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NOTES TO ACCOMPANY A GEOLOGICAL MAP OF THE SOUTHERN LONG RANGE, SOUTHWESTERN NEWFOUNDLAND

K.L. Currie and J.T. van Berkel

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NOTES TO ACCOMPANY A GEOLOGICAL MAP OF THE SOUTHERN LONG RANGE, SOUTHWESTERN NEWFOUNDLAND

Abstract

The southern Long Range comprises five subzones separated by major faults. West of Grand Lake Fault, carbonate rocks of the Saint George Group are structurally overlain by allochthonous shales of the Georges Brook Formation (Humber platform subzone). Between the Grand Lake and Long Range faults, late Precambrian metasedimentary rocks and gneissic Grenvillian (?) basement have been thrust northwest over Proterozoic anorthosite and granulite (Steel Mountain subzone). Between Little Grand Lake, Long Range and Lloyds River-Victoria River faults psammitic and quartzo-feldspathic gneisses, some at granulite grade, contain trains of thin slices of ophiolitic rocks within ductile shear belts, and abundant tonalitic to granitic intrusions (Central Gneiss subzone). North of Little Grand Lake Fault, low grade mafic and felsic volcanic rocks of the Glover Group and high level, commonly peralkaline, granitic rocks form the southern extremity of Notre Dame subzone of the Dunnage zone. Between the Lloyds River and Victoria River faults, the ophiolitic Annieopsquotch complex and low grade felsic and mafic volcanic rocks of the Victoria Lake Group probably also belong to the Notre Dame subzone, but may in part belong to the Exploits subzone of the Dunnage zone. Southeast of the Victoria River Fault (Noel Paul's line), the Meelpaeg subzone comprises rafts of metasedimentary rocks with distinctive calc-silicate lentils intruded by peraluminous beryl-bearing leucocratic granites.

Résumé

La partie sud des monts Long Range regroupe cinq sous-zones que séparent de grandes failles. À l'ouest de la faille Grand Lake, des roches carbonatées du Groupe de Saint George sont recouvertes structuralement par des shales allochtones de la Formation de Georges Brook (sous-zone de la plate-forme de Humber). Entre la faille Grand Lake et la faille Long Range, des roches métasédimentaires de la fin du Précambrien et des roches gneissiques du socle grenvillien (?) ont été charriées vers le nord-ouest sur des anorthosites et des granulites protérozoïques (sous-zone de Steel Mountain). Entre les failles Little Grand Lake, Long Range et Lloyds River-Victoria River, des gneiss psammitiques et quartzo-feldspathiques, dont certains sont métamorphisés au faciès des granulites, contiennent des traînées de minces couches d'ophiolites au sein de zones de cisaillement ductile, ainsi que de nombreuses intrusions tonalitiques ou granitiques (sous-zone centrale de gneiss). Au nord de la faille Little Grand Lake, des roches volcaniques mafiques et felsiques, faiblement métamorphisées, du Groupe de Glover et des roches granitiques souvent hyperalcalines constituent l'extrémité sud de la sous-zone de Notre Dame de la zone de Dunnage. Entre la faille Lloyds River et la faille Victoria River, le complexe ophiolitique d'Annieopsquotch et des roches volcaniques felsiques et mafiques, faiblement métamorphisées, du Groupe de Victoria Lake appartiennent vraisemblablement eux aussi à la sous-zone de Notre Dame; toutefois, ils pourraient appartenir en partie à la sous-zone d'Exploits de la zone de Dunnage. Au sud-est de la faille Victoria River (ligne de Noel Paul), la sous-zone de Meelpaeg se compose de roches métasédimentaires caractérisées par des lentilles à silicate de calcium que percent des granites leucocrates hyperalumineux à béryl.

INTRODUCTION

The southern Long Range Mountains from Grand Lake to latitude 49° form a dissected peneplane with barren flat-topped hills at elevations of 550 to 650 metres, separated by broad, steep-walled wooded valleys. The uplands do not support forest cover above 350 metres, except for local patches of stunted spruce ("tuckamore"). Fixed wing aircraft can use a few of the small, rocky lakes, but a number of hunting cabins and tracks fringe larger lakes usable by small float-equipped aircraft. Helicopters provide ready access to all parts of the uplands. The valleys are reasonably well served by roads and tracks. The Trans-Canada Highway (Route 1) crosses the western boundary of the map area, and the Burgeo Road (Route 480), roughly bisects the region. Privately owned logging roads provide access to Grand Lake and Little Grand Lake as well as considerable areas in the valley of Southwest Brook, and all-terrane vehicle tracks provide access to large areas, including some barren tops.

The southern Long Range was geologically mapped at 1:250 000 scale by Riley (1957, 1962), and some marginal parts have been partially mapped at 1:50 000 scale (Herd and Dunning, 1979; Dunning, 1984; Whalen and Currie, 1983; Knapp et al., 1979; Kean, 1983). The degree of bedrock exposure is generally high on the barren uplands and on precipitous, almost inaccessible, valley tops, but poor to nonexistent in wooded valleys, except for occasional stream exposures. All of the mapped area has been glaciated, and large portions of map areas 12B/1 and 12A/4 are covered by an almost continuous sheet of bouldery till. The latest ice movement was dominantly to the southeast, but northwest movement directions were recorded along the western slopes of the Long Range.

The southern Long Range falls into five distinctive geological subzones or terranes separated by major faults (see map figure). We here utilise the subzone terminology introduced by Williams et al. (1988), and applied to this region by Currie and Piasecki (1989). To the northwest of the Grand Lake Fault, autochthonous Cambrian platformal carbonate rocks of the Saint George Group are structurally overlain by allochthonous shales of the Georges Brook Formation (Humber platform subzone). Between the Grand Lake and Long Range faults, clastic metasedimentary rocks and their gneissic Grenvillian (?) basement have been thrust northwest over middle Proterozoic anorthosite and granulite (Steel Mountain subzone). The southern end of the Steel Mountain subzone is covered by clastic sedimentary rocks of Carboniferous age.

Between the Little Grand Lake, Long Range and Lloyds River-Victoria River faults the rocks consist of psammitic and quartzofeldspathic gneisses, some at granulite grade, with minor semipelitic and calcareous gneisses, trains of thin slices of ophiolitic rocks within ductile shear belts, and abundant tonalitic to granitic intrusions (Central Gneiss subzone). North of the Little Grand Lake Fault, a region containing low grade mafic and felsic volcanic rocks of the Glover Group and high level, commonly peralkaline, granitic rocks (Whalen and Currie, 1983) forms the southern extremity of the Notre Dame subzone of the Dunnage zone of Williams et al. (1988). Between the Lloyds River and Victoria River faults, the ophiolitic Annieopsquotch complex and low grade felsic and mafic volcanic rocks of the Victoria Lake Group probably also belong to the Notre Dame subzone, but may in part belong to the Exploits subzone of the Dunnage zone of Williams et al. (1988). Since the two possible parts of the Notre Dame subzone differ considerably in character, we term them the Topsails region and the Annieopsquotch region respectively. Southeast of the Victoria River Fault (part of the Noel Paul's line of Williams et al., 1989), the Meelpaeg subzone comprises small areas of amphibolite grade metasedimentary rocks with distinctive calc-silicate lentils intruded by peraluminous leucocratic granites, commonly megacrystic, which contain beryl in fractionated phases.

In the synoptic terminology of Williams (1979), the Humber platform and Steel Mountain subzones belong to the Humber zone, thought to represent cratonic North America. The Dunnage zone, defined by Williams (1979) to be the relic of a lower Paleozoic ocean, appears to be represented by the Notre Dame and Central Gneiss subzones, although the latter differs widely from previous characterizations of Dunnage zone terranes. The Meelpaeg subzone forms part of the Gander zone.

DESCRIPTIONS OF UNITS

Humber platform subzone

Within the area mapped by us, the Humber platform subzone contains only two recognizable units, namely carbonates of the Saint George Group and intensely deformed pelites of the Georges Brook Formation. From exposures elsewhere, the Saint George Group (map unit E_{sj}) is known to be of Cambrian age and divisible into several formations (Williams and Cawood, 1986). The rocks observed by us consist mainly of homogeneous fine grained, saccharoidal carbonate. In the extreme northwest corner of the area, limestone and dolostone are interbedded on a millimetre scale to form pale olive rhythmites. Elsewhere rare tectonic inclusions of similar rocks occur within ubiquitous pale grey marble in which thin dolomite layers have been boudined and intricately folded. Some outcrops exhibit thin platy, mylonitic layering, and veins and porphyroblasts of calcite. In most exposures bedding cannot be reliably distinguished from tectonic foliation. In thin section the rocks exhibit post-tectonic recrystallization with mosaic texture, three-point grain boundaries and a few rounded clastic quartz grains. Near the Grand Lake Fault the rocks have been brecciated with introduction of minor amounts of hematite, producing a striking red, coarse breccia. Where bedding can be identified, the strata commonly dip toward the east at angles of less than 20°, but complex west-verging recumbent folds with amplitudes up to 20 m can be observed in steep cliff exposures a few hundred metres west of the Grand Lake Fault, and a later steeply east-dipping cleavage can be observed in outcrops exposed on lumber roads southwest of the tip of Grand Lake.

The Georges Brook Formation (map unit O_{GB}), defined and studied by Williams and Cawood (1986) north and west of the mapped area, can be best observed in road cuts along the Trans-Canada Highway at the northwest corner of the mapped area. The rocks range from intensely deformed olive to black shale, pelitic schist and phyllite to graded siltstone preserved only in tectonic inclusions. The most characteristic and ubiquitous unit is an olive phyllite to phyllonite with large pyrite cubes spaced 3 to 5 cm apart. The rocks commonly consist of tectonic melange, or phacoids a few centimetres in diameter consisting of greenish-black homogeneous chloritic shales. Rare, more competent beds show that the structure is complex, including numerous east-over-west thrust faults, and thrust related west-verging recumbent folds. Williams and Cawood (1986) have shown that the Georges Brook Formation is probably of Ordovician age, and forms part of the trailing edge of the Humber Arm allochthon which was thrust west over the Saint George Group. A selvedge of intensely sheared mylonitic Georges Brook Formation with small tectonic slices of serpentinized ultramafic rocks occurs along the Grand Lake Fault both north and south of Grand Lake.

Steel Mountain subzone

Between the Grand Lake and Long Range faults the rocks consist of pyroxene granulites, anorthosite and gneisses of mid to late Proterozoic age (units P_{DH}, P_{SM} and P_g) unconformably overlain by late Proterozoic (?) sedimentary rocks (unit E_{FL}) and intruded by distinctive leucogranite (E_{HH}). Many lithologic boundaries lie on northeast-trending thrust faults, but sufficient original stratigraphy remains to establish the essential unity of this subzone. The Disappointment Hill complex (unit P_{DH}) comprises salic to intermediate two pyroxene granulites in various stages of retrogression intruded by orthopyroxene-bearing granitoid rocks. On Disappointment Hill the rocks are medium grained, and exhibit nebulous compositional layering, although in outcrop they have a homogeneous pale buff appearance. The rocks consist of various proportions of finely perthitic potassium feldspar, antiperthitic plagioclase, orthopyroxene, commonly with fine lamellae of clinopyroxene, clinopyroxene and minor biotite with accessory apatite and zircon. An orthopyroxene-bearing megacrystic leucogranite from this complex, deduced to have been emplaced under granulite facies conditions, gave a U-Pb zircon age of emplacement of 1498 ± 8 Ma (Currie et al., in press) suggesting the granulites may be correlative to those of the northern Long Range (Owen and Erdmer, 1989). On its west side the Disappointment Hill complex passes by marginal shearing and retrogression into biotitic megacrystic granite gneiss intruded by the younger Hare Hill complex. South of Caribou Brook the complex is largely retrograded to biotite-bearing assemblages. Relations with the Steel Mountain massif-type anorthosite complex (unit P_{SM}) are unclear, but the Steel Mountain complex appears to intrude the granulites. Around its northern and northeastern margin, the Steel Mountain complex displays a marginal phase up to 2 km wide of foliated amphibolite, norite and gabbro (unit P_{smb}) which has a lenticular structure with alternating zones of greenish black amphibolite, brownish gabbro or norite, and white to pale pink anorthosite. Similar rocks appear in a sill-like mass separate from the main body at its northern end. The central core of the massif consists of coarse to pegmatitic labradorite anorthosite with a colour index less than 5, and commonly less than 1. Substantial parts of the complex exhibit a distinctive pale lilac colour. Spectacular pegmatites, with altered pyroxene crystals up to 2 m in length, and cumulate layering textures are locally preserved even where the mafic minerals exhibit well developed multiple coronas, but much of the anorthosite displays cataclastic textures ranging from granulation through brecciation to platy mylonitic layering. Zircon from a strongly foliated amphibolitic marginal phase of the complex gave an upper intercept age of 1274 ± 18 Ma (Currie et. al., in press). South of Hare Hill marginal mafic phases of the Steel Mountain complex can be observed along lumber roads as concordant, strongly foliated, 10 to 100 m thick bodies of amphibolitic gneisses within a gneiss complex (unit P_g) outcropping on both sides of the western arm of Grand Lake. This complex comprises white granoblastic granitoid gneiss of trondhjemitic affinity, pale pink hornblende-biotite granite gneiss with abundant schliers and partings of biotite gneiss, as well as rare bands of garnetiferous biotite gneiss, and of very coarse quartzite and marble up to 3 m thick. Biotite gneiss and feldspathic amphibolitic gneisses are strongly migmatized, and road outcrops north of Goose Hill exhibit spectacular examples of two periods of migmatization. A characteristic feature of the gneiss complex is small scale folding ranging from open, near concentric folds to complex curvilinear folds. The folds exhibit no obvious consistency in style and orientation, and no axial plane cleavage, suggesting an origin by flow rather than flexural slip. Late cleavage in this unit consistently strikes north-northeast, dips steeply, and cuts the gneissosity at a high angle. This late cleavage accompanies a retrograde metamorphism which converted hornblende to biotite and chlorite, and spectacularly overprinted the older gneissosity north of Grand Lake. The gneiss complex outcrops mainly within a roughly rectangular area along the shores of Grand Lake, but a branch of the Long Range fault zone separates the Steel Mountain complex from a narrow slice of mylonitic gneiss which extends for tens of kilometres in the southwestern part of the mapped area. These relations may indicate that the Long Range fault zone follows the contact between the Steel Mountain complex and the gneiss complex where these units are present. We have no direct evidence on the age of the gneiss complex, but it is constrained between the 1274 Ma age of the Steel Mountain complex and the 617 Ma age of the Hare Hill complex, and is therefore in general terms of Grenvillian age. The gneiss complex is cut by a swarm of north-trending altered mafic dykes (unit P_b) which form as much as 3 per cent of the outcrop in almost continuous exposures along Grand Lake. Both the gneisses and the dykes are structurally overlain, apparently concordantly, by a younger metasedimentary sequence which is structurally and metamorphically simpler than the gneisses. Following Knapp et al. (1979) and Hibbard (1983), we assign these metasedimentary rocks to the Fleur de Lys Supergroup (unit E_{FL}). We interpret the original nature of the gneiss-metasediment interface as an unconformity, subsequently obliterated by ductile shearing and east-over-west overthrusting on a regional scale.

In the Grand Lake area, this shearing has resulted in the formation of an imbricate stack of thrust slices in which the sequence of gneisses and metasediments is repeated. The metasedimentary sequence commonly begins with a thin mica-schist mylonite resting above a zone of mylonitic gneiss. This is succeeded by mylonitic calc-schists with large lenses and bands of marble mylonite, overlain by tens of metres of calc-schists locally with thick layers of massive amphibolite, and then by a thick formation of fine grained micaceous flaggy quartzite with thin partings of mica schist. We are uncertain of the facing of this succession. The quartzite could be at the base, but structurally inverted in many exposures. Below the base of the imbricate stack, a short distance above the sheared base of the metasedimentary sequence, a spectacular bed of metaconglomerate (unit E_{FLC}) extends southward from the shore of Grand Lake to Goose Hill. It contains rare rounded cobbles clearly derived from the surrounding gneisses in an otherwise complex assemblage of clast-like fragments in a granitic to psammitic matrix. Our studies suggest this unit represents an original conglomerate that has been metamorphosed and injected by granite, much of its matrix being migmatized and overgrown by feldspar porphyroblasts. It was subsequently injected by quartz veins, and then sheared, so that it now contains more tectonically derived clast-like bodies ("pseudo-cobbles") than original cobbles of gneiss and granite. The nomenclature of the metasedimentary rocks has undergone a complicated evolution summarised by Currie (1986), but on the scale of this map we have been unable to consistently subdivide these rocks, and therefore refer to the whole package as Fleur de Lys Supergroup. The west-directed thrusting of the Supergroup was accompanied and overlapped by amphibolite facies metamorphism. Along Grand Lake and to the south, pelites of the thrust belt contain syntectonic rolled garnets, and are overprinted by late tectonic to post-tectonic (postshearing) garnet, staurolite and kyanite, later replaced by fine grained intergrowths of mica ("shimmer aggregate"). Related calc-schists present outstanding examples of "garbenschiefer" with garnets and tremolite-actinolite porphyroblasts up to 6 cm penetrating the mylonitic schistosity. By contrast, north of Grand Lake the metamorphic grade rarely excedes biotite-muscovite-chlorite. The youngest rocks of the northern end of the Steel Mountain subzone appear to be a complex sequence of granites which we term the Hare Hill complex (unit E_{HH}). The least deformed parts of the complex around Hare Hill consist of massive, but somewhat fractured and strained, red leucogranite containing riebeckite and aegirine, which gave a U-Pb age on zircon of 608 ± 2 Ma (Currie et al., in press). These rocks pass gradationally into strongly lineated leucogranite around Bear Hill and Goose Hill, commonly with spectacular elongate quartz which stands out on weathered surfaces and platy ilmenite possibly secondary after biotite. The Goose Hill leucogranite intrudes and migmatizes the metaconglomerate and is itself foliated and lineated parallel to the regional foliation and lineation, indicating that it is pretectonic or syntectonic. Southwest of Hare Hill these leucogranites appear to pass gradationally to strongly lineated gneisses. Granitoid rocks are everywhere very leucocratic although some of the strongly lineated phases contain deformed spindles of mafics up to a centimetre in length. A leucocratic muscovite-rich granite (E_{HHM}) forms intensely deformed, locally crosscutting sheets within the Fleur de Lys Supergroup. We assign these sheets to the Hare Hill complex, and ascribe the muscovite-bearing character to loss of alkalies during deformation under amphibolite facies conditions. The southern end of the Steel Mountain complex is covered by sandstone and conglomerate of Carboniferous age (Anguille Group, unit C_A). We have made no detailed study of these rocks, which have been described by Knight (1983). In the areas observed by us they consist mainly of red to grey-green sandstones and conglomerates. The unconformity at the base of the section is locally exposed, but for the most part the contact with the Precambrian is faulted with a downthrow to the west probably not exceding a few hundred metres.

Notre Dame subzone

The Notre Dame subzone, as used by us, comprises two separate and rather different parts, namely the Topsails region and the Annieopsquotch region which we shall describe separately. The oldest rocks of the Topsails region comprise an east-facing lower Ordovician ophiolite on Glover Island (map unit O_0) consisting of a lower serpentinized peridotite up to 100 m thick, overlain by 800 m of layered gabbro with layers 10 to 20 cm thick, minor pods of trondhjemite and numerous aphyric dykes in the upper part. At its base the ophiolite is separated from rocks of the Fleur de Lys Supergroup by a major ductile shear zone at least 500 m wide which appears to have been folded and truncated by later movement on the Long Range Fault. Knapp et al. (1979) considered the ophiolite to grade into pillow lavas with mafic dykes, and made a distinction between such ophiolite-related rocks and slightly younger pillow-lavas, crystal tuffs, and sedimentary rocks. They placed the transition at a shale horizon containing many gabbro clasts and some red jasper and purple shale fragments. We observe similar horizons to occur at several stratigraphic levels, and consider the transition to be gradational. We therefore include all the supracrustal rocks in the Glover Group (unit O_G). The lower part of the Glover Group consists mainly of pillowed basalt, although pillows are generally obscured by subgreenschist grade metamorphism and numerous fracture zones. On the west shore of Grand Lake the Long Range Fault juxtaposes basalt and Fleur de Lys Group. The upper part of the Glover Group comprises thick, laterally persistent horizons of felsic volcanic rocks, mainly tuffs, with thin intercalated shales which have yielded Arenigian fossils (Williams and St. Julien, 1978). The Glover Group also contains several persistent gabbroic sills which exhibit the same low grade metamorphism as the basalts. The Topsails region contains granitoid intrusions of Ordovician age (about 460 Ma, Whalen et al., 1987), but such intrusions were not identified in the region mapped by us. Younger mafic intrusions (unit S_m) consist of distinctive massive hornblende gabbro with local lamprophyric textures cut by a variety of more leucocratic phases. One of these bodies was dated by U-Pb on zircon at 438 Ma (Whalen et al., 1987) or early Silurian. Mafic dykes which parallel the Little Grand Lake Fault may be related to these bodies. These dykes are significantly younger than relics of sheeted dykes on Glover Island. The youngest unit of the Topsails terrane comprises massive high level, locally miarolitic, peralkaline to subalkaline red granites and synplutonic mafic dykes of the Topsails Igneous complex (unit S_T) described in detail by Whalen and Currie, (1983). The distinctive one feldspar (now fine perthite) peralkaline units contain riebeckite and aegirine, as well as local aenigmatite (unit S_{TP}). These rocks grade by complex gradations ascribed to mixing processes to more normal two feldspar hornblende and hornblende-biotite granite. Whalen et al. (1987) give U-Pb data on zircon showing the Topsails Igneous complex was emplaced from 428 to 419 Ma.

The Annieopsquotch region is dominated by the east-facing Annieopsquotch ophiolite complex (unit O_{oa}), described in detail by Dunning (1987). From west to east the complex consists of plagioclase-bearing peridotites, which are locally well layered with grading and modal layering marked by appearance and disappearance of phases. This material passes gradationally into heterogeneous, locally pegmatitic coarse gabbro which, in its eastern part contains numerous pods and intrusion breccias of trondhjemite. This material passes through a transition zone into a sheeted dyke complex, and thence into pillowed basalt, minor hyaloclastites and red chert with dykes. The complex is markedly metamorphosed in its northeastern part with recrystallized texture and metamorphic amphibole and plagioclase as well as overgrowths on pyroxene. High quality U-Pb zircon dating reported by Dunning (1987) gives a formation age of 480 Ma. The Victoria Lake Group (unit O_{VL}) lies along the southeast side of the Annieopsquotch complex. Dunning (1987) intepreted the units to be separated by a fault, and most of the Victoria Lake Group is strongly deformed. However an enclave of Victoria Lake Group south of the complex is not obviously faulted and both units contain the ubiquitous north-west trending dike swarm. The Victoria Lake Group in the region examined by us consists of pillowed basalts in the lower part, with mafic to felsic tuffs, lapilli tuff and breccia in the upper part. A distinctive conglomerate with shale clasts as well as dominant flattened clasts of mafic and felsic volcanics separates the two parts. Dunning et al. (1987) report a U-Pb zircon age of 462 Ma for the Victoria Lake Group northeast of the map area where Llanvirn-Llandeil fossils have been recovered from the group (Stouge, 1980). The Annieopsquotch complex is intruded by two later mafic complexes dated by U-Pb on zircon at 435 Ma. In age and petrography these complexes appear identical to mafic complexes in the Topsails region and Central Gneiss Terrane (Currie and van Berkel, 1989). They may also be correlative to parts of the north-trending dyke complex which cuts the Victoria Lake Group. Ordovician rocks are unconformably overlain by interbedded red Silurian sandstone and acid volcanics (unit S_S). The sedimentary rocks comprise beds of red fine grained siltstone and sandstone up to 30 cm thick, with much thicker beds of feldspathic sandstone full of small feldspar laths, probably derived from the intercalated red, flowbanded dacitic to rhyolitic volcanic flows. These rocks are very well exposed in a quarry on the Burgeo Road, where volcanics have been dated by U-Pb zircon at 429 Ma (Chandler and Dunning, 1983), exactly contemporaneous with the Topsails Igneous complex. A small area of undeformed fresh granite on the east side of the Annieopsquotch complex may be correlative to the volcanics. The youngest rocks in this region are a series of grey-green fluvial sandstones, locally tuffaceous, which unconformably overlie the Silurian sequence (unit D_{WP}). South of the mapped region this sequence has yielded Eifelian fossils (Chorlton, 1980). Both Silurian and Devonian strata are openly folded, but unmetamorphosed. They appear to lie within narrow troughs along the boundary of the Central Gneiss subzone and the Annieopsquotch region.

Central Gneiss subzone

No basement has been definitely identified in the Central Gneiss subzone. The oldest known rocks comprise two sequences of high grade metasedimentary rocks of uncertain age. Along the east edge of the Long Range Fault metasedimentary rocks (unit E_{FLG}) can be divided into a western semipelitic-psammitic belt, and a narrow eastern, more psammitic belt which has been largely cut out by voluminous granitoid plutons. Belts of ductile shearing separate the two assemblages, and dissect the eastern belt. Both belts contain recognizable quartzitic and rare calcareous beds, but stromatic to nebulitic migmatites, consisting of strongly zoned plagioclase (albite to oligoclase), quartz and biotite, with minor garnet and chlorite, are the dominant rocks. Most specimens contain muscovite and/or sillimanite and a few calcareous rocks contain hornblende. In the southwestern part of the map area, psammitic sediments contain more calcic plagioclase (up to andesine), and local orthopyroxene with hornblende rims, indicating that granulite facies metamorphism occurred locally. These metasedimentary rocks contain trains of boudin-like inclusions of amphibolite up to several tens of metres in length, presumably representing transposed and disrupted dykes. The correlation of unit E_{FLg} is uncertain. We have very tentatively correlated these high grade metasedimentary rocks with the Fleur de Lys Supergroup, which they petrographically resemble, and with which they are in contact across the Long Range Fault. However they may be of lower Paleozoic age. The narrow eastern assemblage contains at least one, and probably more, kilometre-wide belts of ductile shear with complex kinematic sequences which have been folded by upright folds and intruded by granite. They are characterized by belts of platy schists and swarms of small subconcordant quartz veinlets. In such belts narrow zones of high shear strain anastamose on the regional scale, with shear fabrics sweeping around and modifying earlier high grade mineral parageneses (Piasecki, 1989). Mafic and ultramafic rocks of probable ophiolitic affinities occur as pods, boudins and necked layers within such belts of sheared metasediments. A major belt of ductile shearing in the eastern assemblage of unit E_{FLg} can be traced for at least 10 km across granite-permeated terrane. It contains trains of pods of serpentinized dunite, secondary clino-pyroxenite and gabbro (Fox and van Berkel, 1988). Some pods contain garnet and hornblende suggestive of retrograded eclogite. Within the ultramafic rocks, strained original textures are locally preserved, but gabbros have been converted to amphibolite, and many of the ultramafic rocks have been converted to coarse to pegmatitic unstrained aggregates of clinopyroxene. Primary olivine, chromite, orthopyroxene, and plagioclase as well as a variety of primary textures have been recognized locally (Fox and van Berkel, 1988). The age of the ophiolitic rocks is not directly known, but all ophiolitic remnants in this region are believed to be of early Ordovician age (Dunning, 1984) and broadly correlative to one another.

The Cormacks Lake complex (Herd and Dunning, 1979) comprises leucocratic quartzofeldspathic gneisses with abundant thick layers and lenses of amphibolite and metagabbro. It contains a few highly pelitic lenses containing gedrite+cordierite+garnet, commonly with pyrite and magnetite. The least deformed leucocratic gneisses have granoblastic texture characteristic of high grade metasediments. The rocks probably represent metamorphosed volcanogenic products as suggested by Herd and Dunning (1979) and Kean (1983). An elongate hill north of Cormacks Lake consists of charnockite (perthite, antiperthite, clinopyroxene, orthopyroxene, local garnet) which clearly forms an A-type granite emplaced under granulite facies metamorphic conditions. The mafic layers vary from recognizably gabbroic with partial conversion to amphibolite, to foliated amphibolites.

The age and correlation of the Cormacks Lake complex are uncertain. The charnockite previously referred to gave a Pb-U zircon age of 455 Ma (Currie et al., in press), with no sign of remnance, and previous imprecise ages on granulite facies metamorphic specimens also gave middle Ordovician ages with little remnance (O. van Breemen, pers. comm., 1988). It therefore seems probable that the complex consists mainly of Ordovician volcanogenic rocks, variably altered to give pelitic compositions, and raised to granulite grade shortly after emplacement. Parts of the complex may be correlative to the Keepings gneiss of Chorlton (1980), and if the speculation on origin is correct, the complex could be broadly correlative to the Glover and Victoria Lake groups.

Much of the Central Gneiss subzone consists of granitoid rocks ranging from strongly foliated varieties to essentially massive rocks, commonly with prominent phenocrysts of pink feldspar. We have divided these rocks into two units, an earlier foliated unit commonly rich in aligned amphibolite or biotite schist inclusions (unit O_{if}) and an essentially massive unit (O_{ip}). The division between these two units is transitional, but in general the older rocks are much richer in inclusions, more foliated, and form more elongate plutons. They exhibit migmatitic to sheeted contacts with country rocks, whereas the younger units tend to be poor in inclusions, relatively massive, and form ovoid to equant plutons with sharp, crosscutting contacts. Both units range from diorite through abundant tonalite and granodiorite, to relatively rare granite and leucogranite. In both units the more mafic variants contain hornblende+biotite as the mafic minerals, while more leucocratic varieties contain biotite only. The older unit exhibits strikingly persistent trains of inclusions of biotite amphibolite or biotite gneiss ranging from 5 to 30% of the volume, and suggesting wholesale remobilization of an older metamorphic or dyke complex. Petrographically the older rocks exhibit partly developed granoblastic textures with metamorphic albite, muscovite, chlorite, and epidote overgrowing primary minerals, particularly microcline and hornblende which are partially converted to chess-board albite and hornblende respectively. The more massive rocks show typically granitic textures, locally with muscovite and garnet in the most leucocratic varieties, and chlorite-epidote alteration similar to the older granitoids. Chemically, the older suite exhibits an unusual trend of decreasing K_2O with increasing SiO_2 and a negligible or positive Eu anomaly, whereas the younger, more massive rocks exhibit the opposite trend and a marked negative Eu anomaly (J.T. van Berkel and K.L. Currie, unpun. data, 1987). The age of the foliated suite is uncertain, but thought to be only slightly older than K-Ar and U-Pb zircon ages of about 455 Ma obtained by Stevens et al. (1982) and G.R. Dunning (pers. comm., 1988) for parts of the younger suite.

Several relatively late mafic intrusions (unit S_m) occur in the Central Gneiss terrane, ranging from layered complexes to dyke complexes (Currie and van Berkel, 1989). Layering may be defined by magnetite (Main Gut) or cumulate layers of massive harzburgite and pyroxenite (Bottom Brook). Some (Bottle Pond) contain felsic enclaves with cuspate margins suggestive of magma mingling (Bottle Pond). In the layered complexes the major minerals are slightly zoned labradorite, orthopyroxene, and magnetite. Igneous lamination of plagioclase and orthopyroxene can be observed in the Dashwoods Pond complex, and intercumulus clinopyroxene and biotite in the Silver Pond complex. The dyke-rich parts of the complex exhibit large scale conversion of orthopyroxene to hornblende, as well as apparently primary igneous hornblende. All of these complexes are massive, and essentially unaltered except for minor deuteric alteration. Dunning (1987) has reported a Pb-U zircon age of 435 Ma for the Main Gut complex, and other complexes are believed to be of similar early Silurian age. These complexes closely resemble complexes in the Topsails and Annieopsquotch regions in petrography, age, and tectonic style and provide a reliable "pin" between these subzones.

Meelpaeg subzone

The Meelpaeg subzone within the map area consists essentially of two units, high grade psammitic metasediments (unit OS_p) and a distinctive granite (unit S_{BL}). The metasedimentary rocks comprise monotonous quartzitic psammites, very evenly and regularly layered on a centimetre scale, with biotitic partings. The layering is typically intricately small folded. Lenticular calc-silicate masses up to 4 by 15 cm form a highly characteristic feature of these rocks. In most cases they exhibit an outer partial or complete corona of pink garnet around a central mass of diopside and/or tremolite. The metasedimentary rocks commonly are migmatitic with nebulous coarse patches of pink feldspar surrounded by biotitic rims. These metasediments are usually enveloped by voluminous, variably foliated, steeply inclined granitoids, two generations of which can be identified in many exposures. The earlier granitoids form grey nebulitic granites that enclose screens and pendants of migmatitic metasediments associated with up to 20% amphibolite (dykes?). The metasediments bear syn- and post-tectonic sillimanite. Both this early granite and its host were tightly to isoclinally folded before intrusion of voluminous pink to white biotite-muscovite- garnet leucogranite and related tourmaline-beryl pegmatites of unit S_{BL} (Middle Ridge type of Williams et al. 1988). A phase of this later granite near Peter Strides Pond returned a U-Pb age on zircon of 418 ± 2 Ma (Currie et al., in press).

The age of deposition of the protolith sedimentary rocks is not well established. Regional correlations suggest the strata pass to the north into the Spruce Brook Formation of Ordovician age (Colman-Sadd and Swinden, 1984; Piasecki et al., 1990).

The younger granitoid rocks typically consist of pale grey to pink granites with aligned microcline tablets up to a centimetre in length. Biotite forms the chief mafic mineral, but muscovite is always present in subordinate amount. This host is typically shot through with sheets and veins up to a metre wide of white aplitic muscovite granite which contains small pink garnets, spectacular euhedra and symplectites of tourmaline and quartz, and beryl crystals up to 3 cm long. The intricate and intimate relations between the granite phases and the host metasediments can be examined in a large quarry near Buck Lake, where the sheeted nature of the contact is evident.

STRUCTURAL GEOLOGY

The structure of the southern Long Range is dominated by very large faults separating subzones, but within each subzone folding locally controls the pattern of strata. In the Humber platform subzone recumbent, west-verging mesoscale recumbent isoclinal folds with strong northeast-trending, southeast-dipping axial plane cleavage can be locally recognised in marbles of the Saint George Group, but such folds appear to occur only along the east margin of the subzone. Within the Steel Mountain subzone identical west-verging recumbent folds can be recognised within the Fleur de Lys Supergroup, where they can be directly related to the northwest translation of these allochthonous slices. Their axial surface foliation is also the main foliation in the shear zones and contains an abundance of microfabrics indicating the sense of direction of the shearing movements. This region displays a very pervasive, strong stretching lineation striking 160° and plunging 25° to 45°, corresponding with the orientation of the maximum extension axis in the shear zone system. These fabrics (fold vergence, lineations and sense of movement indicators) consistently indicate an east-over-west sense of thrusting. Older, small scale buckle-type ("parallel") folding can be recognized in the gneiss complex (unit P_g).

East of the Long Range Fault folds are upright, trend north to northwest, and plunge steeply. To the northwest of the Long Range Fault and in a narrow zone along the east side, a very strong stretching lineation strikes and plunges southeast, but this lineation becomes much weaker and more variable towards the east. Large scale folds (up to 10 km in amplitude) have been recognized in the Cormacks Lake complex, as well as numerous small scale folds in the metasedimentary gneisses of unit E_{FLg}. The latter typically exhibit sheared off limbs and resemble interfolial folds. Along the Little Grand Lake Fault, folds strike roughly east and dip north at low angles, indicating southerly transport of the Topsails region rocks over the Central Gneiss terrane. We have observed numerous small folds in the Victoria Lake Group of the Annieopsquotch region, but these all appear to be related to pervasive shearing movements of both dextral and sinistral sense. In the Meelpaeg subzone we have observed large numbers of small folds in the metasedimentary rocks, but in most cases within obviously displaced rafts in the granite. In the Meelpaeg subzone a pervasive stretching lineation which trends and plunges south to southeast suggests northwest tectonic transport, but other lineations indicate sinistral transcurrent movements (Piasecki et al., 1990).

Movement zones form an intricately interlocking network across the map area, with numerous apparently inconsistent sense of motion indicators. The most common pattern appears to be early east-over-west reverse or thrust motion, followed by transcurrent motion in the ductile regime, followed by late brittle motion. Along the Grand Lake Fault late motion appears to have been mainly brittle, with the rocks broken into warped discoid masses of older mylonite. Sinistral, dextral and reverse motions are all recorded in a small exposure along a woods road north of Hare Hill. The fault appears to be a relatively well defined break, not more than 50 m across.

The Long Range fault zone, by contrast is a broad, steep zone several kilometres across. In its vicinity the Proterozoic rocks of the Steel Mountain subzone exhibit Paleozoic reworking. Their regional northwest-trending fabrics swing into the northeast Appalachian trend, and their original high amphibolite/granulite facies assemblages are retrogressed to greenschist/amphibolite. Along Route 480 the coarse anorthosite has recrystallized to a finer grained rock, the gabbros are amphibolitized, and the rocks have developed networks of anastamosing shear zones. This major fault zone has a complex history of ductile to brittle movements, locally recording dextral, sinistral, and vertical movements. Between Little Grand Lake and Grand Lake a slice of metavolcanic rocks of the Glover Group exhibits well developed ductile fabrics surrounded by brittle zones. Glover Island probably also represents a fault slice between shear belts following the channels of Grand Lake. A major S-shaped (folded?) ductile shear zone crossing the island represents older ductile east-over-west motion. Further to the southwest, the Long Range fault is generally less than 2 km across, but contains a mixture of slices from opposite sides of the zone.

The Steel Mountain anorthosite is truncated along its southwest margin by a northwest-trending, southwest-dipping normal fault which is exposed in several creek valleys as a goudge-filled zone up to 1 m across. This fault, which is cleanly truncated by the Long Range fault, appears to have cut across a relatively rugged terrane as witnessed by cup-like outliers of Carboniferous rocks, and inliers of pinnacles of anorthosite. The relations between the faults and Carboniferous rocks clearly show the latest movement to be post-Carboniferous, but the age of earliest motion is unknown.

The Little Grand Lake Fault can be observed in steep rock faces east of Little Grand Lake, where it strikes roughly east and dips northward at about 20 to 30 degrees. Movement indicators suggest north-over-south movement in the brittle regime. About a kilometre to the south in the valley of Lewaseechjeech Brook a vertical ductile shear zone some tens of metres wide is intermittently exposed. This zone may be related to older movements on the Little Grand Lake fault zone, but no detailed relations are known. Youngest movement on the Little Grand Lake Fault affects the Topsails Igneous complex and is therefore post-middle Silurian.

The boundary between the Central Gneiss and Meelpaeg subzones forms an extremely complex zone which broadens to the northeast. Southwest of King George IV Lake the zone is marked by a graben-like feature filled with unmetamorphosed, mildly deformed Silurian and Devonian supracrustal strata. The northwest margin (Lloyds River Fault) appears to form a well defined, high angle brittle fault, with no obvious early ductile phase. However exposures of the actual fault are essentially nonexistent since it follows King George IV Lake, the valley of Lloyds River and Lloyds Lake. Farther northeast, Williams et al. (1988) assign this feature an important role as a separator of subzones within the Dunnage terrane (Red Indian line). The southeastern margin consists of a broad zone of ductile shearing up to 2 km wide in the valley of Victoria Lake and Victoria River. A sharp northwestern boundary to this shear zone appears to have acted essentially as a brittle steep fault, while the southeastern side is more diffuse. The Victoria River Fault forms a part of the Cape Ray-Gunflap Hills-Noel Paul's line system, one of the largest fault systems in Newfoundland (Currie and Piasecki, 1989; Williams et al.,1988). From Victoria Lake to the Gunflap Hills this zone exhibits east-over-west motion followed by local sinistral movement. In the vicinity of Woods Lake this system is offset by northwest-trending cross faults which may be related to a swarm of Silurian or younger mafic dykes to the north.

Times of motion on these fault systems appear to be fairly closely defined by stratigraphic considerations. The Silurian and Devonian rocks northwest of the fault show no intense penetrative deformation whereas the mid-Ordovician Victoria Lake Group does. The very strong ductile deformation therefore is probably of late Ordovician to Silurian age. However Silurian and Devonian rocks have certainly been effected by high level brittle movements. It therefore seems reasonable to assume that much of the indicated transcurrent motion is of post-Silurian age, as indicated by juxtaposition of unmetamorphosed and migmatized Silurian rocks across this fault.

METAMORPHISM

Rocks of the Humber platform subzone exhibit generally subgreenschist facies metamorphism, although carbonates of the Saint George Group are recrystallized to marble along the Grand Lake Fault, and rarely contain a few grains of actinolite. In the Steel Mountain subzone rocks of the Disappointment Hill complex under-went mid-Proterozoic (about 1495 Ma) granulite facies metamorphism, characterised by the assemblage calcic mesoperthite-orthopyroxene-clinopyroxene. Mineral compositions suggest high T-low P granulites with peak conditions near about 900 degrees and 4 kilobars (Owen and Currie, 1990). Most parts of this complex have been retrograded, possibly during a Precambrian amphibolite grade event which migmatized the gneiss complex (unit P_g). These gneisses contain abundant migmatites, and were metamorphosed prior to emplacement of the Hare Hill suite of granitoids at 608 Ma. The Fleur de Lys Supergroup south of Grand Lake exhibits spectacular garnet-staurolite-kyanite assemblages in which the kyanite has been retrogressed to muscovite (shimmer aggregate). North of the Lake the grade is markedly lower, not exceeding muscovite-biotite-chlorite. The western arm of Grand Lake therefore marks a major metamorphic boundary. A late retrogression to biotite-chlorite grade occurs along the northeast-trending steep cleavage which overprints all rocks in the eastern part of the Steel Mountain subzone.

Most of the Ordovician and older rocks of the Central Gneiss Terrane appear to have undergone granulite facies metamorphism, but only local relics of granulite facies assemblages remain. Rocks with calcic mesoperthite-two pyroxene assemblages occur as scattered outcrops within the Cormacks Lake complex, and locally in the southwest corner of the mapped area in the metasedimentary rocks of unit E_{FLg}. Much of the Cormacks Lake complex underwent regression at amphibolite grade conditions, leading to spectacular examples of gedrite-cordierite-sillimanite(±garnet+biotite) assemblages. Conversion of some ultramafic boudins to coarse, massive orthopyroxene is also thought to have occurred during this phase. Possibly the very widespread nebulitic and stromatic migmatites may have developed during this amphibolite grade hydration event. Virtually all of the terrane has been overprinted by a pervasive low grade biotite-muscovite-chlorite-epidote(±actinolite) assemblage. Extensive study of fluid inclusions suggests granulite facies metamorphism took place at temperatures of 750 to 900 degrees and 5 to 8 kilobars, while medium grade overprinting occurred at about 4 kilobars and 550 to 650 degrees (J.T. van Berkel, unpublished manuscript, 1988). The pristine condition of early Silurian plutonic rocks implies that the metamorphic history is entirely of mid to late Ordovician age.

Rocks of the Glover and Victoria Lake groups exhibit only low grade assemblages, typically chlorite-epidote-actinolite in mafic lavas, and chlorite-sericite-actinolite in salic rocks. In both cases the rocks have been sheared and shattered in fault zones, and reduced to masses of chlorite.

In the Meelpaeg subzone psammitic sediments have been raised to amphibolite grade, as demonstrated by the abundance of migmatites, and the presence of the assemblage garnet-staurolite-cordierite in pelitic seams. More calcareous beds commonly contain the assemblage garnet-tremolite-diopside. Unlike the Central Gneiss subzone, rocks of the Meelpaeg subzone show only local and mild retrogression. Dating of migmatites demonstrates metamorphism in this subzone is of Silurian (about 420 Ma) age, and therefore significantly younger than in the adjoining Central Gneiss subzone.

ECONOMIC GEOLOGY

No deposits of immediate economic interest are known within the mapped area, but several regions are thought to be of prospective interest. The Steel Mountain anorthosite contains numerous small pockets of titaniferous magnetite, of which the largest (containing about 7 per cent TiO_2) have been described by Baird (1954). Ultramafic pods enclosed in quartzofeldspathic rocks east of the Long Range Fault locally contain up to 10 per cent chromite and magnetite in the form of thin seams or as dispersed euhedral crystals. Pyroxenite and harzburgite south of Portage Lake contain up to 130 ppb Pt and 100 ppb Pd, while other ultramafic pods contain up to 54 ppb Pt, 36 ppb Pd, and 40 ppb Au.

Major shear zones in southwestern Newfoundland have proved to be highly prospective for Au, so that the mapped area may have some gold potential. Chlorite-rich shears containing visible pyrite in unit S_M contain up to 50 ppm Au, while the broad shear zone running from Grand Lake to Little Grand Lake also returned assays up to 50 ppm Au from various samples of pyritic basalt and diabase. Quartz veins from a brittle fault cutting diabase southwest of Little Grand Lake gave 646 ppb Au from a sample with about 30% pyrite.

Numerous beryl showings were found in the Meelpaeg subzone, including two in quarries along Route 480. Some of the larger aplitic phases might support a hand-cobbed beryl operation.

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