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Preliminary Flow Unit Subdivision of Lower Mississippian Volcanic Rocks in the Eastern Cobequid Highlands, Nova Scotia

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Open File Report ME 2018-005

NOVA SCOTIA
Natural Resources

Halifax, Nova Scotia

March 2018

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Introduction

This report is a brief description of the major volcanic flow units depicted on the preliminary bedrock geology map (Open File Map ME 2018-005, 1:35 000 scale) of lower Mississippian volcanic rocks in the eastern Cobequid Highlands of Nova Scotia (MacHattie, 2018b). More detailed aspects of the volcanology, geochemistry, geochronology and epithermal gold mineralization, and refinement of this preliminary volcanic stratigraphy, are intended for future publications.

Volcanic Stratigraphy

Detailed field mapping, petrography, geochemistry and high-precision CA-ID-TIMS U-Pb zircon geochronology have all been used to define the volcanic stratigraphy, major flow units, and associated sub-volcanic intrusive rocks depicted in this preliminary bedrock geology map. The use of portable X-ray fluorescence (pXRF) technology has been particularly useful in discriminating the various volcanic units in terms of their high field-strength element contents (e.g. Ti, Zr, Y, and Nb). The pXRF data and methods can be found in MacHattie (2018c and 2018d). Felsic volcanic rocks within the succession have currently been informally subdivided with respect to their Zr contents into low Zr (<650 ppm) and high Zr chemical groups (>650 ppm). This informal chemical classification, as well as a less formal ultra-high Zr designation (≥1200-1300 ppm) assigned to some key pyroclastic flow units, has been invaluable in defining the volcanic stratigraphy at both the flow and volcanic succession scales. The petrogenetic implications of these groupings will be addressed in future publications.

Most of the volcanic succession has a west-northwest to east-northeast strike and near vertical dip over a strike length greater than 25 km. With few exceptions (see below) the succession youngs to the north-northeast, and at least 5 km of contiguous stratigraphy are preserved. East of the French River and north of the upper basalt effusive flow unit 1, basalt-dominated structural panels repeat, at least in part, some of the underlying stratigraphy. The volcanic succession has been here informally divided into a lower and upper volcanic sequence. East of Byers Brook, the lower volcanic sequence comprises five major flow units and is overwhelmingly dominated by felsic volcanic rocks. Collectively, these flow units constitute the Byers Brook Formation of Donohoe and Wallace (1982). The upper volcanic sequence, composed of 11 units, 10 of which are volcanic-dominated and consisting of both basalt and rhyolite, coincides largely with the Diamond Brook Formation of Donohoe and Wallace (1982). West of Byers Brook, however, the formational subdivision of the volcanic succession of Donohoe and Wallace (1982) requires some modification as it truncates continuous flow units defined here. A future publication will formally attempt to reconcile the new mapping and data with the formations as they are currently defined.

Lower Volcanic Sequence

The lowermost unit in the volcanic succession is dominated by felsic, moderately to intensely welded, crystal-rich to -poor tuff (ignimbrite) that is overwhelmingly of the high Zr to ultra-high Zr (minor) chemical type. This lower unit has a thickness that approaches 2 km. Minor black to grey siltstone and non-welded mafic and felsic tuff are found within this unit. A welded crystal-rich tuff from the base of this unit has a high precision CA-ID-TIMS zircon crystallization age of 358.45 ± 0.12 Ma (MacHattie and Crowley, personal communication). Immediately above the pyroclastic unit is an equally extensive, but thinner (approximately 450 m thick) felsic effusive flow unit composed predominantly of quartz and K-feldspar phyric, flow banded, spherulitic rhyolite. Minor grey siltstone and sandstone occur within this unit as well as rare basaltic tuff. This effusive flow unit, like the lower pyroclastic unit, is of the high Zr chemical type.

Above the lower high Zr felsic effusive flow unit in the western portion of the map area, a discontinuous but very distinctive non-welded to strongly welded crystal-lithic tuff flow unit occurs below and intercalated with vesicular/amygdaloidal basalt flows. Many of the samples of this distinctive pyroclastic flow unit possess ultra-high Zr contents (>1300 ppm) over its 8 km of strike. This unit is spatially associated with the first significant occurrence of vesicular/amygdaloidal basalt within the succession. In the west, this flow unit is approximately 200 m thick and outcrops semi-continuously, along with the distinctive ultra-high Zr pyroclastic unit, for approximately 9 km.

The last major flow unit of the lower volcanic sequence is dominated by felsic, effusive, K-feldspar ± quartz phyric, flow-banded rhyolite flows. These flows represent the first major appearance of a low Zr chemical type of rhyolite. In the eastern portion of the map area this flow unit has a substantial thickness of approximately 1.5 km and underlies a vast region extending east of Whippey Lake to Nuttby Mountain, where it is spectacularly exposed. A sample from the top of the flow unit in this eastern segment has a high precision CA-ID-TIMS zircon crystallization age of 356.34 ± 0.12 Ma (MacHattie and Crowley, personal communication). To the northwest, this flow unit is approximately 200-400 m thick and similarly effusive, K-feldspar phyric, flow banded, and of low Zr chemical type. A sample from this western portion of the flow unit has a marginally younger high precision CA-ID-TIMS zircon crystallization age (356.15 ± 0.09 Ma) than the sample to the southeast (MacHattie and Crowley, personal communication). The central portion of this flow unit contains more diverse flow units, including felsic pyroclastic flows and effusive flows, which also have significant quartz along with K-feldspar as phenocrysts. All units are, however, of similar low Zr chemical affinity.

Upper Volcanic Sequence

The upper volcanic sequence is distinguished, in part, from the lower sequence by the first occurrence of substantial vesicular/amygdaloidal basalt flows. The upper sequence is overwhelmingly dominated by basalt east of Byers Brook, whereas repeated intercalation of felsic and basaltic flow units characterize the stratigraphy to the west. The upper effusive basalt flow unit 1 (northwest) and the upper mixed assemblage are differentiated on the map by lithology, but are considered to be contemporaneous. The mixed assemblage is dominated by vesicular/amygdaloidal basalt flows, but is characterized by the complex intercalation of felsic, syn-eruptive, non-welded to moderately-welded crystal lithic tuff breccia, minor grey to black siltstone and limestone, and intensely welded felsic tuff with the basalt. East of Byers Brook, before significant basalt flows appear in the stratigraphy, quartz-rich grey sandstone, siltstone and pebble conglomerate are commonly found. This assemblage is interpreted to record a potentially significant hiatus in volcanism coincident with the switchover from felsic- to mafic-dominated volcanism.

Above the upper effusive basalt flow unit 1 and mixed assemblage west of Byers Brook a felsic, effusive quartz + K-feldspar, flow-banded rhyolite flow unit of low Zr chemical type occurs. This flow unit is immediately overlain by a thin (approximately 100 m thick) vesicular/amygdaloidal basalt flow unit, and succeeded by another felsic effusive flow unit of low Zr chemical type and finally another vesicular/amygdaloidal basalt flow unit. East of Byers Brook the two thin basalt flow units in the west appear to merge to collectively form a very thick (up to 1.2 km) vesicular/amygdaloidal basalt unit with only minor maroon paleosol and/or siltstone interbeds. A sample from the first low Zr felsic effusive flow unit above the basalt-dominated base of the upper volcanic sequence has a high precision CA-ID-TIMS zircon crystallization age of 354.25 ± 0.09 Ma (MacHattie and Crowley, personal communication). This age is approximately 2 Ma younger than the similarly low Zr felsic effusive flow unit that defines the top of the lower volcanic sequence, a finding that supports a significant hiatus in volcanism between the lower and upper volcanic sequence.

Above the intercalated basalt and low Zr felsic effusive flow units that occur west of Byers Brook, a distinctive felsic, effusive, K-feldspar + quartz phyric, spherulitic flow-banded rhyolite flow unit of high Zr chemical type occurs. A thin vesicular/amygdaloidal basalt flow unit and minor maroon sandstone and conglomerate occur intercalated with this rhyolite. A sample from this high Zr flow unit has a high precision CA-ID-TIMS zircon crystallization age of 353.2 ± 0.09 Ma (MacHattie and Crowley, personal communication). Above this distinctive high Zr effusive flow unit, the volcanic stratigraphy returns to vesicular/amygdaloidal basalt-dominant volcanism with minor intercalations of felsic, effusive, K-feldspar + quartz physic, flow-banded rhyolite flows of low Zr chemical affinity. Minor maroon sandstone and conglomerate are commonly intercalated with basalt.

North of these uppermost portions of the volcanic stratigraphy the succession is either unconformably overlain by Pennsylvanian sandstone and conglomerate of the Cumberland Basin or in fault contact with poly-deformed mafic-felsic volcaniclastic rocks of suspected Neoproterozoic age.

Upper Volcanic Sequence(s) East of French River

The exception(s) to the orderly stratigraphic and structural orientation of the volcanic succession described above occurs east of French River and north of the upper basalt effusive flow unit 2. Within this region at least two fault-bound, basalt-dominated structural panels appear to represent different portions of the more contiguous stratigraphy to the south and west, respectively.

Immediately east of French River and extending as far east as East New Annan, vesicular/amygdaloidal basalt flows are interbedded with grey sandstone and conglomerate, grey to black siltstone and limestone, and minor felsic non-welded crystal-lithic tuff breccia. Felsic, effusive, K-feldspar-rich, flow-banded rhyolite is also found at several locations within this structural panel. A high precision CA-ID-TIMS U-Pb zircon crystallization age for one of these rhyolites of 356.41 ± 0.11 Ma (MacHattie and Crowley, personal communication) confirms that the effusive rhyolites within this panel are the lower, low Zr, felsic effusive flow unit. A sample of lithic tuff breccia also selected for high precision CA-ID-TIMS U-Pb zircon age dating from this panel has yielded a very robust maximum depositional age of 354.59 ± 0.11 Ma (MacHattie and Crowley, personal communication) derived from four identical zircon analyses. Two samples of limestone from this panel were investigated for palynological age determination, including one from the same outcrop as the lithic tuff sampled for U-Pb zircon age dating. These limestones yielded Tournaisian 3 spores (ChronoSurveys, 2017; MacHattie, 2018a). Overall, the field mapping and similarity in lithological associations and U-Pb zircon age dates currently indicate that this panel is an upward to south-facing portion of the lower, low Zr, felsic effusive flow unit and the lower mixed assemblage, respectively.

A second basalt-dominated panel also located north of the upper basalt effusive flow unit 2 is unconstrained in age but is tentatively assigned to the upper basalt effusive flow unit 5. This assignment is based on its spatial association with a significant maroon sandstone, siltstone, conglomerate assemblage on its eastern margin. Within this unit, vesicular/amygdaloidal basalt flows are locally intercalated with the siliciclastic sediments. This association is identical to that observed in the upper basalt effusive flow unit 5 west of the French River, where very similar maroon siliciclastics are commonly intercalated with basalt. This could suggest that this panel, at least the maroon clastic-dominated portion, is coeval with the youngest basalt. In the western section, the maroon siliciclastics begin to appear in the volcanic stratigraphy as felsic volcanism was waning.

Undivided Volcanic Sequence(s) West of East Branch Swan Brook

West of the East Branch Swan Brook, outcrop of the volcanic succession is scarce and appears to be mainly felsic pyroclastic and lesser effusive flow units that for now are not formally assigned to any of the flow units defined to the east. The northern portion of this area does, however, possess crystal-rich, high Zr, pyroclastic and effusive flow units near a large composite diorite/gabbro body. These relationships could indicate a potential affinity of this northerly portion with the high Zr flow units of the lower volcanic sequence, which occur near an upper diorite sill recognized to the east.

To the south of these units, low Zr felsic pyroclastics are more common. As low Zr felsic pyroclastic flow units are not recognized as significant components of the volcanic stratigraphy defined to the east, some potential exists to document an older assemblage(s) (i.e. >358 Ma) in this western area. Farther to the west, volcanic and volcaniclastic rocks on either side of the Wentworth Valley were assigned by Donohoe and Wallace (1982) to the Byers Brook Formation. Mafic, intermediate, and felsic flows, abundant volcaniclastic, and volcanogenic sedimentary rocks with some preliminary chemical affinities (pXRF data) to volcanic arc type rocks suggest parts of this area may be underlain by Neoproterozoic volcanic assemblages found elsewhere in the Cobequid Highlands (MacHattie, 2017). Follow-up U-Pb zircon geochronology is planned to address the ages of volcanic rock assemblages found west of the East Wallace River.

Intrusive Rocks

The base of the volcanic succession is intruded by the Hart Lake Granite (Donohoe and Wallace, 1982) and a widespread composite diorite sill. This lower diorite sill complex is up to 500 m thick and straddles the interface between the granite and lower felsic pyroclastic unit, and contains large rafts of volcanic rocks. The relative timing of the granite and lower diorite sill are somewhat equivocal as aplitic granite dykes cut diorite and diorite dykes cut granite along this contact. Samples of various phases of the Hart Lake Granite are currently being prepared for high-precision CA-ID-TIMS U-Pb zircon age dating (MacHattie and Crowley, personal communication). Within the volcanic succession, a second diorite sill up to 500 m thick is well exposed between Byers Brook and Porter Brook. This sill straddles the boundary between the lower felsic pyroclastic and effusive flow units. The area between these two prominent diorite sills is pervasively intruded by numerous diorite dykes and sills. Small bodies of diorite (dykes, sills and pods) are common throughout the volcanic stratigraphy west of Byers Brook.

Two prominent porphyritic felsic intrusive bodies are found in the volcanic succession. At Nuttby Mountain (southeast) an extensive effusive, flow-banded rhyolite flow unit is cored by a K-feldspar + quartz phyric porphyry that is locally spherulitic. To the northwest, a very similar porphyry to that found at Nuttby Mountain is well exposed on Byers Brook, immediately north of Byers Lake. The western porphyry body, however, shows extensive evidence for mingling and mixing with syn-plutonic mafic magmas and is locally K-feldspar-rich. Numerous diorite dykes, sills and pods occur within this body. A sample of ‘hybrid’ porphyry is being processed for high precision CA-ID-TIMS U-Pb zircon age dating. At several locations within the lower diorite sill and one in the upper sill variably ‘hybridized’ K-feldspar-rich porphyry dykes have been observed to cut the sills and all have been injected contemporaneously with mafic magmas, the latter occupying the margins of the dykes.

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