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FIELD TRIP 7: GUIDEBOOK

GEOLOGY OF VANCOUVER ISLAND

APRIL 21 - 24

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GUIDEBOOK BY J.E. MULLER

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PREFACE

This guide book has been prepared for the geological field trip on Vancouver Island, preceding the Annual Meeting, Vancouver 1977, of the Geological Association of Canada. It consists of two parts.

The first part, after a brief historical introduction, summarizes what is known about Vancouver Island geology. It is essentially the same as marginal notes for a 1:250,000 geological (uncoloured) map that is in preparation and hopefully will be available for distribution with the guide book.

The second part is a road log for four days of geological sightseeing by motorcoach. The route follows paved highways and there are a few short walks. The overview of Vancouver Island geology is therefore slightly unbalanced. The important Bonanza Group is, except for some outcrops of Bonanza-like lithology of dubious age, not exposed on any accessible road in the south half of the island. Upper Jurassic and Lower Cretaceous shelf sediments are likewise exposed only on northern Vancouver Island. The routes afford a variety of the island's landscapes, even though the beautiful fiords of the west coast are not included.

Part I

General Geology of Vancouver Island

INTRODUCTION

Vancouver Island, the largest island in the eastern Pacific Ocean, is 451 km (280 miles) long, a maximum of 126 km (78 miles) wide, and occupies an area of 32,137 km (12,408 square miles). Most of its area is occupied by the Island Mountains with peaks of 1,000 to 2,000 m (3,000 to 6,000 foot) elevation. Many central valleys are occupied by finger lakes and the west coast is incised by numerous fiords. The middle part of the east coast, facing Strait of Georgia, is occupied by the Nanaimo Lowlands.

The original inhabitants of the island were Indians of the Wakashan language group who, today, are represented by the Nootka and Salishan tribes, numbering about 7,000 in a total population of 430,000.

The Spanish explorer Perez Hernandez was the first white man on record to visit Nootka Sound on the west coast in 1774. James Cook followed in 1778 during his third Pacific voyage. Following reports of Cook's exploration British traders began to use the harbour of Nootka (Friendly Cove) as a base for a promising trade with China in sea-otter pelts but became embroiled with the Spanish who claimed sovereignty over the Pacific Ocean. The ensuing "Nootka Incident" (1790) nearly led to war between Britain and Spain but the dispute was settled diplomatically. George Vancouver on his subsequent exploration in 1792 circumnavigated the island and charted much of the coast line. His meeting with the Spanish captain Bodega y Quadra at Nootka was friendly but did not accomplish the expected formal ceding of land by the Spanish to the British. It resulted however in his naming the island "Vancouver and Quadra". The Spanish captain's name was later dropped and given to the island on the east side of Discovery Strait.

Early settlement of the island was carried out mainly under sponsorship of the Hudson's Bay Company whose lease from the Crown amounted to 7 shillings per year. Victoria was founded as Fort Victoria by that company's chief factor James Douglas in 1843. The existence of this settlement on the south tip of the island and south of the 49th parallel aided British negotiators to retain all of the island when that line was made the northern boundary of the United States by the Oregon Boundary Treaty of 1846. The island became a separate British colony in 1858. British Columbia, exclusive of the island, was made a colony in 1858 and in 1866 the two colonies were joined into one, to become a province of Canada in 1871 with Victoria as capital.

Mining of coal and later of gold, iron and copper ore have been important industries of the island, but in the twentieth century industries associated with logging have become dominant. In addition tourism, fishing and farming are important contributors to the economy.

REGIONAL GEOLOGY

Introduction. The geology of Vancouver Island has been explored mainly by government geologists. Important contributions were made by the following (years of fieldwork in brackets): J. Richardson (1872-1876), G.M. Dawson (1887), C.H. Clapp (1909-1913), H.C. Gunning (1929-1932), A.F. Buckham (1939-1948), J.L. Usher (1945-1948), J.W. Hoadley (1947-1950) and J.A. Jeletzky (1949-1953) of the Geological Survey of Canada, and H. Sargent (1939-1940), J.S. Stevenson (1941-

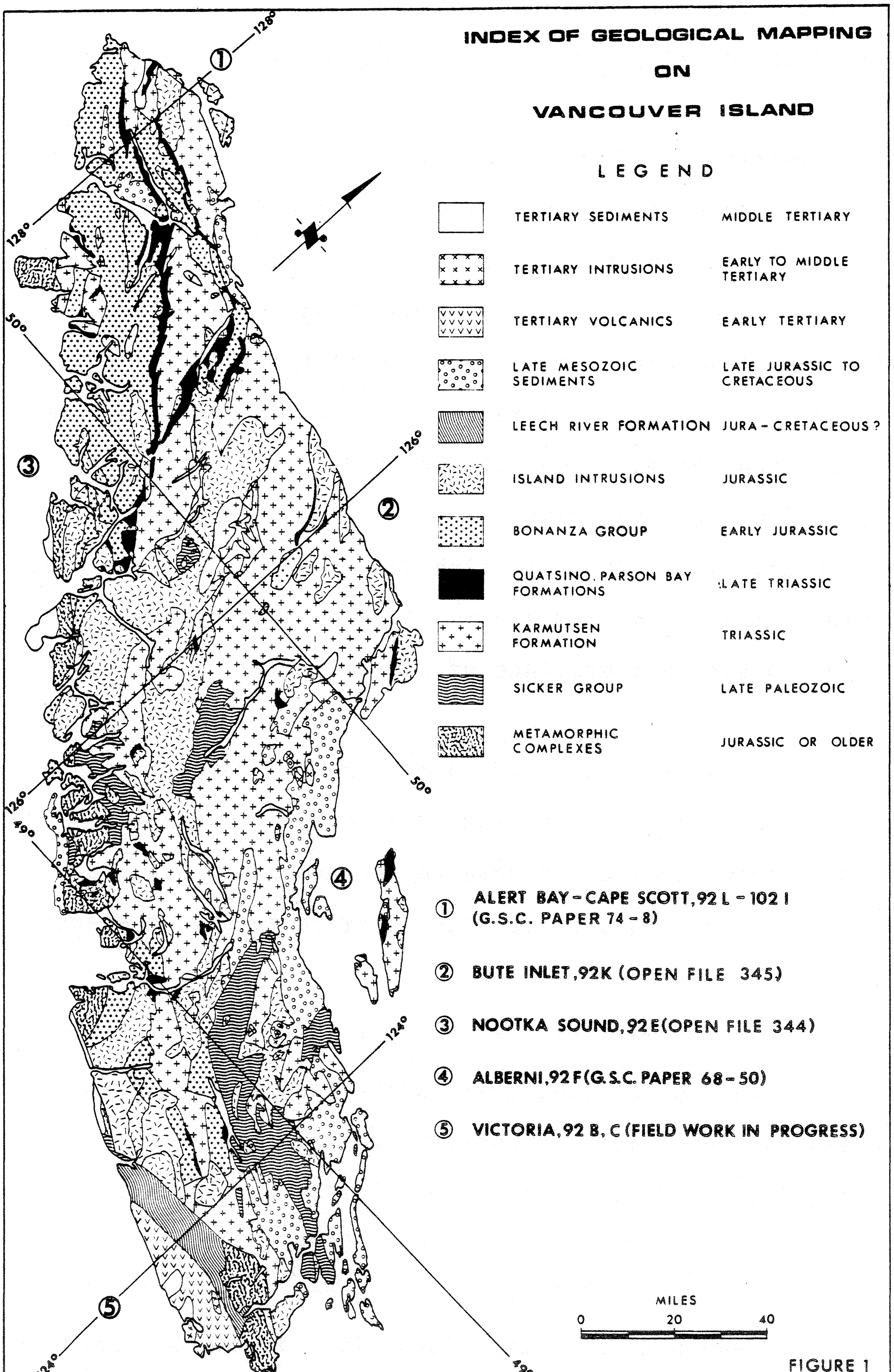

INDEX OF GEOLOGICAL MAPPING
ON
VANCOUVER ISLAND
LEGEND
TERTIARY SEDIMENTS — MIDDLE TERTIARY
TERTIARY INTRUSIONS — EARLY TO MIDDLE TERTIARY
TERTIARY VOLCANICS — EARLY TERTIARY
LATE MESOZOIC SEDIMENTS — LATE JURASSIC TO CRETACEOUS
LEECH RIVER FORMATION — JURA-CRETACEOUS?
ISLAND INTRUSIONS — JURASSIC
BONANZA GROUP — EARLY JURASSIC
QUATSINO, PARSON BAY FORMATIONS — LATE TRIASSIC
KARMUTSEN FORMATION — TRIASSIC
SICKER GROUP — LATE PALEOZOIC
METAMORPHIC COMPLEXES — JURASSIC OR OLDER
① ALERT BAY-CAPE SCOTT, 92 L-102 I (G.S.C. PAPER 74-8)
② BUTE INLET, 92K (OPEN FILE 345)
③ NOOTKA SOUND, 92 E (OPEN FILE 344)
④ ALBERNI, 92 F (G.S.C. PAPER 68-50)
⑤ VICTORIA, 92 B, C (FIELD WORK IN PROGRESS)
MILES
0
20
40
128°
126°
124°
50°
49°

FIGURE 1

1950), J.T. Fyles (1948-1951), G.E.P. Eastwood (1961-1962), W.J. Jeffery (1960-1964) and K.E. Northcote (1968-1973) of the British Columbia Department of Mines and Petroleum Resources. In addition the work of D. Carlisle, D.J.T. Carson, R. Surdam and R.W. Yole in the period 1960 to 1970 deserves special mention. The work of all these geologists and that of the author since 1963 has been compiled into a 1:250,000 map (see also Figure 1). The compiler especially acknowledges the invaliable collaboration in field and office of the following colleages: B.E.B. Cameron, D. Carlisle, D.J.T. Carson, W.G. Jeffery, J.A. Jeletzky, and K.E. Northcote. Fundamental to the work was also isotopic dating by R.K. Wanless and paleontological dating by B.E.B. Cameron, C.A. Ross, H. Frebold, J.A. Jeletzky and E.T. Tozer.

The island is the main component of the Insular Belt, the westernmost major tectonic subdivision of the Canadian Cordillera. Narrow strips of land on the west and south coast are newly discovered fragments of the Pacific Belt that is well developed in the western United States and Alaska (Figures 2, 3). The Insular Belt (Island Mountains) contains middle Paleozoic and Jurassic volcanic-plutonic complexes, both apparently underlain by gneiss-migmatite terranes and overlain respectively by Permo-Pennsylvanian and Cretaceous clastic sediments. A thick shield of Upper Triassic basalt, overlain by carbonate-clastic sediments, separates these two complexes in space and time. Post orogenic Tertiary clastic sediments fringe the west coast.

The Pacific Belt on the western and southern rim of the island contains in its inner (eastern) part an assemblage of Late Jurassic to Cretaceous slope and trench deposits, deformed to melange and schist, and an outer part of Eocene oceanic basalt and subjacent

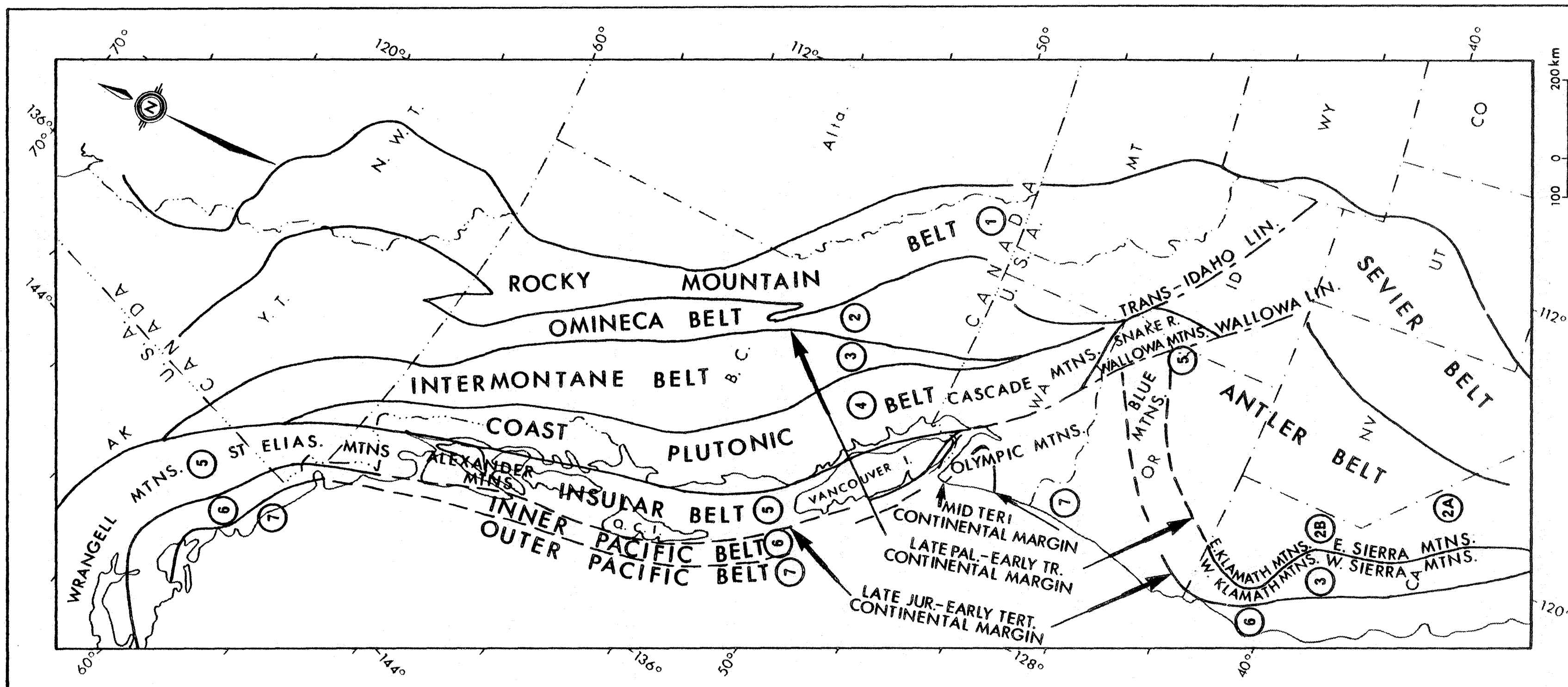
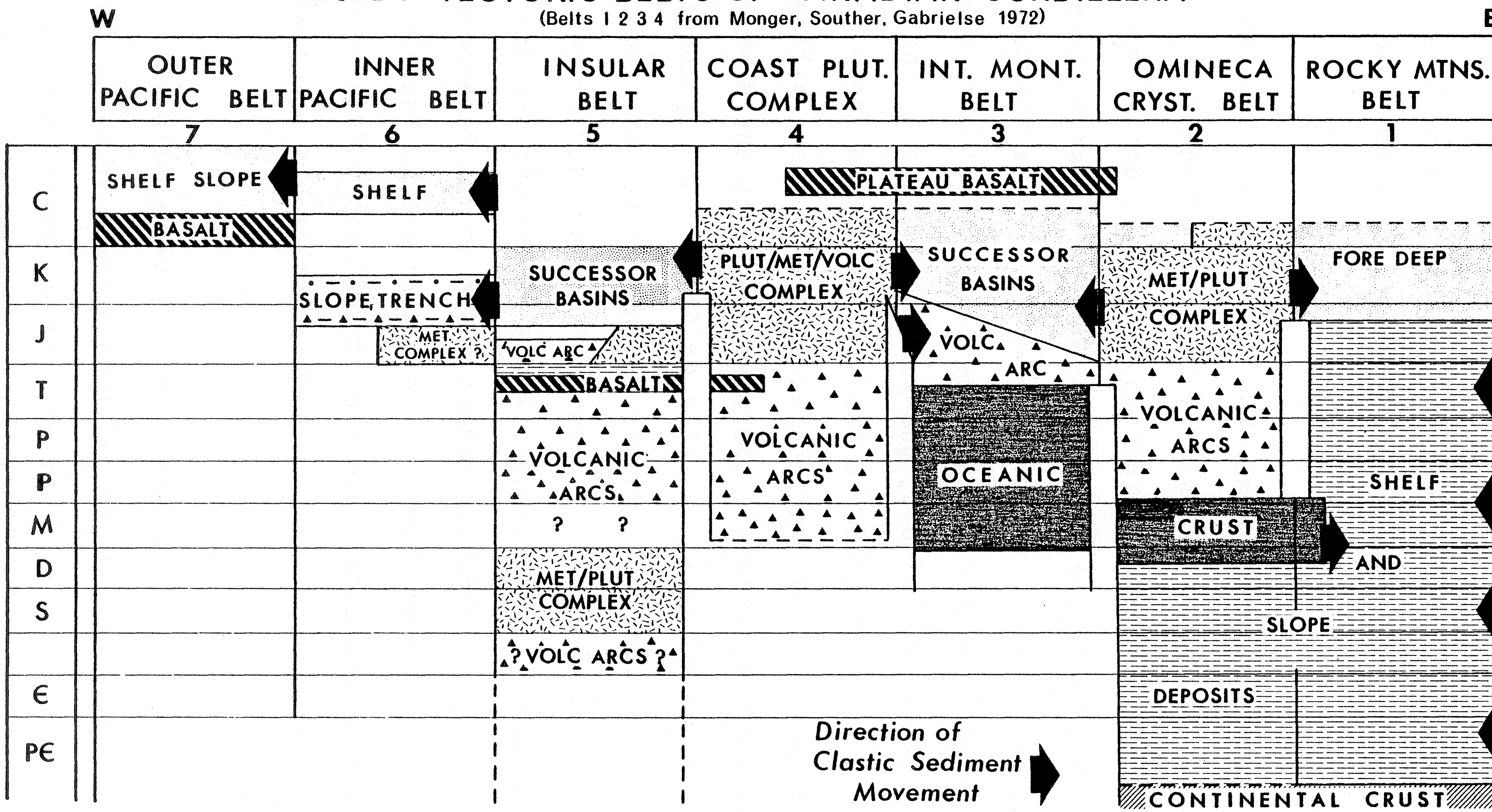

ROCKY MOUNTAIN BELT
OMINECA BELT
INTERMONTANE BELT
COAST PLUTONIC BELT
INSULAR BELT
INNER PACIFIC BELT
OUTER PACIFIC BELT
CASCADE BELT
SEVIER BELT
ANTLER BELT
TRANS-IDAHO LIN.
WALLOWA LIN.
SNAKE R.
WALLOWA MTNS.
BLUE MTNS.
WA MTNS.
OLYMPIC MTNS.
VANCOUVER I.
Q. C. I.
ALEXANDER MTNS.
ST. ELIAS. MTNS.
WRANGELL MTNS.
E. KLAMATH MTNS.
W. KLAMATH MTNS.
E. SIERRA MTNS.
W. SIERRA MTNS.
MID TERT CONTINENTAL MARGIN
LATE PAL.-EARLY TR. CONTINENTAL MARGIN
LATE JUR.-EARLY TERT. CONTINENTAL MARGIN
N. W. T.
Y. T.
B. C.
Alta.
AK
MT
WY
CO
ID
UT
NV
OR
CA
WA
CANADA
U.S.A.
200 km
100
0

FIGURE 2

FIGURE 3 TECTONIC BELTS OF CANADIAN CORDILLERA

(Belts 1 2 3 4 from Monger, Souther, Gabrielse 1972)



basic crystalline rocks.

The following sections briefly describe the lithology, origin and structural relations of the formations of Vancouver Island (see also Figures 4, 5).

Wark and Colquitz Gneiss. The names Wark and Colquitz were applied by Clapp (1913) to the mafic and sialic parts of the gneiss complex exposed in and near the city of Victoria. The Wark Gneiss consists of fine to medium crystalline, massive to gneissic biotite-hornblende diorite and quartz diorite. Colquitz Gneiss is lighter coloured, commonly well foliated biotite-hornblende quartz diorite to granodiorite gneiss. Wark and Colquitz gneisses are in places intimately interlayered, but it is possible to map distinct belts where one or the other predominates. The light coloured gneisses are believed to have been derived from clastic sediments, whereas the dioritic rocks are recrystallized basaltic sills or flows. One zircon age determination from Colquitz Gneiss has yielded discordant ages between 295 and 384 Ma, possibly suggesting early Paleozoic source rocks. K-Argon ages on metamorphic hornblende from Wark diorite are 163 and 182 Ma, indicating early Jurassic metamorphism of the Paleozoic parent rock that was perhaps part of the Sicker Group. No stratigraphic contacts with other formations have been found, but volcanic rocks, tentatively correlated with Jurassic Bonanza volcanics may overlie them unconformably.

Sicker Group. The Sicker Group comprises all known Paleozoic rocks of Vancouver Island and is subdivided into a lower volcanic formation, a middle greywacke-argillite formation, and an upper limestone formation. The group is exposed in narrow, fault-bounded uplifts. The largest, Horne Lake-Cowichan Lake uplift, is the southernmost,

FIGURE 4

TABLE OF FORMATIONS OF VANCOUVER ISLAND

	SEQUENTIAL LAYERED ROCKS								CRYSTALLINE ROCKS, COMPLEXES OF POORLY DEFINED AGE				
ERA	PERIOD		STAGE	GROUP	FORMATION	SYMBOL	AVE. THICK. in m	LITHOLOGY	NAME	SYMBOL	ISOTOPIC AGE Pb/U	ISOTOPIC AGE K/Ar	LITHOLOGY
CENOZOIC					late Tert. volc's of Port McNeill	Tvs							
					SOOKE BAY	mpTSB		conglomerate, sandstone, shale					
			EOCENE to OLIGOCENE		CARMANAH	eoTc	1,200	sandstone, siltstone, coglomerate					
					ESCALANTE	eTE	300	conglomerate, sandstone	SOOKE INTRUSIONS silicic	Tg		32–59	quartzdiorite, trondhjemite, agmatite, porphyry
									SOOKE INTRUSIONS basic	Tgb		31–49	gabbro, anorthosite, agmatite
			early EOCENE		METCHOSIN	eTM	3,000	basaltic lava, pillow lava, breccia, tuff	METCHOSIN SCHIST, GNEISS	TMn		47	chlorite schist, gneissic amphibolite
MESOZOIC		LATE	MAESTRICHTIAN	NANAIMO	GABRIOLA	uKGA	350	sandstone, conglomerate	LEECH RIVER FM.	JKL		38–41	phyllite, mica schist, greywacke, argillite, chert
					SPRAY	uKS	200	shale, siltstone					
			CAMPANIAN		GEOFFREY	uKG	150	conglomerate, sandstone					
					NORTHUMBERLAND	uKN	250	siltstone, shale, sandstone					
					DE COURCY	uKDC	350	conglomerate, sandstone					
					CEDAR DISTRICT	uKCD	300	shale, siltstone, sandstone					
					EXTENSION - PROTECTION	uKEP	300	conglomerate, sandstone, shale, coal					
			SANTONIAN		HASLAM	uKH	200	shale, siltstone, sandstone					
					COMOX	uKC	350	sandstone, conglomerate, shale, coal					
		EARLY	CENOMANIAN ALBIAN	QUEEN CHARLOTTE	Conglomerate Unit	lKQC	900	conglomerate, greywacke					
			APTIAN?		Siltstone Shale Unit	lKQP	50	siltstone, shale					
			VALANGINIAN BARREMIAN		LONGARM	lKL	250	greywacke, conglomerate, siltstone					
	JURASSIC	MID-LATE	TITHONIAN CALLOVIAN		Upper Jurassic Sediment Unit	uJs	500	siltstone, argillite, conglomerate	PACIFIC RIM COMPLEX	JKP			greywacke, argillite, chert, basic volcanics, limestone
		EARLY	TOARCIAN?	BONANZA	Volcanics	lJB	1,500	basaltic to rhyolitic lava, tuff, breccia, minor argillite, greywacke	ISLAND INTRUSIONS	Jg		141–181	granodiorite, quartzdiorite, granite, quartz monzonite
			PLIENSBACHIAN SINEMURIAN		HARBLEDOWN	lJH		argillite, greywacke, tuff	WESTCOAST COMPLEX silicic	PMns	264	163–192	quartz-feldspargneiss, metaquartzite, marble
									WESTCOAST COMPLEX basic	PMnb			hornblende-plagioclase gneiss, quartz diorite, agmatite, amphibolite
	TRIASSIC	LATE	NORIAN	VANCOUVER	PARSON BAY	uTrPB	450	calcareous siltstone, greywacke, silty-limestone, minor conglomerate, breccia					
			KARNIAN		QUATSINO	uTrQ	400	limestone					
					KARMUTSEN	muTrK	4,500	basalic lava, pillow lava, breccia, tuff	diabase sills	PTrb			
		MID	LADINIAN		Sediment-Sill Unit	Tds	750	metasiltstone, diabase, limestone	metavolcanic rocks	PMmv			metavolcanic rocks, minor metasediments; limestone, marble
PALEOZOIC	PENN. and ? PERM.			SICKER	BUTTLE LAKE	CPBL	300	limestone, chert					
					Sediments	CPSS	600	metagreywacke, argillite, schist, marble					
					Volcanics	CPSV	2,000	basaltic to rhyolitic metavolcanic flows, tuff, agglomerate					
	DEV. or EARLIER?								TYEE INTRUSIONS	Pg	>390		metagranodiorite, metaquartzdiorite, metaquartz porphyry
									COLQUITZ GNEISS	Pns	>390		quartz feldspar gneiss
									WARK DIORITE GNEISS	Pnb	>200	163–182	hornblende-plagioclase gneiss, quartz diorite, amphibolite

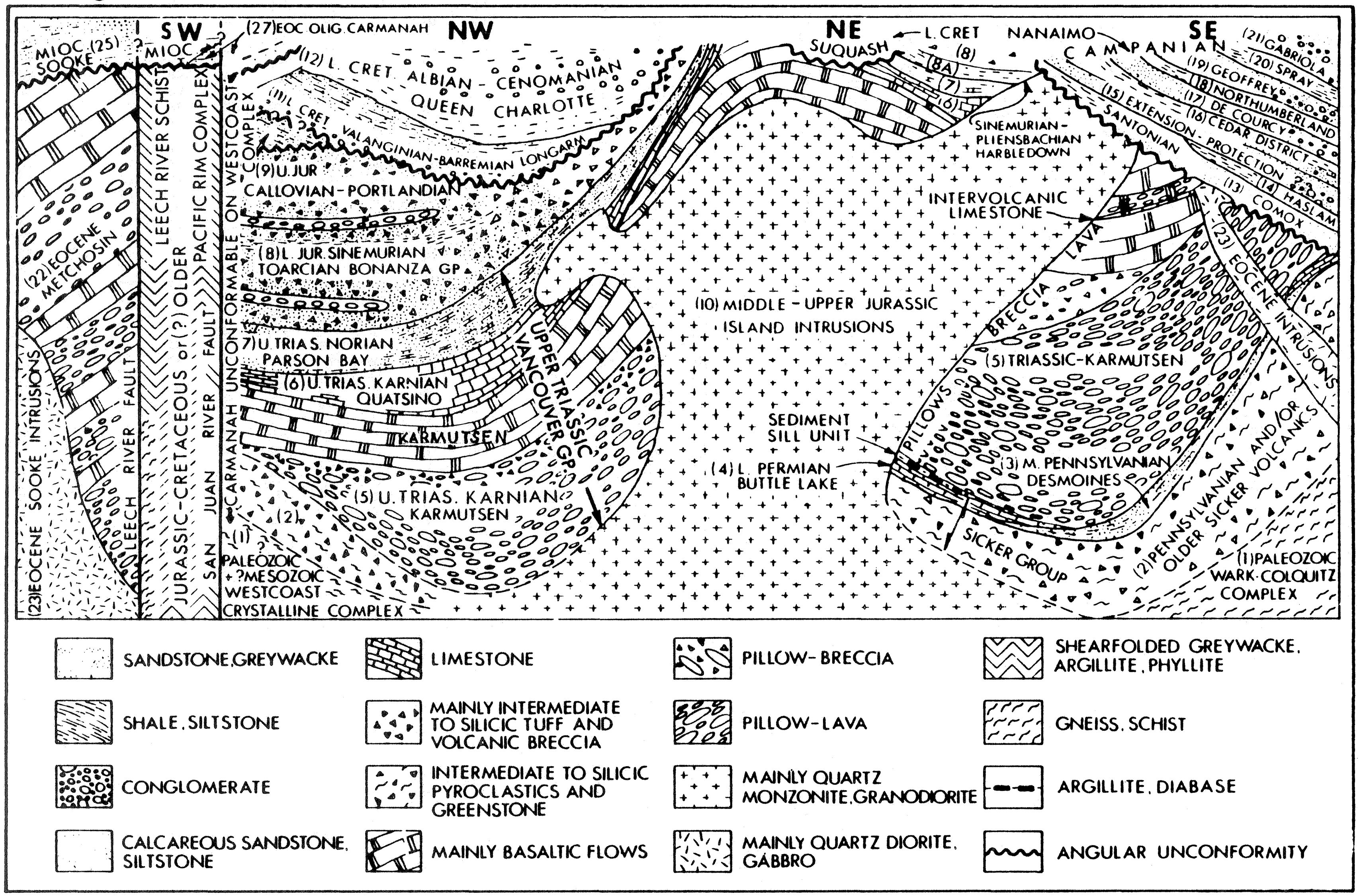
the Buttle Lake uplift lies in the centre, and some smaller outcrop areas occur to the northwest in the Nimpkish region.

The volcanic rocks range from fine grained banded tuffs to breccias with clasts 10 cm or more in size and agglomeratic lava flows. Flows, tuffs and related dykes commonly contain phenocrysts of uralitized pyroxene and albitized plagioclase. A few chemical analyses indicate chemical compositions ranging from basalt to rhyolite. Although internal structure is generally well preserved the rocks are mostly of low greenschist chlorite-actinolite metamorphic rank. Locally they are shear-folded and converted to well foliated chlorite-actinolite schist. The thickness is estimated to be between 1,000 and 3,000 metres. Only one K-Ar age determination on actinolite in uralite porphyry from Saltspring Island yielded an age of 308 $\pm$ 14 Ma (L.R. Armstrong, pers. comm. 1975). The apparent age of metamorphism is thus Pennsylvanian and the primary age must be earlier Pennsylvanian or older.

The greywacke-argillite sequence occurs in graded beds, a few millimetres to several centimetres thick, of argillite and silt-stone, or in beds up to several decimetres thick of greywacke sandstone. The greywacke locally contains lenses of detrital limestone. The formation is commonly silicified and, like the volcanic rocks, its structure varies from almost flat lying to isoclinally folded. Total thickness is estimated to be about 600 metres. Fusulinids and other foraminifera, obtained from the limestones, indicate a Middle Pennsylvanian (Desmoinesian) age.

The Buttle Lake Formation, youngest part of the Sicker Group, is exposed in many places along the margins of the uplifts where Paleozoic rocks are overlain by the Karmutsen Formation. Yole (1969) measured a type section in the mountains west of Buttle Lake

Fig. 5 RELATIONSHIPS OF FORMATIONS OF VANCOUVER ISLAND



of 320 m (1050 feet) of interbedded crinoidal limestone and chert. On the basis of brachiopods and a single fusulinid he dated the rocks as Early Permian (Wolfcamp to Leonard) but Sada and Danner (1974) determined a Middle Pennsylvanian age on the basis of fusulinids for the limestone at Horne Lake.

The Sicker Group formations may be a continuous succession, but the possibility of an unconformity between the broadly folded Buttle Lake limestone and the commonly tightly folded greywacke-argillite sequence cannot yet be excluded. Furthermore, as parts of it are invaded by Devonian or older Tyee Intrusions, the group may represent several tectonic units of which the oldest would appear to be pre Devonian. That question remains to be solved by further structural and isotopic investigation.

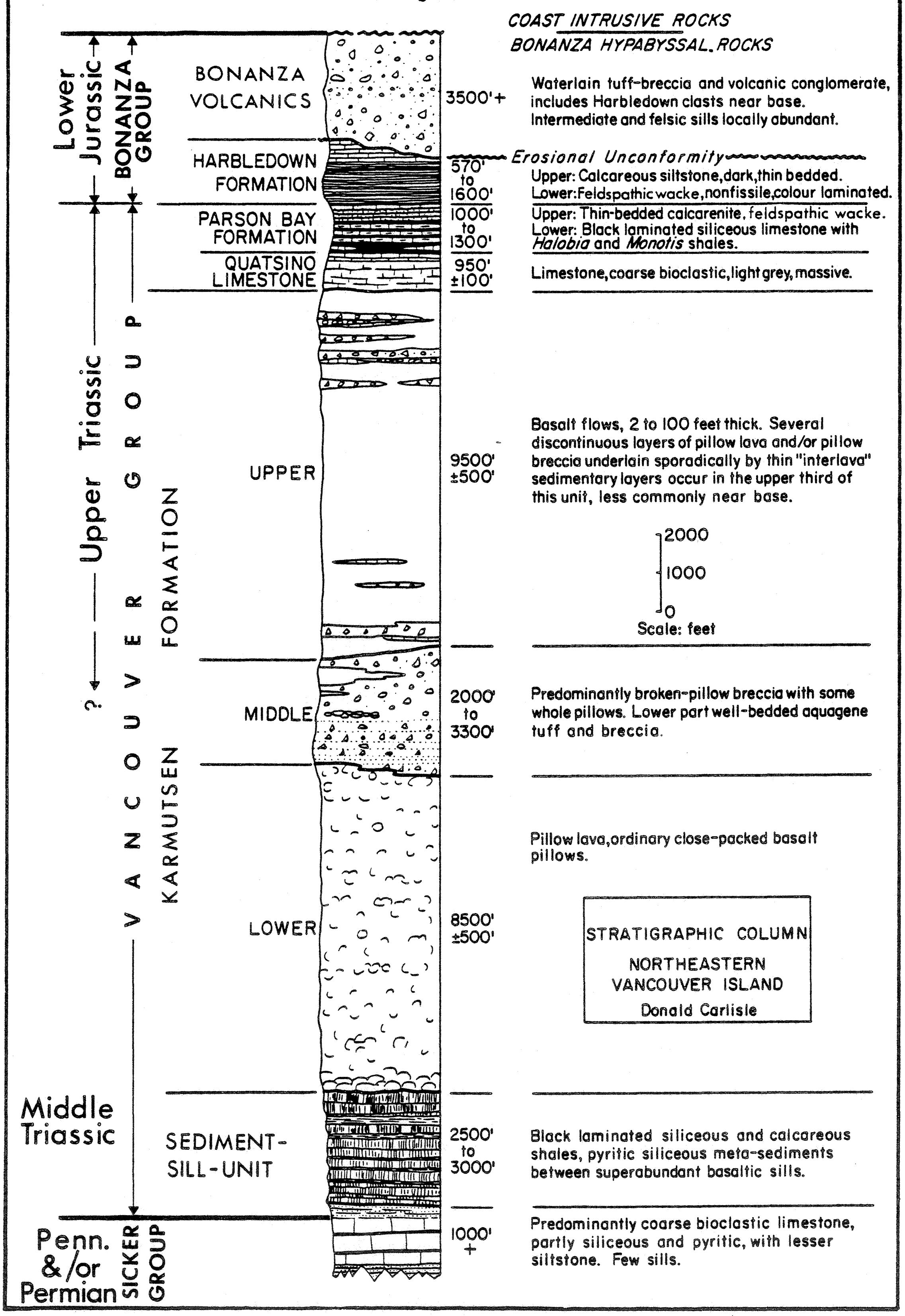
Sicker Group rocks are the apparent remnant of a mid-Paleozoic volcanic arc, built on oceanic crust or perhaps on the continental edge. After volcanism ceased the volcanic rocks were covered by clastic and carbonate sediments.

Tyee Intrusions. Tyee Intrusions were originally mapped by Clapp and Cooke (1917) on Saltspring Island and northwestward to Maple Bay on Vancouver Island. Only recently a pre-Jurassic age was suspected in view of highly altered and partly schistose lithology, entirely distinct from that of Island Intrusions. This has been confirmed by zircon dating, which suggests a minimum age of 360 Ma. They are in part altered granitoid rocks composed mainly of quartz, sericitic albite and microcline-perthite, with minor epidote and chlorite. Commonly the texture is cataclastic. In part they are sericite schist with elongated quartz eyes up to 1 cm long, occurring as sills. The schistosity is parallel to that of the intruded metavolcanics and metagreywacke of the Sicker Group however the intrusive contacts are discordant with the metamorphic grain. The apparent Early or pre-Devonian age, if confirmed, would indicate that part of the Sicker Group is pre-Devonian.

Vancouver Group. The Vancouver Group is composed of an unnamed basal unit and the Karmutsen, Quatsino and Parson Bay Formations. The basalt unit is in part thin-bedded black argillite, containing Middle Triassic (Ladinian) Daonella. The beds, only known from the northeast flank of Mt. Schoen, are about 200 m thick, but are intruded by a greater thickness of diabase sills, bringing total thickness of sediments and sills to about 750 m.

Karmutsen Formation. The Karmutsen Formation, named by Gunning (1932) is composed of tholeiitic volcanic rocks, up to 6,000 m thick and underlying a large part of the island (Figure 6). In Carlisle's (1974) standard section the formation is composed of a lower member, about 2,600 m thick, of pillow lava; a middle member, about 800 m thick, of pillow breccia and aquagene tuff; and an upper member, about 2,900 m thick, of massive flows with minor interbedded pillow lava, breccia and sedimentary layers. Except in contact zones with granitic intrusions the volcanics exhibit low-grade metamorphism up to prehnite-pumpellyite grade. Their age is determined by that of the underlying Ladinian unit and by Upper Triassic, Karnian fossils in sediments in the upper member. The basaltic eruptions apparently started with pillow lavas in a deep marine rift basin, continued with aquagene tuff and breccia as the basin became shallower, and terminated with extrusion of subareal basalt flows. Because the volcanics were formed on a rifting oceanic crust they are probably only in some areas underlain by Sicker Group rocks, whereas elsewhere

Figure 6


COAST INTRUSIVE ROCKS
BONANZA HYPABYSSAL ROCKS
Lower Jurassic
BONANZA GROUP
BONANZA VOLCANICS
3500'+
Waterlain tuff-breccia and volcanic conglomerate, includes Harbledown clasts near base. Intermediate and felsic sills locally abundant.
Erosional Unconformity
HARBLEDOWN FORMATION
570' to 1600'
Upper: Calcareous siltstone, dark, thin bedded.
Lower: Feldspathic wacke, nonfissile, colour laminated.
Upper Triassic
VANCOUVER GROUP
PARSON BAY FORMATION
1000' to 1300'
Upper: Thin-bedded calcarenite, feldspathic wacke.
Lower: Black laminated siliceous limestone with Halobia and Monotis shales.
QUATSINO LIMESTONE
950' ±100'
Limestone, coarse bioclastic, light grey, massive.
KARMUTSEN FORMATION
UPPER
9500' ±500'
Basalt flows, 2 to 100 feet thick. Several discontinuous layers of pillow lava and/or pillow breccia underlain sporadically by thin "interlava" sedimentary layers occur in the upper third of this unit, less commonly near base.
2000
1000
0
Scale: feet
?
MIDDLE
2000' to 3300'
Predominantly broken-pillow breccia with some whole pillows. Lower part well-bedded aquagene tuff and breccia.
LOWER
8500' ±500'
Pillow lava, ordinary close-packed basalt pillows.
STRATIGRAPHIC COLUMN
NORTHEASTERN VANCOUVER ISLAND
Donald Carlisle
Middle Triassic
SEDIMENT-SILL-UNIT
2500' to 3000'
Black laminated siliceous and calcareous shales, pyritic siliceous meta-sediments between superabundant basaltic sills.
Penn. &/or Permian
SICKER GROUP
1000' +
Predominantly coarse bioclastic limestone, partly siliceous and pyritic, with lesser siltstone. Few sills.

they constitute new oceanic floor.

Quatsino and Parson Bay Formations. Upper Triassic sediments overlie the Karmutsen in the northern and western part of the island but in the east they were mostly eroded before deposition of Upper Cretaceous sediments. The Quatsino Formation consists of limestone, mainly massive to thick-bedded calcilutite, varying from 25 m to 500 m in thickness and containing ammonites and other fossils of Late Karnian to Early Norian age. The succeeding Parson Bay Formation is in diachronous contact with the Quatsino and in places lies directly on Karmutsen volcanics. It is composed of interbedded calcareous black argillite, calcareous greywacke and sandy to shaly limestone with the proportion and grain size of clastic material generally increasing upward. The thickness is between 300 m and 600 m. Fossils are the pelagic pelecypods Halobia in the Lower Karnian part and Monotis in the Upper Norian part, together with many ammonite genera. The sediments were formed in near- and off-shore basins in the quiescent Karmutsen rift archipelago.

Bonanza Group. The Bonanza Group was originally named by Gunning (1932) and at that time included Upper Triassic sediments now known to belong to the Parson Bay Formation of the Vancouver Group. Nomenclatural as well as geological arguments indicate that the group should not be included in the Vancouver Group, as was done by Hoadley (1953) and previous reports by the writer and others (1969, 1974). The group is mainly represented in the northwest and the southwest of the island and is composed of lava, tuff and breccia, of basaltic rhyolitic and subordinate andesitic and dacitic composition. It contains intercalated beds and sequences of marine argillite and greywacke. In the northeast part of the island where only the sedimentary part of the group is present the rocks are referred to the Harbledown Formation. The Bonanza represents parts of several eruptive centres of a volcanic arc and consequently its stratigraphy varies considerably. A section 2,568 m thick, measured in the northwest at Cape Parkins, contains two sedimentary intercalations 225 and 75 m thick in the lower and upper part of the section. Fossils from Bonanza and Harbledown sediments indicate mainly Early Jurassic Sinemurian age for the northwest and northeast and Pliensbachian age for the southwest.

Island Intrusions and Westcoast Complex. The Island Intrusions are batholiths and stocks of granitoid rocks ranging from quartz diorite (potash feldspar < 10% of total feldspari quartz 5-20%) to granite (potash feldspar > 1/3 of total feldspar; quartz > 20%). They underlie about one quarter of the island's surface and intrude Sicker, Vancouver and Bonanza Group rocks. Within the Bonanza Group they form high-level stocks and dykes of hornblende-quartz-feldspar porphyry and there is an apparent comagmatic relationship between intrusions and volcanics. About 40 K-Argon determinations have yielded dates of 141 to 181 Ma for the intrusions and a few determinations on the volcanics are in the same age range. Preliminary results of Sb/Sr dating of Island Intrusions and also Bonanza volcanics have yielded a 180 Ma isochron age (R.L. Armstrong, pers. comm).

The Westcoast Complex also is genetically related to the Island Intrusions. It is a heterogeneous assemblage of hornblende-plagioclase gneiss, amphibolite, agmatite and quartz diorite or tonalite, exposed in western coastal areas from Barkley Sound to Brooks Peninsula. One age determination on zircon from the complex has yielded near-concordant U/Pb dates of 264 Ma and two K-Argon dates on hornblende from Westcoast rocks are 192 and 163 Ma. The complex is considered to be derived from Sicker and Vancouver Group rocks, migmatized in Early Jurassic time. Its mobilized granitoid part is considered to be the source of Island Intrusions and, indirectly, Bonanza volcanics. Available dating suggest that the plutonic-volcanic arc that formed these interrelated crystalline formations became extinct in Middle Jurassic time. A period of uplift and erosion followed.

Upper Jurassic sediments. Upper Jurassic siltstone, greywacke and conglomerate, bearing volcanic, subvolcanic and sedimentary, clasts are exposed in a small coastal area south of Kyuquot Sound. They contain fossils of Middle Jurassic Callovian to Late Jurassic Tithonian age and indicate the beginning of deposition of a clastic wedge on the eroded volcanic-plutonic complex.

Longarm Formation and Queen Charlotte Group. Lower Cretaceous formations are only present in the Quatsino Sound region. They are greywacke, siltstone and conglomerate, mainly derived from volcanic and older sedimentary rocks. A very thick boulder conglomerate of the Queen Charlotte Group carries some clasts of high-level plutonic rocks. The formations overlap eastward onto the pre-Cretaceous erosion surface and nowhere is a complete section of Lower Cretaceous rocks exposed. The total thickness probably does not exceed 1,400 m. Marine fossils indicate Early Cretaceous Valanginian to Barremian age for the Longarm Formation and Aptian to Cenomanian age for the Queen Charlotte Group.

Nanaimo Group. Upper Cretaceous sediments are, in contrast to the Lower Cretaceous, exposed exclusively on the east side of the island and on adjacent Gulf Islands. They consist of cyclical, upward fining sequences of conglomerate, sandstone, shale and coal of non-marine or near-shore deltaic origin, succeeded by marine sandstone, shale and thin-bedded, graded shale-siltstone sequences. Five major cycles are distinguished of which the first four have been divided into two formations each, a lower fluvial to deltaic and an upper marine formation. Coal seams in the lowest cycle of the Comox basin and in the second cycle of the Nanaimo Basin were mined from 1850 to about 1950. Macrofossils and microfossils indicate a Late Cretaceous Santonian to Maastrichtian age. The Nanaimo Group was deposited in a fore-arc basin between the Coast Plutonic Belt (then an active volcanic arc) and the Insular Belt.

Carmanah and Escalante Formations. Tertiary clastic sediments overlie bevelled Island Mountain rocks in a narrow strip of land along the west coast and also are exposed on most of the continental shelf west of the island. The Escalante Formation is a basal conglomerate of Eocene age about 300 m thick, and is overlain by the Carmanah Formation of mainly siltstone and sandstone, about 1,200 m thick. The contained microfauna of the Carmanah is mainly correlative to the Refugian stage of the western United States (late Eocene to early Oligocene) but younger beds are of Zemorrian (middle to late Oligocene) age (B.E.B. Cameron and W.W. Rau, personal communications, 1973). The beds overlie Insular Belt rocks as well as the Leech River Formation of the Pacific Belt with clear angular unconformity. They were deposited on the upper part of a coastal shelf area, but many beds are sedimentary melanges that were redeposited by massive slumping. The formations may have extended much farther eastward but were removed from the land-area by Late Tertiary and Pleistocene erosion.

Pacific Rim Complex and Leech River Formation. The Pacific Rim Complex is exposed mainly in the western coastal area between Ucluelet and Tofino in Pacific Rim National Park. It is composed mainly of greywacke and argillite with minor ribbon chert, basic volcanic rocks, limestone and conglomerate. The rocks are generally highly faulted and sheared and in many places are tectonic melanges. Locally the cherts contain radiolarians indicating Tithonian age (A.E. Pessagno, in Muller, 1976) and the greywacke has yielded Buchia's of Valanginian age (J.A. Jeletzky, pers. comm., 1972). The rocks are therefore in part coeval to Upper Jurassic sediments and the Longarm Formation. Granitoid clasts in the conglomerate indicate probable correlation with the Aptian conglomerate of the Queen Charlotte Group.

The Leech River Formation is exposed in a belt, 2 to 12 km wide, between San Juan and Leech River Faults on southern Vancouver Island. Like the Pacific Rim Complex the rocks are greywacke, argillite and minor chert and volcanic rocks but they are largely metamorphosed to schist. Metamorphic grades increase from phyllite in the north to garnet-biotite schist with andalusite porphyroblasts near Leech River Fault in the south. There muscovite gneiss and pegmatite with large muscovite and tourmaline crystals also are present. The age of metamorphism according to several K-Argon determinations is 40 Ma.

The Pacific Rim Complex and Leech River Formation are interpreted as a tectonized assemblage of slope and trench sediments and their metamorphic equivalents, formed in a Late Jurassic to Cretaceous trench off the continental margin. They are equivalent in age and facies to the Franciscan Terrane of California although the metamorphic facies is apparently different. It is postulated that the volcanic arc, paired to this trench, is the Coast Plutonic complex and that Upper Jurassic and Cretaceous clastic sediments of the Insular Belt were deposited in the arc-trench gap.

Metchosin Volcanics and Sooke Intrusions. Metchosin Volcanics underlie most of the south tip of Vancouver Island, south of Leech River Fault. They are pillow lavas, aquagene tuff and breccia and amygdaloidal flows of tholeiitic composition very similar to Karmutsen volcanics in lithology and sequence, but of lesser thickness, estimated at about 4,000 m. Dyke complexes of basalt and diabase intrude and underlie the volcanics. On the basis of Turritella within intercalated volcanic sandstone at Albert Head, in the middle part of the sequence, the volcanics are apparently of early Eocene age.

Chlorite schist and hornblende-plagioclase gneiss, exposed mainly in the area west of Jordan River, are interpreted as highly deformed and metamorphosed equivalents of Metchosin Volcanics. Hornblende from hornblende-plagioclase gneiss yielded a K-Argon date of 47 Ma.

The Sooke Intrusions are in part gabbro, commonly coarse grained, and with minor anorthosite, apparently underlying the Eocene volcanics. Also present are gneissic amphibolite, hornblende gabbro, angular agmatite and small stocks of tonalite, presumably formed by migmatization, mobilization and intrusion into the volcanic sequence. Metchosin Volcanics and Sooke Intrusions could be interpreted as the upper and lower parts of new oceanic crust formed in Early Tertiary time.

Small plutons a few km in diameter intrude various pre-Tertiary rocks of the Insular Belt in many places. They also form sills in flat lying Upper Cretaceous sediments, the thickest one, at Constitution Hill, is about 300 m thick. They also intrude the Pacific Rim Complex near Tofino. They are composed of quartz diorite and quartz diorite porphyry with hornblende and plagioclase phenocrysts, and of breccia that may have formed in a diatreme. K-Argon determinations have yielded dates between 32 and 59 Ma. The intrusions may be subvolcanic eruption centres, aligned on three subcrustal fracture zones, radiating from the Tofino area respectively towards Zeballos, Mt. Washington and the upper Nanaimo River. However, no fractures or faults clearly related to the intrusions have been identified (Carson, 1973).

Sooke Bay Formation. The Sooke Bay Formation (modified from "Sooke Formation" to allow distinction from "Sooke Intrusions") occurs in depressions on the erosion surface of Metchosin Volcanics and Sooke Intrusions. It is probably less than 200 m thick and does not extend north of Leech River Fault. It contains locally coquina's of shallow water pelecypods indicating Miocene age, but the microflora may indicate early Pliocene age as well (Shouldice, 1971). The formation is of fluvial to deltaic origin.

Late Tertiary volcanic rocks are exposed in small areas south of Port McNeill. They are basalt, almost unconsolidated tuff and breccia, volcanic boulder conglomerate and light coloured dacite tuff. Whole-rock K-Argon determinations yielded dates of 7.6 and 7.9 Ma.

Structure. The structure of the island is almost entirely dominated by steep faults. Only the flysch-type Pennsylvanian and Jura-Cretaceous sediments and associated thin-bedded tuffs show isoclinal shear-folding. Faulting and rifting probably occurred during the outflow of Karmutsen lavas in Late Triassic time, establishing the northerly and westerly directed fault systems affecting Sicker and Vancouver Group rocks. Faulting in a northwest direction, accompanied by southwestward tilting in the west, and later by northeastward tilting in the east (the latter affecting Upper Cretaceous sediments) occurred in late Mesozoic to Early Tertiary time. Faulting in a northeasterly direction affected younger Mesozoic and early Tertiary rocks. The important San Juan and Leech River Faults were active respectively in late Mesozoic and Early Tertiary time and may be structures associated with subduction zones.

Mineral Deposits. Much of the coal in the Nanaimo Group, worked since 1850, has been depleted, especially in the Nanaimo Basin. In the Comox Basin there are still some doubtfully economic reserves of high volatile bituminous coal. The most important metallic ore deposits are: (1) massive sulphides of Zn, Cu, Pb, Au, Ag in Sicker volcanics (Western Mines); (2) skarn deposits of Cu and Fe in Quatsino limestone (Argonaut, Texada, Coast Copper, etc.;) (3) porphyry copper deposits surrounding and within high level Island Intrusions (Island Copper) or in the Sooke Intrusions (Mt. Washington, Catface); (4) Cu in shearzones in amphibolized Sooke gabbro (Jordan River).

Glaciation. The entire island was glaciated during the Pleistocene. During an older glaciation, perhaps early Wisconsin, the entire island was covered by an ice-sheet, continuous across the Georgia Depression and generally flowing southwestward. Peaks with ice margins at present 1,000 to 1,500 m levels formed monadnocks and are readily recognized in the landscape. In one or more later glacial events ice probably accumulated in a northern, a middle and a southern centre, formed piedmont glaciers in Nimpkish, Alberni and Cowichan Valleys and flowed out from these with ice tongues into many valleys now occupied by finger lakes. The Strait of Georgia was also occupied by ice that flowed south across the Gulf Islands and the Victoria-Sooke region. Marine transgression during deglaciation attained elevations of 150 m along the east coast and 50 m along the west coast. The complex history of glaciation of the island is still awaiting detailed analysis.

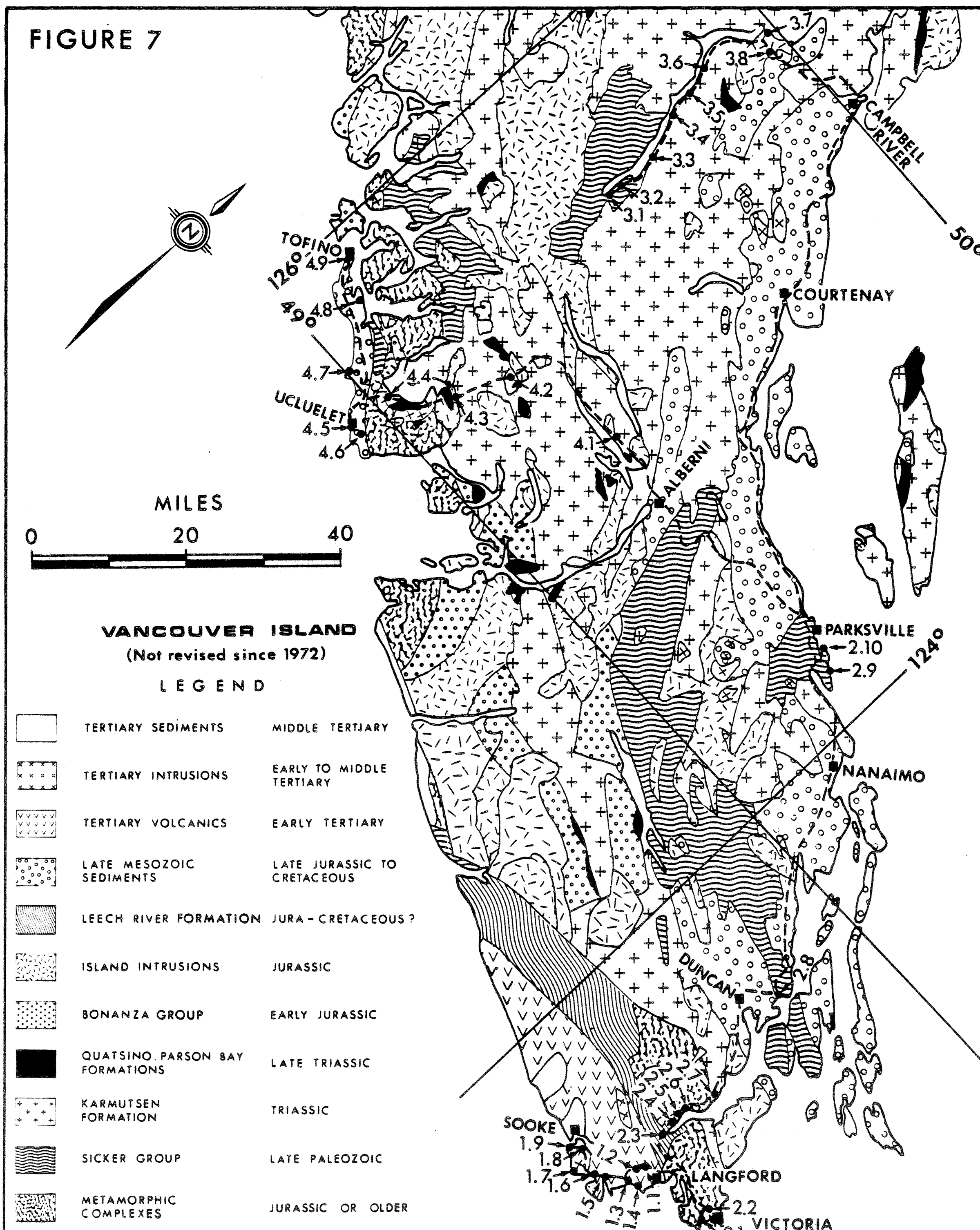

MILES
0
20
40
VANCOUVER ISLAND
(Not revised since 1972)
LEGEND
TERTIARY SEDIMENTS — MIDDLE TERTIARY
TERTIARY INTRUSIONS — EARLY TO MIDDLE TERTIARY
TERTIARY VOLCANICS — EARLY TERTIARY
LATE MESOZOIC SEDIMENTS — LATE JURASSIC TO CRETACEOUS
LEECH RIVER FORMATION — JURA-CRETACEOUS?
ISLAND INTRUSIONS — JURASSIC
BONANZA GROUP — EARLY JURASSIC
QUATSINO, PARSON BAY FORMATIONS — LATE TRIASSIC
KARMUTSEN FORMATION — TRIASSIC
SICKER GROUP — LATE PALEOZOIC
METAMORPHIC COMPLEXES — JURASSIC OR OLDER
CAMPBELL RIVER
50°
COURTENAY
TOFINO
126°
49°
UCLUELET
ALBERNI
PARKSVILLE
124°
NANAIMO
DUNCAN
SOOKE
LANGFORD
VICTORIA
3.1
3.2
3.3
3.4
3.5
3.6
3.7
3.8
4.1
4.2
4.3
4.4
4.5
4.6
4.7
4.8
4.9
2.1
2.2
2.3
2.8
2.9
2.10
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9

FIGURE 7

Part II

Roadlog for 4-day Geological excursion in south and central Vancouver Island

The four days of this field trip deal each with distinct parts of the geological column of the island.

Day 1 is spent in the Sooke-Metchosin area, examing rocks in the Metchosin Block, south of Leech River Fault. They are the pillowed and the layered lava flows, aquagene tuffs and breccias of the Eocene tholeiitic Metchosin Volcanics. The underlying rocks comprise a dyke complex and gabbro and derivative quartz dioritic to trondhjemitic intrusive rocks.

Day 2 begins in the city of Victoria from where the tour proceeds along the Island Highway and some detours via Duncan and Nanaimo to Parksville. Participants will see the Colquitz and Wark Gneiss "basement" complex, the Jura-Cretaceous Leech River Formation and the Paleozoic Sicker Group and Tyee Intrusions.

Day 3 is spent mainly alongside Buttle Lake, following a drive from Parksville via Courtenay and Campbell River. Rocks to be seen include additional volcanics and the Buttle Lake limestone of the Sicker Group, the pillowed, clastic and layered members of the Upper Triassic Karmutsen Formation, overlying Upper Triassic sediments intruded by subvolcanic Jurassic rocks and granitoid Island Intrusions.

Day 4 is spent driving across the island via Beaufort Range, Alberni Valley, Sproat Lake and Kennedy River across the Island Mountains to Pacific Rim Park on the Pacific Ocean. Additional outcrops of the Karmutsen and Island Intrusions plus some of the Triassic Quatsino limestone and Jurassic Bonanza volcanics are seen but the main objective is the sediments and volcanics of the Jura-

Cretaceous Pacific Rim Complex with it characteristic melanges. The return trip leads via Alberni, Parksville to Nanaimo and from there by B.C. Ferries to Vancouver.

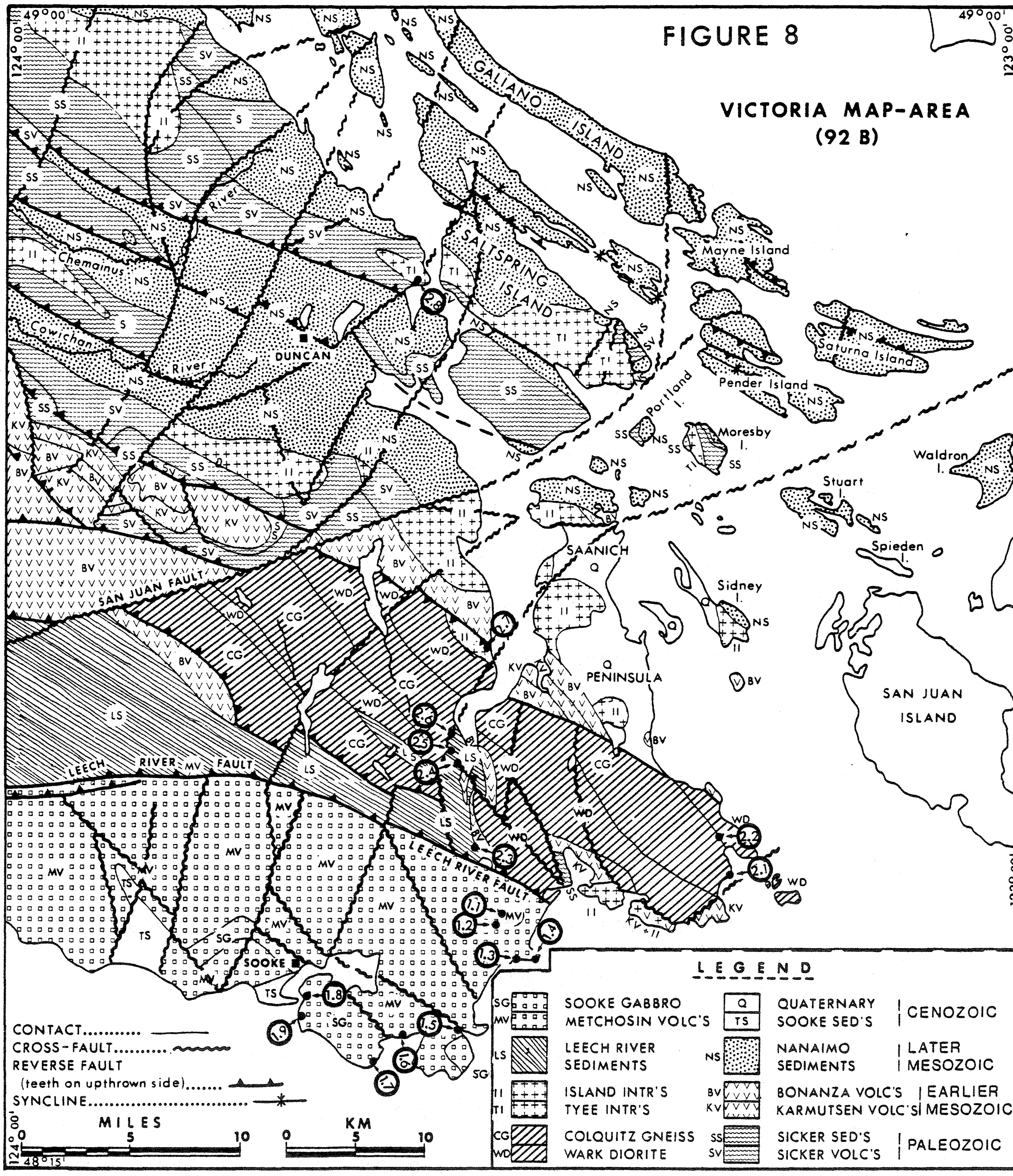


FIGURE 8
VICTORIA MAP-AREA
(92 B)
49°00'
124°00'
123°00'
48°15'
GALIANO ISLAND
SALTSPRING ISLAND
Mayne Island
Saturna Island
Pender Island
Portland I.
Moresby I.
Waldron I.
Stuart I.
Spieden I.
Sidney I.
SAN JUAN ISLAND
SAANICH PENINSULA
DUNCAN
SOOKE
Chemainus
Cowichan River
SAN JUAN FAULT
LEECH RIVER FAULT
CONTACT
CROSS-FAULT
REVERSE FAULT (teeth on upthrown side)
SYNCLINE
MILES 0 5 10
KM 0 5 10
LEGEND
SG SOOKE GABBRO
MV METCHOSIN VOLC'S
LS LEECH RIVER SEDIMENTS
II ISLAND INTR'S
TI TYEE INTR'S
CG COLQUITZ GNEISS
WD WARK DIORITE
Q QUATERNARY
TS SOOKE SED'S
CENOZOIC
NS NANAIMO SEDIMENTS
LATER MESOZOIC
BV BONANZA VOLC'S
KV KARMUTSEN VOLC'S
EARLIER MESOZOIC
SS SICKER SED'S
SV SICKER VOLC'S
PALEOZOIC

DAY 1

METCHOSIN VOLCANICS AND SOOKE INTRUSIONS (EARLY TERTIARY)

From Victoria via Langford to Happy Valley Road

Mileage

11.9 STOP 1-1. Amygdaloidal basalt flows of Metchosin Volcanics at Englewood Road. Like many outcrops in the region the bluff is well glaciated. The subaereal basalt flows are almost horizontal and 2 to 4 m thick. They contain amygdules filled with quartz and locally chlorite and tops and bottoms are distinct in a few places. The rock is composed of a very fine ($\pm$ .05 mm) holocrystalline assemblage of plagioclase (an < 50), colorless pyroxene and olivine, altered to reddish brown iddingsite and magnetite. Metchosin Volcanics are mainly of tholeiitic composition: SiO_2 = 46.5 - 50.4%; K_2O = 0.06 - 0.49%; Na_2O = 1.9 - 4.2%. (8 analyses of random samples). On an AFM diagram they plot in the tholeiitic filed and on the Alkali-SiO_2 diagram they are subalkaline. The flows are the apparent subaereal part of a sequence that begins with submarine pillow lavas.

Continue for 1.6 mile on Happy Valley Road.

13.5 STOP 1-2. Pillow lavas of Metchosin Volcanics. The outcrop shows pillow lavas of the lower submarine part of the formation. The pillows are up to about 30 cm high and more than 1 m wide; there also are some lava tongues. Amygdules appear to be concentrated in the top parts of the pillows.

Continue on Happy Valley Road, turn left towards Colwood and right on Duke Road.

18.3 STOP 1-3. Tuffs with fossil bed and pillow lavas. The tidal exposure behind the residence at 3817 Duke Road exhibits well bedded aquagene tuff and minor basalt. One sedimentary lens, about 1 m thick, contains a great number of slender conical gastropods, identified by W.O. Addicott of the U.S. Geological Survey as Turritella cf T. uvasana hendoni Turner, indicating a probable early Eocene age. Please note: This outcrop is on private property. The owners have over the years been very cooperative in letting many groups of geologists view the outcrop, but do not wish fossils to be collected! A limestone lens farther west has yielded orbitoid foraminifera, probably Discocyclina according to B.E.B. Cameron. The sedimentary layers are believed to be in the middle part of the Metchosin Volcanics. Pillow lavas are well exposed on the islets farther west.

Continue north on Duke Road, turn right on Albert Head Road, enter gate and proceed to "racetrack oval" on south side of Albert Head Military Reserve; turn right .7 mile after gate.

19.8 STOP 1-4. Aquagene tuff and breccia with sills and dykes. In the cove, just east of the oval, breccia with lava fragments up to 30 cm in size is interbedded with aquagene tuff. The breccia is not a typical pillow breccia (they also occur in Metchosin but cannot be shown conveniently) but rather a lahar-like deposit with subangular fragments of fresh, locally scoriaceous basalt in a mudstone matrix. The tuffs are well bedded and show subangular fragments that in thin section appear to be mainly shards and globules of redbrown palagonite, minor feldspar, a few minute shell fragments, bonded by secondary quartz, chlorite and prehnite. Farther west along the shore the beds contain layers with shell debris. The beds are cut by dykes and sills of blocky to columnar basalt. The latter, although they resemble a flow, are different in appearance from typically massive, non-columnar Metchosin flows.

Return to Happy Valley Road and turn left to Metchosin and Rocky Point.

27.1 STOP 1-5. Faultzone near crossing of abandoned C.N. Railway and Rocky Point Road. A wide fault zone from Pedder Bay to Sooke Basin separates northeast dipping Metchosin tuffs from the basal gabbro and dyke complexes of Rocky Point and East Sooke Peninsula. The rocks have been converted to flaky serpentine. The general movement is difficult to see but could be oblique strike-slip, dipping about 20^{o} SE.

Proceed south towards Becher Bay; outcrops where road makes loop near coast.

31.5 STOP 1-7. Dykes and epidotized sediments. The cut shows well layered nearly flat lying epidotized siltstones. In thin section they are a fine-grained (0.02 mm) aggregate of quartz, minor plagioclase, epidote, and prehnite in veinlets. They are cut by numerous dykes that have been recrystallized into a plagioclase-actinolite mesh with scattered magnetite. Plagioclase is in very thin laths, ± 0.3 mm long, and actinolite is in bundles and in veinlets. The dykes were feeders for Metchosin Volcanics but were later thermally metamorphosed.

Proceed and turn left to East Sooke Park.

31.5 STOP 1-7. Sooke Gabbro, East Sooke Park, Aldridge (Petroglyph) Point. There is about a 1 mile hike via a good foot-trail to Aldridge Point, with several markers to "Petroglyphs". The gabbro is coarse grained and has a faint vertical layering, striking northeasterly. A thin section shows an almost unaltered equigranular, anhedral assemblage of variously twinned clear bytownite (An 80$\pm$), colourless pyroxene with exsolution lamellation and including some plagioclase and almost unaltered olivine. Dykelets of lighter coloured rock are of similar composition but richer in feldspar and olivine and with minor interstitial pyroxene. The steep foliation or layering in the gabbro suggests multiple intrusion of vertically planar bodies. The well preserved petroglyphs represent a sea lion and a salmon and are examples of an Indian art form that is wide spread along the Pacific Coast. According to the Indian legend "long years ago a great supernatural animal like a sea-lion killed many of the Becher Bay Indians when canoeing. The tribe became nearly extinct; the remaining members were afraid to go on the water until one day a mythical man caught the sea-lion and turned him into the stone representation as seen on Aldridge Point".

After leaving the park turn left onto East Sooke Road.

38.6 STOP 1-8. Olivine leucogabbro ("anorthosite"). A small roadcut, about ½ mile past East Sooke, shows very coarse grained leucogabbro. Although the hand-specimen appears to consist mainly of plagioclase, a modal analysis showed 77.6% bytownite (An 75$\pm$), 17.0% pyroxene and 5.4% olivine. The rock, with less than 90% plagioclase, does not qualify diorite. The original Paleozoic (?) gabbro has been recrystallized to hornblende-plagioclase gneiss and subsequently has suffered retrograde metamorphism to low greenschist grade. Plagioclase is albitized and sericitized and hornblende is partly changed to epidote, zoisite and chlorite. The gneiss may have been oceanic crust below the Paleozoic Sicker Group volcanic terrane. However, superposition of the volcanics on Wark Gneiss has not been established anywhere.

Via Cedar Hill Crossroad, Mackenzie and Tillicum to Trans Canada Highway; westward on highway to just past Shell station at Goldstream.

21.8 STOP 2-3. Leech River Formation. The formation consists mainly of isoclinally folded flysch-type sediments, converted to phyllitic schists. The outcrop is about 1 km north of the Leech River Fault, the important structure that separates the formation from Metchosin Volcanics. The slaty cleavage of the schist is parallel to the fault at azimuth 300^0. The cleavage shows kinkbands and also slickensides dipping 50^0 southeast, perhaps indicative of oblique movement on the fault. The formation, formerly believed to be Paleozoic, is now with some assurance correlated with the Upper Jurassic to Cretaceous Pacific Rim Complex, although no fossils are known in the Leech River. Both major units are believed to be late Mesozoic slope and trench deposits, formed along the edge of the continent. Several K-Argon dates on metamorphic biotite from schist and gneiss in the formation vary from 36 to 42 Ma indicating late Eocene to earliest Oligocene metamorphism, and probably the time of latest deformation.

Proceed on highway to knoll on right side with hydro-towers, at highway-crossing of power-line.

25.4 STOP 2-4. Leech River Formation, ribbon chert. The base of the hydro-tower is composed of east-west striking vertical ribbon cherts. The beds of black to greenish grey, whitish weathering chert are 1-4 cm thick and separated by films of graphitic matter. Dragfolds in the beds are believed to be soft-sediment slump-folds. Thin sections show them to be silicic rocks, composed of a fine dust of quartz, feldspar and actinolite. Sparse, poorly preserved radiolarians have been found. The rocks are similar to those of Pacific Rim Complex, where in one place less recrystallized dark-red chert has yielded a good radiolarian fauna of Upper Jurassic age (see Stop 4-6). The chert is probably correlative to chert on San Juan Island, about 30 km west of here. The San Juan cherts have until now been dated as Permian on the basis of associated fusulinid-bearing limestone (Danner, 1966), but D.L. Jones and J. Whetten (pers. comm.) have found Tithonian radiolarians in them as well. The outcrop also contains sills of fresh, cataclastic gabbro.

Proceed on highway 1.3 miles to left bend.

26.7 STOP 2-5. Leech River Formation, greywacke and argillite. Outcrops on both sides of highway show thick greywacke units up to 60 cm thick, in places with rip-up shale fragments, separated by thin argillite laminae, thin graded units a few cm thick, and thick argillite units. A thin section shows angular grains of mainly quartz and quartzite, less plagioclase, and minor chloritized mafics and volcanic fragments in a matrix of fine quartz, epidote, and chlorite. The cut shows close folds in the greywacke and locally good axial cleavage.

Proceed on highway 1.0 mile to next curve, just south of the "Dutch Latch".

27.7 STOP 2-6. (If traffic permits). Faultzone. The fault is an important northeast trending cross-fault, exposed on the east side of the highway. It offsets the Leech River Fault and the Leech River Formation that is here in contact with the Wark-Colquitz Gneiss to the northwest.

Proceed to second Malahat Viewpoint.

31.9 STOP 2-7. Tyee Intrusions ?. The altered granitic rock (on the detour partly covered by grouting) is a granite with about 35% andesine (an 35$\pm$), 35% microperthite, just over 20% quartz and a few percent chlorite after biotite, and prehnite. It is similar to some parts of Paleozoic Tyee Intrusions, but the age is still to be determined with zircons. Below the viewpoint the sheared limestone in the Bamberton quarry, in thrust contact with the granite, may be Triassic or Paleozoic. On a clear day the lookout affords a spendid view of Saanich Peninsula, the Canadian Gulf Islands, the American San Juan Islands and the Quaternary volcanic cone of Mount Baker.

Proceed via highway to Duncan and turn right towards Maple Bay. Continue north towards Arbutus Point. On the way there are outcrops of Nanaimo Group siltstone (Haslam Formation, Santonian) that with the basal Comox conglomerate and sandstone unconformably overlies Sicker Group volcanics.

54.7 STOP 2-8. Sicker Group volcanics and Tyee Intrusions. The roadcut for the Arbutus Point residential development shows shear-folded Sicker Group volcanic rocks, in places containing abundant uralite phenocrysts, derived from augite basalt porphyry. Sicker Group volcanics generally underlie sediments of that group and the latter contain locally Middle Pennsylvanian fossils. K-Argon dating of actinolite from similar uralite porphyry on Saltspring Island (to the east of this stop) yielded an age of 249 Ma but is not considered entirely reliable (R.L. Armstrong, pers. comm. 1976). The volcanics are intruded by quartz porphyry, converted to a sericite schist with quartz augen up to 1 cm long. Similar quartz-augen porphyry intrudes schistose greywacke on Saltspring Island. From this metamorphosed porphyry zircons have been obtained that give slightly discordant dates with a minimum of 390 Ma.

If the Devonian or older date represents the age of intrusion the volcanics and sediments are pre-Devonian. On the other hand it may be argued that the zircons are relicts, retained during migmatization of old basement rocks. The problem clearly needs further study.

Return to Island Highway and proceed via Nanaimo towards Parksville. On the way the road passes over Sicker Group volcanics and Nanaimo Group sediments, separated by unconformities and vertical faults. South of Nanaimo there are many good cuts in the Protection sandstone, that overlies the Douglas coal seam (mined since 1850 from many shafts and now practically exhausted). The sandstone was formed in deltaic, and perhaps partly subaereal dune-type environments. It consists of angular quartz, plagioclase and biotite in carbonate matrix and must have been derived from granitoid rocks.

At Nanoose turn right to Dolphin Beach.

112.0 STOP 2-9. Sicker Group sediments. Seashore behind homes on Blueback Drive. The sediments exposed here are unevenly bedded argillite and calc-arenite that exhibit pronounced slump-folding. The beds overlie plagiophyric basalt or andesite that contains patchy (high-low temperature?) plagioclase phenocrysts (an 55±) in a matrix of andesine microlites, biotite and magnetite. Fragments and a few angular blocks of the volcanic rock are present within the calcarenite beds. The clastic beds thus were apparently laid down on a submarine slope of a volcanic landmass that was bordered by carbonate reefs. Biotite in the volcanic rock and recrystallization of the limestone indicate thermal metamorphism by the body of granodiorite that intrudes the sediments less than ½ km east of the outcrop. On Ballenas Islands, about 6 km north of this point, the same argillite-limestone formation has yielded brachiopods as well as fusulinids. The latter are according to C.A. Ross *Wedekindella* sp. and *Eoschubertella* sp., indicating a Middle Pennsylvanian age.

117.1 STOP 2-10. Nanaimo Group sediments, with angular unconformity on Sicker Group. If time and tides permit, return from Dolphin Beach and take road to Clayton's Marina and Cottam Point.

The tidal exposures show shear-folded turbiditic greywacke and argillite of the Sicker Group, overlain with profound unconformity by Upper Cretaceous basal conglomerate containing large blocks of the underlying rock, followed by arkosic sandstone that bears shell fragments. The unconformity surface generally has considerable relief and it is not difficult to imagine an Upper Cretaceous rocky coast, similar to the present one, where these beds were formed.

Proceed to Parksville. Total day's mileage 117 miles.

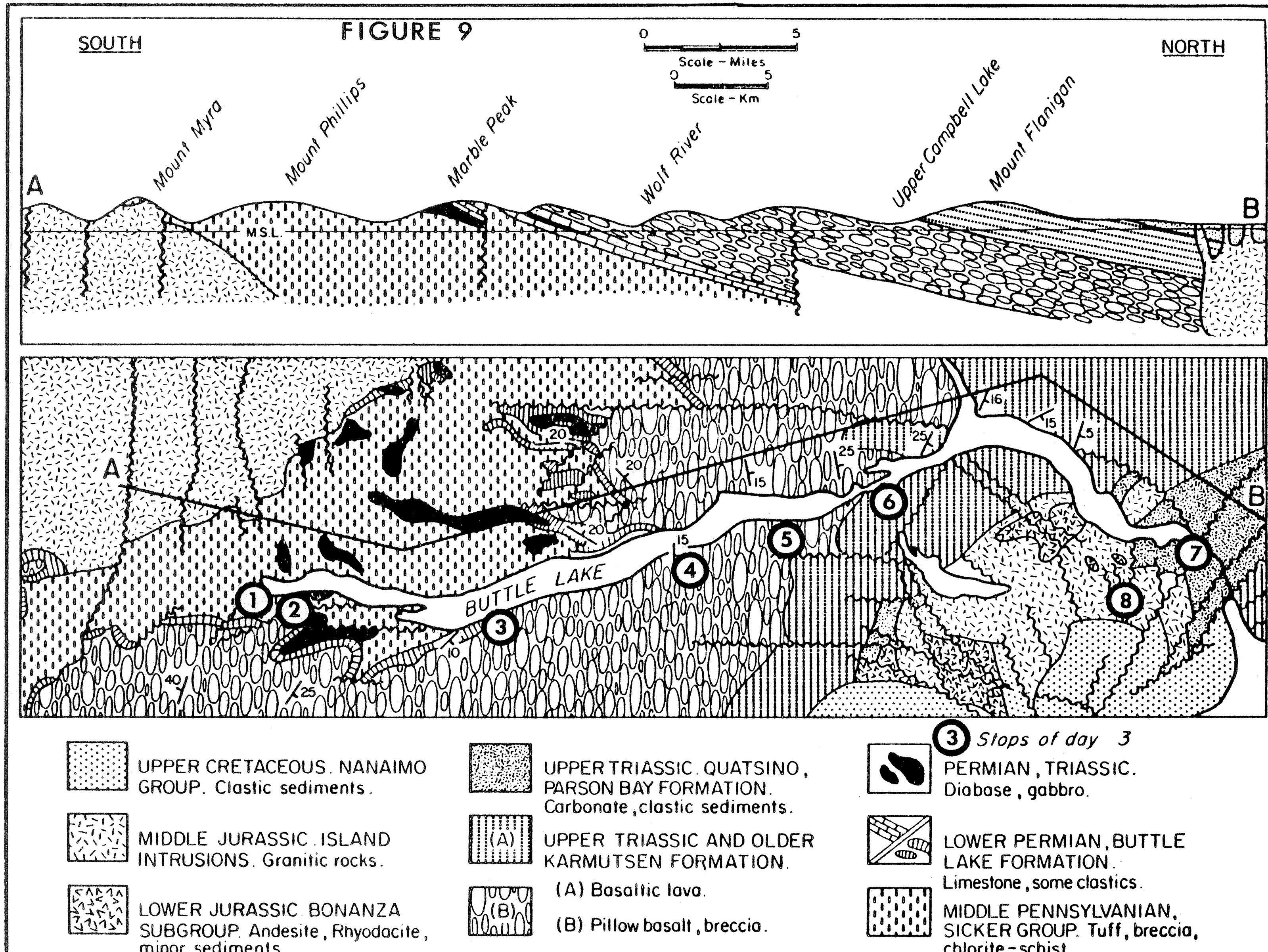


FIGURE 9
SOUTH
NORTH
0 5
Scale - Miles
0 5
Scale - Km
Mount Myra
Mount Phillips
Marble Peak
Wolf River
Upper Campbell Lake
Mount Flanigan
A
B
MSL
BUTTLE LAKE
3 Stops of day 3
UPPER CRETACEOUS. NANAIMO GROUP. Clastic sediments.
MIDDLE JURASSIC. ISLAND INTRUSIONS. Granitic rocks.
LOWER JURASSIC. BONANZA SUBGROUP. Andesite, Rhyodacite, minor sediments.
UPPER TRIASSIC. QUATSINO, PARSON BAY FORMATION. Carbonate, clastic sediments.
UPPER TRIASSIC AND OLDER KARMUTSEN FORMATION.
(A) Basaltic lava.
(B) Pillow basalt, breccia.
PERMIAN, TRIASSIC. Diabase, gabbro.
LOWER PERMIAN, BUTTLE LAKE FORMATION. Limestone, some clastics.
MIDDLE PENNSYLVANIAN, SICKER GROUP. Tuff, breccia, chlorite-schist.

DAY 3

SICKER GROUP
(LATE PALEOZOIC VOLCANICS AND BUTTLE LAKE LIMESTONE);
VANCOUVER GROUP
(UPPER TRIASSIC KARMUTSEN VOLCANICS AND PARSON BAY SEDIMENTS);
BONANZA GROUP AND ISLAND INTRUSIONS
(LOWER JURASSIC VOLCANICS AND INTRUSIONS)

Drive from Parksville via Island Highway to Courtenay and Campbell River, and on to the south end of Buttle Lake. The highway follows the coastal plain (Nanaimo Lowlands) with the Beaufort Range to the right. It passes through Comox Coal Basin, separated from the Nanaimo Basin by the Nanoose Uplift (of stops 2-9 and 2-10). In the Comox Basin the several coal seams that have been worked are in the first depositional cycle (Santonian) of the Nanaimo Group, whereas the coalseams of the Nanaimo Basin are in the second cycle, of Campanian age. The highway passes Union Bay that used to be the shipping point for Comox coal. Past Courtenay Constitution Hill and Mount Washington are seen to the west. They are a 200 m thick sill and a pluton of quartz diorite, with minor diatreme breccia, of Eocene age, that intrude Upper Cretaceous sediments. Minor copper mineralization was mined there in the late 1960's. From Campbell River the road to Buttle Lake traverses Triassic Karmutsen volcanics, Jurassic Island Intrusions and Cretaceous sediments.

Mileage

129.0 STOP 3-1. Sicker Group volcanics; south end of Buttle Lake.
The road cuts show pre-Middle Pennsylvanian fine-grained banded

tuff, coarse grained tuff and volcanic breccia with fragments up to 10 cm in size. The fragments are amygdaloidal epidotized lava and tuff. Thin sections show fragments of feldspar, dacitic lava, some quartz and glass globules in a chloritic prehnite-bearing matrix and the rocks are apparently of low-greenschist metamorphic grade. The Cu-Zn-Pb-Ag-Au sulphide deposits of Western Mines, west of Buttle Lake at the end of the road, are within this same volcanic sequence and are considered to be of the "Kuroko type".

Return northward on Buttle Lake road.

130.3 STOP 3-2. Quartz diabase. The road cut is in medium-grained quartz diabase that in thin section shows a diabasic, partly altered assemblage of labradorite and pyroxene with interstitial quartz and magnetite. Diabase sills are common in the Sicker Group and subvolcanic and comagmatic with Karmutsen volcanics.

Proceed northward.

136.2 STOP 3-3. Buttle Lake Formation, limestone. Recrystallized crinoidal limestone is exposed in road-cuts. R.W. Yole collected probable Lower Permian fossils in an equivalent carbonate unit in the mountains west of Buttle Lake. The limestone overlies greywacke and argillite, not exposed along the road, but similar to that seen in stops 2-9 and 2-10; the sediments in turn overlie the volcanics. The view of the mountains on the west side of Buttle Lake shows the north-dipping Paleozoic volcanics and limestone and overlying Triassic volcanics. Offsets of the limestone along normal faults are visible.

Proceed northward. The route passes some red beds and minor ribbon cherts that constitute the basal part of the Vancouver Group. Near Schoen Lake Middle Triassic, Ladinian Daonella has been found in sediments underlying Karmutsen volcanics.

143.4 STOP 3-4. Karmutsen Formation, pillow lavas. The red beds and cherts are directly overlain by tholeiitic pillow lavas, which at Buttle Lake are some 4,000 m (13,000 feet) thick. Here the pillows are closely packed, ball- to ellipsoid-shaped, and 20 cm to 1 m wide. Chilled rims are visible in places. Nests of quartz and epidote commonly fill the triangular spaces between pillows. Thin sections show diabasic plagioclas-pyroxene-opaque mineral assemblages. Megascopic and microscopic clusters of plagioclase are common. The pillow lavas are the lower submarine part of the Upper Triassic basaltic sequence. Karmutsen pillow lavas and also succeeding tuffs, breccias and flows show remarkable resemblance to Metchosin Volcanics in their lithology (Karmutsen rocks are more indurated) as well as in general sequence, beginning with pillows and terminating with flows.

Proceed northward 4.9 miles.

148.3 STOP 3-5. Karmutsen Formation, aquagene tuff and breccia. Aquagene tuff and pillow breccia commonly overlie pillow lava of Karmutsen volcanics. The tuff consists of globules, granules, shards and basaltic fragments (visible with hand-lens); the breccias contain in addition larger fragments of pillows. These rocks were probably formed in turbulent water and thus indicate the rising of the basaltic sea-floor to shallow depths.

Proceed northward 2.7 miles.

148.3 STOP 3-6. Karmutsen Formation, amygdaloidal lava flows. The outcrop shows the third major type of Triassic volcanic rock - massive basalt flows, in this outcrop 50 cm to about 1 m thick, but elsewhere as much as 5 to 30 m thick. The flows are generally amygdaloidal at top and bottom, with vesicles filled mainly with quartz, epidote or pumpellyite. The bedded lavas are believed to have been extruded subaereally, but greater volatile content and more rapid outflow also have been suggested as reasons for the change from pillows to flows. The upper part of the Triassic volcanic sequence contains a thin sedimentary layer with Karnian fossils, followed by 300 m of pillowed and bedded lavas, but the sediments are not exposed at road level. The Triassic basalt is overlain by Karnian limestone and Karnian to Norian black thin-bedded calcareous siltstone and argillite. These formations are preferentially invaded by sills and laccolithic bodies of Island Intrusions, with resulting Cu-Fe skarn deposits. The abandoned Argonaut iron mine is just east of the excursion route.

Proceed northward to power dam. The route passes Jurassic granodiorite, dacite porphyry, and a small exposure of silicified Quatsino limestone.

163.7 STOP 3-7. Parson Bay Formation, siltstone; porphyry sills. The spillway north of the power dam exhibits mainly porphyry intruded into Triassic sedimentary rocks with only minor blocks of thin-bedded black siltstone with Monotis suncircularis Gabb "floating" in the porphyry.

The cut also affords a small-scale model of the fault-tectonics of the island. The maze of near-vertical faults is not due to a specific fault-zone but rather is the reaction of rock of medium competency to the stress-field that existed throughout the region. Some faults are tensional and contain dykes that mainly trend northeast. One set of faults trending 130^{o} shows northeast downthrow of Monotis-bearing beds. Another set is at approximately right angles to these and offsets them.

Return to main Buttle Lake road and towards Campbell River.

STOP 3-8. Island Intrusions (optional stop, if time permits). Outcrop of pinkish grey, medium grained hornblende granite (according to I.U.G.S. classification: quartz > 20%; K-feldspar > 1/3 of total feldspar).

Return to Parksville; total day's mileage 260.

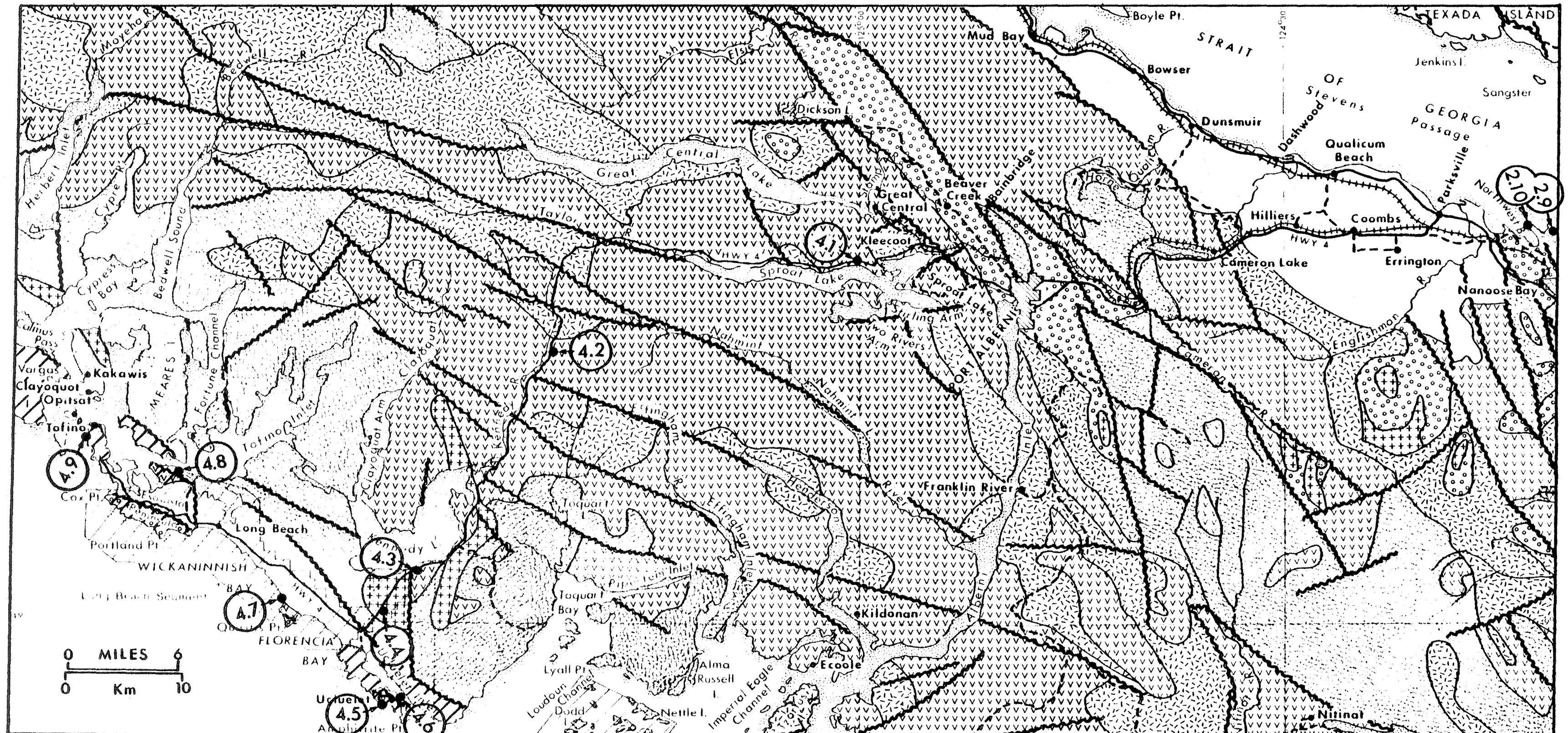


FIGURE 10

- Pleistocene
- Tertiary: Intrusions
- Upper Cretaceous: Nanaimo Group
- Upper Jurassic and Cretaceous: Pacific Rim Complex
- U. Triassic and L. Jurassic: Vancouver, Bonanza Groups
- Paleozoic: Sicker Group and Westcoast Complex

DAY 4

PACIFIC RIM COMPLEX
(JURA-CRETACEOUS FLYSCH, CHERT, MELANGE)
AND SOME ADDITIONAL EARLY MESOZOIC ROCKS

Drive from Parksville via Cameron Lake in Beaufort Range to Alberni and on via Sproat Lake, Taylor and Kennedy River to Ucluelet. The road passes over Nanaimo Group in the lowlands, and through Karmutsen volcanics overlying limestone and Sicker volcanics (here chlorite schist) in Beaufort Range; on the descent to Alberni the Paleozoic-Upper Cretaceous unconformity is visible in several road-cuts. MacMillan Park west of Cameron Lake is of interest for its tall Douglas Fir trees. A few very old ones (not near highway) are 800 to 1,000 years old and up to 2 m diameter, but most grew up after a fire 300 years ago. The understory is Western Hemlock and Western Red Cedar. From Alberni highway 4 passes mainly over Karmutsen volcanics, intruded by Island Intrusions. The total mileage of this day is well over 200, followed by bus and ferry trip to Vancouver. As the main object of the day is to visit the Pacific Rim Complex stops on the way are optional and dependent on time.

From Alberni towards Tofino; 4.0 miles past junction at Sproat Lake Provincial Park.

Mileage

39.7 STOP 4-1. Karmutsen-Island Intrusions contact. A large cut shows pillow lavas, slightly metamorphosed and epidotized, in contact with hybrid granitoid rock, mainly granodiorite, of Island Intrusions.

Proceed to 9.1 miles past bridge over Taylor River.

64.0 STOP 4-2. Bonanza Group volcanics. In Kennedy River, if the water is not too high, the outcrop shows volcanic rocks tentatively correlated with the Bonanza Group. They are a glaciated outcrop of amygdaloidal volcanics with small plagioclase phenocryst-clusters and finely banded tuffs, invade by leucocratic dykes. The flows are converted to albite-hornblende-chlorite rocks, the dykes are albite-quartz-epidote-chlorite rocks.

Proceed and descend to the shore of Kennedy Lake.

81.1 STOP 4-3. Quatsino Formation limestone. The road-cuts show massive to laminated recrystallized Upper Triassic Karnian limestone, the formation that most commonly overlies Karmutsen volcanics. It contains fine-grained diabase sills that must be considered either as part of latest Triassic Karmutsen volcanism, or as part of Jurassic Bonanza volcanism. The abandoned Brynnor Mine, another iron skarn deposit in the limestone, is a few miles east of here. From Kennedy Lake one sees the lowland of the Pacific coastal area with hills rising above it. In late Pleistocene time sea-level was about 50 m above the present level, as shown by the terrace level above the lake, and the lake was an arm of the sea, in which the coastal hills were islands.

Proceed to sharp left turn, 3.2 miles after leaving Kennedy Lake.

86.2 STOP 4-4. Tertiary granodiorite. The road cuts one of several granitoid stocks of Tertiary age. The rock is fine-grained hornblende-biotite granodiorite. K-Argon dating of this stock has given 44.5 ± 2.3 Ma for biotite and 65.7 ± 7 Ma for hornblende. A number of dated Tertiary plutons have yielded ages between 32 and 65 Ma and other hornblende-biotite pairs have yielded ages only a few million years apart. A re-run of this rock for confirmation or correction is still to be carried out.

Proceed to Ucluelet by turning left at "T" in highway.

93.0 STOP 4-5. Pacific Rim Complex, greywacke and argillite. A good trail through typical west coast rain-forest leads from Ucluelet to "Buchia Cove". The rocks are black, splintery argillite with calcareous bands and nodules and minor greywacke and conglomerate. They exhibit obscure shear-folding, striking about east-west, and with vertical cleavage. One bed of fairly well preserved fossils is present. These, originally discovered by S.J. Nelson, were identified by J.A. Jeletzky as *Buchia pacifica* (Jeletzky, 1965) and indicate mid-Valanginian Early Cretaceous age. "The apparent absence of closed or gaping, complete(i.e. double valved) shells could be interpreted as suggestive of re-deposition of fauna either by wave action or by turbidity currents". The deposits are indeed probably deeper water slump and turbidity deposits that in Late Cretaceous to Eocene time were thrust under Island Mountain rocks along the Westcoast Fault, that strikes northwesterly and passes 2 km northeast of the outcrop. The tectonized rocks of the complex, are Late Jurassic to Cretaceous and equivalent in age, sedimentary and structural character to the Franciscan Terrane of California.

Proceed to end of road on Ucluth Peninsula.

94.5 STOP 4-6. Pacific Rim Complex, chert and argillite. Near the end of Ucluth Peninsula several outcrops on the inlet show highly deformed interbedded ribbon chert and argillite. The cherts are generally grey in color due to silicification and contain poorly preserved radiolarians. These occur abundantly and are better preserved in reddish brown unsilicified chert on a small island 6 km southwest of Ucluelet. They have been identified by A.E. Pessagno Jr. and indicate Late Jurassic, Tithonian (subzone 2A) age.

Proceed towards Tofino and turn left to Wickanninnish Inn.

105.5 STOP 4-7. Pacific Rim Complex, greywacke-argillite-volcanic melange. Wickanninnish Inn is built on a rock-island about 2 km long, that separates the beach of Florencia Bay to the south from Long Beach to the north. The beaches are composed of reworked Pleistocene deposits. The rocks below and south of the inn are a tectonic melange of greywacke, argillite, chert and volcanic rock that are similar to late Mesozoic subduction complexes in California and Alaska.

Return to highway and proceed west, turning north past airport towards picnic site on Browning Passage.

119.0 STOP 4-8. Westcoast Complex gneiss. The rocks are biotite-hornblende-plagioclase gneiss. Zircon obtained from gneiss near this location has yielded an almost concordant U/Pb age of 264 Ma (Permian). That date, although too young for pre-Middle Pennsylvanian Sicker volcanics, suggests derivation of the gneiss from Paleozoic volcanic or volcaniclastic rocks. An amphibolized dyke that cuts the gneiss yielded a K-Argon date of 192 Ma indicating metamorphism of the gneiss and Triassic (?) dyke in Early Jurassic time, during the earlier part of the Early Jurassic major plutonic event.

Return to highway and proceed towards Tofino, and on road past the hospital.

121.0 STOP 4-9. Contact of Pacific Rim argillite and Eocene biotite granodiorite. The granite-argillite contact of the small Tertiary pluton, exposed on the coast, is sharp, in contrast to commonly diffuse contacts of Island Intrusions. The granodiorite, on nearby Clayoquot Island dated with K-Argon as 50 ± 5 Ma, is massive and undeformed. Deformation of the Pacific Complex therefore pre-dates 50 Ma in this area.

Return trip from Tofino to Nanaimo 107 miles; total day's mileage to Nanaimo 228 miles. From there by bus and ferry to Vancouver.

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