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FIELD TRIP NO. 6: GUIDEBOOK

# VOLCANIC SUITES OF SOUTHERN BRITISH COLUMBIA

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# FIELD EXCURSION NO. 6

# VOLCANIC SUITES OF SOUTHERN BRITISH COLUMBIA

G.A.C. - S.E.G. Annual Meeting

Vancouver, B. C.

1977

B. N. Church

## INTRODUCTION

Tour No. 6 has been organized for delegates interested in the structural and petrological contrasts of the Paleozoic to Tertiary volcanic sequences of southern British Columbia. For the benefit of those interested in the economic geology of the region there are visits to the Seneca polymetallic deposit near Harrison Lake, the Big Sioux copper prospect in the Aspen Grove area, the Dusty Mac gold-silver mine at Okanagan Falls, and a few uranium prospects in vicinity of White Lake.

This is a three day mini-bus excursion which begins from Penticton and passes through the White Lake basin, then moves on to the Princeton - Aspen Grove area the second day, and finally to the Harrison Lake area and a return to Vancouver on the third day. The excursion will be led by staff members of the British Columbia Ministry of Mines and Petroleum Resources who have completed detailed studies in the respective areas.

# DAY 1: OLALLA AND OKANAGAN FALLS

(B. N. Church)

## Geology of the Tertiary Section between Olalla and Okanagan Falls

The type section of the early Tertiary volcanic formations in south-central British Columbia is viewed in road cuts and panoramas in the White Lake basin south and southwest of Penticton. The focus of this part of the excursion is mainly on the stratigraphy and structure of the relatively unmetamorphosed Eocene pile with side visits to the Dusty Mac gold-silver mine at Okanagan Falls and uranium prospects near Olalla and the White Lake Astrophysical Observatory.

## PHYSIOGRAPHY

The area is characterized by a low, mountainous terrain bounded on the east by the Okanagan and tributary valleys at base elevation of about 1,100 feet, and on the west by valleys of the Similkameen drainage system at about 1,800 feet. White Lake, a small ephemeral body of water, is located in the east central part of the area near the centre of a dish-shaped depression at 1,750 feet. Slopes rise gently from White Lake on the northwest and southwest to concordant summits which underlie a remnant of a once-continuous upland surface at about 4,500 feet, the Thompson Plateau. To the east the depression is separated from the Okanagan Valley by numerous small knobs and ridges and by Mount Hawthorne, which rises to an elevation of 2,750 feet. The basin rim is breached by several valleys containing small intermittent streams.

Low parts and south-facing slopes are open ranch land with plentiful bunch-grass, sagebrush, and cactus.

## GENERAL GEOLOGY AND HISTORY

The erosionally dissected rocks of the White Lake area present an ideal cross-section of one of the many Tertiary fault-bounded basins found throughout the Interior Region of British Columbia. The strata consist of five main divisions. Each stratigraphic division was deposited unconformably on older rocks, the total accumulated succession having a maximum aggregate thickness of about 12,000 feet (3,650 m).

### Springbrook Formation

The Springbrook Formation is the lowest stratigraphic unit. These rocks are best exposed on bluffs in the extreme west part of the area. Discontinuous beds of pebble and boulder conglomerate and talus breccia dip gently to the east, displaying local thickness of as much as 700 feet. The coarse, clastic fragments are of diverse composition, being eroded from pre-Tertiary beds of feldspathic andesite, grey and black chert, argillite, chlorite schist, and gneiss.

## Marron Formation

The Marron Formation is the thickest and most widely distributed stratigraphic division. Five volcanic events are recorded by the sequence and marked by deposition of distinctive mappable rocks. These rocks, which are mainly the product of fissure eruption, buried pre-existing valleys and hill tops to form thick sheet-like deposits.

The lowermost unit of the Marron Formation, the Yellow Lake member, is composed of biotite and pyroxene feldspathic phonolite and mafic phonolite lavas and pyroclastics. A distinctive feature of many feeder dykes and lava flows is that they contain what appears to be primary analcite and rhomb-shaped anorthoclase-sanidine composite phenocrysts. At the time of extrusion the rocks completely covered the Springbrook Formation, filling old valleys in the Yellow Lake area with as much as 1,800 feet of lava and volcanic debris.

The Kitley Lake member represents the second important volcanic event in the Marron succession. These rocks are mainly clot-plagioclase porphyry trachyte and trachyandesite lavas. The lavas were deposited as a more or less uniform layer about 1,000 feet thick on a relatively smooth surface formed by the upper surface of the Yellow Lake volcanics. Potassium-argon analysis by Geochron Laboratories Inc. of biotite from a lava flow immediately east of Yellow Lake gives an age of 51.6 $\pm$ 1.8 million years.

The Kearns Creek member is the middle unit in the Marron assemblage. These rocks are dark brown, highly vesicular basaltic andesite lavas and flow breccias. Normally the rocks have a dense charge of pyroxene phenocrysts with a few interspersed plagioclase laths. The rocks crop out at widely scattered points in the west and southern parts of the area. The unit is relatively thin, attaining a maximum thickness, about 400 feet, west of Mahoney Lake.

The Nimpit Lake member is in the upper middle part of the Marron Formation. The unit consists of a series of trachyte and trachyandesite lava flows similar in chemical composition to the Kitley Lake lavas. Distinctively the rocks contain small rosette-shaped glomerophenocrysts of plagioclase and laths of sanidine. The rocks are well displayed east and southeast of Twin Lakes where the lava flows, totalling more than 1,000 feet thick, correspond to tiered benches on the slopes of the main hills.

The Park Rill member forms a good marker zone at the top of the Marron Formation. The unit consists of medium-brown merocrystalline and vitric andesite lava flows. These rocks were extruded on the relatively smooth surface of the Nimpit Lake member. In places the lavas form accumulations in excess of 1,500 feet thick.

The Marron rocks show important variations in attitude throughout the area. On the west the rocks are almost horizontal or dip gently east, in the north central part they arch over a broad southeast-trending anticlinal axis, and at the centre of the White Lake basin they are deeply buried by down-warped younger rocks.

## Marama Formation

The Marama Formation was deposited during renewed volcanic activity after a period of deep erosion of Marron rocks. Viscous rhyolite and rhyodacite lavas flooded valleys, burying gravel deposits and overtopping local ridges. The Marama rocks are widely distributed in the northern part of the area where the unit is displayed in characteristic precipitous bluffs. The maximum observed thickness of the Marama Formation is about 1,000 feet on the ridge overlooking Marama Creek. Other thick sections are found southeast of Kitley Lake and Peach Cliff, immediately east of Okanagan Falls.

After a period of intense faulting and erosion of the Marama and older rocks, the main deposition occurred in the area near the Okanagan Valley, which by this time was a prominent topographic feature and an important link in the local drainage system.

## White Lake Formation

The White Lake Formation is a composite sedimentary volcanic unit overlapping Marron and Marama rocks in the east part of the area. Deposition of the White Lake sedimentary phase coincided with the eruption of andesite and trachyandesite lavas from vents centred near the Okanagan Valley. It appears that a northerly flowing stream was dammed in this area by volcanic debris forming a lake several miles in diameter (Tertiary White Lake). Large volumes of laharic and pyroclastic material were periodically ejected from water filled vents spilling debris into the Okanagan Valley and the nearby lake. Eventually the lake was filled with carbonaceous shale, sandstone, and tuffaceous sediments resulting in a total accumulation of 3,500 feet of strata.

The White Lake beds are folded and cut by many faults. At the centre of the basin the beds are folded into a broad syncline plunging about 25 degrees east. These rocks are more or less detached from White Lake strata near Skaha Lake by a fault zone along the west side of the Okanagan Valley.

It is noted that the beds in the White Lake syncline are generally more steeply dipping than older Tertiary strata in adjacent areas. These older rocks may have steep dips under White Lake beds, or, alternatively, the fold form changes with depth; shallow dips in Marron rocks may persist at depth in spite of steep inclination of the overlying White Lake beds if the beds are concentrically folded. White Lake beds are possibly accommodated in the core of a concentric fold by reverse faulting or thrust movement subparallel to bedding. Good evidence of reverse faulting is observed on the north limb of the syncline about 2½ miles northeast of White Lake.

At this point a slice of Marama rhyodacite is thrust upward through several hundred feet of White Lake beds.

Skaha Formation

The Skaha Formation is the youngest Tertiary unit. These rocks crop out in a small area located about one-half mile east of White Lake and about 2 miles southwest of Skaha Lake. The unit consists of two members, a lower one mainly composed of slide breccia and some volcanic rocks, and an upper one composed of coarse boulder fanglomerate. The gross nature of these clastic rocks reflects the dynamic condition under which they were deposited. The slide breccias were derived from high terrain underlain by an assemblage of chert, greenstone, and granite, and were deposited on older Tertiary and pre-Tertiary rocks, possibly at the base of a fault scarp. The slide breccias apparently disrupted local drainage and were partly eroded and reworked by stream action. The upper member, the fanglomerate beds, were derived partly from older Tertiary rocks and from the same high terrain that proved to be the source for the slide breccias. This material rests on eroded slide breccias and locally onlaps White Lake beds.

STRUCTURE

The geology of the White Lake area records a history of graben development and transcurrent faulting. Tensional conditions prevailed during the Eocene beginning with the eruption of the earliest Marron lavas and continued through to the final emplacement of the Skaha slide breccias and fanglomerate deposits.

In general, the Tertiary assemblage is tilted to the east forming a trap-door-like structure. It is estimated that close to 8,000 ft. (2,438 m) of continental volcanic and sedimentary rocks accumulated in the White Lake basin, some of the lowermost beds in this pile being down-faulted well below sea level.

Folds are developed in areas of thick accumulation but appear to be without regional pattern and probably reflect faulting of basement rocks.

A system of late northerly trending fractures developed along the Okanagan Valley in the vicinity of Skaha Lake, White Lake, and near Vaseaux Lake. A detailed study suggests that the fractures are the result of lateral stresses and mainly transcurrent movement.

The White Lake basin fits a pattern of northerly oriented grabens extending eastward across the interior region of the Province from Cache Creek through the Penticton area to Greenwood. Moving easterly in this system the frequency of alkaline volcanic rocks increases. Here the association of trachyte and phonolite assemblages with the rift system is well documented.

## PETROLOGY

The Tertiary volcanics of the White Lake basin display a peculiar mixture of siliceous "acid" and aluminous-alkaline rock types. In all, three magma series (labelled A, B, and C) are recognized from detailed petrographic studies.

A series, an acid suite consisting of Marama rhyolite and rhyodacite, Park Rill andesite, White Lake andesite, Kearns Creek basaltic andesite.

B series, an alkaline suite consisting of Kitley Lake trachyte and trachyandesite, Nimpit Lake trachyte and trachyandesite.

C series, an alkaline suite consisting of Yellow Lake phonolites and mafic phonolites and Skaha augite porphyry alkalic basalt.

The rocks of A series are typically siliceous, with relatively low alumina-to-silica ratios, and low to moderate total alkali content. In contrast, C series rocks are alumina-rich and silica poor, showing relatively large alumina-to-silica ratios; B series rocks are alkali-rich but otherwise intermediate to the A and C composition extremes. A hypothetical line of silica saturation would bisect the composition field of B series; and A and C compositions would fall respectively on the oversaturated and under-saturated sides of such a line.

In regional perspective the rhyolite-andesite acid suite appears to be part of a discontinuous Early Tertiary andesite volcanic belt trending meridionally through central British Columbia and western Washington and Oregon. The alkaline volcanic suite seems to be genetically related to the Coryell plutonic intrusions located to the east in south central British Columbia. Together, the alkaline rocks form a distinctive petrographic province similar in many ways to the Highwood petrographic province located east of the Rocky Mountain divide in central Montana.

## MINERAL DEPOSITS

Traditionally the Tertiary basins of the southern interior of British Columbia have been known principally for their coal deposits, zeolite occurrences, some perlite, and opal and agate localities. However, in recent years, with the advent of advanced geochemical and geophysical methods of prospecting and precise methods of rock dating, it is now known that the Tertiary suite is important in the search for base and precious metals and uranium.

## THE DUSTY MAC DEPOSIT

The Dusty Mac deposit has been one of the more interesting recent discoveries and mining developments in the region. In 1966, native silver was discovered in Tertiary rocks about one mile east of Okanagan Falls. After much sampling a small but significant tonnage of gold-silver ore was indicated.

The property was organized under the name of Dusty Mac Mines Ltd., in 1968 and in 1970 it was optioned to Noranda Exploration Ltd. With further work some additional tonnage was outlined, although, this was insufficient to initiate mining at the time. Later, with marked increases in the price of gold and silver, Dusty Mac Mines renewed the program of development drilling. Work completed to the end of 1973 was successful in proving more than 90,000 tons of ore grading gold, 0.26 oz/ton, and silver, 4.67 oz/ton.

Mining commenced in August 1975, and continued into 1976 with a daily open pit production of about 1,500 tons of ore and waste (running on a 1:1 ratio). The ore was custom milled at the Dankoe Mine near Keremeos, the concentrates being shipped from there to Cominco's Trail smelter. Milling was completed in June 1976.

The Dusty Mac deposit, located in a small northerly trending draw east of Peach Cliff, is a lens-like zone of silicified Eocene volcaniclastic rocks. The host rocks, units of the White Lake Formation, are mainly light-coloured feldspathic pyroclastic beds, thick lahar deposits, and some lake and stream sediments. The older Tertiary assemblage in the area belongs to the Marama Formation, composed of rhyodacite lava, minor conglomerate, and the Marron Formation which is a mixture of andesite and trachyte lavas and pyroclastics, (Figure 1:2).

The White Lake Formation underlies most of the detailed map area displaying several facies. The lowermost facies, resting on Marama rocks, is composed of blocky andesitic lahar beds which carry exotic fragments of Marama lava. This is overlain by greenish feldspathic andesite lahars and a few lava flows of the same composition. The uppermost facies, exposed in the northeast part of the map-area, consists of soft cream coloured trachyte tuff and agglómerate. Lenses of carbonaceous shale and sandstone are intercalated locally with the volcanic beds.

The Dusty Mac deposit is on the northeast-dipping limb of a downfaulted syncline. A set of strong cross fractures, striking approximately 025 degrees, are almost perpendicular to the synclinal axis which plunges about 20 degrees to the southeast. In this area the main faults of the Okanagan Rift System strike roughly 100 degrees and 155 degrees, the latter direction dominating.

In the immediate vicinity of the deposit, beds have variable dips ranging from 30 to 50 degrees northeast and are cut by an important system of reverse faults. The system trends generally southeasterly with interwoven easterly and southerly-striking segments and splays. The direction and magnitude of movement on these faults is indicated at a number of points where large slices of Marama lava have been thrust outward and upward from the core of the syncline through several hundred feet of White Lake strata (Figure 1:3). As in the White Lake basin, reverse faulting is thought to be the result of concentric folding and accomodation of the stratigraphic pile to bedding plane slip.

Mineralization appears to be largely controlled by the fault system. Quartz veins and gossans are present on or adjacent to most of the main faults.

The principal zone of mineralization is a gently dipping lens of quartz breccia with varying admixtures of crushed andesite. The body is exposed over a length of about 700 feet striking roughly 140 degrees with a central cross-section width of about 160 feet and a thickness of 30 feet.

Mineralization consists, for the most part, of sparsely disseminated sulphides and silver in quartz breccia. Silver values are characteristically erratic ranging from 1 to 120 ounces per ton. The ratio of gold to silver is generally more constant holding to the range 0.040 to 0.060. Some of the best precious metal values are obtained from samples of dark grey quartz, the dark colouring being due to fine sulphides and small tarnished flakes of native silver.

In addition to the obvious silicification and gossans associated with mineralization, geochemical guides are helpful in the search for similar ore in the area. The relative high concentration of lead, sulphur, tellurium, and arsenic and low strontium and barium levels in the ore compared to the adjacent country rocks is an important feature (see accompanying table):

AVERAGE MINOR ELEMENT COMPOSITIONS

| | No. of Samples | Ba | Sr | Cr | Ni | Pb | Ag | As | Te | S | Quartz % |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A. Marama F. | 17 | 445 | 355 | 8 | <4 | 8 | - | 3 | - | <240 | 38 |
| B. White Lake F. | 11 | 1920 | 680 | 110 | 21 | 15 | - | 4 | - | <300 | 23 |
| C. 'Ore' | 9 | <280 | 325 | <6 | <7 | 235 | 285 | 22 | 65 | 3736 | 84 |
| D. Near 'ore' | 6 | 1420 | 415 | <5 | <1 | 11 | - | 8 | - | 641 | 37 |
| E. No 'ore' holes | 17 | 2040 | 875 | 40 | 8 | 15 | - | 10 | - | 608 | 25 |

(chemical data in ppm)

A good to fair correlation of silver-lead and silver-tellurium suggests mineralogical binding of some silver to galena and tellurides. The low strontium and barium content of the same ore samples may be largely a dilution effect caused by silicification, however, the high ratio of strontium to barium is probably the result of hydrothermal overprinting.

In summary, the origin of the Dusty Mac deposit is thought to be the result of the following events:

1. The development of dilations on major post White Lake Formation shear zone.
2. Filling the dilations with hydrothermal solutions and emplacement of quartz accompanied by gold and silver and minor sulphides and possibly telluride minerals.
3. Late movement on the shears resulted in brecciation of the quartz and intermixing of the quartz with crushed andesite wallrocks.

## URANIUM PROSPECTS

The discovery of Uranium in the Beaverdell area in 1968 by Power Reactor and Nuclear Fuel Development Corporation of Japan has led to the present wave of prospecting interest in the Tertiary volcanic and sedimentary rocks of Interior British Columbia. The two main Tertiary prospects of present note, the Fuki-Donen prospect northeast of Beaverdell and the Tyee prospect east of Kelowna are referred to as "basal-type" occurrences - that is, uranium accumulated by ground water is trapped in clastic beds under a lava cap.

There are many geological situations that would fit the "basal-type" occurrence in the White Lake area. For example, it has long been known that the lower "Yellow Lake" member of the Marron Formation is radioactive, two or three times above background (pers. comm., R.M. Thompson, 1965), and is underlain extensively by the basal Tertiary conglomeratic Springbrook Formation - a potential aquifer for conducting and trapping uranium salts. Current prospecting of radioactive zones in this basal assemblage seems to ride on the theory that the uranium contained in zeolites and apatite of the volcanic rocks is leached by acids then transported on fissures to the underlying conglomerate.

Preliminary investigations by Norwich Resources Ltd., of basal Tertiary rocks on the west side of the White Lake basin near Olalla indicate anomalous radon 222 occurrences using a special sniffing apparatus. Radon 222 is a daughter product of uranium and the presence of this gas in the soil indicates nearby buried uranium.

Prospecting is also currently directed towards other varieties of basal uranium deposits. According to Katayama (1976) the most favourable basal type occurrences in Japan are smallish channels of Tertiary granitic conglomerate and arkose incised in a granite paleosurface. A good example of this in the White Lake area is the granite-clastic channel deposit overlying granitic slide breccia in the Skaha Formation near Green Lake (Figure 1:4). Source of the clasts is thought to be from granite in the McIntyre Bluff area to the southeast or possibly the Oliver granite to the south. These rocks are locally radioactive and are currently being investigated.

That the White Lake basin is a good prospect area for uranium is further emphasized in the recent study of Cameron et.al. 1975 (Radioactivity of Tertiary Lignites in Saskatchewan, Alberta, and British Columbia - G.S.C. Project 680106). According to report a survey of 125 outcrops in British Columbia shows the White Lake basin to be one of the few areas where radioactivity in coal registers more than twice normal background.

## ROAD LOG

The tour follows a course at first moving east parallel to the axis of the White Lake syncline (STOPS 1-1 to 1-5), occupying much of the morning, then to Okanagan Falls for lunch, after which the Dusty Mac Mine site is visited (STOP 1-6), and the traverse being completed returning via the Kaleden Junction and Yellow Lake (STOPS 1-7 to 1-9).

Mileage

0.0 STOP 1 - 1 - Springbrook Formation. The Springbrook Formation is well displayed on bluffs east of Keremeos Creek above the highway. The unit is about 700 feet thick (230 m) and consists of dark chert breccia in the lower part overlain by well-layered pebble and boulder conglomerate. The fragments were eroded from pre-Tertiary beds of feldspathic andesite, grey and black chert, argillite, chlorite schist and gneiss. These rocks are down-faulted slightly and tilted gently to the east.

1.0 STOP 1 - 2 - Base of the Marron Formation, rhomb-porphyries. The basal part of the Marron Formation known as the Yellow Lake member is exposed about 300 feet (90 m) north of the road entering the west end of the White Lake basin. The lowest unit, composed of porphyritic phonolite lava and pyroclastic rocks, is intercalated with upper Springbrook conglomerate. The volcanic rocks are normally zeolite-bearing, containing minerals such as natrolite, analcite, laumontite-leonhardite, mordenite, thomsonite, and brewsterite.

Locally the rocks are severaly weathered displaying hoodoo structures and spheroidal pits on cliff faces.

Columnar jointed rhomb porphyry dykes are fresh and well exposed. These carry distinctive rhomb-shaped anorthoclase phenocrysts similar to the Tertiary dykes and sills near Rock Creek, described by Daly (1912). Chemical analyses of these rocks show an unusually high alumina, alkali, and alkali-earth content.

The rocks of this member are characterized by an above average radioactive background level possibly as a result of small amounts of uranium in zeolites or apatite.

2.5 SHORT PAUSE - Kitley Lake Trachyandesite

The Kitley Lake member, exposed here in a small quarry, is a feldspathic trachyandesite lava sequence - a thick bluff-forming unit distributed uniformly throughout the White Lake basin. Biotite extracted from these rocks yields a K/Ar date of 51.6 ± 1.8 m.y.

Mileage

5.2 SHORT PAUSE - Conformable Contact between Members of Marron Formation. Panoramic view east of Twin Lakes of successive sheets of conformable Marron lavas. The lavas spreading laterally from source fissures were successful in burying pre-existing topography, filling valleys and overtopping ridge crests creating a relatively smooth surface. Marked subsidence in vicinity of the Okanagan Valley resulted in a pronounced eastward rotation of the beds forming a trap-door-like structure.

6.5 STOP 1 - 3 - Panorama of the White Lake Basin. A resistant band of White Lake conglomerate, 200 feet (60 m) south of the main road, forms an excellent vantage point overlooking the eroded core of the White Lake syncline. A view to the southeast shows the south limb of the syncline, composed mainly of soft sedimentary rocks, warped downward to meet a line of high bluffs of lahar beds just beyond White Lake. To the southeast, the sediments of the White Lake Formation onlap andesites that are the uppermost unit of the Marron Formation. The ridges and benches beyond, farther west, are successive trachyte and trachyandesite flows which are the conformable middle members of the Marron Formation.

8.0 SHORT PAUSE - View of Dominion Astrophysical Observatory

The Dominion Astrophysical Observatory, constructed in 1963, features a 26 metre dish antenna radio telescope which was designed especially for solar and stellar astronomical studies. The White Lake site was chosen for this installation because the location afforded unique protection, being contained within a ring of hills, from man-made radio disturbances.

10.5 STOP 1 - 4 - Skaha Formation at Indian Head. Indian Head is a conspicuous erosional remnant one half mile east of White Lake. The Skaha breccias consist of highly comminuted dark chert and greenstone forming a cap on little-disturbed White Lake tuff breccia and agglomerate. Here the breccia is near the projected western edge of a massive slide breccia complex that underlies the ridge immediately east of Indian Head and Mt. Hawthorne.

12.5 SHORT PAUSE - Park Rill Andesite

The Park Rill andesite, uppermost member of the Marron Formation, is exposed on the hill side east of the road. This is a brownish lava charged with small pyroxene and plagioclase crystals (1 to 2 mm across) which are set in a glassy matrix.

18.2 STOP 1 - 5 - Epiclastic Granite Facies of Skaha Formation. A shoe-string deposit of granite slide breccia, granite boulder conglomerate, and arkosic sandstone can be traced from Green Lake two miles to the northwest to a point near the Astrophysical Observatory site. Source of the granite clasts is thought to be from the McIntyre Bluff area to the southeast. This unit bears some geological resemblance to classical Japanese basal uranium occurences described by Katayama and others (although a suitable cap rock is missing in this case). The rocks are locally radio-

Mileage

18.2 STOP 1 - 5 - (continued)

active and are currently being prospected.

22.5 STOP 1 - 6 - Dusty Mac Mine. This deposit is one mile (1.6 km) east of Okanagan Falls. Mineralization consists of free gold and silver in a quartz breccia zone. The deposit is lens-shaped and appears to be associated with reverse faulting on the south limb of a southeasterly-trending syncline. The host rocks, consisting mainly of White Lake lahar beds, have been thrust outward and upward from the axis of the syncline in response to concentric folding. Fissures and dilations resulting from this movement provided access to siliceous ore-bearing solutions. Recurrent movement caused brecciation of quartz veins and lenses, and some dispersal of the ore.

31.5 STOP 1 - 7 - Yellow Lake Volcanics at Switchback. Deep erosion over an anticlinal axis exposes the basal units of the Marron Formation once again. Mafic phonolite flows, feeder tubes, and breccias are displayed cut by a set of steeply dipping laumontite and calcite filled fractures.

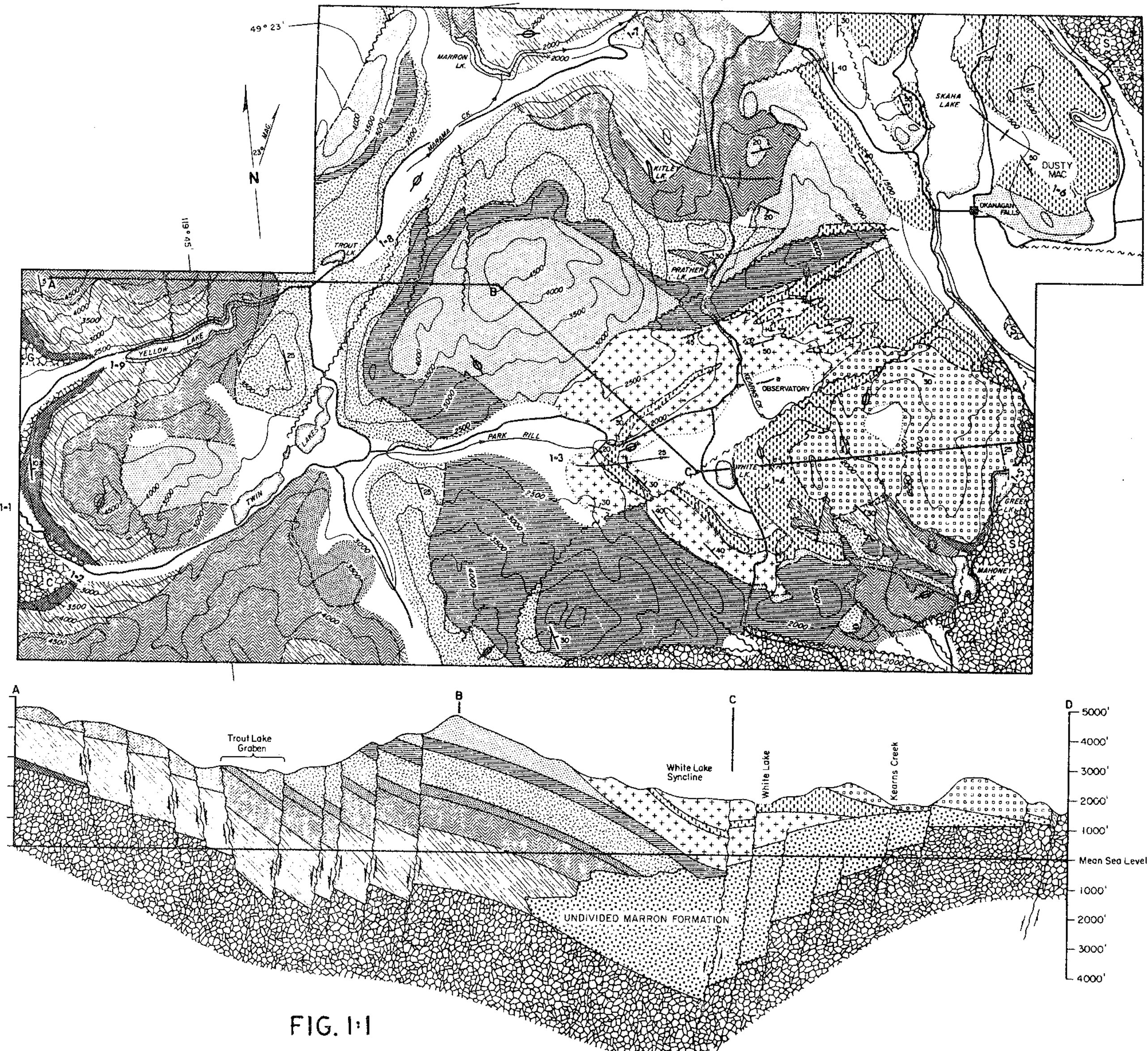
35.5 STOP 1 - 8 - Panoramic View of the Marron Formation. Looking south from an exposure of Marron trachyte, the same lava is manifest in an impressive series of benches cascading to the valley of Marama Creek. The lava flows are traversed by major cross-cutting gravity faults which form the east wall of the Trout Lake graben.

37.2 SHORT PAUSE - Kearns Creek Basaltic Andesite.

This is a thin but distinctive dark brown marker lava occurring in the middle of the Marron section. Typically the rock is amygdaloidal and characterized by abundant chalcedonic fillings.

39.0 STOP 1 - 9 - View from Yellow Lake. This final stop displays pyroxene-zeolite-rich mafic phonolite lavas near the shores of Yellow Lake. These unusual lavas which form the basal member of the Marron Formation, attain a maximum thickness of 1,800 feet in this area. The abundance of zeolites (mostly natrolite and laumontite) may be attributed to load metamorphism, however, it is noted that these minerals are restri to cracks and amygdaloidal fillings and occur from the base to the top of the unit. It seems likely in this case, that the zeolite forming solutions originated at or near the time of volcanism, perhaps before much loading.

1-1




## LEGEND

**EARLY TERTIARY ROCKS**

SKAHA FORMATION
UPPER MEMBER: MIXED BOULDER CONGLOMERATE.
LOWER MEMBER: MAINLY GRANITE, CHERT, AND GREENSTONE SLIDE BRECCIAS WITH INTERCALATED CONGLOMERATE AND SOME AUGITE-PORPHYRY (TELPHRITE) LAVA.

WHITE LAKE FORMATION
MUDSTONE, SANDSTONE, CONGLOMERATE, COAL, AND MINOR PYROCLASTIC ROCKS INTERCALATED/ WITH TRACHYTE AND TRACHYANDESITE VOLCANIC BRECCIA, PYROCLASTIC ROCKS, AND LAHAR.

MARAMA FORMATION
UNDIVIDED RHYODACITE AND RHYOLITE LAVA, SOME VOLCANIC BRECCIA AND PYROCLASTIC ROCK AND MINOR BASAL CONGLOMERATE.

MARRON FORMATION
PARK RILL MEMBER: MAINLY MEROCRYSTALLINE AND VITRIC ANDESITE LAVA.
NIMPIT LAKE MEMBER: MAINLY ROSETTE PORPHYRY, SANIDINE-PLAGIOCLASE BEARING TRACHYTE LAVA.
KEARNS CREEK MEMBER: MAINLY PYROXENE PORPHYRY, VESICULAR BASALTIC ANDESITE LAVA.
KITLEY LAKE MEMBER: MAINLY CLOT PORPHYRY, SANDINE-PLAGIOCLASE BEARING TRACHYTE AND TRACHYANDESITE LAVA.
YELLOW LAKE MEMBER: RHOMB PORPHYRIES, AUGITE-ANORTHOCLASE LAVA, VOLCANIC BRECCIA, AND PYROCLASTIC ROCK.

SPRINGBROOK FORMATION
PEBBLE AND BOULDER CONGLOMERATE, BRECCIA, AND SANDSTONE.

**PRE-TERTIARY ROCKS**

G-OLD TOM FORMATION: MAINLY GREENSTONE.
C-SHOEMAKER FORMATION: MAINLY CHERT.
S-SHUSWAP FORMATION: GNEISSIC BASEMENT COMPLEX.

## SYMBOLS

BEDDING ATTITUDE
ANTICLINAL AXIS
SYNCLINAL AXIS
GEOLOGICAL CONTACT
FAULT ZONE
BOUNDARY OF BEDROCK EXPOSURE
TOPOGRAPHIC CONTOUR, 500' INTERVAL
ROAD
POSITION OF STRUCTURE SECTION
GLACIAL STRIAE

# FIG. 1·1

GEOLOGY OF WHITE LAKE BASIN

GEOLOGY BY - N. CHURCH, 1970

0 1 2
SCALE - MILES

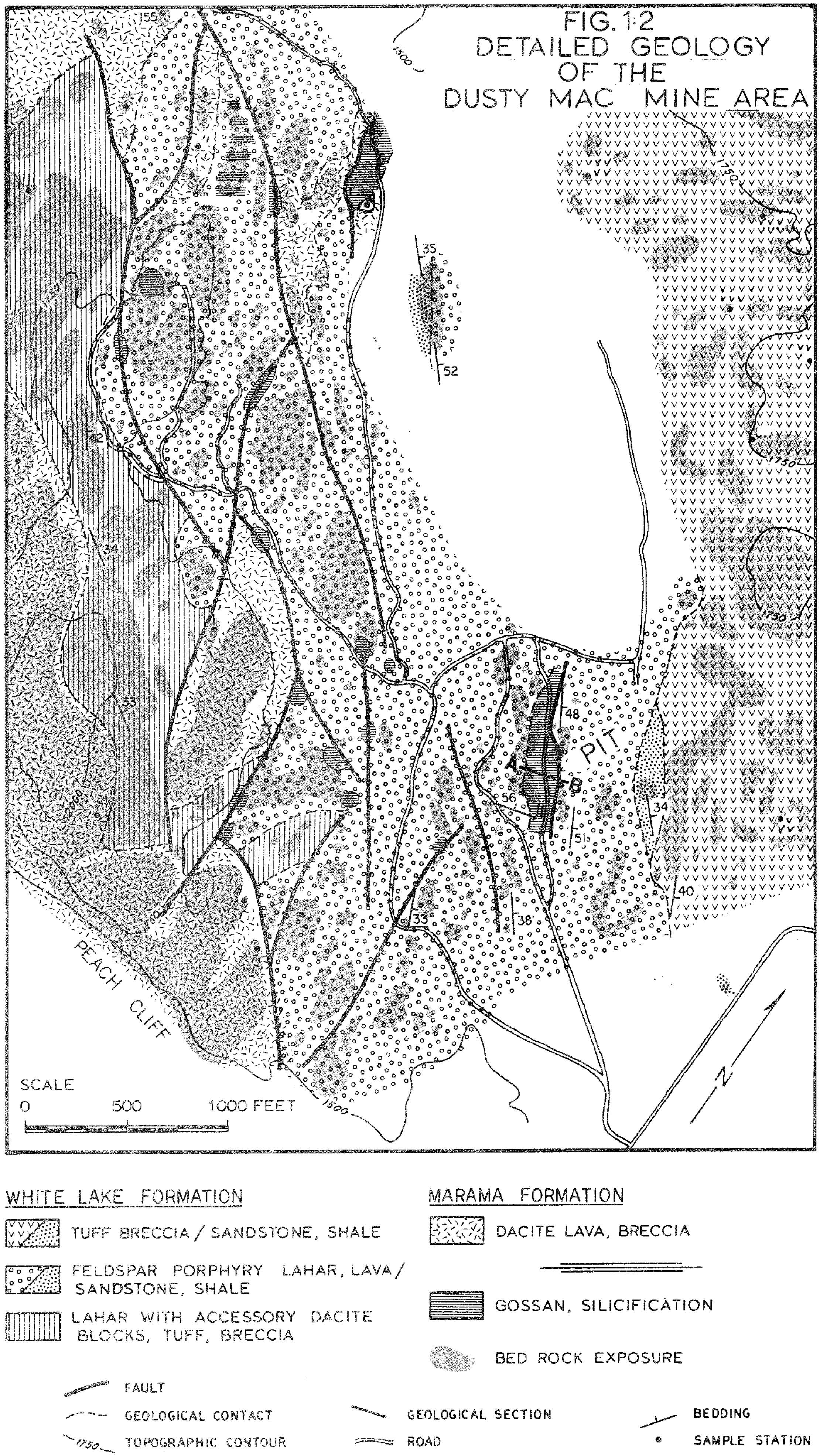



FIG. 1·2 DETAILED GEOLOGY OF THE DUSTY MAC MINE AREA

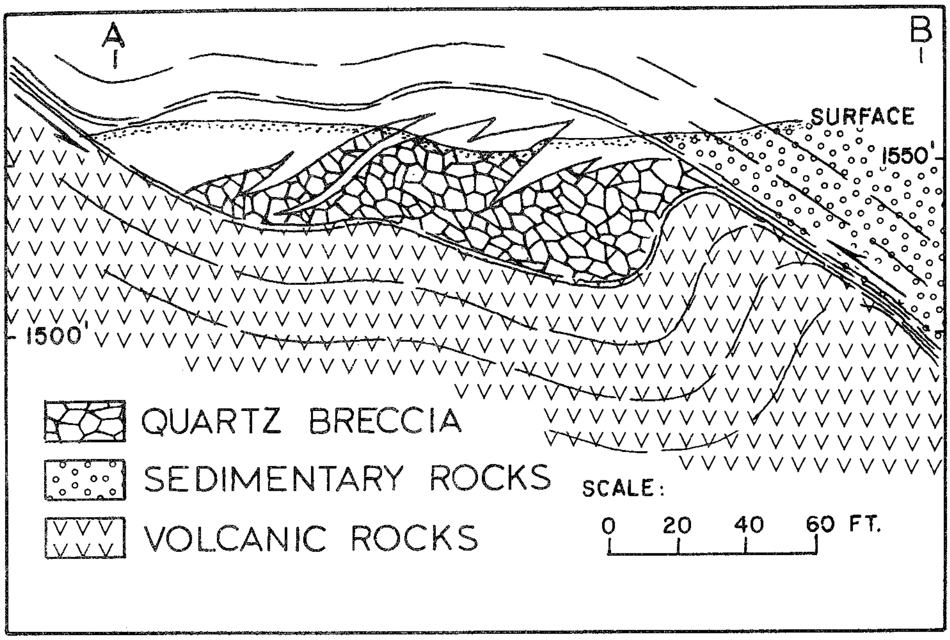



FIG.1:3a CROSS-SECTION OF DUSTY MAC DEPOSIT

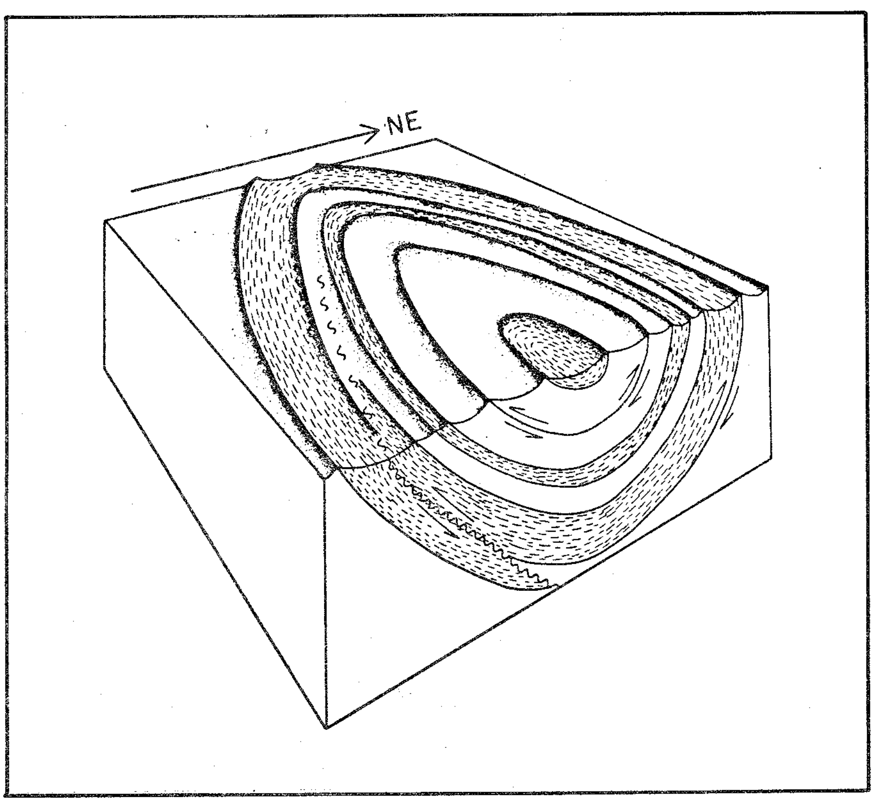



FIG.1:3b MODEL OF OKANAGAN FALLS SYNCLINE SHOWING REVERSE FAULTING ACCOMPANYING CONCENTRIC FOLDING

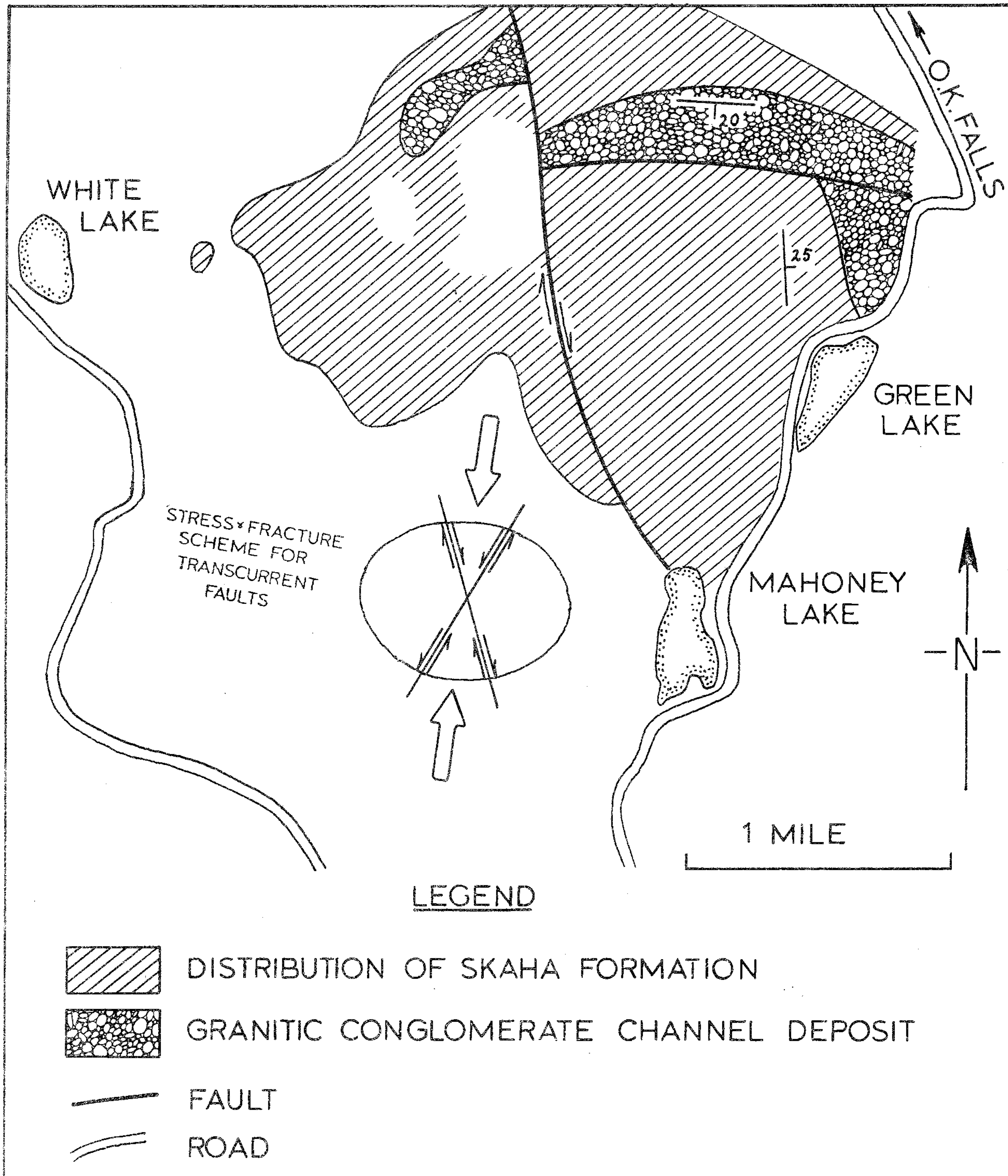



FIG. 1·4 GRANITE SLIDE AND CHANNEL DEPOSIT IN SKAHA FORMATION

## DAY 2: GEOLOGY OF THE NICOLA BELT BETWEEN PRINCETON AND MERRITT

(V. A. Preto)

The region between Princeton and Merritt covers the central part of the Nicola Belt of Southcentral British Columbia, a terrain of Upper Triassic volcanic, sedimentary and intrusive rocks approximately 40 kilometers wide that extends from near the International Boundary 180 kilometers northward to Kamloops Lake. Rocks of the Nicola assemblage continue northward beneath an extensive cover of tertiary strata into the Quesnel Trough, and extend along the full length of the Intermontane Zone into northern British Columbia and Yukon where they are known as the Takla and Stuhini volcanic assemblages.

The Nicola Belt is overlain to the north by an extensive cover of Tertiary volcanic rocks, and is invaded to the south by granitic rocks of the Similkameen Batholith. To the west it is bounded by granitic rocks of the Eagle Complex and by Jurassic and Younger strata and to the east is intruded by granitic rocks of the Okanagan Batholith and related plutons. Between Princeton and Merritt the Nicola rocks can be divided into three roughly parallel, north-trending belts, the boundaries between which are marked largely by high-angle faults that are part of large regional systems. Each belt comprises units of varied lithology and uncertain correlation, but of roughly similar composition, mode of origin and environment of deposition.

### CENTRAL BELT

The Central Belt assemblage occurs along the full length of the area covered by Figures 2:1 and 2:2. It is bounded to the east by faults of the Summers Creek - Quilchena system and to the west by faults of the Allison system. This assemblage includes the oldest Nicola rocks within the map-area and is typified by an abundance of massive pyroxene and plagioclase-rich flows of andesitic and basaltic composition, coarse volcanic breccia, conglomerate and lahar deposits and by lesser amounts of fine-grained pyroclastic and sedimentary rocks. Intrusive rocks of gabbroic and dioritic composition, but including some monzonite and syenite, are abundant throughout the belt. The character and composition of these intrusions and lithologic changes in the surrounding extrusive rocks indicate that at least in some cases these stocks are the eroded remains of Upper Triassic volcanoes.

Rocks of alkalic and calc-alkalic composition and of sub-aerial and sub-marine origin occur in the Central Belt. In general most of the red and purple flows and associated red laharic breccias, such as are found on Fairweather Hills east and southeast of Aspen Grove are considered to be of sub-aerial origin, whereas greenish flows and breccias, generally with associated small lenses of calcareous sandstone and impure limestone, such as are found in the vicinity of Missezula Mountain, are considered to be of sub-marine origin. Most stocks in the Central Belt are elongated in a northerly direction and occur along northerly trending faults. It is apparent that areas of stronger volcanic activity, such as Fairweather Hills, contain a much greater number of faults and more intrusive rocks than areas of less intense volcanism. Many of these faults are subsidiary to and part of the major systems and yet are intimately associated with and dependent on the volcanic history of the Nicola rocks.

## EASTERN BELT

Rocks of the Eastern Belt crop out east of the Summers Creek - Quilchena fault. To the north they are lost under extensive overburden and are intruded by granitic rocks of the Pennask pluton. The belt can be described in terms of a northern and a southern assemblage, the boundary between which is marked by a facies change east of the northern end of Missezula Lake. The northern assemblage consists of a well-bedded, westerly dipping succession of volcaniclastic rocks that range from thinly layered volcanic siltstone and sandstone in the lower parts of the section to coarse volcanic conglomerates and some massive green breccia in the upper part. This part of the Eastern Belt is characterized by a lack of intrusive rocks and of mineralized showings. East of the north end of Missezula Lake, the sedimentary rocks quickly grade southward into a sequence of crystal and lapilli tuff, lahar deposits with clasts of syenite and monzonite, and some flows of analcite-bearing trachybasalt and trachyandesite. These deposits occur within a radius of roughly 3 kilometers of a northerly elongated stock of micromonzonite porphyry and breccia that is believed to represent a shallowly eroded volcanic dome. There is a similarity in composition between intrusive and extrusive rocks in this area and rock fragments in all the clastic units around this dome are clearly derived from it. To the south of this succession, the remainder of the Eastern Belt consists of massive to crudely bedded, reddish to grey, lahar deposits that contain abundant clasts of pink and red microsyenite and micromonzonite porphyry and of purple trachyandesite. Three other stocks of fine-grained monzonite cut these strata but none is surrounded by the assemblage of flows, tuffs, and volcaniclastic deposits that surrounds the stock northeast of Missezula Lake. This probably means that if the three southern stocks ever broke to the surface as volcanic vents they did so at a higher level and their extrusive products were removed by erosion.

## WESTERN BELT

Rocks of the Western Belt form an easterly dipping sequence that occurs only in the northwestern corner of the map-area and in a fault wedge south of Aspen Grove. In the north they are in fault contact to the east with rocks of the Central Belt and with volcanic and sedimentary rocks which may be as young as Lower Cretaceous. In the south they are separated by the Allison fault from rocks of the Central Belt to the east and are in fault contact to the west with a unit of chert pebble conglomerate of probable Jurassic to Cretaceous age and with the same succession of volcanic and sedimentary rocks of probable Lower Cretaceous age. Thus the Western Belt is an assemblage whose top is truncated by faults, and whose bottom is not exposed within the map-area.

Flow and pyroclastic units consisting of grey-green and grey plagioclase andesite and dacite and of reddish to maroon volcanic breccia and lapilli tuff form the lower part of the succession, wheras greenish fine-grained flows, greenish to grey, generally calcareous fine-grained volcaniclastic rocks, and massive to well-bedded fossiliferous limestone make up the upper part. The volcanic rocks of the Western Belt, as contrasted with those of the other two belts, appear to be entirely calc-alkalic and contain considerably more dacite and rhyolite but very little basalt. (Figure 2:5.) Most of the flow units in the upper part of the succession are rhythmically interlayered with limestone and thus are considered to be of subaqueous origin. However, lower in the section widespread flow laminations in the lavas and eutaxitic textures in the pyroclastic units suggest a predominantly sub-aerial environment of deposition. In contrast with the generally Upper Triassic fossil ages obtained from the Central Belt, the Western Belt assemblage in the northwestern corner of the map-area has yielded mainly fossils which range in age from Lower Norian in the mid part to Lower and possibly Mid-Jurassic in the uppermost exposed part.

Mileage

0.0 Similkameen River Bridge at Princeton.

0.4 Toulameen River bridge.

1.9 Kettle holes east of the highway - the route here longitudinally crosses the northern half of the Princeton basin.

5.9 STOP 2 - 1 - Princeton-Nicola unconformity at Summers Creek road. Note the weathered and altered condition of the Nicola rocks and the lack of basal conglomerate in the Princeton sediments.

5.9 to 6.7 - Princeton sedimentary rocks along the east side of the highway.

6.8 Leucogranitic rocks of one of the Allison Creek stocks east of the highway.

7.0 to 7.9 - Road cuts in Nicola volcanic rocks.

7.9 to 8.6 - Road cuts in Princeton sediments - note the coarse boulder conglomerate.

8.6 to 11.1 - Road cuts in Nicola volcanic rocks, mostly sheared and pyritized.

11.2 Andesitic flows and breccias of the Jura-Cretaceous succession begin.

11.7 STOP 2 - 2 - North end of McCaffrey Lake. Greenish-grey, plagioclase-rich flows, bedded tuffs and tuff breccia of Jura-Cretaceous sequence.

STOP 2 - 2 (cont.) These rocks are poorer in alkalis and richer in alumina than Nicola flows. They overlie unconformably Nicola rocks and intrusive rocks of Allison Pluton but are cut by light-coloured porphyritic dykes which are probably derived from granitic stocks along Allison Creek. An Rb/Sr isochron for these volcanics indicates an age of approximately 145 m.y.

13.3 STOP 2 - 3 - South end of Liard Lake. Ash flow tuffs of Jura-Cretaceous volcanic succession. Cliffs west of highway are flows and breccias of the same succession and display prominent sub-horizontal layering.

The Allison Creek valley and other similar valleys in the area, characterized by chains of small lakes, are late glacial meltwater channels. Most of these lakes are dammed by fans of tributary streams.

13.4 Fault and beginning of Allison Batholith.

15.1 Dry Lake - Road cuts in granodiorite of the Allison Pluton.

17.6 The ravine east of the highway is diorite and granodiorite highly sheared along the Allison Fault. This fault can be traced for several miles northward from this point, but cannot be traced southward.

18.4 South end of Allison Lake. Road cuts in granite, sheared and pyritized along Allison Fault.

19.4 STOP 2 - 4 - Red granite of Allison Pluton. Muscovite and biotite from two different phases of this pluton have yielded K-Ar ages of approximately 200 m.y.

20.1 Allison Creek. From here northward dark mafic dykes cut pluton.

21.7 Gouge and shattered granodiorite along Allison Fault in road cuts.

24.6 Crossing Allison Fault. Gouge in volcanic rocks in road cuts. Mile 24.2 to 25.9 is a zone of mixed intrusive and altered volcanic rocks.

24.9 End of Allison Pluton.

30.5 Turn off for side trip to Missezula Lake.

SIDE TRIP A - Highway 5 to Missezula Lake and return.

Mileage

0.0 Turn off Highway 5.

0.1 STOP 2 - 5 - Walk 300 metres north of road to outcrop of purple analcite-augite trachybasalt porphyry of Central Belt.

2.1 STOP 2 - 6 - Monzonite plug near powerline. Note similarity between this intrusive, Lost Horse monzonite at Copper Mountain and Cherry Creek monzonites at Kamloops.

5.4 STOP 2 - 7 - Road cut in brownish green lithic tuff and tuff breccia of Central Belt. This rock is part of a sequence, probably sub-aerial in origin, which includes maroon augite basalt and analcite-augite trachybasalt porphyry, various types of breccias and well-bedded crystal and lithic tuff. Shearing is due to a nearby branch of the Summers Creek fault which follows the bottom of the valley. Cliffs to the east consist of several flows of vesicular olivine valley basalt which covered the valley floor when it was at that level.

6.9 Crossing Shrimpton Creek and main branch of fault system which separates Central Belt from Eastern Belt. Last road cuts before creek are in sheared green augite basalt porphyry of Central Belt.

7.6 STOP 2 - 8 - Gently and northeast dipping well bedded crystal tuff, crystal-rich sand and volcanic conglomerate rich in syenite porphyry clasts. This outcrop is on the north flank of the syenite porphyry plug which is the main object of this stop. To visit plug leave vehicles by creek 300 metres ahead and proceed westward towards lake. Note basalt flows with limestone blocks near the contact with the intrusive. Plug includes pink and grey syenite and monzonite porphyry and breccia. West of intrusive the layered rocks include west-dipping lenses of calcarenite, crystal-rich sands and tuff and some basaltic flows.

9.2 STOP 2 - 9 - Analcite trachybasalt porphyry of Eastern Belt. Exposures in this area include some basaltic flows, some fine-grained tuffaceous sediments and laharic deposits. Return to Highway 5.

30.5 From Missezula Lake road resume travelling north on Highway 5.

31.9 to 32.3 - Road cuts in sheared tuffaceous sediments and volcanic breccias. Shearing is due to a major branch of the Allison Fault system which follows the Valley of Otter Creek a short distance west of the highway.

35.2 Bates Road. Turn off to Miner Lake

SIDE TRIP B - Highway 5 to Miner Lake and return.

Mileage

0.0 Turn off Highway 5.

1.8 Stop to view the valley below, a former late glacial meltwater channel. Note silt and gravel benches, sinuous course of former stream and series of swamps marking the old channel.

2.3 STOP 2 - 10 - Miner Lake and Fairweather Hills. South and west of the lake are excellent exposures of red augite lahars, red and green, amygdaloidal augite basalt porphyry, and red volcanic sandstone. The hills east and north of the lake are in purple and green augite lahar. Several small diorite dykes, co-magmatic with the flows, cut the volcanic rocks. A short walk will be taken south and west of the lake to view a number of interesting features. Return to Highway 5.

35.2 From Bates Road resume travelling north on Highway 5.

38.4 Aspen Grove Store. Numerous copper prospects of various types occur in the hills to the east.

40.5 Turn off to Big Kid breccia pipe.

SIDE TRIP C - Highway 5 to Big Kid breccia pipe and return.

Mileage

0.0 Turn off Highway 5.

1.4 Workings of Big Sioux prospect north of road. Copper sulphides her are found along fractures and in breccia zones in massive grey and green andesite.

2.4 STOP 2 - 11 - Big Kid breccia pipe. Mineralization at this prospect occurs in a vertical, nearly cylindrical breccia pipe approximately 300 metres in diameter and consists of chalcopyrite, pyrite and magnetite. The pipe is bordered to the south, east, and west by a light coloured plagioclase trachyte, and to the north by a fine-grained diorite.

Excellent examples of breccia and of the mineralization can be seen on the dumps of old workings and on exposures at the top of the hill. Return to Highway 5.

40.5 From turn-off resume travelling north on Highway 5.

43.1 Courtney Lake. Road cuts in sheared quartz diorite near picnic si

45.1 Corbett Lake. Between mile 44.0 and 47.3 the route crosses a northeast trending belt of red and maroon sub-aerial andesitic and basaltic flows, breccia and associated sub-aerial sediments probably Lower Cretaceous in age.

47.3 Cross the trace of a northeasterly trending fault into Western Belt. Drumlins in these grass covered hills indicate north-to-south movement of ice.

48.4 to 50.5 - Scattered exposures and road cuts of andesitic and dacitic flows, lithic tuff, tuff breccia and some volcanic sandstone of western belt.

50.5 Old coach road and turn off to Western Belt.

SIDE TRIP D - Highway 5 to Sugarloaf Mountain

Mileage

0.0 Turn off Highway 5.

0.5 Old pits and pyrite-chalcopyrite mineralization in grey andesite on both sides of the road.

0.9 Hamilton Creek.

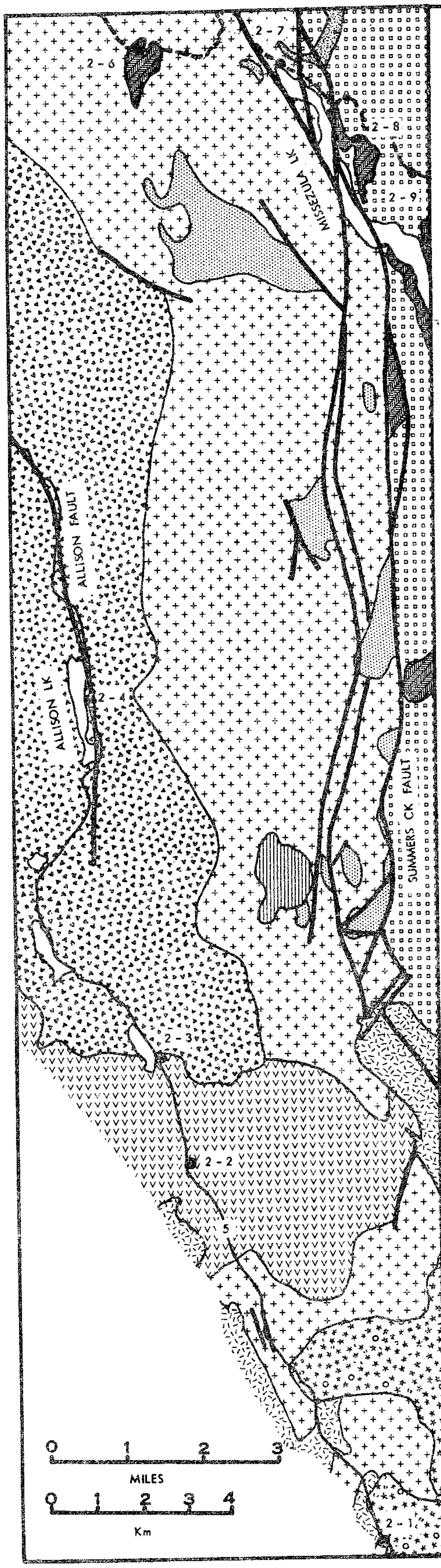
1.7 <u>STOP 2 - 12</u> - Exposures nearby are in grey green augite-plagioclase andesite and dacite, and associated pyroclastic rocks. To the north of Sugarloaf Mountain, is a dacitic plug and an east-dipping and east-facing section of grey plagioclase-rich flows, grey and reddish pyroclastic rocks, prominent beds of limestone, and tuffaceous volcanic sandstone. The westernmost limestone visible from this point belongs to the Lower Norian Kerri Zone. Another limestone higher in the section and closer to Sugarloaf Mountain has yielded Middle Norian fossils. Siltstone and sandstone interbedded with flows and yet higher in the section have yielded fossils of Lower to Mid-Jurassic age.

As a whole, rocks of the Western Belt are younger (Lower and Middle Norian to Lower and Mid-Jurassic) than those of the Central Belt (Upper Karnian to Lower Norian). They also appear to be more acid and sub-alkaline. Return to Highway 5.

50.5 From turn off resume travelling north on Highway 5.

50.9 <u>STOP 2 - 13</u> - Viewpoint. View of Merritt and of Nicola and Coldwater Valleys. The Merritt basin is underlain by Early Tertiary coal bearing strata. This low valley was filled to a considerable height by the waters of Glacial Lake Nicola. Strand lines of this lake are found on the grassy slopes north of this viewpoint and are clearly visible in air photographs.

58.5 GRASSLANDS MOTOR HOTEL




- LEGEND -

PLEISTOCENE AND RECENT

VALLEY BASALT

MIDDLE EOCENE

PRINCETON GROUP: CONGLOMERATE, SANDSTONE, SILTSTONE, BASALTIC FLOWS AND BRECCIA

UPPER CRETACEOUS AND POST-LOWER CRETACEOUS

GRAY GRANODIORITE AND QUARTZ MONZONITE, PINK GRANITE, SYENODIORITE, MONZONITE, GRANODIORITE AND QUARTZ DIORITE

LOWER CRETACEOUS

KINGSVALE GROUP (?): ANDESITIC AND BASALTIC FLOWS BRECCIA AND SILLS. RED CONGLOMERATE, SANDSTONE AND SHALE, MINOR LIMESTONE

UPPER JURASSIC TO LOWER CRETACEOUS

CHERT PEBBLE AND COBBLE CONGLOMERATE; MINOR GRIT AND SANDSTONE

SUB-AERIAL ANDESITIC TO RHYOLITIC FLOWS AND ASH FLOWS, LITHIC TUFF AND LAHARIC DEPOSITS

LOWER JURASSIC OR LATER

PENNASK BATHOLITH: BIOTITE - HORNBLENDE GRANODIORITE AND QUARTZ DIORITE

UPPER TRIASSIC TO LOWER JURASSIC

ALLISON LAKE PLUTON: RED GRANITE AND GRAY QUARTZ MONZONITE, GRANODIORITE, AND DIORITE

PINK AND GRAY MONZONITE AND SYENITE, AND INTRUSIVE BRECCIA

DIORITE, QUARTZ DIORITE, MONZONITE AND DIORITE BRECCIA

NICOLA GROUP WESTERN BELT: ANDESITIC TO DACITIC FLOWS AND TUFF BRECCIA, LIMESTONE, VOLCANIC CONGLOMERATE, SANDSTONE AND SILTSTONE

NICOLA GROUP EASTERN BELT: BASALTIC AND ANDESITIC FLOWS, ANALCITE TRACHYBASALT, TUFF, VOLCANIC SANDSTONE AND LAHARS

NICOLA GROUP CENTRAL BELT: BASALTIC AND ANDESITIC FLOWS AND BRECCIA, TUFF AND TUFF BRECCIA, GREEN AND RED LAHARS, VOLCANIC SANDSTONE, SILTSTONE, ARGILLITE AND REEFOID LIMESTONE

GEOLOGICAL CONTACT

FAULT

EXCURSION ROUTE, HIGHWAY 5

EXCURSION STOP LISTED BY DAY i.e. 2 - 3 MEANS DAY 2, STOP 3

GENERALIZED GEOLOGY OF THE NICOLA BELT BETWEEN PRINCETON AND MERRITT

FIGURE 2 - 1 FOR NORTHERN PART OF MAP SEE FIGURE 2 - 2

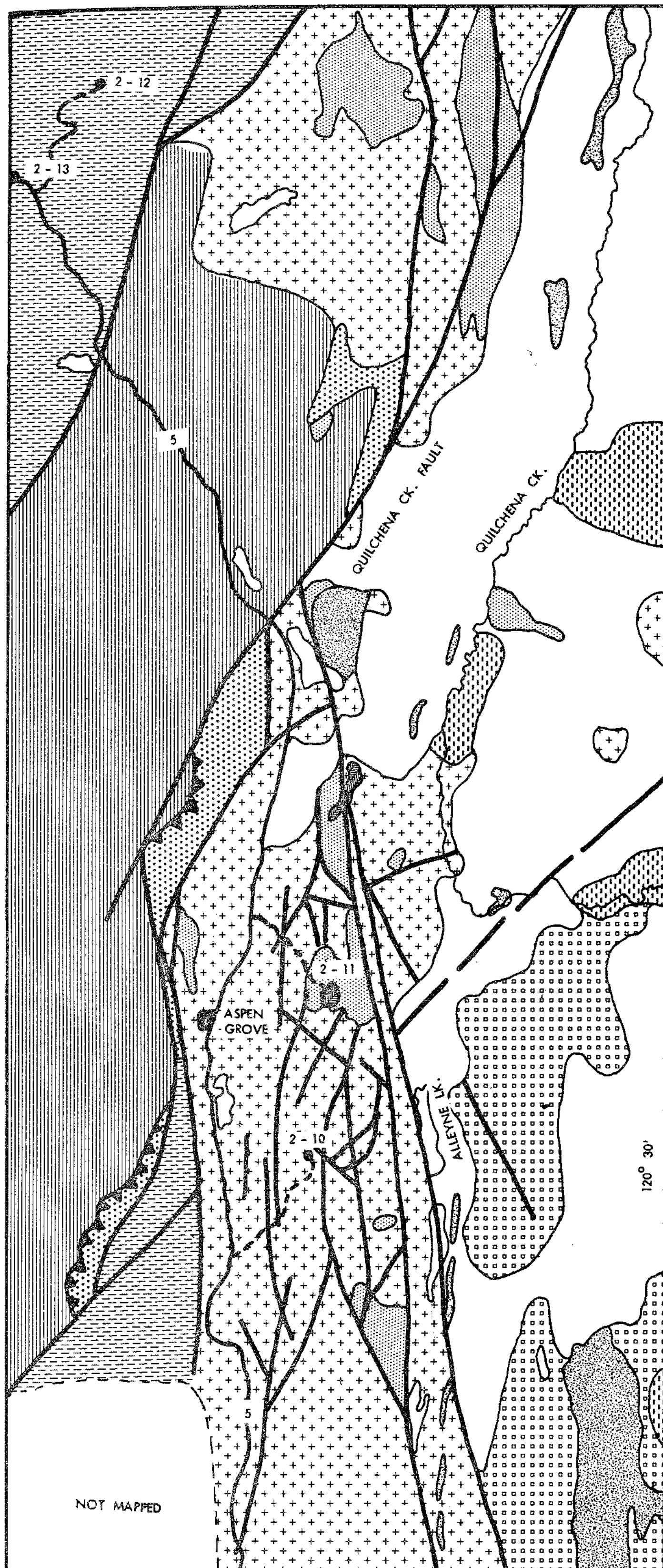



FIGURE 2 - 2 FOR LEGEND AND SOUTHERN PART OF MAP SEE FIGURE 2-1

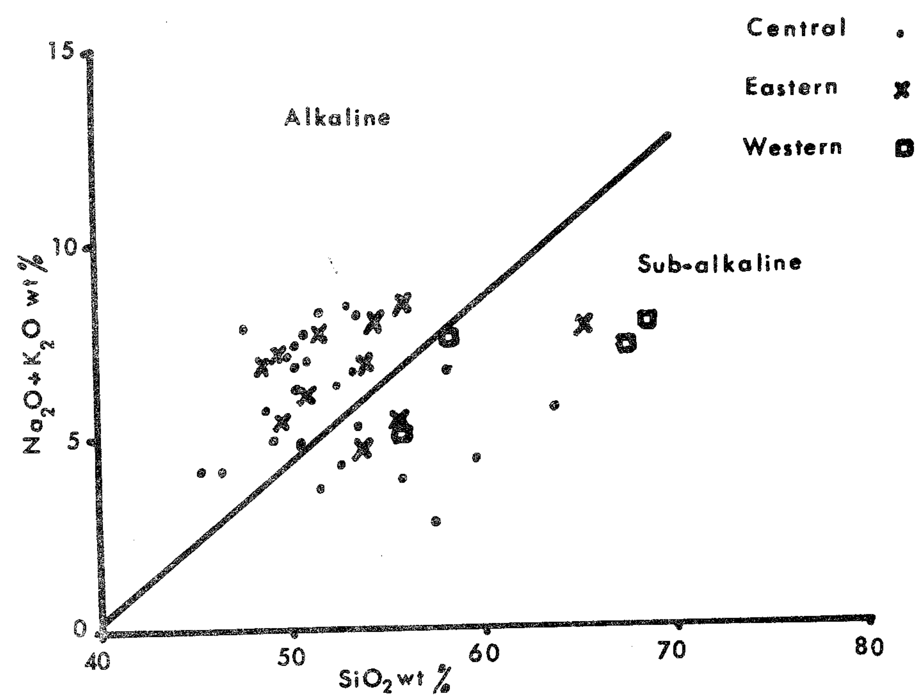



Figure 2:3 Silica-total alkali plot for Nicola volcanic rocks

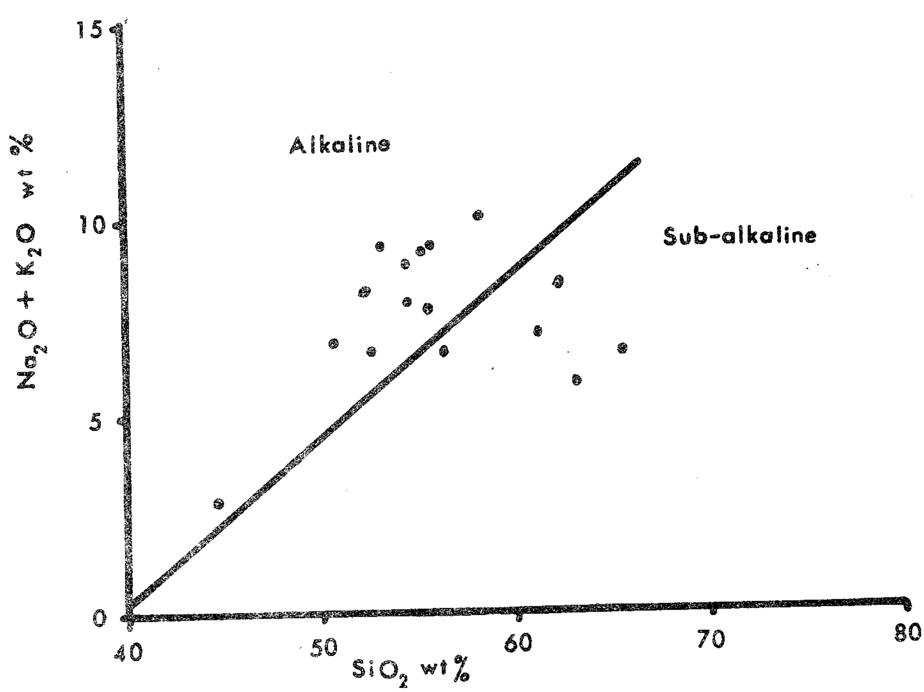



Figure 2:4 Silica-total alkali plot for Nicola intrusive rocks

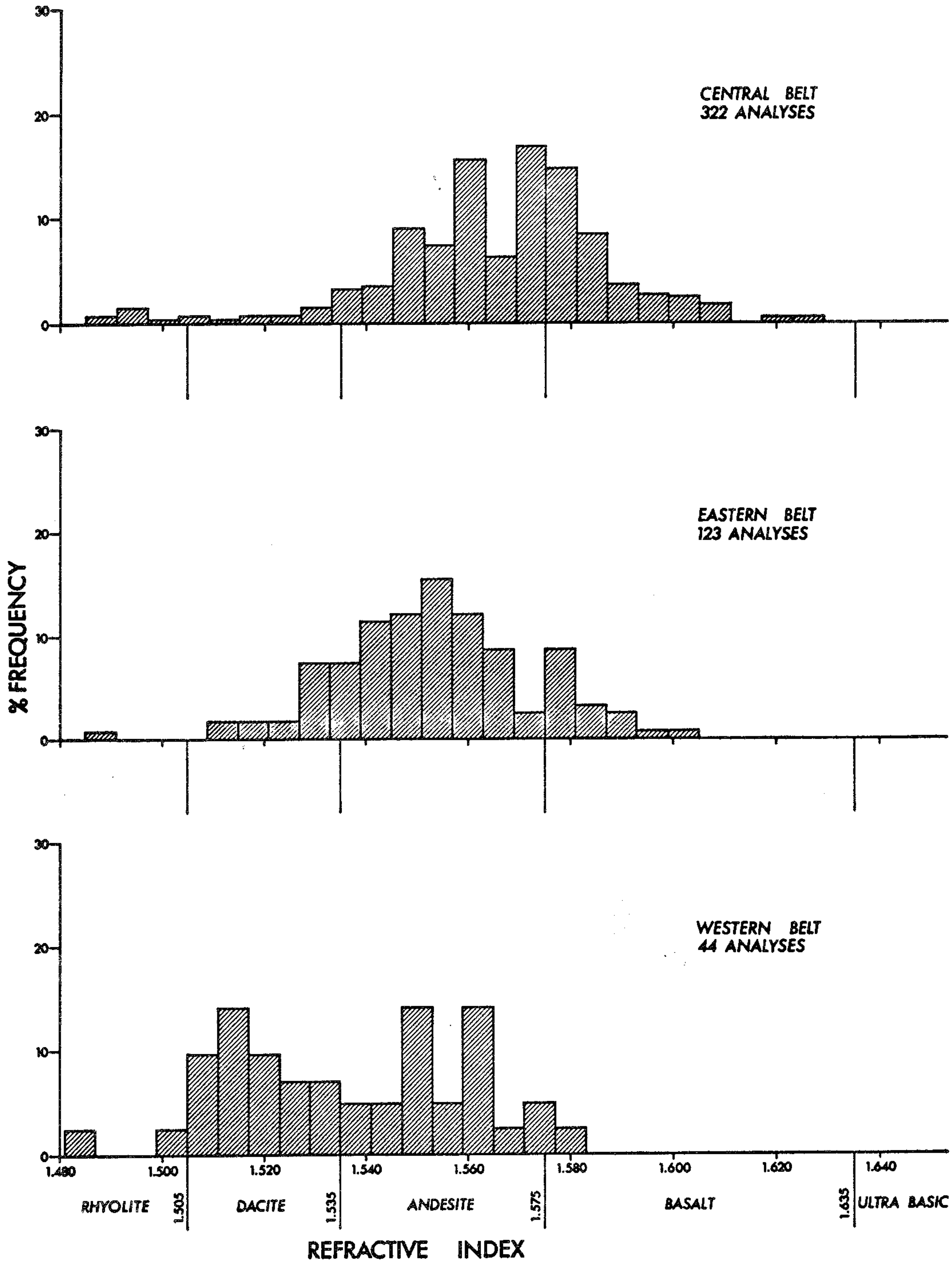



FIGURE 2:5 REFRACTIVE INDICES OF NICOLA ROCKS

## DAY 3: GEOLOGY OF THE HARRISON LAKE FORMATION, B. C.

(David E. Pearson)

The Harrison Lake Formation, which consists of a group of volcanogenic sedimentary rocks and calc-alkaline volcanic rocks, records the emergence of a volcanic island arc of Early to Middle Jurassic (Toarcian to Middle Bajocian) age.

Rocks of the Lower Jurassic Camp Cove Formation which are the oldest in the area, include basinal turbidites, beds and lenses of chert, and limestone-bearing olistostromes that together constitute a pre-arc facies.

Accretionary lapilli in the basal member of the conformably overlying Harrison Lake Formation furnish indirect evidence of the commencement of a volcanic arc facies. Shallowing of the basin is indicated by a Middle Jurassic shelly fauna of brachiopods and scleractinian corals. Continued filling of the basin, principally by breccias of various types, was followed by a period of volcanic quiescence during which well-bedded, convolute laminated epiclastics and crystal tuffs were deposited in a low-energy marine environment.

The upper unit of the Harrison Lake Formation includes pillowed andesites and andesite breccias succeeded by about 1 000 metres of dacite tuff. The lower part of the dacite succession hosts a Kuroko-like massive sulphide deposit. Numerous porphyritic dacite dykes that intrude this upper unit are interpreted as conduits to eruptive centres.

### DETAILS OF REGIONAL GEOLOGY

The regional distribution of volcanic and sedimentary rocks west of Harrison Lake is controlled by the Camp Cove anticline and the Sakwi Creek fault (Figure 3:1). The presence of this fault precludes the identification in this area of a complete stratigraphic section through the Harriso Lake Formation. West of Sakwi Creek fault lies a volcanic terrane in which stratigraphic relationships are not easily established, whereas to the east, a north-northwesterly strike predominates.

The oldest rocks in the area are poorly sorted polymictic conglomerates that form the core of the Camp Cove anticline. These in turn are overlain by graded greywackes and interbedded shales that contain several discontinuous black chert beds. In new roadcuts at the south end of the anticline, above the aforementioned member, a very coarse, poorly bedded exotic conglomerate, possibly a fluxoturbidite, separates the greywackes from an overlying black argillite. Beds of this latter rock type are the highest in the Camp Cove Formation as defined by Crickmay (1925). The presence of Dactylioceras (Brookfield, 1973 and pers. comm.) in the greywacke member indicates that some, if not all, of the Camp Cove Formatior is of Toarcian (Lower Jurassic) age.

A fault at the north end of the Camp Cove anticline brings andesite and andesite breccia into contact with the rocks of the Camp Cove Formation. However, dip measurements on the chert bed (Figure 3:1) and its trace in map view strongly suggest that the fault has bisected the hinge of a fold closing to the north. This implies that the Camp Cove anticline is an eroded plunge culmination, and confirms Crickmay's earlier suggestion that it is 'domed up.'

The basal member of the overlying Harrison Lake Formation is taken as the thick (> 2,000 feet) structurally monotonous dark green tuff, well exposed in the roadcuts in the hinge area of the Camp Cove anticline, and along the Harrison Lake shoreline. Rare graded bedding, and one accretionary lapilli-bearing outcrop attest to the subaerial origins of this deposit.

On the westerly dipping limb of the Camp Cove anticline a fluxion-banded, spherulite-bearing intrusive rhyolite obscures the contact between cherts of the Camp Cove Formation and the basal tuff of the Harrison Lake Formation. At the south end of this rhyolite dyke, a western extension strikes toward Weaver Lake, clearly intrusive to the attitude of the basal tuff member.

Fossiliferous, dark blue-grey shales, that are well exposed at Celia Cove in the hinge of the Camp Cove anticline, overlie the basal tuffs of the Harrison Lake Formation. Faunas from these shale beds at the 700-foot level along the Morris Valley road apparently indicate a Middle Bajocian (Middle Jurassic) age (Frebold, in Monger, 1970).

On the road from Camp Cove up to Mount Klaudt, the basal tuff of the Harrison Lake Formation is succeeded by a thin conglomerate bed, which in turn is overlain by a thin ( > 10 foot) fossiliferous shale, that has yielded a varied fauna including lamellibranchs (trigonids), brachiopods (rhynchonellids and terebratulids), and corals.

Details of the stratigraphy between the mouth of Harrison River and Celia Cove have not been worked out satisfactorily, although the presence of a carbonate bed, a rhyolite flow, and a coarse breccia have been observed.

Along the Morris Valley road, the fossiliferous shale bed is overlain by a thick sequence of andesites and andesitic breccias. Above the fossiliferous shale exposed along the Mount Klaudt road, original textures in the rocks have been obscured by silicification that is unrelated to the granodiorite stock exposed on the north side of the mountain. Thin sphalerite-chalcopyrite-pyrite stringers and one limonite-stained, sphalerite-bearing outcrop appear to be the only surface mineralization at this locality.

West of this belt of variable lithology, is a thick waterlain tuff that is characterized by load-casts and common convolute laminae. On Mount Klaudt this tuff is succeeded upward by a conglomerate bed with a channeled base that is overlain by pillowed andesites and pillow breccias. The waterlain tuff with convolute laminations is 500 feet thick on the east side of Mount Klaudt, and thins to about 100 feet to the west of Weaver Lake, where it is cut out by an intrusive, fluxion-banded rhyodacite. The waterlain tuff member crosses the Morris Valley road by the junction with Weaver Lake road, and obtains its maximum thickness (> 600 feet) in the cliffs above Grace Lake.

On Mount Klaudt the pillow breccias are overlain by bedded ash fall tuffs and breccias.

In contrast to the gently westerly dipping rocks exposed east of Sakwi Creek fault, the volcanic terrane to the west shows more variation in direction and amount of dip. Interbedded shale and sandstone at the 1,400 foot level in Sakwi Creek is subhorizontal, as is the sequence of sandstones exposed at the 3,200 foot level on Mount Keenan, and the erroneous conclusion could be drawn that the sequence is essentially flat lying. However, the contact between laumontite-bearing andesitic breccias and laumontite and other zeolite-bearing dacite tuffs on the east side of Mount Keenan is evidently very steep. Moreover, it cannot be demonstrated that this is a faulted contact.

From the junction with Morris Valley road to the 1,000 foot level on the Hemlock Valley road, the mottled, laumontite-bearing dacite tuffs possess a banding that (with the exception of the summit) is unfortunately absent over most of the rest of the mountain. This is not a cleavage or a tectonic foliation but an original sedimentary feature clearly visible where the tuffs are seen in conformable contact with undoubted, but rare, sedimenta wedges, as for example, at the 900 foot level on Hemlock Valley road. Variation in the attitude of this surface, including steep easterly, steep westerly, and even vertical dips (as for example at the 500 foot level on the Hemlock Valley road), implies the presence of folding on northwesterly trending axes. No such folding has yet been demonstrated west of the Sakwi Creek fault, but it is the writer's opinion that this is due not so much to their absence, as to the difficulty in both finding a marker bed to define them and the absence of bedding in the dacite tuffs at intermediate levels on the mountain.

An alternative explanation, involving the juxtaposition of rotated fault-separated blocks similarly cannot yet be demonstrated.

The outlines of several feldspar porphyry bodies on the east side of the Mount Keenan have been mapped in detail. In each case columnar jointing plunges shallowly, and where found, fluxion banding dips steeply, generally subparallel to the margins of the bodies. The three feldspar porphyries which go above the 3,000 foot level on Mount Keenan are dykes. On the basis of similar shallowly plunging columna jointing and steeply dipping fluxion banding, the other feldspar porphyries above Hemlock Valley road are considered to be dykes. These data are at variance with earlier views expressed on the make-up of the Harrison Lake Formation volcanic rocks, which have tended to stress the dominance of porphyritic flows (Crickmay, 1925; Thompson, G.E.M., 1972).

## GEOLOGICAL SETTING OF THE SENECA DEPOSIT

The geology of the area immediately adjacent to the open pit at Seneca is shown in Figure 3:2. Southwest of the baseline the most abundant rock type is a volcanic breccia characterized by coarse and fine angular volcanic pyroclasts of andesitic to rhyolitic character. Although bedding i not apparent at any one outcrop, this rock-type is presumed to underlie the pit area.

North of the pit in bluffs above the road, a distinctive volcanic breccia with wispy andesite clasts is overlain by about 15 feet of well-bedded convolute laminated tuff. This member, which dips shallowly to the northeast terminates against an intrusive rhyodacite that extends for at least 1,600 feet across the property in a southeasterly direction forming the cliffs at the 1,100 foot level.

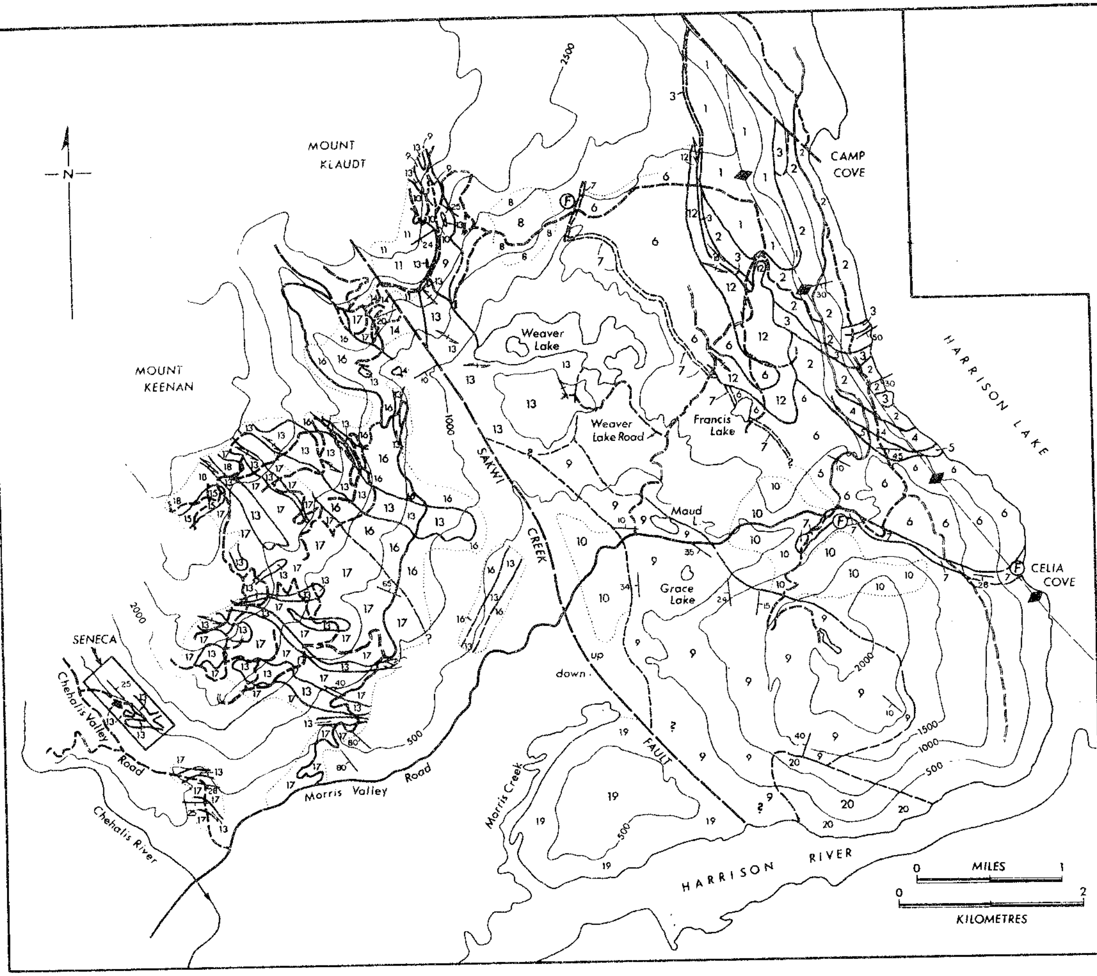
Company work in the summers of 1974 and 1975, after the writer had mapped the area, included a number of bulldozer trenches north of the pit area. At one locality, clastic sulphides in bedded tuffs overlie the earlier described volcanic breccia. The trace of this plane, which goes through the mined out area of the pit, can apparently be identified in core from diamond drill holes southeast of the pit. Thus on either side of the pit the trace of a mineralized horizon is known. In 1961, 287 tons of ore containing 17 ounces of gold, 959 ounces silver, 7,118 pounds copper and 40,657 pounds of zinc was shipped to Britannia for milling.

These field data are interpreted by most workers in the area to indicate that Seneca is one massive-sulphide "pod" in an environment that is typically of Kuroko-type.

The stops to be made on this last leg of the fieldtrip are dependent upon the weather and more specifically, the amount of snow still present at the time of the trip. For this reason no detailed stop-by-stop itinerary is appended.

## GEOLOGY OF AN AREA SOUTHWEST OF HARRISON LAKE

# FIG. 3:1




### LEGEND

**MIOCENE**

- 20 — INTRUSIVE HORNBLENDE GRANODIORITE

**MIDDLE JURASSIC ?**

(A) WEST OF SAKWI CREEK FAULT

ECHO ISLAND FORMATION:
- 19 — INTERBEDDED SANDSTONE AND SHALE

PART OF HARRISON LAKE FORMATION:
- 18 — ANDESITE BRECCIA WITH RHYOLITE FRAGMENTS
- 17 — LAUMONTITE-BEARING DACITE TUFFS
- 16 — LAUMONTITE-BEARING ANDESITE BRECCIA
- 15 — SANDSTONE
- 14 — SANDSTONE, SHALES, AND MOTTLED TUFFS

- 13 — INTRUSIVE FELDSPAR PORPHYRY

(B) EAST OF SAKWI CREEK FAULT

PART OF HARRISON LAKE FORMATION:
- 11 — BRECCIAS AND ASH FALL TUFFS
- 10 — PILLOWED ANDESITES
- 9 — WATER-LAIN TUFF WITH CONVOLUTE LAMINAE
- 8 — SILICIFIED ZONE
- 7 — FOSSILIFEROUS SHALE
- 6 — DARK GREEN TUFF WITH GRADED BEDDING AND ACCRETIONARY LAPILLI

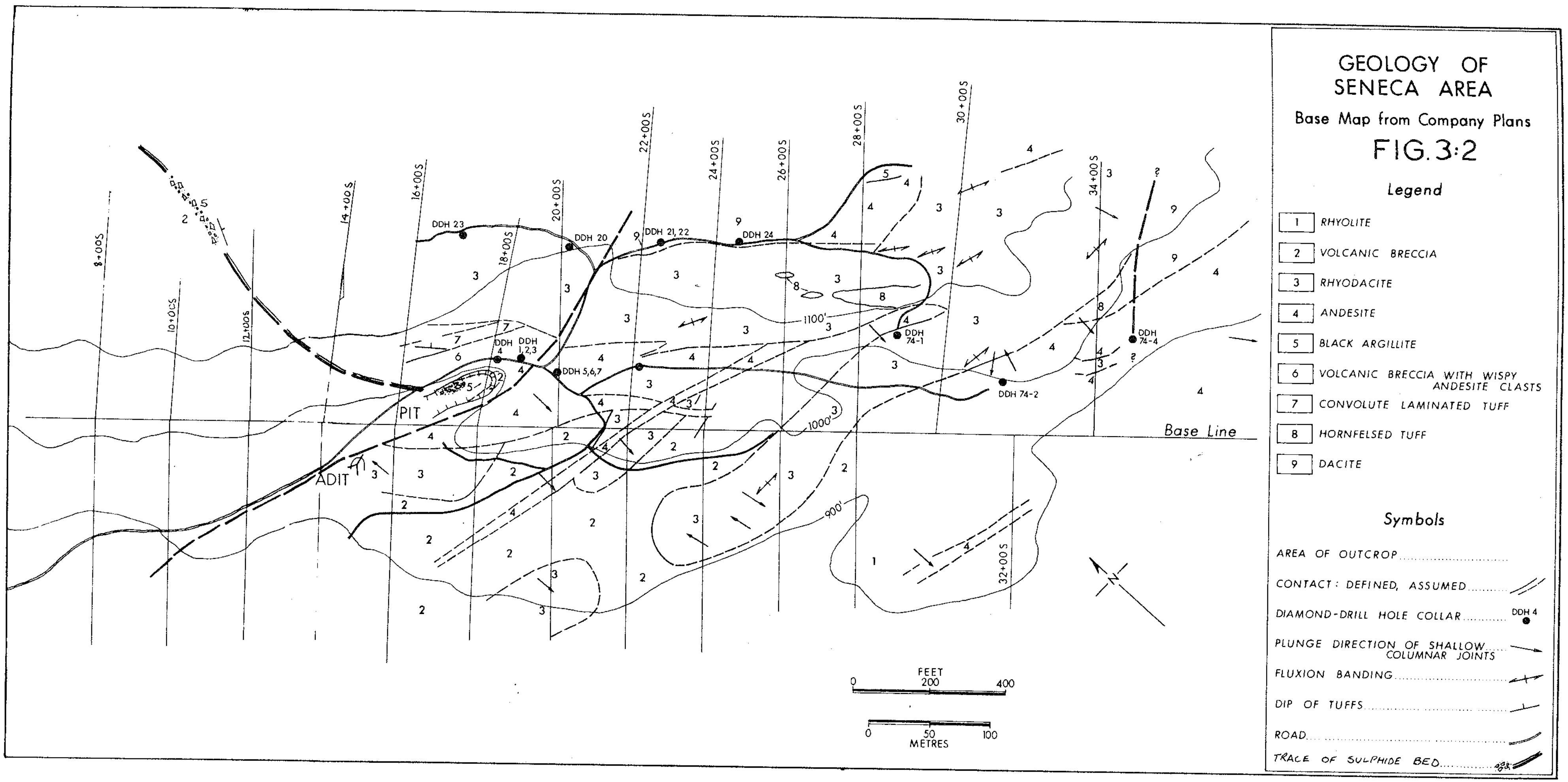
- 12 — RHYOLITE
- 13 — INTRUSIVE FELDSPAR PORPHYRY

**LOWER JURASSIC (TOARCIAN)**

CAMP COVE FORMATION:
- 5 — BLACK ARGILLITE
- 4, 3, 2 — CGL; CHERT — INTERBEDDED GREYWACKES AND SHALES, WITH CHERT BEDS AND CONGLOMERATE
- 1 — POLYMICTIC CONGLOMERATE

### SYMBOLS

- BEDDING
- FLOW-BANDING
- CONTACT: DEFINED, ASSUMED
- FAULT
- ROAD: TWO WHEEL, FOUR WHEEL
- CONTOUR, 500' INTERVAL — 500
- FOSSIL LOCATIONS — (F)
- PROJECTED SURFACE TRACE OF TOP AND BASE OF FOSSILIFEROUS SHALE BED
- AXIAL-PLANE TRACE CAMP COVE ANTICLINE


GEOLOGY OF SENECA AREA
Base Map from Company Plans
FIG. 3:2
Legend
1 RHYOLITE
2 VOLCANIC BRECCIA
3 RHYODACITE
4 ANDESITE
5 BLACK ARGILLITE
6 VOLCANIC BRECCIA WITH WISPY ANDESITE CLASTS
7 CONVOLUTE LAMINATED TUFF
8 HORNFELSED TUFF
9 DACITE
Symbols
AREA OF OUTCROP
CONTACT: DEFINED, ASSUMED
DIAMOND-DRILL HOLE COLLAR
DDH 4
PLUNGE DIRECTION OF SHALLOW COLUMNAR JOINTS
FLUXION BANDING
DIP OF TUFFS
ROAD
TRACE OF SULPHIDE BED
FEET
0
200
400
0
50
100
METRES
Base Line
PIT
ADIT
DDH 23
DDH 20
DDH 21, 22
DDH 24
DDH 4
DDH 1,2,3
DDH 5,6,7
DDH 74-1
DDH 74-2
DDH 74-4
8+00S
10+00S
12+00S
14+00S
16+00S
18+00S
20+00S
22+00S
24+00S
26+00S
28+00S
30+00S
32+00S
34+00S
1100'
1000'
900'
N