G.A.C. NEWFOUNDLAND SECTION

FALL FIELD TRIP 1985

ORDOVICIAN AND SILURIAN VOLCANISM AND SEDIMENTATION IN CENTRAL NOTRE DAME BAY

by

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and

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FIELD TRIP INTRODUCTION

The 1985 G.A.C. Newfoundland Section Fall Field Trip will examine Ordovician and Silurian stratigraphic and structural relationships in central Notre Dame Bay along traverses of Highway 350 between Northern Arm and Leading Tickles and Highway 352 between Fortune Harbour and Point of Bay. The rocks exposed in these traverses form part of the Newfoundland Central Mobile (volcanic) Belt and the Dunnage Terrane of Williams and Hatcher (1983).

The Ordovician to early Silurian stratified rocks of the Dunnage Terrane record the development and destruction of the Iapetus Ocean. Early to Middle Ordovician ophiolitic rocks are widespread and are generally interpreted as oceanic crust generated either at a major oceanic spreading center or in one or more Ordovician marginal basins. Thick packages of volcanic, subvolcanic and volcaniclastic rocks are also generally pre-Caradocian in age and are commonly interpreted as remnants of island arcs, although recent geochemical data suggest that volcanism and sedimentation in marginal basins may also be represented in these packages. Two broad types of volcanic-volcaniclastic sequences are recognized in this group, based on differences in lithologies, metamorphism, nature of the associated volcanogenic mineralization and contrasts in lead isotopic composition of ore leads in galena (Strong, 1977; Dean 1978; Kean et al., 1981; Swinden and Thorpe, 1983; Swinden and Kean, 1984): 1) a widespread association which previous workers have termed the "early arc" or "pre-Caradocian island arc". This type includes the Wild Bight and Exploits groups which will be examined on Days 1 and 2 respectively, and 2) a sequence termed the "Buchans - Roberts Arm belt" which includes the Cottrells Cove Group, to be visited on Day 2.

In the Middle Ordovician, submarine volcanic activity in Central Newfoundland abruptly ceased, roughly coincident with the onset of the Taconian Orogeny and the obduction of large allochthons on the North American continental margin to the west. In the Dunnage Terrane, this event is marked by the sudden deposition of a laterally extensive pelagic facies of sedimentary rocks, consisting mainly of black carbonaceous shale, chert and lesser calcareous rocks. These rocks, which commonly contain a rich Caradocian graptolite fauna, form an important stratigraphic marker across Notre Dame Bay and southwards into the Red Indian Lake area. They are assigned to several formations throughout central Newfoundland and are informally referred to by most workers as the "Caradocian interval". They are overlain by sandy turbidites which tend to coarsen upward on a broad scale. These flysch sequences are generally assigned to the Sansom Greywacke or the Point Leamington Greywacke and are interpreted to record denudation of the nearby Early to Middle Ordovician volcanic terranes. They are overlain by a coarse polymictic conglomerate, the Goldson Formation. These conglomerates contain limestone clasts which have yielded shelly fauna ranging from Mid-Ordovician to Silurian in age and Silurian fossils have locally been recovered from the matrix. Lenses of Goldson-like lithologies also occur within the underlying greywacke sequences.

The flysch sequences are disconformably to unconformably overlain throughout Notre Dame Bay by subaerial volcanic rocks and terrestrial to shallow marine sedimentary rocks. The volcanic rocks consist of both felsic and mafic flows while the sedimentary rocks are typically red to green fluviatile sandstones, conglomerates and argillites displaying mud cracks, ripplemarks and other features indicative of shallow water

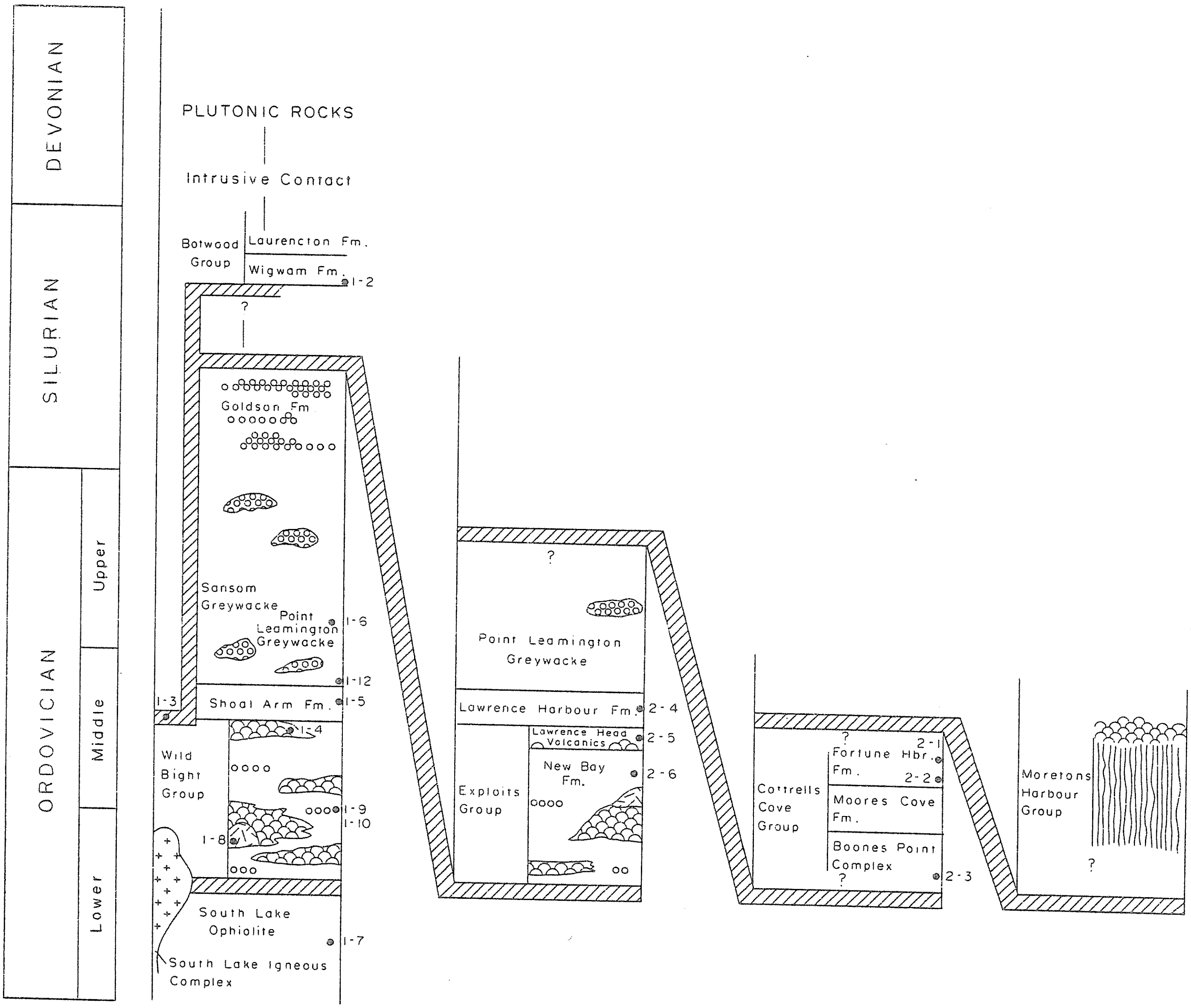

Figure 1: *Schematic illustration of stratigraphic and structural relationships in the field trip area. Cross-hatched zones are fault boundaries.*

Symbols

felsic volcanics
conglomerates

pillow lavas
sheeted dikes

environments. In central Notre Dame Bay, these rocks are assigned to the Botwood Group, with sedimentary rocks generally termed the Wigwam Formation and volcanics the Laurenceton Formation. The best section of these rocks is not easily accessible and will not be visited on this trip. However, some examples will be viewed on Day 1.

Examples of all the environments noted above (except the Goldson Conglomerate) will be examined during this field trip. On Day 1, we traverse the section exposed along Highway 350 starting with red sandstones of the Silurian Botwood Group. We cross the Northern Arm Fault into the uppermost pillow lavas of the Early to Middle Ordovician Wild Bight Group and pass up-section into the Caradocian interval, represented here by carbonaceous shale and chert, and finally into the Point Leamington Greywacke in good coastal exposures in the village of Point Leamington. North of here, we pass down section again and visit turbidites and debris flow volcaniclastic rocks of the lower Wild Bight Group as well as the Lockport volcanigenic sulphide deposit. The last stop of the day will be back at the top of the Caradocian interval in Leading Tickles. Along the way, we look at two somewhat enigmatic plutonic exposures, the South Lake ophiolite and the Leading Tickles mafic to ultramafic "stock". On Day 2, we traverse Highway 352, starting in Fortune Harbour where we examine volcanic rocks of the Cottrells Cove Group before walking through a section of the Boones Point Formation, a spectacular black shale mélange. Crossing a major fault, we stop briefly in fossiliferous shales of the Caradocian interval before visiting pillow lavas of the Lawrence Head volcanics and ending in turbidites of the New Bay Formation, both in the Exploits Group.

LEGEND

Stratified Rocks

SILURIAN

S_B	**Botwood Group**: terrestrial clastic sediments and mafic to felsic subaerial volcanic rocks.
S_G	**Goldson Formation**: polymictic conglomerate, minor greywacke.

ORDOVICIAN AND SILURIAN

OS_S, OS_P	**Sansom Formation** and **Point Leamington Greywacke**: "post-Caradocian flysch", gray to black, well bedded greywacke (turbidite), lesser argillite, minor conglomerate.

ORDOVICIAN

mO_S, mO_L	**Shoal Arm Formation** and **Lawrence Harbour Formation**: "Caradocian interval", black carbonaceous shale, gray to black bioturbated chert, minor calcareous argillite.
O_E, O_W	**Exploits Group** and **Wild Bight Group**: part of units generally termed "pre-Caradocian island arc". Mainly volcaniclastic turbidites, lesser argillite, chert, mafic volcanics, minor felsic volcanics. O_{E1} - **Lawrence Head Volcanics**: pillow basalts.
O_M	**Moreton's Harbour Group**: sheeted dikes with pillow lava and gabbro screens. Generally correlated with "pre-Caradocian island arc".
O_C	**Cottrells Cove Group**: Dominantly mafic pillow lavas, lesser greywacke, argillite, felsic volcanics, chert. Generally considered as part of the "Buchans-Roberts Arm Belt". O_{Cb} - **Boones Point Complex**: chaotic black shale mélange with blocks of carbonate, clastic sediments, volcanic rocks.
O_S	**South Lake Ophiolite**: layered gabbro, sheeted diabase dikes.

Intrusive Rocks

DEVONIAN

2	**Plutonic rocks**: granite, granodiorite, lesser diorite, gabbro.

ORDOVICIAN

1	**South Lake Igneous Complex**: hornblende diorite, tonalite, granodiorite (excludes rocks assigned to South Lake Ophiolite).

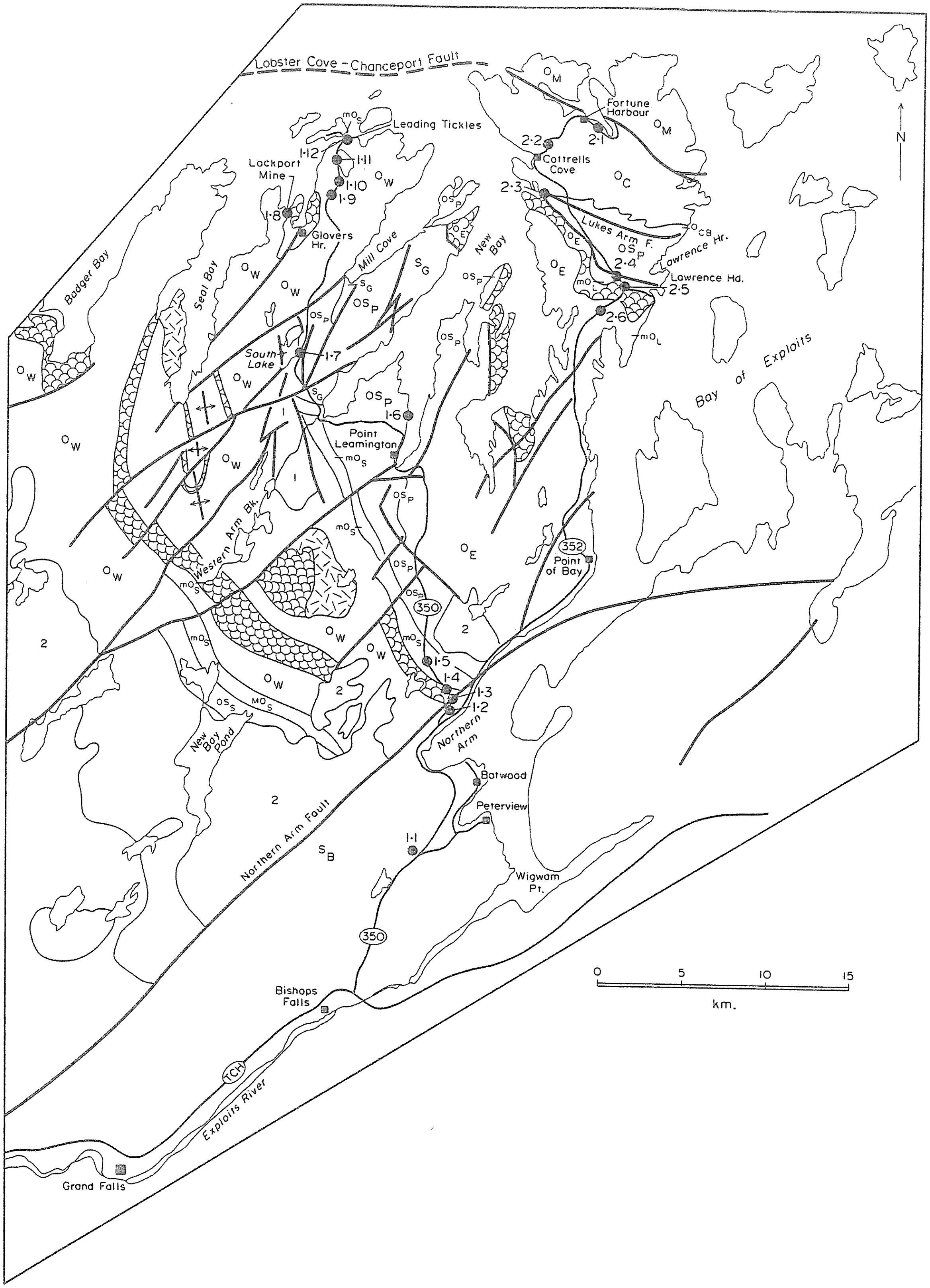

Figure 2: *General geology of central Notre Dame Bay. Field trip stops are indicated by solid circles. Pillow lava and felsic volcanics in the Wild Bight and Exploits groups are indicated as follows:*

felsic volcanics *pillow lavas*

ROAD LOG AND STOP DESCRIPTIONS

DAY 1

From Grand Falls, proceed east on the TCH to the Botwood exit just west of the Exploits River (Sir Robert Bond) Bridge. Red outcrops along this stretch of highway are thick bedded, fairly monotonous sandstones of the Botwood Group. Take the Botwood exit.

Km 0:

Stop sign at the bottom of the Botwood exit ramp. Turn left on Highway 350 and proceed towards Botwood.

Km 11.4 - Stop 1-1:

Pleistocene glacial outwash deposits exposed in the quarry across the road. Sandy foreset beds are well displayed high in the quarry walls. Other sedimentological features may be visible depending on the effects of recent quarrying.

Km 13.4:

The community of Peterview can be seen near the shore on the right. South of Peterview is Wigwam Point, type section for the Wigwam Formation, the upper sedimentary unit of the Botwood Group. Most lithologies which characterize the formation and well preserved sedimentary structures are present in this section. However, it is not sufficiently accessible to be conveniently visited on this trip.

Km 15.2:

Botwood south exit. Continue on Highway 350 towards Northern Arm.

Km 16.1:

Northern Arm can be seen down the hill to the left and a good view of Botwood harbour to the right. This harbour is of major importance to the commerce of central Newfoundland. Newsprint from Grand Falls passes through here as did ore concentrate from Buchans. Botwood also serves as the offshore base for BP exploratory drilling north of Newfoundland. In the late 1930's, it was a refuelling stop for the amphibious Pan-American "Clippers", which made the earliest trans-Atlantic scheduled passenger flights.

Km 16.4:

Stop sign. Beware - it is easily missed. Road to the right provides access to Botwood north. Turn left and proceed towards Northern Arm.

Km 20.9:

Junction with Highway 352 to Fortune Harbour. Turn left here and continue on Highway 350.

Km 21.7 - Stop 1-2:

Red sandstones of the Wigwam Formation, Botwood Group. At this locality, as at those we passed on the TCH, the Wigwam Formation comprises a fairly monotonous succession of red sandstones with few apparent sedimentary structures. We make this stop mainly to emphasize the contrast between this sequence and the older lithologies which we traverse later in the day.

Looking across the road to the northwest, we can see a steep scarp on the near horizon. This is the topographic expression of the Northern Arm Fault which in this area juxtaposes Ordovician to Silurian marine sequences with the terrestrial sediments of the Botwood Group. This is a fault of considerable regional and historical interest, one of many important NE striking faults in central Notre Dame Bay. It can be traced to the northeast where it connects with the Reach Fault in eastern Notre Dame Bay and cuts Devonian plutonic rocks so that latest movement on it is at least this age. It is cut by unaffected lamprophyre dikes of Jurassic age. Early interpretations of the history of movement on the Reach Fault by Kay (1952) suggested that strike-slip displacement in excess of 200 km had taken place. McKerrow and Cocks (1977) interpreted the Reach Fault system as a suture, formed by the final closing of a Silurian Ocean, based on contrasts in Silurian faunal affinities across it. However, pre-Silurian faunas and lithostratigraphy can locally be correlated across the fault and it presently seems unlikely that either large amounts of strike-slip displacement or the closing of a Silurian Ocean are represented here.

Km 22.2 - Stop 1-3:

The highway runs along the trace of the Northern Arm fault in this area. Outcrops on the left of the road are basaltic pillow lavas of the Wild Bight Group (these will be examined in better exposures at the next stop). On the right are badly fractured but still recognizable red sandstones of the Botwood Group.

Km 23.0 - Stop 1-4:

These road cuts expose pillow lavas of the Wild Bight Group. This basalt is the stratigraphically highest volcanic member in the Wild Bight Group and it passes conformably upward into Caradocian shale. It consists of vesicular pillow basalt, locally plagioclase-phyric, with green chert preserved in the pillow junctions. There is a narrow interflow unit of green, volcaniclastic sediments near the middle of the outcrop.

Chemically, these basalts are low Ti (1.5-2% TiO_2) tholeiites, probably generated in a marginal basin environment. Stratigraphically equivalent basalts elsewhere in the Wild Bight Group range from similar tholeiites to alkalic basalts with greater than 3% TiO_2.

Look back down the road for a good view of Botwood and its harbour. If the day is foggy or raining, don't bother.

Km 25.6:

Cross small bridge over Charles Brook.

Km 25.8 - Stop 1-5:

Caradocian shales and chert are exposed in these two outcrops. Since the last stop, we have traversed up-section out of the Wild Bight Group and into the overlying "Caradocian interval". These outcrops are assigned to the Shoal Arm Formation and are referred to by Dean and Meyer (1982) as the "Charles Brook Section". Oldest dated beds in the Shoal Arm Formation are *Nemagraptus Gracilis* zone although there is not a faunal list published for this particular outcrop. The Charles Brook Section contains the two principal lithologies which characterize the Caradocian interval in central and eastern Notre Dame Bay. The first outcrops we encounter are carbonaceous black shales with lesser sandy interbeds. Several species of graptolites can be found in this outcrop; a good collecting site occurs about two-thirds along the outcrop on the left. Structural relationships in this outcrop are complex and have not been mapped in detail.

As we walk along the road, the next outcrops at the top of the hill are bioturbated black to gray chert. This is a distinctive and unique lithology in the Caradocian interval. The laminated chert is locally extensively bioturbated, with black burrows often at high angles to the lamination. They are very siliceous, generally containing greater than 90% SiO_2, and are locally manganiferous. A little Mn staining can be seen on some beds at this locality. Any suggestions as to the perpetrators of the bioturbation are welcome. This rock is very photogenic and makes excellent bookends.

The Charles Brook Section is cut by porphyritic mafic dikes of unknown affinity.

Km 39.0:

Enter village of Point Leamington.

Km 42.8:

Road Junction. Road straight ahead goes to Point Leamington North and Highway 350 continues to the left.

Proceed straight ahead towards Point Leamington North for 1.4 km and park in the gravel area on the right. Walk down to the outcrops along the landwash.

Stop 1-6: Outcrops on the shore are good typical exposures of the post-Caradocian flysch, here assigned to the Point Leamington Greywacke. They comprise well bedded sandy and shaly turbidites which contain abundant graded beds, sole markings, flame structures and various other sedimentary structures. Calcareous nodules, concretions and thin beds are common throughout the sequence and a small sandstone dike cuts across the beds near the high water mark.

After going back to the vehicles, turn around and proceed back to km 42.8. Turn right on Highway 350 towards Leading Tickles.

Km 43.7:

End of paved road. On the left is the Ponderosa Club, a bit of an anomaly in this part of the bay; it is the only club on this road north of Northern Arm. Those who don't feel up to continuing on an unpaved road (e.g. carsick, allergic to dust, etc.) may disembark here. We will retrieve and pour you back into the vehicles upon our return.

Km 48.4:

Cross Western Arm Brook. Good view of cottages and gravel pit suitable for campers. Little geological interest.

Km 53.3 - Stop 1-7:

The lake to the left is South Lake and at this stop we will briefly consider the nature of the South Lake Igneous Complex which is exposed in the road cuts here and in the bare hills across the lake. The Complex contains quite a variety of rock types, including gabbro, diabase, quartz-hornblende diorite, tonalite and granodiorite. Dean (1978) was the first to describe the complex in detail and he suggested that a small part of the complex on the west shore of South Lake, consisting of layered gabbro and sheeted diabase, was an ophiolitic fragment. These ophiolitic rocks are intruded by quartz-hornblende diorite and tonalite and all rock types, as well as the adjacent Wild Bight Group, are intruded by granodiorite. The notion that part of this complex is ophiolitic was supported and expanded by Lorenz and Fountain (1982) who showed that the ophiolitic components consist of incompatible, element-depleted, tholeiites. The felsic phases which intrude them are even more severely depleted in incompatible elements and were interpreted by Lorenz and Fountain (1982) as magmatism related to early stages of an island arc, developed upon ophiolitic basement.

The ophiolitic rocks are generally fault bounded. In this area, their western boundary is the Long Pond Fault, a major NE trending structure which passes along the far shore of South Lake.

The South Lake Ophiolite underlies the bare hills across the lake but unfortunately does not outcrop on this side. The outcrops beside the road are hornblende diorite intruded by dikes and net veins of plagiogranite. This lithology typically intrudes the ophiolitic rocks and is believed to have formed in the roots of an island arc.

Km 56.4:

Mill Cove. At the end of the cove, we cross the Cramp Crazy Fault, another major NE trending structure which here separates Point Leamington Greywacke to the southeast from Wild Bight Group turbidites to the northwest.

Km 59.6:

Mill Cove quarry on the right. This, as well as roadside outcrops just before it, is in Caradocian shale of the Shoal Arm Formation. This quarry provided road metal for parts of the highway near here. It packs to a hard, almost pavement-like surface and sections of the road surfaced with this material are virtually dust-free. However, for the first few days, it slices up the occasional tire and this does not go over especially well with regular road users.

Km 62.6:

Junction with road to Glovers Harbour. Turn left and proceed to the village of Glovers Harbour (approximately 2 km). Drive through the village and park vehicles in wide area to the left of the road just past the sharp right-hand turn at the end of the village. The government wharf and the end of the road are about 50 m ahead.

Stop 1-8: Lockport Mine. Leave vehicles and walk up the bush road that goes up the hill beside the houses on the corner where the vehicles are parked. A walk of approximately 800 m brings us to the old Lockport Mine, a volcanogenic sulphide deposit hosted by mafic pillow lavas of the Wild Bight Group. The Lockport deposit is one of four such occurrences in the Wild Bight Group. One of the others, the Point Leamington deposit, at 20 million tonnes, is the largest volcanogenic sulphide deposit in the Canadian Appalachians, outside the Bathurst camp.

The Lockport deposit is considerably smaller. Published estimates of grade and tonnage are 220,000 t grading 1.2% Zn and a further 392,350 t grading 0.75% Cu. There is a more detailed description of the deposit in Swinden (1983) which is included in your guidebook package.

The rhyolitic rocks which occur along strike from the deposit (see Swinden, 1984) cannot be conveniently visited. However, there are good exposures of the host pillow lava in the vicinity of the mine. These pillow lavas are incompatible, element-depleted, calc-alkaline andesites. The mineralization is interpreted as having formed late in the development of an island arc, probably being related to early rifting of the arc prior to formation of a marginal basin (represented by the pillow basalts veiwed earlier today as well as equivalent volcanic members elsewhere in the upper Wild Bight Group).

The stockwork is well exposed in the open cuts and good sulphide-rich boulders abound on the dumps. **PLEASE BE CAREFUL. THERE ARE SEVERAL OLD SHAFTS ON THE HILL AND THEY ARE EXTREMELY DANGEROUS. DO NOT TAKE UNHEEDED STEPS ON THE HILL OR IN THE NEARBY WOODS AND STAY AWAY FROM THE EDGES OF THE SHAFTS.**

Return to the vehicles. The cliffs beside the road are calc-alkaline andesites similar to those that host the mineralization. The rusty weathering is due to disseminated pyrite, the product of a lean facies of hydrothermal alteration, probably related to that at the mine. Drive back to km 62.6, Highway 350.

Km 65.2 - <u>Stop 1-9:</u>

Polymictic conglomerate in the lower part of the Wild Bight Group. Coarse, poorly sorted, matrix supported conglomerate with abundant, locally derived, volcanic and sedimentary clasts. This lithology is very common in the lower and middle parts of the Wild Bight Group. It generally lacks sedimentary structures and individual units locally reach several tens of meters in thickness and are interbedded with sandy and silty turbidites. The conglomerates locally contain massive sulphide clasts.

Km 66.8 - <u>Stop 1-10:</u>

Spectacular Wild Bight Group turbidite. The basal bed is polymictic conglomerate similar in many respects to the previous stop. Clasts of locally derived chert occur in the adjacent, overlying beds.

Lithologic associations similar to this and the previous stop are common in the lower part of the Wild Bight Group and are normally associated with volcanic rocks of island arc affinity. Sedimentary rocks associated with the overlying rocks of marginal basin affinity are more commonly distal turbidite and pelagic facies.

Km 68.0 - <u>Stop 1-11:</u>

Leading Tickles "stock". This engimatic plutonic body underlies the prominent conical hill at the entrace to the village of Leading Tickles. In this quarry, the outcrops are dominantly serpentinite and peridotite which form the base of the plutonic body on this side of the hill. The higher levels of the hill consist of medium to coarse grained, fairly mafic gabbro and pyroxenite and a few boulders of these lithologies can be viewed in the quarry floor. In a quarry just back up the road, mafic rocks are more abundant.

The Leading Tickles stock has not been mapped in detail and nothing is known of its structural, internal stratigraphic, and contact relationships. It has previously been mapped as an intrusive stock; if this is correct, it is unique in this part of Notre Dame Bay. The alternative possibility is that it forms the fragmented base of an ophiolite but more detailed mapping and geochemistry is needed to test this. This would make an interesting and important B.Sc. thesis if we have any senior students along who are looking for a topic.

Km 69.8 - **Stop 1-12:**

Leading Tickles causeway. This is one of the best exposures of the Caradocian shale and its relationship to the overlying flysch. Red shale an right of the causeway beyond the tickle to part of the Caradoci also underlies the t the basal part of th opposite side. Part cliffs, sandy beds gradually become more section. These beds the Point Leamington record the transition interval to post-Carac

The lower part marked by a flat dike the Jurassic lamproph are common throughout and are interpreted tensional environmen the opening of the Ocean.

End of Day 1. Return to Grand Falls. Remember to retrieve elected to stay at the Ponderosa earlier today.

ROAD LOG AND STOP DESCRIPTIONS

DAY 2

On leaving Grand Falls, proceed directly to Fortune Harbour via Highways 350 and 352 (see Day 1 road log for directions). At Fortune Harbour, proceed through the village until you get to the Catholic Church. This is a large white structure which sits alone in a field on the right side of the road. Only the very hung over are likely to miss it. Turn around at the church and park beside the outcrops just west of it. This is Stop 1 and km 0 for Day 2.

Km 0 – Stop 2-1:

The area between Fortune Harbour and Cottrells Cove to the south (which we passed through on the way up) is underlain by volcanic and sedimentary rocks of the Cottrells Cove Group. The sequence is generally north facing and consists of a basal mélange (the Boones Point Complex), overlain by a sandstone turbidite and chert unit (the Moores Cove Formation), and capped by mafic and lesser felsic volcanic rocks and chert (the Fortune Harbour Formation).

The northern boundary of the Cottrells Cove Group is a major Acadian thrust fault, the Lobster Cove-Chanceport Fault. The trace of this fault passes under the harbour to the west, comes ashore in a meadow directly across the harbour from Stop 1. It forms the base of the cliffs at the east end of the harbour. The high hills to the north of the fault consist of sheeted diabase with screens of pillow lava and gabbro assigned to the Moretons Harbour Group. These are generally correlated on a regional scale with sequences assigned to the "pre-Caradocian island arc".

In western Notre Dame Bay, the Lobster Cove Fault forms the structural top of the Roberts Arm Group, juxtaposing it with ophiolitic rocks of the Lushs Bight Group and with probable Cutwell Group rocks (correlated with the Moretons Harbour Group). The correlation of this structural relationship, coupled with the similarity between mafic volcanic rocks of the Cottrells Cove Group and the Roberts Arm Group prompted the original correlation of the Cottrells Cove and Roberts Arm Groups.

Outcrops along the road at this stop are felsic volcanics and chert. The volcanics are dominantly dacitic and form the only extensive felsic unit in the Cottrells Cove Group. The cherts are commonly bright red, reflecting abundant fine hematite in them. Across the harbour near the fault, there are some very manganiferous beds interbedded with hematitic chert. These beds contain more than 50% MnO and were briefly mined during the last century.

Return to vehicles and proceed back towards Cottrells Cove.

Km 3.6 – Stop 2-2:

Pillow lavas of the Cottrells Cove Group. These well preserved, relatively undeformed pillows, pillow buds and small lava tubes are locally vesicular, strongly hematized, and contain abundant red chert in pillow selvages. The pillow forms, and particularly the hematization, are typical of Roberts Arm Group lavas and provide one of the criteria for the correlation between them and the Cottrells Cove Group.

Km 5.8:

Road junction. Turn right and proceed 0.1 km to a second junction. Turn left at H. Clark & Son store and go a farther 0.6 km. Park vehicles by the large iron gate that blocks the road.

Stop 2-3: Boones Point Complex. Walk along the road past the iron gate. Along this road section, there are very good exposures of the mélange that comprises the Boones Point Complex, basal unit of the Cottrells Cove Group. The mélange consists of black shale, chaotically deformed and containing a complex mixture of limestone, clastic sedimentary and volcanic blocks. The limestone clasts contain a Llanvirnian fauna similar to that in the Cobbs Arm Limestone on New World island.

The outcrop by the gate is mainly complexly deformed black shale with broken beds of sandstone and carbonate.

Along the road, the next series of outcrops have very large volcanic blocks with black shale plastered around the edges. The best exposures are those in the cliff face by the wharf at the end of the road. Large blocks of pillow lava can be seen surrounded by shale. The pillows are thin-rimmed, small, variolitic and distinctly different from those which form the bulk of the Fortune Harbour Formation.

The nature of this mélange is not fully resolved. It has been described as an olistostrome (Helwig, 1969; Dean, 1978) but is also marks a major break in faunal affinities and therefore may be the locus of later significant faulting.

Return to vehicles and drive back to Highway 352, km 5.8. Turn right and proceed south.

Km 9.3:

The pronounced valley crossing the road at this point is the topographic expression of the Lukes Arm Fault which here separates the Cottrells Cove Group to the north from the Point Leamington Greywacke to the south. This is a major structural break in this part of Notre Dame Bay. There are no known occurrences of post-Caradocian flysch north of the fault, and only one occurrence of Caradocian shale (Cutwell Group on Long Island).

Km 14.7 - Stop 2-4:

Turn left into quarry. The Caradocian shale, here assigned to the Lawrence Harbour shale, is well exposed in the quarry and on the shores of Lawrence Harbour, which may be visible to the east. It consists of carbonaceous shale and is generally less cherty than the Charles Brook Section viewed yesterday. In Lawrence Harbour, there are rare fluorapatite nodules grading up to 25% P_2O_5 as well as large limestone concretions.

This locality is very fossiliferous, especially in beds along the south side of the quarry. The quality of preservation of the graptolites is remarkable and many are pyritized. These beds belong to the *Nemagraptus Gracilis* zone and the faunal list for this locality from Dean (1978) is given below. There are also small beds of massive pyrite up to several millimeters thick although they do not appear to have any economic significance.

Faunal List: Collected by J. Helwig and B. Oversby. Identified by J. Riva.

Climacograptus bicornis (Hall)
Climacograptus bicornis tridentatus Lapworth

Climacograptus brevis Elles and Wood
Cryptograptus tricornis (Carruthers)
Dicellograptus divaricatus (Hall)
Dicellograptus sextans (Hall)
Dicellograptus exilis Elles and Wood
Didymograptus superstes Lapworth
Glyptograptus teretiuscules (Hisinger)
Hallograptus mucronatus (Hall)
Nemagraptus gracilis (Hall)
Nemagraptus exilis (Lapworth)
Psuedoclimacograptus scharenbergi (Lapworth)

Km 15.2 - Stop 2-5:

This is the first outcrop of Lawrence Head volcanics which are stratigraphically below the Lawrence Harbour shale. Along the shoreline east of here, these pillow lavas form spectacular exposures of very large pillows and lava tubes in the sea cliffs. In this roadcut, the pillows are well exposed and the selvages contain excellent examples of open space filling by later fluids. The large selvages are commonly concentrically filled. Banded chalcedony and agate generally forms the center of the selvage and are followed outwards by sulphide rich bands and finally by carbonate adjacent to the pillow rims. Local reversals of this sequence are also found. The sequence presumably reflects changing fluid compositions and/or physiochemical conditions during filling.

These basalts form the top of the Exploits Group in this area and are stratigraphically equivalent to the basalts at the top of the Wild Bight Group viewed yesterday at Northern Arm. There are no published geochemical analyses of these rocks.

Km 16.2:

Look to the left to view the mussel farm operated by Atlantic Ocean farms.

Km 18.9 - Stop 2-6:

Turbidites of the New Bay Formation. Similar lithologies make up the bulk of the Exploits Group. At this locality, they are laminated, sandy and shaly turbidites with graded interbeds of polymictic pebble-conglomerate. Bedding planes in these outcrops display a variety of sedimentary structures. Coarser grained beds locally contain rip-up clasts of underlying beds.

Km 51.1:

Junction with highway 350 in Northern Arm.

End of trip. Continue to TCH, turn left and go home. Drive carefully.

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