Bedrock Geological Mapping in the Western Cobequid Highlands, Northern Mainland Nova Scotia

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Introduction

The Cobequid Highlands of northern mainland Nova Scotia form part of the southern margin of Avalonia (Hibbard *et al*., 2006), a fault-bounded terrane positioned inboard from Meguma and outboard of Ganderia (Fig. 1). Previous studies have shown that the area predominantly comprises Late Neoproterozoic to Late Devonian to Early Carboniferous volcanic, sedimentary and intrusive rocks (e.g. Pe-Piper and Piper, 2002).

Investigations conducted within the eastern Cobequid Highlands by the Department of Natural Resources between 2010 and 2011 highlighted the mineral potential of the area through the discovery of a significant granite-related high-field-strength/ rare-earth element (HFSE/REE) prospect (MacHattie, 2011) and widespread occurrences of volcanic-related epithermal-style Au (MacHattie, 2012, 2013). Additionally, new U-Pb zircon ages indicate the presence of some of the oldest Neoproterozoic crust found within Avalonia, as

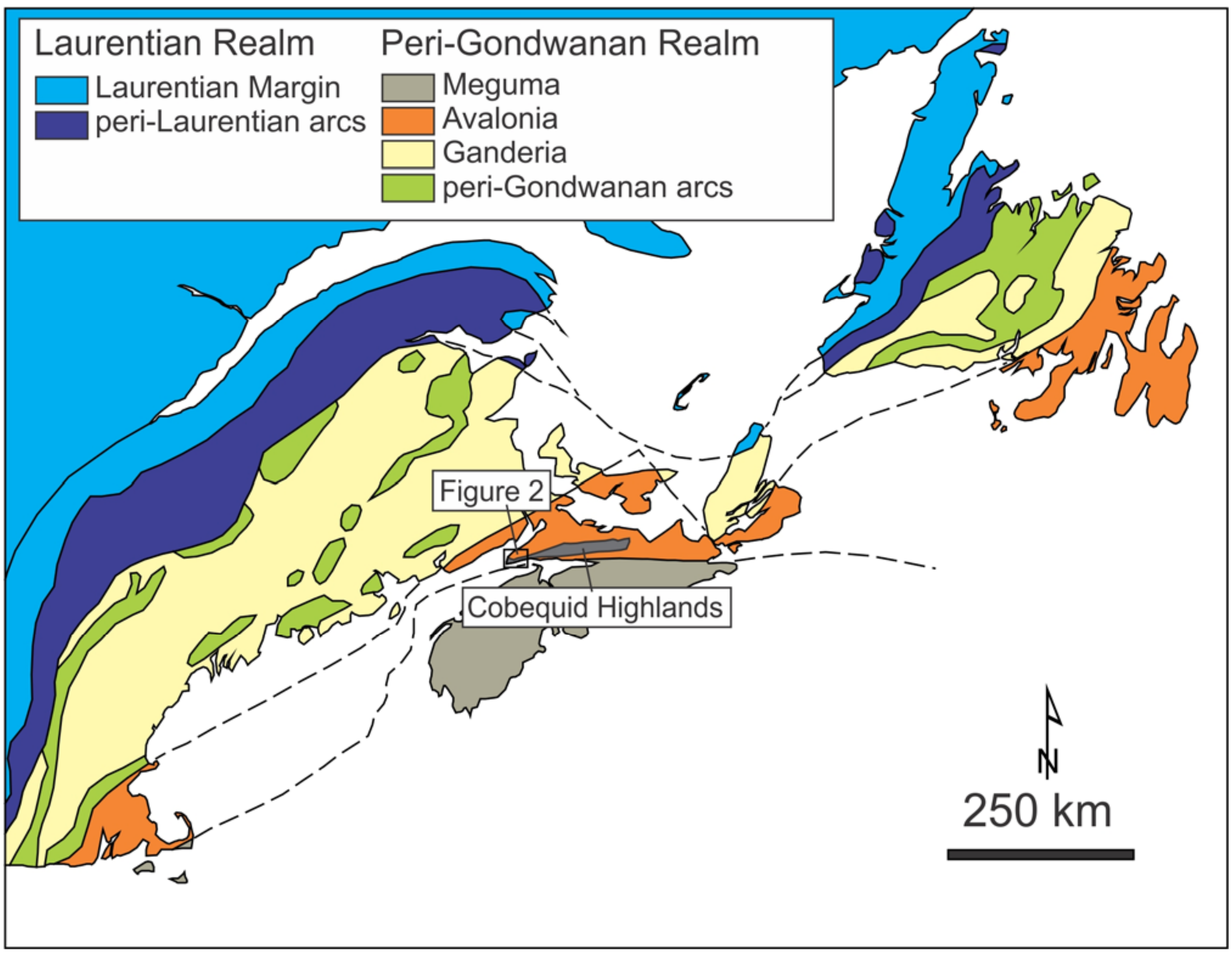

Figure 1. Lithotectonic elements of the northeastern Appalachian Orogen, modified from Hibbard *et al*. (2006).

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well as previously unrecognized Ordovician and Devonian intrusive units (MacHattie and White, 2012; MacHattie *et al*., 2012). As a result of the newly identified economic potential of the area and possibility for significant improvements to the geological framework, the Nova Scotia Department of Natural Resources initiated a bedrock mapping program within the eastern Cobequid Highlands in the summer of 2012 (MacHattie and White, 2014; MacHattie *et al*., 2014; MacHattie and White, 2015). This report summarizes the results of the bedrock mapping conducted during the 2015 field season in the area from Wards Brook in the east to Cape Chignecto and Squally Point in the west (Fig. 2).

Regional Geology

The Cobequid Highlands are an uplifted crustal block composed of Late Neoproterozoic volcanic, sedimentary and plutonic rocks; significant amounts of Late Devonian to Early Carboniferous volcanic, plutonic and lesser sedimentary rocks; and minor Silurian sedimentary rocks. The southern boundary of the Highlands is marked by the Cobequid-Chedabucto Fault Zone, whereas to the north they are unconformably overlain by Late Carboniferous sedimentary rocks of the Cumberland Basin (Fig. 2). The Highlands are part of Avalonia, a composite terrane within the Appalachian Orogen that extends from the Boston area, through southern New Brunswick and northern Nova Scotia, to southeastern Newfoundland (Fig. 1).

Geology of the Westernmost Cobequid Highlands

Introduction

The 2015 bedrock mapping program within the westernmost Cobequid Highlands was undertaken at a scale of 1:10 000 and continued westward from the areas mapped in 2012, 2013 and 2014 (see MacHattie and White, 2014; MacHattie *et al*., 2014; MacHattie and White, 2015). The highland areas from Wards Brook in the east to Cape Chignecto and Squally Point in the west were investigated during this study (Fig. 2). Previous bedrock geological maps of the westernmost Cobequid Highlands include the 1:50 000 scale maps of Donohoe and Wallace (1982) and Pe-Piper and Piper (2005).

Neoproterozoic Rocks and the Kirkhill Fault

Neoproterozoic rocks within the westernmost Cobequid Highlands are restricted to a narrow (less than 1 km wide) but laterally extensive (~25 km long) belt that delineates the east-west-tending Kirkhill Fault. This fault is now interpreted to represent a major lithotectonic boundary within the westernmost Highlands. Overall, the belt of Neoproterozoic rocks delineating the Kirkhill Fault dips steeply to the south (Fig. 3A), is well foliated to mylonitic, and everywhere is affected by a younger and very prominent cataclastic overprint (Fig. 3B). The protoliths are interpreted to be predominantly volcanic and volcaniclastic rocks of the Neoproterozoic Dalhousie Mountain Formation that occur along the easternmost extension of the Kirkhill Fault mapped north of Parrsboro in 2015 (see MacHattie and White, 2014).

Carboniferous Stratified Units

Supracrustal rocks in the western Cobequid Highlands are overwhelmingly Carboniferous in age, and field mapping conducted as part of this study has subdivided them into four distinct tectonostratigraphic assemblages, three dominated by siliciclastic rocks and one by volcanic rocks. The three-fold subdivision of the siliciclastic assemblages is a significant departure from the interpretations of these units based on the mapping of Pe-Piper and Piper (2005). That work failed to recognize differences in the lithological, structural and metamorphic grade of these assemblages and that the Kirkhill Fault represents a significant lithotectonic boundary across which the Carboniferous assemblages in question differ significantly.

South and east of the Kirkhill Fault, within its hanging wall, is the most widespread and presumably oldest of the four Carboniferous assemblages, consisting predominantly of well foliated orthoquartzite, slate and phyllite (Fig. 2; Figs. 3C, D, E and F). The southern margin of this

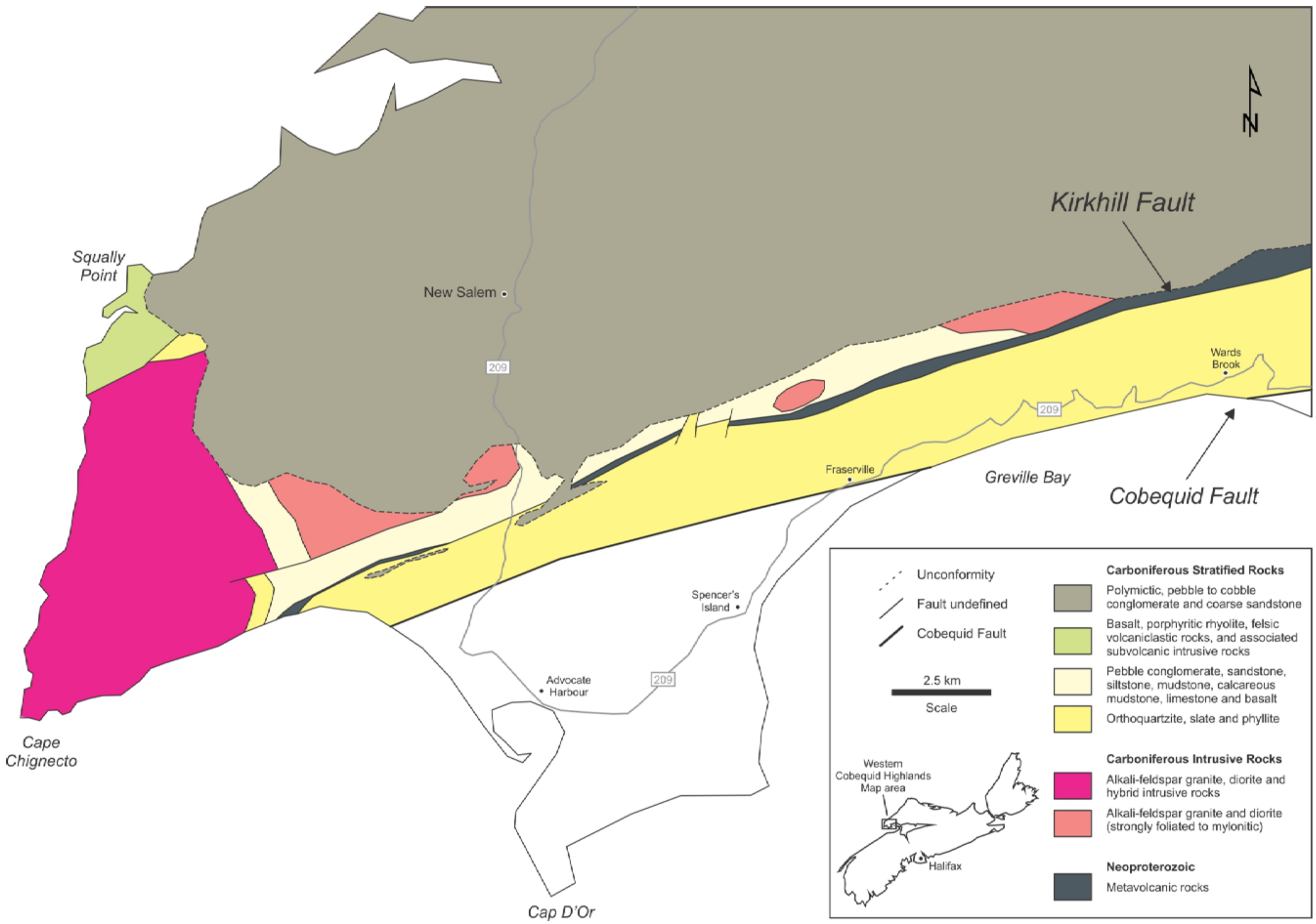

Figure 2. Simplified bedrock geological map of the western Cobequid Highlands.

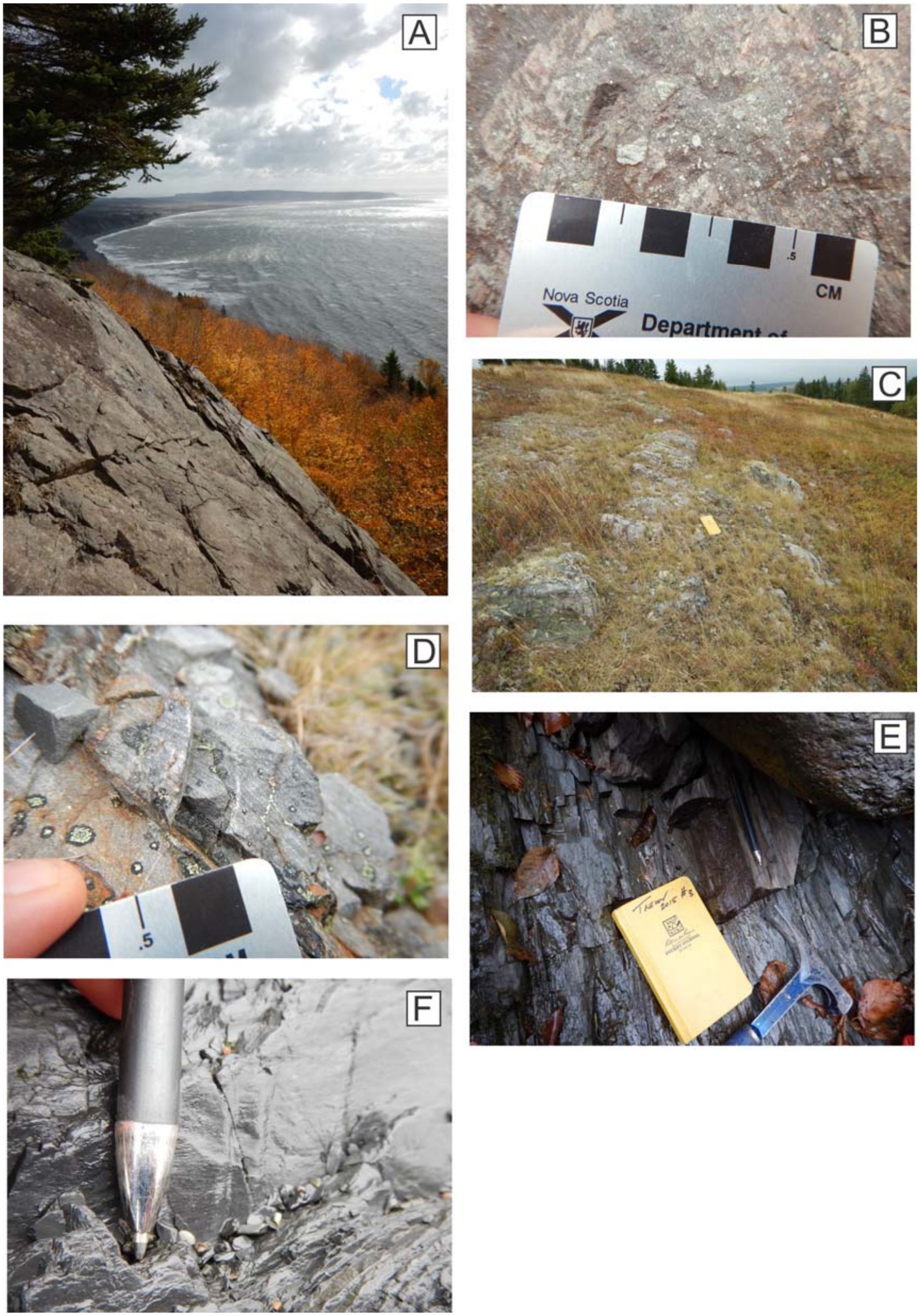

Figure 3. (A) Steeply south-dipping cataclastic Neoproterozoic metavolcanic rocks of the Kirkhill Fault; view looking toward Advocate Harbour. Station 15TM0888. (B) Cataclastic breccia composed of Neoproterozoic metavolcanic rock. Station 15TM0888. (C) Interbedded orthoquartzite and minor slate/phyllite. Station 15TM0539. (D) Bedding parallel foliation in orthoquartzite. Station 15TM0539. (E) Exceptionally well lineated phyllite. Station 15TM0926. (F) Refolding (crenulation) of pre-existing intersection-lineation developed on bedding/foliation surface. Station 15TM1063.

belt is coincident with the Cobequid Fault, an east-west-trending, steeply south-dipping brittle/ductile fault zone. The structural history of this assemblage is complex and a detailed account of its evolution will be discussed in future reports. A minimum of three principal phases of folding and associated cleavage development are recognized. Overall, the structural grain of the assemblage strikes east-northeast, and dips are moderate to steep. Although significant areas remain to be mapped in detail, no intrusive or volcanic rocks have yet been found within or cutting this assemblage. Currently these rocks are interpreted to belong to the Horton Group, and more specifically, lithological similarities suggest that significant portions comprise parts of the Horton Bluff Formation.

To the north of the Kirkhill Fault, within its footwall, there is a distinctive and particularly well preserved sequence dominated by siliciclastic rocks. It comprises conglomerate, sandstone, siltstone, mudstone, calcareous mudstone, limestone, mafic tuff and vesicular basalt (Fig. 2; Fig. 4A-E). Although these rocks preserve evidence of at least two phases of folding and later shearing associated with the Kirkhill Fault, they lack a regionally pervasive and penetrative cleavage, structural features that characterize the siliciclastic assemblage south of the fault. The abundance of calcareous sedimentary rocks, including laminated limestones, is also noteworthy and could suggest a potential correlation with the Windsor Group. The abundance of conglomerate, locally containing a significant amount of granite-derived detritus, strongly suggests that Carboniferous granites were, at least in part, exposed during sedimentation. Evidence that felsic igneous activity overlapped with sedimentation is, however, suggested by the fact that alkali-feldspar granite veins have been observed cutting this assemblage in several locations. A maximum age for this assemblage and potential for significant granite-derived material will be assessed from U-Pb detrital zircon geochronology to be conducted on siliciclastic rocks. These data will in turn be used to evaluate the potential for correlation with the Windsor Group. Although rare, tuffaceous mafic volcanic rocks and vesicular mafic sills indicate that mafic volcanism was also coeval with sedimentation. Taken together, these field observations suggest a dynamic inter-relationship between sedimentation, magmatism and tectonism for this unique assemblage.

Distinct from the two siliciclastic dominated assemblages described above, the area around Squally Point in the most northwesterly portion of the Cobequid Highlands exposes distinctly well preserved Carboniferous bimodal volcanic rocks (Fig. 2). Vesicular basalt (Fig. 4F), quartz- and K-feldspar-phyric rhyolite lava flows (Fig. 4G) and subvolcanic intrusive rocks predominate with lesser interbedded volcaniclastic rocks (Fig. 4H). Numerous fine-grained mafic dykes and sills, interpreted to be cogenetic with the basalts, are also widespread within this assemblage and are interpreted to be feeder dykes to the basalts. This assemblage is in fault contact along its eastern margin with both the Cape Chignecto pluton and well cleaved phyllite and slate, and is unconformably overlain by conglomerate and sandstone along its eastern margin (Fig. 2). The occurrence of mafic volcanic rocks within the siliciclastic dominated assemblage found north of the Kirkhill Fault suggests the potential for some correlation with the volcanic rocks found near Squally Point. U-Pb zircon geochronological investigations are being undertaken to assess this possibility.

The fourth and youngest Carboniferous supracrustal assemblage recognized in the westernmost Cobequid Highlands comprises polymictic conglomerate and sandstone; it unconformably overlies, and contains clasts of, all other rock units along the northern margin of the Highlands (Fig. 2; Figs. 5A-D). These rocks onlap the Highlands, dip moderately to shallowly to the north, and are interpreted to comprise parts of the Late Carboniferous Cumberland Basin strata. The previous mapping of Pe-Piper and Piper (2005) incorrectly placed significant portions of this siliciclastic assemblage within the Early Carboniferous Horton Group. An important discovery with respect to this Late Carboniferous assemblage is that it clearly overlies a segment of the Kirkhill Fault and occurs south of it where gently dipping conglomerate sits directly upon polydeformed rocks interpreted to be part of the Horton Group (Fig. 2 and Fig. 5D). This finding constrains the timing for deformation within the

Figure 4. (A) Interbedded conglomerate and sandstone. Station 15TM0699. (B) Trough in well bedded sandstone. Station 15TM0604. (C) Well laminated mudstone/siltstone and fine sandstone. Station 15TM0696. (D) Well laminated grey siltstone/mudstone and silty limestone. Station 15TM0859. (E) Vesicular mafic sill (right of photograph) intruded into interbedded grey to black siltstone and fine sandstone. Station 15TM0701. (F) Plagioclase-phyric vesicular basalt lava flow. Station 15TM0279. (G) Quartz- and K-feldspar-phyric flow banded rhyolite lava flow. Station 15TM0282. (H) Crystal/lithic-fragment-bearing volcaniclastic rock. Station 15TM0287.

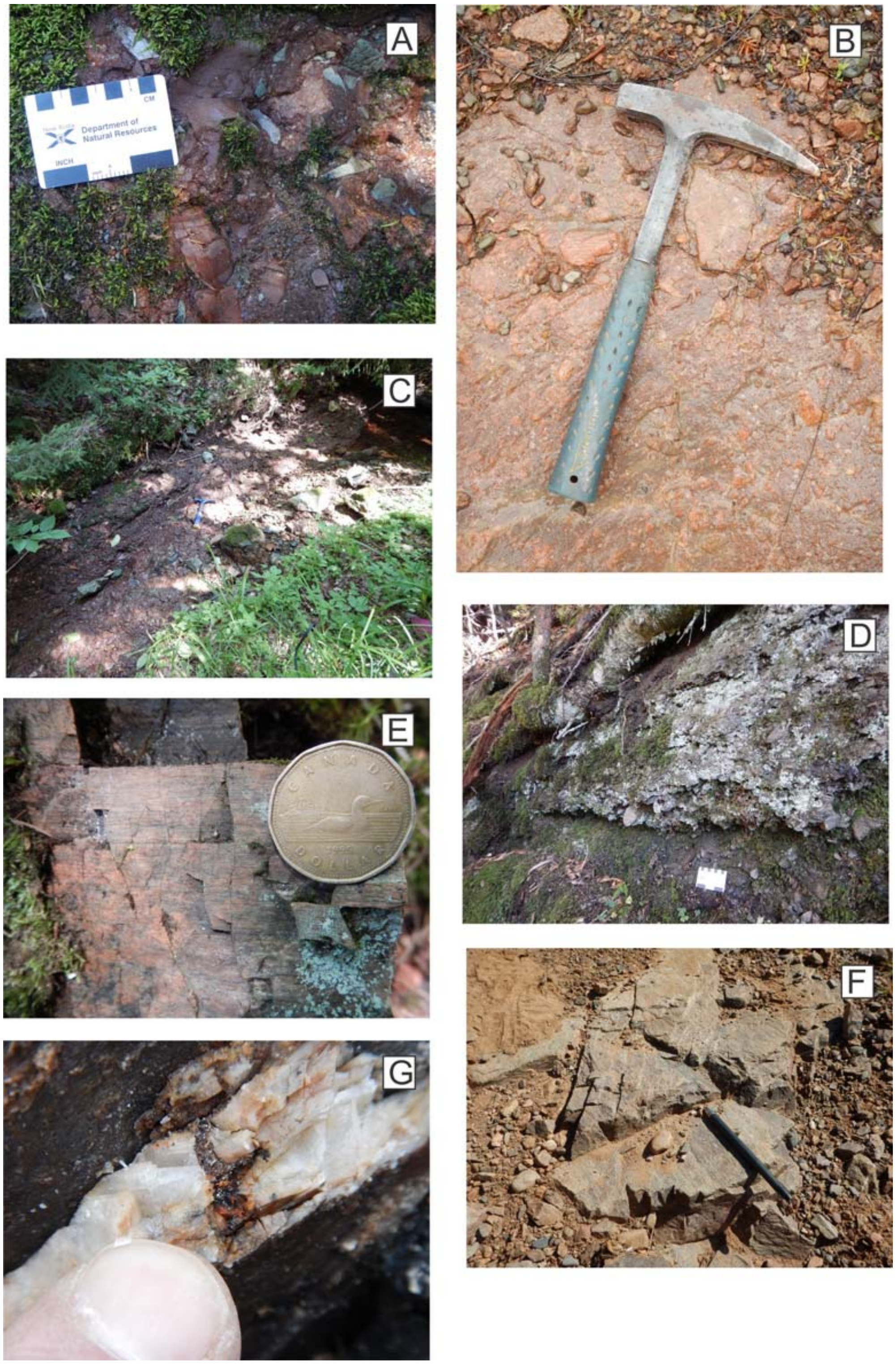

Figure 5. (A) Unconformity, sandstone and angular clasts of phyllite in conglomerate. Station 15TM0290. (B) Bedding surface in conglomerate dominated by granitic detritus; most of the clasts are well foliated to mylonitic alkali-feldspar granite. Station 15TM0003. (C) Bedding surface in flat-lying, poorly indurated conglomerate. Station 15TM0290. (D) Bedding in conglomerate; outcrop is south of the Kirkhill Fault. Station 15TM0763. (E) Mylonitic fabric in alkali-feldspar granite. Station 15TM0335. (F) Strongly foliated to mylonitic granite with well developed stretching lineation. Station 15TM0563. (G) Carbonate-quartz-sulphide vein cutting phyllite and slate within the Cobequid Fault zone along the Greville Bay shoreline. Station 15TM1091.

western Cobequid Highlands and, in particular, the late brittle cataclastic movement on the Kirkhill Fault. Attempts are underway to determine the maximum age of this assemblage.

Carboniferous Intrusive Rocks

Intrusive rocks in the western Cobequid Highlands are Carboniferous in age and are exclusively found in the footwall of the Kirkhill Fault (Fig. 2). The Cape Chignecto pluton within the westernmost Highlands is dominated by variable, fine- to coarse-grained biotite ±amphibole-bearing alkali-feldspar granite. Diorite and hybrid intrusive rocks are minor constituents of this pluton. The pluton is weakly to strongly foliated where it was examined as part of this study. The least accessible coastal exposures remain to be investigated to determine the nature and extent of deformation zones reported in previous mapping.

Carboniferous intrusive rocks like those comprising the Cape Chignecto pluton are strongly foliated to mylonitic along a significant strike-length in the immediate footwall of the Kirkhill Fault (Fig. 2; Figs. 5E and F). Along this segment, these mylonitic intrusive rocks are situated structurally below and infolded with the siliciclastic-rock-dominated assemblage found north of the Kirkhill Fault and occur in structural culminations.

Economic Geology

The new bedrock geological mapping within the westernmost Cobequid Highlands presented here allows for more targeted mineral exploration in the area. The Kirkhill Fault is a major, well defined lithotectonic boundary that could focus fault-related IOCG-style mineralization to the orthoquartzite-phyllite-slate assemblage (Horton Bluff Formation?), which is situated between the Cobequid and Kirkhill faults (Fig. 2). In fact, numerous quartz-carbonate-sulphide veinlets occur within this assemblage along Greville Bay and in particular the shoreline near Wards Brook (Fig. 5G). Preliminary sampling and mobile XRF analyses of these veins indicate that some contain anomalous Cu, Pb and Zn, whereas others contain elevated Co and Ni. Laboratory analyses are planned to more quantitatively determine the scale of these anomalies, and also assess the potential for Au in the vein system.

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