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DESCRIPTIVE NOTES

INTRODUCTION

Rocks underlying Smith Island and the adjoining peninsula on the Quebec mainland form the western end of the Cape Smith Belt segment of the Circum-Superior Belt of Paleoproterozoic (Aphebian) age (Baragar and Scoates, 1981). Relationships within the Cape Smith Belt have been well documented by the mapping of the Québec Ministère de l'Énergie et des Ressources and of the Geological Survey of Canada and, most particularly, by the specialized stratigraphic and petrochemical studies of Hynes and Francis (1982), Francis et al. (1983), Baragar and Scoates (1987), and Picard et al. (1990). Much of this work is now embodied in the recent compilation by St-Onge et al. (2006). Previous work within the present map area include the author's preliminary maps (Baragar and Piché, 1982; Baragar, 1983) and a map of the peninsula on the mainland by Togola (1992). Only a part of the Cape Smith Belt stratigraphy is represented here, but its context is readily interpretable by reference to well studied counterparts to the east as noted above.

The stratigraphy of the Cape Smith Belt, in general, comprises basal Povungnituk and overlying Chukotat groups, together deformed by southward folding and thrusting. The Povungnituk Group rests unconformably upon Archean basement, where early deposits comprise predominantly shelf sedimentary rocks; quartzite, iron-formation, siltstone, and carbonate. Upward in the section and outward from the craton (i.e. toward the north) the sediments change to deeper water facies (shale, semipelite, greywacke) with abundant, subaqueous, tholeiitic basalt units extensively intruded by dolerite sills. The Chukotat Group is predominantly volcanic and ranges in composition, broadly upsection, from komatiitic to essentially tholeiitic basalt, all parts of a consanguineous suite. The relationship between the groups is unclear: St-Onge et al. (1992) (and this study) interpreted the contact as a thrust fault, whereas Hynes and Francis (1982) regarded it as a conformable boundary. Certainly, the Chukotat Group is younger, and if in thrust relationship with the Povungnituk Group, is unlikely to have undergone major displacement as sills of Chukotat Group affinity are present at several levels within the Povungnituk Group.

In the present map area both groups are partly represented. The Povungnituk Group underlies Île Gobin and marginal parts of the adjoining mainland and south coast of Smith Island. The Chukotat Group forms the bulk of Smith Island and extends along strike into the eastward-continuing sequence of the mainland. Only the upper 2000 m of the Povungnituk Group of tholeiite and shale, representing its deeper water facies, is present and the Chukotat Group is limited to its lower 7000 m of komatiitic compositions (cf. Baragar and Scoates, 1987; Picard et al., 1990). A composite straight cross-section of both Povungnituk and Chukotat groups is shown in Figure 1. The Povungnituk Group section strikes northward through Île Gobin to the mainland and the Chukotat Group section transects Smith Island at about the midpoint of Babs Bay.

POVUNGNITUK GROUP

GENERAL GEOLOGY

The Povungnituk Group in this area is formed predominantly of pillowed and massive lava flows with rare, thin (centimetres thick), black shale interlayers, commonly containing pyrrhotite. Overlying the main body of volcanic rocks is a thicker zone of thin-bedded black to grey shale and siltstone intruded by several dolerite and gabbro sills. On Île Gobin the pair of sills that give form to the northeast-plunging folds at its eastern end are seemingly feldspathic, grey-weathering gabbro that are interpreted as Povungnituk Group sills on the basis of lithological similarity to Povungnituk Group dolerite observed farther east (Baragar and Scoates, 1987); however, no chemical data is available and it is entirely possible that they could be of Chukotat Group origin. The much thicker, folded sills intruding Povungnituk Group sedimentary rocks at a higher stratigraphic level on the mainland have a different aspect and, as will be shown later, do have a Chukotat Group chemical affinity.

VOLCANIC PETROGRAPHY AND COMPOSITION

The volcanic rocks are megascopically aphyric, but in thin section most can be seen to be sparsely plagioclase-phyric. The groundmass is a fine-grained intergrowth of tremolite-actinolite and feldspar (probably albite-oligoclase) with interstitial chlorite and a fuzzy brownish overlay of granular sphene. Epidote is generally present, but not abundant. The metamorphic grade is greenschist facies. Most rocks are somewhat foliated in an east-northeast direction with moderate to steep northward dips roughly parallel with the fold axis.

The composition of the volcanic rocks, represented by several analyses from across Île Gobin, is that of a saturated, tholeiitic basalt with notable titania (2%) content. Its average composition is given in Table 1a, where it can be compared with averages of Povungnituk Group basalt from the Kovik section (about 70 km to the east (Baragar and Scoates, 1987)) as well as those of the Chukotat Group suite. The average norm indicates that it is a fairly feldspathic basalt (~65% feldspar) with subordinate pyroxene (~38%). Note that the average normative composition shows both quartz and olivine, indicating that the composition varies on either side of the silica-saturated condition. The rare-earth elements give a light-REE-enriched pattern (Baragar and Scoates, 1987) in conformity with those obtained from Povungnituk Group rocks throughout the Cape Smith Belt (Francis et al., 1983; Picard et al., 1990). In an extended element plot normalized to primitive mantle (Fig. 2b) the curve for Povungnituk Group basalt of Île Gobin shows considerable enrichment through a broad range of the less compatible elements. Hence, the Povungnituk Group basalt units appear to have undergone significant fractionation prior to eruption. The setting of eruption has been interpreted as ensialic in a continental rift zone (Baragar and Scoates, 1981, 1987; Francis et al., 1983).

RELATIONSHIP TO CHUKOTAT GROUP

Because the contact between the Povungnituk and Chukotat groups transects the fairly continuous, low-Mg unit at the base of the latter group (later discussion) on the north flank of the folded sequence northeast of Île Gobin, it is interpreted as a thrust fault. In this region the fault is placed at the upper margin of the folded gabbro sill of Chukotat Group affinity and is folded with the host Povungnituk Group strata. Differential movement between the folded strata and the overlying unfolded Chukotat Group sequence is accommodated by another projected thrust fault interpreted to follow the Illukotat River valley. At the south margin of Smith Island the faulted boundary is assumed to lie within, or at the top of, a thin sedimentary layer that overlies the sill.

CHUKOTAT GROUP

SUBDIVISION AND STRATIGRAPHY

The Chukotat Group comprises a homoclinal, steeply north dipping succession of komatiitic basalt and minor shaly interbeds with an exposed thickness of about 7000 m (Fig. 1). It is subdivided into a number of fairly distinctive, mappable units based mostly on MgO content that relates directly to the fluidity of the lavas and, in consequence, their physical appearance. Accordingly, it is a practical means for distinguishing flows of differing MgO content in the field (Baragar and Piché, 1982). Three basic map units are recognized: low-Mg (< 10% MgO), medium-Mg (10–15% MgO), and high-Mg (> 15% MgO) volcanic rocks. To accommodate mixed sequences, where no one type is dominant, additional categories provide for low- to medium-Mg and high- to medium-Mg lava flows. Other units are based on physical distinctions: onion-skin lavas are low-Mg flows characterized by large pillows with thick (3–10 cm), scaly rims; and thick massive units are differentiated flows as much as 250–300 m thick and kilometres in length.

Layered flows are also shown separately on the map. These are thickened lengths of massive flows or of the upper massive parts of pillow-massive flows in which differentiation has resulted in a basal olivine cumulate layer surmounted by a feldspathic top (Baragar, 1984). Rarely, the upper part is marked by spinifex texture. Most are not more than a few hundred metres in length and commonly lensoid, but some extend for a kilometre or more along strike. They are generally a maximum of 50 m to 100 m thick. On the map only a few are shown in their entirety, most are represented by arbitrary short lengths where they have been crossed in traverse. A majority of the layered flows are found in the high-Mg unit, some occur in the medium-Mg unit, but rarely are they present in the low-Mg unit.

The stratigraphy of the Chukotat Group is far from systematic; units of differing MgO content thicken and thin as they interfinger along strike and seemingly pass arbitrarily upsection from one Mg level to another. Their lateral continuity may not persist for great distances. Note, for example, the passage of the medium-Mg unit at the core of Smith Island, eastward into a mixed unit of high- and medium-Mg lavas on the mainland. Broadly speaking, however, the incidence of high-Mg lavas tends to decrease upsection such that the northern part of the succession is predominantly medium- and low-Mg lavas. This is similar to successions in the western and central parts of the Cape Smith Belt (Francis et al., 1983; Baragar and Scoates, 1987; Picard et al., 1990) where compositions evolve upward by repeating cycles of high- to medium- and/or low-Mg lavas (olivine- to clinopyroxene-phyric), each beginning with a lower Mg level than its predecessor until finally capped, in places, by a monotonous sequence of plagioclase-phyric basalt.

In this map area, similar repeating successions are interpretable from the section shown in Figure 1. Three levels of high-Mg lavas are each overlain by medium- and medium and/or low-Mg lava flows. Note also that the basal Chukotat Group unit here, as in the central and western parts of Cape Smith Belt (Hynes and Francis, 1982; Baragar and Scoates, 1987; Picard et al., 1990) is a low-Mg lava (clinopyroxene-phyric), suggestive of a prenatal stage of fractionation, possibly in crustal magma chambers, prior to the onset of primitive Chukotat Group magmatism from depth (Picard et al., 1990).

NORMAL HIGH- TO LOW-MG UNITS

Petrography

Metamorphism is pervasive throughout the Chukotat Group, but is of low grade (subgreenschist facies) and deformation is slight so that in most places the primary mineralogy is at least partly intact and readily interpretable. In low-Mg and rarely medium-Mg lava flows, where plagioclase is a significant component of the groundmass, pumpellyite is a common secondary constituent. Olivine is generally pseudomorphed by chlorite and/or serpentine and, less commonly, tremolite, but clinopyroxene is mostly fresh. Magnetite is extensively replaced by sphene. Primary igneous textures as described below tend to be well preserved.

The high-Mg lavas are abundantly olivine-phyric with a phenocryst content ranging from 20% to 50% and averaging about 30–35%. Although the higher concentrations are probably cumulative, many of the rocks are pillow lavas where evidence of concentration is not readily apparent. Surprisingly, the content of clinopyroxene phenocrysts tends to be quite high. Although about one quarter of the rocks examined are devoid of clinopyroxene phenocrysts, the remainder contain from 5% to 35%. The groundmass typically displays a quench-like texture marked by fronds and radiating bundles of acicular clinopyroxene and, generally, skeletal olivine in a chloritic serpentinous matrix. In places, plagioclase, interleaved with the clinopyroxene, can be recognized, but is greatly subordinate. Chromite is ubiquitous in both groundmass and olivine pseudomorphs.

Medium-Mg lavas, although highly variable, are generally much poorer in olivine phenocrysts (most 10–25%) and richer in clinopyroxene (most 5–25%) than in high-Mg lavas. In most cases, the groundmass is similarly quenched with finely interleaved clinopyroxene and plagioclase, forming fronds and radiating bundles. In the coarser grained phases, where the proportions are more evident, clinopyroxene dominates over plagioclase. Unlike the low-Mg lavas the groundmass may also contain skeletal olivine, indicative of its greater range of precipitation in this unit, and sparse chromite.

Typical low-Mg lavas are abundantly clinopyroxene-phyric (20–40%), but only sparsely olivine-phyric (0–10%). The groundmass textures vary from quench-like, interleaved plagioclase-clinopyroxene fronds overprinted by finely dispersed sphene to intergranular texture of plagioclase laths and clinopyroxene anhedra. In coarser grained rocks the plagioclase laths generally form a dominating framework enclosing clinopyroxene and rarely interstitial quartz.

Geochemistry

Compositions of low- to high-Mg units can be broadly compared in Table 1a and 1b where their average compositions and norms are presented together with those of some of the other units. Of particular interest are the progressive changes from low- to high-Mg units of key oxides and elements: notably MgO, CaO, Al_2O_3, TiO_2; and, dramatically, Cr and Ni. The last three constituents have the additional significance that their range of variation is so markedly different from that of the Povungnituk Group tholeiite that they serve both as diagnostic elements of the komatiitic suite and as a mark of their consanguinity.

Compositional evolution in the stratigraphic sequence is represented in Figure 1 by the indices MgO/CaO and MgO/TiO_2 plotted above their locations within the cross-section. MgO/CaO is primarily a measure of olivine fractionation and MgO/TiO_2 of an extended range of fractionation that would include less refractory phases such as clinopyroxene and plagioclase (Baragar and Scoates, 1987). The MgO/TiO_2 is particularly applicable to rocks of the komatiitic suite that are characterized by high magnesia and low titania. Note in Figure 1 the following features.

- The Chukotat Group komatiitic suite is distinguished from the Povungnituk Group tholeiitic rocks by their markedly higher MgO/TiO_2 ratios even though the low-Mg komatiitic basaltic rocks are very similar to the tholeiite in many other respects.
- The komatiitic succession begins with a major low-Mg unit (as noted above), followed by an abrupt transition to high-Mg komatiitic basalt.
- Upsequence compositions (as represented by the fractionation indices) vary widely from unit to unit, but the indices do show slight overall decline, suggesting some progressive evolution of composition throughout the succession.

Multi-element plots normalized to primitive mantle are given in Figure 2a and 2b. To simplify the presentation only the averages are plotted, but they are generally representative of the multiple curves for each of the units. Note that the curves for the low- to high-Mg units are roughly parallel and offset from one another in a sense consistent with fractionation of olivine. Thus, for the part of the spectrum (Rb to V) incompatible with olivine, the curves for low- to high-Mg lavas are successively offset to lower values, but for Cr to Ni (olivine compatible), to higher values. For the low- and medium-Mg curves insipient fractionation of clinopyroxene or feldspar minerals might account for some of the irregularities for such elements as Rb, K, and Sr.

The normalized curves also parallel the base of the diagram, thus signifying little fractionation in this spectrum of elements from a primitive mantle composition. Compare these curves with those for N- and E-MORB in the same diagram which show depletion and enrichment, respectively, of the incompatible elements. This presents some problems in interpretation. Francis et al. (1983) demonstrated that chondrite-normalized REE diagrams for the Chukotat Group in central Cape Smith Belt are consistently light-REE depleted and interpreted this as indicative of an oceanic setting for the group, but elsewhere in the Cape Smith Belt and Ottawa Islands equivalent diagrams for Chukotat Group volcanic rocks show REE profiles with a variety of patterns from light-REE enriched, to parallel, to depleted (Baragar and Scoates, 1987; Picard et al., 1990; Togola, 1992). Picard et al. (1990) interpreted the light-REE-enriched profiles from low-Mg rocks at the base of the Chukotat Group as representing a transitional origin from ensialic Povungnituk Group basalt to oceanic Chukotat Group komatiitic basalt, but this would be more difficult to apply to those from higher stratigraphic levels. Hence, the apparent lack of fractionation in the trace-element profiles of Figure 2a is puzzling, but not inconsistent with the varying REE profiles recorded elsewhere. Possibly, a major part of komatiitic lava flows from Smith and Ottawa islands derive from a deeper and less depleted source than those sampled in the central Cape Smith Belt.

ONION-SKIN KOMATIITIC BASALT

Onion-skin lava flows occur principally at two stratigraphic levels: in the upper part of the sequence on Smith Island where they are associated with medium- to low-Mg units, and in the lower part of the mainland sequence where they interlayer with high-Mg lava flows. They have not been reported or described from elsewhere in the Circum-Superior Belt, hence, may be a local phenomenon.

Typically, onion-skin pillow lavas are a light buff, commonly variolitic rock characterized by thick (3–10 cm), scaly pillow rims layered with strings of tiny (~1 mm) variolites. The pillows are generally large and rounded (more than 2 m in diameter), but, in places, may be large mattresses as much as 10–15 m long. Some interlayered massive lavas contain scaly, variolitic, flow-parallel layers similar to thick pillow rims, so themselves may be parts of gigantic pillow tubes. Quartz commonly appears in interpillow interstices and in the flat drainage cavities at pillow centres, indicating the generally more siliceous nature of these lavas relative to that of the more magnesian units of the komatiitic suite.

Clinopyroxene is the most common phenocryst in these lavas (generally 1–30%), but olivine does appear as a phenocryst phase (1–9%) in over half the specimens examined and plagioclase in one. The groundmass is typically dominated by clinopyroxene, commonly in quench-like, acicular radiating bundles or fronds interleaved with plagioclase. Generally plagioclase forms about 40–20% of the groundmass. Opaque minerals (now mainly sphene) are ubiquitous at about 2%. The metamorphism is of subgreenschist facies, commonly marked by pumpellyite development. Deformation is slight and textures are readily interpretable in terms of primary minerals.

Little distinction can be seen in the composition (Table 1a) of the onion-skin lavas at the two stratigraphic levels; both are similar to low-Mg komatiitic basalt. In the cross-section of Figure 1 the Smith Island onion-skin lavas are seen to be remarkably uniform in composition and distinct from the low-Mg unit (Chkl) at the base of the sequence in their persistently higher MgO/TiO_2 index. Extended element profiles normalized to primitive mantle of the two onion-skin lavas are compared in Figure 2b with those of the low- to high-Mg units. Except for minor enrichment in the most incompatible of the elements, the Smith Island profiles are generally similar to those of low- to medium-Mg lavas. Those of the onshore peninsula show extraordinary departures from the low- to high-Mg lava profiles at their incompatible end. These are not readily explained.

The compositional similarity of onion-skin and low-Mg lavas makes it difficult to account for their marked difference in physical character. The large pillows and thick, scaly rims of the onion-skin lavas must signify their much greater viscosity as melts, but their low content of phenocrysts would not indicate unusually low temperatures of emplacement, so perhaps the high viscosity is attributable to very low volatile content, possibly due to loss of pressure and devolatilization prior to eruption.

Layered flows

Layered flows range from meagre olivine concentrations near the base of massive flows, or the massive upper parts of pillow-massive flows (common among flows of the high-Mg unit (Chkh)) to markedly uparched flow segments well differentiated into sharply defined olivine cumulate bases and feldspathic tops. Of those shown on the map several are extraordinarily well developed and are believed to have acted as major distribution conduits for lavas on the surface. They were probably responsible for some of the compositional variation that characterizes the stratigraphy. A detailed map of one such flow (west-island flow, marked WIF on map), given in Figure 3a, shows the divisions effected by differentiation and gives some insight into the mechanism of formation. Compositional variations through this, and another layered flow (mid-island flow, marked MIF on map) are shown in Figures 3b and 4, respectively. Other layered flows within this map area ('Hudson's Bay layered flow' and 'North Island spinifex-textured flow') have been described in detail elsewhere (Baragar, 1983, 1984; Baragar and Scoates, 1987).

West-island flow

The western end of the west-island flow shown in Figure 3a extends eastward, with about the same dimensions, for about 1400 m. The differentiated massive part of the flow rests on a pillowed base (part of the same flow) and is divided into lower dolerite (chill zone), succeeding olivine cumulate, and upper gabbro layers with pegmatitic segregations at mid-upper levels (not shown). Clinopyroxene concentrations observed at the top of the olivine cumulate zone in one place probably marks the presence of a clinopyroxene cumulate layer at that level. The olivine cumulate and overlying gabbroic zones appear to be sharply divided from one another along a foliated contact. This probably indicates that segregation took place in a mobile regime. Of particular interest is the abrupt uparching at the western termination of the flow where overlying pillow lavas parallel the steeply inclined western boundary, indicating that they were in place prior to the uplift that accompanied thickening. Hence, one can postulate that after the initial emplacement of the lava flow and its subsequent burial by overlying pillows, renewal of the magma supply resulted in a surge of magma along the still-molten interior and the rapid uplift of its roof and superincumbent lavas. This was partially achieved by the splay of faults radiating westward from the (then) soft interior, which segmented and lifted the solidified roof and overlying lavas. The renewed magma supply seems to have been sufficiently prolonged to allow olivine accumulation to reach one third of the thickness of the flow while the overriding differentiate was presumably being discharged at the lower termination of the flow.

A compositional profile through the west-island flow is shown in Figure 3b. Several features are of particular note.

- The uniformity of MgO content at bottom and top of the cumulate layer is indicative of its compactness and implies a differential flow between cumulate base and crystal-free top that draws pore fluid from the crystal mush of the former.
- Both CaO and Al_2O_3 decline steadily upward in the gabbroic upper zone, suggestive of feldspar fractionation to more alkaline compositions.
- Pegmatitic segregations at mid-upper levels result in local enrichment of FeO* (total iron as FeO), TiO_2, and Zr.

Mid-island flow

Like the west-island flow, this flow is over 80 m thick and has a length at surface of several hundred metres. Its compositional profile (Fig. 4) shows a compact olivine cumulate base similar to the west-island flow, but with better definition of its upper contact against the overlying gabbroic zone. The contact is sharp, which tends to support the view that it is formed at a zone of differential flowage. Settling in a static environment would be gradational. Other features of interest in the mid-island flow are: the enrichment of Al_2O_3, Ba, and Sr just above the cumulate base; and concentration of FeO*, TiO_2, and Zr at mid-level of the gabbroic zone. These can be attributed to some degree of plagioclase concentration at the base of the upper zone and to pegmatitic segregation near its centre, respectively.

Discussion

The importance of the layered flows is their ability to effect a separation of olivine and, to lesser degree, clinopyroxene, from erupted high- to medium-Mg lavas on surface prior to their final emplacement. The olivine-rich base, which accumulates during transport, lags behind the more fluid, relatively crystal-free, top which arrives at its final destination variably depleted in olivine and, to some degree, clinopyroxene. These are the essential distinctions relating high-Mg to medium- and low-Mg lavas, which makes the layered flows an appropriate mechanism for achieving some of the variability in composition seen within the Chukotat Group.

THICK FLOWS

Extraordinarily thick lava flows (unit Chkt) are present in both the western part of Smith Island and near the southern margin of the mainland peninsula. The western Smith Island flow is about 270 m thick, and although complicated by faulting, is at least several kilometres in length. The peninsular unit is a composite of massive flows, some of which are unusually thick (260 m), but which range down to as little as 25 m. Together they form a resistant, physiographic unit that is distinctive in the field and in airphotos.

A sampled section (marked TFS on map) through the thick flow on Smith Island shows significant petrochemical variations (Fig. 5) that differ from the layered flows described above. The olivine cumulative layer is thin (~20 m) — despite the high-Mg character of the flow base and subjacent pillows — and grades (rather than passing abruptly) into the doleritic zone above. The lower 100 m of this overlying zone is a uniform white-weathering, feldspathic dolerite that passes up into a heterogeneous zone, about 20–30 m thick, composed of a swirly mix of mafic and feldspathic components. Above this, the rock grades into a fairly uniform dolerite with, near the roof, rare suspended mafic blobs. The flow is covered by about 40 m of flow-top breccia containing some rounded, chilled, seemingly leucocratic lava masses.

Certain aspects of the compositional variation seen in Figure 5 are important to note in regard to the origin of the unit. The MgO variation traces out the nature of the olivine cumulate zone with its sharp base and gradational top. This is an attribute better attributed to a static settling regime than a mobile one. The Al_2O_3, CaO, and Sr are enriched in the lower part of the doleritic zone (below the zone of mixed mafic-feldspathic components), indicative of plagioclase accumulation in this region. Above the mixed zone FeO, TiO_2, and Zr show abrupt increases over a broad zone in the upper part of the flow, but decline toward its roof. Alkalis reach a maximum in the same zone. Hence, this probably marks a region of accumulation of late crystallizing magmatic residue. Finally, compositions in the rapidly cooled zones at the base and top of the flow are markedly different. The basal dolerite and related underlying pillows are medium- and/or high-Mg basalt (15–16% MgO), whereas the chilled roof and lava masses in the overlying flow-top breccia are of low-Mg (7–10% MgO) composition. These features might be best explained by a lava lake or thick ponded flow, open initially at the top. Convection within the magma body would tend to enhance the gravity separation of minerals of differing densities and might, with varying and perhaps erratic intensities, lead to zones of mixed rock types, such as the mid-flow zone of mixed mafic-felsic materials. With declining convection rates, parts of the lava surface would stiffen to the point where it could bear an increasing load of debris, resulting from its own surface agitation as well as ejecta from neighbouring, still open and active convection cells. Hence, the solidifying lake surface and incumbent aggregate would be of a composition consistent with the differentiation level reached at that stage at the flow top. Within the magma body, closure of the surface would trap late crystallizing fluids within the upper parts of the body. Thus, the evidence clearly supports the concept of a lava lake as the progenitor of this feature.

Not enough data exists to speculate on the origin of the thick flows of the mainland peninsula. The few analyses available show that the rocks are low in MgO (5–7%) and high in FeO* (15–20%) and TiO_2 (1.5–3%) and are atypical of Chukotat Group compositions. Hence, they may be a variant of the low-Mg lava flows that form the basal unit of the group.

CHUKOTAT GROUP SILLS

Folded gabbro sills that intrude the upper levels of Povungnituk Group sedimentary rocks on the southern margin of the mainland peninsula have characteristics more reminiscent of typical Chukotat Group than of Povungnituk Group compositions. Note in Table 1a not only the general similarity of average Chukotat Group gabbro to average low-Mg komatiitic basalt, but, in particular, the matching of the components most diagnostic of the komatiitic suite; MgO (8.84 vs. 9.16%), TiO_2 (0.93 vs. 0.99%), and Cr (441 vs. 358 ppm) respectively. Compare these with the corresponding values of average Île Gobin Povungnituk Group basalt: MgO (6.49%), TiO_2 (2.00%), and Cr (155 ppm). Also compare the normalized element profile of average Chukotat Group gabbro shown in Figure 2b with corresponding profiles of average komatiitic suite lavas and Île Gobin Povungnituk Group basalt. Despite erratic offsets of some of the REEs, the Chukotat sill profile fits more closely the komatiitic profiles than that of the Povungnituk Group lavas. Clearly, these sills are part of the Chukotat Group magmatic suite that have intruded the Povungnituk Group. Regional maps of the Québec Ministère de l'Énergie et des Ressources, the Geological Survey of Canada, and others document the presence of similar sills at the corresponding stratigraphic level throughout much of the Cape Smith Belt (St-Onge et al., 2006). Thus, there is strong support for the view that the magmatic episodes responsible for these two major volcanic assemblages, the Povungnituk and Chukotat, are not greatly separated in time or space and are an interrelated part of an on-going tectonic process.

SUMMARY AND CONCLUSIONS

The principal stratigraphic components of the Cape Smith Belt — the basal Povungnituk and overlying Chukotat groups — are represented in the map area by the uppermost 2000 m of Povungnituk Group, comprising tholeiitic pillow basalt and black shale, and the lowermost 7000 m of Chukotat Group consisting of komatiitic volcanic rocks. Their relationship is poorly defined, but is interpreted as an overthrust of Chukotat Group over Povungnituk Group. Thick gabbro sills within Povungnituk Group sedimentary rocks subjacent to the thrust contact have the chemical attributes of Chukotat Group volcanic rocks and are interpreted as intrusions of Chukotat Group magma into the earlier succession. Hence, the time and space separation of the two groups may not be of major significance.

The Chukotat Group is subdivided into a number of distinctive units based partly on magnesium content; low- (< 10% MgO), medium- (10–15% MgO), and high-Mg (> 15% MgO) lavas; and partly on distinguishing characteristics; onion-skin (thick, flaky pillow rims) pillow lavas and extraordinarily thick (~250–300 m) massive, ponded flows. All types are interrelated komatiitic basalt. Onion-skin lavas are chemically equivalent to the low-Mg unit, but were seemingly emplaced as highly viscous flows, possibly the result of pre-eruptive devolatilization. The thick flows show some of the attributes of, and are interpreted as having formed as, lava lakes. Among the high- and medium-Mg units in particular, are a number of layered flows formed of thickened, uparched segments of massive, or the massive parts of pillow-massive flows. These are typically differentiated into an olivine cumulate base and overriding gabbroic top, itself commonly differentiated to more evolved compositions. In one layered flow within the map area, spinifex texture, including parallel spinifex (primarily clinopyroxene spinifex), forms the major part of the upper zone.

Broadly based chemical profiles normalized to primitive mantle highlight the distinctions between Povungnituk Group and Chukotat Group magmas and between various units of the latter. For most of the less compatible elements Povungnituk Group lava flows are greatly enriched over those of the Chukotat Group, but for the compatible elements, they are more depleted. This is indicative of the more evolved state of the former relative to the latter consistent with previously expressed views on their respective relations to an opening continental rift (e.g. Francis et al., 1983). Among Chukotat Group units, the high- to low-Mg lavas, showing roughly parallel profiles on multi-element, mantle-normalized plots, are related mainly by progressive depletion of olivine. Surprisingly, these profiles show little fractionation and therefore would be consistent with their derivation from a primitive mantle source; however, this would not be compatible with previous interpretations (based on REE profiles) from the Cape Smith Belt that projected an N-MORB source. Possibly the differences reflect a different source for magmas erupted along the flanking as opposed to the arch position (Cape Smith Belt) of the Circum-Superior Belt.

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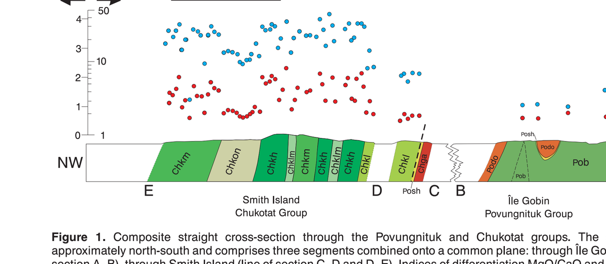


Figure 1. Composite straight cross-section through the Povungnituk and Chukotat groups. The section is approximately north-south and comprises three segments combined onto a common plane: through Île Gobin (line of section A–B), through Smith Island (line of section C–D and D–E). Indices of differentiation MgO/CaO and MgO/TiO_2 (Baragar and Scoates, 1987) are plotted above the section at the sites of sample collection. The lithological identification is the same as for the map.

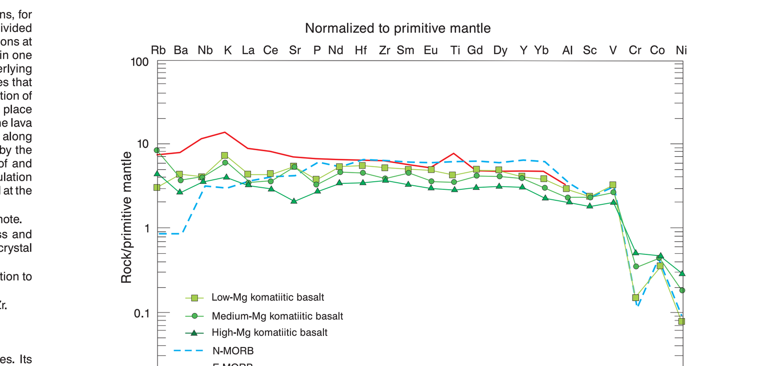


Figure 2a

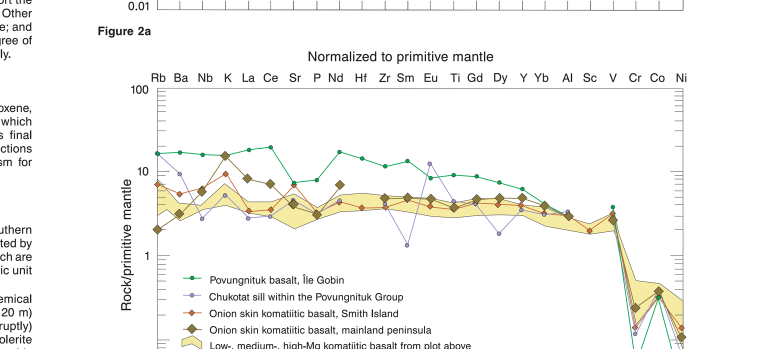


Figure 2b

Figure 2. a) Profiles of average analyses for each of low-Mg, medium-Mg, and high-Mg komatiitic basalt samples normalized to primitive mantle compared to corresponding profiles for N-MORB and E-MORB. b) Region subtended by profiles of komatiitic lava flows shown in Figure 2a compared with corresponding profiles of Povungnituk Group tholeiitic basalt, a Chukotat Group sill intrusive into the Povungnituk Group, and onion-skin lava flows. Normalizing values and order of compatibility are from Sun and McDonough (1989), supplemented by data for major elements from Kerrich and Wyman (1996).

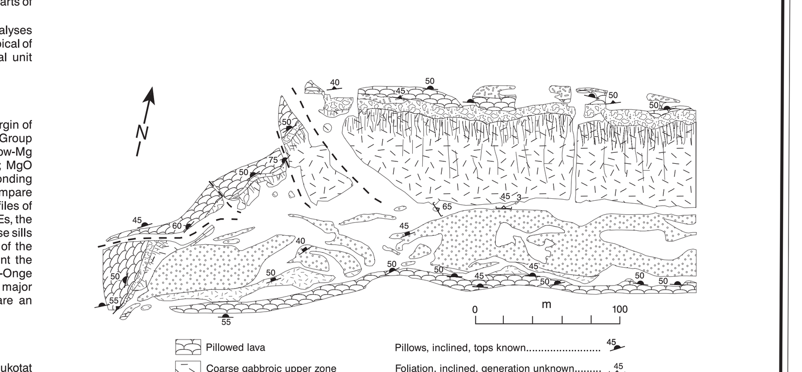


Figure 3a

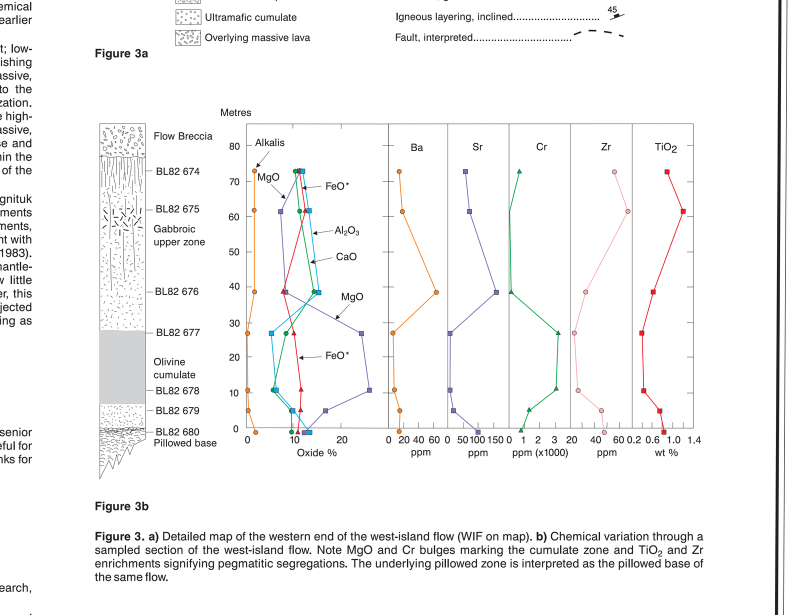


Figure 3b

Figure 3. a) Detailed map of the western end of the west-island flow (WIF on map). b) Chemical variation through a sampled section of the west-island flow. Note MgO and Cr bulges marking the cumulate zone and TiO_2 and Zr enrichments signifying pegmatitic segregations. The underlying pillowed zone is interpreted as the pillowed base of the same flow.

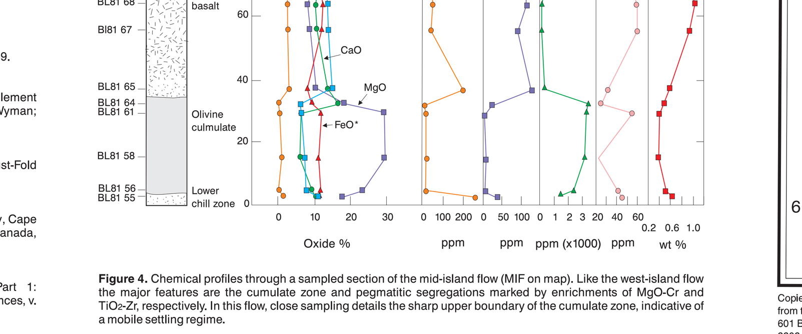


Figure 4. Chemical profiles through a sampled section of the mid-island flow (MIF on map). Like the west-island flow the major features are the cumulate zone and pegmatitic segregations marked by enrichments of MgO-Cr and TiO_2-Zr, respectively. In this flow, close sampling details the sharp upper boundary of the cumulate zone, indicative of a mobile settling regime.

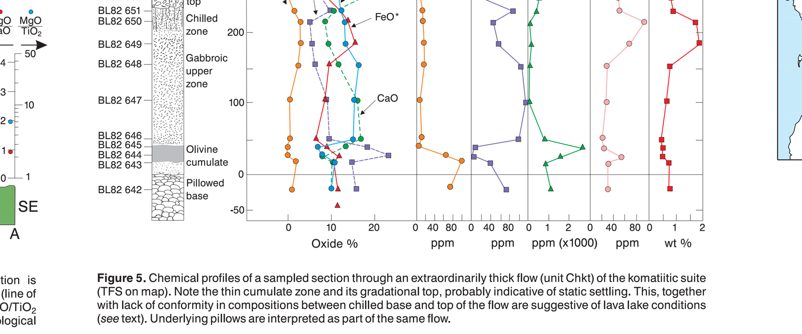


Figure 5. Chemical profiles of a sampled section through an extraordinarily thick flow (unit Chkt) of the komatiitic suite (TFS on map). Note the thin cumulate zone and its gradational top, probably indicative of static settling. This, together with lack of conformity in compositions between chilled base and top of the flow are suggestive of lava lake conditions (*see* text). Underlying pillows are interpreted as part of the same flow.

Table 1a. Average chemical analyses and norms of Smith islands and the mainland peninsula.

Component	Low-Mg[1]			Med-Mg[1]			High-Mg[1]			Onion skin[2] Smith I.			Onion skin[2] mainland pen.			Chukotat dolerite			Île Gobin basalt			Povungnituk		
	No.	Avg	Std	No.	Avg.	Std	No	Avg.	Std	No.	Avg.	Std	No.	Avg	Std	No.	Avg	Std	No.	Avg	Std	No.	Avg.	Std
SiO_2	39	50.38	1.25	38	49.17	1.14	62	48.02	1.12	12	50.40	0.78	4	50.73	1.78	6	48.67	0.66	6	52.00	1.70	31	49.90	1.41
Al_2O_3	39	13.71	0.95	38	11.56	0.97	62	10.03	0.97	12	13.73	0.63	4	13.92	1.69	6	15.08	1.12	6	13.92	0.40	31	13.29	0.79
Fe_2O_3	39	3.20	1.26	38	2.39	0.77	62	2.45	0.98	12	2.92	0.59	4	2.09	0.31	6	2.05	1.04	6	1.75	0.56	31	3.53	0.59
FeO	39	8.08	1.24	38	9.23	0.90	62	9.04	0.90	12	8.07	0.45	4	8.87	0.64	6	9.35	1.53	6	10.66	1.06	31	10.64	1.23
MgO	39	9.16	1.72	38	14.33	2.62	62	18.58	2.75	12	9.64	1.13	4	9.93	3.68	6	8.84	1.53	6	6.49	0.62	31	7.18	0.98
CaO	39	12.23	1.53	38	10.83	0.71	62	9.92	0.87	12	12.56	0.76	4	11.45	3.83	6	12.47	1.45	6	9.06	1.21	31	11.05	1.90
Na_2O	39	1.74	0.69	38	1.22	0.64	62	0.89	0.60	12	1.29	0.39	4	1.32	0.99	6	1.88	0.63	6	3.03	0.78	31	2.12	0.57
K_2O	39	0.23	0.38	38	0.18	0.12	62	0.12	0.11	12	0.29	0.12	4	0.50	0.74	6	0.17	0.15	6	0.46	0.26	31	0.27	0.22
TiO_2	39	0.93	0.16	38	0.75	0.22	62	0.64	0.07	12	0.78	0.08	4	0.82	0.12	6	0.99	0.20	6	2.00	0.44	31	1.49	0.35
P_2O_5	39	0.08	0.01	38	0.07	0.02	62	0.06	0.01	12	0.07	0.01	4	0.06	0.00	6	0.07	0.03	6	0.18	0.05	31	0.16	0.06
MnO	39	0.19	0.02	38	0.20	0.02	62	0.19	0.02	12	0.20	0.01	4	0.18	0.02	6	0.20	0.03	6	0.21	0.02	31	0.26	0.02
S	39	0.08	0.06	38	0.07	0.07	62	0.06	0.07	12	0.05	0.03	4	0.12	0.10	6	0.25	0.19	6	0.25	0.13	31	0.09	0.08
Rb	21	2	2.0	14	4	3.0	27	3	4.4	4	5	4	2	1	1	1	9		6	9	5			
Ba	39	30	31.1	38	25	11.0	62	19	15.0	12	37	11	4	22	16	6	67	25	6	123	71	31	105	85
Nb	22	3	1.6	14	3	1.0	27	3	2.0	6	4	1	4	4	1	1	2		6	12	4			
Ta	7	0.2	0.0	1	0.1		3	0.1											2	1				
Pb	8	13	4.8	1	11		7	13	4.1	2	7	1	1	18	0				2	14	4	31	1	1
Sr	39	117	62.3	38	111	72.6	62	45	37.9	12	149	57	4	90	69	6	103	29	6	118	70	31	198	88
Zr	39	57	13.2	38	43	19.8	62	42	15.8	12	44	6	4	56	16	6	48	14	6	132	34	31	126	43
Hf	7	2	0.2	1	1		3	1	0.1										2	5				
Y	23	19	5.7	27	18	2.7	37	15	4.3	12	19	3	4	23	5	3	17		6	29	4			
La	9	3.0	1.0	1	2.3		7	2.2	0.7	2	2.4		1	5.8		4	2.0	0.04	2	13.0				
Ce	9	7.9	1.8	1	6.6		7	5.5	1.5	2	6.3		1	13.0		1	5.2		2	35.0				
Nd	9	7.2	1.0	1	6.3		7	4.9	1.0	2	5.9		1	9.5		1	6.5		2	23.5				
Sm	9	2.1	0.4	1	2.1		7	1.5	0.3	2	2.1		1	2.2		1	0.6		2	5.8				
Eu	9	0.8	0.2	1	0.6		7	0.5	0.1	2	0.7		1	0.8		1	2.2		2	1.4				
Gd	9	2.9	0.4	1	2.5		7	1.9	0.3	2	2.5		1	2.9		1	2.6		2	5.5				
Dy	9	3.7	0.5	1	3.0		7	2.4	0.3	2	3.1		1	3.6		1	1.4		2	5.6				
Yb	9	1.9	0.3	1	1.5		7	1.1	0.1	2	1.6		1	2.0		4	1.6	0.36	2	2.1				
Zn																4	75	11				31	110	22
Be																4	0	0.04						
Ga	10	20	2.6	9	14	2.4	15	10	4.3	3	15											31	17	3
Mo	8	6	1.7	1	7		6	6	2.9	2	3		1	7					2	4				
Cu	39	127	51.7	38	95	24.1	62	92	46.8	12	104	16	4	79.5	33	6	107	37	6	54	23	31	181	56
V	39	274	46.7	38	216	69.4	62	171	62.9	12	257	15	4	227.5	28	6	247	35	6	322	29	31	465	65
Sc	16	41	9.6	15	38	5.3	27	31	7.4	3	34													
Co	39	40	7.6	38	51	11.4	62	54	10.4	12	36	6	4	44.25	15	6	45	9.82	6	36	3	31	84	81
Ni	39	148	102	38	348	120	62	553	169	12	262	201	4	203.75	218	6	126	43	6	55	9	31	104	128
Cr	39	441	358	38	1009	382	62	1558	511	12	411	124	4	710	638	6	358	305	6	155	37	31	155	117

Major elements are given in wt % and trace elements in ppm.

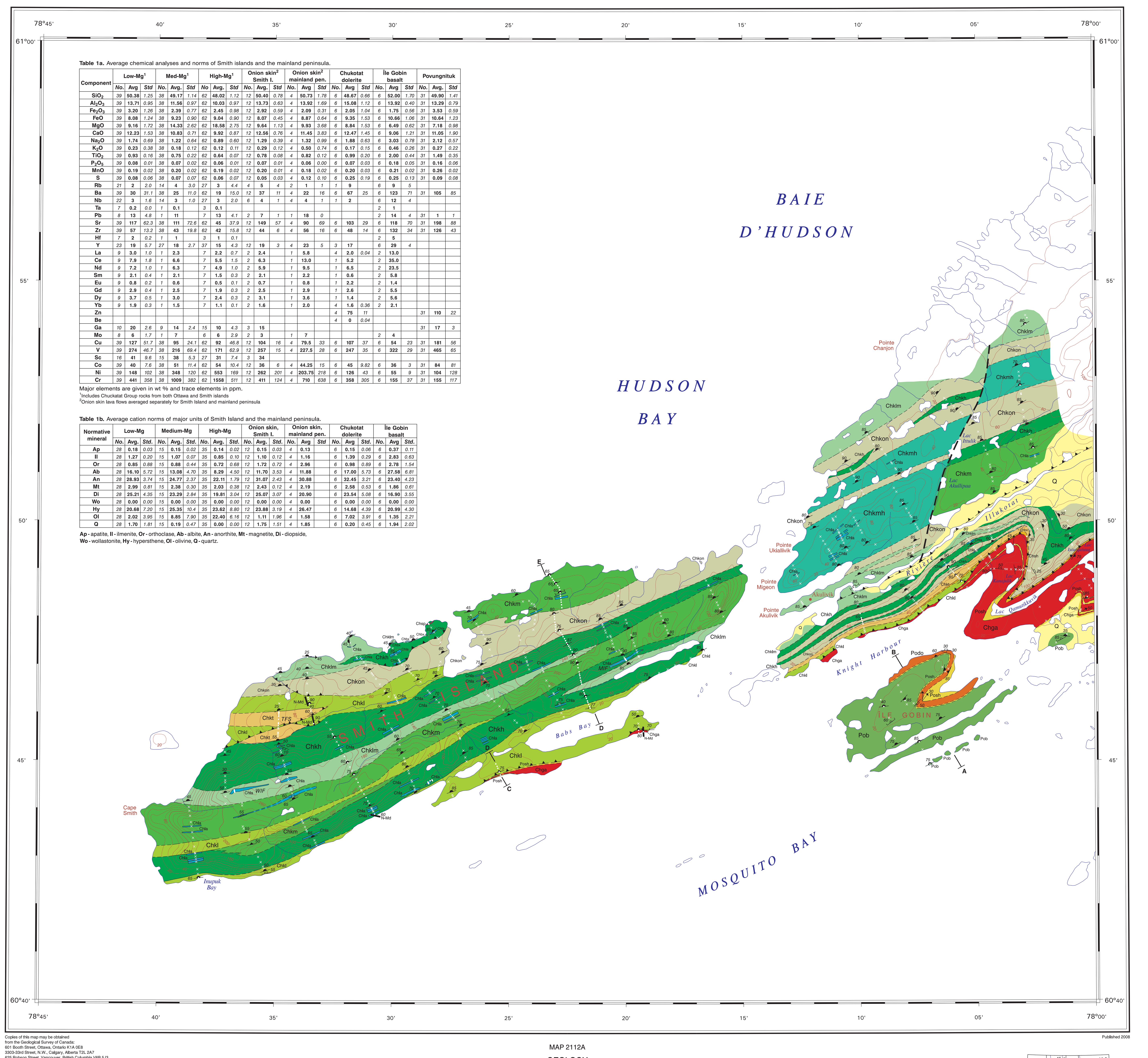
[1]Includes Chuckatat Group rocks from both Ottawa and Smith islands

[2]Onion skin lava flows averaged separately for Smith Island and mainland peninsula

Table 1b. Average cation norms of major units of Smith Island and the mainland peninsula.

Normative mineral	Low-Mg			Medium-Mg			High-Mg			Onion skin, Smith I.			Onion skin, mainland pen.			Chukotat dolerite			Île Gobin basalt		
	No.	Avg.	Std.	No.	Avg.	Std.	No.	Avg.	Std.	No.	Avg.	Std.	No.	Avg	Std	No.	Avg	Std.	No.	Avg	Std.
Ap	28	0.18	0.03	15	0.15	0.02	35	0.14	0.02	12	0.15	0.03	4	0.13		6	0.15	0.06	6	0.37	0.11
Il	28	1.27	0.20	15	1.07	0.07	35	0.85	0.10	12	1.10	0.12	4	1.16		6	1.39	0.29	6	2.83	0.63
Or	28	0.85	0.88	15	0.88	0.44	35	0.72	0.68	12	1.72	0.72	4	2.96		6	0.98	0.89	6	2.78	1.54
Ab	28	16.10	5.72	15	13.08	4.70	35	8.29	4.50	12	11.70	3.53	4	11.88		6	17.00	5.73	6	27.58	6.81
An	28	28.93	3.74	15	24.77	2.37	35	22.11	1.79	12	31.07	2.43	4	30.88		6	32.45	3.21	6	23.40	4.23
Mt	28	2.99	0.81	15	2.38	0.30	35	2.03	0.38	12	2.43	0.12	4	2.19		6	2.58	0.53	6	1.86	0.61
Di	28	25.21	4.35	15	23.29	2.84	35	19.81	3.04	12	25.07	3.07	4	20.90		6	23.54	5.08	6	16.90	3.55
Wo	28	0.00	0.00	15	0.00	0.00	35	0.00	0.00	12	0.00	0.00	4	0.00		6	0.00	0.00	6	0.00	0.00
Hy	28	20.68	7.20	15	25.35	10.4	35	23.62	8.80	12	23.88	3.19	4	26.47		6	14.68	4.39	6	20.99	4.30
Ol	28	2.02	3.95	15	8.85	7.90	35	22.40	6.16	12	1.11	1.96	4	1.58		6	7.02	3.91	6	1.35	2.21
Q	28	1.70	1.81	15	0.19	0.47	35	0.00	0.00	12	1.75	1.51	4	1.85		6	0.20	0.45	6	1.94	2.02

Ap - apatite, **Il** - ilmenite, **Or** - orthoclase, **Ab** - albite, **An** - anorthite, **Mt** - magnetite, **Di** - diopside, **Wo** - wollastonite, **Hy** - hypersthene, **Ol** - olivine, **Q** - quartz.



LEGEND

QUATERNARY–RECENT

- **Q** — *Overburden.*

NEOPROTEROZOIC–MESOPROTEROZOIC

- **N-Md** — *Diabase dyke.*

PALEOPROTEROZOIC

CHUKOTAT GROUP

KOMATIITIC SUITE VOLCANIC ROCKS (units not necessarily in stratigraphic order)

- **Chga** — *Gabbro sills. Medium to locally coarse grained, dark grey, generally feldspathic gabbro.*
- **Chkl** — *Low-Mg komatiitic basalt (MgO < 10%). Well formed pillowed and massive, greenish-grey-weathering lava flows. Abundantly clinopyroxene- and sparsely olivine-phyric rocks.*
- **Chkon** — *'Onion-skin' pillowed and massive lava flows of generally low Mg. Pillows typically buff-weathering and variolitic, marked by thick (3-10 cm), scaly rims. Abundantly clinopyroxene-, but very sparsely olivine-phyric.*
- **Chkt** — *Thick, massive, komatiitic lava flows as much as 270 m thick. In places well differentiated with olivine cumulate base overlain by feldspathic 'dolerite' and a breccia cap.*
- **Chklm** — *Undivided low- and medium-Mg komatiitic basalt.*
- **Chkm** — *Medium-Mg komatiitic basalt (MgO = 10–15%). Generally buff-weathering pillowed and massive lavas, somewhat polyhedrally jointed. Moderately olivine- and clinopyroxene-phyric.*
- **Chkmh** — *Undivided medium- and high-Mg komatiitic basalt.*
- **Chkh** — *High-Mg komatiitic basalt. Orange- to brown-weathering, polyhedrally jointed, pillowed and massive lava flows. Pillows typically thin rimmed and poorly formed. Rocks are richly olivine-phyric and, in part, also clinopyroxene-phyric.*
- **Chla** — *Layered flows formed of thickened segments of massive, or the massive upper part of pillow-massive, komatiitic flows variably differentiated into basal olivine cumulate and overlying 'doleritic' layers.*
- **Chsp** — *Spinifex-textured layered flow, komatiitic basalt.*
- **Chbx** — *Pillow breccia and/or agglomerate.*
- **Chsh** — *Shaly sedimentary rocks.*

POVUNGNITUK GROUP

- **Podo** — *Dark- to grey-weathering, variably feldspathic dolerite sills.*
- **Posh** — *Sedimentary rocks, primarily black shale.*
- **Pob** — *Pillowed and massive tholeiitic basalts. Greenish-weathering, plagioclase-microphyric rocks of greenschist-facies metamorphic grade.*

Geological contact (defined, approximate, interpreted)

Thrust fault (defined, interpreted); teeth on upthrust side

Fault oblique, interpreted

Bedding, inclined (top unknown)

Pillowed flows, inclined (top known, overturned)

Igneous layering, inclined (top undetermined)

Flow contact, inclined (top known, overturned)

Foliation, inclined (generation unknown)

Fault, inclined (sense unknown)

Shear, inclined (sense unknown)

Lineation, generation unknown

Geochemical site (shown in white on map)

Station not othervwise identified (shown in white on map)

Line of section — B A

West-island flow — WIF

Mid-island flow — MIF

Analyzed section trough thick flow (unit Chkt) — TFS

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Published 2008

MAP 2112A

GEOLOGY

SMITH ISLAND AND ADJOINING MAINLAND EASTERN HUDSON BAY

NUNAVUT–QUEBEC

Scale 1:75 000/Échelle 1/75 000

kilometres 1 0 1 2 3 4 5 6 kilomètres

Universal Transverse Mercator Projection
North American Datum 1983

Projection transverse universelle de Mercator
Système de référence géodésique nord-américain, 1983

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Author: W.R.A. Baragar

Geology by W.R.A. Baragar 1981–1992; and M. Piché, 1981

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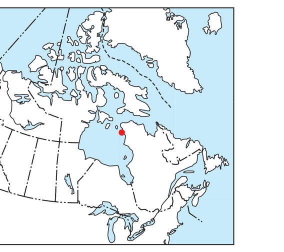
Any revisions or additional geological information known to the user would be welcomed by the Geological Survey of Canada

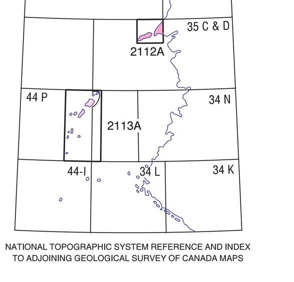
Digital base map from data compiled by Geomatics Canada, modified by DDD

Mean magnetic declination 2008, 22°20' W, decreasing 17.4'annually. Readings vary from 21°46' W in the SW corner to 22°53' W in the NE corner of the map

Elevations in metres above mean sea level



LOCATION MAP



NATIONAL TOPOGRAPHIC SYSTEM REFERENCE AND INDEX TO ADJOINING GEOLOGICAL SURVEY OF CANADA MAPS

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