Fossil ages and isotopic dates from the Paleozoic Sicker Group and associated intrusive rocks, Vancouver Island, British Columbia

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Abstract

The Late Silurian to Early Permian Sicker Group represents the oldest rocks of the Wrangellia terrane of Vancouver Island. This paper summarizes isotopic dates and fossil ages for the group and associated intrusives. The oldest unit, the Nitinat tuff, is preDevonian, possibly Silurian. It is intruded by Early Devonian quartz porphyry and granodiorite of the Saltspring Intrusions. In the Buttle Lake area, U-Pb dates for the Myra volcanics indicate a pre-Late Devonian age. Therefore, the Myra could be an extrusive equivalent of the Saltspring Intrusions. In the Cowichan Lake area, a chert that overlies the Nitinat tuff yielded Early Mississippian microfossils. No equivalents of the Myra volcanics occur in the Cowichan area. The highest unit in the Sicker is the Buttle Lake Limestone. New conodont ages span the interval early Middle Pennsylvanian (Atokan) through Early Permian (probably Sakmarian). The Sicker has been variably deformed in the early Mesozoic.

Résumé

Le groupe de Sicker du Silurien supérieur ou du Permien inférieur renferme les roches les plus anciennes du terrain de Wrangellia de l'île de Vancouver. Cette étude présente des datations isotopiques et des âges des fossiles du groupe et des intrusions associées. L'unité la plus ancienne, le tuff de Nitinat, date du pré-Dévonien et peut-être du Silurien. Elle est pénétrée par un porphyre quartzifère du Dévonien inférieur et une granodiorite faisant partie des intrusions de Saltspring. Dans le secteur du lac Buttle, la datation U-Pb des roches volcaniques de Myra indique un âge pré-Dévonien inférieur. Par conséquent, les roches de Myra pourraient être un équivalent extrusif des intrusions de Saltspring. Dans le secteur du lac Cowichan, un chert qui recouvre le tuff de Nitinat renferme des microfossiles du Mississippien inférieur. On ne trouve pas d'équivalent des roches volcaniques de Myra dans le secteur de Cowichan. L'unité la plus récente dans le groupe de Sicker est le calcaire de Buttle. Les âges de conodontes récents vont du début de Pennsylvanien moyen (Atokien) jusqu'au début du Permien (probablement le Sakmarien). Le groupe de Sicker a été plus ou moins déformé au début du Mésozoïque.

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Introduction

The Paleozoic Sicker Group comprises the oldest rocks of Wrangellia (Jones et al., 1977), a large allochthonous terrane that underlies most of Vancouver Island. This paper summarizes available fossil and isotopic data for the Sicker and associated intrusive rocks with the objective of providing a framework for ongoing stratigraphic and tectonic studies of the unit. One of the goals of these studies is to better resolve the origin of the Wrangellia terrane. The Sicker contains stratigraphic units ranging from at least Late Silurian through Early Permian, and therefore provides a long record, about 150 million years, of the early history of Wrangellia.

The Sicker Group was originally used by Clapp (1912) to refer to deformed volcanic and sedimentary rocks in the vicinity of Sicker Mountain on southern Vancouver Island (near N1 on Fig. 82.1). As presently defined (Fyles, 1955; Yole, 1969; Muller, 1980), the Sicker includes all stratified Paleozoic rocks of the Wrangellia terrane on Vancouver

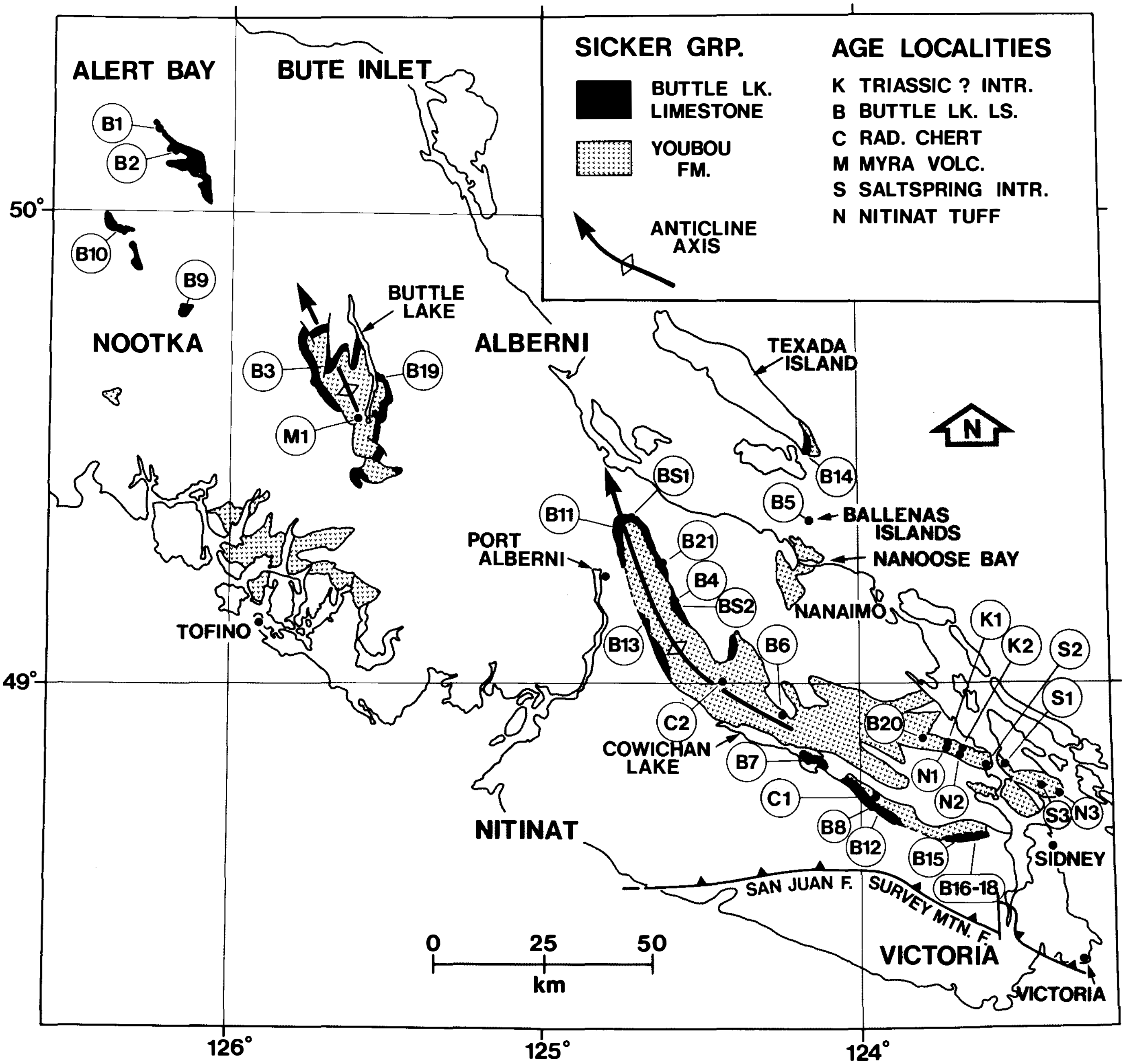

Figure 82.1. Location of fossil ages and isotopic dates from the Sicker Group. Labels refer to data summarized in Tables 82.1 and 82.3 through 82.6. BS1 and BS2 are localities where stratigraphic collections of conodont samples were made in the Buttle Lake Limestone (Table 82.5). The San Juan and Survey Mountain faults mark the southern limit of Wrangellia on Vancouver Island. The figure outlines the following GSC map areas: Alert Bay (Muller et al., 1974), Bute Inlet (Roddick and Woodsworth, 1977), Nootka (Muller et al., 1981), Alberni (Muller and Carson, 1969), Nitinat (Muller, 1982) and Victoria (Muller, 1983).

Table 82.1. Isotopic dates for lower Paleozoic rocks of the Sicker Group

No.	Rock type, Location (Sample no.)*	Dating method	Date** (Ma)	Ref.	Comments
NITINAT TUFF					
N1	Pyroxene crystal tuff. E of Mt. Sicker along Highway 1, Victoria map area. 48°51.3' 123°43.1' (UBC/Sicker 3)	K-Ar uralitic amphibole after pyroxene	421 ± 36	(1)	Date is a minimum age for the tuff and uralite alteration. The analyst noted that the date may be anomalous due to very low K content. Tuff in this outcrop is cut by quartz porphyry of the Saltspring Intrusions (Fig. 82.3).
N2	Pyroxene crystal tuff. Near Mt. Richards, SW of Crofton, Victoria map area. 48°50.9' 123°41.1' (UBC/E80-77 no. 24517M)	K-Ar uralitic amphibole after pyroxene	288 ± 28	(1)	Date is a minimum age for uralite alteration. This unit is intruded by Saltspring quartz porphyry on Mt. Richards (ref. no. 6).
N3	Pyroxene crystal tuff. Beaver Pt., Saltspring Is., Victoria map area. 48°46.10' 123°22.60' (UBC/28SM)	K-Ar uralitic amphibole after pyroxene	257 ± 20	(1)	Date is a minimum age for uralite alteration. The analyst noted that the very low K content of the amphibole is cause for concern. A nearby Saltspring quartz porphyry intrudes this tuff.
SALTSPRING INTRUSIONS					
S1	Quartz porphyry. Mt. Maxwell, Saltspring Is., Victoria map area. 48°50.05' 123°33.20' (GSC/MEZ-77-1)	U-Pb zircon	$UI=393^{+25}_{-10}$ $LI=92^{+120}_{-130}$ (n=5)	(2,3)	Discordant zircon dates. U-Pb dates define a good linear array (Fig. 82.4) which was used to calculate the intercept dates. UI date is presently the best estimate of the age of the Saltspring Intrusions.
S2	Schistose quartz porphyry. Arbutus Pt., Maple Bay, Victoria map area. 48°49.40' 123°35.60' (GSC/WN-19-74 for U/Pb, GSC/80-21 for K/Ar)	(a) U-Pb zircon	>370 (n=4)	(2,3)	Discordant zircon dates. Pb-Pb dates of 361-395 Ma indicate an approximate minimum age. Intercept dates are very poorly defined due to a lack of dispersion in U-Pb dates.
		(b) K-Ar muscovite	180 ± 8	(5)	Minimum age. Very low K content for muscovite, might be sericite.
S3	Granodiorite. Lake Stowell, Saltspring Is., Victoria map area. 48°46.90' 123°26.60' (GSC/MEZ-76-3)	U-Pb zircon	>370 (n=5)	(2,3)	Discordant zircon dates. Pb-Pb dates of 357-379 Ma indicate an approximate minimum age. Intercept dates are very poorly defined due to a lack of dispersion in U-Pb dates.
MYRA VOLCANICS					
M1	Quartz-feldspar porphyry. H-W mine(Westmin), Buttle Lake, Alberni map area. 49°34.25' 125°35.33' (GSC/P13-307-Sicker)	U-Pb zircon	>370 (n=2)	(7)	A minimum age base on preliminary analyses with Pb-Pb dates of 370 and 371 Ma.

* UBC = analysis at Univ. of British Columbia; GSC = analysis at Geol. Survey of Canada.
** Error limits are ±2 sigma (95% conf. interval). For U-Pb dates: UI = upper intercept date, LI = lower intercept date, n = no. of zircon analyses.

References: (1) Geochronology Data File of R.L. Armstrong (Univ. of British Columbia), writ. comm., 1985; (2) Muller, 1980; (3) see Table 82.7 in Appendix for analytical data; (4) unpublished results from GSC Geochronology Laboratory; (5) Stevens et al., 1982; (6) Eastwood, 1980; (7) Collected by R.V. Kirkham (GSC), analyzed by Parrish.

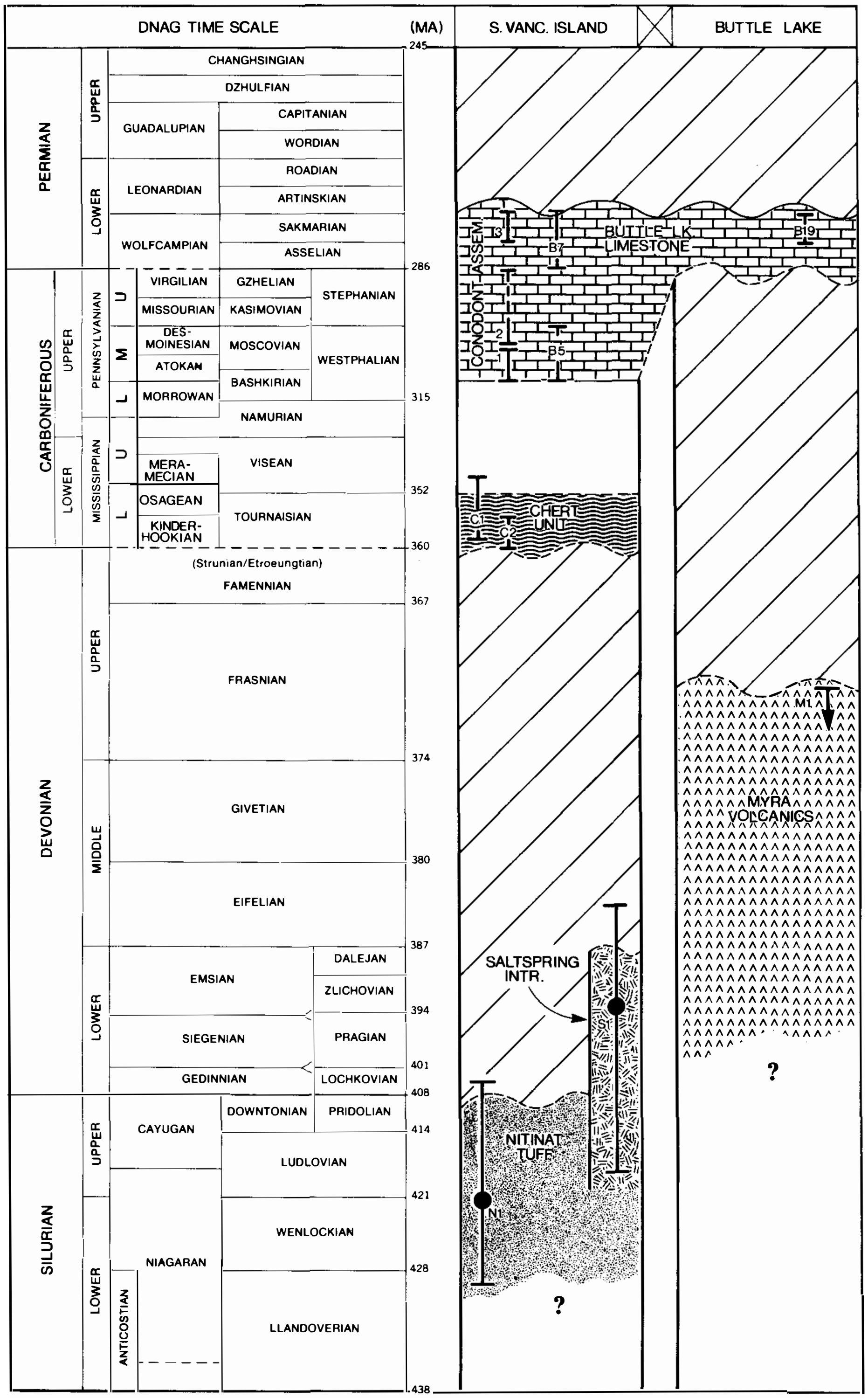

Figure 82.2. Time stratigraphic summary of the Sicker Group on southern Vancouver Island and in the Buttle Lake area on the northern part of the island. Selected age data are portrayed with vertical bars which indicate the possible time range for each determination. The range for isotopic dates (N1, S1) is the 95% confidence interval. The arrow at M1 indicates a minimum age (Table 82.1). The preferred age range for each conodont fauna is shown with a solid line; the dashed line indicates the total possible range. The time scale is after that proposed for the Decade of North American Geology (DNAG) project (Harland et al., 1982; Palmer, 1983).

Island (Insular Belt of Muller, 1977). The Sicker is exposed chiefly in three anticlinal uplifts (Fig. 82.1) located at Cowichan Lake, Nanoose Bay and Buttle Lake. Yole (1969) summarized previous stratigraphic studies of the Sicker Group and divided it into two formal units (Fig. 82.1):

1. An upper unit, called the Buttle Lake Formation, consists mainly of limestone with subordinate clastic rocks, and ranges from 30 to 470 m thick, although locally it is absent (Fig. 82.1; Yole, 1969).
2. A lower unit, called the Youbou Formation, comprises all stratified rocks beneath the Buttle Lake Formation. This lower sequence is dominated by volcanic and pyroclastic rocks with subordinate epiclastic sandstone, mudstone and radiolarian ribbon chert; its true thickness is unknown. Muller (1980) proposed to replace Yole's Youbou Formation with three new units, which, in order of increasing age, are: sediment-sill unit (informal name), Myra Formation and Nitinat Formation. As is shown below, there are significant problems with the definition and practicality of these new units. Therefore, in this paper Muller's units are considered as informal subdivisions of the Youbou Formation, applicable only in some areas. Nitinat tuff (Muller, 1980, p. 6) refers to a distinctive pyroxene-phyric tuff exposed in the Cowichan Lake uplift; Myra volcanics (Muller, 1980, p. 16; Fleming et al., 1983) refer to silicic pyroclastic rocks exposed in the Buttle Lake uplift.

The Sicker Group also is closely associated with two suites of intrusive rocks:

1. The Early Devonian Saltspring Intrusions of Muller (1980, 1983) which are apparently restricted to Saltspring Island (S1 and S3 in Fig. 82.1) and the area east of Cowichan Lake; and
2. Triassic(?) mafic intrusions which are widespread in the Sicker and are probably feeders to overlying Triassic basalts of the Karmutsen Formation. These intrusive rocks are important because they provide crosscutting relationships that can be used to determine stratigraphic ages and timing of deformation for the Sicker Group. These relationships are critical to our studies because conventional stratigraphic studies are hampered by the absence of reliable marker horizons and by structural complexities due to folding and faulting.

Tables 82.1 and 82.3 through 82.6 summarize available fossil and isotopic data, including a number of new conodont ages and U-Pb and K-Ar dates, for the Sicker Group and associated intrusions (some of these new isotopic dates are from R.L. Armstrong who has kindly allowed us to include them in our compilation. All isotopic dates were calculated using new decay constants (Harland et al., 1982). In addition to our own sampling, many of the localities of previous workers were re-examined in order to verify geological relationships exposed there (note that in some cases location descriptions have been corrected and therefore differ from the original sources). These data were used to construct the two time stratigraphic columns in Fig. 82.2, which focus on stratigraphic relationships amongst well-dated units of the Sicker. These units are discussed below, proceeding from oldest to youngest.

Nitinat tuff

The Nitinat tuff in the Cowichan Lake uplift is mainly pyroclastic with subordinate volcanic flows. Commonly, the tuff is agglomeratic with rounded, cobble-sized clasts of pyroxene-phyric volcanic rock comprising up to 20% of the rock. The unit is characterized by the conspicuous presence of stubby, black phenocrysts of augite which comprise up to 10% of the rock and which have been variably altered to actinolite (uralite). The Nitinat shows extensive development of static metamorphic assemblages of chlorite, epidote, actinolite and plagioclase indicating upper greenschist conditions. The main deformational fabric is a variably developed flattening foliation which is vertical and strikes northwesterly. Excellent descriptions of this unit are available in Clapp and Cooke (1917, p. 127-136) and Fyles (1955, p. 13-14) who described its occurrence in the southern part of the Cowichan uplift. In the northern part of the uplift, the Nitinat tuff is equivalent to units PS5, and possibly PS4, of Sutherland Brown and Yorath (1985).

The Nitinat tuff is clearly pre-Devonian because it is intruded in many places by Early Devonian porphyry of the Saltspring Intrusions. A particularly good example of this relationship is shown in Fig. 82.3. K-Ar dates for the Nitinat (Table 82.1, N1-N3) show a large scatter which is probably due to the fact that the dated mineral separates consisted of uralitized pyroxene and not hornblende. The two younger dates (N2, N3) are Permian and therefore clearly reset. The oldest date (N1) is Silurian and may approximate the actual age of the unit.

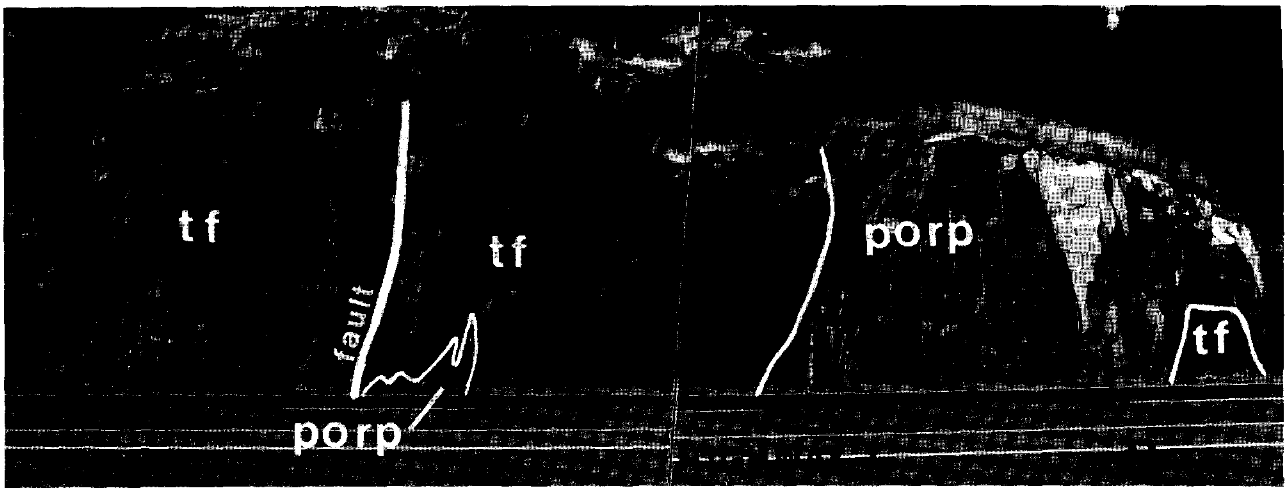

Figure 82.3. *Saltspring quartz porphyry (porp) intruding Nitinat tuff (tf). The outcrop is about 6 m high and is located on the west side of Highway 1 about 2.3 km south of the Chemainus River (third outcrop south of river). Nitinat tuff from near this locality yields a 421 Ma K-Ar date (N1; 2.9 km south of river) on uralitized clinopyroxene which occurs as phenocrysts in the tuff.*

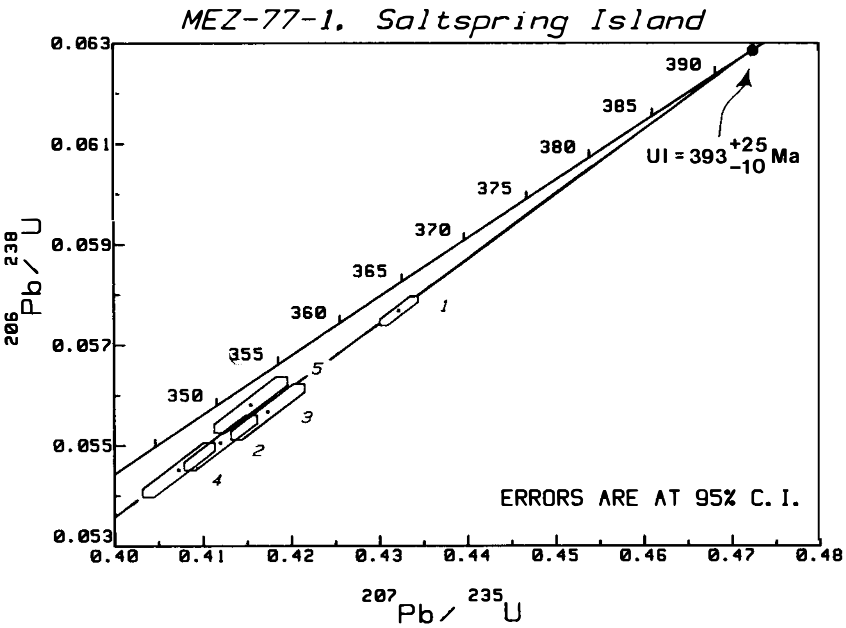

Figure 82.4

U-Pb concordia diagram for zircon dates from Saltspring quartz porphyry from Mount Maxwell, Saltspring Island (S1). Analytical data is summarized in Appendix A. The upper intercept date (UI) of 393 Ma is presently the best estimate of the igneous age of the Saltspring Intrusions.

Table 82.2. Stratigraphic sequence at the west fork of Shaw Creek

Approximate thickness (metres)	Rock type
	Top not exposed
60-90	Purplish volcanic breccia
400	Green tuffaceous greywacke.
80	Amygdaloidal basalt.
310	Thin and thick beds of tuffaceous greywacke.
240	Black feldspathic and argillaceous tuff, thin limestone lenses.
180	**Chert unit** (Early Mississippian and older?) Thin bedded cherty tuff, radiolarian ribbon chert.
	------------------ unconformity? ------------------
1400	**Nitinat tuff** (Silurian?) Massive green volcanic breccia.
	Base unknown

Note: After Fyles (1955, p. 18). This is the type section for the Youbou Formation of Yole (1969).

Saltspring Intrusions

The Saltspring Intrusions (Muller, 1980, 1983) occur on southern Saltspring Island and in the area east of Cowichan Lake, and include a suite of small quartz-feldspar porphyry intrusions and some larger stocks of granodiorite. This intrusive suite has previously been called Tyee quartz-feldspar porphyry by Clapp and Cooke (1917, p. 167-169, informal name) and Tyee Intrusions by Muller (1977). Muller (1980, 1983) introduced the new name Saltspring Intrusions, apparently to avoid conflict with the formally named Tyee Formation of Oregon. The following description of the unit is largely after Clapp and Cooke (1917, p. 167-169).

The Saltspring Intrusions typically occur as irregular bodies of porphyry with variable amounts of rounded quartz and lath-shaped feldspar phenocrysts. The larger stocks on Saltspring Island contain quartz, albitized plagioclase and potassium feldspar with minor mafic minerals now altered to chlorite and epidote (Muller, 1980). These intrusions show the same steeply dipping flattening foliation present in the Nitinat tuff, and locally are recrystallized to quartz-sericite schist.

U-Pb zircon analyses from three localites in the Saltspring Intrusions give a discordant set of dates (Table 82.1, S1-S3). Muller (1980), who reported on an early set of these U-Pb dates, concluded that the intrusions were Late Silurian or Devonian. Appendix A contains a table of the analytical results for these U-Pb dates, including several unpublished analyses. Zircon fractions from localities S2 and S3 are discordant but yield similar U-Pb dates so that a discordia line and intercept dates are very poorly defined. Pb-Pb dates indicate a minimum age of about 370 Ma (Late Devonian). For the Mount Maxwell locality (Table 82.1, S1), further dating of a handpicked, air-abraded fraction from the

Table 82.3. Microfossil ages for radiolarian chert from the Sicker Group

No.	Location (GSC locality no.)	Fossils identified	Age determination	Ref.
C1	South of Skutz Falls, Logging road S5K, Victoria map area. 48°45.37' 123°57.03' (no GSC locality)	radiolaria	Early to early Late Mississippian (middle Kinderhookian to early Meramacian)	(1)
C2	West of north Shaw Creek logging road (top of chert unit in Table 82.2), Alberni map area. 49°00.45' 124°26.28' (C127519-C127521)	conodonts	Early Mississippian (Kinderhookian)	(2)

References: (1) Muller, 1980, p. 23. Note the following corrections to Muller's text: Sample No. 79-42H, 48°45.37'N, 123°57.03'W, 3 km south of Skutz Falls. (2) Collected by Brandon, determined by Orchard.

original zircon separate allows a more precise age determination. When plotted on a concordia diagram (Fig. 82.4), the five zircon fractions define a good linear array with an upper intercept date of 393 Ma (Early Devonian). In this array, the handpicked fraction (no. 1 in Fig. 82.4) shows the least discordance which indicates that discordance is probably due to Pb-loss either from the surface of each zircon, which was removed by abrasion, or from the more highly cracked and metamict zircons, which were avoided by handpicking. This result precludes the possibility that the upper intercept date represents the age of an inherited zircon component assimilated in a younger pluton. Therefore, we conclude that the upper intercept date for the Mount Maxwell locality approximates the age of the Saltspring Intrusions. Further dating in progress should verify this conclusion.

Myra volcanics

In their type area on Myra Creek at the south end of Buttle Lake, the Myra volcanics of Muller (1980) underlie upper Paleozoic Buttle Lake Limestone (Fig. 82.2; Yole, 1969) and consist of a sequence of silicic pyroclastic rocks and related hypabyssal intrusions of dacite and quartz-feldspar porphyry (Fleming et al., 1983). The relationship of the Myra to the Nitinat tuff is not known at Buttle Lake since the base of the Myra is not exposed there. In general, metamorphic grade and deformation in the Myra at Buttle Lake are similar to that described above for the Nitinat tuff and Saltspring Intrusions (Fleming et al., 1983, p. 14).

Preliminary U-Pb determinations on two zircon fractions from quartz-feldspar porphyry in the type area of the Myra volcanics (M1 in Table 82.1) indicate a minimum age of 370 Ma (pre-Late Devonian). These dates suggest that the Myra volcanics may be the extrusive equivalents of the Saltspring Intrusions, a possibility originally suggested by Muller (1980, p. 16).

The pre-Late Devonian age of the Myra volcanics has another important implication. Muller (1980) argued that the Myra volcanics of Buttle Lake are equivalent to a sequence of volcaniclastic sandstone, cherty tuff and volcanic rock exposed in the Cowichan uplift. This sequence, which was mapped by Fyles (1955, p. 18) and is summarized in Table 82.2, lies above volcanic rock that is probably equivalent to the Nitinat tuff. As discussed below, a chert unit at the base of this sequence yielded Early Mississippian conodonts, which precludes a correlation with the Myra volcanics.

Chert unit

The chert unit corresponds to the thin bedded cherty tuff unit that Fyles (1955) described as a relatively continuous marker unit in the area north of Cowichan Lake. In the Shaw Creek area where it is best exposed (Table 82.2; C2 in Fig. 82.1), the chert unit consists of red and green radiolarian ribbon chert and thin-bedded green tuffaceous chert, and concordantly overlies pyroxene-phyric volcanic rocks (see map in Fyles, 1955) that are petrographically similar to, and probably correlative with, the Nitinat tuff. Northeast of Cowichan Lake, Clapp and Cooke (1917, p. 136-137) described three areas where similar stratigraphic relationships occur with thin bedded cherts overlying Nitinat-type volcanic rocks. This chert unit is also present in the northern part of the Cowichan uplift where it forms the base of unit PS3 of Sutherland Brown and Yorath (1985).

Radiolarian chert from near the top of the chert unit in the Shaw Creek area yielded the conodonts **Siphonodella** and **Pseudopolygnathus** (C2 in Table 82.3), which clearly are early Mississippian, Kinderhookian (approximately early and middle Tournaisian, Fig. 82.2). Radiolaria from chert in this area were too poorly preserved to be identified; however, southeast of Cowichan Lake, radiolaria from Sicker chert give a similar Mississippian age (C1 in Table 82.3). The geological setting of this locality is not known. Since the chert unit is relatively thick, and since only the top of the unit has been dated, it is likely that the unit could range down into the Devonian. Further systematic dating is needed.

The Early Mississippian age for the Shaw Creek chert unit has some important implications. If the chert unit does in fact rest depositionally on the Nitinat tuff, then, based on their pre-Late Devonian age and their dominantly pyroclastic character, the Myra volcanics cannot be equivalent to the sequence above the Nitinat tuff. Another possible implication is that the sequence overlying the chert unit (Table 82.2) is Mississippian and younger. One problem, however, is that in the Shaw Creek area, this sequence, at least locally, contains tight, outcrop-scale folds and, therefore, should not be considered a simple stratigraphic sequence. Fyles (1955, p. 25-26, also cross-sections on his map) also presented convincing evidence for larger, map-scale folds. The Shaw Creek sequence, however, also occurs in the northern part of the Cowichan uplift where it is relatively undeformed. With further work, that area may yield a more suitable type section for the Youbou Formation.

Table 82.4. Fossil ages for isolated outcrops of Buttle Lake Limestone

No.	Location (GSC locality no.)	Lat., Long.	Fossils identified*	Age determination**	Ref.
B1	NE of Schoen Lk., Alert Bay map area. (no GSC locality)	50°11.5' 126°14.0'	coral	Mississippian-Permian	(1)
B2	SE of Mt. Schoen, Alert Bay map area. (86301)	50°07.95' 126°10.87'	(a) coral	Mississippian-Permian	(1)
			(b) ostracods, foraminifera, conodonts	Pennsylvanian-Early Permian (prob. Late Pennsylvanian)	(2,1)
B3	W of Buttle Lake, Alberni map area. (no GSC locality)	49°41.65' 125°39.15'	(a) bryozoans	Permian	(3,4)
			(b) brachiopods	Pennsylvanian-Permian(4)	
B4	W fork of Cameron River, quarry at beginning of logging road E10, Alberni map area. (C-82857)	49°10.10' 124°32.90'	foraminifera	Permian (probably Early Permian)	(5)
B5	E side of North Ballenas Is., Alberni map area. (57588)	49°20.65' 124°09.35'	(a) fusulinids	Middle Pennsylvanian (prob. early Desmoinesian)	(6)
			(b) brachiopods	Pennsylvanian-Permian	(6)
B6	Mount Landalt, NE of Cowichan Lk., Nitinat map area. (no GSC locality)	48°56.90' 124°13.75'	no age-diagnostic fossil	age unknown	(7)
B7	Peninsula at E end of Cowichan Lake, Nitinat map area. (GSC locality unknown)	48°50.45' 124°08.15'	(a) brachiopods	Early Permian	(7)
			(b) fusulinids	Early Permian (Wolfcampian)	(7)
B8	E of Fairservice Crk. and NW of Waterloo Mtn., Victoria map area. (no GSC locality)	48°43.90' 123°58.00'	foraminifera	Pennsylvanian-Permian (probably Pennsylvanian)	(8)
B9	E side of McGee Crk., Nootka map area. (GSC locality unknown)	49°47.3' 126°08.4	foraminifera	Late Mississippian- Pennsylvanian (probably Early Pennsylvanian-	(9)
B10	SE of Vernon Lake, Nootka map area. (79150)	49°58.15' 126°19.00'	bryozoan, brachiopods	Ordovician-Permian	(9)
B11	W side of Horne Lake, Alberni map area. (no GSC locality)	49°20.0' 124°45.2'	fusulinids	probably early Middle Pennsylvanian	(10)
B12	E of Fairservice Creek and NW of Waterloo Mtn., Victoria map area. (C-86895)	48°43.85' 123°57.00'	algae	Mississippian or younger	(11)
B13	W of Douglas Peak, Alberni map area. (no GSC locality)	49°07.82' 124°39.81'	brachiopods	possibly Pennsylvanian or Permian	(12)
B14	SW coast of Texada Is., S of Mt. Dick, Alberni map area. (C-102163)	49°29.90' 124°09.35'	conodonts (CAI=5)	M. Pennsylvanian, Atokan (1)	(13)
B15	CNR railroad trestle, Koksilah River, Victoria map area. (C-087059)	48°40.75' 123°41.65'	conodonts (CAI=5)	M. Pennsylvanian, Atokan (1)	(13)
B16	Cobble Hill quarry, Victoria map area. (C-087058)	48°40.65' 123°38.15'	conodonts (CAI=5)	M. or L. Pennsylvanian, Desmoinesian to Virgilian (2)	(13)
B17	Cobble Hill quarry, Victoria map area. (C86308)	48°40.65' 123°38.15'	conodonts (CAI=6-7)	probably E. Permian (3?)	(13)
B18	Cobble Hill quarry, Victoria map area. (C-086309)	48°40.65' 123°38.15'	conodonts (CAI=6-7)	probably E. Permian (3?)	(13)
B19	Buttle Lake road, 3.3 km N of Ralph R., Alberni map area. (C-102165)	49°39.60' 125°31.45'	conodonts (CAI=6-7)	E. Permian, probably Sakmarian (3)	(13)
B20	Copper Canyon Chemainus River Victoria map area. (C-127506)	48°53.12' 123°47.45'	conodonts (CAI=6-7)	probably E. Permian (3?)	(13)
B21	S of St. Mary's Lk., Mt. Arrowsmith Regional Park, Alberni map area. (C-127712)	49°15.60' 124°37.60'	conodonts (CAI=6-7	probably E. Permian (3?)	(13)

* Conodont alteration index (CAI) is given for conodont localities.
** ( ) refer to conodont faunal associations discussed in text.

References: (1) Muller et al., 1974, p. 7; (2) B.E.B. Cameron (GSC), writ. comm., 1972 (GSC report no. P-2-1972-BEBC); (3) Fritz, 1932; (4) Yole, 1963 (see p. 143 in Yole for a discussion of revised age of brachiopods); (5) Muller, 1980, p. 23; (6) Muller and Carson, 1969, p. 9; (7) Fyles, 1955, p. 19; (8) Muller, 1971, p. 29, (no GSC locality or official report); (9) Muller et al., 1981, p. 8; (10) Sada and Danner, 1974, p. 250, 255, 262-263. Note that at this locality the age diagnostic fusulinid was not confidently identified; (11) unpublished locality of Muller, collected near B8 (GSC report no. 4-BM-1980, identified by B.L. Mamet); (12) Stevenson, 1945, p. A144; (13) Conodont determinations by Orchard on collections by Brandon, Muller, Sutherland-Brown and Yorath.

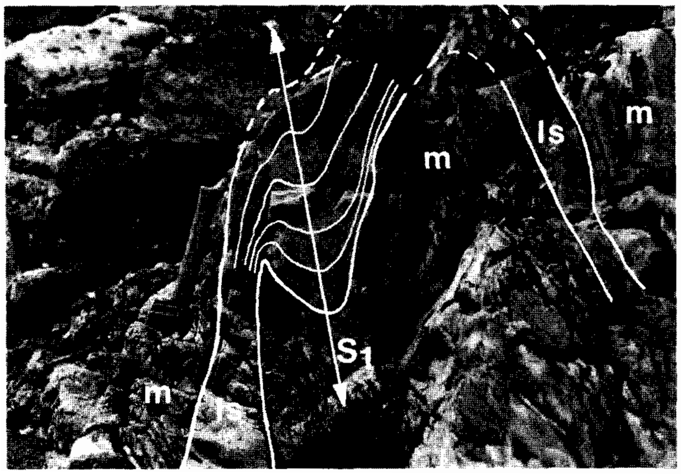

Figure 82.5. *Tight folds of Buttle Lake Limestone exposed in the Chemainus River at Copper Canyon. At this locality, the unit consists of interbedded limestone (ls) and black mudstone (m). The axial plane of these folds (S_1) is parallel to schistosity in nearby quartz-sericite schist and schistose metavolcanic rocks. Conodonts from the limestone (B20) are Early Permian and give a maximum age for Sicker deformation.*

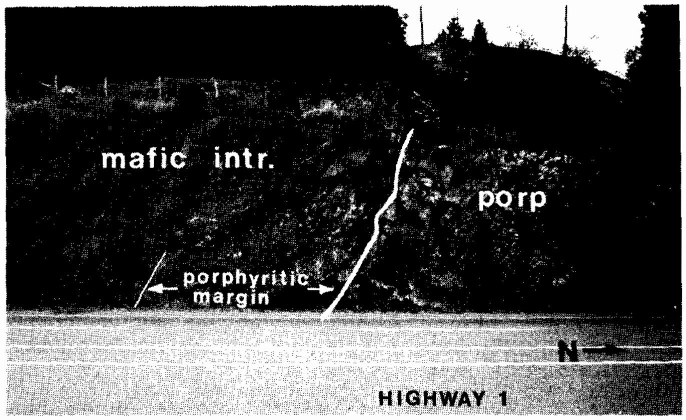

Figure 82.6. *Triassic mafic intrusion cutting Saltspring quartz porphyry (porp). The margin of the mafic intrusion is porphyritic near the intrusive contact. Concordant U-Pb zircon dates from this locality (K1) indicate a Late Triassic age for the intrusion. The outcrop is about 6 m high and is located on the west side of Highway 1 about 1.5 km south of the Chemainus River (second outcrop south of river).*

Buttle Lake Limestone

The highest unit in the Sicker Group is the Buttle Lake Limestone of Yole (1969). Yole (1969) described a section in the type area at Buttle Lake (B3 in Fig. 82.1) and two sections in the Cowichan Lake uplift (near BS1 and B8 in Fig. 82.1). The Buttle Lake typically consists of massive and bedded limestone with lenses and nodules of chert (Yole, 1969; Fyles, 1955); locally it also contains interbeds of siltstone and mudstone. In some areas, a thin clastic unit is present at the top of the Buttle Lake Limestone (PS1 of Sutherland Brown and Yorath, 1985). A gentle unconformity separates the Buttle Lake from overlying Triassic basalts of the Karmutsen Formation (Sutherland Brown and Yorath, 1985).

Based on extensive fossil collections (Tables 82.4 and 82.5), the age of the Buttle Lake is now known to range from Middle Pennsylvanian through Early Permian (Fig. 82.2). The macrofossil localities (B1-B13 in Table 82.4) generally give imprecise Pennsylvanian-Permian ages, although two fusulinid localities (B5, B7) do give more specific ages of Middle Pennsylvanian and Early Permian.

New conodont ages from twenty-one localities provide more complete data on the age and stratigraphy of the Buttle Lake Limestone. Table 82.4 summarizes eight isolated conodont localities (B14-B21); Table 82.5 shows ages for two stratigraphic collections, located at Mount Mark and on the Cameron River (BS1, BS2 in Fig. 82.1). The conodont collections are divided into three faunal associations (Fig. 82.2, Appendix B): (1) early Middle Pennsylvanian, Atokan; (2) late Middle or Late Pennsylvanian, Desmoinesian to Virgilian; and (3) Early Permian, probably Sakmarian. The stratigraphic collections, especially BS2, indicate that this age range is present, at least locally, in a single vertical section. This result contrasts with Yole (1963). Based on systematic sampling of macrofossils, he concluded that in its type area, the Buttle Lake Limestone is restricted to the Early Permian (Fig. 82.2), which is consistent with the one conodont age from the Buttle Lake area (B19). Further sampling for conodonts, however, is needed to determine the presence or absence of Pennsylvanian limestone at Buttle Lake.

The conodont alteration index (CAI; (Epstein et al., 1977) can be used to estimate the maximum temperature to which the Buttle Lake Limestone was exposed. CAI values for the Buttle Lake (Table 82.4 and 82.5) are all relatively high, ranging from 5 to 7; they indicate temperatures in excess of 300°C and are typical of conodonts from greenschist facies metamorphic rocks (Epstein et al., 1977). For comparison, Triassic limestones above the Sicker Group typically have CAI values of 3 to 4, indicating maximum temperature of about 200°C. In the Buttle Lake Limestone, there appears to be a general pattern of higher CAI values in younger parts of the unit (e.g., BS2 and B16-B18), which probably is due to high temperatures beneath the thick Triassic basaltic sequence that was erupted over the Buttle Lake Limestone (Muller, 1977). The CAI of the lower part of the Buttle Lake is probably related to the same greenschist metamorphism recorded in the underlying Youbou Formation.

One of the conodont localities in Table 82.4 comes from a newly discovered exposure of Buttle Lake Limestone in the Chemainus River at Copper Canyon. In this area, the Buttle Lake consists of interbedded limestone and mudstone which are highly deformed into a series of tight, upright folds (Fig. 82.5). Associated with these folded limestones are quartz-sericite schist and schistose mafic volcanic rocks, which probably correlate with the Saltspring Intrusions and Nitinat tuff, respectively. The foliation in these rocks parallels the axial plane of the folded limestones. Together these relationships indicate that all of these rocks were affected by the same deformational event. Schistose fabrics are common in the Sicker Group, but are more widely developed in the southeast part of the Cowichan uplift (Clapp and Cooke, 1917; Eastwood, 1980). One interpretation is that the more highly deformed rocks represent an older portion of the Sicker. The Copper Canyon locality, however, indicates that deformation of the Sicker occurred after the Early Permian. In fact evidence discussed below suggests that this deformation happened in the early Mesozoic. The more widespread occurrence of deformed Sicker rocks in the southeast part of the Cowichan uplift probably indicates that a deeper structural level is exposed there, which is consistent with the northwest plunge of the uplift.

Triassic(?) mafic intrusions

The Triassic(?) mafic intrusions occur as thick sills and dykes, typically with a porphyritic texture, and are composed of plagioclase and clinopyroxene (commonly altered to uralite) with minor skeletal ilmenite. These intrusions are fairly common in the Saltspring Island – Cowichan Lake area (gabbro-diorite porphyrite of Clapp and Cooke, 1917, p. 169-172; "hornblende shonkinite" of Eastwood, 1980; Franklin Creek intrusions of Fyles, 1955, p. 20-22). Muller (1980, p. 6) speculated that some of these intrusions may be related to the Nitinat tuff. A Triassic age, however, is preferred for the following reasons: (1) the intrusions are compositionally and texturally similar to the overlying Triassic Karmutsen basalts (Fyles, 1955, p. 20-22; Karmutsen basalts = Franklin Creek Volcanics of Fyles); (2) one of these intrusions yielded concordant U-Pb dates of about 220 Ma (Late Triassic; K1 in Table 82.6, Fig. 82.6); and (3) a mafic sill in the Copper Canyon area intrudes dated Buttle Lake Limestone (B20), and therefore must be post-Early Permian.

This conclusion is at variance with a K-Ar date of 363 Ma (Mississippian) reported by Eastwood (1983) for a mafic intrusion in the Mount Richards area (K2 in Table 82.6, Fig. 82.1). This intrusion, however, is identical, both in outcrop and in thin section, with the dated Triassic intrusion on Highway 1 (K1, Fig. 82.6). The dated sample at Mount Richards was obtained from a drill core, so that instead of mafic intrusion, Nitinat tuff may have been sampled accidently. Unfortunately, no thin section was made nor was any reference material retained. In any case, dating in progress of another sample from this locality should resolve this question.

Clapp and Cooke (1917) argued convincingly that the schist-producing deformation of the Sicker postdates the mafic intrusions and predates emplacement of Jurassic granitic plutons which are widespread in the outcrop areas of the Sicker Group (Fyles, 1955; Muller, 1983). Therefore, if the mafic intrusions are in fact Triassic, then deformation of the Sicker would be constrained to the early Mesozoic.

Table 82.5. Conodont ages for stratigraphic sections in the Buttle Lake Limestone

Metres above base of unit (GSC locality no.)	Age determination**	CAI*
BS1--Mt. Mark composite section, Alberni map area (49°21.60' 124°43.90')		
215 m (C127679)	E. Permian? (3?)	6-7
163 m (C127669)	M. Pennsylvanian-E. Permian (1-3)	5-6
69 m (C127674)	M. Pennsylvanian?, Atokan? (1?)	6-7
30 m (C127672)	M. Pennsylvanian, Atokan (1)	5
8 m (C127711)	M. Pennsylvanian, Atokan (1)	6-7
4 m (C127710)	M.Pennsylvanian?, Atokan? (1?)	6-7
2 m (C127660)	M. Pennsylvanian, Atokan (1)	6
0 m (C127670)	M. Pennsylvanian, Atokan (1)	6-7
BS2--Cameron River section, Alberni map area (49°10.30' 124°32.80')		
365 m (C127690)	E. Permian, probably Sakmarian (3)	6
200 m (C127688)	E. Permian, probably Sakmarian (3)	6
168 m (C127686)	E. Permian, probably Sakmarian (3)	6
79 m (C127683)	M. or L. Pennsylvanian, Desmoinesian to Virgilian (2)	5-6
67 m (C127681)	M. or L. Pennsylvanian, Desmoinesian to Virgilian (2)	5
*,** See Table 82.4		

Conclusions

The main conclusions are as follows:

1. The oldest known unit in the Sicker Group is the Nitinat tuff, which is definitely pre-Devonian, and possibly Silurian.
2. The Saltspring Intrusions, which intrude the Nitinat tuff, are Early Devonian.
3. Preliminary U-Pb dates indicate that the Myra volcanics of the Buttle Lake uplift are pre-Late Devonian, and therefore could be extrusive equivalents of the Saltspring Intrusions.
4. A Lower Mississippian chert unit is present in the Cowichan uplift and probably lies depositionally above the Nitinat tuff. Thus, in this area, rocks above the Nitinat tuff are not equivalent to the Myra volcanics as originally suggested by Muller (1980).
5. The Buttle Lake Limestone, which is the highest unit in the Sicker, ranges from Middle Pennsylvanian through Early Permian.
6. Deformation of the Sicker Group, which resulted in tight folds and a widespread schistose foliation, is definitely post-Early Permian, and probably early Mesozoic.

Acknowledgments

We are grateful and indebted to R.L. Armstrong of the University of British Columbia for access to his geochronology data file and for permission to use unpublished isotopic dates. We also thank K.J. Kveton of the University of Washington for helpful discussions about the geology of Saltspring Island.

Table 82.6. Isotopic dates for Triassic(?) mafic intrusions in the Sicker Group

No.	Rock type, location (sample no.)*		Dating method	Date** (Ma)	Ref.	Comments
K1	Pyroxene-phyric mafic dyke. East of Mt. Sicker along Highway 1 (Fig. 82.6), Victoria map area. 48°52.0' 123°42.6' (UBC/Sicker lam)	(a)	U-Pb zircon	217-222	(3)	Concordant U-Pb date, represents primary age of dyke.
		(b)	K-Ar uralitic amphibole after pyroxene	190 ± 14	(1)	Minimum age of uralite alteration.
K2	Mafic rock of uncertain affinity. W of Crofton, N of Mt. Richards Victoria map area. 48°51.7' 123°40.4' (UBC/E80-24 no. 24566M)		K-Ar uralitic amphibole after pyroxene	363 ± 26	(1,2)	Minimum age of uralitic alteration. Sample was from a drill core and was identified as a mafic intrusion (ref. 2). Might be Nitinat tuff (no sample or thin section available).

*,** see Table 82.1.

References: (1) Geochronology data file of R.L. Armstrong (Univ. of British Columbia), writ. comm., 1985; (2) Eastwood, 1983; (3) Isachsen et al., 1985.

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APPENDIX A

U-Pb zircon dates from the Saltspring Intrusions

Table 82.7. U-Pb zircon results for Saltspring Intrusions

Sample/fraction[1]	Wt. (mg)	U (ppm)	Pb (ppm)	Pb isotopic abundance,[2] Pb 206 = 100: 208	207	204	$^{206}Pb/^{204}Pb$ measured	Ratios and ages (Ma)[4]: $^{206}Pb/^{238}U$	$^{207}Pb/^{235}U$	$^{207}Pb/^{206}Pb$
MEZ-77-1	Mt. Maxwell, Saltspring Island									
[3]+200 HP, AB (1)	2.53	361.9	20.86	10.572	5.508	0.0050	6743	0.05767 (361.5)	0.4322 (364.8)	0.05435 (385.7)
-200 + 325 MAG (2)	3.06	549.9	30.37	11.021	5.511	0.0057	2038	0.05505 (345.5)	0.4120 (350.3)	0.05428 (382.6)
-140 + 200 NMAG (3)	9.48	470.0	27.61	13.742	6.7809	0.0920	121	0.05567 (349.2)	0.4174 (354.2)	0.05437 (386.5)
-200 + 325 NMAG (4)	14.37	474.0	25.82	10.784	5.421	0.0001	4162	0.05451 (342.1)	0.4073 (346.9)	0.05419 (378.8)
-140 + 200 MAG (5)	3.87	481.9	28.12	13.183	6.544	0.0783	888	0.05581 (350.1)	0.4154 (352.8)	0.05399 (370.6)
WN-19-74	Arbutus Point, Vancouver Island									
[3]+200 HP, ABR	1.89	502.9	29.13	11.404	5.435	0.0019	14067	0.05764 (361.3)	0.4298 (363.0)	0.05407 (374.2)
-200 + 250	9.39	594.3	35.01	13.405	5.538	0.0055	5108	0.05751 (360.5)	0.4327 (365.1)	0.05457 (394.8)
-250 + 325	19.25	623.3	36.75	14.184	5.737	0.0199	3133	0.05694 (357.0)	0.4276 (361.5)	0.05446 (390.1)
-100 + 140	2.81	465.0	27.06	12.491	5.938	0.0385	1253	0.05671 (355.6)	0.4204 (356.3)	0.05376 (360.8)
MEZ-76-3	Lake Stowell, Saltspring Island									
+200 HP	1.43	491.8	27.66	12.490	5.925	0.0382	2454	0.05480 (343.9)	0.4055 (345.6)	0.05367 (357.1)
-140 + 200 NMAG	18.66	485.0	27.16	11.768	5.592	0.0139	1542	0.05534 (347.2)	0.4112 (349.8)	0.05389 (366.6)
-140 + 200 MAG	11.47	563.6	31.30	12.546	5.895	0.0326	6126	0.05417 (340.1)	0.4047 (345.1)	0.05419 (378.9)
-200 + 230 NMAG	24.04	553.7	30.77	11.951	5.424	0.0015	3817	0.05503 (345.3)	0.4098 (348.8)	0.05401 (371.6)
-200 + 230 MAG	14.68	682.6	36.90	12.536	5.494	0.0077	730	0.05317 (334.0)	0.3946 (337.7)	0.05381 (363.2)

[1] Symbols refer to mesh size; HP = hand-picked; ABR = Abraded; MAG = magnetic fraction; NMAG = non-magnetic fraction; ( ) refers to numbers on concordia diagram in Fig. 4

[2] blank corrected

[3] 1983 analyses; these have smaller errors than other analyses

[4] Decay constants: $\lambda_{238} = 0.155125 \times 10^{-9}$/year; $\lambda_{235} = 0.98485 \times 10^{-9}$/year; $^{238}U/^{235}U = 137.88$

Isotopic composition of common Pb assumed to be $^{208}Pb:^{207}Pb:^{206}Pb:^{204}Pb = 37.93:15.60:19.11:1$

APPENDIX B

Conodont faunas from the Buttle Lake Limestone

Twenty-one conodont collections recovered from the Buttle Lake Limestone can be grouped into three conodont faunal associations (Fig. 82.2) ranging in age from Middle Pennsylvanian (Atokan) through Early Permian (probably Sakmarian). None of the faunules is large, and several consist of only a few fragmentary specimens, so that it is not possible to determine many elements to species level. The faunal associations are described below. Ages and locality descriptions are summarized in Table 82.4 for locality numbers beginning with B and Table 82.5 for those beginning with BS.

(1) Middle Pennsylvanian (Atokan) fauna. This fauna occurs at B14 and B15 and at 0 m, 2 m, 8 m and 30 m above the base of the Mount Mark section (BS1); it may also be present at 4 m and 69 m in BS1.

Faunules from 0 m and 30 m in BS1 contain specimens that are homeomorphic after **Declinognathodus.** These elements resemble **Idiognathoides opimus** morphotype 2 described from the Canadian Arctic by Bender (1980) and **I. marginodosus** morphotype B described from Oklahoma by Grayson (1984), both of which are from strata of Atokan age. The faunule from 0 m in BS1 also contains a specimen of **Rhachistognathus minutus declinatus** Basemann & Lane; this subspecies ranges from the early (but not basal) Morrowan into at least early Atokan strata in western United States (Baesmann and Lane, 1985, p. 108-109.

Simple elements of **Idiognathoides** lacking accessory anterior nodes occur alone, or associated with fragments that may represent **Idioprioniodus,** in four or five faunules: at B14 and B15 and at 2 m, 8 m and possibly 69 m in BS1. Most of the specimens of **Idiognathoides** correspond to **I. marginodosus** Grayson morphotype C, or **I. opimus** morphotype 1 sensu Bender, indicating an early Middle Pennsylvanian, Atokan age.

The faunule at B14 also contains fragmentary specimens of the **Idiognathodus – Streptognathodus** plexus. This group, which ranges through much of the Upper Carboniferous and earliest Permian, is found alone at 4 m in BS1. The stratigraphic position of the latter implies it too is Atokan in age (Table 82.5).

(2) Middle or Late Pennsylvanian (Desmoinesian to Virgilian) fauna. This fauna occurs at B16 and at 67 m and 79 m above the base of the Cameron River section (BS2).

The most distinctive element of this fauna is a species of 'naked' Gondolella, although none of the elements recovered are complete. The species has a very narrow platform and simple, robust denticles; the character of the posterior termination is uncertain. Similar elements have been referred to **G. gymna** Merrill & King, a species of probable late Middle Pennsylvanian, Desmoinesian age. However, because of the uncertainty about the specific identity of the Sicker Group specimens, a Late Pennsylvanian age is also considered possible. Poorly preserved specimens of the long ranging **Idiognathodus** and **Adetognathus** are present.

(3) Early Permian (probably Sakmarian) fauna. This fauna occurs at B19 and at 168 m, 200 m and 365 m above the base of the Cameron River section (BS2) and probably is present at B17, B18, B20 and B21 and possibly at 215 m in the Mount Mark section (BS1). A faunule from 163 m in BS1 is also included with this assemblage, but its age is very poorly resolved.

Faunules from 168 m, 200 m and 365 m in the upper part of the Cameron River section (BS2), are characterized by typical Early Permian **Neogondolella** elements together with the long ranging **Adetognathus** sp. (at 200 m and 365 m) and/or **Hindeodus** sp., an association of probable Sakmarian age. Four or five other localities, B17, B18, B20, B21 and possibly 215 m in BS1, have yielded only **Neogondolella.** These localities may therefore be slightly younger than the Cameron River fauna or, alternatively, the difference may be ecological: **Adetognathus** is known to favour restricted shallow water conditions.

Faunules from B19 and 168 m at BS2 contain fragments of what are considered to be a new genus probably related to species of 'naked' Gondolella. One difference, however, is that these elements have laterally enlarged, icriodid-type denticles. Elsewhere in western Canada, the same species has been found in the Iskut River area of northwestern British Columbia and in the Nahanni map area of east-central Yukon, in both cases associated with conodonts of latest Pennsylvanian or earliest Permian age. In the faunule from 168 m in BS2, this new element is associated with **Neogondolella** and is therefore considered to be Early Permian in age, which is consistent with its stratigraphic position (Table 82.5). The same age is attributed to B19 from Buttle Lake, where the new element occurs with long-ranging **Hindeodus.**

A faunule from 163 m in BS1 only contains specimens of long ranging **Adetognathus** sp. and **Hindeodus**, and therefore has been assigned a Middle Pennsylvanian to Early Permian age (Table 82.5). However, the fact that these two genera are present in several of the Early Permian faunules (168 m, 200 m and 365 m in BS2) may suggest a similar age for the faunule at BS1.