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PRELIMINARY REPORT ON THE LITHOLOGY OF VOLCANO-SEDIMENTARY ROCKS OF THE AILLIK GROUP, AILLIK DOMAIN, MAKKOVIK PROVINCE

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ABSTRACT

Detailed 1:10 000-scale mapping within the Aillik domain of the Makkovik Province has defined the rock types and structural evolution of two areas within the Aillik Group. The Aillik domain is composed of the Aillik Group, a sequence of Paleoproterozoic volcano-sedimentary rocks, which has been intruded by various Paleoproterozoic intrusive suites. The Aillik Group has been deformed and metamorphosed during the Makkovikian orogeny, intruded by several generations of intrusive suites and cut by numerous swarms of mafic and felsic dykes. Volcanic rocks of the Aillik Group are dominantly felsic and lesser mafic units; sedimentary rocks include felsic tuffaceous sandstone, sandstone and conglomerate.

The rocks of the two study areas, within the Aillik Group, have different degrees of deformation and preservation of their primary features. The Pomiadluk Point area is interpreted to represent a section of the Aillik Group that is stratigraphically below the Middle Head area; the latter is considered to be a younger section of the Aillik Group.

This report presents descriptions of rocks from these two sections based on field observations, provides preliminary structural interpretations, and presents two preliminary bedrock geological maps.

INTRODUCTION

This paper provides the results of detailed (1:10 000-scale) bedrock mapping of two study areas within the Aillik domain, one of three domains that comprise the Makkovik Province of Labrador (Figures 1 and 2). Field work during the summer of 2008 comprised mapping and sampling of two stratigraphic sections within the Ironbound Islands and Monkey Hill map areas (NTS 13O/02 and 13J/14).

The Aillik domain comprises the Aillik Group, a sequence of Paleoproterozoic metasedimentary and metavolcanic rocks, which has been intruded by numerous suites of variably deformed Paleoproterozoic intrusions and swarms of mafic and felsic dykes (Figure 2). A multiyear, regional-scale (1:50 000) project to map and interpret the bedrock geology of the Aillik domain is being undertaken at the Geological Survey of Newfoundland and Labrador by the second author. This project facilitated the detailed work reported here. Subsequent work will include petrological, geochemical, geochronological and isotopic studies as part of the first author's M.Sc. thesis at Memorial University.

LOCATION, ACCESS AND PHYSIOGRAPHY

Two areas are the focus of this project. Both study areas are adjacent to the coast and are readily accessible and generally well exposed compared to the more forested terrain inland. Access to these study areas (Figure 3) is possible by boat and by helicopter from the town of Makkovik.

Middle Head is located 14 km southwest of Makkovik and encompasses an area of 12 km^2. Bedrock exposure is poor in the heavily wooded areas to the north and south and in the central area because of bog/swamp; exposure is best on four prominent hills. In the southwest, about half of the forest cover has been destroyed by a fire more than a decade ago; consequently bedrock exposure is good. Relief is moderate and elevation ranges from sea level at the coast to 450 m at the top of the highest hill.

Thirteen km to the east of Makkovik is Pomiadluk Point, a peninsula covering an area of 16 km^2. In contrast to Middle Head, the coastal region of Pomiadluk Point dis-

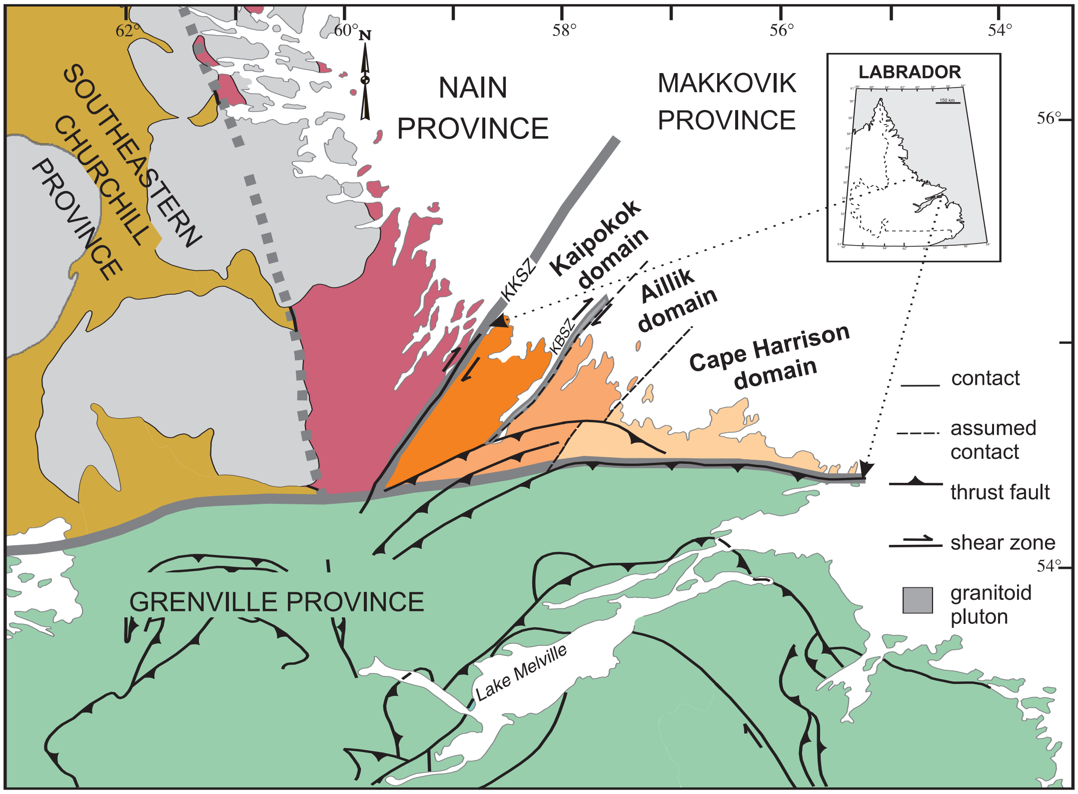

Figure 1. *Simplified tectonic framework of south-central Labrador after Wardle* et al. *(1997). The map shows the three domains of the Makkovik Province, the Kaipokok, Aillik and Cape Harrison domains. KBSZ – Kaipokok Bay shear zone; KKSZ – Kanairiktok shear zone.*

plays 85 to 90% exposure with the only hindrance being minor lichen cover. Exposure is best near the coast but outcrop is well exposed inland. Relief at Pomiadluk Point is relatively low with topography gently rising from sea level at the coast to 200 m inland. The peninsula provides a good cross-section through the north–south-striking units of the Aillik Group.

PREVIOUS WORK

In the late 1930s to 1950s, both the Geological Survey of Canada and the then Geological Survey of Newfoundland began mapping in the Makkovik Province (Kranck, 1939, 1953; Christie *et al.*, 1953; Douglas, 1953). Regional bedrock maps that encompassed both of the current study areas were published for the Makkovik Bay area (Gandhi *et al.*, 1969) and for the Aillik domain, at the scale of 1:100 000, by the Geological Survey of Newfoundland and Labrador (Bailey 1981; Gower *et al.* 1982; Gower and Ryan, 1987). The geochemistry and geochronology of the various intrusive suites have been reported in numerous papers and reports including Kerr (1989), Kerr *et al.* (1992), Kerr and Fryer (1994), Barr *et al.* (2001, 2007), Ketchum *et al.* (2001, 2002), Sinclair *et al.* (2002) and Hinchey and Rayner (2008). The lamprophyres have been investigated by King and McMillan (1975), Hawkins (1976), Foley (1982), Malpas *et al.* (1986), and Tappe *et al.* (2006). Both study areas, Pomiadluk Point and Middle Head, were included in a regional-scale study of the Makkovik Bay area by Clark (1973). The Aillik Group at Pomiadluk Point has been part of several geochemical and metallogenic studies (Wilton, 1996; Sinclair, 1999; Sinclair *et al.,* 2002) and a regional-bedrock study (Hinchey, 2007).

REGIONAL GEOLOGY

The Makkovik Province of Labrador is part of a Paleoproterozoic accretionary orogen wedged between the Nain Province to the north and the Grenville Province to the south (Figure 1; Ketchum *et al.*, 2002 and references therein). The Makkovik Province comprises Paleoproterozoic volcano-sedimentary units, variably deformed intrusive suites, reworked Archean rocks and abundant mafic dykes (Kerr *et al.*, 1992); it was affected by several episodes of metamorphism and plutonism from orogenic events, including the Makkovikian orogeny (1900–1710 Ma; Gower and Ryan, 1986; Ketchum *et al.*, 2002) and to a lesser extent the Labradorian (1710–1655 Ma; Gower and Krogh, 2002) and Grenvillian (1080–985 Ma; Gower and Krogh, 2002) orogenies. The province has been divided into three domains: the

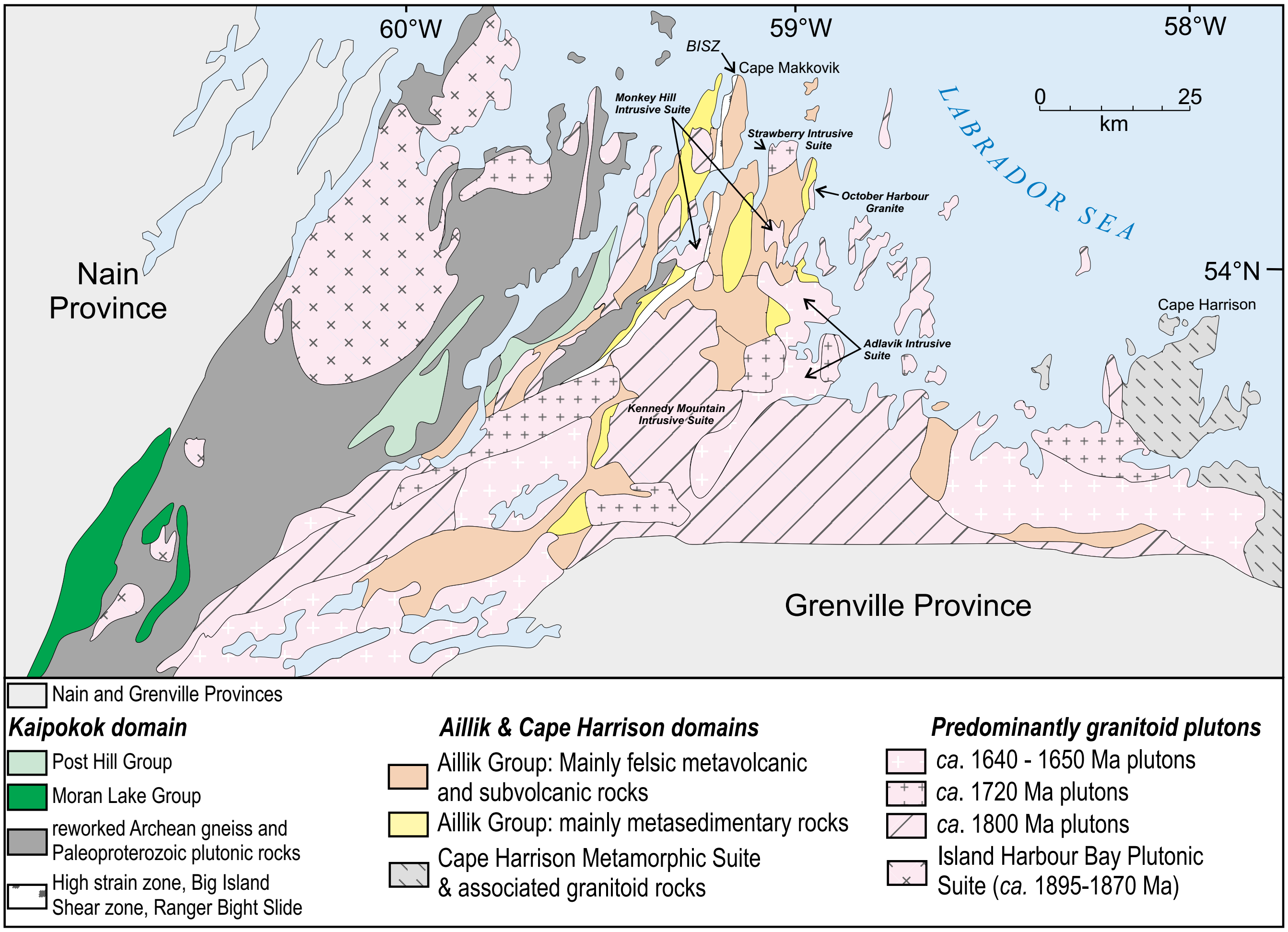

Figure 2. *Simplified geology of the Makkovik Province after Ketchum* et al. *(2002). Figure highlights plutonic and metamorphic suites and stratigraphic groups of interest. BISZ – Big Island shear zone.*

Kaipokok, the Aillik, and the Cape Harrison domains (Figures 1 and 2; Kerr *et al.*, 1996).

The Kaipokok domain contains amphibolite-facies polydeformed rocks, which include reworked Archean gneiss of the Nain Province and the unconformably overlying, volcano-sedimentary units of the Post Hill Group (previously termed Lower Aillik by Marten, 1977) and Moran Lake Group (Marten, 1977; Ryan, 1984). These two groups are thin belts of supracrustal strata and are interpreted to be stratigraphic equivalents (Wardle and Bailey, 1981). Foliated calc-alkaline plutons of the Island Harbour Bay Plutonic Suite (1895–1870 Ma) intrude the Kaipokok domain as well as lesser granitoid plutons of various ages (Figure 2; Barr *et al.*, 2001). The domain is bounded to the northwest by the Kanairiktok shear zone that separates Archean gneiss of the Nain Province from correlative deformed gneiss in the Makkovik Province; the latter gneiss was reworked during the Paleoproteozoic (Ermanovics and Ryan, 1990; Ermanovics, 1993; Ketchum *et al.*, 2002). The southern boundary is marked by a system of transpressive, ductile shear zones, termed the Kaipokok Bay shear zone that separates the Kaipokok domain from the Aillik domain (*cf.*, Kaipokok Bay structural zone of Kerr *et al.*, 1996; Ketchum *et al.*, 1997; Culshaw *et al.*, 2000). The Kaipokok domain is interpreted to be the foreland zone to the Makkovik Province (Kerr *et al.*, 1996).

The Aillik domain comprises: a) the Aillik Group, a sequence of metamorphosed, dominantly felsic and lesser mafic volcanic and sedimentary units; b) a slice of Paleoproterozoic reworked Archean orthogneiss; c) several foliated and non-foliated Paleoproterozoic intrusive suites dated at *ca.* 1858, 1800, 1720 and 1650 Ma and d) numerous swarms of dominantly mafic dykes (Kerr, 1989; Kerr *et al.*, 1992; Hinchey and Rayner, 2008). The southern boundary of the Aillik domain with the Cape Harrison domain is obscured by abundant younger plutonic rocks.

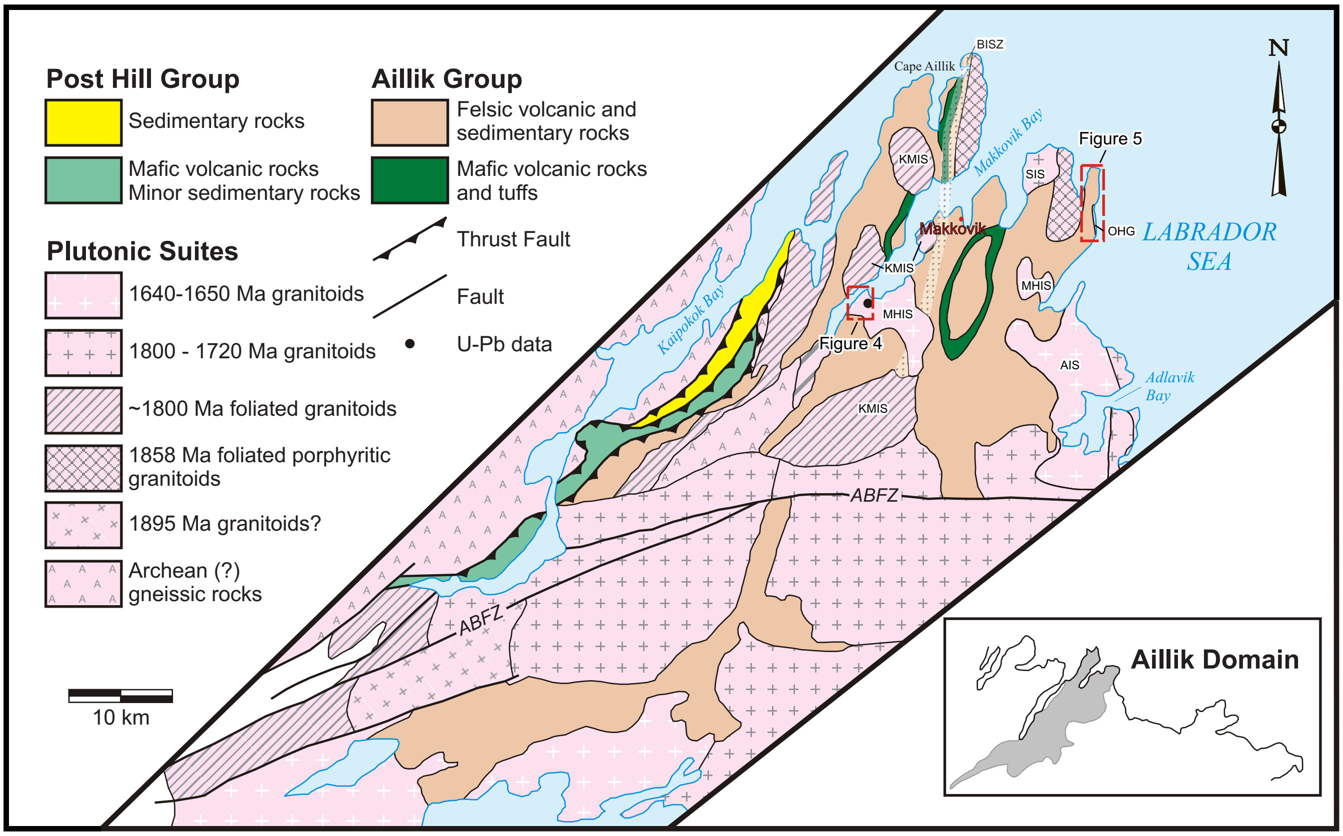

Figure 3. *The simplified geology of the Aillik Domain modified after Kerr* et al.*(1996) and Hinchey (2007). Location of study areas for a) Middle Head area (Figure 4); and, b) Pomiadluk Point area (Figure 5) are outlined in red. BISZ – Big Island shear zone; KMIS – Kennedy Mountain Intrusive Suite; MHIS – Monkey Hill Intrusive Suite; AIS – Adlavik Intrusive Suite; SIS – Strawberry Intrusive Suite; OHG – October Harbour granite.*

The Cape Harrison domain is composed primarily of plutonic suites dated at around 1800, 1720 and mainly 1650 Ma (Kerr, 1989, 1994; Kerr *et al.*, 1992). Most of the 1800 Ma plutonic suites are foliated and are interpreted to have been emplaced during the late stages of the Makkovikian orogeny (Gower and Ryan, 1986; Kerr, 1994). The undeformed 1720 and 1650 Ma suites are interpreted to be post-tectonic intrusions emplaced after the Makkovikian orogeny (Kerr *et al.*, 1992; Kerr, 1994). The Cape Harrison domain also contains tonalitic orthogneiss (Cape Harrison Metamorphic Suite) composed of juvenile material and minor supracrustal rocks (Figure 2; Kerr and Fryer, 1994; Ketchum *et al.*, 1997, 2002).

The Aillik and Cape Harrison domains are interpreted as a rifted-arc to composite-arc, based on field evidence as well as the composition and chemistry of preserved units (Ketchum *et al.*, 2002). The accretion of the Aillik and Cape Harrison domains marks the initiation of the 1900–1710 Ma Makkovikian orogeny, characterized by a penetrative planar fabric, abundant plutonic intrusions, regional deformation and upper greenschist- to lower amphibolite-facies metamorphism (Gandhi *et al.*, 1969; Sutton, 1972; Marten, 1977; Clark, 1979; Gower *et al.*, 1982; Kerr, 1994; Kerr *et al.*, 1996; Culshaw *et al.*, 1998; Ketchum *et al.*, 2001, 2002).

LOCAL GEOLOGY OF THE MAKKOVIK BAY AREA

The following section gives details of the rock types, structure and metamorphism of the Makkovik Bay area and is based on the reports by Gandhi *et al.* (1969), Clark (1973), Bailey (1981), Culshaw *et al.*(2000), Ketchum *et al.* (2002) and Hinchey (2007). Previous geochronological work from Schärer *et al.* (1988), Kerr (1989), Sinclair (1999), Cox *et al.*(2003), and Hinchey and Rayner (2008) is also included. This provides a tectonic framework and current understanding of the evolution of the area within which the two detailed study areas are located (Figures 4 and 5).

AILLIK GROUP

The Aillik Group (Figure 3) is composed of Paleoproterozoic metasedimentary and metavolcanic rocks (Gandhi *et al.*, 1969; Bailey, 1981; Gower *et al.*, 1982, Ketchum *et al.*, 2002). The stratigraphy of the Aillik Group is complicated because most of the units are not laterally continuous, and it has locally complex structures as a result of Makkovikian deformation; it is further complicated by late brittle faulting (Hinchey 2007; Hinchey and LaFlamme, *this volume*).

Aillik Group volcanic rocks are bimodal, composed dominantly of felsic units and lesser preserved mafic units (Clark, 1973; Gower *et al.*, 1982). In the Makkovik Bay area, the felsic volcanic rocks are dominated by rhyolite and felsic tuff, whereas the mafic volcanic rocks are dominated by basalt and lesser mafic tuff units. Abundant tuffites occur including primarily tuffaceous sandstone. Minor volcaniclastic sedimentary rocks outcrop in the area and are dominated by polymictic volcaniclastic breccias.

In the Makkovik Bay area, the Aillik Group sedimentary rocks are dominated by interbedded sandstone–siltstone and lesser polymictic conglomerate. Primary sedimentary structures include graded-bedding, crossbedding, ripple marks and load casts (Hinchey, 2007). Conglomerate occurs throughout the Aillik Group; three units in the Makkovik Bay area were described in detail by Hinchey (2007). Each of these units may contain several distinct beds of conglomerate separated by thinner beds of felsic volcanic and sedimentary units. Calc-silicate-rich beds and marble lenses locally occur within the sandstone and conglomerate (Hinchey, 2007).

INTRUSIVE SUITES

In the Makkovik Bay area, there are widespread intrusions of quartz–feldspar-porphyritic granite and various foliated and non-foliated plutonic suites. The sheet-like bodies of quartz–feldspar-porphyritic granite are interpreted to have intruded during formation of the Aillik Group at *ca.* 1858 Ma (Hinchey and Rayner, 2008). The abundant foliated and non-foliated plutonic suites that occur are interpreted to have formed either during the final compressional stages of the Makkovikian Orogeny or to postdate this event. These plutonic suites have largely been divisible into three age groupings: *ca.* 1800 Ma, which includes both foliated and non-foliated suites; *ca.* 1720 Ma non-foliated suites; and, ca. 1650–1640 Ma non-foliated suites (Kerr, 1989; Kerr *et al.*, 1992). The youngest plutonic event at *ca.* 1650–1640 Ma has been attributed to a far-field effect of the Labradorian orogeny (Kerr *et al.*, 1996).

ca. 1858 Ma Porphyritic Granite

In the Makkovik Bay area, the oldest plutonic intrusions are a suite of medium-grained, foliated, quartz–feldspar-porphyritic granites that intruded during the formation of the Aillik Group, at *ca.* 1858 Ma (Hinchey and Rayner, 2008). This suite of porphyritic granites occurs as sill-like, hypabyssal bodies within the Aillik Group (Hinchey, 2007).

ca. 1800 Ma Plutonic Suites

Only one plutonic suite with an age of ca. 1800 Ma outcrops in the Makkovik Bay area and has been termed the Kennedy Mountain Intrusive Suite (Kerr, 1994). These granitoid plutons contain a single penetrative fabric. They demonstrate an A-type granite geochemical signature, and are interpreted to have intruded during the final transpressive phase of the Makkovikian Orogeny (Kerr, 1994; Ketchum *et al.*, 2002).

ca. 1720 Ma Plutonic Suites

In the Makkovik Bay area, the *ca.* 1720 Ma granitoid suites include only the Strawberry Intrusive Suite, which yielded a U–Pb age of 1719 ± 2 Ma (Kerr, 1988; Kerr *et al.*, 1992). Kerr and Fryer (1994) have demonstrated that these undeformed plutons have an A-type granite geochemical signature. The October Harbour granite, located at Pomiadluk Point, was originally interpreted to be part of the Strawberry Intrusive Suite (Kerr, 1994); however, new data from Cox *et al.* (2003; *see* Geochronology page 212) suggest that it is a younger *ca.* 1640 Ma intrusion.

ca. 1650–1640 Ma Plutonic Suites

In the Makkovik Bay area, the *ca.* 1650–1640 Ma suites include the Monkey Hill Intrusive Suite and the Adlavik Intrusive Suite. Both suites intrude the Aillik Group. The Adlavik Intrusive Suite has been dated at *ca.* 1649 Ma (Kerr *et al.*, 1992) and the Monkey Hill Intrusive Suite is, based on intrusive relations, interpreted to be younger than the Adlavik Intrusive Suite (Kerr, 1994). The Monkey Hill Intrusive Suite is a biotite quartz monzonite to monzogranite and the Adlavik Intrusive Suite comprises layered gabbroic and dioritic rocks (Gandhi *et al.*, 1969; Gower *et al.*, 1982; Kerr, 1994). These plutons have been interpreted to have formed as a result of the Labradorian orogeny.

DYKES

Numerous syn- to post-volcanic dykes crosscut the Aillik Group in the Makkovik Bay area (King, 1963; Gandhi *et al.*, 1969; Malpas *et al.*, 1986; Hinchey, 2007). The dykes include at least two swarms of mafic dykes that are deformed and metamorphosed to amphibolite facies. One type is a fine-grained, garnet amphibolite, whereas the other contains recrystallized plagioclase-feldspar phenocrysts (Hinchey, 2007). Several generations of dykes postdate the regional penetrative fabric in the Aillik Group and in some

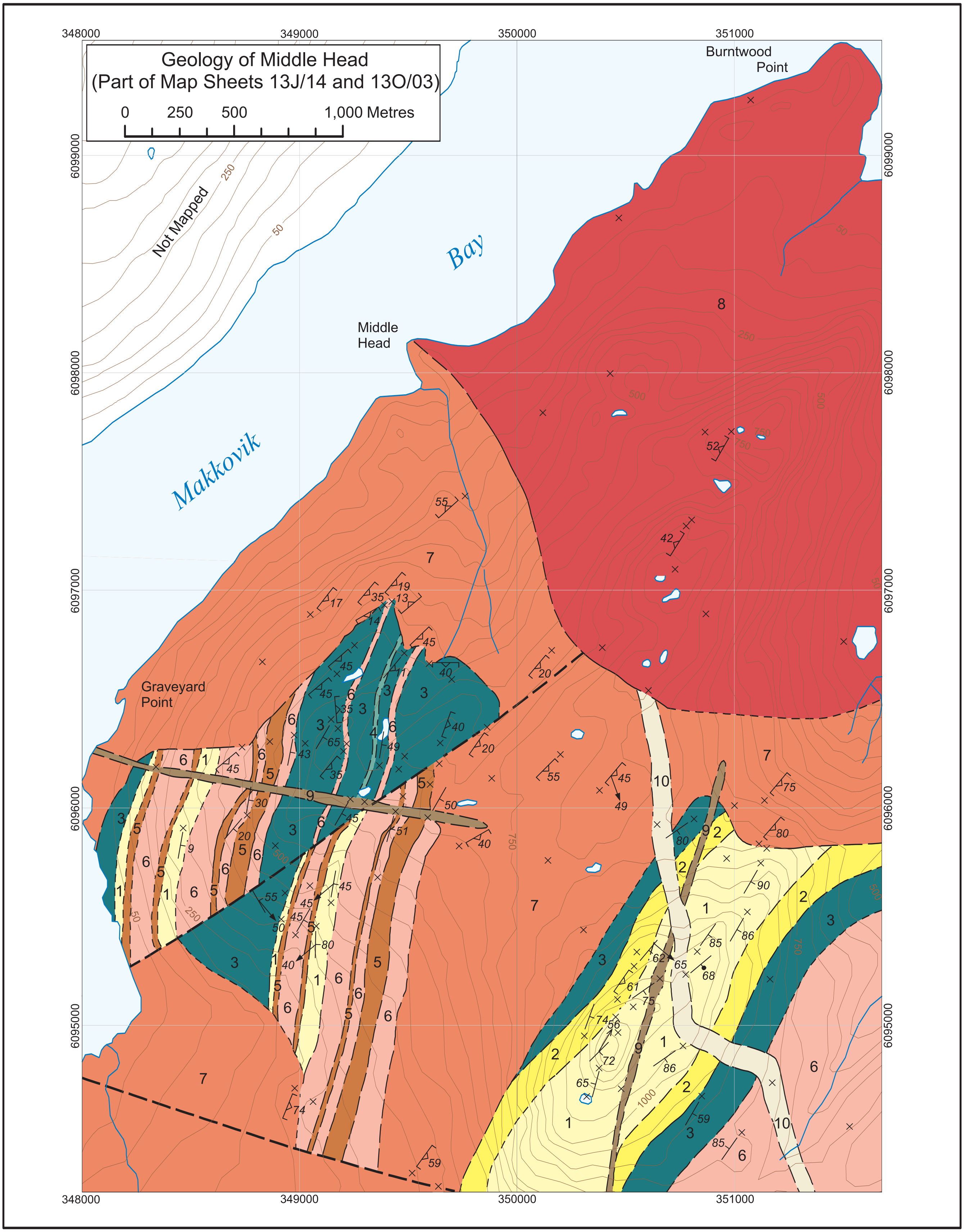

Figure 4. *Preliminary detailed geological map of the Middle Head area.*

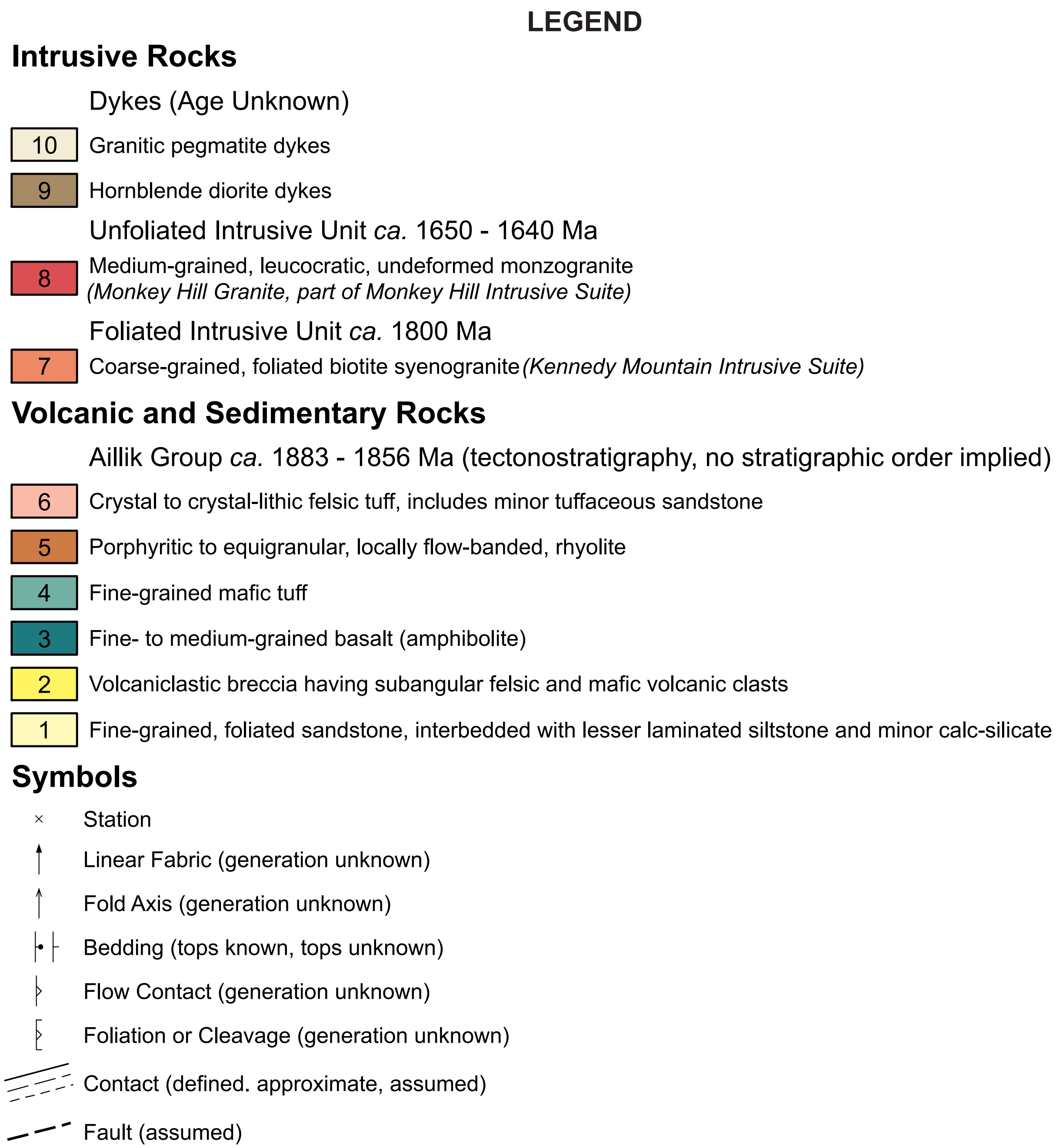

Figure 4. *Legend.*

of the ca. 1800 Ma intrusions. Hinchey (2007) identified at least seven types of dykes that intrude all volcano-sedimentary units of the Aillik Group including: diabase dykes, net-veined gabbroic dykes, metre-wide lamprophyric dykes, plagioclase megacrystic diabase dykes, aplitic granitic dykes, pegmatitic granitic dykes and diatreme dykes. Granitic aplite dykes are 2–10 m wide; they cut the amphibolite dykes but predate undeformed mafic dykes (Hinchey, 2007). Ultramafic lamprophyre dykes from Aillik Bay have been divided into two lithological groups: a) olivine lamproites with an age of 1374 ± 4 Ma and b) carbonatites having ages of 590–555 Ma (Tappe *et al.*, 2007). Rare breccia filled lamprophyre (diatreme) dykes from Ford's Bight were originally dated, based on fossil evidence, at *ca.* 197–164 Ma (King and McMillan, 1975), but a refined age of *ca.* 141 Ma, based on the U–Pb geochronology of perovskite, has now been determined (Tappe *et al.*, 2007). A swarm of undeformed feldspar-porphyritic felsic dykes outcrops at Pomiadluk Point.

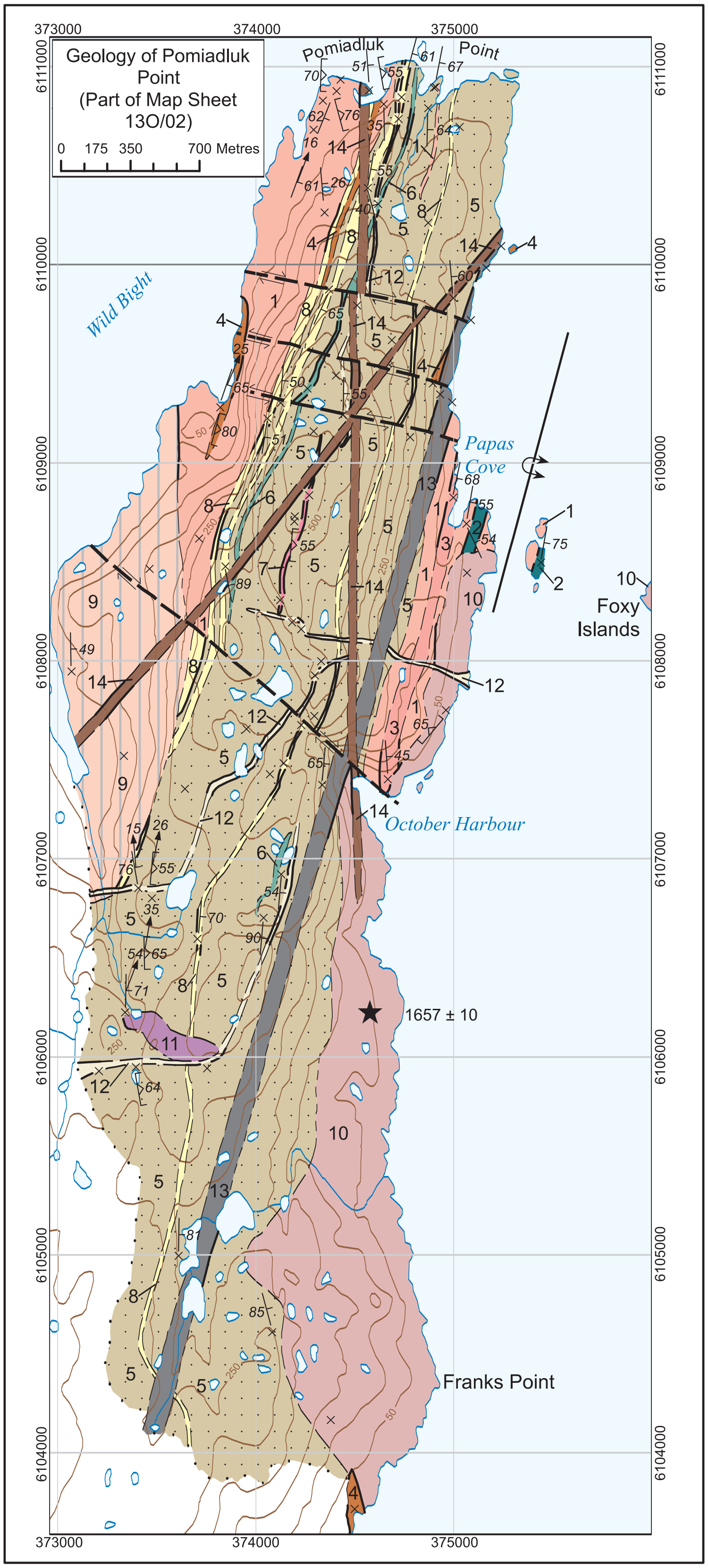

Figure 5. *Preliminary detailed geological map of the Pomiadluk Point area. The location of the zircon U–Pb age determined by LA-ICP-MS of 1657 ± 10 Ma for the October Harbour granite is plotted (Cox* et al.*, 2003).*

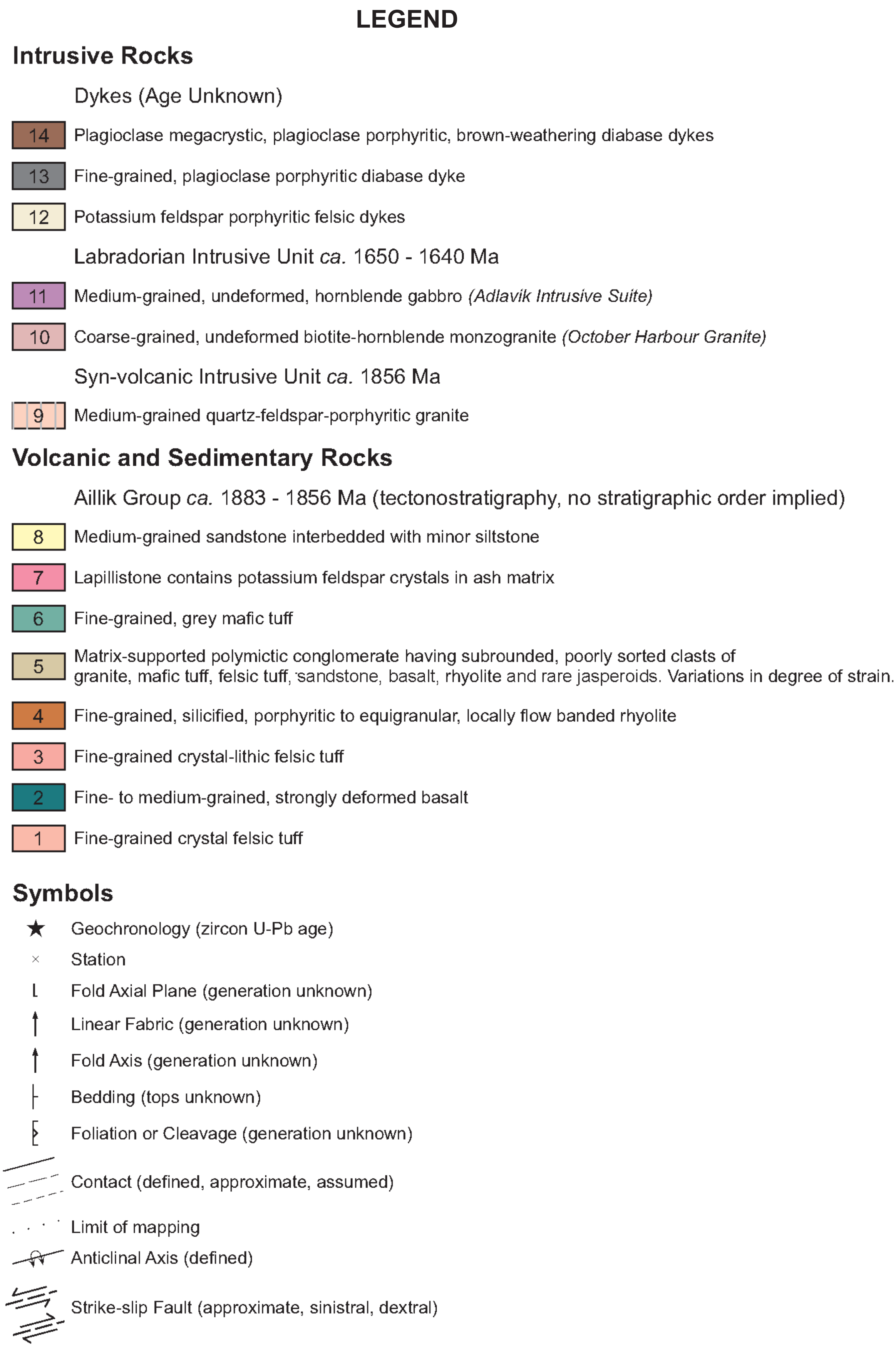

Figure 5. *Legend.*

STRUCTURE

Early studies of deformation in the Aillik Group characterized folding as large, gently plunging, upward-facing structures (Clark, 1973, 1979; Gower *et al.*, 1982). Clark (1979) reported that the Aillik Group, in the Makkovik Bay area, has undergone four stages of deformation that produced regional folding, a penetrative fabric and late brittle faulting. Culshaw *et al.* (2000) indicated that six stages of deformation are required to explain structures in the whole of the Makkovik Province of which only D_3 to D_6 affected the Aillik domain. Culshaw *et al.* (2000) proposed that the folding and the penetrative fabric are the result of sinistral transpression, regionally a D_3-event, and that shear zones in the Aillik Group were subsequently reactivated during D_4- and $D_{5\text{-}6}$-events.

Hinchey (2007) and Hinchey and Rayner (2008) concluded that to explain the patterns of rock units, the structural data, and the range in ages, the deformational history of the Aillik Group must be more complex than previously interpreted. Hinchey (2007) suggested that the Aillik Group, in the Makkovik Bay area, is characterized by regional-scale, closed to tight, moderately plunging, upright to overturned folds (F_1 locally) that were subsequently refolded (F_2 locally). A 1-km-wide, highly strained zone extends southward from Cape Makkovik through Big Island and inland to the south of Ranger Bight. This was previously defined as the Ranger Bight slide by Clark (1979) or straightened zone by Culshaw *et al.* (2000) and the Big Island Shear zone (BISZ) Ketchum *et al.* (2002). Hinchey (2007) suggested that the BISZ likely represents one of a series of ductile shear zones that excise parts of the Aillik Group. The vergence of the regional folds changes about this shear zone, from ones that verge to the northwest in the west to folds that verge to the northeast in the east (Hinchey, 2007).

METAMORPHISM

Previous work has indicated that the volcanic and sedimentary rocks of the Aillik Group have undergone upper greenschist- to lower amphibolite-facies metamorphism during the Makkovikian Orogeny (Clark, 1973; Bailey, 1981; Gower *et al.*, 1982; Sinclair, 1999; Hinchey, 2007). In the Makkovik Bay area, the Aillik Group exhibits a variation in metamorphic grade. Some sections of the Aillik Group demonstrate chlorite-grade metamorphism, and only minor deformation, resulting in the preservation of primary features including crossbedding and ripple marks (Hinchey, 2007). Other parts of the Aillik Group show lower amphibolite-grade metamorphism, are highly strained, and most primary features are destroyed (Clark, 1973, 1979; Bailey, 1981; Sinclair, 1999; Wilton, 1996; Hinchey, 2007). Geochemistry and field observations indicate that sodic and alkalic alteration is widespread throughout the Aillik Group, whereas metavolcanic and sedimentary units to the south of Cape Makkovik are commonly silicified (Gandhi, 1978; Bailey, 1981; Gower and Ryan, 1987; MacDougall, 1988; Sinclair, 1999; Hinchey, 2007).

GEOCHRONOLOGY

Relevant U–Pb geochronological data from the Makkovik Bay and surrounding area are summarized below. The first U–Pb zircon ages, measured via TIMS analysis, for the Aillik Group were reported by Schärer *et al.* (1988), who reported two intercept ages at 1861 +9/-3 Ma and 1856 ± 2 Ma for a rhyolite flow and an ash-flow tuff, respectively. Hinchey and Rayner (2008) reported three zircon dates from the Aillik Group using SHRIMP geochronology: a) a felsic tuff from a high-strain zone at Aillik Bay yielded an age of 1861 ± 6 Ma; b) a rhyolite from the eastern side of Kaipokok Bay yielded an age of 1883 ± 7 Ma; and 3) a rhyolite from Ford's Bight area yielded an age of 1876 ± 6 Ma. Hinchey and Rayner (1980) also reported a U–Pb SHRIMP age of 1858 ± 6 Ma from the quartz–feldspar-porphyritic granite, interpreted to be syn-volcanic with the Aillik Group. Sinclair *et al.* (2002) investigated a porphyritic granite, and reported a discordant intercept TIMS U–Pb age of 1929 +10/-9 Ma. The interpretation of this age is difficult to reconcile with the geological field relationships (Hinchey, 2007).

Kerr (1989) produced 10 U–Pb TIMS ages for zircon crystallization from abundant post-volcanic, variably foliated to undeformed plutons that occur throughout the Aillik domain. The plutonic rocks relevant to this study include the Kennedy Mountain Intrusive Suite, the Adlavik Intrusive Suite and Monkey Hill Intrusive Suite (Figure 3). The Kennedy Mountain Intrusive Suite, at Kennedy Mountain, was dated at 1801 ± 2 Ma (Barr, 2007). The Adlavik Intrusive Suite yielded an emplacement age of 1649 ± 1 Ma and the Monkey Hill Intrusive Suite yielded a discordia line giving an imprecise lower age limit of *ca.* 1641 Ma (Kerr *et al.*, 1992). The upper age limit for the Monkey Hill Intrusive Suite is *ca.* 1649 Ma based on the occurrence of xenoliths interpreted to be Adlavik Intrusive Suite near the margins of the Monkey Hill Intrusive Suite (Kerr *et al.*, 1992; Kerr, 1994).

The October Harbour granite was originally interpreted as being part of the ca. 1720 Ma Strawberry Intrusive Suite because its compositions of primary and secondary minerals are similar to those in members of the suite (Gower *et al.*, 1982; Kerr, 1989). Cox *et al.* (2003) dated a sample of this granite from the study area by LA-ICP-MS (Laser ablation –inductively coupled plasma–mass spectrometer) and determined a zircon U–Pb age of 1657 ± 10 Ma indicating that this intrusion is actually part of the *ca.* 1650–1640 Ma intrusive suites (*see* Figure 5 for location).

GEOLOGY OF THE STUDY AREAS

The geology of two study areas is presented in detail below. Figure 4 is the detailed (1:10 000 scale) map of the Middle Head area; whereas, Figure 5 shows the detailed (1:10 000 scale) map of the Pomiadluk Point area.

MIDDLE HEAD

The Aillik Group at Middle Head occurs as two separate, northeasterly trending areas (referred to as the western and eastern areas) separated by the intrusion of foliated granite (Figure 4). Each area contains mafic and felsic volcanic rocks and sedimentary rocks metamorphosed to lower amphibolite-facies. The volcanic rocks, largely exposed in the western area, are dominated by rhyolite, felsic tuff, tuffaceous sandstone and basalt with lesser mafic tuff. The eastern area is dominated by sandstone and lesser mafic volcaniclastic breccia and basalt. Two granites occur at Middle Head; an older foliated biotite–hornblende syenogranite intrudes the Aillik Group, and is, in turn, intruded by a younger undeformed biotite–hornblende monzogranite. Several sets of undeformed mafic dykes and granitic pegmatite dykes cut the Aillik Group and the deformed granite.

Aillik Group

Sandstone (Unit 1)

Unit 1 (Figure 4) consists of five, roughly north- to northeast-striking units of recrystallized grey sandstone, which vary in width from 20 to 300 m, are exposed in the study area. The sandstone is composed of feldspar, quartz and biotite, is fine grained and is interbedded with lesser siltstone and is foliated parallel to weak bedding. Calc-silicate bands are present toward the contact with the stratigraphically overlying volcaniclastic breccia (Unit 2) in the southeast part of the study area. The sandstone locally preserves small-scale folds in its more competent layers (Plate 1A) and the only primary feature preserved is bedding.

Volcaniclastic Breccia (Unit 2)

Unit 2 is a dark green–grey volcaniclastic breccia located solely in the eastern area of Middle Head (Figure 4). The unit has an epidote-rich matrix and contains clasts of felsic and mafic volcanic rocks (Plate 1B). These clasts are subangular to angular, range up to 7 cm in diameter, and are matrix supported. The contact of this unit with the underlying sandstone is gradational over several tens of metres, the sandstone showing increasing alteration and clast content toward the breccia.

Basalt (Unit 3)

Unit 3 is a sequence of black, grey-weathering, fine- to medium-grained basalt flows. The unit outcrops in both the western and eastern sections of the Aillik Group in Middle Head (Figure 4). The flows are up to 60 m thick and small relict elongated pillows are seen within various parts of the basalt pile. The pillows weather preferentially and are up to 15 cm long and 10 cm wide. A facing direction could not be determined from the pillows because of deformation in the unit.

Grain-size coarsening is evident in layers that are up to 25 m wide. These layers are a metamorphic feature, reflecting amphibolite-facies metamorphism. Locally, the basalt contains quartz and epidote veins and abundant epidote nodules (Plate 1C). Beds of dark, recrystallized quartzite (relict chert) layers (up to 2 m wide) occur within the basalt.

Mafic Tuff (Unit 4)

Unit 4 (Figure 4) is a 25-m-wide, continuous, south-striking, grey-weathering, mafic tuff that lies within the basalt sequence south of Middle Head. Unit 4 is overlain and underlain by basalt. The tuff is fine grained, has a sugary texture and is foliated parallel to bedding.

Rhyolite (Unit 5)

Unit 5 comprises several porphyritic to equigranular, dark pink to light pink-weathering rhyolite flows that form north-trending, continuous layers within the western outcrop area of the Aillik Group (Figure 4). The rhyolite flows are approximately 35 m wide and are locally flow-banded. In the porphyritic rhyolite, phenocrysts are feldspar crystals that range in length from 2 to 3 mm. The rhyolite flows are moderately foliated, prominently laminated, recrystallized and silicified.

Felsic Tuff (Unit 6)

Unit 6 (Figure 4) is a fine-grained, felsic crystal to crystal-lithic tuff (Plate 1D) that occurs as several horizons throughout the map area. The tuffaceous sandstone is bedded, fine grained and pinkish-grey, and are 2–8 cm thick. The tuff locally contains elongated clasts of a darker coloured tuff that are up to 2 cm long. Minor, thin layers of tuffaceous sandstone are interbedded with the tuff. The crystal-lithic tuff weathers white to pink, is silicified and commonly contains very small (<1 cm) lithic fragments. The felsic tuff has been recrystallized and contains a foliation.

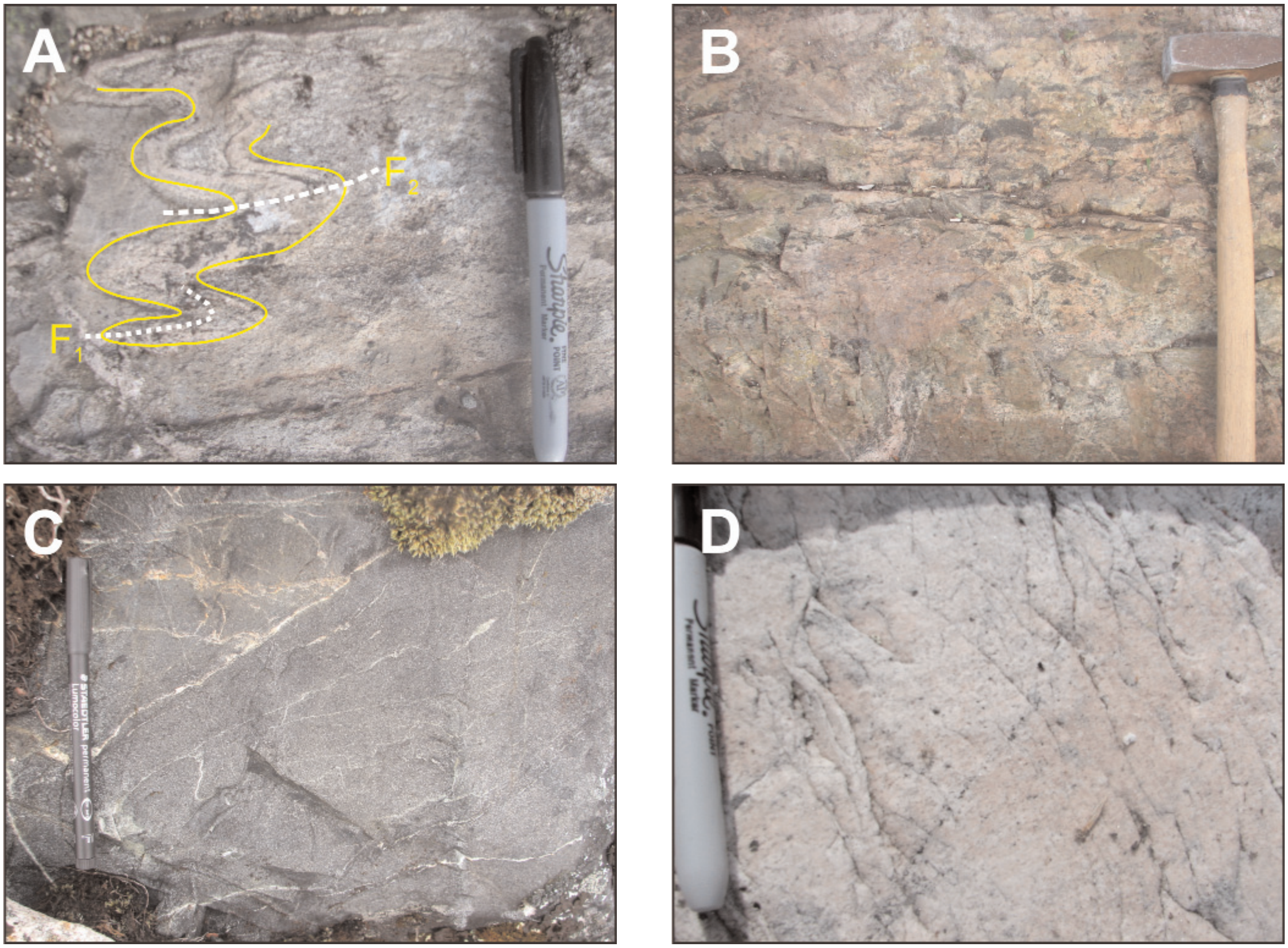

Plate 1. *Representative photographs of volcanic and sedimentary rocks of the Aillik Group exposed at Middle Head: A) folds in sandstone, note the axial trace of both F_1 and F_2 folds are illustrated; B) epidote altered volcaniclastic breccia; C) quartz veining in basalt; and D) felsic crystal tuff.*

Foliated Syenogranite

Biotite–Hornblende Syenogranite (Unit 7)

Unit 7 (Figure 4) is a coarse-grained, equigranular to potassium feldspar porphyritic, biotite–hornblende syenogranite (Plate 2A) that has intruded the Aillik Group at Middle Head (Plate 2A). The syenogranite is orange-grey and weathers pinkish grey. The syenogranite is very strongly foliated and moderately lineated. Accessory phases include: hornblende (3%), biotite (1 to 2%), and magnetite (0.5 to 1%), and these minerals characteristically define the variably developed foliation. This syenogranite is lithologically similar to the nearby Cross Lake granite, the latter being part of the Kennedy Mountain Intrusive Suite, and is interpreted as being part of that suite.

Undeformed Monzogranite

Biotite–Hornblende Monzogranite (Unit 8)

Unit 8 is a beige, light orange-weathering, equigranular to slightly plagioclase-porphyritic, biotite–hornblende monzogranite (Plate 2B) belonging to the Monkey Hill Intrusive Suite. It has intruded the deformed syenogranite (Unit 7) in the northern part of the Middle Head study area. The monzogranite is leucocratic undeformed, massive, and medium grained. Locally developed plagioclase phenocrysts are typically 1 to 2 cm long. Accessory biotite, chlorite, hornblende, fluorite, and magnetite occur throughout the unit.

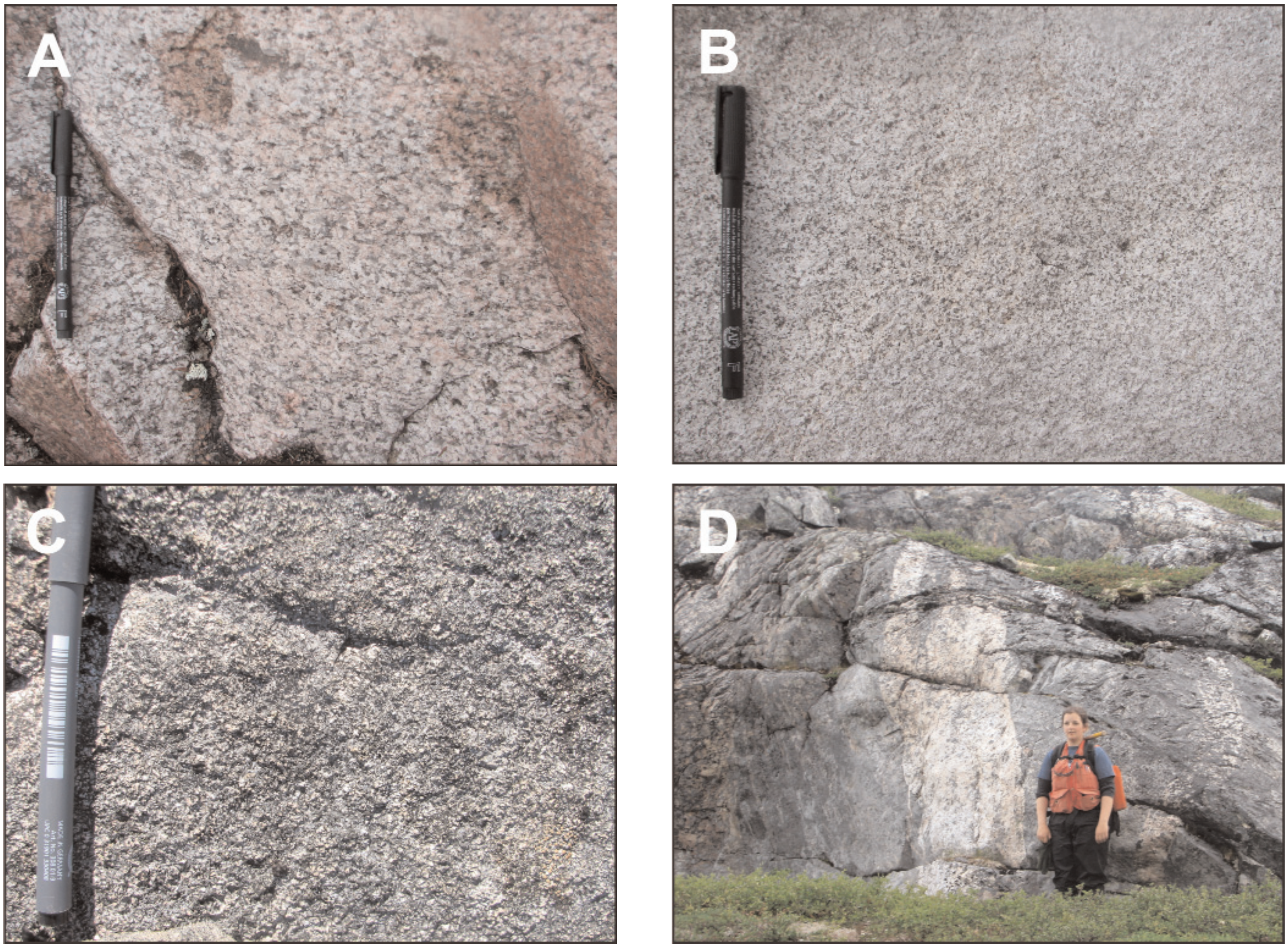

Plate 2. *Representative photographs of intrusive rocks at Middle Head: A) coarse-grained, foliated biotite–hornblende syenogranite; B) medium-grained, undeformed biotite–hornblende monzogranite; C) medium-grained, hornblende diorite dyke; and D) granitic pegmatite dyke intruding thin-bedded sandstone–siltstone of the Aillik Group.*

Dykes (Unit 9)

Variably trending deformed amphibolite dykes (not shown on Figure 3) cut the Aillik Group at Middle Head. The dykes are fine grained, green, and vary in width from 0.5 to 5 m. Mappable mafic dykes comprise Unit 9 and are typically up to 25 m wide, undeformed, steeply dipping, hornblende–diorite dykes that cut the Aillik Group (Plate 2C). The dykes are medium grained, weather grey-green and contain euhedral prismatic hornblende that gives rise locally to appinitic texture in the rock. Unit 10 is the largest of a pervasive swarm of granite pegmatite dykes that has intruded all units in the Middle Head area, apart from the undeformed monzogranite (Plate 2D). These granitic pegmatite dykes are considered to be related to the intrusion of the biotite–hornblende monzogranite (Unit 8) based on their field relationships and similar composition.

Preliminary Structural Interpretation

The dominant fold style in the area is that of regional-scale, tight to isoclinal, overturned and moderately plunging F_2 folds that verge to the northwest. Locally small-scale F_1 folds are preserved. The axial traces of the regional F_2 folds are parallel to the main, pervasive northeast-trending foliation in the area.

POMIADLUK POINT

Pomiadluk Point is composed almost entirely of deformed and metamorphosed, felsic tuff and conglomerate, and lesser rhyolite and basalt of the Aillik Group (Figure 5). Crossbedding and graded-bedding within the conglomerate and felsic tuff indicate that the successions 'youngs' to the west; whereas, a baked contact of a felsic tuff on an island to the east of Papas Cove, indicates younging to the east, supporting at least one regional anticline in the area. A deformed syn-volcanic intrusion and an undeformed granitic intrusion also outcrop in this area, along with several suites of deformed and undeformed mafic dykes and felsic dykes. The rocks at Pomiadluk Point have undergone greenschist- to amphibolite-facies metamorphism and display evidence of at least three phases of deformation accompanied by at least two phases of folding.

Aillik Group

Felsic Tuff (Units 1 and 3)

Felsic tuff forms two distinct units (Units 1 and 3) across Pomiadluk Point (Figure 5). Unit 1 is a grey, white-weathering, foliated, laminated, fine-grained felsic crystal tuff. It locally contains up to 4% fragments of intermediate volcanic material, less than 1 cm in length, and up to 2% calc-silicate-rich pods. There are compositional variations within Unit 1. The easternmost exposure of Unit 1, interpreted to be the base of the section exposed at Pomiadluk Point, is 40 m wide and is contact metamorphosed by the overlying basalt, indicating that the sequence faces to the east. A 500-m-wide horizon occurs at the top of the Pomiadluk Point section and is locally sheared (Plate 3A). Unit 1 contains thin veins of orange calcite and green diopside.

Unit 3 is a crystal-lithic felsic tuff, 50 m wide, occurring south of Papa's Cove. It weathers a pale pink–orange colour but is grey on fresh surface. It is thin and well bedded, fine grained, and contains 2% grey fragments of intermediate composition.

Basalt (Unit 2)

Unit 2 (Figure 5) is a dark green to grey, foliated, fine- to medium-grained, epidote-altered basalt (Plate 3B) that is exposed in two 30-m-wide outcrops near Papa's Cove and the adjacent islands. It is likely the same unit repeated by folding. Hinchey (2007) reported that this unit is cut by numerous thin calcite–epidote–titanite–diopside veins and contains galena–covelite–molybdenite vugs and nodules. The basalt displays a well-developed tectonic fabric characterized by the alignment of amphibole and biotite (Hinchey, 2007).

Rhyolite (Unit 4)

Unit 4 (Figure 5) is composed of several distinct rhyolite flows, which are 30 to 40 m wide, and are interbedded within Units 1, 6 and 9; these flows are laterally discontinuous. The rhyolite is typically dark pink, weathers white to orange and is locally flow-banded (Plate 3C). It is mainly equigranular but locally it is porphyritic containing feldspar crystals 2 to 3 mm in diameter. The rhyolite is moderately foliated, recrystallized and silicified.

Conglomerate (Unit 5)

Unit 5 (Figure 5) is composed of several polymictic conglomerate beds separated by thin and laterally discontinuous beds of felsic tuff, lapillistone and mafic tuff; the unit is about 700 m wide. The conglomerates are poorly sorted and contain, subrounded to rounded clasts of granite (70%), felsic tuff (20%), mafic tuff (10%), rhyolite (5%) and sandstone (5%) as well as minor quartzite, basalt and jasperoid all supported by a quartz–feldspar matrix. The clasts in the conglomerate are variably elongated due to deformation and preservation of size varies with rock type (Plate 3D); granite clasts range up to 35 cm in length and 30 cm in width; tuff clasts range up to 12 cm in length and 8 cm in width; rhyolite and sandstone clasts are generally rounded and range up to 10 cm in diameter. Unit 5 exhibits graded bedding indicating 'younging' to the west and it is moderate to strongly foliated and lineated. The felsic tuff clasts in the conglomerate are strongly attenuated due do the ductile behaviour of this lithology during deformation.

A belt of highly strained conglomerate occurs on the eastern edge of this unit. This belt is characterized by strongly attenuated clasts, relative to the western exposures of this unit. The subrounded to elongate granite clasts, up to 3 cm in diameter, make up 5% of the unit. Volcanic clasts and tuffite clasts are elongate to strongly attenuated, forming compositional bands that define the foliation. The conglomerate is locally characterized by a pervasive epidote alteration.

Mafic Tuff (Unit 6)

Mafic tuff of Unit 6 (Figure 5) outcrops as two horizons, up to 8 m thick, that pinch out to the north and south and are interbedded with the conglomerate of Unit 5. The eastern exposure of mafic tuff occurs just west of October Harbour, and is only 20 m in strike length whereas the western exposure of mafic tuff is around 2 km in strike length. Both tuffs are light grey weathering, fine grained, well bedded, and are recrystallized (Plate 3E).

Lapillistone (Unit 7)

Unit 7 (Figure 5) is a 5-m-wide unit of pink, silicified lapillistone that occurs interbedded within conglomerate and outcrops inland, west of Papa's Cove. This lapillistone contains prominent subrounded, 4 to 5 mm in diameter lapilli fragments making up 65% of the rock.

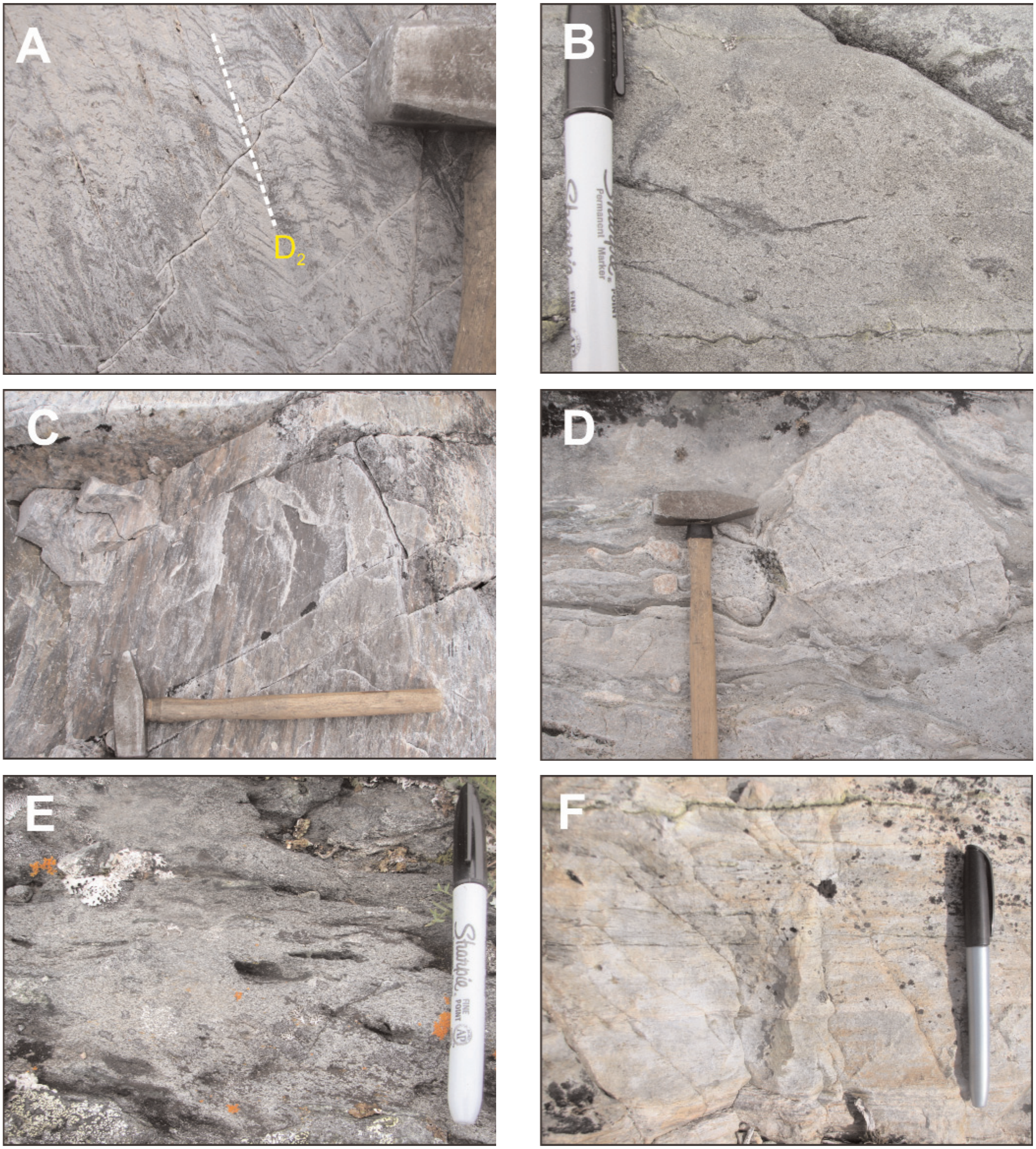

Plate 3. *Representative photographs of the Aillik Group exposed at Pomiadluk Point; A) foliation development (D_2) in a felsic tuff; B) basalt; C) foliated flow-banded rhyolite; D) a large granite clast and smaller clasts of varying lithology in a polymictic conglomerate; E) foliated, sugary textured mafic tuff; and, F) bedded sandstone-siltstone.*

Siltstone–sandstone (Unit 8)

Unit 8 comprises two horizons of interbedded siltstone–sandstone that are separated by a thin horizon of conglomerate. The siltstone–sandstone beds are about 10 m thick and composed of laminated to thinly bedded, grey siltstone and beige, thin- and parallel-bedded sandstone (Plate 3F). Crossbedding and graded-bedding are preserved in the sandstone on the western side of Pomiadluk Point, and indicate younging to the west. The unit contains a foliation that is parallel to planar bedding.

Foliated Granite

Quartz–Feldspar-Porphyritic Granite (Unit 9)

Unit 9 (Figure 5) is a pink, brown–pink-weathering, foliated, medium-grained, recrystallized quartz–feldspar-porphyritic granite that outcrops on the southwestern side of Pomiadluk Point (Plate 4A). The subhedral phenocrysts of quartz and feldspar are 3 to 5 mm in diameter. Discontinuous, rusty, sulphide horizons, 2 to 6 m wide, occur within the granite. Locally, this unit contains ellipsoidal mafic-oxide pods of biotite, magnetite and amphibole that are typically 2 to 8 cm long, 1 to 4 cm thick, and account for less than 2% modal abundance of the rock. Accessory phases of magnetite and biotite occur throughout the unit. This granite is part of the *ca.* 1858 Ma suite of granites, which have been interpreted as sheet- or sill-like bodies that intruded synchronous with formation of the volcanic sequence (Hinchey, 2007).

Non-Foliated Plutonic Rocks

October Harbour Granite (Unit 10)

The October Harbour granite (Unit 10; Figure 5) is an undeformed, beige–orange, pink- to orange-weathering, coarse-grained, potassium-feldspar-porphyritic, biotite–hornblende monzogranite (Plate 4B). It has intruded the Aillik Group along the coast between Papa's Cove and Frank's Point. The potassium-feldspar phenocrysts are 8 mm long and are set in an equigranular matrix of plagioclase and quartz. The biotite and hornblende are 3 mm in length and form about 15% of the rock. The monzogranite also contains accessory fluorite.

Hornblende Gabbro Sheet (Unit 11)

Unit 11 (Figure 5) is a single flat-lying sheet of hornblende gabbro exposed at Pomiadluk Point, 1200 m southwest of October Harbour. It has a thickness of less than 10 m and has intruded the polymictic conglomerate of Unit 5, displaying chilled margins along its edges. The dyke is undeformed, medium grained, net veined and contains 3-mm-long, euhedral hornblende crystals (Plate 4C). This dyke is tentatively interpreted being part of the Adlavik Intrusive Suite based on its similarity and proximity to the latter, more extensive plutonic rocks, which outcrop to the south of the current study area (*see* Hinchey, 2007).

Dykes (Units 12–14)

Several generations of mafic and felsic dykes that have intruded the Aillik Group are exposed at Pomiadluk Point. The earliest generation forms a series of dark green, amphibole-bearing metadiabase dykes, which range from 4 to 8 m in width. These dykes have been folded, boudinaged and metamorphosed (Plate 4D).

Three groups of undeformed dykes (Units 12–14; Figure 5) are also exposed in the study area and they cut all the older rock units. Unit 12 is the oldest swarm and consists of a number of orange, beige- and orange-weathering, medium-grained, feldspar-phyric, felsic dykes (Plate 4E). The dykes are 5 to 30 m wide and their orientation is locally controlled by jointing in the host rocks. Unit 13 is a single, black, north-northeast-striking, 50-m-wide, plagioclase-porphyritic diabase dyke (Plate 4F). The plagioclase porphyries are up to 10 cm wide and have been extensively altered by epidote. Unit 14 is a suite of 2-m- to 30-m-wide, northeast-striking, brown, medium-grained, plagioclase-megacrystic, biotite–hornblende diabase dykes (two of which are large enough to be mapped in Figure 4).

Mineralization

At Pomiadluk Point mineralization occurs in two units. The polymictic conglomerate (Unit 5) contains 10-cm-wide clasts of undeformed monzogranite containing about 3% disseminated grains of galena and molybdenite. Within the basalt flows (Unit 2), diopside–feldspar±calcite±epidote pods rich in galena, covelite and molybdenite have been documented by Hinchey (2007). An auriferous quartz vein (up to 82 ppm in grab sample) hosted within a deformed biotite-bearing diabase dyke has been reported by Wilton (1996) on the northern coast of Pomiadluk Point.

Preliminary Structural Interpretation

Field work and unit distribution indicate at least three stages of deformation in the Aillik Group, including two stages of folding. Evidence for the earliest period of folding (F_1) is preserved locally by small-scale, re-oriented isoclinal folds. The area is locally highly strained and contains metre-wide shear zones that may have developed contemporaneously with the pervasive planar fabric (D_2) that is preserved in the area. Continued shortening resulted in folding (F_2) at

Plate 4. *Representative photographs of intrusive rocks of the Aillik domain at Pomiadluk Point: A) foliated, quartz–feldspar porphyritic granite; B) fine-grained, undeformed October Harbour biotite–hornblende monzogranite; C) net-veined gabbro sill; D) amphibolite dyke that is infolded (F_2) with, but cutting the foliation of, a felsic tuff from the Aillik Group; E) potassium feldspar-phyric felsic dyke; and, F) undeformed plagioclase-megacrystic diabase dyke.*

a regional scale. At Pomiadluk Point, these regional-scale folds vary from open to isoclinal, are upright to overturned, verge to the northwest and their axial planes strike north to northeast. The fold axial traces are parallel to the foliation in the area, which strike north to northeast.

FUTURE WORK

This report is part of the initial stages of the first author's M.Sc. project at Memorial University. The goal of this project is two-fold: a) to create detailed maps and tectonostratigraphic sections for the Aillik Group; and b) to use these detailed maps and tectonostratigraphy to unravel the formation and evolution of the Aillik Group, through geochronological, geochemical and isotopic laboratory studies. This work will provide much needed detailed stratigraphic control for the Aillik Group that can then be correlated with regional-scale mapping. The rocks of the Aillik Group preserve the timing of formation as well as the timing of deformational and structural events of the Makkovik Province. Analyzing and constraining these events is of critical importance in placing robust constraints on the regional evolution.

Laboratory work will include major- and trace-element geochemistry, isotope analyses of Sr, Nd and Hf, petrographic analyses, and U–Pb geochronology. Five samples from the study areas have been submitted for U–Pb zircon geochronology and hopefully will provide insights into the formation and structural evolution of the Aillik Group.

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