LEGEND

QUATERNARY
- Q_d till, boulder clay; (s) stratified sand and gravel
- ----- unconformity -----

TRIASSIC
- T_l LEPREAU FORMATION; chocolate-brown massive conglomerate, cross-stratified sandstone, red siltstone and shale
- ----- unconformity -----

CARBONIFEROUS
MISPEC GROUP (units C_l and C_{bl})
- C_l LANCASTER FORMATION: grey sandstone (lithic arenite) with quartz pebble beds and black, fossiliferous shale-siltstone beds. Mainly Westphalian A-C in age
- ----- gradational contact -----
- C_{bl} BALLS LAKE FORMATION: Red polymict conglomerate, shale and sandstone; red to green limestone, black cryptalgal laminite; pink to green altered and silicified siltstone. Rocks of Visean to Westphalian age.
- ----- unconformity on unit H_e -----
- C_k KENNEBECASIS FORMATION: red-brown massive conglomerate and cross-stratified sandstone. Basal grey to black siltstone and sandstone. Rocks of Famennian to post-Visean age
- ----- unconformity -----

DEVONIAN OR MISSISSIPPIAN
- D_{md} MOUNT DOUGLAS PLUTON: red to pink coarse leucocratic biotite granite, commonly quartz porphyritic, rapakivi granite; biotite-plagioclase porphyry
- ----- intrusive contact (to unit S_w and S_{jc}) -----

SILURIAN
- S_w WELSFORD PLUTON: riebeckite granite and syenite, porphyry
- ----- intrusive contact (to unit S_{jc}) -----
- S_{jc} JONES CREEK FORMATION: thinly laminated grey green to black shale, siltstone and clcareous shale; hornfels
- ----- interfingering contact -----
- S_{lr} LONG REACH FORMATION: plagioclase-porphyritic basalt flows minor calcareous siltstone and chert
- ----- tectonic contact -----

CAMBRO-ORDOVICIAN
- C_{Osj} SAINT JOHN GROUP: grey green sandstone and siltstone, capped by black shale. Basal red to green sandstone with thin tuffaceous beds
- ----- disconformity -----

EOCAMBRIAN
- E_d red feldspathic sandstone, siltstone, tuff; vesicular basalt flows and sills; red sandstone, conglomerate with porphyry cobbles
- ----- disconformity? -----

HADRYNIAN
(age relations between the Coldbrook Group, Kingston complex and Golden Grove suite are uncertain. All are thought to be approximately coeval)
- H_k KINGSTON COMPLEX: sheeted dyke complex of diorite and felsite dykes
- ------ relations uncertain, probably gradational -----
- GOLDEN GROVE SUITE (units H_w,H_g,H_h,H_p)
- H_w red felsite, granoblastic epidote alaskite, plagioclase and quartz-plagioclase porphyry; (hh) Harvey Hill pluton, (l) Lingley pluton, (rl) Rocky Lakes pluton
- ------ intrusive to gradational contact -----
- H_g pink to grey, coarse chloritized hornblende and biotite-hornblende granodiorite to granite and leucogranite plutons. (hs) Hansen Stream (10 cm rounded diffuse mafic inclusions); (l) Ludgate Lake; (la) Loch Alva; (eb) East Branch; (rf) Ragged Falls; (m) Musquash
- ------ intrusive to gradational contact -----
- H_e coarse-grained hornblende plgioclase rocks, variously chloritized and epidotized; diorite, tonalite, minor granodiorite; (l) Lepreau pluton, (tr) Talbot Road pluton; (rb) Red Bridge pluton
- ------ gradational contact -----
- H_h hybrid rocks, strongly schliered and dyked mixtures of H_e,H_g and H_w with minor H_k. Prince of Wales pluton
- ------ relations uncertain -----
- H_c COLDBROOK GROUP; acid to intermediate volcanic rocks; (p) massive pink rhyolite, ignimbrites, quartz-feldspar porphyry; (g) grey to green pyroclastics, red laharic breccia, conglomerate, minor conglomerate; undifferentiated sheared grey-green rocks
- ------ interfingering contact -----
- H_m MARTINON FORMATION: grey to black turbiditic sandstone and siltstone; proximal debris flow with marble clasts; rhythmically banded cherty siltstone; hornfels with sills of basalt
- ------ unconformity -----

HELIKIAN?
- H_{gh} GREEN HEAD GROUP: grey to buff marble, locally stromatolitic; olive to grey fine-grained quartzite; black pelitic schist
- ------ mobilized unconformity -----

APHEBIAN?
- A_b BROOKVILLE GNEISS; biotite+/-hornblende tonalitic gneiss, agmatite, migmatite; commonly severely chloritized

- contact, approximate, assumed
- fault, high angle
- thrust fault
- mylonite zone
- bedding, tops known, unknown
- foliation, gneissosity
- cleavage, first, second
- lineation
- trend of dykes
- outcrop, small, large

Geology by K.L. Currie 1984,1986, with additions from McCutcheon and Ruitenberg 1984, McCutcheon 1984, and unpublished work by R.H.Grant

MARGINAL NOTES TO THE GEOLOGICAL MAP OF THE MUSQUASH–LOCH ALVA REGION, SOUTHERN NEW BRUNSWICK
(PARTS OF 21G1 AND 21G8)

The eastern and southern edges of the map area are readily accessible by major highways and connecting roads, and much of the rest is accessible by lumber roads and all terrane vehicle tracks. The region around Musquash Reservoir and Loch Alva can be accessed by boat. The map area comprises wooded, rolling country except for the sea cliffs along the Bay of Fundy. Outcrop is fair by regional standards (2–5 percent), but considerable areas are obscured by northerly derived boulder till, and the lower Nerepis River valley is deeply covered by stratified glacial deposits.

The Brookville gneiss (map unit Ab, Wardle 1977), a variably migmatized and metasomatized hornblende-biotite tonalite gneiss occurs only in a small area of the southeast corner of the map, No trace of the Brookville gneiss occurs within the central belt of plutons.

The Green Head Group (map unit Hgh), a platformal sequence of marble, quartzite and minor pelite, which overlies the Brookville gneiss (Currie and others 1981) occurs as a narrow belts in the southeast part of the mapped area. A slice within the Kingston complex east of Nerepis River consisting of medium-grained, granoblastic white marble with strong slaty cleavage containing phlogopite may be a fault slice of Green Head Group.

The Martinon Formation (unit Hm) which unconformably overlies the Green Head Group south of Martinon, consists mainly of massive, brownish-black siltstone and sandstone of turbiditic origin with minor amounts of cherty siltstone and thin carbonate interbeds (Wardle 1977) and abundant sills or intercalations of basalt and dacite to rhyolite. Much of the Martinon Formation has been hornfelsed to a featureless brown, flinty rock particularly in screens separating plutons. The Martinon Formation appears to be a lateral equivalent of the lower part of the Coldbrook Group. A small area south of Little Dipper Harbour, formerly mapped as Green Head Group (Alcock 1959) is here included with the Martinon Formation since it seems to form part of the volcanic package in this region. The Martinon Fm. is massive and featureless compared to the bedded slaty character of the juxtaposed Jones Creek Fm. which contains distinctive skarn beds.

The Coldbrook Group (map unit Hc) consists of acid to intermediate volcanic rocks and very minor sedimentary rocks. The rocks can be divided into two major types, namely pink to purple rhyolite and quartz-feldspar porphyry, and greenish fragmental rocks associated with red laharic breccia and minor grey rhyolite. The pink unit tends to be very massive and dense. Quartz phenocrysts, commonly hexagonal, are ubiquitous and pink feldspar phenocrysts occur in about half the outcrops. In a few places the rocks exhibit fiamme or flow banding and clearly represent densely welded ignimbrites. Much of the unit appears featureless and could be hypabyssal rather than volcanic. There appears to be continuous transitions from porphyry to felsite and aplite plutons. The fragmental rocks range from grey rhyolite tuff and pyroclastic rocks to laharic breccias with a fragment content up to 40 percent in a dark silty matrix. Grey-green rocks with disseminated chloritic fragments through various types of also commonly occur as indeterminate sheared material.

The Golden Grove suite (map units Hp, Hd, Hg, He, Hayes and Howell 1937) includes four units: (1) medium- to coarse-grained, plagioclase-hornblende rocks with colour indices ranging from 15-50 (unit Hd, Lepreau, Talbot Road, Red Bridge plutons); (2) massive, coarse-grained granodiorite to granite, commonly with quartz phenocrysts (map unit Hg Hansen Stream, Ragged Falls, Loch Alva, East Branch, Ludgate Lake, Henderson Lake plutons); (3) red, fine to medium grained granoblastic granite to granodiorite with large amounts of pink felsite and plagioclase porphyry (map unit He Harvey Hill, Musquash, Rocky Lake, Lingley plutons); (4) a hybrid pluton in which all the above varieties occur as schliers, screens, blocks and hybrid-looking rocks suggesting magma mixing (map unit Hp Prince of Wales pluton). Individual plutons can be easily mapped by physical characteristics such as proportion and character of inclusions.

The belt of plutons from Lepreau to Ludgate Lake are all deep-seated, with the possible exception of Harvey Hill. Contact relations vary from migmatized screens in the east to gradational without dykes or felsite in the west. The Harvey Hill pluton is finer grained than the others and contains discrete inclusions of the surrounding bodies. It could be significantly younger than the other plutons. The Prince of Wales pluton is heterogeneous on every scale and includes spectacular megascopic examples of mixing and hybridization, as well as numerous screens of more homogeneous material.

Plutons northwest of the Kingston complex and along the Bay of Fundy are of high-level type compared to the central belt. Grain size is generally fine to medium, with many felsitic and aplitic patches, and the plutonic rocks grade within tens of meters to porphyries, and to igneous breccias and volcanics. Screens of sedimentary or volcanic rocks, commonly dyked and incorporated in igneous breccias separate plutons. Northern and southern belts strongly resemble one another in their plagioclase porphyritic character and the association of textures. The Musquash pluton returned a Pb-U zircon age of 550+/-8 Ma, which probably dates the latest pahse of Golden Grove magmatism.

The Coldbrook Group, Golden Grove suite and Kingston complex (unit Hk) share a pervasive epidote-chlorite alteration which is not found in younger igneous rocks. Alteration sufficiently changes the appearance of the rocks toward grey and green shades that considerable caution is necessary in mapping the plutonic rocks.

The Kingston complex (unit Hk) consists of salic and mafic dykes which vary from 20 cm to 50 m in width. Either mafic or salic dykes may predominate over widths up to 400 m in ratios as high as 9:1, and at the southern end of Loch Alva mafic dykes predominate over a width of nearly a km. Dyke contacts are of three types; mutually chilled, intrusive, or sheared. Mutually chilled contacts form more than 75 percent of exposed contacts. Shearing is always parallel to dyke walls, although the trend of dykes varies through nearly 90 degrees across the region.

Mafic dyke lithologies vary from medium-grained hornblende-plagioclase rocks, locally with large ovoid or irregular phenocrysts, to fine grained amphibole-rich rocks with nebulous micro-pegmatitic schliers. Most of the mafic dykes show a fining of grain size toward the margins, but true chilled margins are absent. Salic dykes consist mainly of pale buff weathering felsite which commonly contains plagioclase phenocrysts. In some dykes the core is distinctly coarser-grained and granitoid.

Mylonite zones bounding both sides of the Kingston complex consist of a marginal zone of fissile schists in which the salic-mafic alternation can be discerned, and a central core of uniform, flinty rock banded on a scale of a few mm. Like the dykes, mylonites show marked changes in trend and appear to be truncated against younger, more brittle faults.

The mylonite zone contains distinctive augen schists with plagioclase augen developed from the "blotchy" mafic dykes noted above, which are cut by lithologically similar massive dykes. The dyke complex cuts bounding granitoid plutons, for example the Loch Alva pluton, but is deflected by and included in the Lingley pluton. Mylonite and dyke complex are both pervasively epidotized and chloritized. Silurian basalt of the Long Reach Formation shows no such alteration, even though it locally occurs as a slice within the Kingston complex. These observations strongly suggest that emplacement of major plutons, emplacement of the dyke complex, mylonitization and epidote/chlorite alteration were all closely related Late Proterozoic events.

Eocambrian rocks (unit Ed) of the red bed-basalt sequence (Currie 1984) occur in the southeastern corner of the mapped area. Fault slivers of red sandstone and conglomerates were previously mapped as Carboniferous, or even Triassic, but (1) the conglomerates are essentially monomict, containing only fragments of fine-grained, porphyritic salic igneous rocks, (2) the dips of the conglomerates are vertical or very steep, and the occurrences appear to be fault bounded on all sides, and (3) the conglomerates contain partially epidotized salic rocks. The slivers of conglomerate probably developed in small local grabens along the edges of major Late Proterozoic deformation zones.

The Cambro-Ordovician Saint John Group (unit COsj) of grey green to black sandstone and shale outcrops east of Musquash Harbour, and in two small fault slivers within the Lingley pluton. The latter occurrence is of particular interest since it not only defines the northwestern limit of the Saint John Group, but also shows that the Lingley pluton must be older than the unmetamorphosed sedimentary rocks, and demonstrates an important north northwest trending faulting.

The Lower Silurian (Llandovery) Long Reach Formation (unit Slr) consists mainly of plagioclase porphyritic basalt, commonly vesicular, with intercalations of siltstone and calcareous siltstone (Berry and Boucot 1970). Along the Long Reach the formation forms a fault bounded sliver separated from the younger (Pridolian) Jones Creek Formation (Sjc) by Late Precambrian rocks and the Wheaton Brook fault. Along Cunningham Creek black slaty siltstone apparently part of the Jones Creek Formation contains numerous 15-30 cm sills of basalt. In this region the Long Reach and Jones Creek Formations appear to be interbedded. The contact of Silurian rocks with older rocks in this region has not been observed, but close to the contact the rocks are extensively shattered, so that a major fault has been assume.

The Welsford complex (unit Sw) consists of coarse peralkaline (riebeckite+/-aegirine) granite with porphyritic phases and a marginal red felsite phase which passes into correlative salic volcanics (McCutcheon and Ruitenberg 1984). Payette and Martin (1987) showed that volcanics equivalent to the Welsford complex are interbedded with the Jones Creek Formation. the complex is therefore of Silurian age.

The Mount Douglas pluton (unit Dmd) consists mainly of coarse pink biotite granite with distinctive large ameboid quartz grains. Commonly large potash feldspar grains are rimmed and partially replaced by plagioclase, which may also rim quartz and biotite. Plagioclase porphyritic, and aplitic screens and dyke show gradational boundaries with the main phase. A narrow (100 m) marginal phase of biotite diorite which is veined by the other phases appears to be the source of the rare mafic inclusions within the pluton. The pluton dykes and agmatizes its surroundings and contains large rafts of the host felsite. A Rb/Sr isochron age gave 745+/-15 Ma with an initial Sr ratio of 0.707 (Fyffe and others 1991).

The Carboniferous section within the mapped area consists of red siltstone, sandstone and conglomerate of the Balls Lake Formation and grey to black lithic arenite of the Lancaster Formation (Currie and Nance 1985). The Balls Lake Formation locally exhibits a basal carbonate member, either in the form of a caliche horizon, or as a thin black to red limestone which has yielded Visean fossils (McCutcheon 1984). The underlying rocks were strongly weathered and fractured prior to deposition of the Balls Lake. The top of the Balls Lake Formation is marked by several meters of very fine grained, pink silicified siltstone conformably overlain by grey lithic arenite (Lancaster Formation) which tends to be virtually massive except for quartz pebble conglomerate beds and black, fossiliferous siltstone-shale beds.

A basal unconformity below the Triassic Lepreau Formation (unit Tl) is exposed in the southeast corner of Dipper Harbour, south of Little Lepreau Harbour, at Boyles Cove and on the north side of the Lepreau River. The map pattern suggests that the occurrence on Lepreau River is bounded on the northwest side by a normal fault, but otherwise the formation appears to be entirely bounded by an unconformity. The base of the conglomerate consists of large, angular, locally derived debris. Toward the southwest dips steepen abruptly across step-like features and red siltstone and sandstone become major lithologies. These relations suggest faulting of the underlying basement during deposition.

Quaternary deposits are varied and extensive in this region, to such an extent that they totally obscure the bed-rock over considerable areas. In general the deposits are either stratified sand and gravel, or a boulder-mud mixture which locally overrides the stratified deposits.

Structure

In the northern part of the map area, dominated by the massive Mount Douglas and Welsford plutons, the Silurian supracrustal rocks generally face north and dip vertically to steeply southward, consistent with essentially vertical isoclinal folding (McCutcheon 1981). The brittle Wheaton Brook fault bounds this zone to the south. West of the Nerepis River the fault not only changes strike, but is stepped along a swarm of north to northwest trending ainor faults.

South of the Mount Douglas pluton a lunate zone of granitoid plutons separates the Mount Douglas pluton from the Kingston complex. These plutons are little deformed, except along the bounding mylonite zone, but are pervasively epidotized and chloritized. They resemble Late Proterozoic high level plutons further south.

The mylonite zones bounding the Kingston complex contain abundant S-C and C-C' fabrics indicating major dextral movement (Leger and Williams 1986). Deformation occurred at temperatures near 450° C, compatible with the observed greenschist grade metamorphism. On the west side of the mapped area mylonite zones bounding the Kingston complex merge into the Pocologan mylonite zone (Rast and Dickson 1982).

Plutons south of the mylonite zones exhibit relatively little deformation, although the northern fringe of the Talbot Road pluton has been involved in mylonitization, and the Henderson Lake pluton exhibits a complex series of stopped small brittle faults.

Along the Bay of Fundy folded Carboniferous rocks sit unconformably on volcanic and plutonic rocks of Late Precambrian age. The structure is dominated by major dextral transcurrent faulting of Late Carboniferous and younger age, with a master fault located just offshore in the Bay of Fundy. As a result of curvature of this fault, the area along the shore exhibits a combination of high-angle transverse movement and low-angle thrusting from the south-southwest. The contrast in mechanical competence between the sediments and volcanics has produced a complex synclinorium in the Carboniferous rocks in which the crystalline core to the central anticline has been faulted upward as an essentially undeformed block. Spectacular, but small, thrust allochthons along the Fundy shore form festoons around the end of small scale splays from the hidden master fault.

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