fine biotite.

Argillaceous siltstones, including dense dark grey and light to dark grey well-banded varieties, have been metamorphosed to chocolate-brown-coloured biotite hornfels, for a distance of between 1,000 and 3,000 feet outward from the quartz diorite stock.

Pyrite and pyrrhotite are widely disseminated in all intrusive and adjacent sedimentary rocks. Several small isolated zones containing variable amounts of copper mineralization are grouped in a semicircular pattern within the area of porphyry dykes adjacent to the western margin of the central quartz monzonite mass. Chalcopyrite and minor bornite occur with magnetite as disseminations and in fractures in both the quartz diorite and hornblende-biotite-feldspar porphyry dykes. Molybdenite flakes are found in some fracture planes rimmed by one-eighth to one-quarter-inch fine-grained pink K-feldspar veinlets.

The most northerly zone of mineralization, near the central part of the stock, has been exposed in a 200-foot-long trench. Copper mineralization is most widespread in the eastern half of the trench, where porphyry dykes intrude quartz diorites. Chalcopyrite occurs as disseminations in both rock types and in north-trending fractures and irregular 1-inch zones rich in mafic minerals and magnetite in quartz diorites. A grab sample from the east end of the trench assayed 0.43 per cent copper.

NC-67-1 – Biotite Feldspar Porphyry

Sample is from a trench in the most northerly mineralized zone near the central part of the stock (Figure C.20). The porphyry is a medium to dark grey rock with hairline fractures containing chalcopyrite and molybdenite. Chalcopyrite is also finely disseminated in the rock matrix.

The rock is a crowded porphyry with 1 to 2-millimetre phenocrysts of euhedral plagioclase (An_{25-35}) and biotite making up 50 per cent of the rock volume. Original hornblende phenocrysts are altered to a mixture of chlorite and hornblende. The matrix is a cryptocrystalline mixture of quartz and feldspar. Poikilitic biotite plates and books are unaltered.

NC-67-2 – Biotite Quartz Monzonite

Sample is from a sill which intrudes argillaceous sedimentary rocks 2 miles south of the Old Fort stock (Figure C.20).

The rock is light grey and medium grained, and is actually a crowded porphyry with 2-millimetre phenocrysts of plagioclase (An_{25-40}), quartz, hornblende, and biotite making up 50 per cent of the rock. The matrix is a fine-grained mosaic of quartz and K-feldspar.

Biotite occurs as 1-millimetre, shredded, poikilitic plates and as fine-grained aggregates in the matrix. Up to 15 per cent chlorite alteration was noted.

C.4.5 Trail Peak (after Carter, 1969)

The property is on the south slope of Trail Peak, north of Babine Lake and 70 miles northeast of Smithers.

Trail Peak is underlain by dark grey to black cherty siltstone which is intensely fractured and iron-stained due to the presence of disseminated pyrite. Light grey crystal lithic tuffs are interbedded with the sedimentary rocks on the west side of Trail Peak.

The cherty siltstones have been intruded by medium-grained diorites and granodiorites and by dykes and irregular masses of biotite feldspar porphyry which host copper mineralization. Hornblende feldspar porphyries may in part be extrusive equivalents of the biotite feldspar porphyry dykes (Figure C.21).

The earliest intrusive rocks are medium-grained diorites and granodiorites which occur in small stock-like masses 1,500 feet or so in diameter in the central part of the map-area. An unaltered variety, on the south side of Trail Peak, has a hypidiomorphic granular texture and consists of the following: euhedral plagioclase (An_{38-46}), 57 per cent; hornblende, 13 per cent; reddish brown biotite, 7 per cent; interstitial perthitic K-feldspar, 7 per cent; anhedral quartz, 5 per cent; and chlorite, opaque minerals, etc., 11 per cent.

Cutting the diorites and granodiorites and the sedimentary rocks are northwest-striking dykes and irregular masses of biotite feldspar porphyry which are most abundant in the western trench area (Figure C.21). These porphyries are typical of the Babine Lake area and are of quartz diorite composition. Typically, the rock is medium to dark grey with phenocrysts making up 25 per cent of the rock by volume. These include 1 to 2-millimetre euhedral zoned plagioclase (An_{25-35}) and 1-millimetre books and plates of fresh biotite which are set in a fine-grained matrix of quartz, feldspar, and biotite. Secondary biotite is present as an aggregate of fine flakes replacing

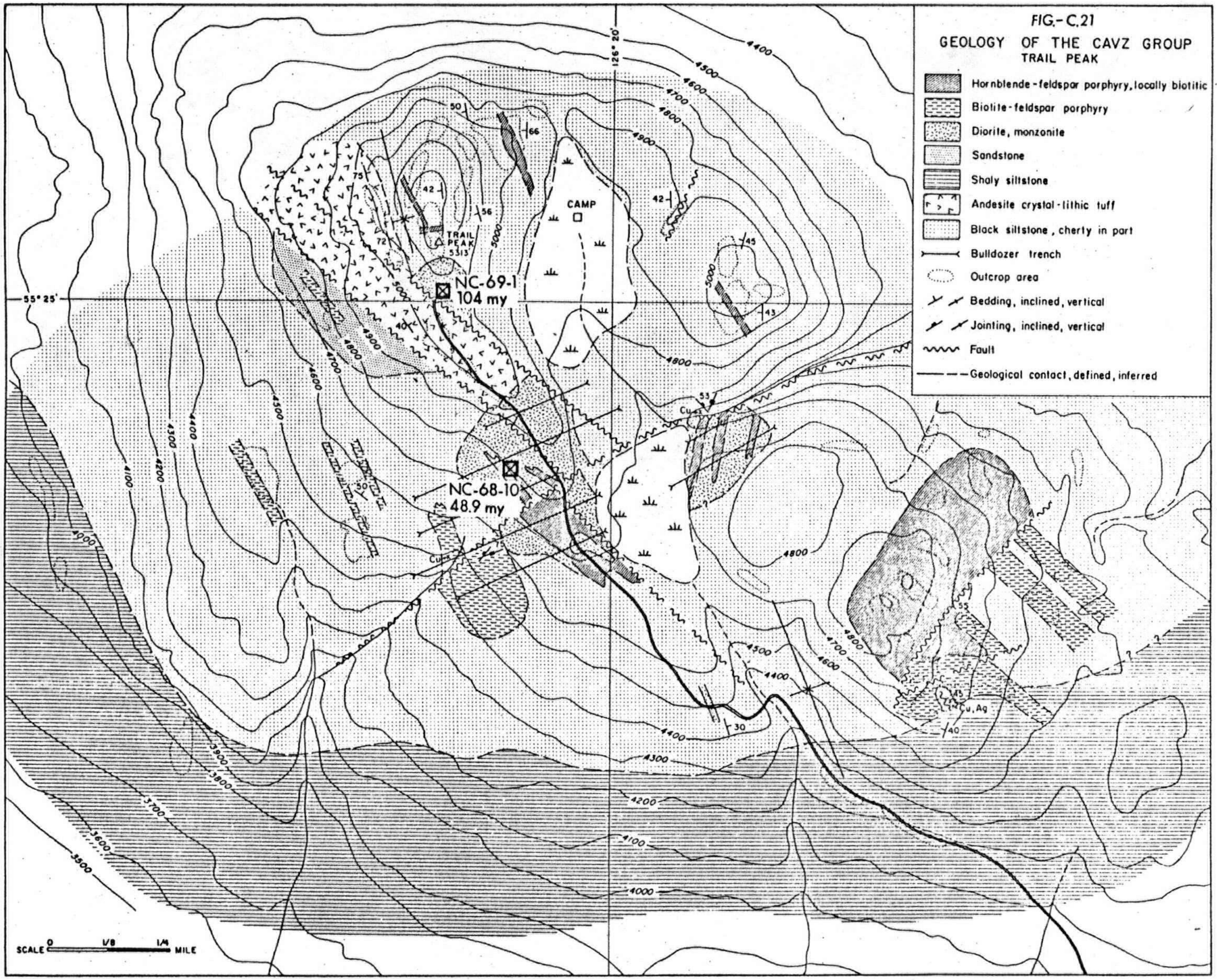


FIG.- C.21
GEOLOGY OF THE CAVZ GROUP
TRAIL PEAK
Hornblende-feldspar porphyry, locally biotitic
Biotite-feldspar porphyry
Diorite, monzonite
Sandstone
Shaly siltstone
Andesite crystal-lithic tuff
Black siltstone, cherty in part
Bulldozer trench
Outcrop area
Bedding, inclined, vertical
Jointing, inclined, vertical
Fault
Geological contact, defined, inferred
NC-69-1
104 my
NC-68-10
48.9 my
CAMP
TRAIL PEAK 5313'
126° 20'
55° 25'
SCALE 0 1/8 1/4 MILE

original hornblende and as fine flakes in the matrix. The porphyry is relatively fresh, with only minor sericite-carbonate alteration of feldspar and incipient chloritization of biotite. A typical specimen from the west trench area consists of plagioclase, 46 per cent; quartz, 23 per cent; biotite, 23 per cent; chlorite, 6 per cent; apatite, 1 per cent; and sphene, 1 per cent.

Hornblende feldspar porphyries are closely related to the biotite feldspar porphyries. These occur as narrow northwest-striking dykes or sills on the north slope of Trail Peak, as larger dyke-like masses in the west trench area, and as a large mass capping the hill southeast of the trench area. All varieties display a trachytic texture in which phenocrysts of plagioclase and hornblende are aligned in subparallel fashion as are the fine-grained feldspar laths which make up the matrix. Crude columnar jointing noted in the large area of hornblende feldspar porphyry southeast of the trenches suggests that some phases may be partly of extrusive origin.

The sedimentary rocks of the Trail Peak area are contained in a northwest-trending synform. Northeast and northwest faults dominate the structure of the area and were no doubt instrumental in localizing intrusive activity near the axis of the fold structure. Later post-intrusive movement along these faults has contributed to the complex form of the intrusive bodies.

Copper mineralization was observed in close proximity to the major northeast fault through the central part of the area. In the creek north of the east trenches at an elevation of 4,600 feet, fractures spaced 2 to 6 inches apart in hornblende feldspar porphyry contain pyrite and chalcopyrite with quartz and tourmaline. One-quarter to one-half-inch-wide quartz veins contain chalcopyrite and tourmaline needles and are rimmed by an alteration envelope in which plagioclase is altered to K-feldspar, hornblende to actinolite, and abundant quartz has been introduced.

In the western trench area, chalcopyrite is mainly associated with biotite feldspar porphyry in which it occurs with pyrite as disseminations on fracture planes and in one-quarter-inch-wide quartz veinlets which also contain magnetite. Malachite staining is common. In the same area, tourmaline is abundant in the rocks near the northeast fault zone, occurring in fractures and veinlets and as irregular clots in brecciated hornblende feldspar porphyry and diorite.

Southeast of the trenches, a 2-inch-wide quartz vein, containing galena and sphalerite, occurs in a northwest-striking shear zone in shaly siltstone.

NC-68-10 – Biotite Feldspar Porphyry

Sample is from the trenched area south of Trail Peak (Figure C.21).

The rock is dark grey and contains scattered 2 to 3-millimetre phenocrysts of subhedral plagioclase (An_{25-40}) and 1-millimetre plates of biotite. Original hornblende is almost completely altered to chlorite. Poikilitic biotite plates are up to 15 per cent chloritized.

NC-69-1 – Granodiorite

Sample is from a small stock that underlies Trail Peak.

The granodiorite is a grey, medium-grained, equigranular rock which contains prominent biotite plates. The rock has a hypidiomorphic granular texture and consists of quartz, plagioclase (An_{38-46}), K-feldspar, hornblende, and biotite. Hornblende and biotite are intimately associated and most of the biotite may represent a deuteric alteration of hornblende. The biotite occurs as 1-millimetre poikilitic, shredded plates and is unaltered.

C.4.6 Newman Peninsula

Extrusive equivalents of intrusive biotite feldspar porphyries are exposed near the south end of Newman Peninsula on Babine Lake (Figure 26).

These rocks are sheet-like in form and may have a vertical thickness of several hundred feet. Well-devloped columnar jointing is exposed along the southwest shore of the peninsula. The extrusive equivalents are fine to medium-grained hornblende feldspar porphyries of andesite composition. Parallel arrangement of the hornblende and feldspar phenocrysts impart a flow texture to the rock.

NC-67-43 – Hornblende Feldspar Porphyry

Sample is from columnar-jointed porphyry exposed along the southwest shore of Newman Peninsula (Figure 26).

The porphyry is fine to medium grained, grey in colour, and has a trachytic texture. One to 2-millimetre phenocrysts of plagioclase (An_{40}) and hornblende make up 35 per cent of the rock and are contained in a matrix of very fine-grained plagioclase laths. Hornblende needles are slightly poikilitic and are essentially free of alteration.

C.4.7 Lennac Lake (after Carter, 1972)

The Lennac Lake porphyry copper prospect is 9 miles southwest of Topley Landing (Figure 26).

Hazelton Group volcanic rocks are intruded by an oval stock-like body of quartz-horbnlende-biotite-feldspar porphyry, elongate in a northeast direction and measuring 4,000 by 2,000 feet. The porphyry is of granodiorite composition and phenocrysts constitute 30 per cent of the rock. Trenches south of the small lake expose relatively unaltered porphyry and a typical specimen from this area consists of quartz, 15 per cent, usually occurring as 2 to 4-millimetre anhedral phenocrysts; plagioclase (An_{30-35}), 45 per cent, occurring both in the matrix and as 4 to 7-millimetre euhedral phenocrysts; K-feldspar, 15 per cent, restricted to the matrix and marginal to fractures; biotite, 10 per cent, in the form of 5-millimetre books; and hornblende, 5 per cent, usually exhibiting incipient alteration to fine-grained brown biotite.

Potassic alteration is weak to moderate within the main trench area and consists of secondary K-feldspar adjacent to fractures and secondary biotite, an alteration of hornblende. To the east of the stock are two northeast-striking porphyry dykes and there the intrusive rocks exhibit features typical of a quartz-sericite-pyrite alteration zone. Plagioclase is almost totally altered to sericite-carbonate, hornblende is altered to a mixture of chlorite and epidote, and biotite is completely chloritized. Pyrite is disseminated throughout the rock as well as being intimately associated with altered mafic minerals.

Hazelton Group volcanic rocks have been metamorphosed to biotite hornfels marginal to the porphyry stock and dykes. Inclusions of hornfelsed Hazelton volcanic rocks are numerous within the stock and these rocks also contain significant amounts of magnetite.

Sulphide mineralization is centred about the porphyry stock and occurs over an area of 1.5 by 1 mile. The major copper showings are within the porphyry stock where chalcopyrite, pyrite, magnetite, and minor chalcocite and molybdenite occur in northwest-striking one-sixteenth to one-eighth-inch veinlets with quartz and some K-feldspar. Chalcopyrite mineralization was also noted as films on dry fractures in inclusions of volcanic rocks within the stock and in hornfelsed rocks in a trenched area 1 mile to the east.

NC-72-1 – Quartz-hornblende-biotite Feldspar Porphyry

Sample was collected from a trench near the central part of the stock. Chalcopyrite occurs in narrow quartz-filled fractures.

Thirty per cent of the rock is composed of 4 to 7-millimetre phenocrysts of plagioclase (An_{30-35}), biotite books and hornblende needles to 5 millimetres, and 2-millimetre quartz eyes. These are set in a fine-grained matrix of quartz, biotite, plagioclase, and K-feldspar. Magnetite also occurs in the matrix.

Green hornblende is partially altered to biotite and primary biotite books are poikilitic and exhibit incipient (10 per cent) alteration to chlorite.

C.4.8 Tachek Creek (after Carter, 1969)

The Tachek Creek copper-molybdenum prospect is 4 miles south of Topley Landing (Figure 26).

The oldest rocks exposed are intermediate volcanic rocks of Lower Jurassic age. These are intruded by Topley granitic rocks which underlie the central part of the property. These rocks range from granodiorite to quartz monzonite in composition.

Biotite-quartz feldspar porphyry dykes were observed cutting the granitic rocks in the vicinity of the principal mineral showings near 2,900 feet elevation on Tachek Creek. The dykes have irregular, commonly brecciated contacts with the granites and strike predominasntly east. Where seen in the creek, they are several feet wide, although drill intersections in the order of 50 feet were encountered. The dyke rock, while lithologically similar to the typical Babine porphyries with which the copper deposits of the region are associated, differs from them in age and by having quartz phenocrysts. Typically, the rock is a crowded porphyry, with phenocrysts making up 50 per cent of the rock by volume, including 2 to 4-millimetre euhedral, zoned, plagioclase crystals, 2-millimetre resorbed quartz phenocrysts, and 1 to 2-millimetre books of fresh biotite, all set in a fine-grained matrix of quartz, feldspar, and secondary shredded biotite. Hornblende phenocrysts, 2 to 4 millimetres in size, are not uncommon, and these are commonly altered to a mixture of chlorite, sericite, and flaky biotite. A typical specimen of porphyry is of quartz diorite composition and contains the following constituents: quartz, 35 per cent; plagioclase (An_{28-35}), 45 per cent; biotite, 7 per cent; chlorite and sericite, 10 per cent; and metallic minerals, 3 per cent.

Sulphide mineralization, in the form of pyrite, chalcopyrite, and molybdenite, appears to be most widespread marginal to biotite-quartz feldspar porphyry dykes. In general, molybdenite is restricted to K-feldspar-rimmed fractures, while chalcopyrite occurs both in fractures and as disseminations in both the granitic rocks and the porphyries.

Biotite-lamprophyre dykes, 3 feet wide and magnetic, were seen cutting the granitic rocks and are apparently of post-mineral age.

NC-69-4 – Biotite-quartz Feldspar Porphyry

Sample is from a porphyry dyke near the main mineralized zone in Tachek Creek.

The rock is a crowded porphyry, with about 50 per cent of the rock composed of 2 to 3-millimetre phenocrysts of euhedral plagioclase (An_{28-35}), biotite books, hornblende needles, and anhedral quartz eyes. The matrix is very fine-grained anhedral quartz, feldspar, and shredded biotite and chlorite.

Hornblende is partially altered to chlorite and biotite. Biotite plates are poikilitic and display some chlorite alteration along grain boundaries.

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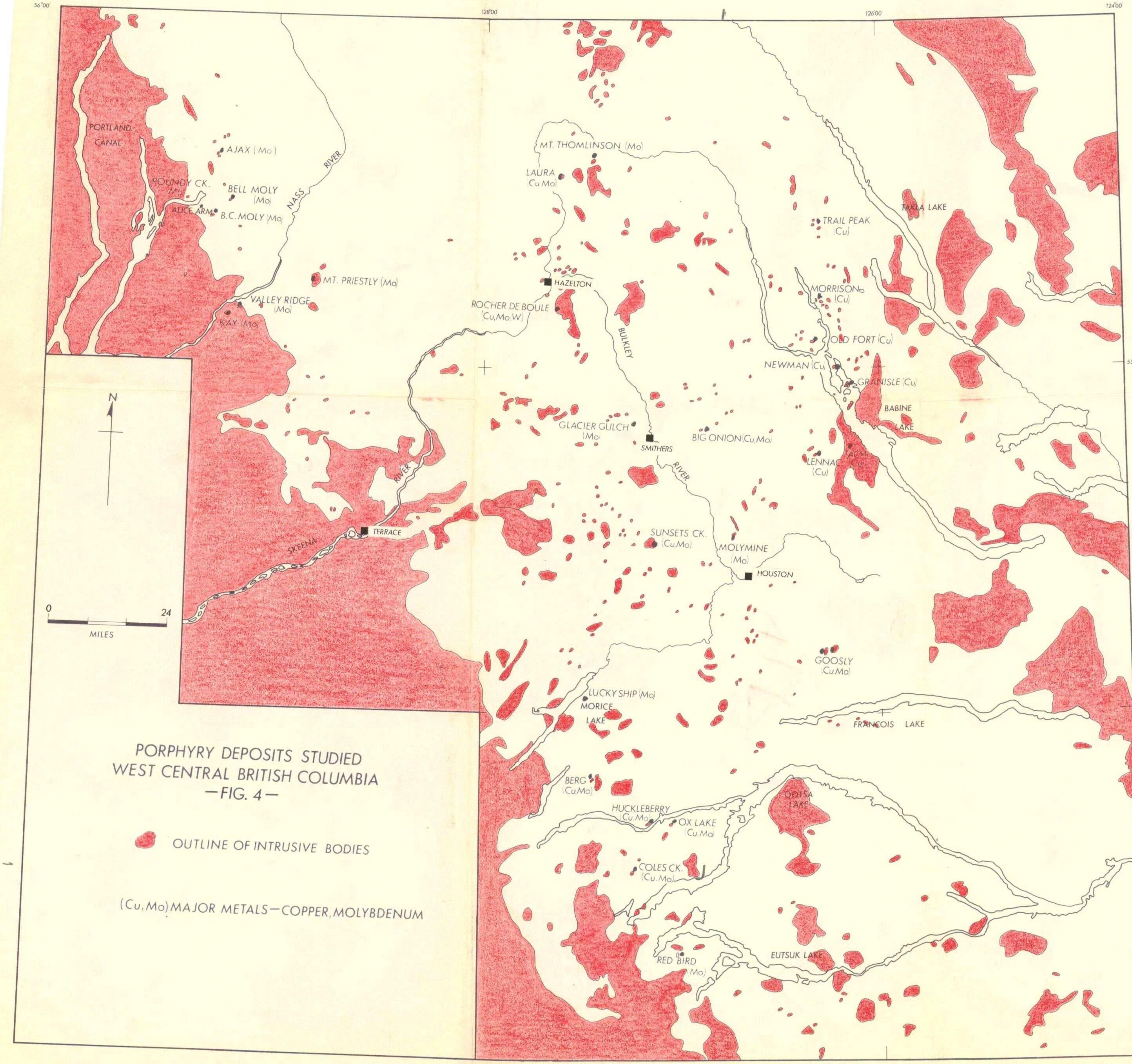
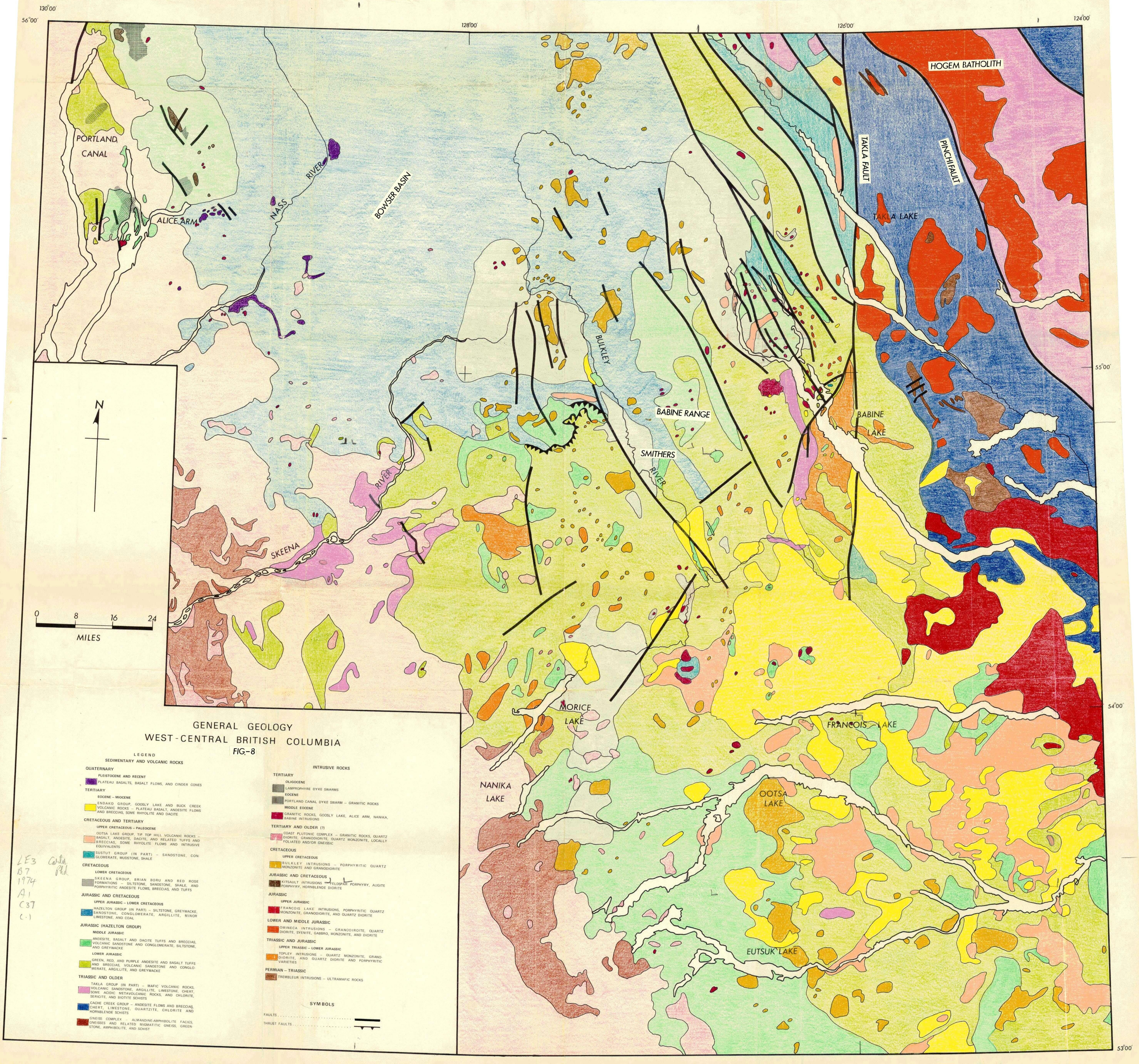


PORPHYRY DEPOSITS STUDIED
WEST CENTRAL BRITISH COLUMBIA
—FIG. 4—


130°00'
56°00'
128°00'
126°00'
124°00'
55°00'
54°00'
53°00'
PORTLAND CANAL
ALICE ARM
NASS RIVER
BOWSER BASIN
HOGEM BATHOLITH
TAKLA FAULT
PINCHI FAULT
TAKLA LAKE
BULKLEY
BABINE RANGE
SMITHERS
RIVER
BABINE LAKE
SKEENA
RIVER
N
0 8 16 24
MILES
MORICE LAKE
FRANCOIS LAKE
NANIKA LAKE
OOTSA LAKE
EUTSUK LAKE
GENERAL GEOLOGY
WEST-CENTRAL BRITISH COLUMBIA
FIG.-8
LEGEND
SEDIMENTARY AND VOLCANIC ROCKS
QUATERNARY
PLEISTOCENE AND RECENT
PLATEAU BASALTS, BASALT FLOWS, AND CINDER CONES
TERTIARY
EOCENE – MIOCENE
ENDAKO GROUP, GOOSLY LAKE AND BUCK CREEK VOLCANIC ROCKS – PLATEAU BASALT, ANDESITE FLOWS AND BRECCIAS, SOME RHYOLITE AND DACITE
CRETACEOUS AND TERTIARY
UPPER CRETACEOUS – PALEOCENE
OOTSA LAKE GROUP, TIP TOP HILL VOLCANIC ROCKS – BASALT, ANDESITE, DACITE, AND RELATED TUFFS AND BRECCIAS, SOME RHYOLITE FLOWS AND INTRUSIVE EQUIVALENTS
SUSTUT GROUP (IN PART) – SANDSTONE, CONGLOMERATE, MUDSTONE, SHALE
CRETACEOUS
LOWER CRETACEOUS
SKEENA GROUP, BRIAN BORU AND RED ROSE FORMATIONS – SILTSTONE, SANDSTONE, SHALE, AND PORPHYRITIC ANDESITE FLOWS, BRECCIAS, AND TUFFS
JURASSIC AND CRETACEOUS
UPPER JURASSIC – LOWER CRETACEOUS
HAZELTON GROUP (IN PART) – SILTSTONE, GREYWACKE, SANDSTONE, CONGLOMERATE, ARGILLITE, MINOR LIMESTONE, AND COAL
JURASSIC (HAZELTON GROUP)
MIDDLE JURASSIC
ANDESITE, BASALT AND DACITE TUFFS AND BRECCIAS, VOLCANIC SANDSTONE AND CONGLOMERATE, SILTSTONE, AND GREYWACKE
LOWER JURASSIC
GREEN, RED, AND PURPLE ANDESITE AND BASALT TUFFS AND BRECCIAS, VOLCANIC SANDSTONE AND CONGLOMERATE, ARGILLITE, AND GREYWACKE
TRIASSIC AND OLDER
TAKLA GROUP (IN PART) – MAFIC VOLCANIC ROCKS, VOLCANIC SANDSTONE, ARGILLITE, LIMESTONE, CHERT, SOME ACIDIC METAVOLCANIC ROCKS, AND CHLORITE, SERICITE, AND BIOTITE SCHISTS
CACHE CREEK GROUP – ANDESITE FLOWS AND BRECCIAS, CHERT, LIMESTONE, QUARTZITE, CHLORITE AND HORNBLENDE SCHISTS
GNEISS COMPLEX – ALMANDINE-AMPHIBOLITE FACIES, GNEISSES AND RELATED MIGMATITIC GNEISS, GREENSTONE, AMPHIBOLITE, AND SCHIST
INTRUSIVE ROCKS
TERTIARY
OLIGOCENE
LAMPROPHYRE DYKE SWARMS
EOCENE
PORTLAND CANAL DYKE SWARM – GRANITIC ROCKS
MIDDLE EOCENE
GRANITIC ROCKS, GOOSLY LAKE, ALICE ARM, NANIKA, BABINE INTRUSIONS
TERTIARY AND OLDER (?)
COAST PLUTONIC COMPLEX – GRANITIC ROCKS, QUARTZ DIORITE, GRANODIORITE, QUARTZ MONZONITE, LOCALLY FOLIATED AND/OR GNEISSIC
CRETACEOUS
UPPER CRETACEOUS
BULKLEY INTRUSIONS – PORPHYRITIC QUARTZ MONZONITE AND GRANODIORITE
JURASSIC AND CRETACEOUS
KITSAULT INTRUSIONS – FELDSPAR PORPHYRY, AUGITE PORPHYRY, HORNBLENDE DIORITE
JURASSIC
UPPER JURASSIC
FRANCOIS LAKE INTRUSIONS, PORPHYRITIC QUARTZ MONZONITE, GRANODIORITE, AND QUARTZ DIORITE
LOWER AND MIDDLE JURASSIC
OMINECA INTRUSIONS – GRANODIROITE, QUARTZ DIORITE, SYENITE, GABBRO, MONZONITE, AND DIORITE
TRIASSIC AND JURASSIC
UPPER TRIASSIC – LOWER JURASSIC
TOPLEY INTRUSIONS – QUARTZ MONZONITE, GRANODIORITE, AND QUARTZ DIORITE AND PORPHYRITIC VARIETIES
PERMIAN – TRIASSIC
TREMBLEUR INTRUSIONS – ULTRAMAFIC ROCKS
SYMBOLS
FAULTS
THRUST FAULTS

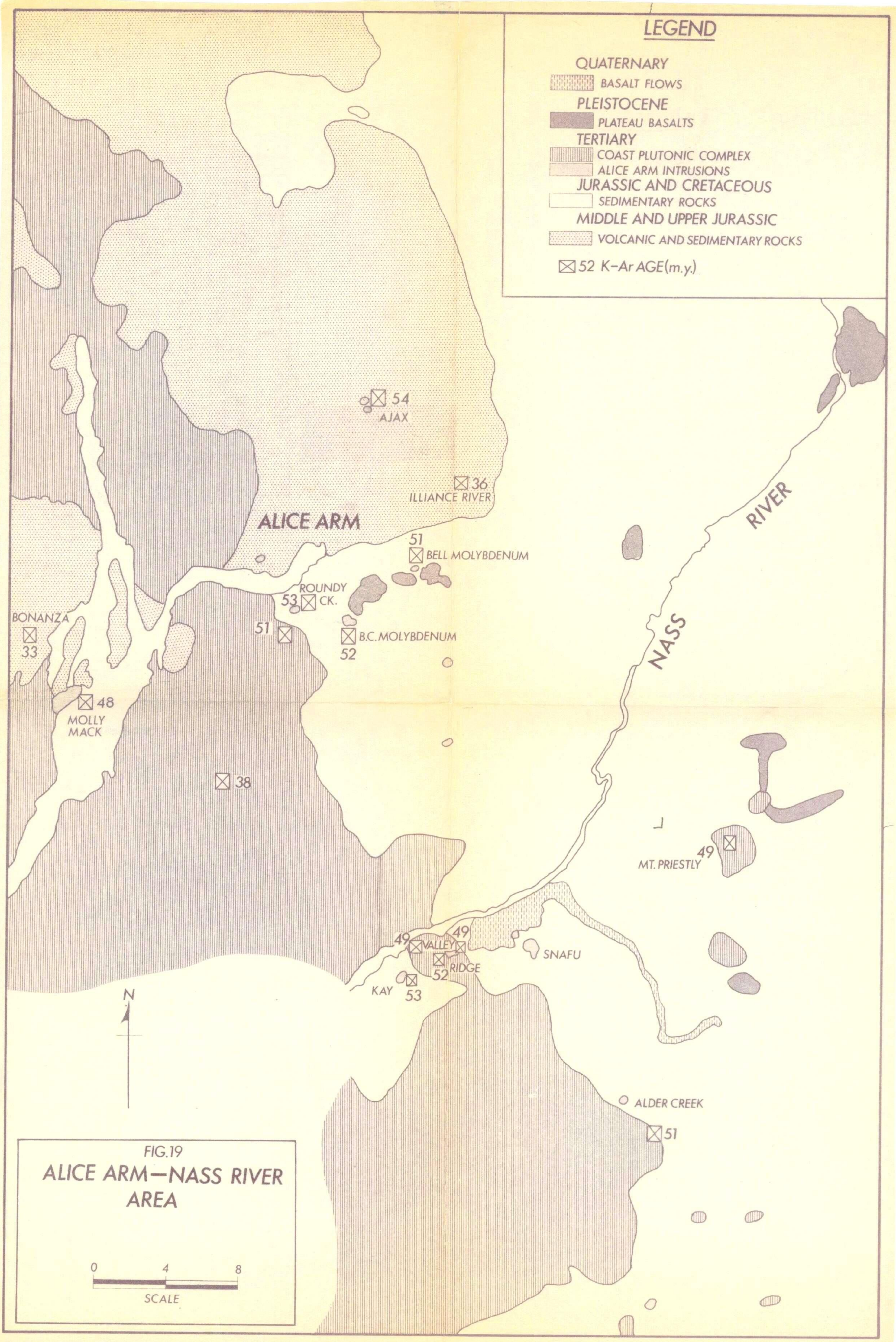
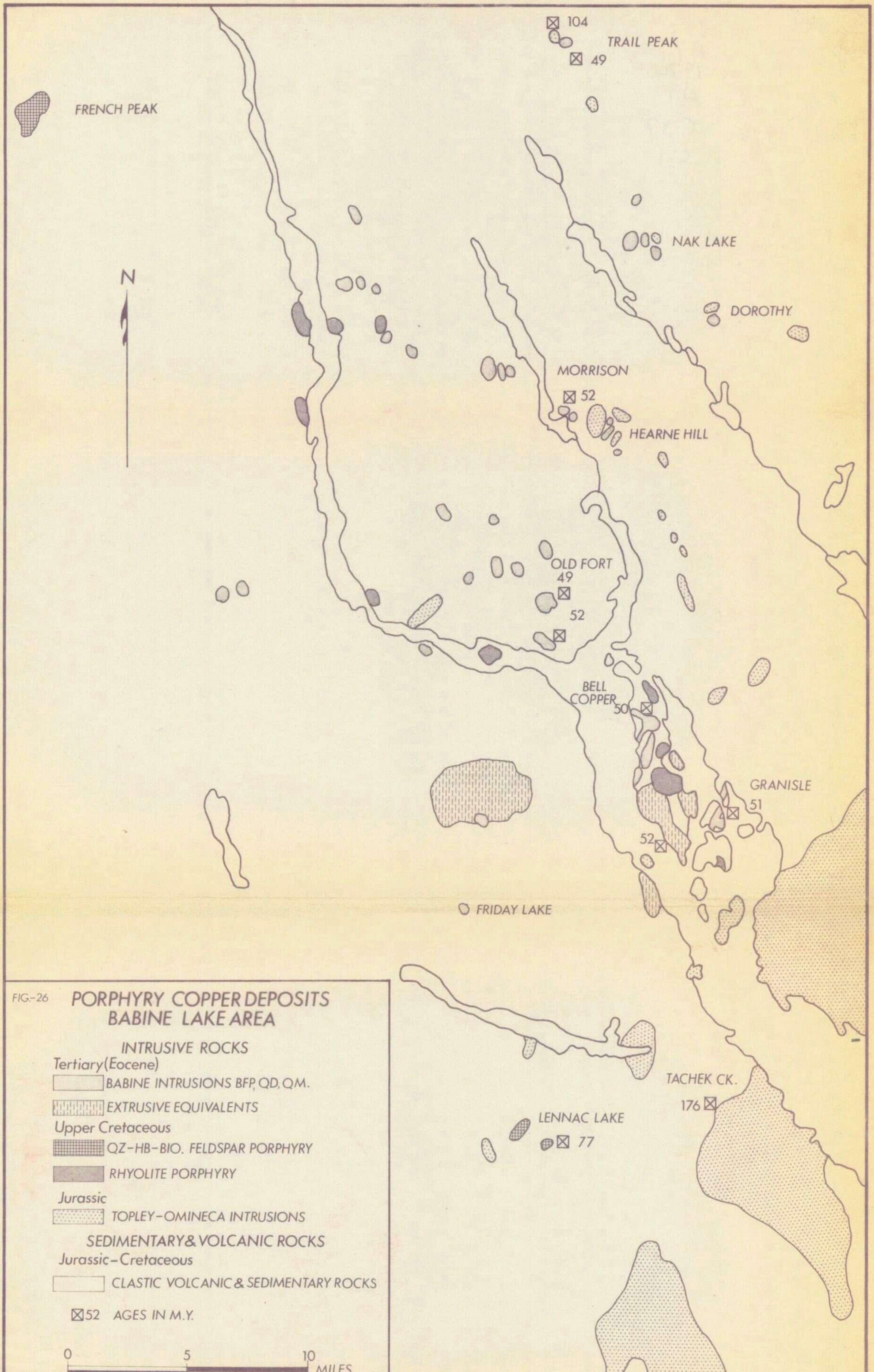


FIG.19
ALICE ARM—NASS RIVER AREA



104
TRAIL PEAK
49
FRENCH PEAK
NAK LAKE
N
DOROTHY
MORRISON
52
HEARNE HILL
OLD FORT
49
52
BELL
COPPER
50
GRANISLE
51
52
FRIDAY LAKE
TACHEK CK.
176
LENNAC LAKE
77
FIG.-26
PORPHYRY COPPER DEPOSITS
BABINE LAKE AREA
INTRUSIVE ROCKS
Tertiary (Eocene)
BABINE INTRUSIONS BFP, QD, Q.M.
EXTRUSIVE EQUIVALENTS
Upper Cretaceous
QZ-HB-BIO. FELDSPAR PORPHYRY
RHYOLITE PORPHYRY
Jurassic
TOPLEY-OMINECA INTRUSIONS
SEDIMENTARY & VOLCANIC ROCKS
Jurassic-Cretaceous
CLASTIC VOLCANIC & SEDIMENTARY ROCKS
52 AGES IN M.Y.
0
5
10
MILES