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GEOLOGY OF THE PUDDLE POND (12A/5) AND LITTLE GRAND LAKE (12A/12) MAP AREAS, SOUTHWESTERN NEWFOUNDLAND

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ABSTRACT

The Puddle Pond and Little Grand Lake map areas consist of four diverse terranes separated by major high-strain zones. Northwest of the Long Range Fault, late Precambrian metasedimentary rocks and unconformably underlying gneiss (Steel Mountain terrane) are thrust to the northwest to form duplex structures. Between the Long Range and Victoria Lake faults, leucocratic and nebulitic to stromatic quartzofeldspathic to pelitic gneisses of uncertain age (Central Gneiss terrane) are invaded by mafic intrusions and a variety of granitoid rocks. Basalt, felsic volcanics and sedimentary rocks of the Victoria Lake Group in the Victoria Lake terrane experienced very mild metamorphism. North of the Little Grand Lake Fault, the Topsails terrane consists of little metamorphosed volcanic–sedimentary rocks of the Ordovician Glover group and distinctive granites.

The Long Range and Victoria Lake faults exhibit major early ductile deformation, late minor brittle movement, and a complex movement history. The Little Grand Lake Fault appears to be a southward-directed thrust with a small ductile component. Foliated granitoid rocks occur only in the Central Gneiss terrane. Mafic intrusions appear to be controlled by the major faults, but do not occur northwest of the Long Range Fault.

INTRODUCTION

The Puddle Pond (12A/5) and Little Grand Lake (12A/12) map areas form part of the Long Range uplands, a rolling surface that has been deeply dissected by erosion. Outcrop is good on the upland barrens, except in areas of stunted-spruce growth ('tuckamore'), but poor to nonexistent in the valleys. Highway 480 (the Burgeo road) crosses the Puddle Pond map area, and other woods roads, as well as Grand Lake and Little Grand Lake, provide access to parts of the area. However, easy access to much of the region can only be obtained by aircraft.

This region has been investigated by 1:250,000 geological mapping (Riley, 1957). Herd and Dunning (1979) and Dunning (1984) mapped part of the Puddle Pond sheet at 1:50,000, and Whalen and Currie (1983a,b), Knapp (1982) and Kennedy (1981) have mapped parts of the Little Grand Lake sheet. The present work was undertaken as part of a systematic mapping program of the southern Long Range uplands (van Berkel *et al.*, 1986; van Berkel and Currie, 1986; Currie, 1986, 1987; van Berkel, 1987a,b,c).

GENERAL GEOLOGY

The mapped area (Figure 1) falls into four diverse geological terranes that are separated by major faults (van Berkel *et al.*, 1986). Northwest of the Long Range Fault, late Precambrian metasedimentary rocks and underlying Grenvillian gneisses of the Steel Mountain terrane (van Berkel *et al.*, 1986) have been thrust to the northwest. This region fits well into the Humber tectonostratigraphic zone of Williams (1979). Between the Long Range Fault and close to the Victoria Lake Fault, the rocks consist of quartzofeldspathic to semipelitic and calcareous gneisses invaded by mafic and granitoid intrusions. This Central Gneiss terrane (van Berkel *et al.*, 1986) does not resemble either the Humber or Dunnage zones of Williams (1979) but has some similarities to the Gander Zone. A narrow strip, forming the Victoria Lake terrane, between the Annieopsquotch Complex and the Victoria Lake Fault consists principally of low-metamorphic-grade mafic and felsic volcanic rocks of the Victoria Lake Group (see also Kean, 1983), a typical Dunnage Zone assemblage. North of the Little Grand Lake Fault, the Topsails terrane comprises very low-metamorphic-grade mafic and

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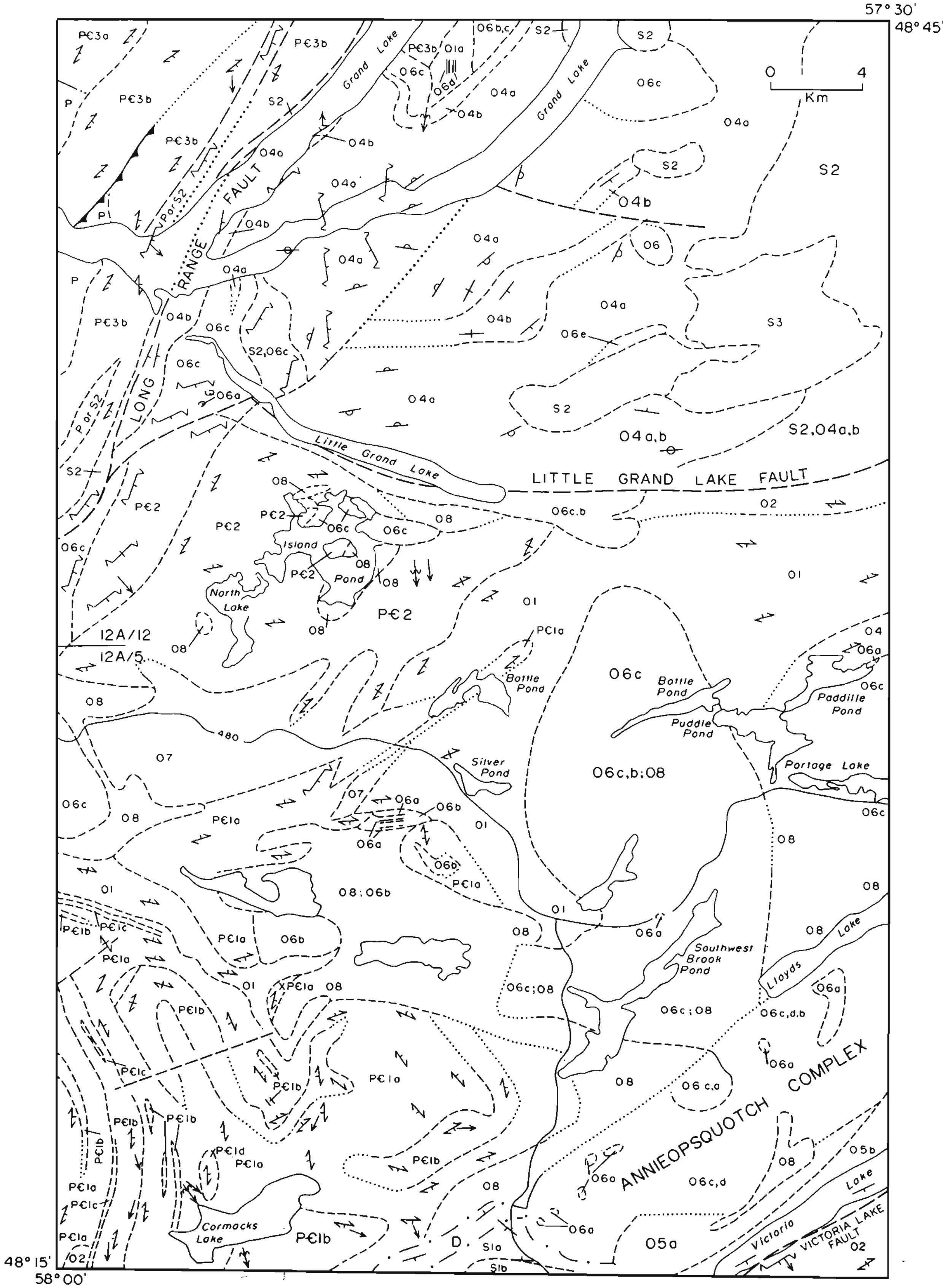


Figure 1. *Generalized geological map of the Puddle Pond (12A/5) and Little Grand Lake (12A/12) map areas, southwest Newfoundland. Note that, except where constrained by fossil or radiometric dates, all ages are tentative.*

LEGEND

DEVONIAN

D Windsor Point Group: *grey sandstone, grit, mudstone, conglomerate (Emsian fossils, ca. 372 Ma)*

SILURIAN

S3 *peralkaline granite (429 ± 5 Ma)*

S2 *mostly unfoliated hornblende and/or biotite granite, often with porphyritic feldspar*

S1 a, *red sandstone and conglomerate;* b, *rhyolite (431 ± 5 Ma)*

ORDOVICIAN OR YOUNGER

O8 *mostly unfoliated biotite granite and leucogranite, locally with porphyritic feldspar*

O7 *massive, locally flow-banded quartz diorite and tonalite*

O6 composite mafic intrusions: a, *dunite, harzburgite, pyroxenite, olivine gabbro;* b, *medium- to coarse-grained gabbro;* c, *medium grained diabase;* d, *fine grained diabase dyke;* e, *leucogabbro–diabase (Colour Index = 20-30)*

ORDOVICIAN

O5 Victoria Lake Group (462 ± 4 Ma): a, *basalt;* b, *felsic volcanics and sediments (with intrusions of subunit O6c)*

O4 Glover group (ca. 480 Ma): a, *pillow basalt (with intrusions of subunit O6b to Unit O3);* b, *felsic volcanics (ash tuff, minor crystal tuff), minor shale and conglomerate*

O3 Ophiolite (?): a, *serpentinized dunite and harzburgite;* b, *pyroxenite;* c, *coarse grained metagabbro and amphibolite*

ORDOVICIAN OR OLDER

O2 *mostly foliated biotite granite and leucogranite, locally with porphyritic feldspar*

O1 *foliated granodiorite–tonalite with abundant mafic inclusions*

UPPER PROTEROZOIC TO CAMBRIAN

PC3 Fleur de Lys Supergroup: a, *phyllite, calcareous phyllite and marble;* b, *actinolite (± garnet) schist, marble, pelitic quartzite and quartzite*

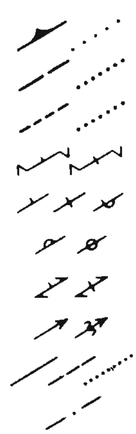
PC2 Higher-grade metamorphic equivalents of the Fleur de Lys Supergroup (?): *nebulitic to stromatic quartzofeldspathic and semipelitic gneisses*

PC1 Cormacks Lake complex: a, *leucocratic quartzofeldspathic gneisses;* b, *with pyrite, gedrite ± garnet-bearing layers and minor pelitic and quartzitic rocks;* c, *amphibolite and coarse grained metagabbro (part of subunit O3c?);* d, *granulite*

UPPER PROTEROZOIC (Grenvillian)

P *intermediate and granitic gneisses; minor amphibolite*

SYMBOLS



thrust fault (approximate, assumed)

major fault (approximate, assumed)

minor fault (approximate, assumed)

shear zone (inclined, vertical)

bedding (inclined, vertical, overturned)

orientation of pillows in basalt (inclined, vertical)

foliation (inclined, vertical)

lineation; mesoscopic multiple folding

geological boundary (defined, approximate, assumed)

unconformity (approximate)

Geology by J.T. van Berkel, 1985-1987; K.L. Currie and M.A.J. Piasecki, 1985, 1986; H.P. Johnston, J. Martin and S. Dawson, 1985; and D. Machin and D. Fox, 1987. Partly after Herd and Dunning (1979); Kennedy, (1981); Knapp (1982); Whalen and Currie (1983a,b) and Dunning (1984).

felsic volcanic rocks of the Glover group, typical of the Dunnage Zone, and massive, commonly peralkaline, high-level granitic rocks that define the unique character of this terrane.

DESCRIPTION OF ROCK UNITS

Steel Mountain Terrane

South of Grand Lake, the oldest rocks consist of granitic to intermediate gneisses, minor amphibolite and rare quartzite beds (Unit P). These gneisses are unconformably overlain by metasedimentary cover rocks (Unit PC3) consisting of actinolite ($\pm$ garnet) schist, marble, calcareous phyllite, pelitic quartzite (with staurolite + garnet assemblages) and quartzite. Some details of the stratigraphy and petrography of this sequence are given by Currie (1986), who followed earlier workers in correlating it with the upper Precambrian–lower Paleozoic Fleur de Lys Supergroup (Knapp *et al.*, 1979; Kennedy, 1981; Hibbard, 1983a,b; Williams, 1985).

The gneissic basement and its metasedimentary cover have been thrust to the northwest, forming spectacular duplexes in which the basement–cover unconformity is repeated several times (Currie, 1987). The thrust deformation has variably overprinted the fabric of the gneisses, producing new growth of oriented micas (Currie, 1987), and grain-size reduction of feldspar, quartz and amphibole. The degree of overprinting is generally low, but locally high enough to produce fissile schists in which the older gneissosity is destroyed. Sheets of very fissile, two-mica granitoid schists often found in the thrust zones may have been produced by such overprinting, in combination with alkali loss, rather than by synkinematic intrusion as suggested by Currie (1987).

Currie (1987) has shown that west of the Little Grand Lake (12A/12) map area, the gneisses of Unit P are younger than the Steel Mountain anorthosite and two-pyroxene granulites of the Disappointment Hill complex. A posttectonic peralkaline granite at Hare Hill gave a U–Pb date on zircon of 617 $\pm$ 8 Ma. Given these constraints, it seems reasonable to identify the metamorphism of the gneisses of Unit P as Grenvillian in age, that is ca. 1000 Ma.

Central Gneiss Terrane

The oldest rocks of the Central Gneiss terrane consist of quartzofeldspathic gneisses of the Cormacks Lake complex (Unit PC1) and quartzofeldspathic to semipelitic and calcareous gneisses of Unit PC2.

The Cormacks Lake complex (Herd and Dunning, 1979; van Berkel, 1987a) contains banded rocks with pyrite + gedrite $\pm$ garnet and minor pelitic and quartzitic rocks (subunit PC1b), and thick layers, lenses and inclusions of amphibolite (Plate 1; Figure 1) and coarse grained metagabbro (subunit PC1c). Some of the amphibolite exhibits relict igneous textures that could mean it represents metamorphosed remnants of ophiolite complexes (Unit O3). The predominant quartzofeldspathic gneiss was formerly interpreted as deformed biotite granite (van Berkel, 1987a), but a more detailed examination showed that the least deformed portions have a granoblastic texture (Plate 2), which is characteristic of statically recrystallized gneisses formed during medium- to high-grade metamorphism. An elongated hill north of Cormacks Lake consists of a slightly retrograded, two-pyroxene granulite (subunit PC1d). The Cormacks Lake complex may consist of a deformed basement–cover complex. Early tight folding is commonly obliterated by a gneissose banding, which is itself folded to give a map pattern showing macroscopic folds.

Plate 1. *Amphibolite inclusions in quartzofeldspathic gneisses of the Cormacks Lake Complex (subunit PC1a). Note the L–S fabric with lineation parallel to hammer. Outcrop in the Lloyds River, 5 km east of Cormacks Lake. GSC 204461.*

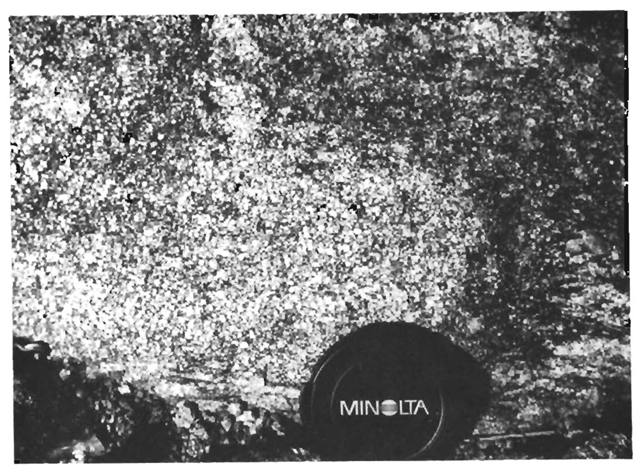


Plate 2. *Granoblastic quartzofeldspathic gneisses of the Cormacks Lake Complex (subunit PC1a). Location 8 km northeast of Cormacks Lake.*

Quartzofeldspathic and semipelitic gneisses (Unit PC2) form stromatic to nebulitic migmatites, but are clearly developed from a supracrustal sedimentary sequence, as indicated by the presence of quartzitic and calcareous beds. The gneisses form an extension of the metasedimentary gneisses in the Main Gut (12B/8) and Dashwoods Pond (12B/1) map areas, where they appear to be possibly correlative with the Fleur de Lys Supergroup northwest of the Long Range Fault. Unlike the Cormacks Lake complex, the gneisses of Unit PC2 are openly folded on a mesoscopic scale. Numerous small veins of biotite granite (Plate 3) form a characteristic feature of this unit. A thin layer and an inclusion of serpentinite were observed in this unit east of North Lake.

Plate 3. *Nebulitic to stromatic gneiss (Unit PC2). Note the crosscutting granitic veins. Location northeast corner of the Puddle Pond map area (12A/5). GSC 204460-U.*

The region from Padille Pond to Battle Pond is predominantly underlain by granitoid rocks ranging from medium- to coarse-grained, foliated biotite granite and leucogranite (Unit O2) to a distinctive, mafic-enclave-rich, foliated granodiorite–tonalite (Unit O1). This large region probably includes several plutons of uncertain age.

Intrusions of massive to slightly foliated, medium grained, diabasic gabbro and coarse grained, leucocratic gabbro (Unit O6; Plate 4) are cut by fine grained diabase dykes (Plate 5), tend to trend northeast or east-west, and are bounded by faults. Although these bodies locally contain enclaves of dunite (Plate 6), harzburgite or pyroxenite, they can be readily differentiated from remnants of ophiolites (Unit O3) by lack of deformation and associated ophiolitic units (ultramafic rocks, sheeted dykes, pillow lavas), common presence of minor amounts of biotite and local presence of lamprophyric texture. Mapping of the large body around Bottle Pond is hampered by poor exposure, but road and powerline exposures suggest a complex mixture of mafic phases including many dykes and granitoid enclaves (Units

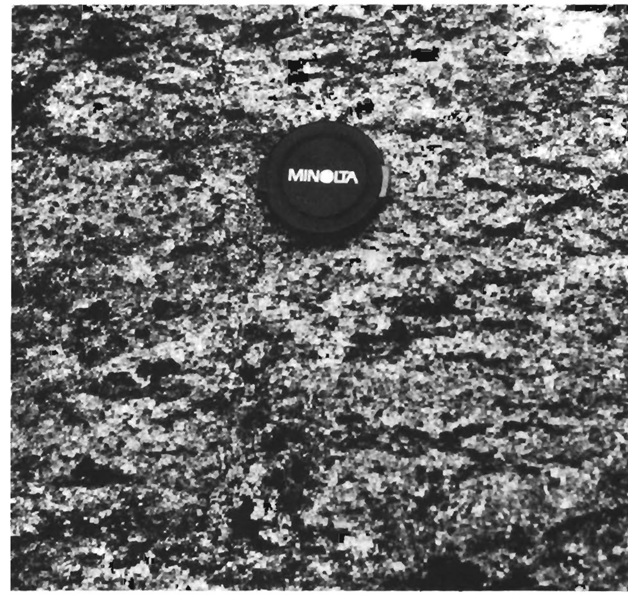


Plate 4. *Foliated, leucocratic, medium- to coarse-grained gabbro (subunit O6b). Location 3 km southwest of Silver Pond. GSC 204461-B.*

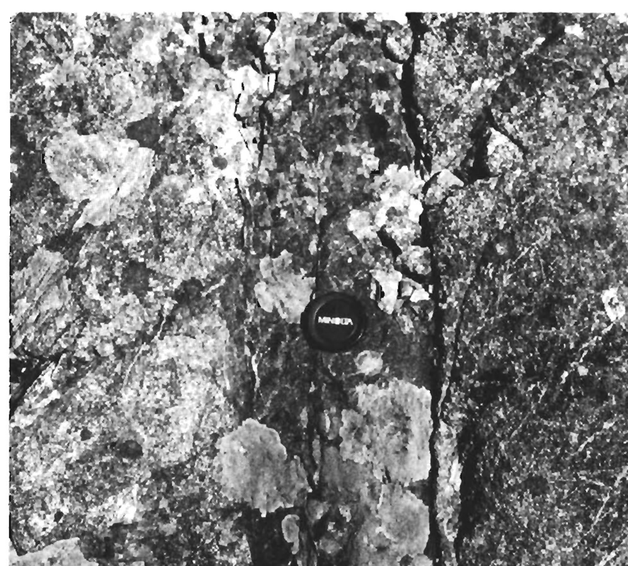


Plate 5. *Fine grained diabase dyke in medium grained diabase. Location 4 km northeast of Island Pond. GSC 204460-Z.*

O1 and O2) and intrusions (Unit O8). H. Miller (personal communication, 1986) found a large positive Bouguer anomaly in this region, which can be modelled by assuming about 70 percent mafic rocks of density 2.9 g/cm^3 to a depth of 8 km (M.D. Thomas, personal communication, 1987).

The large Annieopsquotch Complex has been generally interpreted as an ophiolite (Dunning, 1984, 1987; Dunning and Herd, 1980; Dunning and Chorlton, 1985). However, our

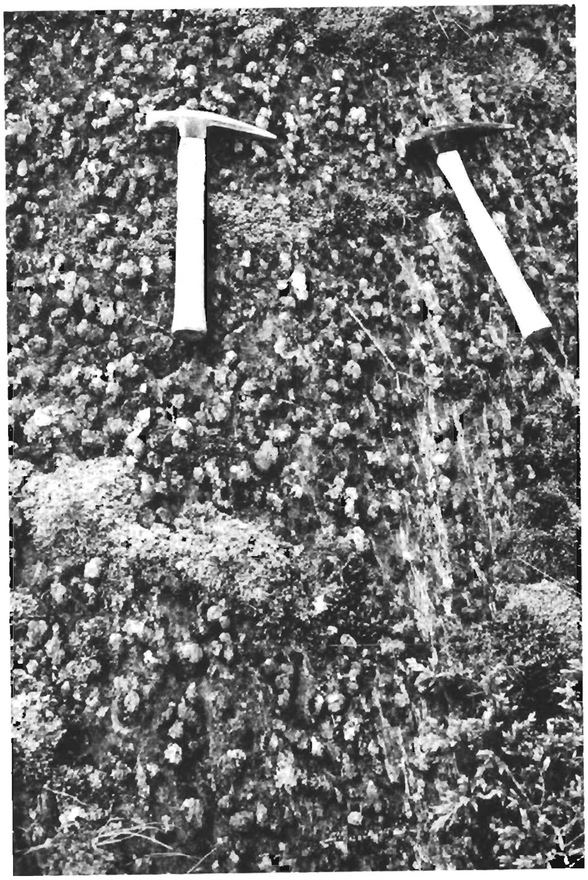


Plate 6. *Serpentinized dunite (subunit O6a) with chlorite-rich aggregates and a weak cleavage (white). Location 3 km southwest of Silver Pond. GSC 204461-E.*

re-examination shows that the ultramafic portions form small pods in a gabbroic matrix, that the dykes of the complex cut a gabbroic matrix, and that other lithologies typical of complete ophiolite complexes are notably absent. We therefore suggest that the Annieopsquotch Complex is not ophiolitic but is a postobduction mafic complex emplaced under a sinistral shear regime. This explains the 160-200° orientation of the dykes.

A large intrusion of quartz diorite and tonalite (Unit O7) outcrops along the Burgeo road (Route 480). The rocks contain inclusions of diabase and gabbro thought to be derived from Unit O6, and are cut by granite veins. A faint mineral banding and alignment of inclusions may be due to flow processes.

The youngest intrusive rocks (Unit O8) comprise massive medium grained biotite granite and leucogranite that cut all the previous units. Large intrusions of this type occur south of Southwest Brook Pond and west of Lloyds Lake.

Silurian red sandstone, conglomerate and rhyolite (Unit S1) unconformably overlie gabbro (Unit O6) and basalt of the Victoria Lake Group (Unit O5) in the southern part of the map area (Chandler, 1982; Chandler and Dunning, 1983). Devonian sedimentary rocks of the Windsor Point Group (Unit D) unconformably overlie this unit and also unfoliated biotite granite of Unit O8.

Victoria Lake Terrane

The Victoria Lake terrane lies between the Annieopsquotch Complex and the Victoria Lake Fault, a major structure that may be part of the Cape Ray fault system. The dominant rock unit in this area is the Victoria Lake Group (Unit O5) which consists of basalt, felsic volcanic rocks, and intercalated sedimentary rocks with numerous diabase dykes and sills (H. Williams, personal communication, 1987). Zircons from rhyolite of the Victoria Lake Group gave an age of 462 $^{+2}_{-4}$ Ma (Dunning *et al.*, 1987). Southeast of the fault, a strongly foliated granite and migmatite complex has been tentatively correlated with Unit O2. It appears to be similar to the Central Gneiss terrane.

Topsails Terrane

Much of the Topsails terrane (Whalen and Currie, 1983a,b) in the Little Grand Lake map area is underlain by well preserved, locally pillowed (Plate 7), basalt of the Glover group (Unit O4). Several layers of felsic volcanic rocks and sedimentary rocks, and one 15-m-thick layer rich in hematite were observed in the basalt. Intrusions of gabbro–diabase (subunits O6b,c,d) and Silurian granite (Units S2 and S3; Whalen *et al.*, 1987) are common. A late phase of east- to west-striking mafic dykes cuts the granites (Unit S2) east of Little Grand Lake.

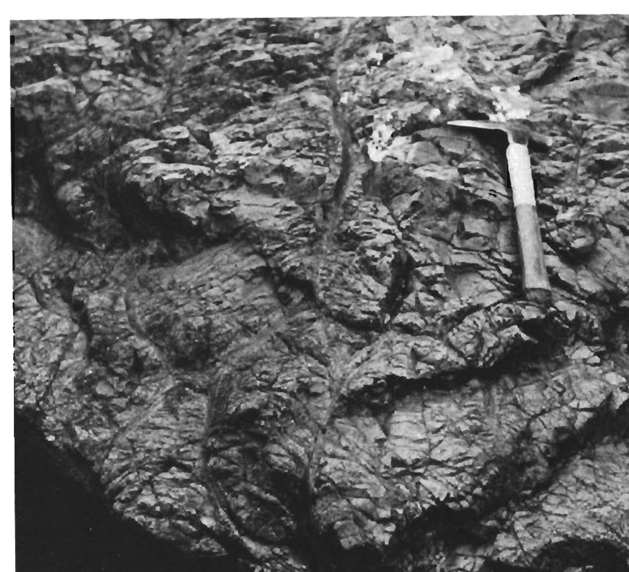


Plate 7. *Pillow basalt in the Glover Group (subunit O4). Location 7 km east of Little Grand Lake. GSC 204461-A.*

The transition from the Topsails terrane to the Steel Mountain terrane on Glover Island occupies a zone 0.5 to 1 km wide comprising highly deformed, felsic volcanic rocks and sedimentary rocks(?) of the Glover Group (Unit O4), two mafic intrusions (subunits O6b,c) and north-trending diabase dykes (subunit O6d), which cut the ophiolitic (Knapp, 1982) serpentinite of Unit O3. This transition clearly lies in a roughly north-south-striking deformation zone, which overprints and folds all earlier fabrics, foliates the mafic intrusions (subunits O6b,c) and crosscuts geological boundaries. The origin of this zone is not presently understood, but the structural character of the metasedimentary and volcanic rocks of Unit O4b suggest a dextral component of shear in this region.

ECONOMIC GEOLOGY

Rusty quartzofeldspathic rocks of the Cormacks Lake complex (subunit PC1b) contain a few percent pyrite and magnetite, but no detectable Au, Pt and Pd, even in large shear zones.

Ultramafic and mafic rocks of Unit O6 contain up to 9 ppb Au, 10 ppb Pt and 9 ppb Pd. Fissile zones with macroscopically visible pyrite contain up to 50 ppb Au.

DISCUSSION

Much of the southern Long Range uplands consist of amphibolite-grade metamorphic rocks derived from supracrustal protoliths, minor layers of highly deformed mafic to ultramafic rocks (Fox and van Berkel, *in press*), and pervasive granitoid plutonism. The derivation of the supracrustal rocks is not definitely known, but the rock types strongly suggest that they represent units of the Humber Zone northwest of the Long Range Fault. Lithologies of Unit PC3, presumed to be correlative with the Fleur de Lys Supergroup, can be correlated with many of the lithologies of Unit PC2 south of the fault. The Cormacks Lake complex, with its contained granulites, correlates well with the older gneisses (Unit P), which rest on granulite northwest of the fault. The presence of late Precambrian granitoid plutons has not been proved in the Central Gneiss terrane, but their presence in the Steel Mountain terrane suggests the possibility. In sum, the present work suggests that North American crust extended as far southeast as the Victoria Lake Fault.

The nature of the event that sutured this crust to other zones of Newfoundland during the Ordovician remains unclear. Brown (1976), Dunning (1984) and Dunning and Chorlton (1985) argued that large slices of ocean crust were emplaced in this region, and subsequently deformed and intruded. We find this highly improbable since the large mafic complexes such as the Annieopsquotch and those around Bottle Pond are essentially unaltered and undeformed. We feel they must be younger than the closure. Dunning and Krogh (1985) reported two Early Ordovician U–Pb zircon ages of about 480 Ma for trondhjemite of the Annieopsquotch Complex. We do not consider that these ages necessarily date the diabase dykes and gabbro of the Annieopsquotch Complex, which may be of Late Ordovician or Early Silurian age as documented by Whalen *et al.* (1987) for similar rocks in the Topsails terrane. This would be compatible with intrusion of the Lower Ordovician Glover group and Middle Ordovician Victoria Lake Group by diabase dykes and sills apparently related to the major mafic bodies. We draw attention to the work of Bédard (1986) who indicated that postorogenic mafic bodies of midocean ridge basaltic (MORB) chemistry occur in the Gaspé Peninsula. We feel that if major ophiolite allochthons were present, they must have passed over the southern Long Range uplands well above the present exposure level, as suggested by the high metamorphic grade suitable to the root of a collisional zone. Layers and lenses of highly deformed mafic to ultramafic rocks in the Central Gneiss terrane may mark thrust faults formed during a collisional event (van Berkel *et al.*, 1986; van Berkel, 1987a; Fox and van Berkel, *in press*). Thrust faults in the gneisses would be extremely difficult to detect due to extensive static recrystallization.

Major faults such as the Long Range, Victoria Lake and Little Grand Lake faults form impressive lineaments, but their role during collision remains obscure. Their present configuration results from late (Silurian–Carboniferous) brittle movement. Detailed examination of the ductile phase of movement of the Long Range and Victoria Lake faults suggests that dextral, sinistral and vertical motion all occurred. There is at present no evidence that the near vertical dip of these features decreases with depth. The drastic difference in metamorphic grade across these faults suggests that regardless of other motions, the Central Gneiss terrane is now uplifted with respect to its surroundings. The Annieopsquotch Complex may be separated from the Central Gneiss terrane by a major fault but we have been unable to find any major movement along this lineament. Minor structures associated with the Little Grand Lake Fault suggest that it could be a relatively late thrust, dipping northward at a moderate angle. As pointed out by Whalen and Currie (1983a,b), the lack of deformation in the Topsails terrane suggests that it is allochthonous and presumably thrust southward to truncate the surficial northeasterly trend of the southern Long Range.

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