CHAPTER 19

PHANEROZOIC

19.1 EARLY CAMBRIAN

19.1.1 UPPER LABRADOR GROUP

At the start of Section 18.1.3 it was clarified that the Labrador Group can be subdivided into two parts. The lower Labrador Group is assigned as Neoproterozoic (Bateau and Lighthouse Cove formations) and was addressed in that section of this report. The upper Labrador Group is Early to Middle Cambrian (Bateau and Forteau formations) and is briefly reviewed here. The review is short because these rocks were never seriously included as part of the eastern Labrador project, having already been adequately mapped at 1:100 000 scale by Cumming (1983) and the subject of several research articles. In addition, during the author's mapping of the Pinware region (Gower *et al.*, 1994), both the lower and upper parts of the Labrador Group were examined by his colleague I. Knight. Localities visited by Knight are included in the author's database and a summary of his findings is given in excursion guides (Gower *et al.*, 1997b, 2001).

19.1.1.1 Bradore Formation (C*Br*)

A detailed study of the Bradore Formation in Labrador (Figure 19.1) was completed by Hiscott *et al.* (1984). They subdivide the Bradore Formation into three members. The Blanc-Sablon member forms the basal 30 m and is a pebbly, subarkosic, trough and planar–tabular crossbedded sandstone and pebble conglomerate. This is succeeded by the Crow Head Member, which comprises 20 m of texturally similar sandstone, but containing abundant vertical burrows that obliterate all primary structures. The upper 10 m is termed the L'Anse-au-Clair member and comprises quartzose coarse sandstone with polymodal trough and planar–tabular cross-bedded orientations. They conclude that the Blanc-Sablon member represents braided–fluvial deposits and the succeeding members are estuarine and nearshore sandstones. The sedimentary rocks are the product of rapid denudation of a barren interior under tropical conditions. Knight (*in* Gower *et al.*, 2001) states that the upper Labrador Group preserves the first record of oceanic flooding of northeast North America cratonward of the Iapetan rift system.

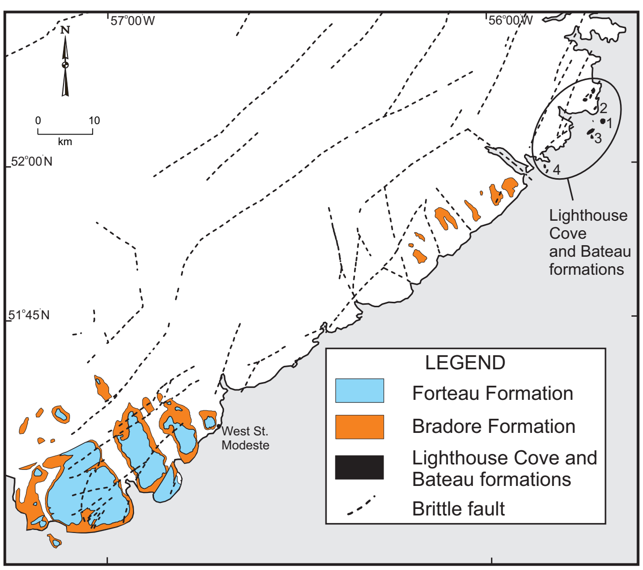

Figure 19.1. *Lighthouse Cove, Bateau, Bradore and Forteau formations.*

A more recent interpretation of the depositional history of the Bradore Formation is given by Long and Yip (2009), who include a thorough summary of previous literature. They suggest that deposition of the Bradore Formation occurred on a current-swept shelf defining the (then) southern margin of Laurentia. They concur with Hiscott *et al.* (1984) that deposition took place during marine transgression, but suggest that the marine transgression was linked to drift-related margin collapse, rather than global changes in relative sea level.

A sample of what is probably the regolith underlying the Bradore Formation, collected at the basal unconformity exposed in a gravel pit at West St. Modeste (Plate 19.1) was examined by the author in thin section (CG93-193A). It consists mainly of K-feldspar (both perthite and microcline), anhedral to rounded quartz, minor plagioclase, white mica, opaque minerals (hematite and leucoxene) and a clay mineral groundmass. A second sample, collected from the underlying altered basement (CG93-193B) has recognizable quartz, biotite, opaque oxides (some of which is hematite), and aggregates of white to pale-greenish mica. The white mica is clearly a pseudomorph, but the original mineral is a matter of speculation (corundum?, plagioclase?, cordierite?).

19.1.1.2 Forteau Formation (C*Fo*)

The following information on the Forteau Formation is taken from James and Kobluk (1978). For more recent references and regional tectonic context, the reader is referred to James *et al.* (1989) and Knight *et al.* (2017). The Forteau Formation comprises flat-lying limestones, siltstone and

Plate 19.1. *Unconformity between Grenville Province crystalline basement and overlying Bradore Formation (CG93-193).*

shales about 120–140 m thick. The lower 3–4 m consist of poorly bedded to nodular dolomitized calcarenite and interlaminated shale, grading up into archaeocyathid-rich patch reefs, calcarenites and silty shales averaging about 20 m thick. This package is overlain by 18–20 m of interbedded calcareous and dolomitic siltstone and shales, characterized by abundant ichnofossils. The uppermost sequence is a complex of oolite shoals and mounds up to 12 m thick. Recent investigation of the archaeocyathan reefs has been carried out by Pruss *et al.* (2012).

19.2 DEVONO–CARBONIFEROUS AND/OR LATER (Dd)

Near pristine mafic dykes are found in four areas in eastern Labrador, and are termed here, from northwest to southeast, the Sandwich Bay, Norman Bay, Charlottetown Road, and Battle Harbour mafic dykes. Apart from the Sandwich Bay dykes, these are new names. It is emphasized that they are not necessarily Devonian despite their assigned unit designator.

19.2.1 SANDWICK BAY DYKES

The Sandwich Bay dykes were discovered during 1:100 000-scale mapping in 1981, but they only received terse mention in the post-field-season report of Gower *et al.* (1982b), in which they were suggested to be Mesozoic. The name ‘Sandwich Bay dykes’ was introduced by Murthy *et al.* (1989a). Their mainly paleomagnetic study also included petrographic and geochemical information, as well as a whole-rock K–Ar age of 327 ± 13 Ma (CG84-476). The age was taken to document the time of intrusion and a Carboniferous age was assigned by Murthy *et al.* (1989a). The maximum age of emplacement is 615 ± 2 Ma, imposed by a Long Range dyke dated at the same locality and host to the Sandwich Bay dyke. Gower (2010a) opted for a Devonian age, given the presence of Devono–Carboniferous mafic magmatism elsewhere in eastern Canada (*cf.* Murthy *et al.*, 1989a).

The dykes are mostly located in the southwest part of Sandwich Bay, although Murthy *et al.* (1989a) included one dyke from Hawke Bay, about 115 km to the southeast (Figure 19.2). The trend of the dykes is mainly east to east-southeast, and their width ranges from 0.3 to 15 m. The dykes are black-weathering, fine to medium grained, massive, and unmetamorphosed (Plate 19.2A). They are characteristically plagioclase-phyric, having euhedral, well twinned and zoned phenocrysts up to 1 cm long. Olivine phenocrysts, up to 0.5 cm across, are also evident in hand samples.

Thin sections were prepared from several of the dykes found in Sandwich Bay (CG81-146B, CG81-175B, CG81-226, CG81-279B, CG84-476B, CG84-476C, CG84-476D, CG84-480, CG84-481) and from the dyke in Hawke Bay (GM85-435B). The groundmass of the dykes contains olivine, plagioclase, clinopyroxene, and accessory phases. Olivine is euhedral to subhedral and partly or completely serpentinized; plagioclase is elongate, commonly skeletal, well twinned, zoned and lightly sericitized; clinopyroxene is purplish brown (*cf.* titanaugite) and anhedral; accessory phases are an opaque mineral (probably titanomagnetite), skeletal apatite and possibly perovskite.

Farther afield, as pointed out by Murthy *et al.* (1989a), the Aillik Bay dykes in the Makkovik area have yielded a ca. 345 Ma K–Ar date, and, like the Sandwich Bay dykes, have a southeast trend. A southeast-trending line linking the Aillik, Sandwich Bay and Norman Bay (next section) areas may imply a more fundamental structural control.

19.2.2 NORMAN BAY DYKES

Whole-rock geochemical data demonstrates that some Norman Bay dykes have Sandwich Bay dyke affinity and some have Battle Harbour dyke affinity. To avoid circular reasoning and acknowledging a lack of geochronological control, however, they are distinguished separately here, and their geochemical relationships addressed below.

The dykes were found at four localities (three in the Norman Bay area and one in St. Michaels Bay) during mapping in 1986 (JS86-349, JS86-360, MN86-368, SN86-319). An additional site may be located at RW75-443 (*cf.* 1975 field notes), but this requires field verification. Note that data station SN86-319 is very close to the Cooper Island Long Range dyke, providing a potentially rewarding area in a search for crosscutting relationships between the two dyke swarms.

The dykes trend east-northeast or east-southeast and vary in width from less than 1 m to about 5 m (Table 19.1).

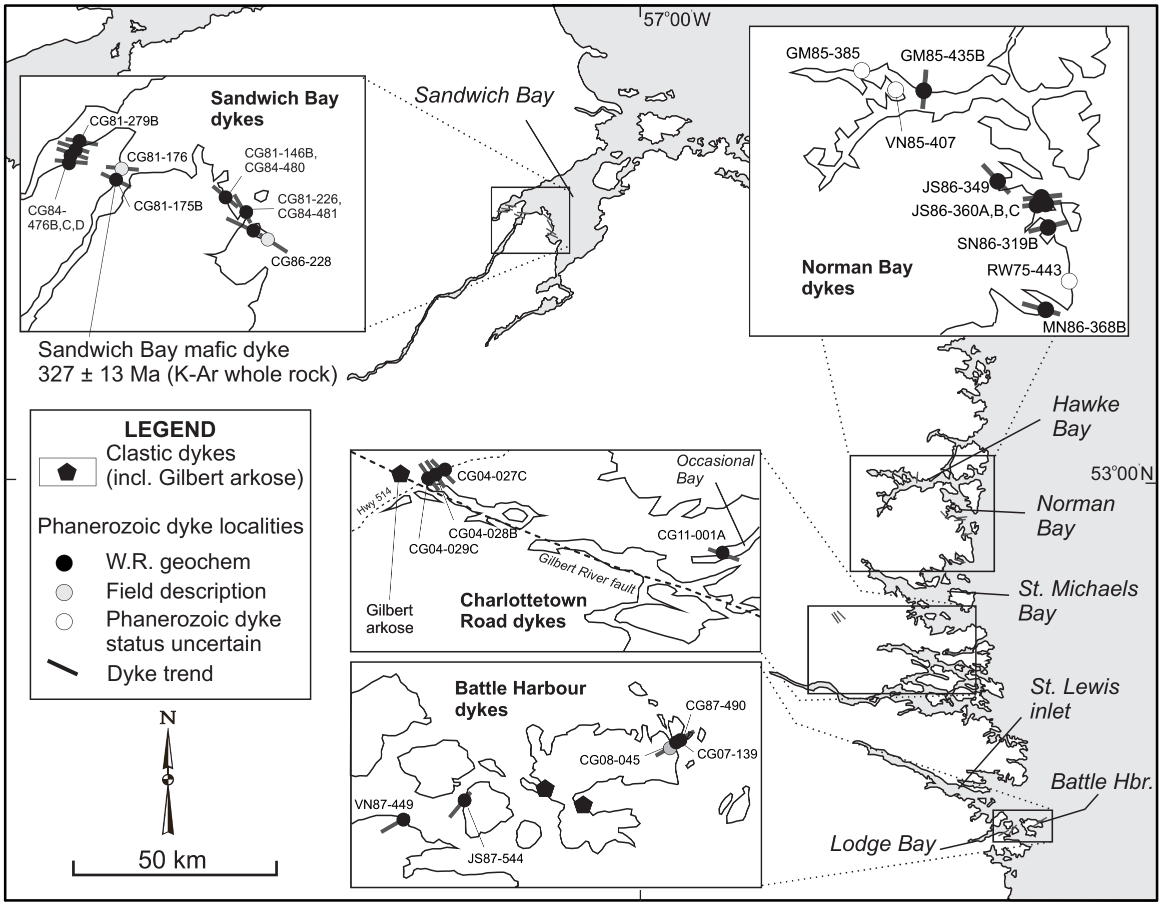

Figure 19.2. *Phanerozoic mafic dykes (Sandwich Bay, Norman Bay, Battle Harbour and Charlottetown Road dykes).*

Table 19.1. Norman Bay dykes

Data Station	Trend	Width (m)	Comments	Affiliation
JS86-349	137/68	3	Plagioclase-phyric	Sandwich Bay dykes
JS86-360B	84/90	4	Parallel to JS86-360C	Battle Harbour dyke
JS86-360C	84/90	1	Parallel to JS86-360B	Battle Harbour dyke
MN86-368	106/90	0.6		Sandwich Bay dykes
SN86-319B	76/70	5	Seven dykes (5 m widest)	Battle Harbour dyke

They are rusty-brown-weathering, aphanitic to fine to medium grained, massive, and show obvious chilled margins against their host rocks (Plate 19.2B). A few of the dykes carry plagioclase phenocrysts up to 1 cm long, and one dyke is amygdaloidal (SN86-319B). More than one dyke is present at some localities.

Dykes from all four localities were examined in thin section (JS86-349, JS86-360B, JS86-360C, MN86-368B, SN86-319B). Thin sections JS86-360B and JS86-360C are from two separate, similar-trending, dykes at the same locality, 4 m and 1m wide, respectively. The rocks have simple mineral assemblages, comprising plagioclase, clinopyroxene, olivine and opaque oxides. Plagioclase forms euhedral, well-twinned, zoned, elongate primary igneous crystals that are skeletal in part. They are unaltered to very slightly sericitized. Clinopyroxene occurs as equant, subhedral to anhedral, colourless, pale-lilac, mauve or brown primary igneous crystals (*i.e.*, probably titaniferous augite) in subophitic texture with plagioclase. Olivine is only preserved as a primary phase in MN86-368B, and even in this thin section there is a gradation from fresh grains to totally serpentinized material, according to decreasing distance from a late-stage fracture. In the other thin sections, olivine is pseudomorphed to various green, orange and brown serpentine products. The opaque mineral in all samples is mostly oxide (*cf.* ilmenomagnetite), although larger grain clusters in SN86-319B are sulphide, probably pyrrhotite. The opaque oxide is characteristically skeletal, exhibiting well-developed dendritic form. The amygdules in SN86-319B are filled with serpentine, quartz and carbonate, and carbonate is an interstitial phase in the groundmass of the same sample.

19.2.3 BATTLE HARBOUR DYKE

The name Battle Harbour dyke is newly introduced here for a dyke recorded at four outcrops between Battle Harbour

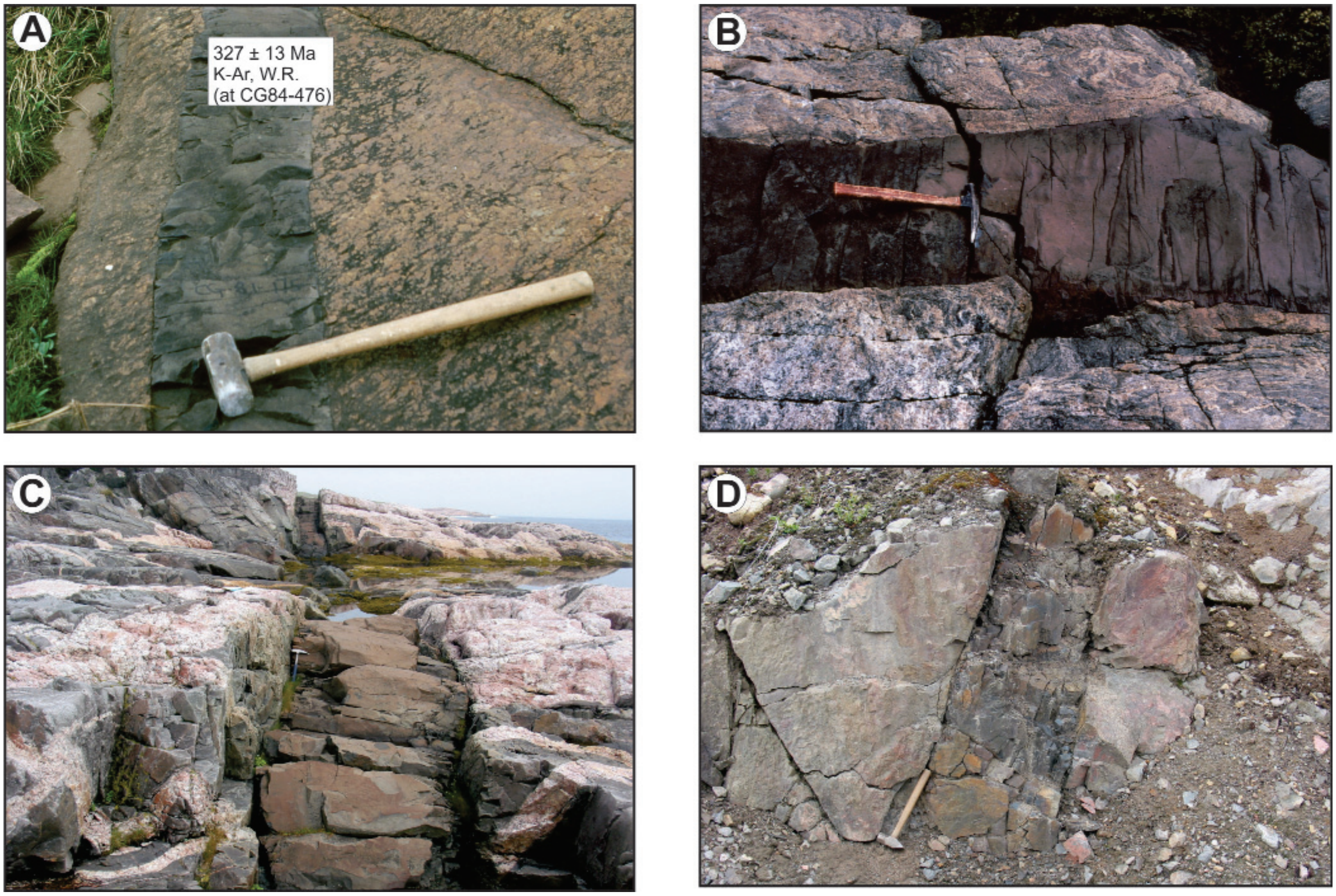

Plate 19.2. *Phanerozoic mafic dykes in eastern Labrador. A. Sandwich Bay dyke (CG81-175), B. Norman Bay dyke (Sandwich Bay dyke chemistry) (MN86-368), C. Battle Harbour dyke (CG07-159), D. Charlottetown Road dyke (CG04-028).*

and Lodge Bay (CG87-490, CG08-045, JS87-544, VN87-449, east to west). Three of these were discovered during 1:100 000-scale mapping in 1987 (Gower *et al.*, 1988), and the additional (previously suspected) occurrence was confirmed in 2008 (Gower, 2008, 2009). Not all the coastal islands were examined during 1:100 000-scale mapping and the dyke is likely exposed on some of these.

The dyke occurrences are aligned on a 060° trend, which is comparable overall with dyke trends measured at the individual localities. The outcrops are interpreted to belong to a single, possibly *en échelon*, intrusion. The outcrops are dark-grey- or brown-weathering, fine grained, and have widths between 0.2 and 2.0 m. They are vertical to steeply south-southeast dipping, planar, unmetamorphosed, and have well defined chilled margins (Plate 19.2C). They also show bifurcation, offshoots and sharp changes in trend. The latter feature, in particular, suggests high-level emplacement along pre existing brittle fractures. A line linking the three localities, when extrapolated west-southwest, would coincide with the Charles River, suggesting the dyke and the river might have both exploited a line of weakness. No search was made during 1:100 000-scale mapping for additional outcrops of the dyke that might be exposed in riverside exposures. Two clastic dykes (Section 18.1.2.6) more-or-less fall on the same alignment inviting the notion that they could be linked to the Battle Harbour dyke fracture, rather than being Neoproterozoic as tacitly previously assumed.

A sample of the dyke at Battle Harbour was processed for U–Pb isotopic analysis, but no dateable material was extracted. The only age constraint is that the dyke discordantly truncates north-northeast-trending hematite-filled fractures that are readily interpreted to be related to Iapetan rifting.

Four samples from three localities were examined in thin section. They show a range in grain size; VN87-449 is fine to medium grained, CG87-490.1 is fine grained, CG87-490.2 is fine to medium grained, and JS87-544 is very fine grained, having been collected from the quenched margin of the dyke. The groundmass mineral assemblage shows well-developed ophitic texture and comprises quenched plagioclase, clinopyroxene, opaque oxide(s), dark brown granular material that might be titanite, and secondary greenish-yellow serpentinous material that might be after olivine. Plagioclase also occurs as extensively sericitized, euhedral phenocrysts up to 0.5 cm long.

19.2.4 CHARLOTTETOWN ROAD DYKES

The Charlottetown Road dykes are the most recently distinguished group of mafic dykes in eastern Labrador. Only four localities are known. Three of these (CG04-027C, -028B, -029C) are in roadcuts on Highway 514 (which links the Trans-Labrador highway to Charlottetown). The other (CG11-001A) is at the head of Occasional Bay, 30 km to the east-southeast. The dykes at the first three sites were discovered in 2004 by the author during examination of roadcuts created during the construction of the Charlottetown highway. They were assigned to the Gilbert Bay dyke suite (Section 17.4.8.3) on the 1:100 000-scale maps of Gower (2010a), but whole-rock geochemical data obtained later demonstrates that they are compositionally distinct and have greater similarity to the Phanerozoic dykes than the Gilbert Bay dykes.

The dykes along the Charlottetown Road (Plate 19.2D) range in width from 0.15 to 0.8 m, and in trend from 135° to 145°. They are black-weathering, aphyric and very fine grained, and, at CG04-029, the dyke has irregular, anastomosing form. The intrusion at the head of Occasional Harbour also has a very irregular shape. It is plagioclase-phyric and amygdaloidal. The situation at Occasional Harbour is made more complicated by the presence of a Gilbert Bay dyke at the same locality (CG11-001B).

Thin sections are available from all four sites. The mineral assemblage consists of euhedral to subhedral, moderately or well-twinned plagioclase; clinopyroxene, amphibole and/or biotite (all relict or primary, anhedral to euhedral); no olivine; relict igneous opaque minerals; and (in CG11-001A) quartz and carbonate in amygdules.

19.2.5 LITHOGEOCHEMISTRY OF PHANEROZOIC MAFIC DYKES

Some lithogeochemical features of the above described Phanerozoic mafic dykes are illustrated in Figure 19.3 using standard discrimination plots for basaltic rocks. One key feature effectively demonstrated in Figure 19.3A, is the

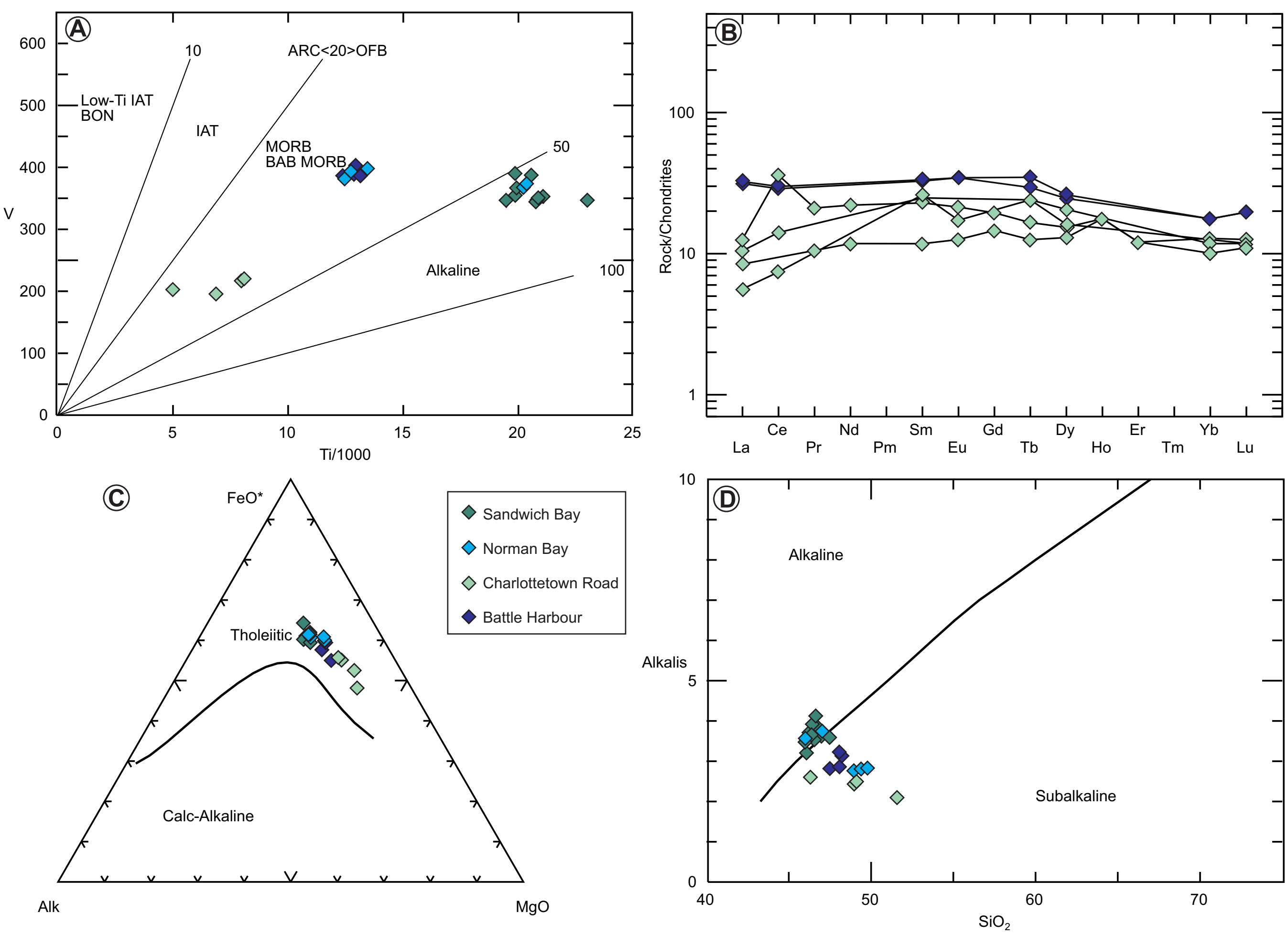

Figure 19.3. *Lithogeochemical characteristics of the Sandwich Bay, Norman Bay, Charlottetown Road and Battle Harbour mafic dykes.*

presence of three data clusters, representing the Sandwich Bay, Charlottetown Road and Battle Harbour dykes. Three of the Norman Bay dyke samples group with the Battle Harbour dykes and two of them plot with the Sandwich Bay dykes. The analyzed three dykes clustering with the Battle Harbour dykes also have similar east-northeast trends (JS86-360A, B, C), whereas the two analyzed dykes clustering with the Sandwich Bay dykes have east-southeast trends (JS86-349, MN86-368). It seems fairly clear that the so-called 'Norman Bay' dykes belong to either the Battle Harbour or Sandwich Bay dykes. In Figure 19.3A, the Charlottetown Road dykes are distinct from either the Battle Harbour or Sandwich Bay dykes. Further depiction that the 'Norman Bay' dykes belong to either the Battle Harbour or Sandwich Bay dykes, and that the Charlottetown Road dykes are distinct from both, is evident from Figure 17.9B–D.

In Figure 19.3C, D, it can be seen that all the Phanerozoic mafic dykes have a more tholeiitic/less alkalic aspect than either the late-Grenvillian mafic dykes or Long Range dykes (compare with Figures 17.8 and 18.4). In addition, it is evident that the Sandwich Bay dykes are more alkalic than the Battle Harbour dykes. In the rare-earth-element plot, from the representative samples of the Battle Harbour and Charlottetown Road dykes (and partial data for other samples in the author's database), it is also evident that these dykes have a more tholeiitic character.

19.3 SURFICIAL DEPOSITS

As was noted in Section 4.8, it was never the intention of this project to address surficial deposits. A listing of some relevant studies was given at that point. One additional point that would otherwise not receive mention is out-of-context rocks, of which two examples are given here, but, no doubt, there are many others.

The first is the recording at data station CG85-533 of limestone boulders at Shoal Bay (located on Figure 10.1). One boulder is rounded and 15 cm in diameter, and another found, for which details were not recorded. They are presumed to be glacial erratics, but the source has not been identified. The closest limestone is the Forteau Formation, but ending up at Shoal Bay requires an unlikely transport direction. An alternative source is limestone in Ungava Bay.

The second is cherty cobbles at Battle Harbour. These very closely resemble flint found in chalk in England, and most likely arrived as ships' ballast.