An Update on Bedrock Mapping and Exploration for Epithermal Gold in the Northeastern Cobequid Highlands

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Introduction

Since the initial discovery of epithermal-style gold (Au) in silicified and sulphidized Carboniferous basalt and rhyolite in the northeastern Cobequid Highlands by the Nova Scotia Department of Natural Resources in 2011 (MacHattie, 2011; MacHattie, 2013), little effort or progress outside government has been made toward the exploration of these new occurrences. These new Au discoveries, the first reported in bedrock from the Carboniferous volcanic succession, coupled with some significant Au levels obtained during reconnaissance stream sediment sampling in the 1990s (e.g. Hogg, 1990), were expected to precipitate a significant exploration effort for this new epithermal Au target(s), which has yet to happen. Comparisons were also drawn between the setting and style of plume– or rift-related Carboniferous bimodal volcanic rocks hosting these new Au occurrences and those which host the world-class Miocene epithermal Au deposits in northern Nevada (e.g. MacHattie, 2013).

The current lack of investment in exploration is not considered a result of low potential, in fact several observations recognized early on suggested the potential that these new discoveries represented components of a much larger (tens of km), district-scale Au-bearing magmatic-hydrothermal system. For example, although generally found at low levels, Au was documented at both occurrences discovered and assayed in 2011-2012, including up to ~650 ppb at the Warwick Mountain occurrence, and up to ~150 ppb at Nuttby Mountain, respectively. Both Au occurrences were associated with anomalous As, Sb, Cd, Se and Pb and formed in spatially unrelated hydrothermal systems within completely different parts of the volcanic stratigraphy (MacHattie, 2013). At the regional scale, the bedrock mapping and geochemical analyses of rock slabs by portable XRF available at that time indicated that As, Sb, Cd and Pb anomalies were widespread in the Byers Brook and Diamond Brook formations that constitute the volcanic succession and, hence, the possibility for more regionally pervasive Au mineralization (see MacHattie, 2011). Furthermore, following up on some of these bedrock XRF anomalies in 2015 conclusively demonstrated that key epithermal Au tracers (e.g. As and Sb) were indeed concentrated at a regional-scale (>10 km) along the transition between the Byers Brook and Diamond Brook formations (Fig. 5B in Baldwin, 2016), a finding that suggests the presence of a large alteration system(s). Significant Hg (> 1000 ppb) was also documented at the main Warwick Mountain Au occurrence in that follow-up study (Baldwin, 2016), another important tracer in epithermal Au systems.

Because of the potential for the volcanic succession to contain one or more epithermal Au-deposits is still considered significant, a renewed emphasis on bedrock geological research in the volcanic succession was initiated during the 2016 field season. This research was intended to target some of the existing knowledge gaps in the area's bedrock geoscience, which may be hindering exploration efforts in the volcanic succession of the Warwick Mountain area. The lack of detailed bedrock mapping and geochemical sampling peripheral to the Au occurrences, including the areas south and east where significant Au was recovered during reconnaissance stream sediment sampling by Seabright Explorations Incorporated (Hogg, 1990). Nearing the end of the 2016 field season a pilot till and stream sediment sampling program was incorporated into the bedrock initiative. Details related to those surveys can be found in Brushett (this volume, p. 5-7) and Baldwin (this volume, p. 1-2), respectively.

MacHattie, T. G. 2017: *in* Geoscience and Mines Branch, Report of Activities 2016-17; Nova Scotia Department of Natural Resources, Report ME 2017-001, p. 49-52.

Bedrock Volcanic Stratigraphy

New detailed bedrock mapping and sampling conducted within the Carboniferous bimodal volcanic succession of the northeastern Cobequid Highlands during the 2016 field season were primarily focused in the areas northwest and southeast of the original Au occurrences discovered in the Warwick Mountain area, in the Diamond Brook Formation (Fig. 1; MacHattie, 2013).

To the northwest and west of the Warwick Mountain Au occurrences, the volcanic stratigraphy of the lower Diamond Brook Formation is distinctly composite, consisting of alternating (100-500 m thick) vesicular basalt-dominated volcanic layers and those consisting predominantly of effusive rhyolite lava flows and lesser felsic volcaniclastic rocks and rare siltstone and sandstone. This bimodal stratigraphy is sub-vertical, with an average strike of 105-110º, and well-defined with respect to its alternating high and low airborne magnetic signature (Fig. 1). Petrography, magnetic properties and whole-rock lithogeochemical data (mobile XRF and ICP-MS) indicate that distinctive eruptive flow units, particularly the felsic flows, can be traced for several kilometres within this stratigraphy, providing important chemostratigraphic markers. In stark contrast to the volcanic stratigraphy of the lower Diamond Brook Formation west of the Warwick Mountain Au occurrences, where basalt

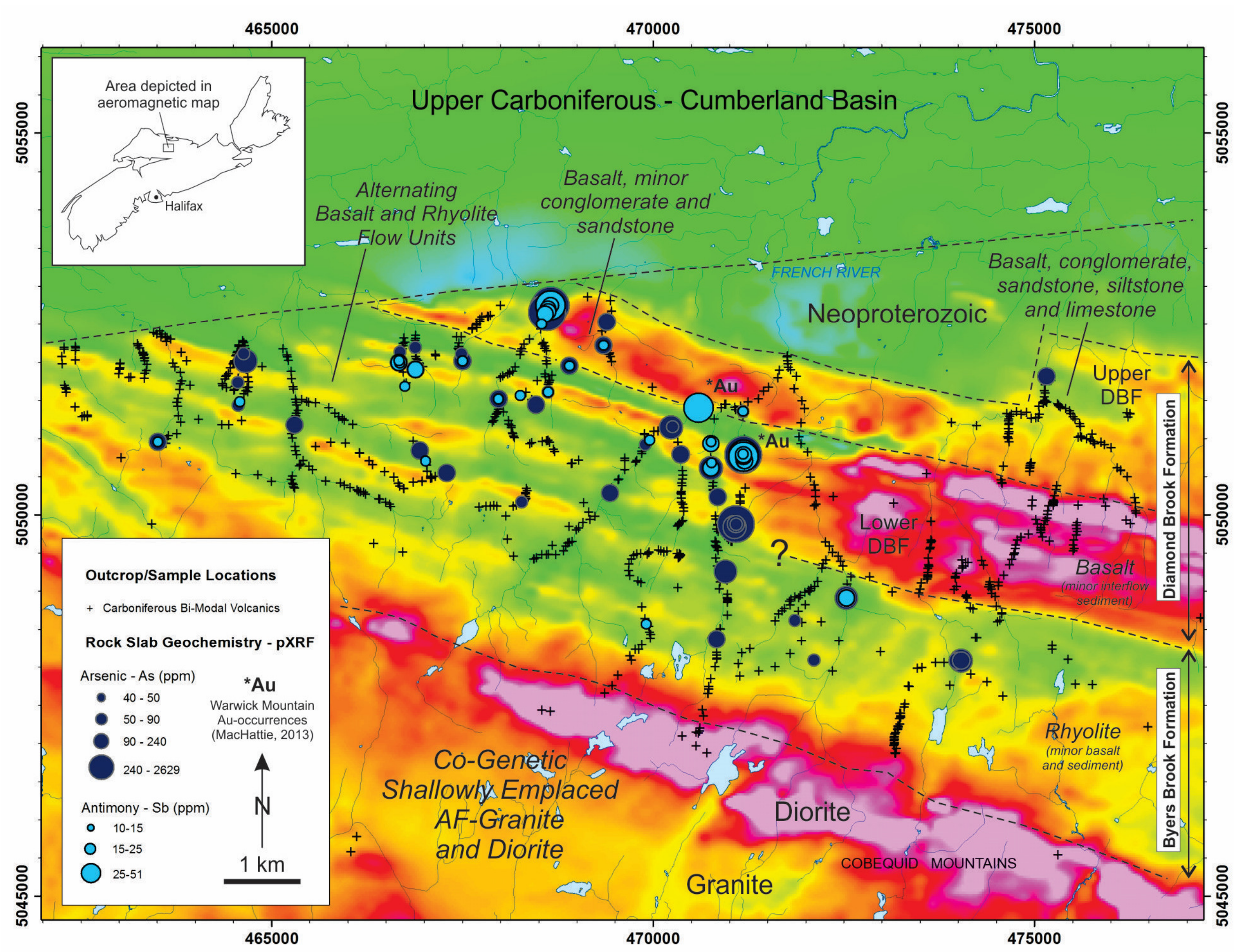

Figure 1. Aeromagnetic map of the Warwick Mountain area showing outcrop and sample locations, as well as arsenic and antimony concentrations in rock samples.

and rhyolite are regularly intercalated, the eastern portions of this lower stratigraphy are entirely composed of basalt within minor inter-flow sediments and associated paleosols. Lacking a change in the orientation of flows, this break is interpreted to reflect a facies change, with input from separate but co-eval rhyolite and basalt source vents or volcanic centres.

New mapping conducted in 2016 in the upper Diamond Brook Formation has revealed some important findings relevant to the tectonic and magmatic evolution of the volcanic succession. West of the Warwick Mountain Au occurrences, the upper Diamond Brook Formation consists predominantly of vesicular basalt with lesser intercalations of sandstone and conglomerate units. Importantly, this westerly portion of the upper Diamond Brook volcanic stratigraphy maintains the same structural orientation as the bimodal components of the lower Diamond Brook volcanic stratigraphy, and similar sandstones also occur interbedded with the uppermost rhyolite flow units of the lower Diamond Brook Formation. These observations suggest some continuity between the lower and upper parts of the formation, at least in this westerly portion, and that the major changes reflect the transition to basalt-dominated volcanism and initiation of siliciclastic sedimentation.

In contrast to the upper Diamond Brook Formation volcanic stratigraphy found to the west of the Warwick Mountain Au occurrences, the upper parts of the formation in the east do contain minor rhyolite flows, although still basalt dominant, and in addition to sandstone and conglomerate like the stratigraphy to the west, fossiliferous limestone and calcareous black siltstone occur. Where sedimentary bedding has been measured most of the units strike approximately north-south and possess highly variable dips, ranging from near vertical to as shallow as 20-30º. Flow-alignment of vesicles and amygdales in the basalt flows interbedded with the sedimentary rocks display similar structural orientations. This portion of the upper Diamond Brook Formation's unique lithological association and structural orientation compared to that of the east-west striking, steeply dipping lower portions of the formation suggest significant uplift and rotation prior to deposition of this unique portion of the upper Diamond Brook Formation. In addition, several of the clasts in a conglomerate interbedded with laminated limestone contain abundant silicified rhyolite clasts, indicating that some of the alteration preceded this uplift.

Bedrock XRF Geochemistry: a Tool to Identify Epithermal-style Au Alteration Systems

The bedrock Au occurrences discovered in the Warwick Mountain area were accompanied by highly anomalous As (200-900 ppm) and Sb (15-55 ppm) as well as other important epithermal Au tracers found in lower concentration (e.g. Cd and Se; MacHattie, 2013). The concentrations of As and Sb (as determined by portable XRF on both pulverized rock powders and cut rock slabs from the Warwick occurrences) are comparable to the laboratory data obtained by ICP-MS. As such, employing portable XRF data acquisition provides a rapid and inexpensive way to assess the regional distribution of these elements within the volcanic succession and identify prospective areas for gold.

Geochemical data for As and Sb obtained on cut rock slabs of volcanic, volcaniclastic and rare sedimentary rocks from the western Byers Brook and Diamond Brook formations using DNR's portable XRF (Olympus/Innov-X X5000) are displayed as graduated symbols in Figure 1. The known Au occurrences in the Warwick Mountain area are well defined, as is a pronounced coupled As and Sb alteration zone that extends westward from the occurrences for several kilometres. This zone of anomalous As and Sb is primarily concentrated in the upper parts of the lower Diamond Brook Formation (DBF) volcanic stratigraphy, nonetheless a few highly anomalous samples were found in the westernmost portions of the upper DBF stratigraphy, over 3 km from the Warwick Mountain Au occurrences (Fig. 1). A more subtle, but regionally pervasive zone of anomalous As and Sb also appears to straddle the transition zone between the Byers Brook and Diamond Brook formations (Fig. 1; Fig. 4B in Baldwin, 2016).

The bedrock XRF geochemical data currently available for both the lower and upper Diamond Brook Formation east of the Warwick Mountain Au occurrences has revealed some surprising and informative results. The prominent As and Sb anomalies to the west are absent to the east (Fig. 1), even though many of the more prominent Au concentrations obtained in the reconnaissance stream sediment sampling conducted by Seabright were found in the lower and upper Diamond Brook Formation east of the Warwick Mountain Au occurrences (see Hogg, 1990). This suggests the Au found in the streams is not 'local' and this finding was part of the impetus to initiate a high-resolution till and stream sediment sampling program in the area (see Brushett, this volume, p. 5 -7; Baldwin, this volume, p. 1-2).

Future Work

Detailed bedrock mapping and geochemical sampling in the Byers Brook and Diamond Brook formations will continue in the 2017-2018 fiscal year. The rivers and streams not yet examined in the western Byers Brook and Diamond Brook formations will be completed (e.g. Fig. 1), as well as their extensions to the southeast. A preliminary series of digital 1:10 000 scale maps for the entire volcanic succession is expected to be ready in early 2018. A digital database of rock descriptions, structure and photos, as well as portable XRF and laboratory
ICP-MS geochemical data will accompany the digital bedrock maps.

Samples have been collected from throughout the volcanic stratigraphy and are in preparation for U-Pb zircon age dating by LA-ICP-MS at the University of New Brunswick. To compliment the laser dating, ultra-high-precision U-Pb zircon age dating by CA-ID-TIMS is being conducted for selected rhyolite samples at Boise State University. Deposit-scale research is being initiated on the Warwick Mountain Au occurrences by Dr. Jacob Hanley from St. Mary's University and students within his group. They will undertake a detailed characterization of the epithermal system (e.g. P-T-x of hydrothermal fluids), high-spatial resolution geochemical mapping of pyrite, and *in situ* Re-Os age dating of pyrite co-genetic with Au mineralization.

As part the broader geoscience initiative undertaken to assess the potential for epithermal Au in the Byers Brook and Diamond Brook formations, a thorough till and stream sediment geochemical sampling program initiated in 2016-2017 will be continued in 2017-2018 (see Brushett, this volume, p. 5-7; Baldwin, this volume, p. 1-2). This mapping and sampling, like that conducted in the bedrock, will cover the entire volcanic succession and preliminary reports and data will be ready in 2018.

References

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