GEOLOGY AND MINERAL DEPOSITS OF THE LUSH'S BIGHT GROUP IN THE LITTLE BAY HEAD - HALLS BAY HEAD AREA

by

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INTRODUCTION

This report summarizes the initial results of a project designed to investigate the regional geology and mineral deposits of the Springdale Peninsula. The objectives of this project are to establish a stratigraphic and structural framework for the Lush's Bight Group, to study the deposits in the area, to evaluate their economic significance in terms of the regional geology and to provide a model for the area that will prove useful in the search for economic mineral deposits.

Access to the area is via the Springdale and Little Bay Roads and via boat from Springdale and St. Patricks. Bedrock exposure along the coast is excellent and nearly continuous; elsewhere it is poor.

Approximately six weeks of field studies were carried out in the Little Bay Head - Halls Bay Head area during the 1982 field season. This area provides the best sections through the Lush's Bight Group and contains a large number of mineral occurrences as well as past-producing mines at Little Bay and Whalesback (Andrews, 1980). Much of the area has been extensively mapped and explored by Brinex during the 1960's and early 1970's. A number of theses (*e.g.* Donohoe, 1968; Fleming, 1970; Marten, 1971a; DeGrace, 1971; West, 1972; Kean, 1973; O'Brien, 1975) supported by Brinex have been done on the area and these add to a voluminous data base. MacLean (1947) and Williams (1962) have produced regional maps of the area, and Dean and Strong (1975) compiled the area on a scale of one inch to one mile.

However, despite this great volume of geological data, the Lush's Bight Group has generally been shown (and mapped) as an undivided sequence of pillow lava, chlorite schist and basic intrusive rocks. Consequently, the main objective of the field season was to elucidate the stratigraphy and structure of the Lush's Bight Group in the Little Bay Head - Halls Bay Head areas and to establish whether the stratigraphy and/or structure had any control on the mineralization in the group.

The main results of the 1982 field season are:

1. The Lush's Bight Group does contain an identifiable and mappable ophiolite stratigraphy;
2. The stratigraphy is discontinuous and is mappable within fault boundary blocks;
3. Structural repetition by folding and faulting accounts for the present large exposure area of the Lush's Bight Group and its thickness is probably 3-4 km although the base is not exposed;
4. The mineralization occurs in chlorite schist zones at different stratigraphic levels within the pillow lava sequence at various distances from the sheeted dike-pillow lava contact;
5. The chlorite schist zones are early structures that are not lithologically controlled, are not primary controls for mineralization, and are both barren and mineralized.

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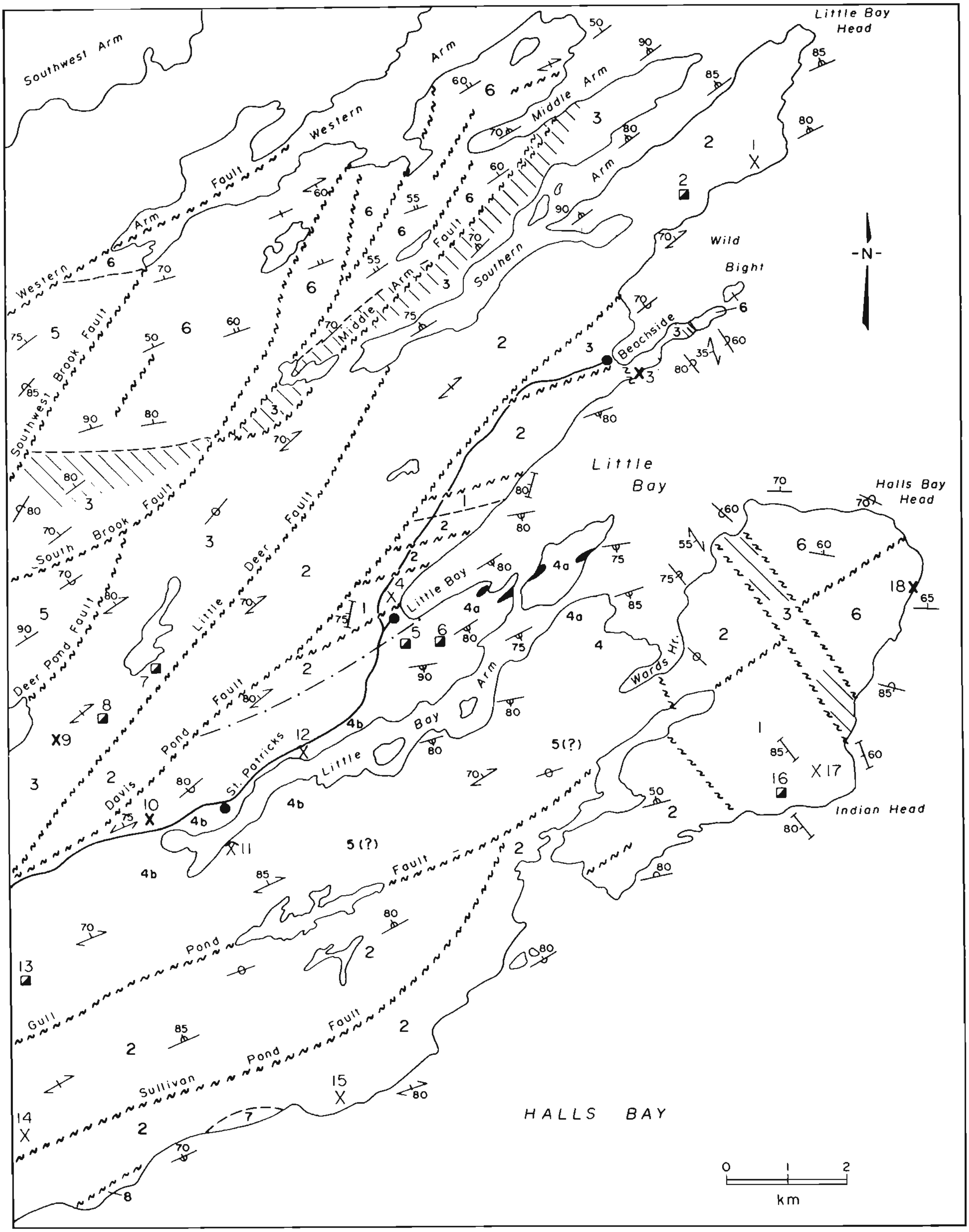
Southwest Arm
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Little Deer Pond Fault
Deer Pond Fault
Davis Pond Fault
St. Patricks
Little Bay Arm
Little Bay
Beachside
Wild Bight
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Halls Bay Head
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Sullivan Pond Fault
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LEGEND

SILURIAN OR DEVONIAN

8 **SPRINGDALE GROUP:** red and brown conglomerate, sandstone and siltstone.

ORDOVICIAN

7 **BOB HEAD PLUTON:** medium to coarse grained hornblende diorite and gabbro; pink to red quartz monzonite and granite.

6 **CUTWELL-WESTERN ARM GROUPS:** calc-alkaline mafic to felsic volcanic, epiclastic and sedimentary rocks.

CAMBRO-ORDOVICIAN

LUSH'S BIGHT GROUP

5 Undivided mafic pillow lava and pyroclastics, and diabase and gabbro dikes, sills and plugs.

4 **4a,** fine grained to aphanitic, green, commonly variolitic, altered pillow lava, minor breccia, agglomerate and tuff; quartz amygdules common; diabase dikes. **4b,** fine to medium grained, green pillow lava, massive flows and poorly pillowed flows; common gabbro dikes and sills.

3 Fine grained to aphanitic, gray to gray-green, epidotized pillow lava, minor breccia, agglomerate and tuff; black pillow lava with interpillow red chert common in upper parts of the unit; contains less diabase and gabbro than Unit 2. Feldspar, amphibole, feldspar-amphibole and pyroxene porphyry dikes are locally common.

2 Fine grained to aphanitic, gray-green to green, epidotized pillow lava with extensive diabase and gabbro dikes. Local sheeted dike zone. Minor agglomerate and breccia.

1 Sheeted diabase dikes; locally with gabbro and pillow lava screens.

6. The primary control is interpreted to be stratigraphic with 'shear zones' as a secondary structural control;

7. Zones of leaching and silicification occur at the same stratigraphic level, but laterally along strike, as the Little Bay and Sleepy Hollow Mines.

REGIONAL GEOLOGY

The regional geology of the Springdale Peninsula has previously been described by a number of workers including MacLean (1947), Williams (1962) and Peters (1967). Dean (1978) summarized the regional geology of Notre Dame Bay and the map area is included in a 1:250,000 scale geological compilation of the Newfoundland Central Volcanic Belt (Kean, 1977). The following regional discussion is in part adapted from Dean (1977).

The Lush's Bight Group occurs in western Notre Dame Bay, north of the Lobster Cove Fault. It outcrops between Southwest Arm in the west and Badger Bay in the east. The group is faulted against the Silurian-Devonian Springdale Group and the Ordovician - (?) Silurian Roberts Arm Group along the Lobster Cove Fault to the south. There are local outliers of the Springdale Group within the Lush's Bight Group north of the Lobster Cove Fault. These rocks are generally fault bound; however, an unconformity on the Lush's Bight Group possibly exists in the Davis Pond area (McGonigal, 1970). It is conformably overlain by the Lower Ordovician Western Arm Group and presumably by the Lower Ordovician Catchers Pond Group to the north and west. The Lush's Bight Group is faulted against the upper part of the Cutwell Group on the northeast coast of Sunday Cove Island. This fault is presumed to continue underwater between Long Island and Pilley's Island and juxtapose these groups in that area.

The Lush's Bight Group is considered to be of ophiolite affinity. However, the Lush's Bight Group as defined by Espenshade (1937) and used by MacLean (1947) also included sedimentary and volcanic rocks now considered to be of island arc affinity. These rocks have subsequently been assigned to the Western Arm Group (Marten, 1971a) and the Cutwell Group (Kean, 1973; this report). Thus the group now includes only mafic pillow lava, breccia and agglomerate, sheeted diabase dikes, gabbro dikes and sills and small bodies of ultramafic rock of ophiolite type. These rocks are low potash tholeiites with strong chemical similarities to modern oceanic crust (Papezik and Fleming, 1967; Smitheringale, 1972; Strong, 1973).

The Lush's Bight Group is folded into a major northeast trending anticlinorium and synclinorium with the limbs displaced or cut off by northeast trending wrench faults.

The Lush's Bight Group is intruded by various intrusives of probable Ordovician age including the Colchester Pluton, the Burlington Granodiorite and many small stocks and plugs interpreted to be contemporaneous with volcanism. It is also intruded by the Brighton Gabbro Complex, which gives an $^{40}Ar/^{39}Ar$ radiometric age of 495 $\pm$ 5 Ma (Stukas and Reynolds, 1974). An Upper Cambrian age is thus suggested for most of the group.

MacLean (1947) reported a single Lower Ordovician brachiopod, *Discotreta* sp., from the lowermost part of the conformably-overlying Western Arm Group.

The Lush's Bight Group and overlying calc-alkaline sequences are correlative on the basis of age and stratigraphy with the Snooks Arm Group, which includes the Betts Cove ophiolite. The two groups are interpreted to lie on opposing limbs of a major syncline.

THE LUSH'S BIGHT GROUP

General Statement

The Lush's Bight Group in the study area is an ophiolitic sequence consisting predominantly of a monotonous succession of altered mafic lava with minor intercalated pillow breccia, agglomerate and tuff. Locally, excellent examples of sheeted diabase dikes are preserved.

The contact with the overlying island arc assemblages of the Western Arm - Cutwell Groups (Unit 6) is generally faulted, but locally has been interpreted as conformable (Marten, 1971a, b). A conformable relationship between the two sequences is exposed in the Fox Neck area on the southeast side of Wild Bight and was mapped during this study. In the Fox Neck area altered black basalt, with epidotization occurring in veins and irregular patches, and with interpillow red chert and local hematization, is overlain by bedded sedimentary rocks. The base of the sedimentary section consists of interbedded red chert and chocolate brown argillite. Fine grained green tuff and chert, yellow-green tuff, gray and black argillite, and siliceous argillite first appear as thin interbeds in the red and brown sediments but are the main lithology within 100 m. Coarse pyroclastic breccia and pyroxene-plagioclase crystal vitric tuffs constitute the top of the succession in this area. Minor intercalated pillow lava occurs in the lower parts of the sequence.

The above described sequence is characteristic of the Lush's Bight/ Western Arm - Cutwell Groups contact in this area, even where the contacts are faulted. Similar relationships and rocks have been described for the ophiolite/ island arc contact in the Betts Cove area (Upadhyay *et al.*, 1971, page 31).

Fluviatile sedimentary rocks and terrestrial volcanic rocks of the Silurian-Devonian Springdale Group (Unit 8) generally have fault contacts with the Lush's Bight Group; however, an unconformity on the Lush's Bight Group possibly exists in the Davis Pond area (McGonigal, 1970).

The strong epidote alteration which is so characteristic of the Lush's Bight Group accompanied or predated the early stages of the regional deformation. This alteration and the L-S fabric accompanying the regional deformation decrease upwards in the sequence and are only very weakly developed in the overlying Western Arm - Cutwell Groups. Marten (1971a, b) referred to the resultant two types of lava found within the Lush's Bight Group as the "main facies" and the "black facies." The "main facies" is composed of green and gray-green, epidotized mafic lavas and is characteristic of the lower parts of the Lush's Bight Group. The "black facies" is composed of black, fresh to chloritic lava with epidote as veins and irregular patches. It is concentrated in the upper parts of the Lush's Bight Group but has no formational status. Marten (1971b) suggested a correlation with the "Whalesback type" and "St. Patricks type" lava divisions, respectively, proposed by Papezik and Fleming (1967) for the volcanic rocks in the Whalesback mine area.

Studies of metamorphism in ophiolites (*e.g.* Spooner and Fyfe, 1973) indicate that intense alteration and metamorphism of lower pillow lava units prior to deposition of upper pillow lava units is a common phenomenon. This is postulated to result from sub-seafloor hydrothermal metamorphism at active spreading ridges. The alteration facies developed in the Lush's Bight Group is thus interpreted to be a 'primary' alteration feature developed during the formation of the ophiolite.

Folds are mappable only on a large scale and the Lush's Bight Group is inferred to lie on the south limb of a major northeast plunging synclinorium, north of the Davis Pond Fault and on the north limb of a southeast facing synclinorium south of the fault. The anticlinal crest has been partially removed along the Davis Pond Fault. This fault is one of many postfolding wrench faults that cut the Lush's Bight Group. The present large area of exposure is a result of structural repetitions and the true thickness is probably between 3 and 4 km.

Lithologies of the Lush's Bight Group

Generally, there is no recognizable stratigraphy in the Lush's Bight Group. However, sheeted dikes are locally recognizable. The group can be divided into a number of fault-bound blocks. The geology within each block is fairly homogeneous and regionally the blocks represent a rough stratigraphy; however, there is a repetition of lithologies or stratigraphy within and between blocks. The geology is discussed in terms of each block and the numbers on units do not reflect a strict chronological sequence.

Unit 1 - Sheeted Dikes

There are three main areas of 100% sheeted dikes in the map area, namely the Indian Head area of Halls Bay and two areas along the west side of Little Bay. The dikes trend slightly east of north with slight variation to the east and west and dip steeply to the west. In the Indian Head area the sheeted dikes are in fault contact with the pillow lavas, although pillow screens are common near the southwest contact. Facing directions are not known for this sequence. At the two localities on Little Bay, the dikes feed overlying pillow lavas to the southeast.

The sheeted dikes average about 0.5 m thick and vary from less than 0.25 m to 2 m thick. There are rare dikelets of aphanitic diabase less than 2 cm in width. The dikes are fine to medium grained, green, equigranular diabase with associated gabbro dikes and aphanitic black basalt dikes. The dikes generally display the classic chilling on one margin, but locally both margins are chilled against gabbro screens and larger gabbro dikes. The dikes generally grade into areas with dikes and pillow screens and in the Little Bay area into pillow lava with extensive dikes (Unit 2). The sheeted dike zones commonly develop rusty weathering scree slopes because of the abundant disseminated pyrite in them.

Unit 2 - Pillow Lava and Diabase Dikes

This unit varies from dominantly sheeted dikes with pillow screens in the contact area with the sheeted dikes to pillow lavas with extensive to common diabase dikes in other areas.

The Little Bay Head area and the area northeast of Little Ward's Harbour is characterized by extensive dikes. In the Little Bay Head area there are sections over 50 m that consist of multiple intrusions of medium grained diabase and gabbro dikes which are individually up to 2 m wide. Locally, these extensive dike sections are sheeted, *i.e.*, they possess one chilled margin. The dikes trend slightly east of north at a high angle to the enclosing pillow lava.

Unit 2 in the Halls Bay and Southern Arm areas is predominantly pillow lava with common diabase and gabbro dikes. These dikes have the same orientation and relationship to the pillow lavas as do the dikes described above.

The pillow lavas are fine grained to aphanitic, green to gray-green and equigranular. They are epidotized, generally with their cores completely replaced by epidote. There are local areas where chloritic alteration predominates, in particular in the shear zones that are developed in this unit. Quartz and calcite veining is common. The pillows are characterized by thin selvedges and are generally nonvesicular. They are closely packed and interpillow material is minor, although locally white, gray, and green interpillow chert is common. Interpillow aquagene tuff is rare. Minor horizons of pillow breccia and agglomerate are intercalated with the pillow lava. The pillows vary in size from 15 cm to 1 m and vary in shape from round to elliptical. They are quite commonly flattened and moderately elongated in the plane of deformation.

The dikes are fine to medium grained, green, equigranular diabase and gabbro. Epidote veins and patches are scattered throughout. The dikes vary from a few centimetres to about 2 m wide. They commonly are highly pyritic. In places the dikes are boudinaged.

<u>Unit 3 - Pillow Lava</u>

Unit 3 consists dominantly of pillow lava with common diabase and gabbro dikes. It does not differ substantially from Unit 2 and the distinction is subjective in many places. There appear to be fewer dikes of diabase and gabbro (see also Fleming, 1970). The unit generally grades into the 'black facies' of Marten (1971a, b) and commonly contains red chert in its upper parts. It is therefore interpreted to represent a higher stratigraphic level than Unit 2. It must be emphasized, however, that much of the lower parts of the unit could be, and probably is, equivalent to Unit 2.

The pillow lavas are fine grained to aphanitic, and locally medium grained. They are highly epidotized except for near the contact with Unit 6, where they are black and either fresh or chloritic. They are also chloritic in shear zones. The epidote occurs as veins, veinlets and patches and commonly completely replaces the pillow cores. The pillows vary in size from 15 cm to 1 m across. They vary from round and fan shaped to toed and tubular; some tubes are >10 m long. Interpillow material is generally common and consists of white and green chert and minor aquagene tuff and pillow fragments. Narrow discontinuous beds or lenses of aquagene tuff and agglomerate are locally intercalated with the pillow lava. The agglomerate-tuff consist of bombs with chilled rims and lapilli that range in size from <2 cm to 0.5 m in length and generally show evidence of preconsolidation deformation. A few of the larger bombs are feldspar-phyric. The matrix is fine grained to aphanitic tuff, some of which appears to be aquagene.

The gabbro and diabase dikes and sills are fine to medium grained, green and equigranular. Minor feldspar-phyric phases are present; however, they may be feeders to the overlying Western Arm Group. The dikes consist of plagioclase and pyroxene and are variably epidotized.

Porphyritic dikes are common in this unit and are rarely found elsewhere. They are particularly common in the Whalesback - Little Deer Mines area. They can be classified into four types containing, respectively, phenocrysts of feldspar, amphibole, amphibole and feldspar, and pyroxene in a green, aphanitic matrix. They intrude the Lush's Bight Group, but according to Fleming (1970) were metamorphosed and deformed with it. The dikes vary in width from several centimetres to several metres and trend generally either northwest or slightly east of north.

<u>Unit 4 - Pillow Lava</u>

The contact between Units 2 and 4 is gradational in the Little Bay area, the distinction between the two units being based on the extensive occurrence of variolitic pillow lava in Unit 4a and massive flows in 4b. Interpillow chert is also very common in Unit 4.

Unit 4a consists of fine grained to aphanitic, gray-green to dark green, equigranular pillow lava. The pillows are moderately to strongly epidotized, with the cores generally completely replaced by epidote. Quartz, calcite and epidote veins are common. Quartz veining is locally extensive. The thin rims are generally chloritic, and, as is common in all these units, form a chlorite schist envelope around the epidotized cores. Chlorite alteration is the pervasive type in the many shear zones. The pillows are closely packed with extensive gray, green and white interpillow chert in the area of the Little Bay and Sleepy Hollow Mines. Red chert occurs as a minor constituent throughout the unit. The pillows vary from <30 cm to 76 cm in size and are round to bulbous and elongate in shape with a flattening and slight stretching in the plane of the deformation. Quartz amygdules are also common in this unit. Minor breccia and pyroclastic breccia and rare agglomerate occur throughout the sequence.

The presence of variolites is a diagnostic feature of Unit 4a. Variolites, altered to epidote, are common in the Little Bay Mine area and are particularly well developed in the Shoal Arm area. The variolites are disseminated throughout the pillows but are locally concentrated either in the cores or near the rims of the pillows. In places, they are up to 1 cm across.

Laterally along strike to the northeast from both the Sleepy Hollow and Little Bay Mines, the basic volcanic rocks have been leached and silicified so that they are a white to whitish-green, siliceous rock. Minor quartz veins with pyrite and chalcopyrite cut these rocks. Disseminated pyrite is common. Fine to medium grained, equigranular, green diabase and gabbro dikes are common. They vary from a few centimetres to about 1 m wide.

The basic volcanic rocks (4b) constituting the top part of Unit 4 are not very variolitic, and massive flows, locally with poorly developed pillow structures, and large gabbro dikes and sills are common, particularly in the St. Patrick's area. These rocks are intercalated with normal pillow lava. The pillows are fine grained, green, equigranular and moderately to extensively epidotized. The massive flows and gabbro dikes and sills are fine to medium grained, green and equigranular. They consist of a saussuritized yellow-green feldspar and a chloritized mafic mineral. The gabbro dikes and sills vary from 1 m to 40 m in width. Locally vesicular and scoriaceous zones are developed. Fine grained diabase dikes intrude these rocks. Feldspar porphyritic dikes are locally present.

Unit 5 - Unseparated Lush's Bight Group

Large areas of pillow lava, basic intrusions and minor pyroclastics that have not been looked at in detail are herein referred to as Unit 5.

STRUCTURE

Early Structures

The Lush's Bight Group contains a single, fine grained foliation which trends northeast and dips steeply, generally to the northwest. This fabric is commonly nonpenetrative in the pillow lavas where it is restricted to the pillow margins or the matrix. It is an L-S fabric associated with a steep stretching lineation and is defined by chlorite and fibrous amphibole. This foliation is axial planar to major northeast trending and plunging folds. The study area appears to consist of the limbs of folds separated from each other by steep late faults.

Chlorite schist shear zones are widely developed in the Lush's Bight Group. They form elongated or lenticular zones, from a few metres wide to over 100 m wide, of coarse chlorite schist. These zones of strongly flattened rock pass into the normal weakly deformed host rocks with gradational contact. This gradation occurs over a metre to tens of metres depending on the width and intensity of the shear zone. The country rocks in these shear zones become totally schistose and it is generally difficult to determine the protolith. Dikes in these zones are transposed into the plane of deformation and in places boudinaged. The schist zones are not lithologically controlled, although they parallel stratigraphy, and are both mineralized and barren. However, the schist zones are generally more highly pyritized than the country rocks.

Kennedy and DeGrace (1972) demonstrated that the foliation in the chlorite schist zones is a composite fabric derived by folding and transposition of an earlier chlorite foliation. They further demonstrated that the chlorite schist zones resulted from the superimposing of a homogeneous deformational fabric on an older inhomogeneously developed fabric in shear belts. The regionally developed foliation in the Lush's Bight Group is thus the result of a second deformation (D_2).

Marten (1971b) mapped a series of faults having sinistral displacements subparallel to the regional foliation in the Western Arm area. He interpreted them to be slides related to the regional deformation. Kennedy and DeGrace (1972) also noted gently inclined faults, parallel to the trend of the regional foliation, separating various units of the Lush's Bight Group in the King's Point area. Similar faults can be seen on the Lush's Bight Group in the study area.

Late Structures

Crenulations of the regional foliation (S_2) can locally be seen. These crenulations are folded by kinks/flexures and by major open folds. These kinks/flexures and open folds are well developed in the chlorite schist zones where they fold the schist. They are rarely developed, or seen, outside of the schist zones. The axial planes dip steeply and trend approximately north-south. They are steeply plunging. The open folds do not affect the kinks/flexures and are interpreted to be contemporaneous with the kinks.

A number of post-folding, major faults transect the Lush's Bight Group in this area. The most prominent are the Deer Pond Fault, the Little Deer - Davis Pond Fault system, the Gull Pond Fault and the Sullivan Pond Fault. Numerous splays and subsidiary faults are related to them. Similar faults in the Western Arm area are believed to have dominant dextral strike-slip movements on account of their large horizontal components, straightness and lateral continuity (MacLean, 1947; Marten, 1971b). Similar dextral strike-slip movement is inferred for the faults in this area on the basis of movement along the Davis Pond Fault and the 4 km dextral offset of the Lobster Cove Fault (MacLean, 1947; Neale and Nash, 1963); however, a component of dip-slip movement is also present. Many of the faults appear to have cut out the axial zones of the major folds in the region. Narrow, less intense shear zones, breccia zones and brown carbonated breccia zones accompany the faulting.

MINERALIZATION

The Lush's Bight Group contains more base metal sulphide showings per square kilometre than any other group of rocks in Newfoundland (Dean, 1978). The group has been extensively prospected and two major mines, Little Bay and Whalesback, and about two dozen prospects have made this area the copper center of Newfoundland.

The many deposits differ greatly in size but all have several features in common which were noted by earlier workers. All are roughly ellipsoidal with their long axes approximately coplanar with bedding. They occur almost exclusively in chlorite schist shear zones developed in pillow lavas

(Peters, 1967). These schist zones are parallel to or conformable with the stratigraphy and the sulphide lenses conformable with the schist. They consist mostly of pyrite with lesser amounts of chalcopyrite, pyrrhotite and sphalerite and minor values of gold and silver.

Douglas, Williams and Rove (1940) and MacLean (1947) considered the deposits to be replacements of chlorite schists in the shear zones during late stages of faulting and thus to have a common origin. MacLean also concluded that there might be a genetic relationship between the sulphides and granodiorite in the area. Williams (1963) reasoned that a genetic relationship to volcanism might exist but that the final emplacement and distribution of sulphides postdated the volcanics and resulted from structural deformation. Kanehira and Bachinski (1968) concluded that the sulphide mineralization at least in part predated deformation and metamorphism but also must have postdated the end of volcanism. West (1972) concluded that the mineralization at the Little Deer mine was post-volcanic.

Kennedy and DeGrace (1972) considered the deposits to predate the main regional deformation (D_2) because pyrite bands are commonly folded about the associated folds and chalcopyrite is concentrated in fold hinges. Also in the Whalesback area the sulphides are cut by the predeformation porphyry dikes (Fleming, 1970). They also concluded that in most showings banding resembling layering is present and that with the exception of the Whalesback and Little Bay Mines the deposits occur in layered tuffaceous rocks. They thus concluded that the mineralization was syn-volcanic.

During the course of this study six old deposits and showings were looked at. They were the Hearn Gold Prospect, the Delaney prospect, the Sleepy Hollow Mine, Little Bay Mine, Whalesback Mine and Little Deer Mine. Unfortunately, there is not much to be seen on surface at most of the deposits and showings, except for old dumps. Two previously unreported showings were also studied. They are located near Bartletts Cove and at Bob Point near Halls Bay Head.

Hearn Gold Project

The Hearn Gold Prospect is located on the west side of Little Bay. The reader is referred to Snelgrove (1935) and MacLean (1947) for a detailed account of the exploration and development history of the prospect.

The prospect consists of sulphide- and gold-bearing quartz veins and disseminated pyrite in chlorite schist in the sheeted dike zone of an ophiolite. The contact with pillow lava is only a few tens of metres away and pillow lava screens are locally present. Shearing and chlorite schist are inhomogeneously developed and the pillow screens generally take up most of the deformation.

The mineralization occurs in a chlorite schist zone up to 2 m wide intermittently developed over a distance of a kilometre or more. The mineralization occurs as disseminations and veins, up to 2 cm thick, of pyrite in the schist. It also occurs in quartz $\pm$ calcite veins and veinlets containing pyrite, chalcopyrite, sphalerite, arsenopyrite, galena and gold in that order of abundance. There is no visible gold but it occurs associated with arsenopyrite, sphalerite and minor galena (Snelgrove, 1935).

Delaney Prospect

This prospect, consisting of a shaft and an old dump, lies immediately east of the government wharf at St. Patricks. MacLean (1947) gives an historical review of the prospect.

The prospect is in pillow lavas of Unit 4b. The mineralization occurs as disseminations, concentrated disseminations, and thin veinlets in chloritized and silicified pillow lava with common gabbro dikes. Quartz veining is common. The mineralization consists of pyrite, chalcopyrite, pyrrhotite, quartz and carbonate.

Sleepy Hollow Mine

The Sleepy Hollow Mine is located approximately 400 m south of the community of Little Bay and about 400 m west of the Little Bay Mine. See Douglas *et al.* (1940) and MacLean (1947) for a detailed account of the exploration history and geology of the mine.

Except for a number of shafts, broken rock from development and a few outcrops, there is little to see on surface. According to MacLean (1947) the deposits occur in two parallel chlorite schist zones that are derived from pillow lava. These schist zones are roughly parallel to the main shear zone at Little Bay Mine. Pillow structures with variolites, and interpillow chert and jasper are locally preserved in the schist zone. Sericite and quartz-sericite schist can be seen in rubble and mine waste and appears to be an alteration of basic rocks. Diabase dikes are common.

The mineralization occurs mainly in the form of massive lenses within the chlorite schist. Pyrite and chalcopyrite are the principal minerals. The mineralization, in particular pyrite, also occurs as disseminations in the chlorite schist.

On the coast at Shimmy Cove, approximately 1.5 km northeast along strike from the mine, the pillow lavas have a distinct yellowish-white alteration color due to leaching and silicification.

Little Bay Mine

The mine is situated on a peninsula approximately 0.75 km southeast of the community of Little Bay. Douglas *et al.* (1940), MacLean (1947) and Peters (1967) discuss the geology, exploration and production history of this mine. Between 1878 and 1892, Little Bay produced 103,000 tonnes of copper of 2.5-10% grade. In the period 1952-1969 it produced 2,500,000 tonnes of 2% copper (West, 1972).

The deposit(s) occur(s) in a chlorite schist zone in generally highly variolitic basaltic pillow lava with common diabase dikes. White and green interpillow material is common in this pillow sequence. Barren chlorite schist zones are also developed in the area of the mine. All of the schist zones are gradational into less deformed pillow lavas.

On the coast about 1.5 km northeast along strike a zone of intensely bleached and silicified pillow lava, breccia and agglomerate occurs. This alteration zone is best exposed near the old smelter site opposite Otter Island. The zone is approximately 400 m wide and extends for about 300 m to the southwest. Less intense and minor alteration of this type occurs along strike on the west and east coast of Otter Island, a distance of 1.5 km.

The pillow lavas are highly epidotized in the cores and the rims are chloritic. As the shear zone is approached the rims become chlorite schist enveloping an epidotized core, with common quartz and calcite veins and pods. Quartz amygdules are locally common.

The Little Bay deposits occur as massive lenses and pods, as veins and veinlets of pyrite and chalcopyrite and as sulphide-bearing quartz veins in chlorite schist. The mineralogy is pyrite, chalcopyrite, wurtzite, magnetite, marcasite, pyrrhotite and covellite (MacLean, 1947). Quartz is the principal gangue mineral. The schist zone has a mineralized length of about 300 m and a maximum width of 25 m.

In the glory hole at the old mine site, the mineralized zone within the chlorite schist is approximately 10 m wide. The mineralized zone consists of massive lenses, veins and disseminated sulphides. The massive zones are underlain by a 1 m thick zone of disseminated euhedral pyrite, thin pyrite veinlets and minor quartz veins in chlorite schist. In the chlorite schist there are small, irregular patches of white, sericite(?) schist that appear to grade into chlorite schist. This zone is overlain by a zone consisting of bands (or veins) of sulphide 1 cm to 15 cm thick with interbanded chlorite schist 0.5 cm to 5 cm thick. This zone is up to 5 m thick and consists mostly of pyrite with minor chalcopyrite and pyrrhotite. Chalcopyrite increases towards the top of this zone. These sulphide bands have cross-cutting relationships to the chlorite schist and many appear to be veins that are transposed coplanar with the chlorite schist.

Massive lenses, 40 cm to 1 m thick, of coarse, granular, grey pyrite and minor chalcopyrite in a quartz-rich gangue are locally present. These massive lenses have a streaky banding defined by pyrite and quartz-pyrite layers.

The hangingwall contact is marked by a dike or by disseminated and veined pyrite in chlorite schist.

Whalesback Mine

MacLean (1947), Peters (1967), Kanehira and Bachinski (1968) and Fleming (1970) all deal with various aspects of the geology of this area and/or the mine.

The Whalesback deposit occurs in a chlorite schist zone within pillow lava. Small interpillow pillows, minor breccia and lapilli tuff also occur in the pillow sequence. The pillow lava is fine grained, grey-green, nonvesicular and nonvariolitic. Epidote veining is common and quartz veins are locally abundant. White and green interpillow material is common. Amphibole, feldspar, amphibole-feldspar and pyroxene porphyritic dikes and gabbro/diabase dikes are common. Kanehira and Bachinski (1968) stated that the porphyritic dikes cut the schist zone and the sulphide ore.

The mineralization occurs as lenses, pods, veins and disseminations in the chlorite schist. In order of decreasing abundance the mineralogy is pyrite, chalcopyrite, pyrrhotite, sphalerite, mackinawite, pentlandite, magnetite, cubanite, galena and ilmenite (Fleming, 1970).

Little Deer Mine

West (1972) studied the structure and ore genesis of the Little Deer Mine and the reader is referred to his thesis of which the following is a summary.

The Little Deer Mine consists of a number of lenses and associated disseminated mineralization in chlorite schist derived from pillow lava and possibly minor pyroclastics. This chlorite schist shear zone parallels the Whalesback shear zone. The main ore zones consist of three lenses of medium grained, massive and disseminated pyrrhotite and chalcopyrite with minor pyrite and sphalerite. Fragments of chlorite schist in the sulphides are common. Other lenses to the southwest consist largely of pyrite and sphalerite with thin laminations. Pyrite laminae are from 1 mm to 7 mm thick and are interlaminated with chlorite schist containing disseminated pyrite.

The lenses are about 3 m thick and from 50 to 120 m wide. The hangingwall contact is sharp with no sulphide mineralization but the footwall contact is marked by disseminated chalcopyrite, pyrite and pyrrhotite veinlets up to 30 m from the massive sulphide lenses.

West (1972) concluded, "the sulphide lenses of the Little Deer deposit formed after the volcanism that produced the Lush's Bight Group pillow lavas, in a post-volcanic schist zone."

Bartlett's Cove

This showing occurs just to the north of Bartlett's Cove in a chlorite schist shear zone in pillow lava of the Lush's Bight Group. Leaching and alteration of the chlorite schist also marks this schist zone. The mineralization occurs as 'veins' of sulphide 3 cm thick and 30 cm long. The 'veins' are interpillow material between flattened pillows. The mineralization also occurs associated with carbonate in fractures, joints and along shear planes. Pyrite and minor chalcopyrite constitute the sulphide minerals.

Bob Point, Halls Bay Head

This showing occurs in mafic volcanics of the Cutwell Group near Halls Bay Head. It consists of pyrite as disseminations and as a vein 5 cm thick by 60 cm long.

SUMMARY AND CONCLUSIONS

The Lush's Bight Group consists of a number of fault-bound blocks, some of which contain an identifiable ophiolite stratigraphy. Chlorite schist zones within this sequence are early structures, are not lithologically controlled and are both barren and mineralized. The mineralization may have acted in part as zones of weakness along which shear zones developed.

The major sulphide deposits and showings in the Lush's Bight Group occur within chlorite schist zones. The schist zones are generally within pillow lava and/or intercalated pyroclastics and are conformable with the enclosing rocks. The sulphide lenses are in turn conformable with the schist zones, although sulphide veins crosscut the chlorite schist.

The mineralogy is simple and commonly there is a sharp hangingwall contact and a gradational footwall contact. Deformation has obliterated all primary structures and the sulphides are remobilized and recrystallized. Therefore, any paragenesis or mineral zoning is suspect.

There are several theories for the origin of these deposits, but the following evidence from this study suggests a syngenetic volcanic origin for the deposits: (a) they have an early, predeformational origin; (b) they are essentially conformable bodies in mafic volcanics of ophiolite affinity, *i.e.* they are stratabound; (c) they possess a simple mineralogy that is similar to volcanogenic ophiolite deposits; and (d) the chlorite schist shear zones are interpreted as early tectonic features that did not control mineralization. However, there is no doubt that the deposits have been remobilized and recrystallized.

The deposits differ from the Betts Cove Mine (ophiolite deposit) in that they do not occur at the sheeted dike - pillow lava contact. However, they do occur at a similar stratigraphic position and in rocks similar to the well preserved ophiolitic sulphide deposits at York Harbour (Duke and Hutchinson, 1974).

The chlorite schist shear zones have generally been considered as 'controls' for mineralization. However, chlorite schist zones also occur in the pillow lavas that overlie the sheeted dikes of the Betts Cove Ophiolite Complex (Douglas *et al.*, 1940; Upadhyay and Strong, 1973). Primary volcanogenic sulphide mineralization at the pillow lava - sheeted dike contact has been remobilized and redistributed along the schist zones (Kennedy and DeGrace, 1972). Duke and Hutchinson (1974) also described chloritic shear zones in the York Harbour mine area. They attributed them to late movement along a synvolcanic fault-fissure that controlled the distribution of ore deposition. However, the chlorite schist shear zones are conformable to stratigraphy and as such were probably flat zones at the time of their formation. The schist zones are thus interpreted as early shear belts which were initiated at points of greatest mechanical weakness, commonly, but not exclusively, the sulphide bodies. A similar conclusion was reached by DeGrace (1971) and Kennedy and DeGrace (1972) for the Lush's Bight Group in the King's Point area.

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MAJOR SULPHIDE MINERALIZATION IN THE AREA

1. Little Bay Head: Pyrite, chalcopyrite, pyrrhotite, sphalerite, arsenopyrite and marcasite in chlorite schist derived from pillow lava. Common diabase dikes.

2. Shoal Arm: Same as Little Bay Head.

3. Bartlett's Cove: Pyrite and minor chalcopyrite as stringers and associated with calcite veins in chlorite schist derived from pillow lava.

4. Hearn Prospect: Pyrite, chalcopyrite, sphalerite, arsenopyrite, galena and gold in quartz veins and as stringers and disseminations in sheared sheeted dikes with minor pillow screens.

5. Sleepy Hollow: Pyrite and chalcopyrite in chlorite schist within pillow lavas and minor diabase dikes.

6. Little Bay Mine: Pyrite, chalcopyrite, pyrrhotite and magnetite as massive lenses and pods, as stringers and disseminations in chlorite schist within pillow lava and diabase dikes.

7. Whalesback Mine: Pyrite, chalcopyrite, pyrrhotite and sphalerite as disseminations, stringers and banded lenses and pods in chlorite schist in pillow lavas. Mackinawite, pentlandite, magnetite, cubanite, galena and ilmenite are also present.

8. Little Deer Mine: Pyrite, chalcopyrite, pyrrhotite and sphalerite as disseminations, stringers and lenses and pods in chlorite schist in pillow lavas.

9. Duck Pond: Pyrite and chalcopyrite and sphalerite in chlorite schist in pillow lava.

10. St. Patrick's: Pyrite and chalcopyrite in chlorite schist derived from pillow lava and diabase dikes.

11. St. Patrick's Southwest: Pyrite and chalcopyrite as disseminations and in quartz veins in pillow lava and gabbro dikes and sills.

12. Delaney Prospect: Pyrite, chalcopyrite and pyrrhotite stringers and disseminations in silicified zone within pillow lava and diabase dikes. Quartz veining is extensive.

13. Lady Pond Mine: Pyrite, chalcopyrite and pyrrhotite in a series of lenses in chlorite schist in pillow lava and diabase dikes.

14. Sullivan Pond: Pyrite, chalcopyrite and minor sphalerite in chlorite schist.

15. Bob Head: Pyrite and chalcopyrite in quartz and calcite veins in chlorite schist.

16. Indian Head: Disseminated pyrite and chalcopyrite in a silicified schist zone in sheeted diabase dikes.

Lush's Bight Group *B.F. Kean*

17. Indian Beach: Pyrite, chalcopyrite and pyrrhotite in a chlorite schist zone in sheeted diabase dikes. Possible pillow lava screens.

18. Bob Point Showing: Disseminations and stringers of pyrite and rare chalcopyrite in mafic volcanics, dikes and sills.