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Geological map of the central Lewis Hills massif, Newfoundland

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Notes to accompany
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Introduction

The Lewis Hills is the southernmost massif of the Bay of Islands ophiolite, western Newfoundland. The accompanying 1:10,000 scale geological map of the central Lewis Hills massif covers an area of 55 sq km. Mapping was carried out on a colour air photo base, enlarged to a scale of 1:6,250. Mapping was carried out over three field seasons in four contiguous sub-areas - Springers Hill, Mount Barren, Lewis Hill and Bud's Pond (see inset on map). The purpose of the mapping was to provide a geological framework to better understand the distribution and context of occurrences of chromite, sulphides and platinum group minerals in the Bay of Islands ophiolite complex.

The mapping was also designed to provide insight into mantle prcesses which have significance to the genesis of these potential mineral resources. Of fundamental importance is the mode of generation of deep oceanic lithosphere. The western edge of the map sheet lies within the central Mount Barren region, an area previously interpreted by Karson and Dewey (1978), Karson (1979), Casey and Karson (1981) and Karson et al. (1983) to represent a fossil oceanic fracture zone. The eastern part of the map area is within the Bay of Islands Assemblage, a group of rocks previously interpreted by Karson and Dewey (1978), Karson (1979) and Casey and Karson (1981) to represent relatively undeformed, younger oceanic crust that had formed in a steady state magma

chamber and had been accreted to the older Mount Barren Assemblage. The map area was therefore taken to represent a spectrum of deep crustal conditions.

OVERVIEW

The map of this Open File documents the lithologies and geological relations that occur within the deeper, plutonic levels of the Bay of Islands ophiolite. An extensive section of polydeformed mantle peridotite tectonites outcrop in the southern part of the map area. Variably deformed ultramafic to gabbroic metacumulate and cumulate lithologies dominate the central and northern parts of the map. The geological features and relationships exposed in the map area indicate that the central Lewis Hills massif has a complex history of oceanic crustal accretion which involved both penetrative high temperature ductile deformation and synkinematic multiple intrusion.

The plutonic complex is divided into an older suite of penetratively deformed upper mantle/lower crustal rocks (UNITS 1-4) and a younger suite of synkinematic and heterogeneously deformed ultramafic-mafic plutons (UNITS 5-6). Contacts between these two magmatic suites are distinguished in the field on the basis of: (1) xenolith-bearing margins; (2) truncation of planar and linear structural fabrics; and (3) abrupt textural and lithological changes.

The older suite tectonites consist of residual harzburgite (UNIT 1), minor amounts of massive dunite (UNIT 2), small quantities of troctolite, wehrlite and flaser gabbro metacumulates (UNIT 3), and variably amphibolitized, layered olivine and pyroxene-gabbro metacumulates with diabase dykes (UNIT 4). Outcrops of Units 1 and 2 occur mainly in the southern quarter of the map area, and outcrops of Units 3 and 4 occur mainly in the contiguous area to the north covering the central southern part of the map area.

The younger intrusive bodies (UNITS 5 and 6) consist of wehrlite, feldspathic-wehrlite, clinopyroxenite, clinopyroxene-dunite, chromitiferous-dunite, minor troctolite, and dykes of gabbro and diorite. Outcrops of these units occur mainly in the northern part of the map area.

An older S_1 mantle tectonite fabric, which occurs within the harzburgite and associated dunite $\pm$ chromite in the southern part of the map area, is truncated by the younger suite plutons and is variably overprinted by a younger, penetrative $L_2<>S_2$ mylonitic fabric. This later, high temperature $L_2<>S_2$ fabric is variably developed within all lithological units throughout the map area. Contacts of major lithological units and the internal fine-scale igneous layering of some lithologies have been progressively transposed from their original geometries during the penetrative ductile deformation.

The classification scheme of older versus younger suites is based upon: (1) the penetrative nature of the ductile deformation within the older suite rocks, and (2) the intrusive contacts between the penetratively deformed older suite rocks and the heterogeneously deformed younger suite plutons. The grouping of rock types within a particular suite is, therefore, based upon spatial and temporal structural relationships and is not intended to reflect petrogenetic affiliation. Additional geochemical studies are required before the individual lithological units can be assigned to specific genetic suites.

LITHOLOGIES

The Older Suite

Harzburgite tectonite (UNIT 1), representing the residual mantle component of the ophiolite, exhibits a penetrative S_1 and/or S_2-L_2 fabric that is defined by the preferred dimensional alignment of the orthopyroxene $\pm$ spinel grains (porphyroclasts and aggregate trails of neoblasts). A fine to coarse (1-10mm) S_1 fabric dominates in the southern Springers Hill area whereas in the northern Springers Hill area and westward within the Mount Barren area this older S_1 fabric is variably overprinted by a fine grained mylonitic S_2-L_2 fabric.

The harzburgite is cut by multiple swarms of discontinuous, variably chromitiferous dunite bands that range from 1cm to 5m in width and up to 10m in length. These bands have been variably transposed so that their original attitudes have been reorientated towards the regional structural trends and are now parallel, subparallel, or discordant to S_1. A number of bands exhibit both asymmetric and symmetric F_1 minor fold closures with axial planar S_1 foliation. Within the Springers Hill area (southeastern part of the map area), the form surface trace of these bands appears to define a major, inclined, northeast plunging mantle synform structure with an axial planar S_1 fabric.

The massive dunite (UNIT 2) bodies occur within the Springers Hill area. These small zones show both gradational and sharp contacts with the enclosing harzburgite. The attitude of the S_1 fabric, defined by inequant spinel grains, is concordant with the S_1 fabric in the enclosing harzburgite.

The ultramafic metacumulates (UNIT 3), consisting of penetratively deformed wehrlite, troctolite, pyroxenite and flaser gabbro, outcrop within the northern part of the Springers Hill area. Lithologies of this Unit exhibit a penetrative L_2-S_2 fabric that imparts a characteristic rodded appearance to the elongate grains and aggregates (L_2) on the foliation/layering plane (S_2/S_0). Within the coarser grained lithologies of Unit 3, the pyroxene, plagioclase and

hornblende augen (porphyroclasts) exhibit both dextral and sinistral senses of shear rotation as defined by trails of recrystallized neoblasts.

Designation of Unit 3 lithologies as part of the Older Suite is based upon: (1) the penetrative nature of the L_2-S_2 fabrics and their concordance with the surrounding harzburgite fabrics; (2) the transposed interlayering of large (up to 250 m by 75 m) boudins of Unit 3 lithologies within the harzburgite in the Carol Mountain area; and (3) the intrusion of penetratively deformed (L_2-S_2) Unit 3 lithologies by isotropic to moderately deformed (L_2-S_2) lithologies of Unit 5 in the Carol Mountain area.

The penetratively tectonized and variably amphibolitized layered gabbro metacumulates (UNITS 4a and 4b) outcrop in the western part of the map area between Rope Cove Canyon and the southern Mount Barren area, and in the Carol Mountain area to the east. In general, the gabbro is medium to fine grained size and exhibits a pronounced phase layering, ranging from a few mm to 25cm in thickness. Unit 4b comprising strongly amphibolitized layered gabbro, outcrops mainly in the western part of the map area. It exhibits gradational to obscure contacts with lithologies of Unit 4a and is spatially associated with an increase in the frequency of diabase dykes in the layered gabbro.

Layered gabbro metacumulates of Units 4a and 4b show strong $L_2 \geq S_2$ fabrics, that are defined by the alignment of inequant grains and aggregates, and the rotation (transposition) of primary igneous layering to orientations that are parallel or subparallel to the regional S_2 foliation. Mesoscopic, asymmetric fold closures (F_2), with axial planar S_2 foliation and fold axis parallel/subparallel to the L_2 lineation, occur throughout Units 4a and 4b. Symmetric F_3 minor-folds with folded S_2/S_0 and axial planes orientated parallel to the regional S_2 foliation were observed in two outcrops of gabbro in the western map area. Contacts between the layered gabbro and the harzburgite tectonite are structural, such as

being infolded and concordant with S_2 foliation or such as the thrust fault contact in the Carol Mountain area, whereas contacts with the younger suite plutons are intrusive.

The Unit 4c pyroxene and pyroxene-hornblende gabbro is fine to medium grained, massive to poorly phase layered and sporadically foliated. The unit outcrops in the northwestern Springers Hill area and is in faulted contact with Units 1, 4 and 6. Its correlation with the older suite Unit 4 is tentative.

The Younger Suite

The Younger Suite(s) occur as intrusive bodies throughout the Lewis Hills area, and forms the majority of outcrops in the north and northeast. The intrusive nature of these rocks relative to the older suite is indicated by xenolith-bearing margins, contacts which truncate structural fabrics of the Older Suite tectonite, and abrupt lithological and textural changes across contacts. Structural infolding of the contact between older suite layered gabbro and younger suite intrusives occurs in a number of places throughout the map area. In such areas, the intrusive contacts are obscure, requiring detailed mapping to delineate lithologies of the two different suites.

Plutons the younger suite are divided into two main units (UNITS 5 and 6), contacts between which are both gradational and abrupt. UNIT 5 consists of:

UNIT 5a, isotropic and commonly poikilitic wehrlite feldspathic-wehrlite with gradations to clinopyroxene-dunite and minor troctolite;

UNIT 5b, strongly tectonized (L_2-S_2) wehrlite, clinopyroxene-dunite with minor clinopyroxenite and troctolite;

UNIT 5c, heterogeneously deformed (L_2-S_2) clinopyroxenite with minor wehrlite and clinopyroxene-dunite; and

UNIT 5d, rare zones of massive dunite within UNITS 5a and 5b.

Mutual contacts between UNITS 5a through 5d are gradational or transitional and represent fractionated phases of the same intrusive body(ies).

Unit 6 consists of:

UNIT 6a, chromitiferous-dunite with abundant chromite bands and minor clinopyroxene-dunite;

UNIT 6b, clinopyroxene-dunite with rare wehrlite and troctolite.

UNITS 6a and 6b represent fractionated phases of the same pluton and both are heterogeneously deformed (L_2-S_2).

The contacts between lithologies of UNITS 5 and 6 are both gradational or transitional, as for example the north-south contact exposed in the centre of the Lewis Hills map area, and abrupt (intrusive), as for example that contact exposed in the northern half of the map area where structural fabrics in deformed UNIT 5b are truncated by the isotropic UNIT 6b.

The Younger Suite rocks exhibit primary igneous cumulate textures (e.g.: poikilitic and rare cumulate layering features) that are variably overprinted or obliterated by secondary deformation fabrics (L_2-S_2). Within the least deformed sections of the plutons, the grain size ranges from about 1mm to 3.5cm, and within poikilitic rocks the clinopyroxene and plagioclase oikocrysts range up to 3cm in diameter. The high-temperature L_2-S_2 deformation is heterogeneously distributed throughout the younger intrusives, and is expressed as interconnected shear zones of intense deformation which range from a few centimeters to tens of metres in width, that enclose lens-shaped zones of lower strain in which the primary igneous textures are preserved. The density of shear zone development is highly variable, and varies from low within essentially undeformed intrusives, through moderate where undeformed rocks contain small, discrete shear zones less than 1m wide and which tend to taper out within 20m laterally, to strong, in

which multiple, anastomosing shear zones containing small, lens-shaped low strain domains, pervades the entire rock.

UNIT 7 diabase to dioritic dykes intrude the older suite gabbro (UNIT 4) and younger suite plutons (UNIT 5). The dykes range from aphyric to fine grained with subhedral plagioclase phenocrysts. The occurrence of dykes is most intense along the western map margin. The dykes range from being virtually undeformed to being strongly deformed by L_2-S_2 fabrics. The petrogenetic relationships between the various dykes are not known.

STRUCTURE

Both ductile and brittle deformation events are evident throughout the Lewis Hills map area. A variably developed, high temperature-high strain ductile deformation history is indicated by penetrative, plastic deformation fabrics (e.g. S_1 and L_2-S_2), and the progressive structural transposition of original attitudes of major lithological contacts and fine-scale layering towards regional structural trends. Brittle deformation features occur primarily as fault zones along the northern Springers Hill area and in the Rope Cove Canyon area.

The S_1 foliation (D_1) occurs within harzburgite in the Springers Hill area and is defined by the alignment of attenuated orthopyroxene grains and crystal aggregates. The S_1 foliation strikes consistently 020^0 to 040^0, dips steeply 60^0 to 85^0 NW and is axial planar to a major, inclined, NE-plunging mantle synform structure. This fold structure is defined by the form trace of dunite bands in the harzburgite.

Towards the northern part of the residual mantle or harzburgite in the Springers Hill area, the S_1 mantle fabric is gradually overprinted by L_2<>S_2

mylontitic shear zones (D_2). This D_2-deformation occurs throughout the rest of the map area and affects the lithological units of both the Older Suite (i.e.: UNITS 1,2,3 and 4) and those of Younger Suite (UNITS 5 and 6 $\pm$ 7). The L_2-S_2 fabrics are penetratively developed throughout the Older Suite units but within the Younger Suite plutons are only heterogeneously developed as L_2-S_2 shear zones. Porphyroclastic to granuloblastic textures and strongly lineated and/or foliated L_2-S_2 fabrics of the D_2 deformation are similar in both Older and Younger Suites lithologies. The L_2 fabric exhibits a consistently gentle northward plunge throughout the map area. The attitude of the S_2 fabric varies from a moderately NE-NW dip and NW-NE strike in the northern Springers Hill area, via a moderate to steeply eastward dip and N-NW strike in the western map margin (Mount Barren area), to a consistently moderate NE dip and NW strike in the Bud's Pond area (northern part of map area).

CHROMITE MINERALIZATION

Chromite concentrations of the Lewis Hills map area are spatially associated with lithologies of the Older Suite in the southern part of map area and with plutons of the Younger Suite in the central and northern parts of the map area.

The main Springers Hill chromite deposit occurs in harzburgite tectonite (residual mantle) and consists of numerous, discontinuous bands of massive to heavily disseminated chromite within and surrounded by dunite. The main chromitiferous zone is generally less than 3m wide but over 600m long. It has an east-west strike and dips between 45^0 and 60^0 to the northwest. The chromite forms discontinuous bands, lenses and schlieren which commonly exhibit small fold closures. The chromitite zone is cross-cut by small dunite bands and is also offset by small scale sinistral and dextral shear zones of limited displacement.

The main Springers Hill chromite body has been interpreted by Suhr et al. (in prep.) as a dyke-like body which is discordant to the regional S_1 fabric.

The Chrome Point chromitite occurrence, located just south of Fox Island River, consists of a number of thin (2cm to 6cm in width) chromitite bands that strike 150^0 and are exposed in outcrop for up to 75m. The chromite occurs in dunite within the harzburgite unit.

Chromite occurrences of two distinct modes occur within the younger suite plutons. The first type consists of discontinuous bands of disseminated to heavily disseminated chromite within chromitiferous-dunite and clinopyroxene-dunite in the Bud's Pond area. These chromitiferous bands generally range up to a few centimeters in width and extend along strike for a few metres. The bands are parallel to the regional penetrative foliation and lineation fabrics of the Bud's Pond area. The second type of chromitite consists of a few angular and folded massive chromite fragments, up to 35cm in length, that occur within heterogeneously deformed clinopyroxene-dunite and wehrlite of the northern Springers Hills area.

CONCLUSIONS

The mapping reported in this Open File shows that the lithological, structural and multiple intrusive features of the Mount Barren area are equivalent to those that characterize the eastern Lewis Hills area (the Bay of Islands Assemblage). Therefore, the criteria cited by Karson (1977, 1979) and Karson and Dewey (1978) in proposing that the Mount Barren area represents an oceanic fracture zone that is distinct from younger and essentially undeformed oceanic crust represented by the Bay of Islands Assemblage, are not consistent with the geological features exposed in the Lewis Hills map area. Similarly, because the

original geometry of the major lithological contacts and fine-scale internal layering within penetratively deformed sections of the plutonic complex have been variably transposed towards the regional structural trends, the present-day geometry of these features reflects the patterns of plastic flow within a dynamic spreading regime and do not represent the primary igneous geometry of a steady-state, single magma chamber as proposed by Casey and Karson (1981) for the Bay of Islands assemblage.

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