BRITISH COLUMBIA HYDRO AND POWER AUTHORITY

GEOTHERMAL EXPLORATION OF THE AIYANSH-TERRACE AREA

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GEOTHERMAL EXPLORATION OF THE AIYANSH-TERRACE AREA

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SECTION 1.0 - INTRODUCTION

The area investigated in this study extends from the south end of the Queen Charlotte Islands (52°N latitude) to a point north of Revillagigedo Island (56°N latitude) and from the Queen Charlotte Islands on the west (135°W longitude) to Babine Lake on the east (126°W longitude). The area was visited by P.T. McCullough and R. Kuerbis of B.C. Hydro between 9 June 1981 and 12 June 1981. Lakelse Hot Springs, the Tseax River lava flow and nearby volcanic features were examined specifically.

The areas of particular interest are accessible from highways 16, 25 and 37 and by private logging roads. Scheduled airline flights are available from Vancouver to Terrace.

The Tseax River lava flow was investigated as a potential geothermal source because it resulted from one of the most recent volcanic eruptions in British Columbia (approximately 220 y.b.p.), a 69 kV transmission line crosses the lava flow and electrical load is expected to increase rapidly in the Prince Rupert area. The Lakelse Hot Springs were examined because of their proximity to the Tseax River lava flow.

The investigation took the form of a literature review and a site visit for regional reconnaissance. The following aspects of the eruption were examined:

1. The regional tectonic setting.

2. The relationship of other nearby recent volcanic rocks to the Tseax River lava flow with the associated Aiyansh volcanic cone.

3. The variability of rock types in the volcanic flow(s).

4. The hot springs and recent fumarolic activity in the area.

5. The possible relationship between the Aiyansh volcanic cones and the Lakelse Hot Springs.

Sections 2.0 to 4.1 of this report establish the setting for volcanism and potential geothermal activity. Subsequent sections describe the relationship between volcanism, structural features and hot springs in the Prince Rupert area, with particular emphasis on Aiyansh.

SECTION 2.0 - PHYSIOGRAPHY

The regional study area extends from the Insular Mountains of the Outer Mountain Area, through the Hecate Depression of the Coastal Trough, the Coast Mountains of the Coast Mountain Area and into the Hazelton Mountains, Nass Basin, Skeena Mountains and Interior Plateau of the Central Plateau and Mountain Area (Table 2-1, Fig. 2-1).[1] Volcanic activity has occurred in several of these regions. The Tseax River lava flow originated in the Nass Ranges of the Hazelton Mountains and flowed into the Nass Basin. Other Tertiary and Quaternary lava flows originated in the Nass Basin, the Coast Mountains and in the Hecate Depression. All of the volcanoes are basaltic. The southernmost volcanoes appear to be part of the Anahim Volcanic Belt and they have been dated at 14.5 Ma and 13.0 Ma (Miocene). The Tow Hill sills, on the Queen Charlotte Islands, were emplaced in Late Pliocene or earliest Pleistocene and they range from basalt to medium-grained diabase.

The Insular Mountains consist of the Queen Charlotte Ranges and the Skidegate Plateau. The Queen Charlotte Ranges have a granitic core flanked by Triassic and Jurassic volcanic rocks. Although the relief is low, the mountains are rugged. Mesozoic sedimentary and volcanic rocks are exposed in the southern part of the Skidegate Plateau, but Paleocene lava flows cover the surface in the north.

The Hecate Depression ranges from 170 m above sea level to 370 m below sea level, although much of it is at only 90 m. Relief is low on the Queen Charlotte lowland. Much of the lowland is covered with muskeg which overlies Early Tertiary volcanic rocks and Late Tertiary sedimentary rocks. The Argonaut Plain, at the northeastern tip of Graham Island, consists of a Post-Pleistocene outwash plain and sand beach. The Hecate lowland is on the east side of Hecate Strait. The lowland lies below 600 m elevation and it is the remains of a Late Tertiary erosion surface. The area is underlain by granitic rocks with lesser quantities of sedimentary, volcanic and metamorphic rocks.

TABLE 2-1

PHYSIOGRAPHIC SUBDIVISIONS

<u>Western System</u>

- Outer Mountain Area
  - Insular Mountains
    - Queen Charlotte Mountains
      - Skidegate Plateau
      - Queen Charlotte Ranges

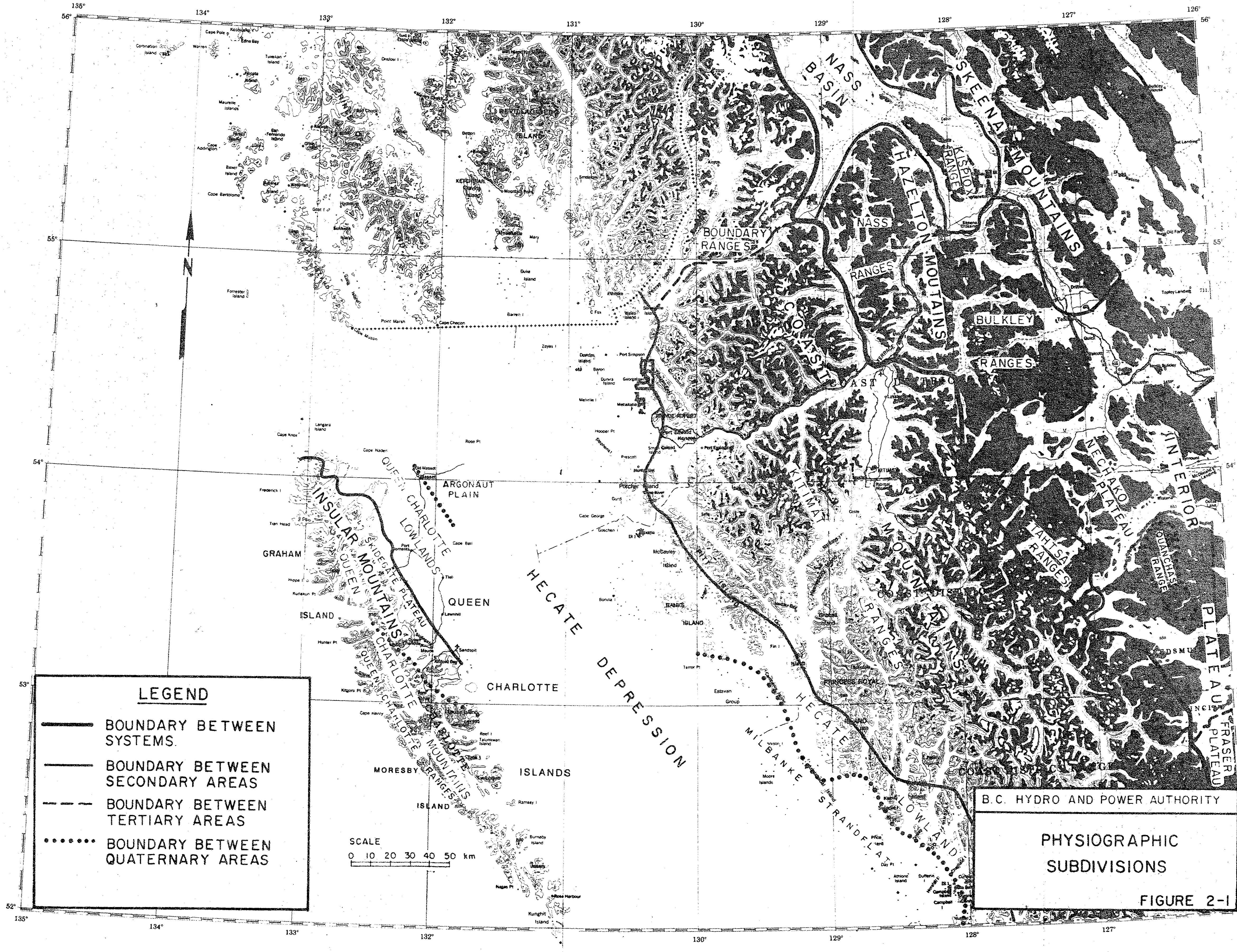
- Coastal Trough
  - Hecate Depression
    - Queen Charlotte Lowland
      - Argonaut Plain
    - Hecate Lowland
      - Milbanke Strandflat

- Coast Mountain Area
  - Coast Mountains
    - Boundary Ranges
    - Kitimat Ranges
    - Pacific Ranges

<u>Interior System</u>

- Central Plateau and Mountain Area
  - Skeena Mountains
  - Nass Basin
  - Hazelton Mountains
    - Nass Ranges
    - Kispiox Range
    - Bulkley Ranges
    - Tahtsa Ranges

- Southern Plateau and Mountain Area
  - Interior Plateau
    - Nechako Plateau
      - Quanchus Range
    - Fraser Plateau


LEGEND
BOUNDARY BETWEEN SYSTEMS
BOUNDARY BETWEEN SECONDARY AREAS
BOUNDARY BETWEEN TERTIARY AREAS
BOUNDARY BETWEEN QUATERNARY AREAS
SCALE
0 10 20 30 40 50 km
N
NASS BASIN
SKEENA MOUNTAINS
HAZELTON MOUNTAINS
KISPIOX RANGE
NASS RANGES
BOUNDARY RANGES
BULKLEY RANGES
KITIMAT RANGES
NECHAKO PLATEAU
TAHTSA RANGES
QUANCHUS RANGE
INTERIOR PLATEAU
FRASER PLATEAU
ARGONAUT PLAIN
QUEEN CHARLOTTE LOWLANDS
SKIDEGATE PLATEAU
QUEEN CHARLOTTE RANGES
INSULAR MOUNTAINS
QUEEN CHARLOTTE MOUNTAINS
GRAHAM ISLAND
MORESBY ISLAND
QUEEN CHARLOTTE ISLANDS
HECATE DEPRESSION
HECATE LOWLAND
MILBANKE STRANDFLAT
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PHYSIOGRAPHIC SUBDIVISIONS
FIGURE 2-1

The Kitimat Ranges of the Coast Mountains have high relief, rising from sea level to over 2700 m. The ranges consist predominantly of granitic rocks with some belts of older volcanic and sedimentary rocks. These belts control the alignment of many northwesterly-trending lineaments.

The Skeena Mountains are in the northwest part of the study area. These mountains have moderate relief of approximately 1000 m. The peaks and ridges are generally rugged, but the valleys are broad and filled with sediments. The Skeena Mountains consist largely of folded Upper Jurassic and Lower Cretaceous sedimentary rocks.

The Nass Basin is an area of low relief bordering the Nass and Kispiox rivers. The maximum width of the basin is approximately 40 km. The basin is underlain by Jurassic volcanic rocks of the Hazelton Group.

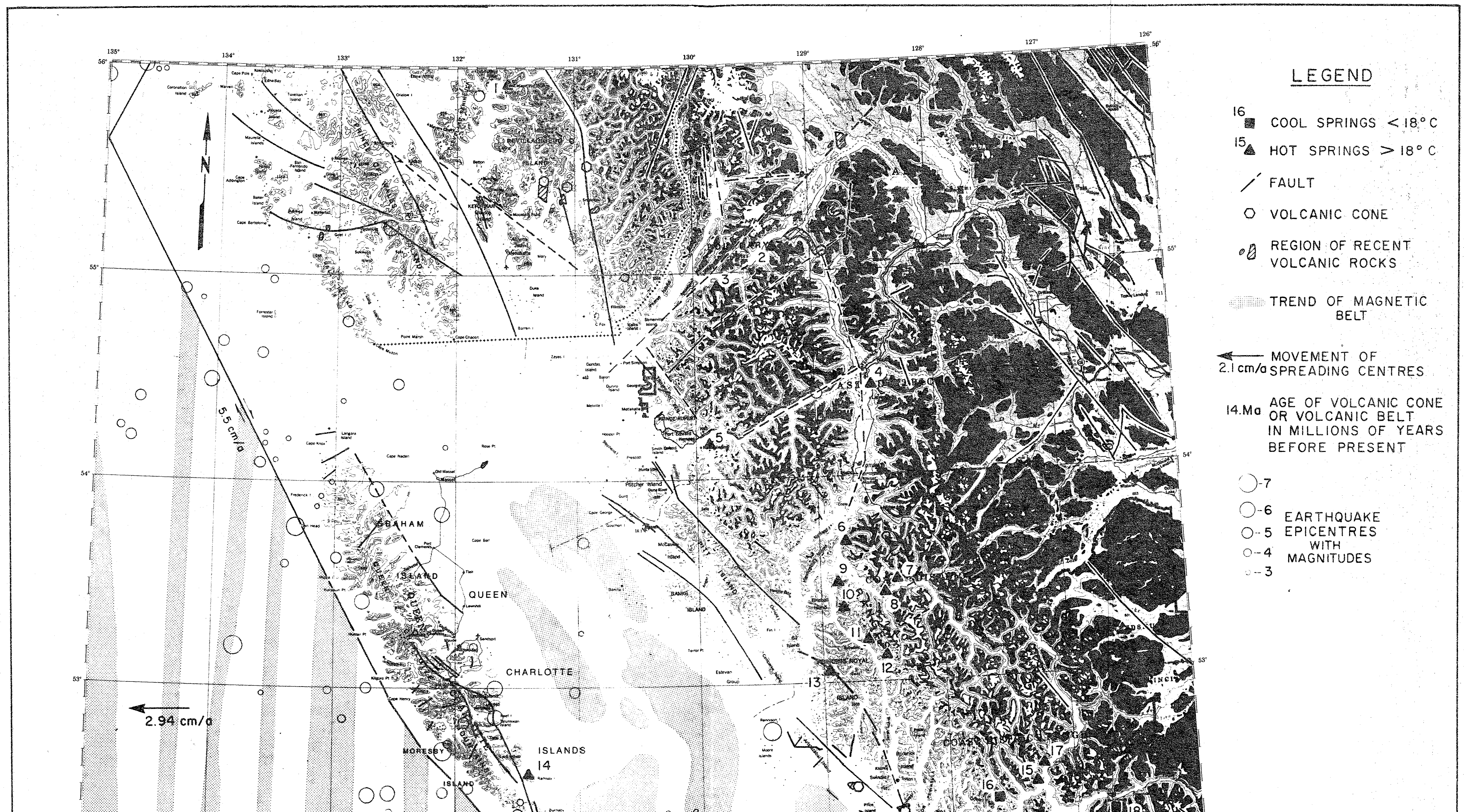
The Hazelton Mountains comprise an area of moderate relief. The mountains are underlain principally by Mesozoic sedimentary and volcanic rocks and locally by granitic stocks and small batholiths.

SECTION 3.0 - PLATE TECTONICS

The oceanic and continental crust consist of a series of plates bounded by faults (Fig. 3-1). These plates are in motion because of convective movement in the mantle of the earth. The Pacific Plate, off the Queen Charlotte Islands, is moving westward associated with the growth of this plate. This movement is accompanied by a relative, north northwesterly, right-lateral movement of the Pacific Plate along the northwest-trending Queen Charlotte Fault.[2] In addition there is some underthrusting of the Pacific Plate under the North American Plate. The resulting motion vector is northwest trending.

Although some earthquake epicentres lie east of the Queen Charlotte Islands and others lie west of the Queen Charlotte Fault, most of these locations are in error because of problems in transferring data from small scale maps and from errors indicative of the inadequate distribution of seismic stations.[3] However, some earthquake epicentres are undoubtedly located east of the Queen Charlotte Fault. The significance of the disappearance of the Pacific Rise at the edge of the American Plate and near the southern tip of the Queen Charlotte Islands, as well as the occurrence of earthquake epicentres east of the Queen Charlotte Islands, is unknown.

For the most part, suboceanic plates consist of elongate slices of oceanic crust bounded by transform faults that trend subperpendicular to spreading centres (oceanic ridges) and by subduction zones. The situation off the coast of British Columbia is exceptional. The oceanic crustal plates are presently being broken apart by a series of northwest and west northwest trending faults off the coast of Vancouver Island and as far north as the southern tip of the Queen Charlotte Islands. The resulting oceanic ridges or spreading centres are approximately perpendicular to the coastline and the western boundary of the American plate.[4] The sea floor originating off the coast of



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GEOTECTONIC FEATURES OF THE PRINCE RUPERT AREA

Figure 3-1

Vancouver Island is being subducted under the Olympic Peninsula and there is active volcanism east of this region.[5] Most of the movement along the Pacific Plate-American Plate boundary, off the Queen Charlotte Islands, consists of transform movement along the Queen Charlotte Fault, although there is a small component to underthrusting.[2]

Andesitic volcanoes of the calc-alkalic suite (silica content: 61 percent to 56 percent) commonly develop approximately 150 km inland from subducting oceanic plate boundaries and comprise island arcs. The Tseax River volcano and lava flow differ from this pattern in several respects. Although the volcano is 300 km inland from the plate boundary, this plate boundary is not subducting significantly and there is no resulting island arc in British Columbia. The Tseax River flow consists of alkalic rocks (silica deficient olivine basalt) rather than calc-alkalic rocks and there is no associated andesitic volcanism.

Earthquakes, faults and hot springs are also related to tectonism. A series of strike-slip faults and lineaments trending 150° are probably related to right-lateral shear between the Pacific Plate and the American Plate. Similarly a lineament trending 020° and extending from Kitimat to Terrace, may be part of a conjugate set of fractures (Fig. 3-1). North of Terrace the lineament is oriented subparallel to the Queen Charlotte Fault. A series of valleys trending approximately 065° comprise the remaining lineaments. The Skeena Valley is one of these lineaments and it was the site of a shallow focus earthquake, of moderate intensity, 20 km southwest of Terrace, on 5 November 1973.[6] The origin of these northeast trending lineaments is unknown.

SECTION 4.0 - GEOLOGY

4.1 REGIONAL GEOLOGY

The geology of the area is extremely variable because the area consists of several geological provinces. From east to west these provinces are the Intermontane Belt which includes the Nechako Belt, Skeena Arch, Sustut Basin and Bowser Basin, the Coast Plutonic Complex, the Gravina Belt, the Alexander Belt, the Pacific Continental Shelf and the Insular Belt (Fig. 4-1). The rock units over these provinces range from Ordivician to Recent.

The Nechako Belt consists of Triassic, Jurassic and Cretaceous volcanic rocks. These rocks are andesite, basalt, tuff and breccia of the Hazelton Group as well as other unnamed units.

The Skeena Arch consists mainly of volcanic rocks of the Lower Jurassic or Lower Cretaceous, Telkwa, Nilkitkwa and Brian Boru formations and sedimentary rocks of the Lower and Middle Jurassic Hazelton Group, Smithers Formation and Ashman Formation. The volcanic rocks are predominantly basalt, andesite and rhyolite and the sedimentary rocks are shale, greywacke, tuff and conglomerate.

The Sustut Basin contains mainly rocks of the Sustut Group of Cretaceous age. The Sustut Group consists of conglomerate, shale, greywacke, breccia and coal.

The Bowser Basin is a large sedimentary basin with Jurassic and Cretaceous rocks. The eastern part contains Lower Jurassic sedimentary rocks of the Hazelton Group, the Telkwa Formation and the Nilkitkwa Formation. The Jurassic to Cretaceous Bowser Lake Group, the Lower Cretaceous Skeena Group and the Cretaceous Red Rose Group comprise most of the basin in the map area. These units consist of conglomerate, greywacke, shale and coal.

GEOLOGICAL PROVINCES

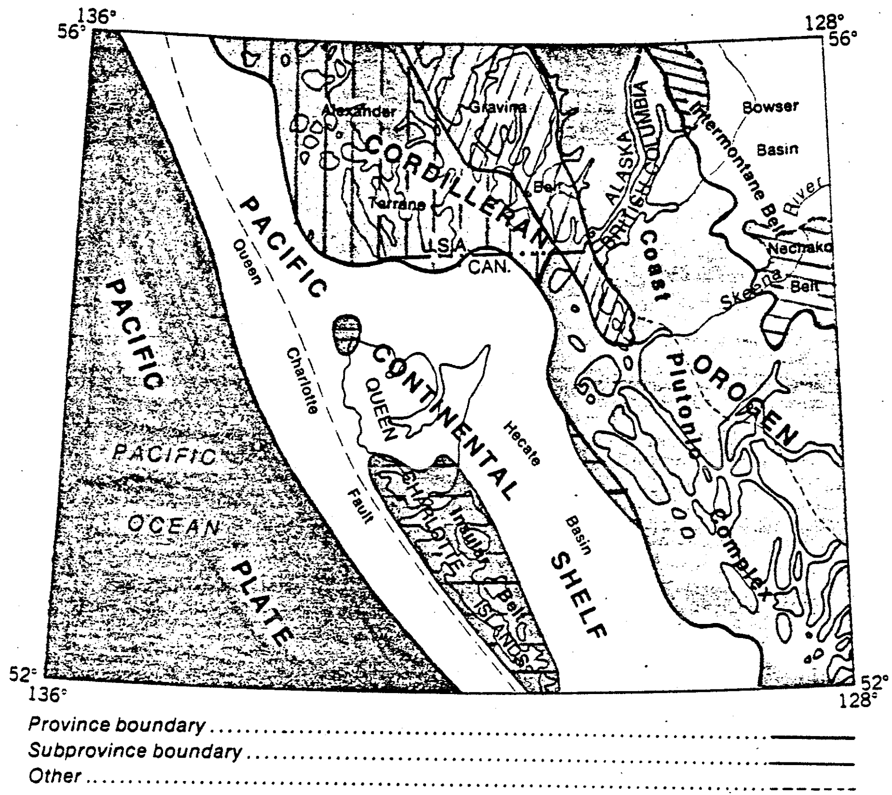


FIGURE 4-1

The older rock units were intruded by numerous plutons from Jurassic to Tertiary in age. They range from granite to diorite in composition; some plutons are gneissic.

Upper Cretaceous to Mid-Tertiary volcanic rocks overlie the south-eastern part of the map area. They comprise the Ootsa Lake and Endako groups, as well as other unnamed volcanic sequences. The units consist of olivine basalt, andesite, dacite, rhyolite and trachyte with some interlayered sedimentary rocks.

The Coast Plutonic Complex is a varied assemblage of plutonic rocks and metamorphosed roof pendants. The plutons have intruded Upper Paleozoic schists, gneisses, quartz diorite, diorite, granodiorite, amphibolite and metasedimentary rocks. These units form northwest-trending belts subparallel to the coastline that are intruded by Jurassic to Late Tertiary plutons of variable composition.

The Gravina Belt extends along the coast of Alaska and into British Columbia. This belt consists mainly of amphibolite, gneiss, schist, marble, phyllite, quartzite and slate of unknown age. It is bounded on the west by Triassic and Jurassic volcanic and sedimentary rocks; these units include andesite, greywacke, argillite, siltstone, conglomerate, basalt and rhyolite. The belt is bounded on the west by the Clarence Strait Lineament.

The geology is markedly different in the Alexander Terrane which is west of the lineament. The rocks range from Ordivician to Devonian amphibolite, hornfels, schist, gneiss, greenstone, phyllite, limestone, marble, greywacke, slate, conglomerate and metavolcanic rocks. These rocks belong to the Descon, Heceta, Port Refugio, Coronados, Peratrovich and Klawak formations.

The Queen Charlotte Islands form the northern limit of the Insular Belt. The oldest rocks on the islands are Triassic basalts and pillow lavas of the Karmutsen Formation. The Karmutsen volcanic rocks are overlain by Kunga Limestone and argillite of Triassic and Jurassic age.

These units are overlain by Jurassic andesite and agglomerate of the Yakoun Formation and they are in turn intruded by Jurassic quartz diorite and Early Tertiary granodiorite. The Cretaceous Queen Charlotte Group consists of shale, siltstone and sandstone. The Masset Formation comprises gently dipping Paleocene to Eocene basalt and rhyolite and extends throughout much of the Queen Charlotte Islands. These units are overlain by sandstone, mudstone and lignite of the Miocene to Pliocene Skonun Formation and subsequently intruded by the Pliocene or Pleistocene Tow Hill olivine basalt sill.

4.2 PREVIOUS WORK ON LOCAL GEOLOGY

The main sources of information on the Tseax River lava flow are papers by Hanson (1918)[8] and Sutherland Brown (1969).[9] Hanson described briefly the age, petrology, chemistry, dimensions and extent of the Tseax River lava flow. Sutherland Brown described the morphology, dimensions, extent, petrology, chemistry, age and origin of the lava flow. He estimated the volume of the flow at 0.455 km^3.

4.3 LOCAL GEOLOGY

The Tseax River lava flow originated at a volcanic cone, 4.8 miles up the valley of a small tributary of the Tseax River, approximately 220 years ago (Fig 4-2). The volcanic cone developed on dark grey shales of the Bowser Group (Fig. 4-3) which strike 043° and dip 36°NW. The flow passes through valleys carved into well-bedded siltstone and sandstone, also of the Bowser Group. The flow reaches a maximum width of approximately 3.2 km and terminates in the Nass River valley 22 km from its source (Fig. 4-4).

The vent area contains one large cone (Fig. 4-5) with a smaller one inside the first (Fig. 4-6) along with several other small cones. The main cone is approximately 100 m high and consists of loose scoria with

FIGURE 4-2

Tseax River lava flow in a tributary valley above Tseax River.

Figure 4-3

Shale country rock exposed through black lapilli on the southern edge of the main volcanic cone.

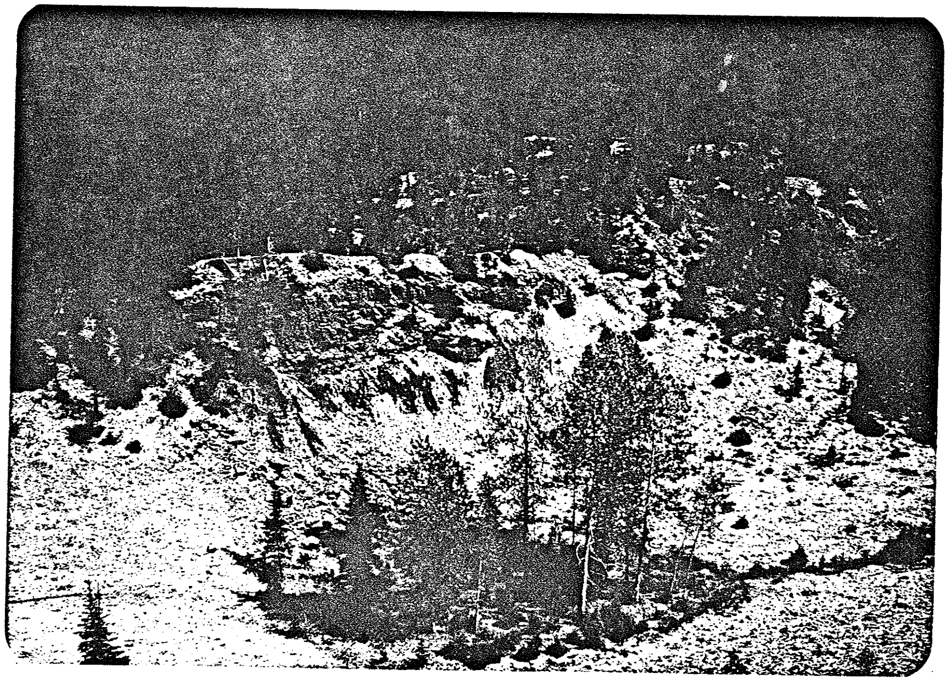


Figure 4-5

Main crater at Aiyansh cinder cone with fused clinker forming a cliff on the far wall.

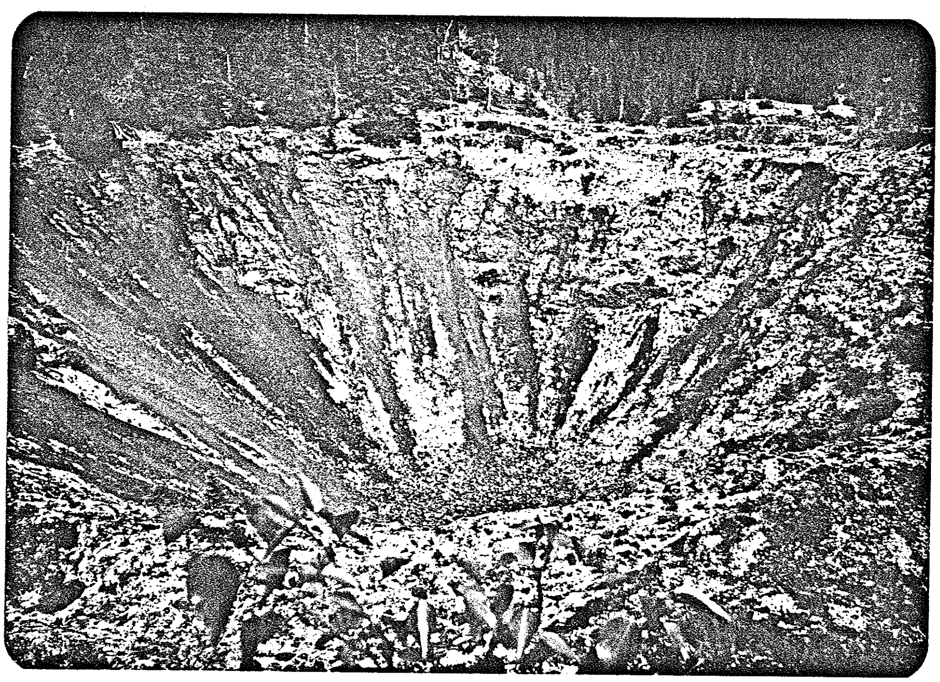


Figure 4-6

Smaller crater within the main crater. Slumping is indicated by the small scarps on the far wall.

fused scoria comprising the inner, steep walls of the main cone (Fig. 4-7). Most of the cones are composed of loose scoria. Fine, black scoria is common along the south and southwest flanks and up the hill to the south of the main cone. The cones were probably constructed by the eruption of fountains of fluid, gaseous lava. A depression on the north side of the main cone appears to have resulted from slumping associated with late stage readjustment or a small extrusion of lava from the base of the cone (Fig. 4-8).

Much of the lava flow consists of blocky lava (aa), although pahoehoe is also common particularly in the Nass Valley. There are numerous lava tubes, collapsed lava tubes and pressure ridges (Fig. 4-9).

A series of lava flows of olivine basalt form a cliff face on the north side of the Tseax River tributary (No. 1, Fig. 4-4). The base of these flows is obscured by talus. The lower 1 m is rubbly basalt which is overlain by 2 m of lahar. These are overlain successively by 3.6 m of columnar jointed basalt, 9.1 m of rubbly basalt, 1.5 m of columnar jointed basalt and 4.6 m of rubbly basalt (Fig. 4-10). The rubbly appearance is caused by the breaking of columar joints due to flow in an almost solidified state. The exposure is believed to consist of at least three and possibly more volcanic eruptions, although these were not separated by significant periods of time; no soil horizons were developed between the flows.

The eruptions of these flows were pre-Pleistocene or Pleistocene. This is concluded from the deep erosion in the creek valley adjacent to the outcrop.

A tuya was examined north of the junction of the Tchitin and Nass rivers (Fig. 4-11, 4-12). The tuya is an elongate, flat-topped ridge approximately 25 m high and 1.5 km long that formed by volcanic eruption under a glacier. The tuya consists of rubbly olivine basalt; the rubble was formed by the breaking apart of columnar jointed lava.

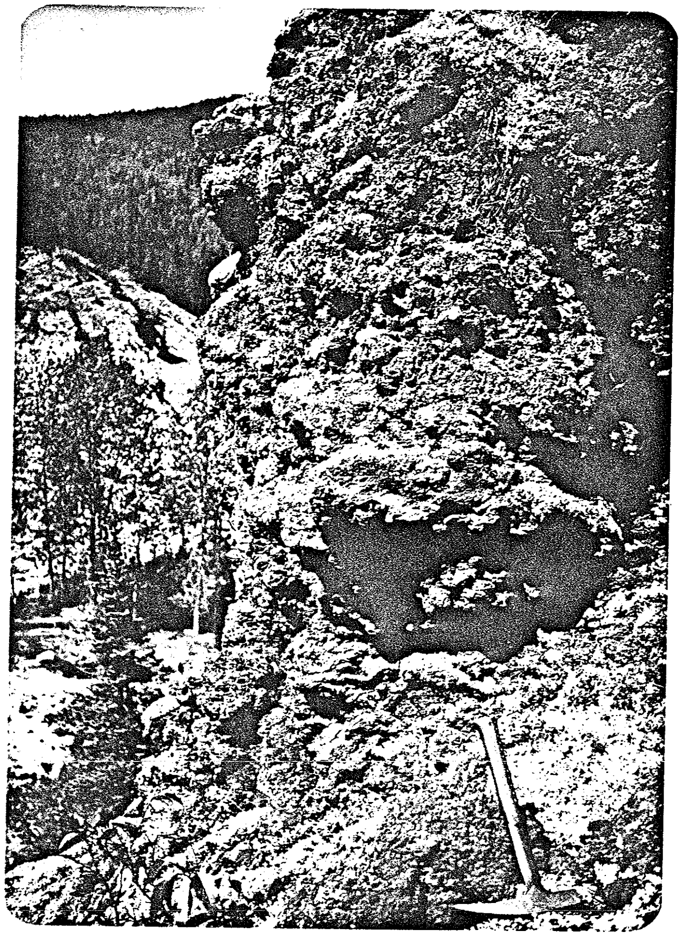


Figure 4-7

Fused clinker on east wall of the main crater at Aiyansh volcano.

Figure 4-8

Breached portion on the north wall of the main crater on the Aiyansh volcano.

Figure 4-9

Pressure ridge on the lava flow at the base of the main volcanic cone at Aiyansh.

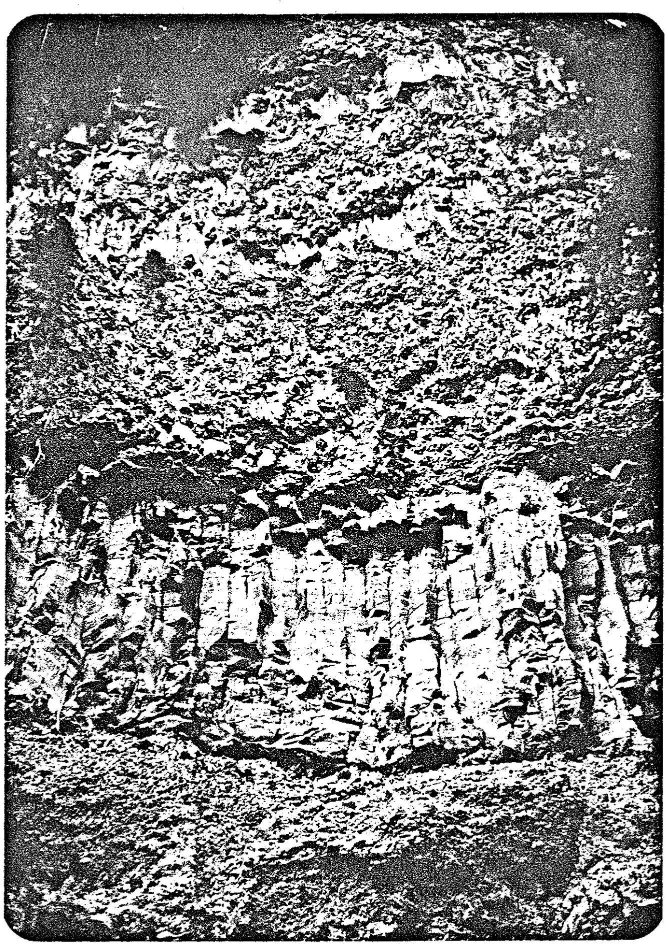
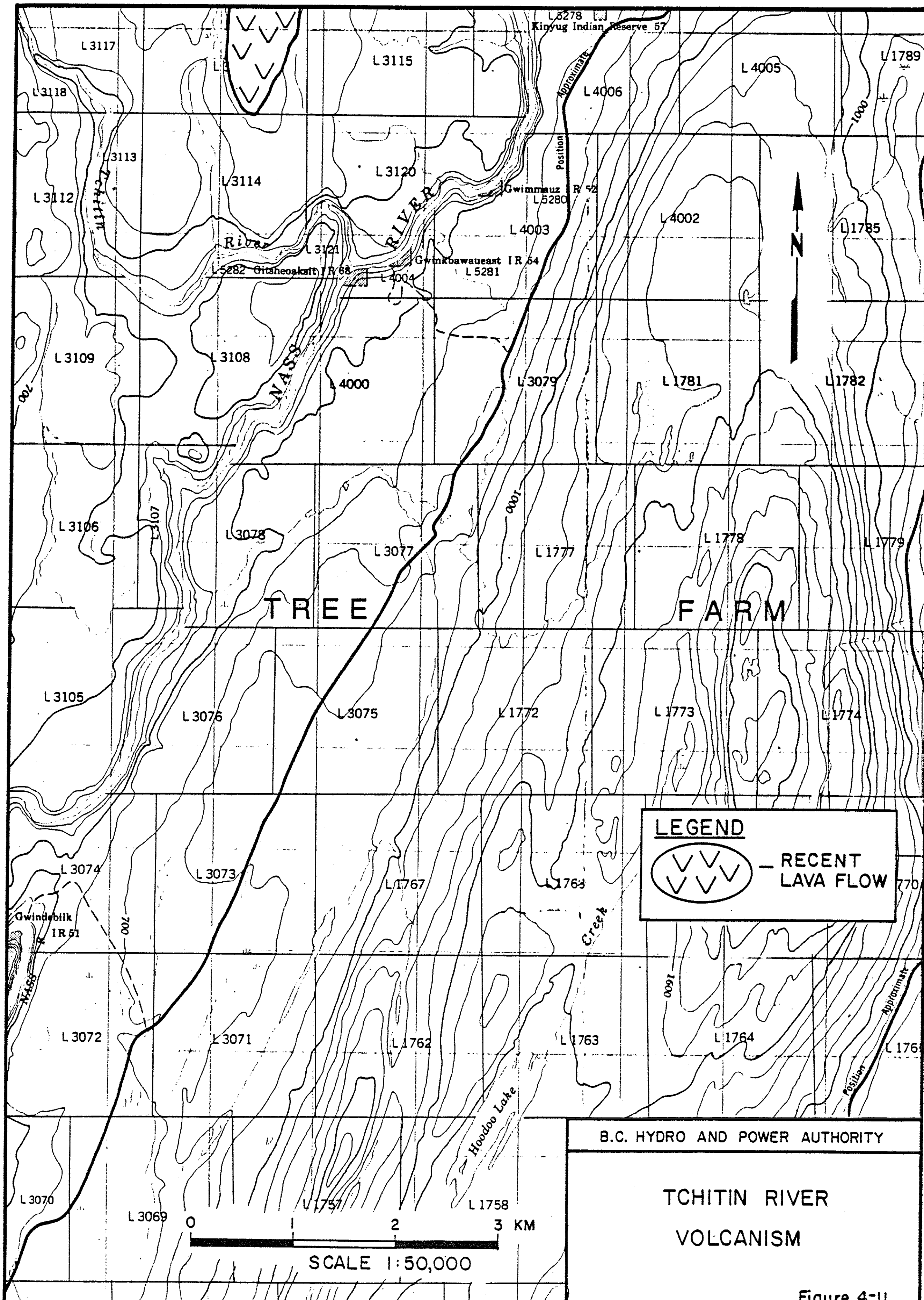


Figure 4-10

Cliff face on the north side of the Tseax River lava flow.



B.C. HYDRO AND POWER AUTHORITY
TCHITIN RIVER
VOLCANISM
LEGEND
RECENT LAVA FLOW
SCALE 1:50,000
0 1 2 3 KM
TREE
FARM
NASS RIVER
Tchitin River
Hoodoo Lake
Creek
Kinyug Indian Reserve 57
Gwimmauz IR 52
Gwinkbawaueast IR 54
L 5282 Gitsheoaksit IR 88
Gwindebilk IR 51
Approximate Position
L 3117
L 3118
L 3115
L 4006
L 4005
L 1789
L 3113
L 3112
L 3114
L 3120
L 5280
L 4003
L 4002
L 1785
L 3121
L 4004
L 5281
L 3109
L 3108
L 4000
L 3079
L 1781
L 1782
L 3106
L 3107
L 3078
L 3077
L 1777
L 1778
L 1779
L 3105
L 3076
L 3075
L 1772
L 1773
L 1774
L 3074
L 3073
L 1767
L 3072
L 3071
L 1762
L 1763
L 1764
L 3070
L 3069
L 1757
L 1758
700
1000
1600

Figure 4-11

Figure 4-12

Tuya west of the Nass River and north of Aiyansh.

Figure 4-13

Pool at Lakelse Hot Springs.

The country rocks for these volcanic units are shales and sandy shales of the Bowser Group. Metamorphism of these units is very lowest greenschist facies.

Other similar volcanic centres are scattered over the area. They were not examined, but they are expected to be glacial or interglacial and not nearly as recent as the Tseax River lava flow.

4.4 MICROSCOPIC DESCRIPTIONS (Refer to Appendix A)

The lava flows, tuyas and cinder cones consist of aphanitic, vitrophyric and/or scoriaceous olivine basalt. The olivine basalts range from holocrystalline to hypohyaline and some samples contain abundant devitrified glass. Textures range from hyalopilitic to pilotaxitic. The samples are all porphyritic and some are seriate porphyritic. Vesicles are common and these have unaltered margins. Phenocrysts consist of plagioclase, some are weakly zoned, and olivine. The ground mass consists of plagioclase, olivine and opaques with or without clinopyroxene, quartz, calcite, apatite and glass.

Samples from cliffs on the north side of the Tseax River lava flow (Site No. 1, Fig. 4-4) contain irregular fragments of basalt similar to the basalt that comprises the groundmass, but the fragments are darker, glassy and more vesicular. The fragments are believed to comprise partly assimilated crust from the surface of the lava flow.

The country rock at the main volcanic cone is very fine, dark grey, fissile shale, consisting mostly of a quartz and clay mineral matrix. There are irregular clasts of quartz and plagioclase as much as 0.07 mm long. Calcite veins, 0.1 mm across, are parallel to bedding; quartz veins, 0.1 mm across, are perpendicular to bedding.

The country rock that was examined north of Cranberry Junction and adjacent to Highway 37 is a sandy shale. This sandy shale consists of angular clasts of plagioclase and quartz with calcite-filled interstices; together they constitute 50 percent of the sample. Most plagioclase is fresh, but some is intensely altered to clay minerals. The larger grains are between 0.2 mm and 0.4 mm in diameter. The matrix is very fine, recrystallized quartz with some clay minerals, organic material, iron oxide stain, opaques, sericite and chlorite.

SECTION 5.0 - CHEMISTRY

The Tseax River lava flow closely resembles a normal alkali basalt, except for a few elements (Table 5-1). The Tseax River lava flow is enriched in iron (FeO) and alkalies (K_2O + Na_2O) at the expense of magnesium (MgO) and calcium (CaO) respectively.

TABLE 5-1

CHEMISTRY OF THE TSEAX RIVER LAVA FLOW

	Sutherland Brown (1969) (%)	Hanson (1924) (%)	Nockolds (1954) Normal Alkali Basalt (%)
SiO_2	45.80	46.24	45.78
Al_2O_3	14.75	15.79	14.64
Fe_2O_3	2.12	2.86	3.16
FeO	13.64	11.81	8.73
P_2O_5	0.87	1.00	0.39
CaO	9.81	7.94	10.74
MgO	2.30	4.43	9.39
TiO_2	3.79	3.00	2.63
MnO	0.22	0.15	0.20
SO_3	0.15	0.09	-*1
Na_2O	3.83	2.40	2.63
K_2O	2.60	3.90	0.95
CO_2	0.01	-*1	-*1
H_2O	0.06	-*1	-*1
H_2O*1	0.11	0.10	0.76

*1 Indicates that no analysis was conducted.

SECTION 6.0 - HOT SPRINGS

There are numerous hot and warm springs in the area and the characteristics of these springs are summarized in Table 6-1. The locations of the springs are illustrated in Fig. 3-1. Descriptions of the hot-springs are taken from McDonald (1978)[10] and Souther and Halstead (1973).[11]

The Bell Island Hot Springs are located in Alaska and they are not of interest in this investigation.

The Aiyansh hot springs are 19 km west of the toe of the Tseax River lava flow. The hot springs reportedly consist of 4 to 6 springs with pools ranging to 6 m in diameter. Sulphurous odors eminate from some of the springs. At one spring the flow is 45.4 L/min. and the temperature is 60°C.

The Burton Creek Hot Springs is approximately 60 km southwest of Aiyansh. The water is clear, odourless, tasteless, with minor gas discharge, algae and mineral precipitates. The flow is small, but the temperature of the water is 45.0°C and the pH is 6.62.

The Lakelse Hot Springs are 16 km south of Terrace. The springs issue from a 30.5 m cavern at the resort and in the nearby swamp. There are at least four other springs, including one on the east side of the highway at a temperature of 73.5°C and the pH is 6.52, although flow is small (Fig. 4-13). The temperature at the resort is 52.0°C, the flow is 457 L/min. and the pH is 7.96. The water is clear odorless, tasteless with an abundant discharge of gas, probably CO_2.

The Frizzell Hot Springs are on the south side of the Skeena River, 32 km east of Prince Rupert. The water is clear, odorless, tasteless and with a slight gas discharge. There are three and possibly four

TABLE 6-1

HOT AND WARM SPRINGS OF THE PRINCE RUPERT AREA

No.	Name	pH	Flow (L/min.)	Temperatures: Measured	Geothermometers*1: Quartz (adiabatic)	Quartz (conductive)	Chalcedony (conductive)	NaKCa
1	Bell Island							
2	Aiyansh		45.4	60.0				
3	Burton Creek	6.62		45.0				
4	Lakelse	7.96 6.52	457.0	52.0,73.5	32.3	21.9	13.3	
5	Frizzell	7.86 7.68 7.66	915.0	46.0,38.0, 40.5				
6	Weewannie Creek		60.0	47.5				
7	Brim River				91.0	87.3	54.4	
8	Shearwater Point		484.0	45.0	128.9	131.4	102.7	49.7
9	Bishop Bay		60.0	43.5	114.6	114.5	84.0	
10	Goat Harbor				110.5	110.0	78.8	
11	Kleklane Inlet		264.0	45.0,28.0				158.9
12	Khutze Inlet							
13	Surf Inlet							
14	Hot Spring Island		153.0	76.0,52.5				
15	Eucott Bay	7.44 7.25	634.0	41.5,54.0	64.8	57.7	23.3	
16	Link Lake							
17	Nascall Bay	9.04	46.0	43.4				
18	Thorensen Creek							
19	Talheo	7.87 to 8.01	264.0	46 to 64				
	Meager Creek	6.0	500.0	59.0	157.5	165.5	141.5	212.9

*1 Note: Four geothermometers are given because insufficient information is available for most of the hot springs in order to determine which geothermometer should be used. The equations are from Fournier (1973) and Fournier and Tresdell (1973, 1974) and are as follows:

1. Silica Geothermometer:

   (a) Quartz, Adiabatic Cooling (125° to 275°C):

$$t°C = \frac{1533.5}{5.768 - \log SiO_2} - 273.15$$

   (b) Quarta, Conductive Cooling (125° to 250°C):

$$t°C = \frac{1315}{5.205 - \log SiO_2} - 273.15$$

   (c) Chalcedony, Conductive Cooling:

$$t°C = \frac{1015.1}{4.655 - \log SiO_2} - 273.15$$

2. NaKCa Geothermometer:

$$t°C = \frac{1647}{\log(Na/K) + B\log(\sqrt{Ca}/Na) + 2.24} - 273.15$$

where $B = 1/3$ for $\sqrt{Ca}/Na < 1$ or $t_{4/3} > 100°C$ and the concentrations are expressed in molalities.

springs in the area with pH's ranging from 7.66 to 7.86. The water discharge is 915 L/min. and temperatures range from 38.0°C to 46.0°C.

The Weewanie Creek Hot Springs is 35 km south of Kitimat, on the east side of Devastation Channel. There are two springs at the site; the hotter spring has a temperature of 47.5°C and a flow of 60 L/min. The water is clear, odourless and tasteless.

The Brim River Hot Springs is on the north side of Gardner Canal. Two small springs below the high tide mark. No further information is available.

The Shearwater Point Hot Springs is also on Gardner Canal. There are several springs above and below the high tide mark. They issue from a horizontal fracture. The water is clear, odorless and colorless, with a mineral taste, and there is a white mineral alteration on the rock; algae is also common. Other springs issue from a dipping fracture and from talus. The volume of discharge is 484 L/min. and the temperature is 45°C.

The Bishop Bay Hot Springs are on the east side of Ursula Channel. One spring flows from a fracture near the high tide mark. The water is clear, odorless, tasteless and there is algae at the stream outlet. The temperature of the spring is 43.5°C and the discharge is 60 L/min.

The Goat Harbor Hot Spring is in the intertidal zone on Ursula Channel. No further information is available.

The Kleklane Inlet Hot Springs is on the east shore of Finlayson Channel. There are four springs with a total flow of 264 L/min.; temperatures of 45.0°C and 28.0°C have been measured. The water is clear, odorless and tasteless, with some algae at the outlet. There is a sulphurous odor in the area.

The Khutze Inlet Hot Spring is on a branch of Finlayson Channel. There is no further information available.

The Surf Inlet Hot Spring is on the 275 m level of the Surf Inlet Mine, on Princess Royal Island. There is no further information available.

The Hot Spring Island Hot Springs are on Hotspring Island, on the east side of Moresby Island. There are 15 springs and seeps. The discharge is 153 L/min. and the temperatures of the two largest springs and collection of seeps are 76.0°C and 52.5°C. The water is clear with some CO_2 and H_2S discharge as well as a distinct taste and abundant algae.

The Eucott Bay Hot Spring is on the west shore of Dean Channel. The flow is 634 L/min. from the main spring which issues from boulders near the high tide mark. The water is clear with a distinct taste and a white mineral depositing at the outlet. There are numerous seeps. Temperatures of 41.5°C and 54°C and pH's of 7.44 and 7.25 have been measured.

The Nascall Bay Hot Spring is on Labouchere Channel, a branch of Dean Channel. The discharge is only 46 L/min., the temperature is 43.4°C and the pH is 9.04. Hot water percolates from the ground near the high tide mark and from the middle of a cold stream. The water is colorless, odorless and tasteless.

The Talheo Hot Spring is 25.6 km southwest of Bella Coola, on south Bentinck Arm. There are 16 springs along 400 m of shoreline and many seeps below high tide. The discharge is 264 L/min., the temperature ranges from 46°C to 64°C and the pH ranges from 7.87 to 8.01. The water is colorless, odorless and tasteless and there is algae at the outlets.

The Link Lake and Thorensen Creek warm springs have not been described in the available literature. The Link Lake spring is near Ocean Falls and the Thorensen Creek spring is near Bella Coola.

The chemistry of some of the hot springs in the region have been described by Souther and Halstead (1973)[11] and it is summarized in Table 6-2. The Meager Creek main vent has been included for comparison. The Lakelse, Shearwater Point and Kleklane Inlet Hot Springs are particularly high in dissolved solids. They are all high in sodium and sulphate, the Lakelse and Klekane Inlet Hot Springs contain anomalous chloride ion and the Shearwater Point Hot Springs are high in bicarbonate ion. The particularly high sodium and chlorine at the Klekane Inlet Hot Springs may be partly due to flooding by sea water.

The highest temperatures based on the silica geothermometer were approximately 130°C and these were calculated for the Shearwater Point Hot Springs (Table 6-1). The temperatures for Lakelse, Brim River and Eucott Bay are below those considered reliable for the silica (quartz) geothermometer, possibly due to a high degree of dilution. Each of these geothermometers assumes that a state of equilibrium exists. These systems are obviously open and subject to substantial mixing with cold surface water; therefore, the geothermometers are probably not indicating temperatures that can be correlated with geothermal reservoir temperatures. In addition the presence of minerals containing the respective elements would limit the solubility of these elements in the geothermal solutions. Some elements will be controlled by other factors, for example, silica content is a function of pH as well as temperature; above a pH of 8.5 dissociation occurs and there is more silica in solution.

In general geothermal fluids high in SiO_2, SO_4, Na and K are from higher temperature sources. The hot springs at Shearwater Point has the highest silica content. Only Brim River and Eucott Bay, of the hot springs where data is available, are low in sulphate. There are only two analyses for K, but Lakelse, Shearwater Point and Kleklane Inlet springs are high in Na.

TABLE 6-2

CHEMISTRY OF HOT AND WARM SPRINGS OF THE

PRINCE RUPERT AREA

No.	Name	TDS	Ca	Mg	Na	HCO_3	CO_3	SO_4	Cl	F	SiO_2	Fe	P	Li	K
1	Bell Island	*1													
2	Aiyansh														
3	Burton Creek														
4	Lakelse	1109.6	46.6	50.2	320.6	43.6	2.3	457.2	215.9	3.3	5.6	18.2	8.2	10.2	
5	Frizzell														
6	Weewannie Creek														
7	Brim River	281.0	17.0	12.0	43.0	40.0		78.0	52.0		36.0	3.0*2			
8	Shearwater Point	1229.0	67.0	5.0	259.0	167.0		546.0	60.0		90.0	5.0*2			29
9	Bishop Bay	400.0	18.0	0.3	92.0	4.0	7.0	179.0	32.0		65.0	5.0*2			
10	Goat Harbor	395.0	22.0	0.3	81.0	2.0	10.0	174.0	24.0		59.0	23.0*2			
11	Kleklane Inlet	8640.0	385.0	179.0	2523.0	58.0		717.0	4600.0			58.0*2			82
12	Khutze Inlet														
13	Surf Inlet														
14	Hot Spring Island														
15	Eucott Bay	192.0	35.0	Trace	16.0	33.0		80.0	8.0		17.0	3.0*2			

TABLE 6-2 - (Cont'd)

No.	Name	TDS	Ca	Mg	Na	HCO_3	CO_3	SO_4	Cl	F	SiO_2	Fe	P	Li	K
16	Link Lake														
17	Nascall Bay														
18	Thorensen Creek														
19	Talheo														
	Meager Creek- Main Spring		51.0	15.0	330.0	504.0	<.01	190.0	600.0		161.0				54

*1 Where there are blanks in the table, no information is available.

*2 FeO + Al_2O_3 combined.

SECTION 7.0 - ORIGIN

The Tseax River lava flow originated by partial melting of mantle material. This material rose rapidly through the crust resulting in little discharge of gas or contamination on passing through the crust. The lava was very hot and fluid, which account for the broad extent resulting from a small lava discharge.

The volcanic cone near Aiyansh developed at the intersection of a northeast trending lineament that passes through another recent volcanic centre and a lineament that passes through or adjacent to Lakelse Hot Springs. Most of the volcanic centres in the region lie at or near lineaments. Some of these latter lineaments trend northwesterly.

The volcano associated with the Tseax River lava flow appears to have resulted from deep-seated faulting and the mobilization of mantle material. Therefore, no near surface source of magma is expected. Volcanic activity to the north extends in an east-west chain extending from Alaska to the Nass Valley and it may be related to a mantle hotspot, moving rapidly from west to east. Similarly, this activity would also be associated with a deep-seated source of magma.

Many hot springs lie along the boundary between the high and low parts of the Kitimat Ranges (Fig. 3-1). This situation may be analagous to that of the Cascade Ranges of the United States where the hot springs are a similar distance from the boundary between the Pacific and American plates. There are no hot springs at the Tseax River volcano, but the Aiyansh Hot Spring is situated on the Nass River near the volcano. The hot spring is controlled by a different lineament and the hot spring does not appear to be related directly to the Tseax River volcano.

SECTION 8.0 - CONCLUSIONS

The Quaternary volcanic activity in the Aiyansh area consisted only of isolated volcanic cones and tuyas. The rocks are olivine basalts that are believed to be primary mantle-derived material. This suggests that little time was spent in the crust because differentiation into a variety of magma compositions did not occur. Therefore, there was little heat transferred to the crust. There are no hot springs directly associated with the volcanoes, but some hot springs are probably related to the same deep-seated structural discontinuities.

It is concluded that the area is one of only secondary importance for geothermal activity. No further work on this area is required at this time.

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APPENDIX A

ROCK DESCRIPTIONS

THIN SECTION DESCRIPTION

Sample No.: TR-81-1

Location: Aiyansh, cliff northeast side of Tuya.

Rock Name (Field): Basalt

Hand Speciment Description: Black, aphanitic, porphyritic, few small phenocrysts of plagioclase to 1 mm long. There are a few vesicles scattered throughout sample.

Thin Section Description: Hypocrystalline, matrix mainly microcrystalline, subophitic, seriate porphyritic, microlites randomly oriented.

Minerals:

Plagioclase:	48% - microlites approximately 0.4 mm long.
Plagioclase:	6% - phenocrysts to 0.6 mm long, some are zoned.
Clinopyroxene:	9% - interstitial to plagioclase microlites and olivine, approximately 0.3 mm long.
Olivine:	10% - phenocrysts, anhedral to subhedral.
Opaque:	11% - cubic, approx. 0.1 mm on a side.
Devitrified glass:	13% - interstitial, with small opaques approx. 0.02 mm.
Glass:	3% - interstitial
Vesicles:	<1% - irregular
Apatite:	<1% - small, subhedral crystals.

Rock Name (Thin Section): Olivine Basalt

THIN SECTION DESCRIPTION

Sample No.: TR-81-2

Location: Aiyansh, summit of larger volcanic cone.

Rock Name (Field): Basalt

Hand Specimen Description: Black, vesicular, with subspherical vesicles to 2 mm diameter, porphyritic, with a few plagioclase phenocrysts to 0.5 mm long, glassy matrix.

Thin Section Description: Hypohyaline, hyalopilitic, seriate porphyritic with phenocrysts of plagioclase.

Minerals:

Plagioclase:	4% - mostly microphenocrysts, but some are 0.5 mm on a side, subhedral, mostly prismatic, some are equant, An_{43}.
Plagioclase:	8% - microlites most are subhedral and 0.2 mm long, some are acicular.
Olivine:	4% - usually anhedral and as much as 0.3 mm long, larger grains are euhedral and zoned with numerous opaque inclusions; some have reaction rims.
Opaques:	2% - anhedral, commonly less than 0.1 mm, few as large as 0.3 mm.
Glass:	49% - dark brown, completely opaque at low power, but actually devitrified with numerous opaque minerals, when viewed at high power.
Vesicles:	23% - irregular to subrounded.

Rock Name (Thin Section): Olivine Basalt Vitrophyre

THIN SECTION DESCRIPTION

<u>Sample No.</u>: TR-81-3

<u>Location</u>: Aiyansh, north side of main lava flow, on cliff.

<u>Rock Name (Field)</u>: Basalt

<u>Hand Specimen Description</u>: Black, aphanitic, vesicular with elongate vesicles less than 1.0 mm long, porphyritic, few small phenocrysts of plagioclase; there is some yellow-green, soft, clay alteration; the composition is probably similar to the associated flows.

<u>Thin Section Description</u>: Dark grey, hypohyaline, but partly devitrified, vesicular, fragmental, fragments as much as 8.0 mm across; vesicles are larger in the black fragments than in the grey groundmass. Moderately developed pilotaxitic texture.

<u>Minerals</u>:

Plagioclase:	7% - microlites, commonly 0.07 mm long.
Plagioclase:	2% - microphenocrysts usually 0.3 mm, some as much as 0.8 mm, some zoned.
Olivine:	3% - microphenocrysts to 0.9 mm, some are as small as 0.05 mm.
Opaques:	4% - usually finely disseminated, few grains or clusters of grains to 0.2 mm.
Vesicles:	9% - irregular
Devitrified Glass:	75% - with numerous small opaques, hematite and limonite stain common.
Apatite:	Trace - subhedral

<u>Rock Name (Thin Section)</u>: Olivine Basalt Flow Breccia

THIN SECTION DESCRIPTION

Sample No.: TR-81-4

Location: Aiyansh, Cliff on north side of main lava flow.

Rock Name (Field): Basalt

Hand Specimen Description: Black, aphanitic, vesicular with vesicles to 1.5 mm, although most are less than 0.5 mm, fragmental, with yellow-green clay alteration.

Thin Section Description: Black, aphanitic, fragmental, with irregular, elongate fragments in excess of 2.0 cm; fragments have a glassy matrix and they are subparallel; microlites in the groundmass are not well aligned.

Minerals:

Plagioclase:	17% - microlites, 0.2 mm.
Plagioclase:	4% - phenocrysts to 1.3 mm, most are equant, some are tabular.
Opaques:	2% - equant, commonly 0.3 mm.
Olivine:	1% - few phenocrysts to 0.4 mm, most are smaller.
Pyroxene:	Trace - one grain 0.8 mm long.
Quartz:	Trace - interstitial, planar extinction, 0.3 mm.
Apatite:	Trace - subhedral, prismatic.
Devitrified glass:	74% - brown with disseminated opaques.
Vesicles:	2% - most are irregular, but some have sub-circular outline, 0.4 mm across.

Rock Name (Thin Section): Olivine Basalt Flow Breccia

THIN SECTION DESCRIPTION

Sample No.: TR-81-5

Location: Aiyansh, cliff on north side of main lava flow.

Rock Name (Field): Basalt

Hand Specimen Description: Grey-black, aphanitic, columnar-jointed flow, with few plagioclase phenocrysts. Phenocrysts are aligned.

Thin Section Description: Holocrystalline, microcrystalline, mainly consisting of aligned plagioclase microlites (trachytic texture). Some apparent phenocrysts of plagioclase are actually clusters (glomeroporphyritic) to 1.2 mm in diameter. Microfractures and phenocrysts sub-parallel to flow direction.

Minerals:

Plagioclase:	6% - few phenocrysts to 1.6 mm and partly altered to calcite and clay minerals, some are poikilitically, partly enclosing olivine.
Plagioclase:	49% - microlites, commonly 0.1 mm.
Olivine:	15% - usually less than 0.01 mm,but some are as much as 0.1 mm; many have reaction rims.
Opaque:	13% - angular, to 0.3 mm, but usually much smaller.
Pyroxene:	Trace - usually less than 0.01 mm in matrix.
Quartz:	Trace - planar extinction, with tension gashes.
Calcite:	2% - alteration of plagioclase, locally abundant.
Devitrified glass:	15% - interstitial with numerous fine disseminated opaques, iron-stained, more recrystallized than other samples.

Rock Name (Thin Section): Olivine Basalt

THIN SECTION DESCRIPTION

Sample No.: TR-81-6

Location: Aiyansh, north side of main lava flow on cliff.

Rock Name (Field): Basalt

Hand Specimen Description: Dark grey to black, aphanitic with a few, small, aligned plagioclase phenocrysts.

Thin Section Description: Fragmental, elongate, irregular fragments more than 2 cm long. Seriate porphyritic groundmass, pilotaxitic texture.

Minerals:

Plagioclase:	5% - phenocrysts, most are tabular, some equant, some zoned, subhedral, some as much as 2.2 mm long.
Plagioclase:	72% - microlites, 1 mm long.
Olivine:	4% - mostly broken, up to 0.6 mm long.
Pyroxene:	2% - fine grains in groundmass.
Opaque:	10% - usually very small, some subhedral grains to 0.4 mm, some with associated iron oxide stain.
Calcite:	Trace - deuteric alteration, in matrix or as infilling.
Devitrified glass:	7% - finely crystalline, clear, with disseminated fine opaques.
Unknown:	Trace - opaques clustered on margin of rounded grain, both inside and outside of margin; biaxial negative; 2 V = 52°, birefringence approximately 0.008, relief low, R_o > 1.56, 0.3 mm in diameter.

Rock Name (Thin Section): Olivine Basalt Flow Breccia

THIN SECTION DESCRIPTION

Sample No.: TR-81-7

Location: Aiyansh, north of Cranberry Junction, adjacent to Highway 37.

Rock Name (Field): Sandy Shale

Hand Specimen Description: Dark grey, fine sandy texture, thick-bedded.

Thin Section Description: Quartz and plagioclase comprise angular, irregular clasts to 0.4 mm and 0.2 mm respectively, together they comprise 50 percent of sample. Most plagioclases are fresh, but some are extensively altered to clay minerals. Some quartz grains have undulatory extinction; others have planar extinction.

Matrix is largely fine-grained, recrystallized quartz with some fine clay minerals, sericite, chlorite, opaques, iron oxide stain and organic material.

Rock Name (Thin Section): Sandy Shale

THIN SECTION DESCRIPTION

Sample No.: TR-81-8

Location: Aiyansh, south side of Tseax River cinder cone.

Rock Name (Field): Shale

Hand Specimen Description: Grey with black flecks, thinly bedded, brown weathering.

Thin Section Description: Groundmass comprises 90% of sample; consists of quartz and clay minerals, both very fine. Irregular patches of iron staining throughout. Coarser grains, 0.07 mm long consist of irregular, angular quartz and plagioclase. All minerals aligned parallel to bedding.

Few stringers of calcite parallel to bedding and stringers of quartz perpendicular to bedding.

Rock Name (Thin Section): Shale