Geology of the Quinsam Lake Area
Vancouver Island

PAPER 1984–3

BCEMPR
PAPER
1984-3 EMPR
c. 2
MAI

Province of British Columbia

Ministry of
Energy, Mines and
Petroleum Resources

GEOLOGICAL BRANCH
MINERAL RESOURCES DIVISION

0005037629

GEOLOGY OF THE QUINSAM LAKE AREA
VANCOUVER ISLAND

PAPER 1984–3

By

G.E.P. EASTWOOD

VICTORIA, BRITISH COLUMBIA
CANADA

SEPTEMBER 1984

Canadian Cataloguing in Publication Data

Eastwood, G. E. P.
Geology of the Quinsam Lake area, Vancouver Island

(Paper, ISSN 0226-9430 ; 1984-3)

ISBN 0-7718-8435-4

1. Geology - British Columbia - Quinsam Lake Region. I. British Columbia. Ministry of Energy, Mines and Petroleum Resources. II. Title. III. Series: Paper (British Columbia. Ministry of Energy, Mines and Petroleum Resources) ; 1984-3.

QE187.E27 1984 557.11'34 C84-092191-8

CONTENTS

APPENDIX

TABLES

CONTENTS *(CONTINUED)*

Page

TABLES *(CONTINUED)*

FIGURES

INTRODUCTION

The Quinsam coal measures and adjacent terrane described in this report underlie an area of about 130 square kilometres west and southwest of Campbell River on Vancouver Island. Figure 1 shows the location and the principal features of the surrounding area.

The area is more or less centred on the northwest end of the belt of coal-bearing Upper Cretaceous rocks. The original purpose of this study was an assessment of the coal potential; however, in outlining the extent of the coal measures, identification and correlation problems arose with the surrounding older rocks, and the mapping was necessarily extended. It was further extended northwest to Strathcona Dam to locate more accurately the north contact of the Quinsam stock and to show, in reconnaissance fashion, the occurrence of pyritic rocks containing minor amounts of copper and southwest to include known mineral showings west of Gentian Lake.

GEOGRAPHY

ACCESS

Principal access roads in the area are shown on Figure 2 (in pocket). Highway 28, between Campbell River and Gold River, crosses the northern third of the area; from it the West Main Haul logging road leads west to a bridge over Upper Campbell Lake, and the Mine road leads southwest to Upper Quinsam Lake, past the Iron Hill mine. Another main road leads from the highway up the east side of Upper Campbell Lake to Strathcona Dam. Of the numerous branch roads the most important runs east from the Mine road along the north side of Middle Quinsam Lake to its outlet, then south, southwest, and west to rejoin the Mine road as Branch K. At the south end of the area Branch J provides access to a camp of Gentian Resources and both sides of Gentian Lake. Lesser branches, which provide local access, have undergone varying degrees of erosion and overgrowth by alders; some are impassable. Collapsed culverts are a hazard. The bridge over the Quinsam River at the outlet of Middle Quinsam Lake was replaced by a strong new one in 1977-1978. A group of roads leading east from this bridge provides access to a skarn deposit below a coal outcrop on the Iron River. A high-tension transmission line crosses the north end of the area from the powerhouse at Strathcona Dam, and service roads along it provide access. A road leading east from the dam provides limited vehicular access but extended access on foot. Another road leaves the West Main Haul road west of Beavertail Lake and a left fork leads to the outlet of Squiggly Lake, where the roadbed has been blasted; access

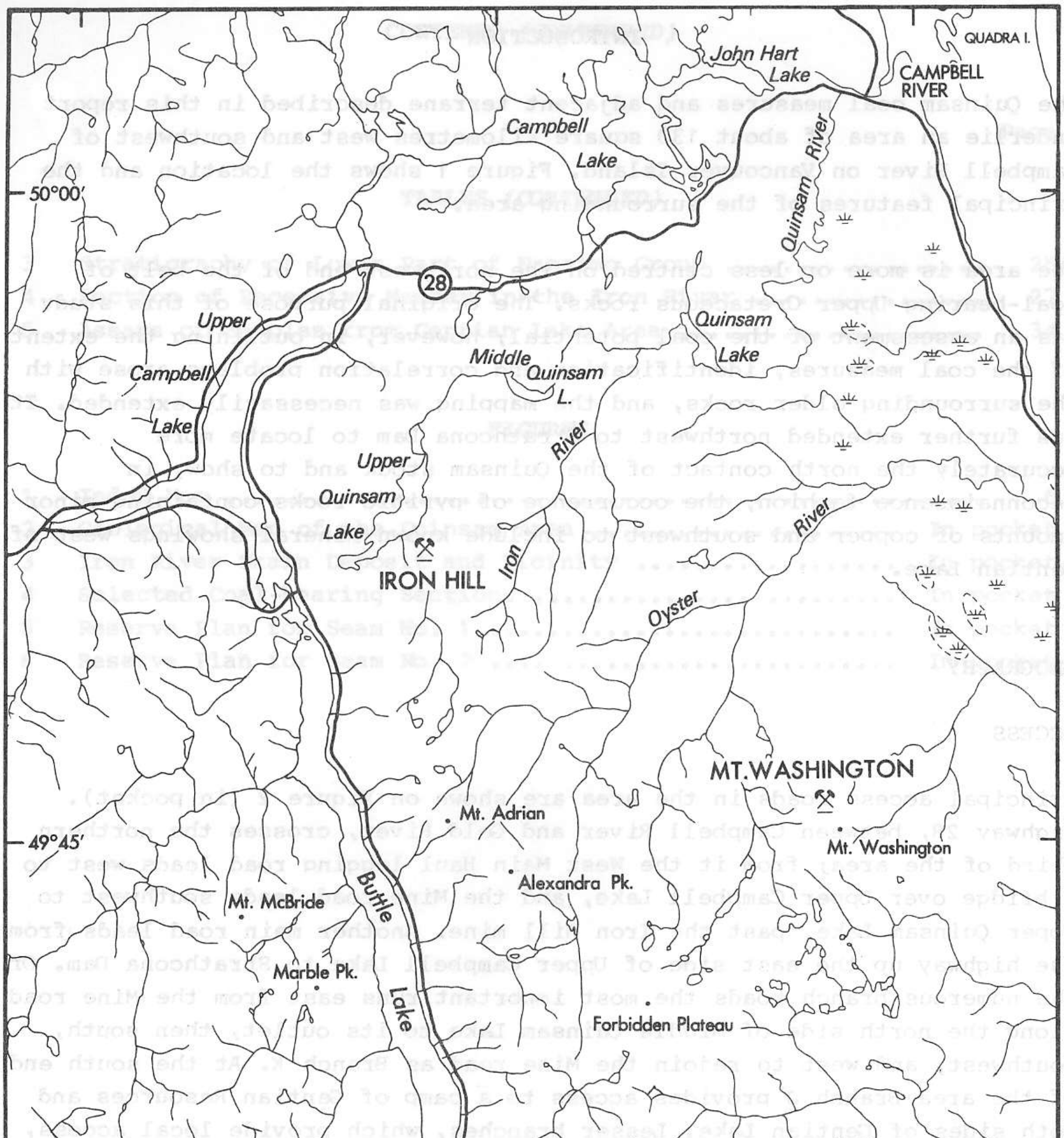


Fig. 1. Index Map

thence to the Northwest Tower is on foot. Bulldozed grid lines are generally passable when dry but are rough. In some parts of the area overgrown logging-railway grades facilitate aocess on foot.

TOPOGRAPHY

The topography is varied. The north-central part, between Middle Quinsam and Campbell Lakes, is generally flat to undulating with many swamps, ponds, and lakes. Ridges near Beavertail Creek appear to be end moraines; Beavertail Creek has cut deeply into Pleistocene drift without exposing bedrock. A shallow overburden-filled valley extends from the Mine road at Quinsam River northeast to the north end of the north-flowing section of the river; it is probably an old section of the river channel that was blocked by ice late in Pleistocene time. Southeast of this valley the land starts to rise, forming low hills north of Middle Quinsam Lake. The present north-flowing section of the Quinsam River is, in part, deeply incised.

A large bedrock ridge flanks this generally flat area on the east. The local topography is rough, and the ridge is breached by the broad valley of the Quinsam River and the narrow valley of the Iron River. South of Iron River the ridge becomes mountainous.

The northwest part of the area is hilly, with varying amounts of bedrock outcrop. The two highest hills rise west of Reginald Lake. The easterly has moderate to steep slopes, whereas the westerly has nearly vertical sides and is termed the Northwest Tower. A valley extends west from Beavertail Lake to Upper Campbell Lake.

A dissected low plateau is bounded by Middle Quinsam Lake and the Quinsam River on the north, by the Quinsam River on the west, and by Long Lake and a broad swampy valley that extends nearly to Upper Quinsam Lake on the southeast. Swamps and small lakes are fairly common on the plateau, less so than in the north-central area. Bedrock exposures are abundant in the central part, petering out on the edges.

An undulating to rolling upland area slopes gently down from Gentian Lake toward Upper Quinsam Lake, and on the south drops sharply into a valley followed by Branch J. Bedrock is well exposed on the highest part, known locally as Cedar Hill, but outcrop is sporadic elsewhere.

Another upland area lies between the Iron River and the north-flowing section of the Quinsam River; it slopes up to the segment of the east ridge between the rivers. This upland continues south to the junction of

Chute Creek with the Iron River and west to the valleys of Long and Gull Lakes. A narrow bedrock ridge extends between these lakes into the middle of the swampy valley. The upland surface is undulating with some swamps and ponds. Natural exposures are scarce, but overburden is mostly thin; bedrock is fairly well exposed along roads and bulldozed grid lines. In the northeast there are few rock exposures of any kind.

Southwest of this upland area and south of the swampy valley the land is mountainous. A peak north of Gentian Lake has near-vertical north and east sides, and is called here Gentian Tower. East of this tower the lower slope has been dissected by streams into steep-sided ridges and benches with flat or gently sloping tops. The peaks above are steep sided but not markedly tower-like. Northeastward, near Iron River the mountains descend to a small hilly area south of the upland area.

STREAMS

The principal streams in the area are the Quinsam and Iron Rivers. For most of its course the Quinsam River flows in a mature valley, but has apparently been deflected through Middle Quinsam Lake and incised between the lake and its former valley. The lower part of the river, outside the map-area, has sandbars which provide spawning beds for Tyee salmon. For a short distance above the confluence with the Quinsam River the valley of the Iron River is broad with low banks, but for most of its length it is youthful. Some meander-like bends suggest rejuvenation, and near the mouth of Chute Creek clearly the river is incised in the bottom of an early-mature valley. Bedrock exposure is about 70 per cent in the riverbed and its lower banks. In the northwest corner of the area a short section of the Campbell River leads from the tailrace and spillway of Strathcona Dam into Campbell Lake.

VEGETATION

Much of the northern part of the area is covered with second-growth timber, largely conifers. A few charred logs and stumps are relics of a hot fire which swept through the area in 1938, thus most of the timber is less than 45 years old. There is little deadfall, and underbrush is light in better-drained areas, though heavy near water. A few parts have been made difficult to traverse by the forestry practice of 'thinning.' In the southern part of the area extensive older stands survived, to be partly logged in recent years. Underbrush is light almost everywhere, and deadfall is light to moderate.

HISTORY

In 1883 a consortium headed by Robert and James Dunsmuir incorporated the Esquimalt and Nanaimo Railway, and received a grant of land of nearly 800 000 hectares (2 million acres) on the northeast side of Vancouver Island as partial consideration for construction of the railway. In 1902 James Dunsmuir became sole owner and in 1905 he sold the railway and land grant to the Canadian Pacific Railway; however, he reserved the rights to coal, coal oil, fireclay, and iron within the land grant. He also had become sole owner of the family's coal mines and lands in the Nanaimo and Cumberland areas, and consolidated this ownership in the Wellington Colliery Co. Ltd. In 1910 he sold this company to MacKenzie and Mann of the Canadian Northern Railway. They recapitalized the property and sold it to British interests, who formed Canadian Collieries (Dunsmuir) Limited, to operate the mines. As holder of the reserved rights the Wellington Colliery Co. Ltd. was continued as a wholly-owned subsidiary. Between 1945 and 1960 exploratory borings were made in the Quinsam (three holes) and Campbell River (27 holes) areas. In 1957 the company name was changed to Canadian Collieries Resources Limited. In 1964 Weldwood of Canada Limited commenced the purchase of all outstanding shares, converting the company to a wholly owned subsidiary and thereby acquiring the Wellington Colliery Co. Ltd. This latter subsidiary in 1973 concluded an agreement with PanCanadian Petroleum Limited, The Esquimalt and Nanaimo Railway Limited, and Canadian Pacific Limited, by means of which the rights to the reserved minerals over most of the land grant were surrendered to the Crown. The coal rights were retained in an irregular strip of land between Qualicum River and Campbell Lake.

In 1973 Weldwood of Canada Limited compiled all available data on coal reserves in this strip and began investigation of several areas. In 1975, 11 holes were drilled in the Quinsam area and Michela P. Curcio, coal consultant, prepared a structural map at a scale of 1:15 840; copies of this map and an accompanying report were made available to the Ministry of Energy, Mines and Petroleum Resources. Weldwood applied for coal licences on adjoining lands and made a preliminary joint venture agreement with Luscar Ltd. During 1976 and 1977 a grid was surveyed with a base line running 307 degrees and cross lines 037 degrees; selected portions of the grid lines were cleared by bulldozer, and grid drilling on 150-metre (500-foot) centres was begun. In this period 158 holes were drilled, aggregating 10 400 metres. In 1978 a further 353 holes were drilled, aggregating approximately 20 000 metres; this was mainly fill-in drilling at 75-metre spacing on the cross lines. Cores taken of the coal were used for testing. A short adit was driven and five open cuts made to obtain additional fresh coal for testing. No further work was done up to the summer of 1982.

In the country rock adjacent to the coal measures, the Iron River copper-iron skarn deposit was discovered and an 18-metre adit driven sometime prior to 1907, when Einar Lindeman made the first recorded examination. No further work was done until 1951, when the Argonaut Mining Co. Ltd. leased the property from Canadian Collieries (Dunsmuir) Limited. Diamond drilling from 1951 until 1956 was followed by small-scale mining for mill tests. Texada Mines Ltd. optioned Lot 242 from Canadian Collieries Resources Limited and in 1965, 1966, and 1971 did detailed geological mapping and further diamond drilling, followed by a magnetometer survey in 1974.

R. B. Hopton and Lewis McCall prospected the area between Gentian and Upper Quinsam Lakes and to the southeast; in 1972 they located two Cedar Hill claims west of Gentian Lake. By 1976, 13 small pits and trenches had been opened on these claims. With partners a private company, Gentian Resources, was formed. By 1982 three of the trenches had been considerably enlarged, and some trenching had been done east of Gentian Lake.

H. C. Gunning established the broad outlines of the geology in 1930 in his map of the Buttle Lake area. J. E. Muller subdivided the rocks and revised the boundaries in mapping the Alberni area at 1:250 000 in the 1960's.

PRESENT WORK

The writer spent about 100 days in the area in the years 1977 to 1979 and 1982. In 1977 a reconnaissance was made of the north-central and central parts, using 1:63 360 aerial photographs and 1:50 000 topographic maps, by driving all passable roads and walking out other roads, bulldozed lines, and Beavertail Creek. This was followed up with systematic mapping using 1:15 840 base maps and, for part of the area, 1:20 000 aerial photographs. Most rock exposures could be located on the aerial photographs, but pacing was necessary along some grid lines and in part of the bed of Iron River. Brunton and polychain were used to tie surveyed boreholes in to the Iron River and to a detailed geological map made for Texada Mines Ltd. by P. T. McCullough. An area of granitic rock between Middle Quinsam Lake and the Mine road was mapped only in reconnaissance fashion. In the northwest part of the area the contact of the granitic stock was delineated but two patches, east and west of the contact, were not mapped. Logs of borehole cuttings were submitted by Weldwood of Canada Limited to the Ministry and were used to construct sections through the coal seams.

REFERENCES

Barnstable, D. R. (1980): The Quinsam Coal Project, *C.I.M.*, Bull., Vol. 73, No. 816, pp. 89-97.

B.C. Ministry of Energy, Mines & Pet. Res.: GEM, 1971, p. 252; 1974, p. 182.

Carlisle, D. (1976): Geology of Bute Inlet Map-Area (Southwest Part), *Geol. Surv., Canada,* O.F. Map 345.

Dept. of Energy, Mines & Res.: Coal Resources and Reserves of Canada, Rept. ER 79-9, 1979, 37 pp.

Eastwood, G.E.P. (1974): Island Copper to Keogh River, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1974, Paper 1975-1, p. 76.

.... (1977): Cedar Hill, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1976, Paper 1977-1, p. 35.

.... (1978a): Quinsam Area, Vancouver Island, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1977, Paper 1978-1, pp. 55, 56.

.... (1978b): Washlawlis Hill, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1977, Paper 1978-1, p. 24.

.... (1979): Quinsam Area, Vancouver Island, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geological Fieldwork, 1978, Paper 1979-1, p. 66.

.... (1983): A, *B.C. Ministry of Energy, Mines & Pet. Res.*, Geology in B.C., 1976, pp. 43, 44.

Gunning, H. C. (1931): Buttle Lake Map-Area, Vancouver Island, British Columbia, *Geol. Surv., Canada,* Summ. Rept., 1930, Pt. A, pp. 61-64.

Lindeman, E. (1910): Iron Ore Deposits of Vancouver and Texada Islands, *Dept. of Mines, Canada,* Mines Br., Pub. No. 47, pp. 20, 21.

McCullough, P. T. (1974): Geophysical Report on the Iron River Property, *B.C. Ministry of Energy, Mines & Pet. Res.*, Assessment Rept. 5300.

Minister of Mines, B.C.: Ann. Rept., 1952, p. 228; 1956, p. 131; 1965, p. 233; 1966, p. 70.

Muller, J. E. (1965): Geology, Comox Lake Area, British Columbia, *Geol. Surv., Canada,* Map 2-1965.

.... (1977): Geology of Vancouver Island, *Geol. Surv., Canada,* O.F. Map 463.

Muller, J. E. and Atchison, M. E. (1971): Geology, History, and Potential of Vancouver Island Coal Deposits, *Geol. Surv., Canada,* Paper 70-53, 50 pp.

Muller, J. E. and Carson, D.J.T. (1969): Geology and Mineral Deposits of Alberni Map-Area, British Columbia, *Geol. Surv., Canada,* Paper 68-50, 52 pp., Map 17-1968.

Muller, J. E. and Jeletzky, J. A. (1970): Geology of the Upper Cretaceous Nanaimo Group, Vancouver Island and Gulf Islands, British Columbia, *Geol. Surv., Canada,* Paper 69-25.

Muller, J. E., Northcote, K. E., and Carlisle, D. (1974): Geology and Mineral Deposits of Alert Bay-Cape Scott Map-Area, Vancouver Island, British Columbia, *Geol. Surv., Canada,* Paper 74-8, 77 pp.

Tobi, A. C. (1963): Plagioclase Determination with the Aid of the Extinction Angles in Sections Normal to (010), A Critical Comparison of Current Albite-Carlsbad Charts, *Am. Jour. Sci.,* Vol. 261, pp. 157-167.

Turner, R. D. (1973): Vancouver Island Railroads, *Pacific Railroad Publications, Inc.,* San Marino, California.

Young, G. A. and Uglow, W. L. (1926): The Iron Ores of Canada - British Columbia and Yukon, *Geol. Surv., Canada,* Ec. Geol. Series, No. 3, Vol. 1, pp. 71-73.

GENERAL GEOLOGY

The sequence of rocks in or near the area is shown in the following Table of Formations (Table 1) and their distribution in the area is shown on Figure 2. The Nanaimo Group underlies the flattish, north-central part of the area and the upland area to the southeast. It unconformably overlies a complex of Early Mesozoic rocks. The oldest, the Karmutsen Formation, constitutes the east ridge. The Quatsino limestone is not present within the area, but occurs at Iron Hill mine a short distance to the southwest. The Parson Bay argillite occurs near Strathcona Dam and north of the Iron River skarn deposit; it is missing in the upper Iron River, where Lower Bonanza rocks directly overlie the Karmutsen Formation. The Lower Bonanza division is exposed extensively in the northwest part of the area and at intervals in the bed of the Iron River. Middle Bonanza rocks form much of the mountainous area in the south part of the area and probably most of the Northwest Tower. Many porphyry dykes intruding Lower Bonanza division in Iron River resemble the Middle Bonanza lavas and are probably an intrusive phase of the Middle Bonanza rocks. Grey dioritic to gabbroic dykes, sills, and stocks extensively intrude Lower Bonanza rocks in the northwest part of the area. The Quinsam intrusions consist of the Quinsam stock, lying more or less along the west side of the area, and scattered dykes of similar rock in the older rocks. These dykes are most common cutting Karmutsen rocks between the highway and the Quinsam River.

TABLE 1. TABLE OF FORMATIONS

AGE	LAYERED UNIT	MAP UNIT NO.	INTRUSIVE UNIT	MAP UNIT NO.	LITHOLOGY
Quaternary	Surficial deposits				Till, sand, silt, clay
Late Cretaceous	Nanaimo Group	10			10a: Conglomerate 10b: Sandstone 10c: Siltstone, shale 10d: Coal
Middle Jurassic			Quinsam intrusions	9	
?			Grey intrusions	8	Quartz-bearing diorite and gabbro
Early Jurassic	Upper Bonanza?	7			Variegate red and grey lavas
Early Jurassic	Middle Bonanza?	5	Porphyry dykes	6	5: Massive tower-forming andesite and basalt lavas 6: Andesite porphyry
Late Triassic or Early Jurassic	Lower Bonanza	4			Mainly banded siltites; mixed sedimentary-volcanogenic layers; basal striped tuff locally
Late Triassic	Parson Bay Formation	3			Black argillite
Late Triassic	(Quatsino Formation)	(2)			Limestone
Late Triassic	Karmutsen Formation	1	Gabbro	1a	1 : Massive grey basalt lavas 1a: Fine to coarse-grained gabbro

KARMUTSEN FORMATION

The Karmutsen lavas are typically dark grey and fine grained; commonly they are porphyritic and/or amygdaloidal. Half the specimens taken are detectably magnetic with a pencil magnet, and some contain pyrite or pyrrhotite. Thin sections from both the segment of the east ridge between Quinsam and Iron Rivers and from the south shore of Campbell Lake near Reginald Creek, show a brown or reddish brown dust through the groundmass, which is interpreted to be devitrified volcanic glass. Assignment of the exposures near Reginald Creek to the Karmutsen is based largely on this similarity. Proximity to outcrops of the Parson Bay argillite on the east ridge suggests that the glass-bearing flow(s) may lie close to the top of the Karmutsen Formation. Thin sections of samples from the lower Iron River, presumably from deeper in the volcanic pile, show no dust in the groundmass and the basalt was probably holocrystalline when solidified.

Many bands of gabbro occur in the section along the lower Iron River; they range in width from a few metres to 200 metres. A few distinct contacts are evident, but for the most part there is a continuous gradation from porphyritic basalt to medium-grained gabbro and back again. This medium-grained gabbro could be the slowly cooled interior of a thick flow or an intrusive sheet with wide chilled margins. Some medium-grained gabbro bands and one or two coarse-grained bands transect the regional strike and are probably intrusive. The intrusive gabbro has about the same composition as the basalt, and these dykes probably were feeders to flows in the upper part of the sequence. One band of gabbro was found in the segment of the east ridge between the rivers.

A breccia exposed in this segment consists of pale green, dense fragments in a mixed light brown and dark greenish grey fine-grained matrix. In thin section the fragments and brown matrix are seen to be porphyritic basalt with devitrified groundmass; the dark green matrix is devitrified glass only. Less amphibole has been produced in the devitrification of the groundmass of the brown matrix, allowing the colour of the brown crystallites and dust to show, whereas it is masked by amphibole in the fragments. This composition difference would indicate an eruptive breccia, although the structure in the hand specimen is more suggestive of autobrecciated lava.

The principal primary minerals are plagioclase and amphibole, probably a hornblende. The larger amphibole crystals commonly contain ragged cores of relict pyroxene. Amphibole and pyroxene together are almost as abundant as plagioclase. Accessory magnetite (and magnetite-ilmenite) generally ranges between 5 and 10 per cent. The amphibole is generally fairly fresh, whereas plagioclase alteration ranges from a light allophane dusting to about 50 per cent secondary minerals. These secondary minerals include chlorite, sericite, carbonate, epidote, actinolite, and locally biotite.

PARSON BAY FORMATION

Parson Bay argillite is exposed in three outcrops near Strathcona Dam and in at least three more to the north of the Iron River skarn deposit. One isolated outcrop area is in the lower part of a large gully which empties into the Campbell River just below the spillway. In a road cut just east of the south end of the dam, a block of argillite forms an inclusion in a grey intrusion. In the next road cut, outcrop to the south Lower Bonanza beds overlie the argillite on a contact dipping 35 degrees northeast. Near the Iron River, black argillite dips into the east end of a low ridge; its contacts with other rocks are covered (*see also* Fig. 3, in pocket). McCullough (1974) mapped two small outcrops of Quatsino Formation on the north slope of the knoll containing the Iron River skarn deposit. One of these was examined by the writer; it is clearly Parson Bay argillite, with some quartzite.

A thin section from near the spillway discharge is of silty argillite containing about 10 per cent carbonaceous material and, in one bed, abundant and varied microscopic fossil protists. The rock is reticulated by pyrite-bearing carbonate veins parallel to bedding and thin cross 'veinlets.' In thin section these 'veinlets' are seen to be narrow sections of rock from which the carbonaceous material has been removed. The rock at the east end of the low ridge is a finely laminated carbonaceous argillite that has been deformed to a wavy to kinky schist. Carbonate has been introduced as veinlets along the laminations, but also occurs as a fine-grained, apparently primary constituent. Near the skarn deposit the finely laminated carbonaceous argillite is interbedded with unsorted quartzite containing pyrite and limonite; the quartz grains range from 0.35 millimetre down to dust size.

The Parson Bay Formation is probably separated by disconformities from both the underlying Karmutsen Formation and the overlying Lower Bonanza unit. The absence of the Quatsino Formation would indicate a substantial interval of nondeposition. It is unlikely that the Quatsino Formation was eroded from the area prior to Parson Bay Formation deposition, for in other areas it passes gradationally up into Parson Bay Formation. In the road cut south of Strathcona Dam, the abrupt change from carbonaceous argillite up to white and light grey siltite indicates at least a change in the depositional environment, hence a probable break in sedimentation.

The Parson Bay Formation is not present in the Iron River above the skarn deposit, and either was eroded prior to Lower Bonanza deposition or was never deposited in that part of the area.

In mapping the Alert Bay-Cape Scott map-area Muller, *et al.* (1974) reintroduced the name Parson Bay Formation from Parson Bay on Harbledown Island for Upper Triassic clastic-carbonate sedimentary rocks overlying the Quatsino Formation on Vancouver Island. Fossils collected within that map-area indicated that the age of the Parson Bay Formation spans most of the Norian stage. Fossils collected from a 300-metre section southeast of the Iron Hill mine indicated a Middle and Late Norian age (Muller and Carson, 1969). The erosional remnants of Parson Bay in the east part of the Quinsam area are therefore probably Middle Norian, whereas the argillite exposed near Strathcona Dam could be Late Norian.

BONANZA FORMATION

The Bonanza unit, as redefined by exclusion of the Parson Bay Formation, is largely volcanic or volcanogenic. With this unifying characteristic, and because it is part of the Vancouver Group, it can properly be termed the Bonanza Formation. It is divisible into at least two and probably three units on the basis of lithogenetic characteristics. In the present state of knowledge it is preferable to designate these units informally as divisions rather than as formally named members. The Lower Bonanza division is characterized by both volcanic and sedimentary components, whereas the Middle Bonanza division is entirely, or almost entirely, volcanic. The Middle Bonanza division is characteristically grey in colour, and is overlain in several areas on Vancouver Island by red and purple volcanic rocks. The red and purple colours are due to free, if finely divided, hematite and suggest oxidizing, possibly emergent, conditions of deposition. In terms of the measured section at Cape Parkins (Muller, *et al.*, 1974), which is at the mouth of Quatsino Sound on the west coast, the Lower Bonanza division would include units 1 to 3; the Middle Bonanza, units 4 to 7; and the Upper Bonanza, units 8 to 12. The red in units 1 and 4 is atypical and may indicate earlier intervals in which oxidizing conditions occurred in this remote locality.

Up to 1974 only Sinemurian fossils had been collected from the Bonanza Formation in the Alert Bay-Cape Scott map-area; subsequently fossils were found in the north wall of the Island Copper open pit and tentatively dated as Bajocian. Since the host rocks are in the Middle Bonanza division, Upper Bonanza rocks in that area would be Bajocian or younger.

This suggests that the divisions are not coeval from area to area. No absolute ages were obtained from the Quinsam area, but from time constraints imposed by the well-dated Parson Bay Formation and by intrusive rocks the Bonanza Formation should be Lower Jurassic.

LOWER BONANZA DIVISION

Lower Bonanza rocks overlie Parson Bay argillite south of Strathcona Dam and Karmutsen basalt in the Iron River. Though in part volcanic, the Lower Bonanza division is characterized by thin beds of chert-like siltite and silty argillite in tones of whites, greys, and greens. Similar rocks were examined in cores from diamond-drill holes north of the Island Copper open pit, where buff tones also occur. On Washlawlis Hill, east of Island Copper, volcanic rocks overlying Parson Bay argillite contain two interlayers of strikingly banded sedimentary rock (Eastwood, 1974, 1977). The unit evidently thins southward from the Quinsam area, for on the A property south of Sproat Lake (Eastwood, 1983) Parson Bay calcareous argillite is separated from Bonanza volcanic rocks by only a metre or so of thin-bedded white quartzite and pale green chert. On the east fork of St. Andrew Creek, west of the A property, a thin sequence of greenish grey calcareous shale and greywacke was found (Muller and Carson, 1969) between Quatsino limestone and Bonanza volcanic rocks.

The Lower Bonanza division is extensively exposed to the south and east of Strathcona Dam, where it is also extensively intruded by grey dykes and sills. In the road cut exposing its base the beds dip 35 degrees northeast, but in most outcrops between it and the Northwest Tower the Lower Bonanza beds are essentially flat lying. The difference of elevation between the base of the division and the top, which is taken as the base of the Northwest Tower, is about 150 metres. From observations over this interval, the sills probably do not contribute more than half the observed thickness, and the thickness of the Lower Bonanza division in this part of the area can be taken as roughly 75 metres. The grey intrusions are more extensive to the northeast, and north of Reginald Lake the Lower Bonanza division is cut off by them. These exposures are separated by extensive cover from Karmutsen outcrops on the shore of Campbell Lake. To the southeast the Lower Bonanza division is cut off by the Quinsam stock.

In this northwest part of the area the basal metre and the upper two-thirds of the Lower Bonanza division are banded siltite and silty argillite, whereas most of the lower third is massive porphyritic andesite lava. Near the top of the lavas there is a fluxion-textured basalt flow. At the base of the upper two-thirds there is a layer of detrital epidote and minor amounts of quartz containing fragments of a finely and evenly ribbed pelecypod. This is exposed in the bank of a small creek just east of the Strathcona Dam road, 1 400 metres south of the head of the spillway. The siltite consists basically of quartz and epidote, the greenish bands containing more epidote; some bands contain feldspar and altered amphibole. The siltites are probably partly volcanogenic.

Parts of the Lower Bonanza section are exposed along and near the Iron River. In the low ridge north of the skarn deposit xenoliths of banded rock are caught up in a porphyritic basalt that appears to be a correlative of the grey intrusions. The following section was compiled from several partial sections displayed in the bed and banks of the river:

Limestone
Calcareous, argillaceous quartz-siltite
Sedimentary breccia
Thin-banded siltites; some silty tuff
Bedded epidosite, white-striped with feldspar-quartz siltite beds
Tuffaceous siltite

The tuffaceous siltite rests on Karmutsen basalt. If the bedded epidosite is the same unit as the pelecypod-bearing one south of Strathcona Dam, most of the lower third of the division is missing from the Iron River section. The thin-bedded siltites were estimated to be at least 10 metres thick; the whole section may be as much as 18 metres. The limestone is preserved only in a fault-bounded section 600 metres upstream from the skarn deposit, where it is unconformably overlain by Nanaimo Group rocks. A supposedly complete section is preserved in the Iron River above Chute Creek, from Karmutsen Formation to the Middle Bonanza division, but the area is structurally disturbed and partly covered, and neither the sequence nor the thickness was determined. From the outcrop width, however, it seems unlikely that the thickness is much more than 18 or 20 metres. This is thin compared with the upper two-thirds of the division southeast of Strathcona Dam, and the section may be more condensed. The sedimentary breccia consists of large chunks of siltite beds evidently ripped up from the sea floor and disposed at various attitudes. It probably represents an interval during which no new material was supplied to the basin. The outcrops closest to the top of the Lower Bonanza division are fine greywacke and a coarser greywacke containing small rock fragments that is partly carbonatized.

MIDDLE BONANZA DIVISION

The Middle Bonanza division constitutes most of the mountains in the south part of the area and almost surely the Northwest Tower. It was not found in actual contact with the Lower Bonanza division and could, as far as the exposures in the Iron River are concerned, be a repetition of the Karmutsen Formation. However, it differs from the Karmutsen in many ways:

(1) It tends to form high, steep-sided mountains whereas the Karmutsen is more subdued, thongh rugged in detail.

(2) The plagioclase is mostly in the range An_{30-38} and the rock is andesite, whereas the Karmutsen contains labradorite and is basalt.

(3) It is commonly lighter in colour, due to a smaller content of ferromagnesian minerals.

(4) The east (lower) part lacks magnetite, whereas the Karmutsen normally contains enough magnetite to be detectably magnetic.

(5) It lacks the brown dust produced by devitrification of basalt glass found in the upper part of the Karmutsen Formation.

The Middle Bonanza division in the south part of the area consists of a thick pile of massive volcanic rock. Crystal-lithic tuffs were identified in thin sections from four outcrops, but they show no sorting. The internal structure is unknown. The rocks presumably dip west near Iron River, but the overall structure could be broadly synclinal. In a probably faulted segment south of the area, along the south slope of Steve's knob, Lower Bonanza beds dip gently northeast to north-northeast. On the other hand, there appears to be an overall progression from east to west of sodic to calcic feldspar in the Middle Bonanza division. The outcrop in the Iron River nearest the Lower Bonanza division is trachyte, and a road cut outcrop 1 000 metres west of the mouth of Chute Creek contains antiperthite and is therefore trachyandesite. A road cut outcrop on Branch J, southwest of Gentian Lake, comprises a dark grey, Karmutsen-like rock with a magnetite content that is about average for Karmutsen rocks. The plagioclase is An_{50}, and the rock is a porphyritic amygdaloidal basalt. Three possible explanations are suggested:

(1) The outcrop is indeed Karmutsen Formation, and the intervening Lower Bonanza division is not exposed. This seems unlikely because Quatsino limestone is present in Iron Hill, 1 800 metres to the southwest, and it and the Parson Bay argillite would also have to be covered.

TABLE 2. MINERALOGY OF GREY INTRUSIONS AND QUINSAM INTRUSIONS
(APPROXIMATE PER CENT)

FIELD NO.	PLAGIOCLASE	An	K-SPAR	QUARTZ	AMPHIBOLES	BIOTITE	MAGNETITE	EPIDOTE	CHLORITE
Grey Intrusions									
77- 69	60	40+		10	25		1		
77- 77	75	34		tr.	1		2	14	
77- 79	60	51		5	15			15	5
77- 81	40	29		tr.	40		tr.		
79- 54	75	54			15		5		
79- 75	50	36			47		3		
78-212*	24	62		4	35				
78-213	70	73		1	6	3	5	5	7
78-217	(80)	47+		tr.	14				
78-218	65	45			34				
79- 69	85	61			15				
82-142	70	53		10	6		7	7	
82-164	62	68		2	25		5	5	tr.
82-174	57	60		3	30		7		1
82-180	55	30			35			7	tr.
Quinsam Intrusions									
77-104	47	61			30	20	2		
78-200	40	38+			40		5		10
78-206	37	07	29	19	1	14	tr.		7
79- 83	35	50		5	38	15	5		
82-135	45	12	5	20	10	5	5		10
82-137	47	18(50)**		8	35		5		5
82-158	53	35		12	23		7		5
82-160	48	07		40	2	tr.	5	5	tr.
82-166	75	42		12	10		3		

*(matrix 30); **rim(core)

OCCURRENCE AND LOCATION OF SPECIMENS

77- 69 Outcrop at mouth of Campbell River.
77- 77 Isolated outcrop near power line north of Reginald Lake.
77- 79 Irregular dyke in Lower Bonanza tuff, Strathcona Dam spillway.
77- 81 Intrusions in Lower Bonanza tuff, on power line 650 metres east of Campbell River.
79- 54 1.5-metre dyke in Lower Bonanza siltites, Strathcona Dam road.
79- 75 Inferred to be intrusive into Lower Bonanza siltites and intruded by Quinsam intrusions; near junction of West Main Haul road with Strathcona Dam road.

78-212 Intrusion in Middle Bonanza; beside branch road 1 000 metres southeast of Gull Lake.
78-213 Outcrop on branch road 600 metres east-southeast of 78-212.
78-217 Brown basalt containing xenoliths of Lower Bonanza siltites; low ridge 350 metres northwest of Iron River skarn deposit.
78-218 Same as 78-217.
79- 69 Gabbro porphyry within area of Lower Bonanza siltites; Iron River 120 metres above Chute Creek.
82-142 Gabbro apparently intruding Middle Bonanza; road junction 75 metres east of Genetian Lake.
82-164 Gabbro apparently intruding Middle Bonanza; ridge 800 metres south of west end of Gull Lake.
82-174 Isolated outcrop between Quinsam stock and Middle Bonanza; branch road 1 000 metres south of east end of Gull Lake.
82-180 Isolated, weir-forming outcrop in area of Lower Bonanza; Iron River 275 metres above Chute Creek.

77-104 Quinsam stock, early phase; outcrop ridge in angle between Long and Middle Quinsam Lakes.
78-200 Quinsam stock; small quarry northwest of Gull Lake.
78-206 Quinsam stock; bed of Long Creek below coal adit.
79- 83 Same as 77-104.
82-135 Typical coarse-grained main phase of Quinsam stock; 1150 metres south-southwest of mine road bridge over Qinsam River.
82-137 Quinsam stock; mine road 2 700 metres southwest of bridge over Quinsam River.
82-158 Dark grey phase of Quinsam stock; 1 040 metres southeast of west end of Gull Lake.
82-160 Border zone of Quinsam stock; cut of branch road 1 000 metres south of west end of Gull Lake.
82-166 Border zone of Quinsam stock; 110 metres southeast of 82-158.

(2) The outcrop is a block of Karmutsen Formation rafted up by the Quinsam stock.

(3) The upper flows of the Middle Bonanza division grow basic and hence resemble the Karmutsen Formation. This interpretation best fits the rock distribution.

UPPER BONANZA DIVISION (?)

A road cut outcrop beside the mine road just east of Upper Quinsam Lake shows red, buff, and grey phases and may possibly be Upper Bonanza division. A thin section of the grey phase shows the rock to be a highly altered porphyritic trachyte. This outcrop is isolated from other layered rocks, and is possibly a xenolith or roof pendant in the Quinsam stock.

PORPHYRY DYKES

In the Iron River, for 750 metres below the mouth of Chute Creek, the Lower Bonanza division is cut by a swarm of light-coloured, fine-grained porphyry dykes. One of them forms a natural weir for the highest falls below Chute Creek. They do not intrude the Nanaimo Group and evidently predate it. They resemble fine-grained phases of the Middle Bonanza division, and it is tempting to regard them as an intrusive phase, feeders to the flows. However, the plagioclase in the one dyke thin-sectioned has a composition of An_{50}, and the dykes may be too basic to have come from the same magma. They have no other apparent relationship.

GREY INTRUSIONS

A swarm of medium-grained, medium to dark grey dykes and sills intrude the Lower Bonanza division in the northwest part of the area, coalescing into a virtual stock north of Reginald Lake. On a high hill west of this lake a grey intrusion is cut by a typical Quinsam dyke, and generally the grey intrusions are truncated by the Quinsam stock. Similar-appearing bodies intrude both Lower and Middle Bonanza rocks in the south part of the area. Carlisle (1976) interpreted the grey intrusions to be an intrusive phase of the Bonanza, but differences in composition render this doubtful. The thin section mineralogy of the grey intrusions is listed in Table 2; considerable variability is evident. The first six thin sections are from the northwest part of the area, and are therefore typical. The rest are from the south part of the area, and their assignment to the grey intrusions is based on macroscopic similarity. The rocks are more or less altered, and in two thin sections there was too little plagioclase left to fully determine it. The hornblende is commonly fresh, but in a few thin sections it is altered to a fine-grained, fibrous amphibole, probably actinolite. In Table 2 there is considerable similarity tb darker phases of the Quinsam stock, and the grey intrusions are probably the initial phase of the Quinsam intrusions.

QUINSAM INTRUSIONS

These include a large stock in the west part of the area, a small stock within the Iron River skarn deposit, and numerous similar-appearing dykes cutting Karmutsen rocks in the east part of the area. These dykes are most concentrated in outcrops near the highway. The stock in the skarn deposit was not seen by the writer, and its outline is taken from McCullough's (1974) map, based apparently on drill core. Muller (1965) shows a granitic stock east of the Iron River near the skarn deposit and crossing the river farther north. The writer did not map east of the river and found only a few small granitic dykes cutting Karmutsen basalt and gabbro along the river. A granitic stock east of Iron River could be the source of granitic detritus in basal Nanaimo Group rocks along the river.

The north boundary of the Quinsam stock has been delineated, and is fairly smooth. The west boundary lies mostly outside the map-area. The east boundary is covered by overburden and Nanaimo Group sedimentary rocks, and the shape of the boundary and the full extent of the stock in that direction are undetermined. Certain features of the Nanaimo basal member, however, suggest that the stock may not extend far beneath it. The most easterly exposures of the stock are astride Long Creek, south of the outlet of Middle Quinsam Lake. From there the boundary would have to swing abruptly southwest to the contact with Middle Bonanza rocks southeast of Gull Lake. Possibly it is offset by a fault along Long Lake valley. The south boundary has been partly outlined, and found to be irregular. One large tongue extends up into the mountains south of Gull Lake. West of this tongue the boundary is covered by extensive overburden. The contact shown on Gentian Tower is the trace of a subhorizontal zone in which many narrow tongues of the stock finger up into Middle Bonanza rocks. Southward the boundary is covered by Gentian Lake and extensive overburden; the outline shown is merely a reasonable guess. A large low-lying area between Branch J and the Iron Hill mine is completely covered, and granitic rocks in and around the mine may or may not be part of the stock.

The main phase of the Quinsam stock is a coarse-grained, light pink rock, speckled with hornblende, biotite, and magnetite; specimen 82-135 is typical (Table 2). This main phase constitutes at least the mapped part of the stock from the north end to the ditch draining into Gooseneck Lake. Similar rock in the low plateau southwest of Middle Quinsam Lake is probably a continuation of the main phase. Normally this rock is completely massive, but in the ditch mentioned it is horizontally sheeted and superficially resembles sandstone. South of the low plateau the rock starts to change. In an outcrop on the mine road the rock is a rather dark grey tonalite, near diorite (specimen 82-137), and in an outcrop 850 metres to the southeast it is similar. A further 180 metres northeast, the main phase is replete with small dark xenoliths. The final outcrop in this direction has the light pinkish grey colour of the main phase, but it is medium grained. Taken together, these features suggest that these outcrops may be close to a contact of the main phase, either with an early dark phase or with a wedge or roof pendant of Bonanza Formation rocks.

Between Long and Middle Quinsam Lakes and on the low ridge west-northwest of Gull Lake the main phase is intrusive into mafic igneous rocks generally containing some quartz and/or biotite. These almost surely constituted an early, possibly marginal, phase of the stock. In places the rock is a striking intrusive breccia. The large outcrop 220 metres west of the outlet of Long Lake shows medium-grained dark grey porphyritic gabbro (specimens 77-104, 79-83) at the southeast end increasingly intruded and replaced by coarse-grained light grey tonalite, which develops a tinge of pink at the northwest tip. The large tongue south of Gull Lake consists mostly of the lighter coloured main phase rock, but locally passes gradationally to darker phases (specimen 82-158). Along a small creek in the middle of the tongue, the rock is fine grained and sooty black. The rock in the lower part of Gentian Tower is similar to the main phase, but it and nearby outcrops are isolated from the main phase by extensive overburden. The cluster of outcrops west of Gentian Lake is similarly isolated, and continuity with the stock is not certain. Indeed, a group of small outcrops on the northwest side of the cluster resemble Middle Bonanza division more than Quinsam intrusions. The dominant rock in this cluster is coarse grained but medium to dark grey.

A granite dyke in Middle Bonanza division near the tongue south of Gull Lake is probably injected from a late differentiate of the Quinsam stock. A few granite and rhyolite dykes intruding pre-Nanaimo rocks in the Iron River are probably also late differentiates of the Quinsam intrusions.

The Quinsam intrusions have not been radiometrically dated. From the Adam River batholith, in the same general belt, Muller, *et al.* (1974) obtained a K/Ar age on hornblende of 160±7 Ma. Similarly, from the northwest end of the Bedwell batholith, to the southwest, Muller and Carson (1969) obtained K/Ar ages on biotite of 162±9 and 166±8 Ma. The Quinsam intrusions are therefore probably Callovian or possibly Bathonian in age.

NANAIMO GROUP

In this report no attempt is made to correlate Nanaimo rocks of the Quinsam area with the standard Nanaimo formations. In the first place it is unnecessary for present purposes, and secondly the Quinsam area is isolated from the main belt of Nanaimo rocks and lithological correlation across strike without adequate paleontological control is of questionable validity.

Sedimentary rocks of the Nanaimo Group underlie an irregular area between Campbell Lake and the Iron River, which was made the limit of mapping. An isolated exposure near Strathcona Dam indicates a more extensive area of deposition. Natural exposures are scarce outside the Iron River and the north-flowing section of the Quinsam River below Middle Quinsam Lake. North of the West Main Haul road outcrops are virtually confined to the shore of Campbell Lake. Artificial exposures have been made in a few road cuts and, in the central and south parts of the area, more abundantly in the course of coal exploration.

The parts of the area which preliminary drilling had shown to be underlain by coal seams were grid drilled on lines running approximately perpendicular to the formational strike. A solid bit was used, except for sections through coal and some 3 metres above and below, which were cored. The coal core was removed for testing and the remaining core stuffed into plastic tubes. About half the tubes were unidentified and most had been slit for re-examination, exposing the core to the weather. The writer made no attempt to log these cores. Drillers' logs of the cores and cuttings were submitted for assessment purposes by Weldwood of Canada Limited, and sections were constructed from these logs, largely by winter assistants, from which the writer built up a generalized stratigraphy of the lower, coal-bearing part of the group. As elaborated by exposures in the Iron River, the section is shown in Table 3.

In addition to the Iron River, the conglomerate is exposed on a bulldozed line southeast of Gull Lake, on the north side of Middle Quinsam Lake, in a large cut of Highway 28 north of Gooseneck Lake, and in a small outcrop to the north of this. On the east side of the area it is exposed on the shore of Campbell Lake and in the creek draining Lukwa Lake. It is therefore inferred to underlie most of the area of the Nanaimo Group, but may be missing from the northwest part.

TABLE 3. STRATIGRAPHY OF LOWER PART OF NANAIMO GROUP

THICK SANDSTONE SEQUENCE	Metres	
Shaly member	6	Shale locally containing a coal seam
Sandstone member	25	Thin to medium-bedded sandstone
Recessive member	11.5	Mostly shale or siltstone containing coal seams
Basal member	0 - 15	Mostly conglomerate, some sandstone

In the highway cut and nearby outcrop, and north of Middle Quinsam Lake it consists almost entirely of detritus of a dark greenish grey volcanic rock: well-rounded pebbles, cobbles, and a few boulders in a sparing dark greenish grey shaly matrix. Both clasts and matrix weather yellow-brown and, in natural exposures, the conglomerate resembles the widespread glacial till; however, the conglomerate matrix shows clear signs of compression by the weight of overlying sediments, whereas the till matrix shows no compression. The clasts resemble Karmutsen Formation and some dark finer grained phases of the Middle Bonanza division. The drillers' logs reported no conglomerate and had most holes ending in Karmutsen. It is reasonable to conclude that cuttings of Karmutsen-derived detritus would differ little from cuttings of Karmutsen bedrock, and therefore most holes probably ended in the conglomerate.

The conglomerate exposed on the bulldozed line is strongly weathered, but on a sawn surface can be seen to differ considerably from the conglomerate farther north. The pebbles are mostly subrounded or subangular; they consist of chert-like Lower Bonanza division rocks, mafic and felsic phases of the Quinsam intrusions, and felsite, in addition to the dark volcanic rock. The matrix has in part weathered dark red, as in some places in the Iron River.

In the area of the present Iron River, at least, the Nanaimo Group sediments were deposited on a very rough erosional surface. About 12 metres of pebbly sandstone and pebble and cobble-conglomerate accumulated in some of the hollows, and over some of the humps the basal member is missing. In the bed of the river 400 metres below the mouth of Chute Creek, Lower Bonanza striped tuffs dip gently upstream off a hump of Karmutsen volcanic rocks, and pebble conglomerate is plastered onto the steep downstream face. There was evidently a deep hollow just south of the Iron River West Magnetite orebody (*see* Fig. 3, in pocket). The lowest deposits in it are claystones that have been more or less replaced by calcite and siderite. The siderite has in turn been more or less altered to goethite and limonite. The clay is mainly kaolinite. These rocks grade up through quartz claystone and clayey sandstone to pebble and cobble conglomerate. Kaolinite pseudomorphs after feldspar occur in the clayey sandstone, along with slightly altered feldspar grains. A few per cent of biotite is present in the quartz claystones and clayey sandstone as books more or less altered to vermiculite and replaced by siderite-goethite. The clayey sandstone in part superficially resembles arkose or even granite. Boulder-like structures in it are probably concretions. Irregular replacement by calcite and siderite-goethite continues up into the conglomerate. Upstream, in the first 200 metres of conglomerate outcrop, the matrix is splotched white and dark red, due to a patchy, thick, fine dissemination of goethite through the clay matrix. About two-thirds of the pebbles and cobbles are granitic and rounded to subrounded; Karmutsen-like clasts are subordinate, as are angular blocks of the strikingly striped epidosite from near the base of the Lower Bonanza division. In places a metre of bedded sandstone separates the conglomerate from the recessive member.

The detrital mineralogy, clast composition, and sequential change just described are what could be expected from progressive erosion of a weathered granitic terrane. A granitic stock has been reported to occur east of the Iron River, as already noted, but it is questionable whether it was large enough to supply the quantity of granitic detritus observed. It is possible that the Quinsam stock continues east under Nanaimo Group sediments from Middle Quinsam Lake to nearly the Iron River. On the other hand, the volcanic-derived conglomerate north of Middle Quinsam and Gooseneck Lakes indicates a nearby source and suggests that the stock there does not extend far under the Nanaimo Group rocks. The source and time of introduction of the carbonate rocks are unknown. Possibly the carbonate ion was derived from the limestone near the top of the Lower Bonanza division, and the iron for the siderite from the sulphides, skarn minerals, and even the magnetite of the skarn deposit.

Where it is exposed in the Iron River, 300 to 425 metres upstream from the west magnetite orebody (*see* Fig. 3), the recessive member is characterized by coaly material, culminating in a thick, composite coal seam. The following section was observed, with thicknesses estimated (Table 4). The overlying sandstone lies in a shallow syncline, and the sequence is repeated upstream in inverse order. Thicknesses are comparable, except for the coal which thins to 1.5 metres. The basal member is missing, and the coaly pebble conglomerate rests directly on Lower Bonanza rocks. Northward, the recessive member is represented by a road cut exposure of coal northwest of the skarn deposit; it is not further exposed on the east side of the area of Nanaimo Group exposures.

TABLE 4. SECTION OF RECESSIVE MEMBER IN THE IRON RIVER

Metres	
5.00	Coal with at least two interbeds of coaly shale
0.45	Brown sandstone
0.60	Coaly shale
0.18	Brown sandstone
1.38	Coaly paper shales
0.30	Brown sandstone
0.90	Coaly, gritty grey sandstone
3.00	Coaly, pebbly shales and pebble conglomerate
11.51	

At the sharp west loop of the Iron River a small lens of coal is contained within grey sandstone, which passes down through brown sandstone to conglomerate, and up through mudstone to a 1.5-metre conglomerate lens consisting of rounded and angular clasts of granitic rock in a mudstone matrix. Impressions of tree leaves in the brown sandstone may indicate fluvial deposition. A final possible exposure of the recessive member in the Iron River is 400 metres above the mouth of Chute Creek. There, some 45 centimetres of coal appears to rest directly on Lower Bonanza rocks; it is overlain by grit and sandstone.

The contact between the basal and recessive members is in effect a disconformity. When the hollows were filled with the basal sediments, capped in places by a metre or two of sand, further sands were bypassed. When sedimentation resumed conditions had changed, the sediments being generally finer and mixed with organic material. The initial organic debris may be allochthonous, but interleaving of coal in the shales suggests accumulation of the organic material *in situ*. Thia would imply deposition in shallow water, that is, a marsh or swamp. Such swamp, or swamps, would probably have been paralic and brackish, while the land slowly sank relative to sea level.

On the western side the recessive member is exposed only in openings on coal. However, the sections constructed from the drillers' logs show that it is present virtually throughout the area drilled, a belt extending from near the highway to the Quinsam Biver and inoluding the area of Nanaimo Group rocks southeast of Long and Gull Lakes.

A rugged trigoniid pelecypod was collected from the sandstone member at the foot of the falls in the Quinsam River, and found to most closely resemble *Myophorella*. Since all trigoniids are marine, the sandstone member represents a marine incursion. It is not clear whether the shaly member is marine, with transported organic debris, or whether it represents a shoaling to renewed paralic conditions. It is exposed in the Quinsam River, but it is known mostly from the drill logs, from which it is found to be less extensive than the recessive member. Drill sections on the east side show that the sandstone member pinches out southward, and a thinned shaly member coalesces with the recessive member.

A short distance above the shaly member the sandstone is crossbedded coarsely and at large angles, suggesting deltaic conditions. Farther down the Quinsam River, and up in the section, there are two more shaly interbeds, containing 35 and 17 centimetres of coal respectively. They are not exposed elsewhere but appear to have been intersected by some drill holes.

STRUCTURAL GEOLOGY

For the most part the bedded rocks have been only gently folded, and dips are generally low. In the Iron River above Chute Creek, however, deformation is more intense and clearly pre-Late Cretaceous. Lower Bonanza beds have been thrown into small tight folds and are overlain by virtually flat-lying Nanaimo Group beds. The fold axes trend about 340 degrees and plunge approximately 10 to 20 degrees. In one outcrop vertical beds are sinuous, indicating some compression parallel to the axes. No satisfactory explanation for this increased deformation is apparent. In the northwest part of the area the Lower Bonanza beds are generally close to flat lying. Parson Bay beds near the mouth of the spillway are warped, with an average dip of 30 degrees east. Thin beds in a nearby Nanaimo outlier dip 13 degrees west.

Faulting can be inferred to be both pre and post-Late Cretaceous. One major fault probably underlies Long Lake and the swampy valley continuing to the southwest. The abrupt southwestward shift in the boundary of the Quinsam stock has been noted previously. The early mafic phase intrusive rock on the northwest side of Long Lake could be interpreted as a marginal phase on the southeast side of a large tongue, but this mafic phase itself appears to have been shifted southwest, to the low ridge between the valleys of Long and Gull Lakes. The lineament peters out in a short distance to the northeast, where the fault passes under Nanaimo sediments, and sections of them across the fault extension indicate a maximum possible downthrow on the southeast side of 12 metres. There does not appear to be much post-Nanaimo-time horizontal movement because there is no apparent displacement of the east margin. The lobe of Nanaimo Group rocks southeast of Long Lake valley can be explained if the granitic ridge between Middle Quinsam and Long Lakes is an exhumed pre-Nanaimo ridge, on which the lower Nanaimo members were never deposited and from which the higher beds have been eroded.

Overall, Nanaimo Group rocks form a shallow asymmetric syncline. Smaller flexures are superimposed on it in the south part as, for example, the syncline noted in describing the sequence in the recessive member in the Iron River. The overall axis apparently trends west of north, although local bedding may diverge. The west limb dips gently; 8 degrees was measured on coal in the shaly member in the Quinsam River. The east limb dips more steeply, commonly around 20 degrees, for possibly several combined reasons. On the south shore of Campbell Lake beds turn up sharply over 30 metres, from 50 degrees west in sandstone to vertical in the basal conglomerate. The conglomerate is rubbled at the end of exposure, and the contact with the Karmutsen Formation is covered. Clearly, Nanaimo Group rocks here have been downfaulted against the

Karmutsen Formation, and the basal beds dragged up in the process. Southward, exposure is insufficient to indicate the nature of the contact. At Lukwa Lake it may be an unconformity. Derived sections just west of the skarn deposit indicate that Nanaimo beds steepen toward it, but this may be explained by draping and differential compaction on the steep flank of a bedrock hill. If the upturning is caused by down-faulting, the outcrop distribution (Fig. 3) requires that the fault lie within the Nanaimo Group. In addition to faulting and draping, the steepening of the east limb could have been caused by pressure on Vancouver Island from the west-drifting North American plate.

A fault almost surely underlies the west tail of Beavertail Lake and the narrow swampy valley to the west. The contact of the Nanaimo Group with the Quinsam stock is effectively displaced to the right. This could have been accomplished equally well by right lateral movement or by downthrow on the south of the gently dipping beds. A small right-hand deflection of the west contact of the stock may or may not be caused by right lateral faulting.

Many small fanlts, with displacements of 3 metres or less, can be seen in well-exposed bedded rocks. Two in Iron River form a graben which has preserved the Lower Bonanza limestone but do not appear to cut Nanaimo beds. On the other hand, the upper contact of the Nanaimo recessive shaly member is downthrown on the south of a tight fracture. Just south of Strathcona Dam the Parson Bay-Lower Bonanza contact is repeatedly faulted and downthrown on the south.

ALTERATION AND METAMORPHISM

The igneous rocks have been altered to varying degrees. In the Karmutsen lavas primary pyroxene has been replaced by amphibole, which has not been further altered, and the plagioclase has been variably saussuritized. This alteration may be deuteric. Lavas in the Lower Bonanza division show moderate alteration to epidote; more intense alteration is associated with fracture veinlets of epidote, feldspar, chlorite, and calcite. The Middle Bonanza lavas show a widespread but slight propylitic alteration. Locally there has been moderate to strong alteration of plagioclase to saussurite. Middle Bonanza tuffs are more strongly altered than the lavas, indicating that the alteration is largely post-depositional rather than deuteric. With their more open structure the tuffs would provide readier access to circulating fluids than would consolidated lava. The grey intrusions are fresh to moderately propylitized and saussuritized. Alteration of the Quinsam stock is weak but persistent, mainly partial alteration of biotite and hornblende to chlorite.

Metamorphism of the older sedimentary rocks has generally not proceeded beyond complete induration. A little of the carbonaceous material has been removed from the Parson Bay argillite near the spillway. Against the Quinsam stock Lower Bonanza beds look somewhat hornfelsed and are cut by garnet veinlets. The epidote in the fossil-bearing epidosite clearly has not formed by metamorphism *in situ*, and presumably was eroded from the underlying volcanic rocks.

Diagenesis of the Nanaimo Group seems to increase somewhat from north to south. A bit of unaltered bark was found in soft sandstone on the shore of Campbell Lake. Along the Quinsam River the sandstone is harder and concretionary, and along the Iron River leaves in sandstone are thoroughly coalified. The coal in the Iron River seems harder than it should be, and it has been suggested that it has been metamorphosed by the stock east of the river, which may be of Tertiary age. However, there are very fine-grained carbonate rocks at the base of the Nanaimo Group just south of the skarn deposit that are not recrystallized; clearly they were not subjected to appreciable heat.

ECONOMIC GEOLOGY

COAL

The principal potential mineral resource of the area is coal in the Nanaimo Group. Five seams are known, but only the lower three show economic thickness and extent. Nos. 1 and 2 seams are in the recessive member and No. 3 is in the thin shaly member, as shown in the sections on Figure 4 (in pocket). On Figure 4d, on the east limb of the syncline, No. 1 seam pinches southward and Nos. 2 and 3 converge due to thinning and pinching of the sandstone member. The thick coal section in the Iron River is thus a composite of Nos. 2 and 3 seams, with some interbedded shale. As noted, this composite seam thins markedly upstream across a subsidiary syncline, and is represented only by lenses at the large westward loop of the river. The northward extent of the seams on the east limb of the main syncline was not determined by the drilling. On the west limb the systematic drilling traced at least one seam to line 195, near the highway, and two earlier exploratory holes along the West Main Haul road east of Beavertail Lake also found coal; a hole south of this lake was barren.

The seams contain interbeds of shale, and pyrite films along the cleat. The interbeds are commonly 25 to 50 centimetres thick, and could not be shown on the sections. The seam thickness used in calculating reserves is the aggregate of coal only. Two samples taken from the No. 1 seam beside the adit were partially analysed:

77-110 Composite of 25-centimetre rider, above a shale interbed, and exposed part of main part of seam; sulphur, 1.97 per cent; phosphorus, 0.62 per cent; and ash, 5.21 per cent

78-205 Upper 90 centimetres of main part of seam; sulphur, 1.80 per cent; and phosphorus, <0.1 per cent

Clearly the rider is higher in sulphur (as pyrite) and much higher in phosphorus than the main part of No. 1 seam. Weldwood of Canada Limited's coal consultant, Mr. Curcio, told the writer that Nos. 2 and 3 seams contain more sulphur than No. 1. Some of the pyrite can be washed out, but Barnstable (1980) stated that the cleaned coal would contain 0.91 per cent sulphur. It is therefore thermal, not metallurgical, coal.

Reserves were calculated for each seam in the drilled areas. All intersections were shallower than the 300 metres recommended in *Coal*

Resources and Reserves of Canada (1979). For Nos. 2 and 3 seams holes with intersections less than 1.5 metres (5 feet) were not included. For No. 1 seam the minimum was set in error at 1.2 metres (4 feet); however a mere eight holes would have to be discarded to bring the minimum to 1.5 metres, and inspection shows that this would decrease the areas very little. The productive holes were replotted and rectangles drawn around them such that no part of a rectangle was more than 300 metres (1,000 feet) from a productive hole. Where the side of a cluster was a row of productive holes, the side of the rectangle was placed 75 metres (250 feet) beyond. Figures 5 and 6 (in pocket) show this plot for Nos. 1 and 2 seams. An arithmetic average of the thickness was calculated for each rectangle. The computed volumes within the rectangles were summed for each seam and converted from cubic feet to metric tonnes. A back-calculation showed a specific gravity of 1.29 had been used in calculating the reserves for the Quinsam area given by Muller and Atchison (1971), and that figure was used in the present calculations. The computed reserves are: No. 1 seam, 15 400 000 tonnes; No. 2 seam, 9 090 000 tonnes; and No. 3 seam, 1 250 000 tonnes - total of 25 740 000 tonnes.

METALLIFEROUS DEPOSITS

Magnetite and associated chalcopyrite in garnet-epidote skarn form two orebodies on the Iron River. The west orebody is exposed on a knoll topping the bank on the inside of a river bend and is surrounded by overburden. The east orebody is exposed to the east in the riverbed and evidently continues under overburden in the right bank; the host skarn grades outward to altered Karmutsen basalt. Reserves were estimated in 1956 at 730 000 tonnes (800,000 tons) of probable ore grading 36 per cent iron and 0.35 per cent copper. The 1965-1966 and 1971 drilling of the east orebody appears to have increased the tonnage significantly.

South and east of Strathcona Dam the Lower Bonanza division contains abundant disseminated pyrite. A grab sample of some of the most heavily pyritized rock assayed gold <0.3 ppm; silver <10 ppm; and copper 0.10 per cent. The grey intrusions in this part of the area are also pyritized, but less strongly.

The Middle Bonanza division is somewhat pyritized. Sample 82-140 was taken from a recent trench beside the road along the east side of Gentian Lake, and 82-154 from a road cut of Branch J. Assays are given in Table 5.

In 1976, 13 pits and trenches had been made in a medium grey phase of the Quinsam stock west of Gentian Lake. These workings were on R. B. Hopton's

Cedar Hill No. 2 claim. Most exposed only minor pyrite, but three were more promising. By 1982 these three had been deepened and lengthened, and they are shown on Figure 2 as Nos. 9, 10, and 11. Trench No. 9 exposes chalcopyrite in massive pyrite in a narrow shear zone; sample 82-155 was taken of the sulphides. Trench No. 10 exposes lenses of chalcopyrite in two small shear zones; sample 82-156 was taken of sulphide and sheared rock. Trench No. 11 runs in 10 metres to a 4-metre-high face; a weak, vertical shear zone strikes 075 degrees; it carries lenses of chalcopyrite and sphalerite; sample 82-157 was taken across the zone.

TABLE 5. ASSAYS OF SAMPLES FROM GENTIAN LAKE AREA

	GOLD ppm	SILVER ppm	COPPER per cent*	LEAD per cent	ZINC per cent
82-140	<1	0.9	43 ppm		
82-154	<1	0.3	60 ppm		
82-155	0.3	148	12.9	0.02	1.51
82-156	0.3	154	6.71	0.08	0.05
82-157	0.3	169	12.9	0.14	14.2

*Except as noted.

APPENDIX

PETROGRAPHIC NOTES

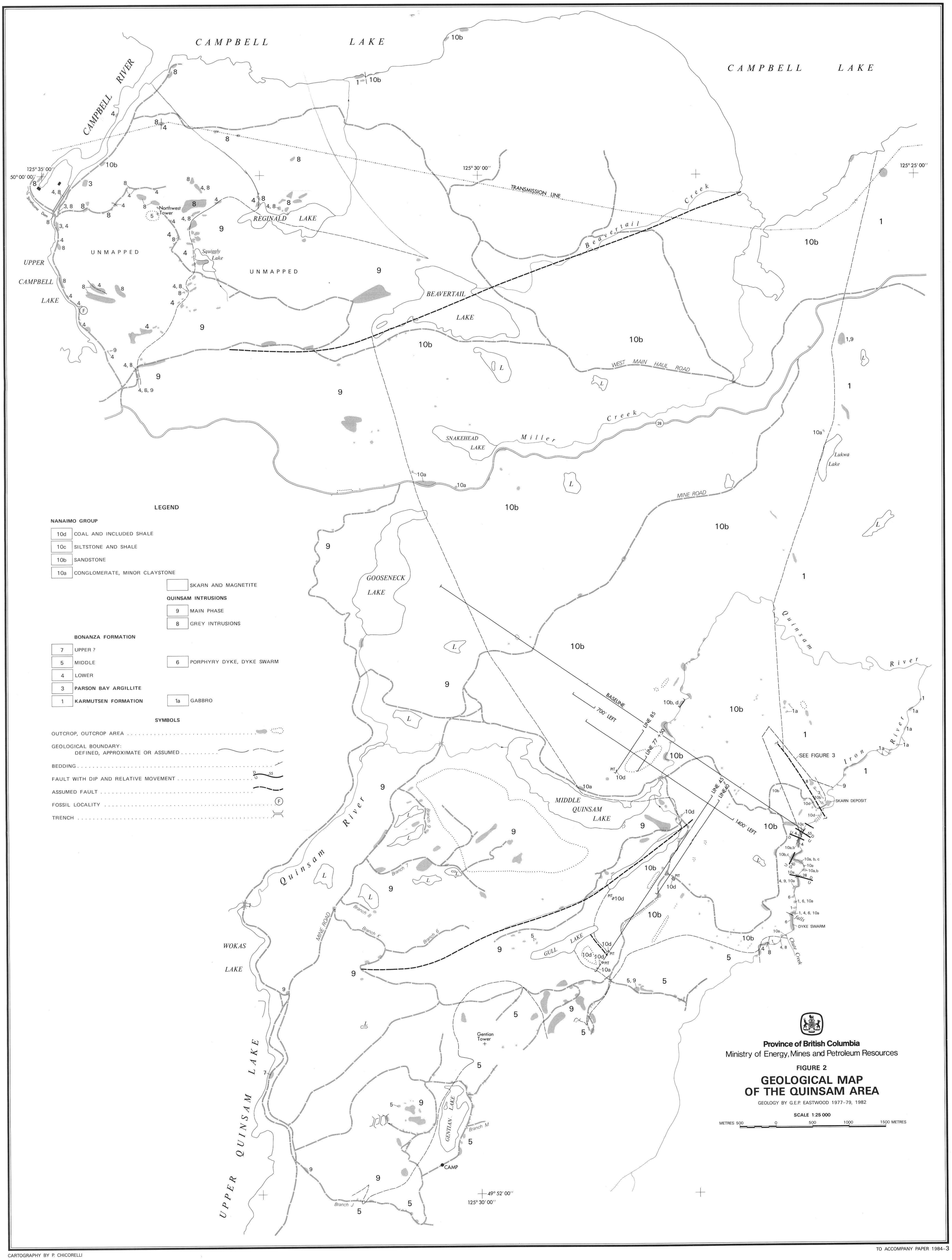
WHITE OPAQUE

Most textbooks assert that an opaque mineral that is white in reflected light is leucoxene. This is a reasonable conclusion where it encloses ilmenite, but most does not. Some of it encloses pyrite and is clearly limonite. Some lies on siderite and can also be assumed to be limonite. Most of the white opaque, however, coats epidote. In plane-polarized transmitted light the grains are dark grey, and they are dark between crossed nicols. In thinner parts of the slide and with increased illumination, however, the strong birefringence of epidote can be discerned. The identification is confirmed in various ways, such as near-parallel extinction and association with clinozoisite showing similarly high relief and the usual abnormal interference colours. The clinozoisite is unaltered, so the opaque white dust in the iron-bearing epidote is probably limonite also.

PLAGIOCLASE DETERMINATION

Most igneous rock classifications are based on the content of quartz and the various feldspars, and in the absence of potash feldspars the composition of the plagioclase is particularly important. The refractive index relative to the mounting medium can be reliably determined only on fresh grains. Plagioclases containing an average amount of allophane dust usually break to a line of alteration, and the Becke effect is that of the allophane. If the alteration is fairly light, an aggregate Becke line may be obtainable using a medium power objective and reduced aperture. The determination relative to quartz is easier and surer - provided quartz is present. For more altered plagioclases and for more precise determination, recourse is normally had to the extinction angles of albite twins. For batholiths and stocks curves based on analysed material have long since been established, but some uncertainty pertains to small intrusions and volcanic rocks.

As related by Tobi (1963), Kohler in 1923 found that he obtained smooth curves for his charts for combined Albite-Carlsbad twinning only when data for certain lava phenocrysts were left out. Tertsch constructed a chart for high-temperature plagioclase in 1942, and Tobi reconstructed the charts in 1963, based on data collected and reviewed by van der Kaaden. The high-temperature data are from a mixture of natural, heated and quenched natural, and synthetic plagioclases; the validity of the curves has been questioned. It is reasonable to assume that crystals in naturally quenched material, such as welded tuffs, should approximate the artificially quenched crystals in character, but crystals in lava flows, sills, and dykes, which cool more slowly, must surely be intermediate between the high and low-temperature forms. For andesine the low-temperature curves yield a composition that is about 5 anorthite percentage points above that from the high-temperature curves. For oligoclase the difference is less, and for labradorite it is about 9 percentage points. In this study one-third of the difference has been assumed for lavas and two-thirds for hypabyssal rocks.



CARTOGRAPHY BY P. CHICORELLI

TO ACCOMPANY PAPER 1984-3

Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources

FIGURE 3

IRON RIVER SKARN DEPOSIT AND VICINITY

GEOLOGY BY G.E.P. EASTWOOD 1977–79, 1982

SCALE 1:2 500

METRES 50 0 50 100 150 METRES

LEGEND

NANAIMO GROUP

10f	SANDSTONE
10e	COAL
10d	SHALE, COALY SHALE, PEBBLY SHALE
10c	CONGLOMERATE
10b	QUARTZ CLAYSTONE, CLAYEY SANDSTONE
10a	CARBONATIZED CLAYSTONE
	MINERALIZATION
6b	MAGNETITE
6a	SKARN–BASALT
6	SKARN
	QUINSAM INTRUSIONS
5	QUARTZ DIORITE
4	BASALT PORPHYRY
	LOWER BONANZA
3	THIN–BANDED SILTITES
	PARSON BAY FORMATION
2	BLACK ARGILLITE
	KARMUTSEN FORMATION
1	BASALT

SYMBOLS

OUTCROP

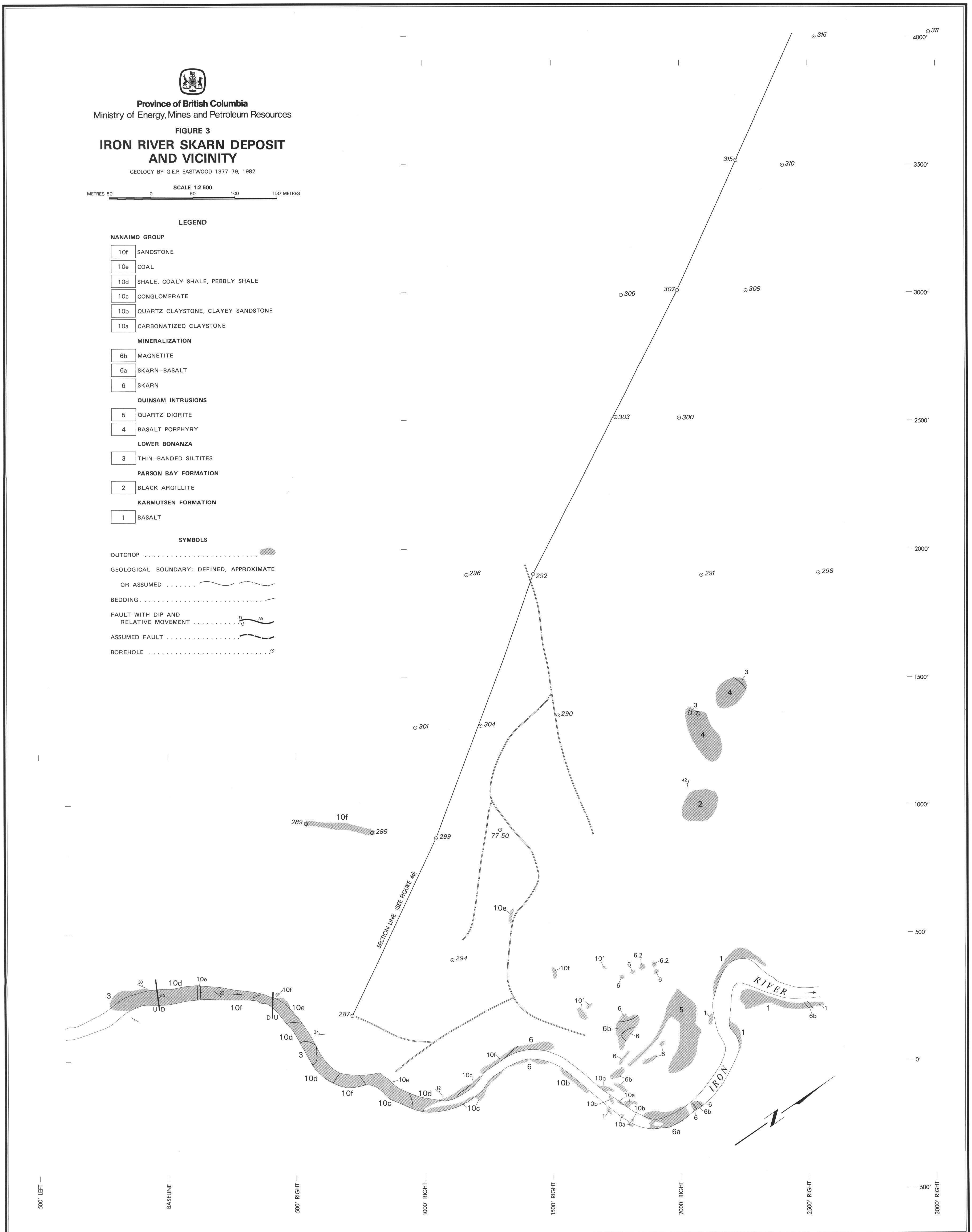
GEOLOGICAL BOUNDARY: DEFINED, APPROXIMATE OR ASSUMED

BEDDING

FAULT WITH DIP AND RELATIVE MOVEMENT

ASSUMED FAULT

BOREHOLE



CARTOGRAPHY BY P. CHICORELLI

TO ACCOMPANY PAPER 1984–3

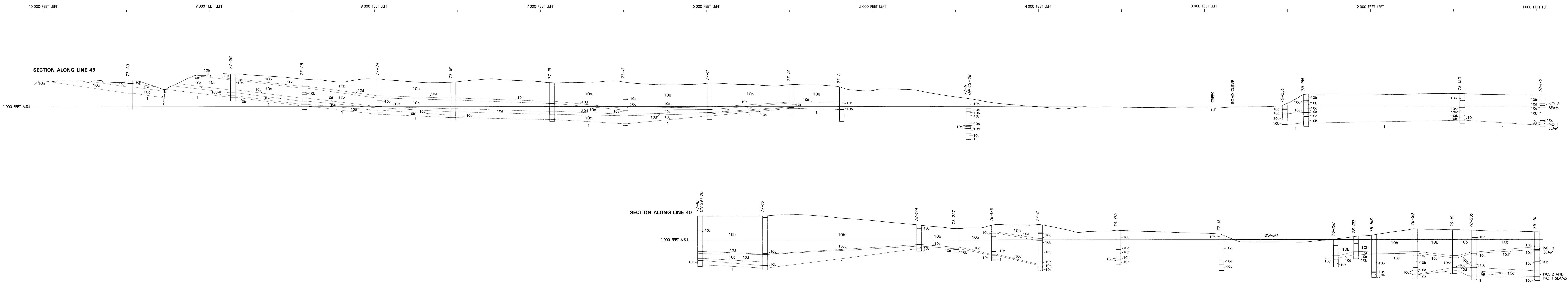


FIGURE 4a

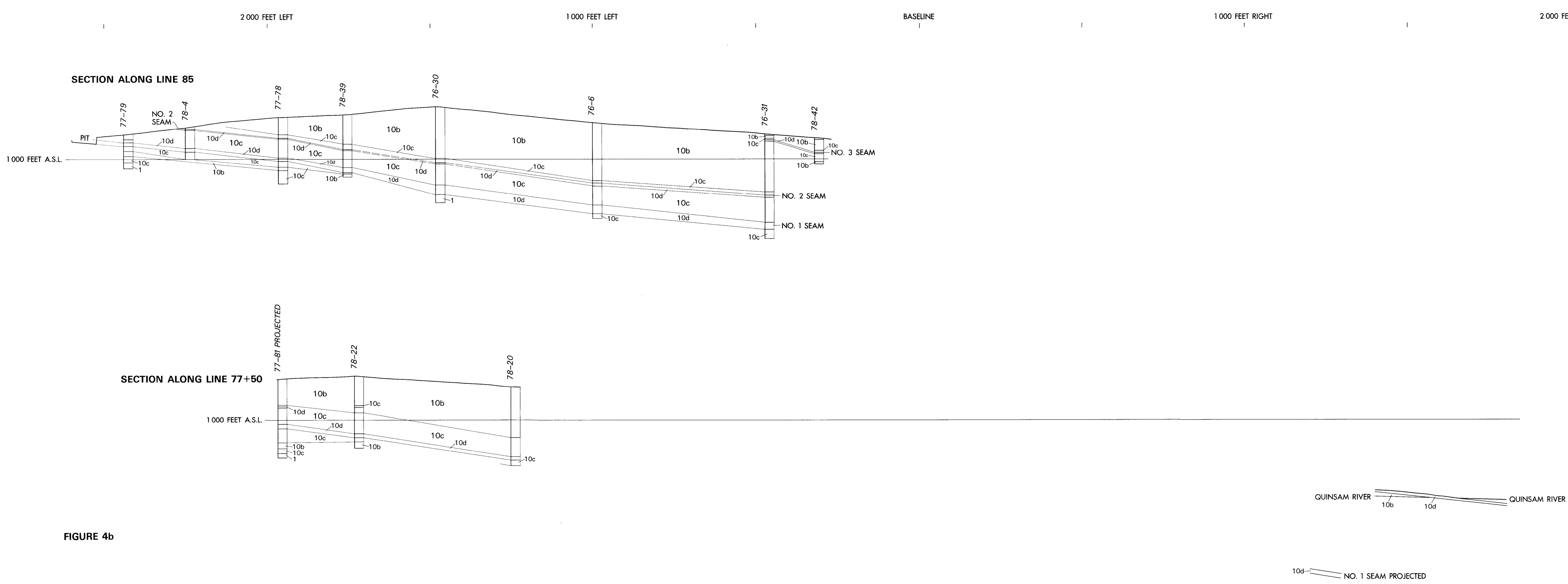


FIGURE 4b

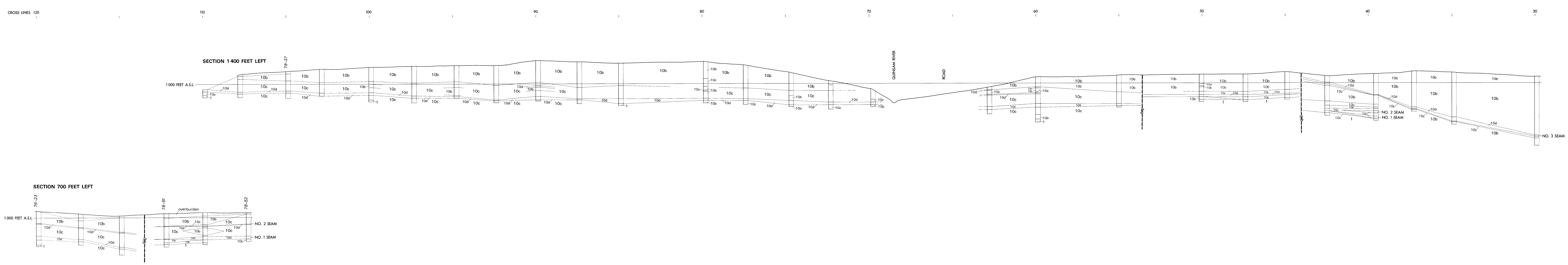


FIGURE 4c

OBLIQUE SECTION NEAR IRON CREEK
(For location see Figure 3)

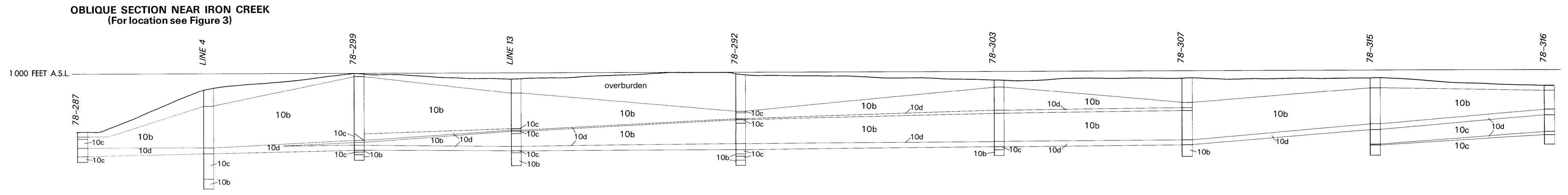


FIGURE 4d

Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources

FIGURE 4

SELECTED COAL–BEARING SECTIONS

GEOLOGY BY G.E.P. EASTWOOD 1977–79, 1982

HORIZONTAL AND VERTICAL SCALE 1:2 500

METRES 50 0 50 100 150 METRES

LEGEND

NANAIMO GROUP

10d	COAL
10c	SHALE AND SILTSTONE
10b	SANDSTONE
10a	CONGLOMERATE

KARMUTSEN FORMATION

1	"BASALT"

SYMBOLS

INFERRED FAULT ....

BOREHOLE 77–33

CARTOGRAPHY BY R. CHICORELLI

TO ACCOMPANY PAPER 1984–3

Province of British Columbia
Ministry of Energy, Mines and Petroleum Resources

FIGURE 5

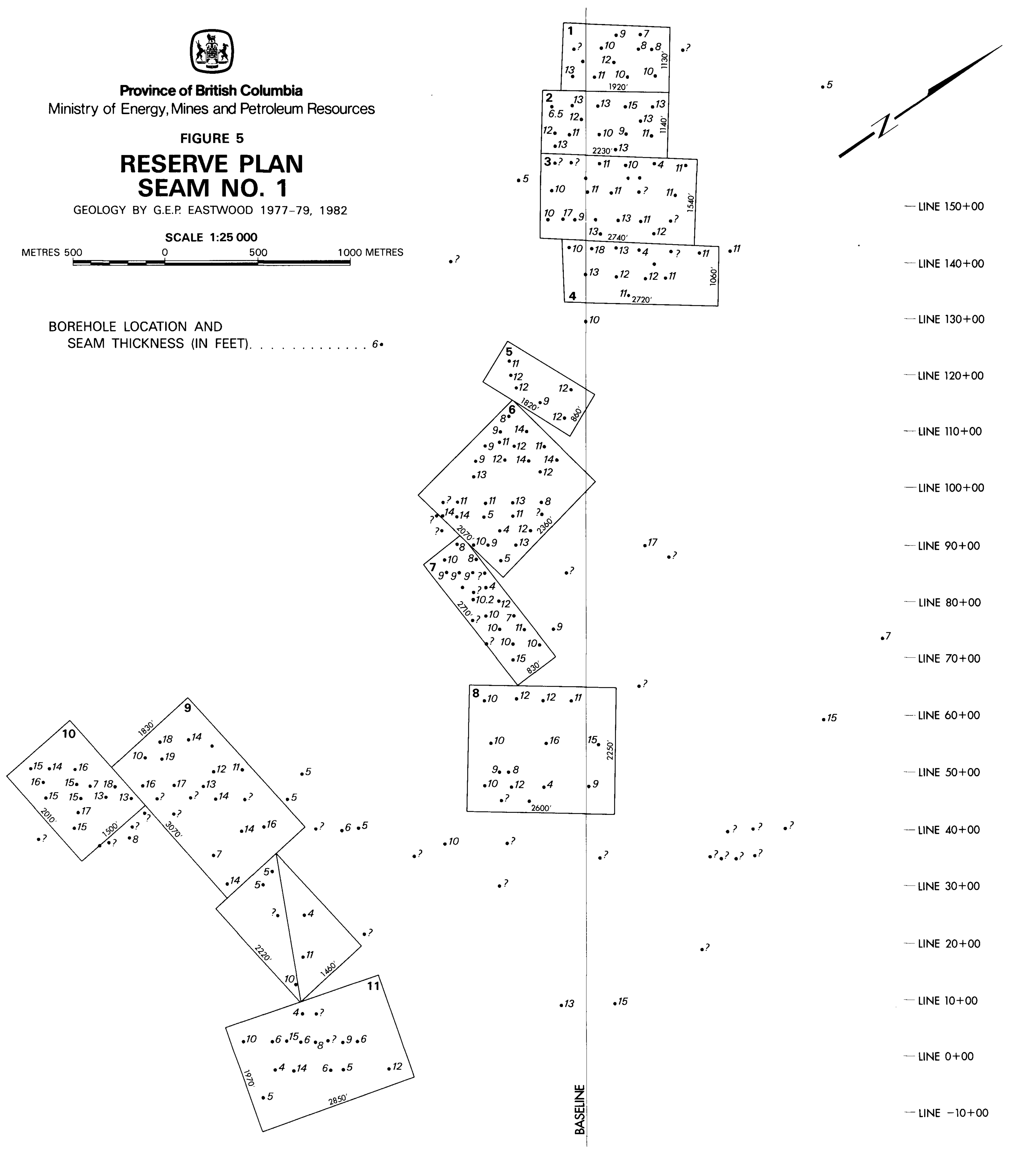
RESERVE PLAN
SEAM NO. 1

GEOLOGY BY G.E.P. EASTWOOD 1977–79, 1982

SCALE 1:25 000

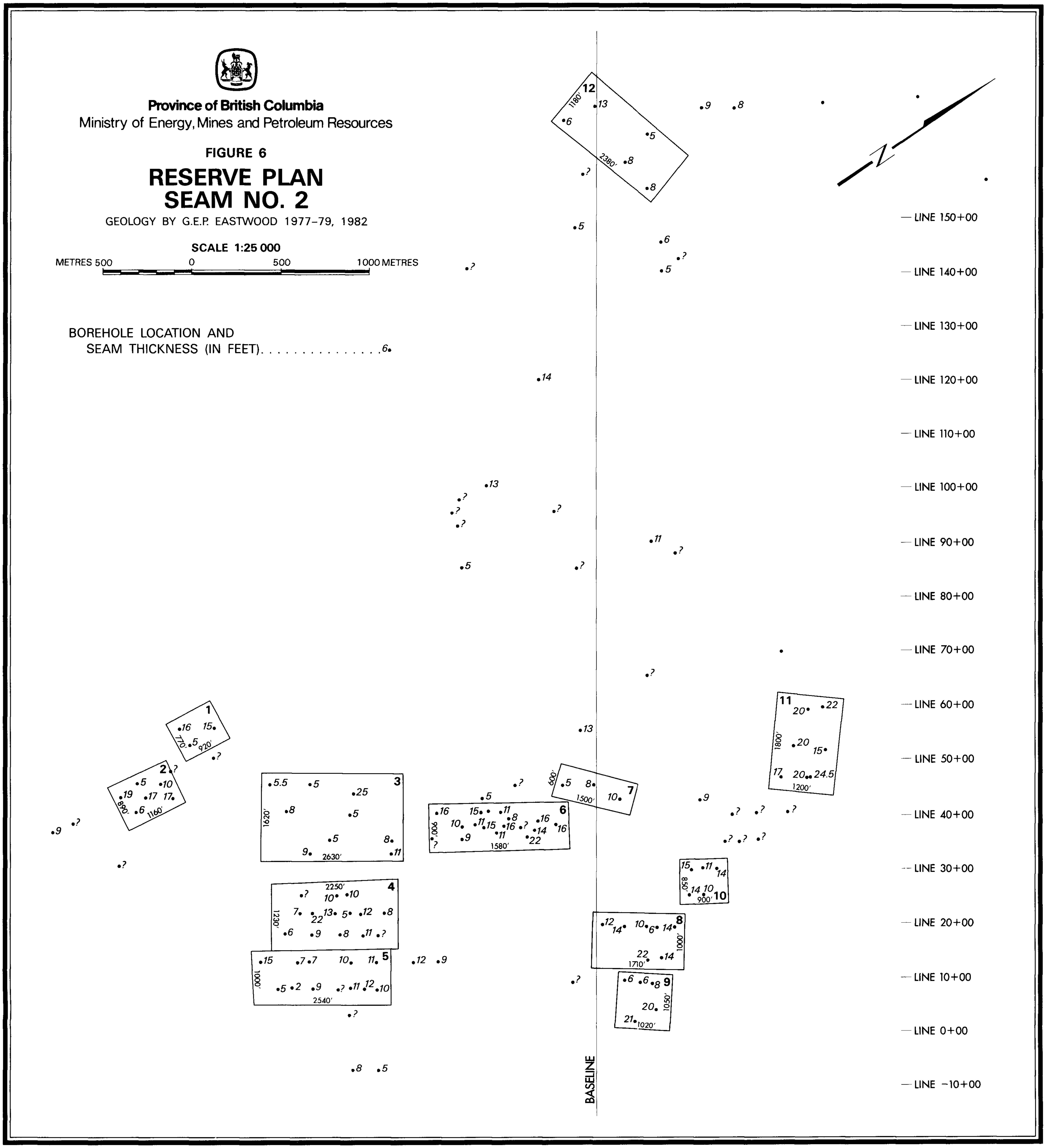
METRES 500 0 500 1000 METRES

BOREHOLE LOCATION AND SEAM THICKNESS (IN FEET) . . . . 6•



CARTOGRAPHY BY R CHICORELLI

TO ACCOMPANY PAPER 1984-3



CARTOGRAPHY BY R CHICORELLI

TO ACCOMPANY PAPER 1984-3