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Preliminary geological and petrographic study of the Poplar Mountain Au occurrence, southwestern New Brunswick[1]

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Abstract: The Poplar Mountain Volcanic Complex consists of three principal volcanic and subvolcanic units in the Poplar Mountain area, i.e. porphyritic dacite, dacitic volcaniclastic rocks, and basaltic volcanic rocks. The porphyritic dacite is a subvolcanic intrusion located in the centre of a volcanic dome and is surrounded by dacitic volcaniclastic rocks. The basaltic unit is stratigraphically above the felsic units.

Gold mineralization is mainly associated with arsenopyrite, and to a lesser extent with pyrite and stibnite. The sulphides are disseminated in the dacite, and in various quartz-carbonate-sericite veins and quartz-cemented breccia. The mineralized zones are characterized by a higher degree of fracturing and veining than the barren zones, and are closely related to phyllic (sericite+carbonate+quartz+illite) alteration. Propyllitic (chlorite+carbonate+illite) alteration is widespread, and is mainly preserved in nonmineralized zones. The mineralization and alteration share some analogies with low-sulphidation epithermal deposits, or the outer zone of a porphyry-type system.

Résumé : Dans la région du mont Poplar, le complexe volcanique de Poplar Mountain est composé des trois grandes unités volcaniques et subvolcaniques suivantes : dacite porphyrique, dépôts volcanoclastiques dacitiques et roches volcaniques basaltiques. La dacite porphyrique forme une intrusion subvolcanique qui occupe le centre d'un dôme volcanique et est entourée de dépôts volcanoclastiques dacitiques. L'unité basaltique repose en contact stratigraphique sur les unités felsiques.

La minéralisation en or est associée principalement à l'arsénopyrite et, dans une moindre mesure, à la pyrite et à la stibine. Les sulfures sont disséminés aussi bien dans la dacite que dans les divers filons de quartz-carbonates-séricite et brèches à ciment de quartz. Relativement aux zones stériles, les zones minéralisées sont caractérisées par des réseaux plus denses de fractures et de filons, et elles sont étroitement liées à une altération phylliteuse (séricite + carbonates + quartz + illite). L'altération propylitique (chlorite + carbonates + illite) est généralisée et se manifeste principalement dans les zones non minéralisées. La minéralisation et l'altération présentent des analogies avec celles des gisements épithermaux à faible degré de sulfuration, ainsi qu'avec la zone extérieure des systèmes de type porphyrique.

[1] Contribution to Targeted Geoscience Initiative

INTRODUCTION

The Poplar Mountain gold occurrence, which is located in York County in western New Brunswick (Fig. 1), is one of the most important gold occurrences found in New Brunswick to date. It is hosted in volcanic and subvolcanic rocks, and may be related to subvolcanic intrusions (Freewest Resources Canada Inc., unpub report, 1998; unpub. report on exploration on Golden Ridge property 1999; unpub. report on 1999 diamond drilling on Golden Ridge property, 1999; McLeod and McCutcheon, 2000). Little is known about the local geology and the controlling parameters and the nature of gold mineralization. As a part of a Geological Survey of Canada project entitled 'Metallogeny of Magmatic Intrusion-Related Gold Systems in Southwestern New Brunswick', this study aims to better characterize the mineralization system at Poplar Mountain. Preliminary results of this study are presented in this paper, mainly based on field observation and core examination, preliminary petrographic work, as well as on previous exploration results. More detailed petrographic work, and geochronological and geochemical studies will follow.

GEOLOGICAL SETTING

In the regional tectonic framework, the Poplar Mountain area lies near the southwestern end of the Miramichi Terrane (Fig. 1), which belongs to the Gander Zone of the Appalachian Orogen (Williams, 1995). In western New Brunswick, exposure of the Cambrian to Middle Ordovician Miramichi Terrane is limited to the northwest by the Woodstock Fault across which lies the Late Ordovician to Late Silurian Matapedia Basin. To the southeast, the Miramichi Terrane is bounded by the Meductic Fault, which separates it from the Late Silurian to Early Devonian Canterbury Basin (Fig. 1). The Miramichi Terrane consists of the Cambrian to Early Ordovician Woodstock Group and the Early Ordovician to Middle Ordovician Meductic Group (Fyffe, in press). The Meductic Group comprises mafic, intermediate, and felsic volcanic rocks in the lower part and clastic sedimentary rocks in the upper part. The Matapedia Basin consists of the Late Ordovician to Early Silurian Carys Mills Formation and the Early to Late Silurian Smyrna Mills Formation (Bourque et al., 1995). Abundant volcanic and volcaniclastic rocks occur in the Ellen Wood Ridge Formation in Maine, U.S.A., which may be correlated to the upper part of the Smyrna Mills Formation (Hopeck, 2001). The Canterbury Basin contains marine clastic rocks and minor carbonate rocks of the Late Silurian Perham Group and shallow marine clastic and volcanic rocks of the Early Devonian Tobique Group (Rast et al., 1980). The strata of the Miramichi Terrane were subject to deformation during the Middle to Late Ordovician, and the strata of the Matapedia and Canterbury basins were deformed during the mid-Devonian Acadian Orogeny.

The volcanic rocks occurring in the Poplar Mountain area constitute a part of the Poplar Mountain Volcanic Complex, which extends across the Monument Brook into Maine (Fig. 1). A number of gold occurrences and anomalies have been discovered within the Poplar Mountain Volcanic Complex, among which the Poplar Mountain occurrence is the most significant one known so far (Freewest Resources

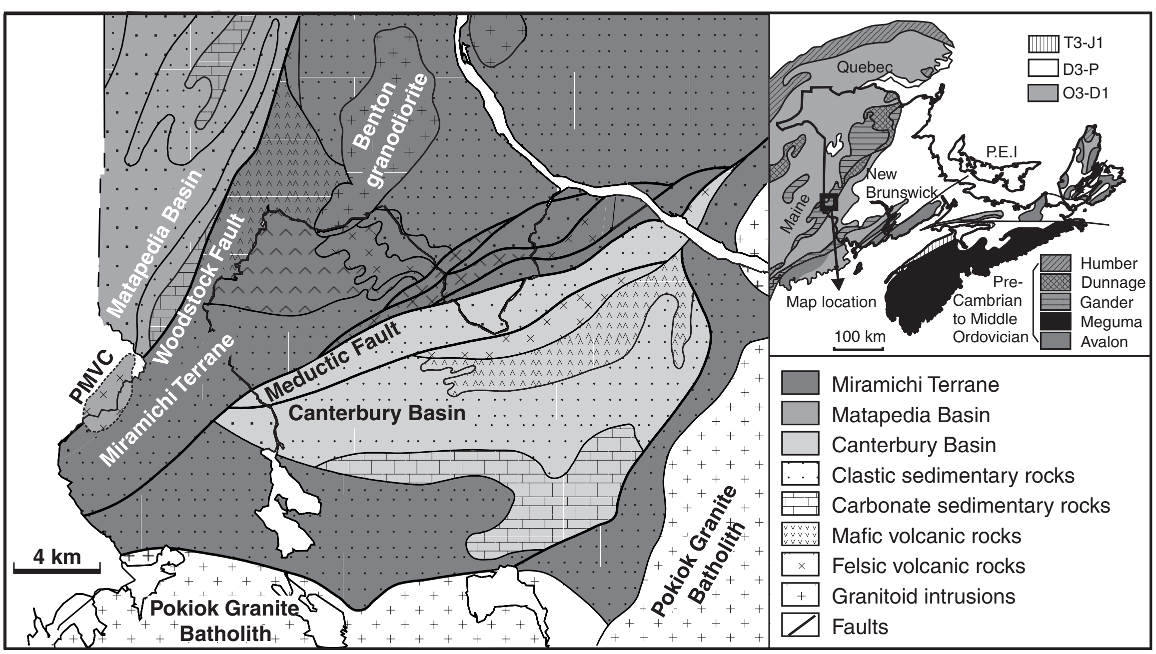

Figure 1. *Regional geological map of Poplar Mountain and adjacent areas in western New Brunswick, showing the location of the Poplar Mountain Volcanic Complex (PMVC) relative to other tectonostratigraphic units (*modified from *New Brunswick Department of Natural Resources and Energy, 2000).*

Canada Inc., unpub report, 1998; unpub. report on exploration on Golden Ridge property 1999; unpub. report on 1999 diamond drilling on Golden Ridge property, 1999). The Poplar Mountain Volcanic Complex, which has an ellipsoid shape about 4.5 km long and 1.5 km wide mainly based on geophysical data, is proximal and parallel to the Woodstock Fault (Fig. 1). No direct contact between the Poplar Mountain Volcanic Complex and the strata of any of the above-mentioned three major tectonostratigraphic units is exposed. Neither has the contact been observed between the Poplar Mountain Volcanic Complex and the dark grey slate of the Middle Ordovician Belle Lake Formation which occurs to the east and to the south of the Poplar Mountain area (Fig. 1, 2). Therefore, the relative geochronology and age of the Poplar Mountain Volcanic Complex is at present uncertain.

The Woodstock Fault is not exposed in the Poplar Mountain area. This regional fault was defined as the boundary between the Miramichi Terrane and the Matapedia Basin (Fyffe and Fricker, 1987). Therefore, if the volcanic rocks at Poplar Mountain belong to the Miramichi Terrane (e.g. the Meductic Group), then the fault should lie to the west of the Poplar Mountain Volcanic Complex (Lutes, 1979). Conversely, if the volcanic rocks belong to the Matapedia Basin (e.g. the Ellen Wood Ridge Formation), the fault should lie to the east of the Poplar Mountain Volcanic Complex (S.E. Watters, unpub. report, 1998). Another possibility is that the emplacement of the Poplar Mountain Volcanic Complex is controlled by the Woodstock Fault, and that the fault transects the complex.

PETROGRAPHY AND STRATIGRAPHY OF VOLCANIC AND SUBVOLCANIC ROCKS

The volcanic and subvolcanic rocks in the Poplar Mountain area can be divided into three principal units, including porphyritic dacite, dacitic volcaniclastic rocks, and basaltic volcanic rocks. The distribution of the three units is shown in Figures 2 and 3.

Porphyritic dacite

The porphyritic dacite, which underlies the topographic high of Poplar Mountain (Fig. 2), is exposed in outcrops, in exploration trenches, and was intersected in eight of the ten holes drilled on the property. It is characterized by its overall massive and coherent appearance (Fig. 4A), although local irregular brecciated zones with abundant angular fragments (Fig. 4B) were frequently encountered. Some centimetre-long, millimetre-spaced, pervasive and parallel wavy lines defined by green illite filling microfractures were locally observed, which may reflect some flow textures or bedding.

The porphyritic dacite consists of 5–30% phenocrysts, typically 0.2–0.5 mm, in an aphanitic (≤0.01 mm) feldspar-quartz matrix. The phenocrysts are generally euhedral to subhedral, and consist mainly of plagioclase and lesser K-feldspar, some hornblende, pyroxene, and leucoxene, and occasionally quartz. Most feldspar phenocrysts are intensively altered to sericite±carbonate. Hornblende and pyroxene are completely replaced by chlorite and to a lesser extent

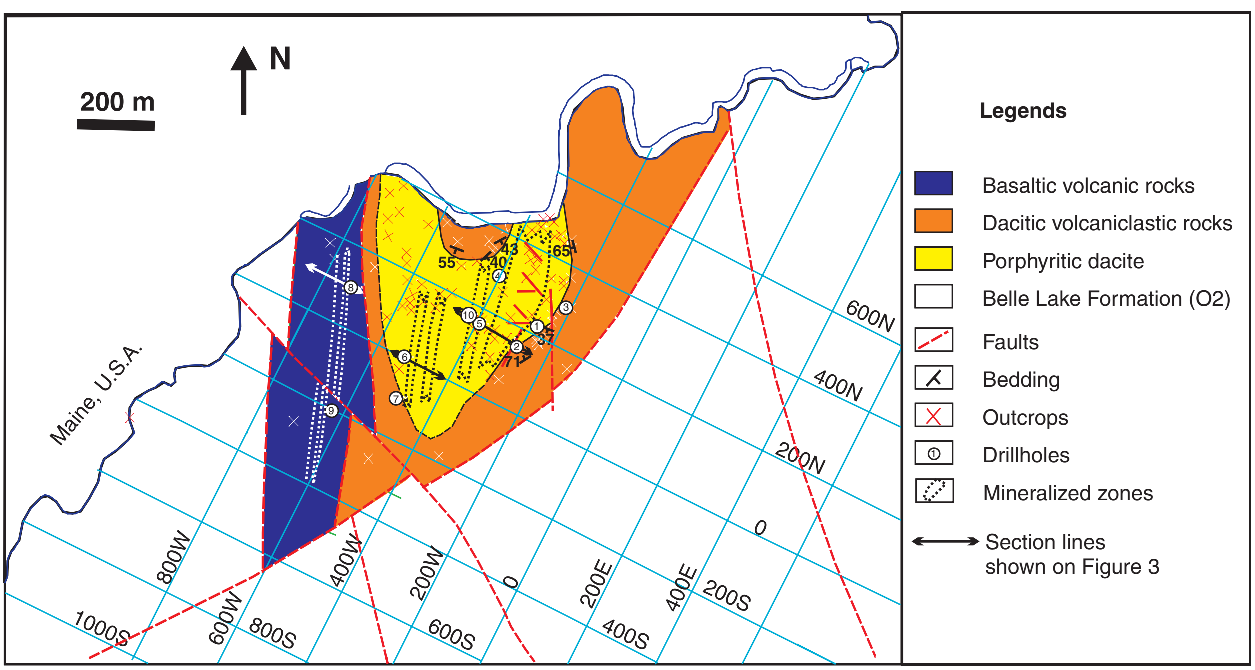

Figure 2. *Local geological map of Poplar Mountain area.*

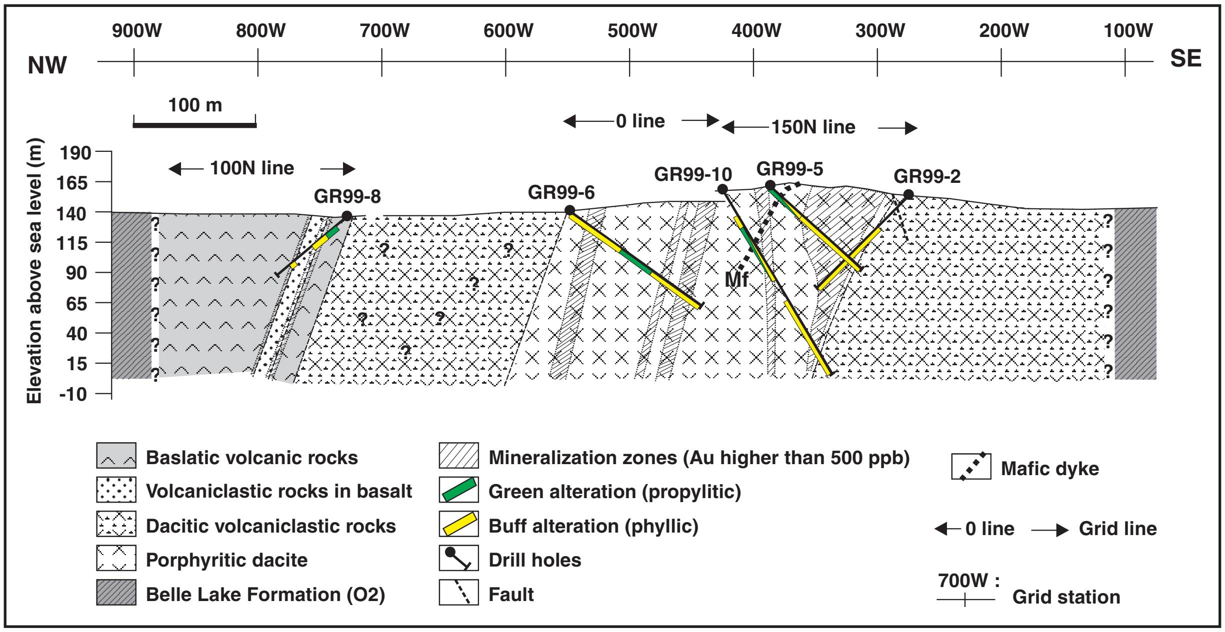

Figure 3. A composite geological cross-section of the Poplar Mountain prospect. Note the attitudes of most of the geological boundaries are not constrained by drillholes or surface measurements, and the distribution of alteration types is not complete yet.

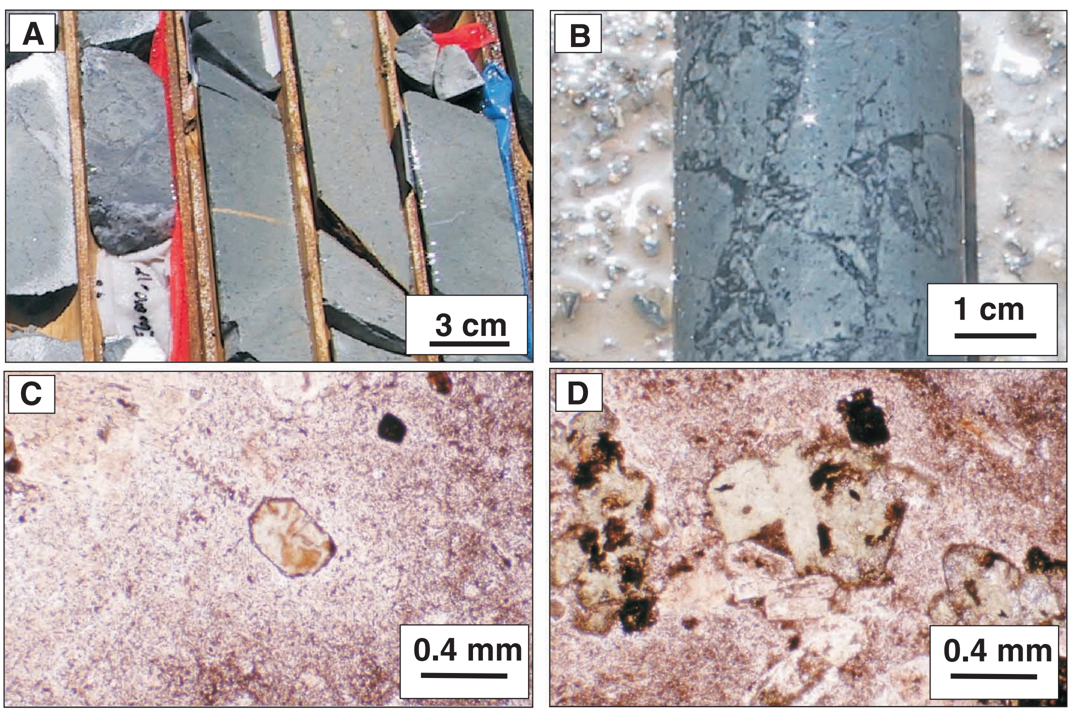

***Figure 4. A**) Porphyritic dacite showing massive texture (from drillhole GR99-5). **B)** Brecciated porphyritic dacite (sample GC01-78, from drillhole GR99-10). **C)** A phenocryst showing pseudomorph of pyroxene, altered by chlorite, in porphyritic dacite (sample 01SW34, from drillhole GR99-3). **D)** Glomerocrysts in porphyritic dacite (sample 01SW34, from drillhole GR99-3).*

by carbonate, but their crystal shapes are well preserved (Fig. 4C). Feldspar glomerocrysts with or without associated hornblende and/or pyroxene, which range from submillimetre to a few millimetres, are common (Fig. 4D). Although the phenocryst population is suggestive of andesitic composition, chemical analysis of a weakly altered sample yielded 66.0% SiO_2, plotting in the domain of dacites in the SiO_2-(Na_2O+K_2O) diagram of Cox et al. (1979) (S.E. Watters, unpub. report, 1998). Until more geochemical data are available, this lithological unit is referred to as porphyritic dacite.

Dacitic volcaniclastic rocks

The dacitic volcaniclastic unit is sparsely exposed in outcrops within 50 m of the margins of the porphyritic dacite unit (Fig. 2), and was also intersected by drillholes on both east and west sides of the porphyritic dacite unit. In contrast to the massive and coherent appearance of the porphyritic dacite, the dacitic volcaniclastic unit consists of variably sized volcanic fragments sitting in texturally variable matrix. The shape of the volcanic fragments varies from rounded to angular (Fig. 5A), and their size varies from a few millimetres to tens of centimetres. In many cases, adjacent fragments fit with each other, suggesting in situ brecciation. Both the fragments and matrix are mainly composed of dacitic volcaniclastic rocks. Fragments of slate and porphyritic dacite are occasionally seen. Bedding indicated by flattening of glassy tuff fragments, and by change of abundance of crystals and colour, is observed in a few places east of and north of the porphyritic dacite (Fig. 2).

The most common volcanic fragments are crystal tuffs, which are mainly composed of crystals and glassy ash matrix. The matrix to these volcanic fragments is itself crystal tuff, which may be similar or different from the fragments in terms of texture and composition. Both fragments and matrix are characterized by the abundance of feldspar (mainly plagioclase) crystals, generally 30% or more (Fig. 5B), although the matrix generally contains less crystals and is more glassy than the fragments. Quartz crystals are more frequently seen than in the porphyritic dacite. Hornblende and pyroxene crystals are occasionally seen, and are completely altered to chlorite. Glass shards and glassy ash matrix are commonly devitrified and altered to chlorite, and some spherulitic textures can still be recognized (Fig. 5C). Occasionally, nondevitrified glass, showing complete extinction under crossed nicols and some hairy cracks (Fig. 5D), is preserved. A chemical analysis of this unit, showing a SiO_2 content of 67.9%, plots in the domain of dacites in the SiO_2-(Na_2O+K_2O) diagram of Cox et al. (1979) (S.E. Waters, unpub. report, 1998).

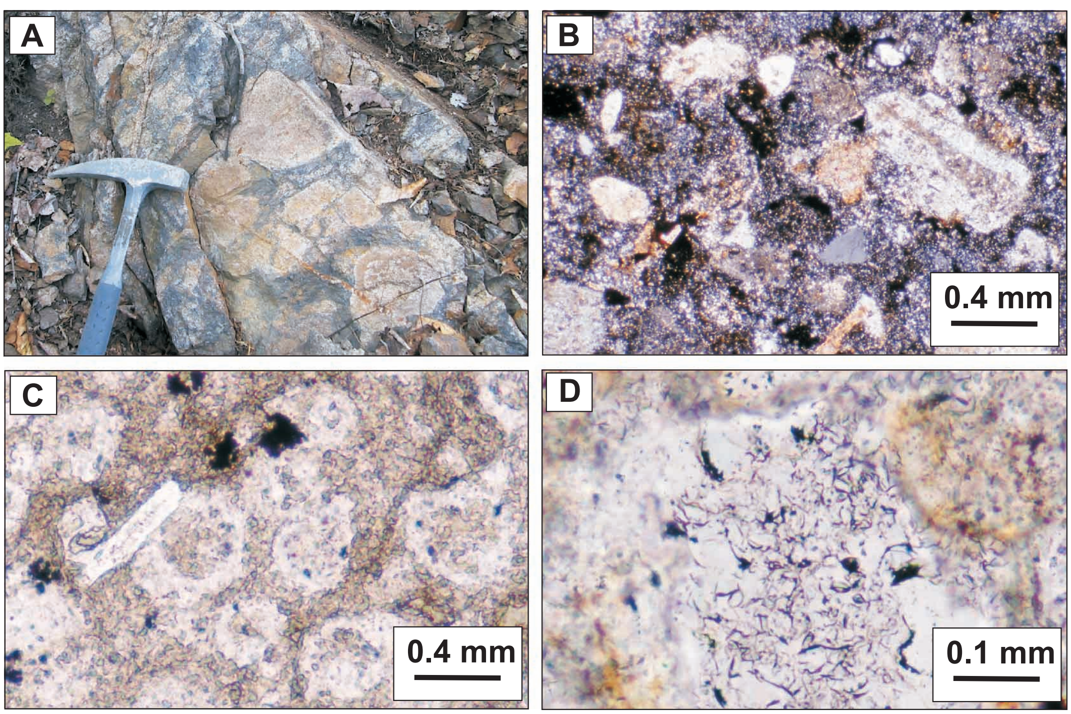

***Figure 5. A**) Rounded and angular volcanic fragments in the dacitic volcaniclastic unit (near trench 1). **B)** Abundance of feldspar crystals in dacitic volcaniclastic rocks (sample GC01-55, from trench 5). **C)** Spherulitic texture in dacitic volcaniclastic rocks (sample 98SW138, from an outcrop to the north of the dacite intrusion). **D)** Volcanic glass in the matrix of the dacitic volcaniclastic rocks, showing hairy cracks (sample GC01-55, from trench 5).*

Basaltic volcanic rocks

The basaltic volcanic unit is poorly exposed, but was intersected by two drillholes west of the porphyritic dacite unit (Fig. 2). Its distribution in the swamp area west of Poplar Mountain is mainly based on ground magnetic data. The basaltic volcanic rocks are massive, homogeneous, and are composed of fine-grained plagioclase, hornblende, pyroxene, minor quartz, and glass. Pyroxene and hornblende crystals are irregular in shape, and are fairly fresh. The glass is devitrified and altered to chlorite. Amygdales filled by carbonate are common. Trails of millimetre-sized, lensoid, blackish spots, composed of glass altered to chlorite, are frequently seen in subparallel planes.

A volcaniclastic subunit, only seen in two drill cores (GR99-8 and GR99-9), is intercalated within the basaltic volcanic rocks. It is characterized by centimetre-sized, elongated volcanic fragments, and by the presence of bedded chert. The volcanic fragments contain abundant plagioclase crystals and are similar to the dacitic volcaniclastic rocks.

Relative timing and stratigraphy of the volcanic and subvolcanic rocks

The volcanic rocks in the Poplar Mountain area are characterized by the absence of subaqueous sediments (except the volcaniclastic subunit within the basaltic volcanic unit). We interpret the dacitic volcanic rocks to represent a volcanic dome in a terrestrial environment, with the porphyritic dacite representing a subvolcanic intrusion, and the dacitic volcaniclastic rocks fringing the dome. The presence of porphyritic dacite fragments in the dacitic volcaniclastic unit near the contact (Fig. 6A), seen in two drill cores, suggests that at least part of the dacitic volcaniclastic rocks were formed during or after the porphyritic dacite. Elsewhere, the porphyritic dacite may have intruded the dacitic volcaniclastic unit. The basaltic volcanic unit is interpreted to be younger than the dacitic units based on two observations. First, a basaltic dyke, seen in two drill cores and traced to the surface (trench 5), cuts the porphyritic dacite (Fig. 3, 6B). Second, some of the volcanic fragments in the volcaniclastic subunit intercalated within the basalt may have been derived from the dacitic volcaniclastic unit.

STRUCTURES

Due to the paucity of exposures and bedding indicators in the volcanic rocks and the nonexposure of the contact between the Poplar Mountain Volcanic Complex and surrounding stratigraphic units, the overall structural pattern of the volcanic rocks remains unclear. From the limited bedding measurements (Fig. 2), it appears that the strike of the dacitic volcaniclastic unit is parallel to the margin of the intrusion and its dip angle is variable (37–71°). The dip angle of bedding (71°) measured near drillhole GR99-2 (Fig. 2) is also similar to the apparent dip angle of the intrusive margin, which is constrained by drill core and outcrop correlation (Fig. 3). The small angles (0–20°) between the bedding in the volcaniclastic subunit intercalated within the basaltic unit and the drillholes, which dip at 45° to the northwest, suggest that the basaltic unit may also dip to the northwest at moderate to high angles. The distribution of the dacitic volcaniclastic rocks around the porphyritic dacite might suggest that there is an anticline with the porphyritic dacite intrusion in the core flanked by the dacitic volcaniclastic rocks. Alternatively, this distribution pattern may reflect the original configuration of a volcanic dome. In either case, the volcanic rocks appear to have been tilted by tectonic deformation.

Structurally, the volcanic and subvolcanic rocks are characterized by brittle deformation, and by the lack of foliation in surface exposures. Foliation shown by preferential orientation of sericite is observed only in the deeper part of a few drill cores. The porphyritic dacite is extensively fractured (Fig. 7A, B) and cut by a few minor brittle faults (Fig. 2). Closely spaced (centimetre-scale) parallel fractures (Fig. 7B), which show very thin quartz-carbonate vein fillings in drill cores (Fig. 7C), are widespread in the porphyritic dacite. Their orientations are fairly stable at outcrop scale (e.g. Fig. 7B), and can be traced over metres to tens of metres, but are highly variable at prospect scale (Fig. 8A).

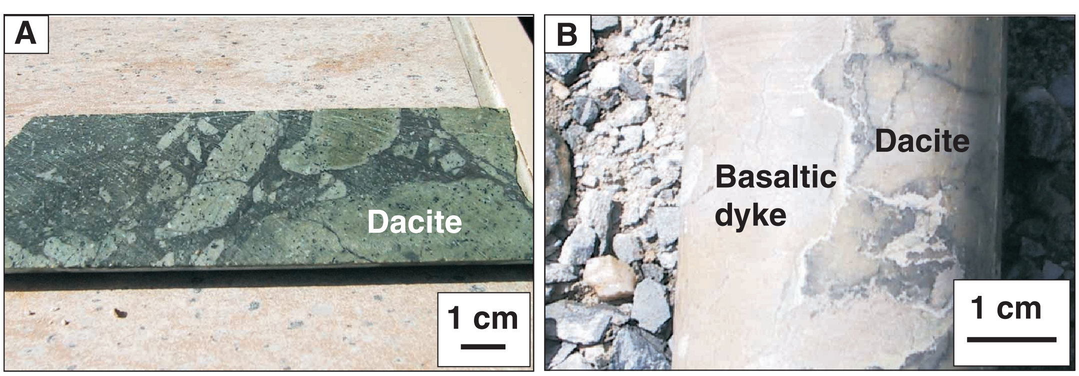

Figure 6. A) *Porphyritic dacite fragments in dacitic volcaniclastic rocks (sample GC01-140, from drillhole GR99-6).* ***B)*** *Basaltic dyke cuts the porphyritic dacite (sample GC01-73, from drillhole GR99-10).*

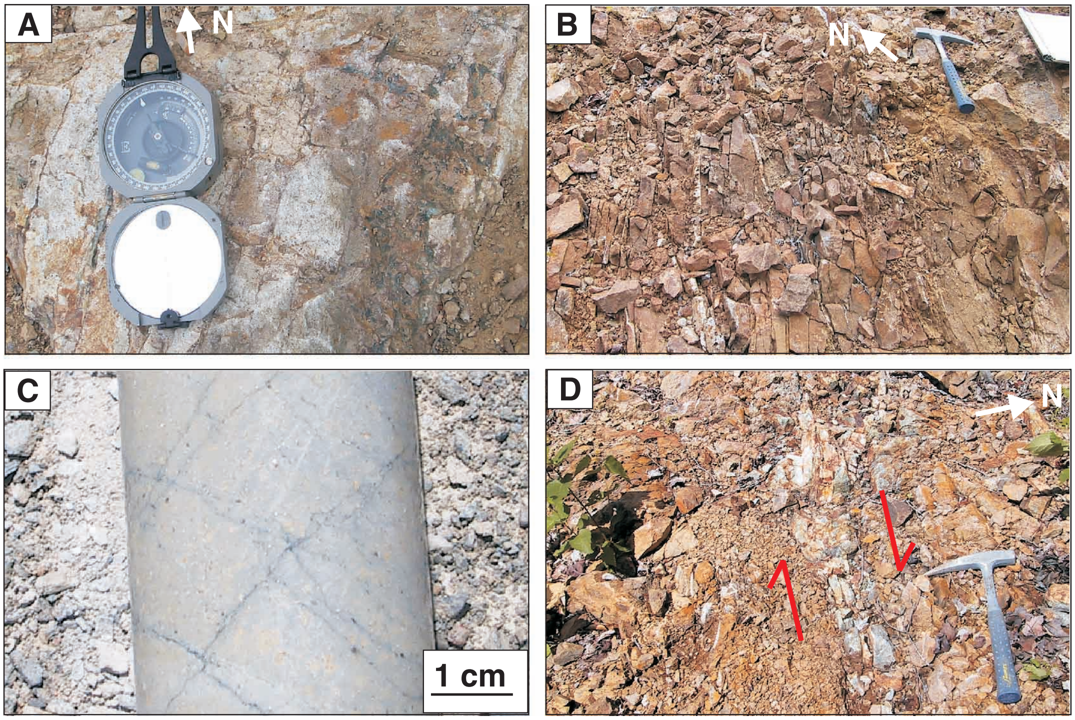

Figure 7. ***A)*** *Fractured and brecciated porphyritic dacite (trench 5).* ***B)*** *A set of northeast-trending closely spaced fractures (trench 2).* ***C)*** *Closely spaced fractures filled by thin quartz-carbonate veins (sample GC01-76, from drillhole GR99-10).* ***D)*** *Closely spaced fractures cut by a east-trending fault filled with quartz vein (trench 4).*

A few northwest-, north-northwest-, and east-striking faults were mapped within the porphyritic dacite (Fig. 2). Some of them are filled with quartz veins and bordered by quartz-cemented breccia, and are mineralized. Movements postdating mineralization along the faults are indicated by slikensides on fracture planes cutting the veins. Subsidiary fractures associated with these faults, and slikensides and/or fibres on the fault planes, generally indicate sinistral strike-slip movements along the northwest- and north-northwest-trending faults and dextral strike-slip movements along the east-striking faults. The orientation of these faults and the movement senses suggest that they are conjugate and related to northwest-southeast oriented shortening. The fault veins cut the closely spaced fractures (e.g. Fig. 7D).

MINERALIZATION AND ALTERATION

Mineralization

The Poplar Mountain gold occurrence contains several mineralization zones, the widths of which vary from a few metres up to 60 m, and the assay values of gold range from 0.26 ppm to 5.53 ppm (Freewest Resources Canada Inc., unpub. report on 1999 diamond drilling on Golden Ridge property, 1999). Gold mineralization known so far is mainly hosted in the porphyritic dacite, and to a lesser extent in the basaltic volcanic rocks (Fig. 2, 3). The mineralization zones shown in Figure 2 are mainly based on assay data and inference from airborne magnetic data (Freewest Resources Canada Inc., unpub. report on exploration on Golden Ridge property 1999; unpub. report on 1999 diamond drilling on Golden Ridge property, 1999). In vertical direction, it appears that zones of mineralization narrow with depth (Fig. 3).

Gold mineralization is mainly associated with arsenopyrite, and to a lesser extent with pyrite, stibnite, and sphalerite (Freewest Resources Canada Inc., unpub report, 1998; unpub. report on exploration on Golden Ridge property 1999; unpub. report on 1999 diamond drilling on Golden Ridge property, 1999). Gold is strongly correlated with arsenic, and to a lesser extent with antimony. Arsenopyrite, which is typically acicular, and pyrite occur in three modes, i.e. 1) disseminated in host rocks (Fig. 9A), 2) in sulphide veinlets or stockworks (Fig. 9B), and 3) in quartz-carbonate veins or breccia matrix (Fig. 9C, D). Minor amounts of sphalerite and stibnite occur in some quartz-carbonate veins. The quartz-carbonate veins are generally millimetres to centimetres wide, and a few are tens of centimetres wide (Fig. 9E). Locally the quartz-carbonate veining is intensive and forms stockworks. Arsenopyrite disseminated in the porphyritic dacite occurs both in the phenocrysts and in the groundmass; however, it is commonly more adjacent to phenocrysts, especially leucoxene (Fig. 9A), suggesting that the iron in arsenopyrite may be derived from alteration of the phenocrysts. Although dissemination is the most important mineralization style, the mineralized zones appear to be characterized by higher density quartz-carbonate veining than the barren zones (Fig. 9F).

There is no clear geological or structural boundary between mineralized and nonmineralized zones. At outcrop scale the quartz-carbonate veins show preferred orientations, but at prospect scale, their orientations are highly variable (Fig. 8B). Some northwest-, north-northwest-, and east-trending faults and associated veins and breccia are mineralized, suggesting a possible structural control; however, these fault veins and breccia are sparsely distributed and are generally small in size (centimetre to tens of centimetres wide), and represent only a small proportion of the known mineralized system.

Host-rock alteration

The most common alteration minerals are chlorite, carbonate minerals, sericite, quartz, and illite. Chlorite commonly totally replaces the entire phenocrysts of hornblende and pyroxene and partly replaces plagioclase phenocrysts and most of the glass fragments and glassy matrix (Fig. 4C, D). It is the most widespread alteration mineral in each of the three principal volcanic and subvolcanic units and is best preserved in nonmineralized zones (Fig. 3). Sericite selectively replaces feldspar phenocrysts (Fig. 10A), but with increasing intensity of alteration, it replaces the matrix as well as other minerals. It is mainly developed in the mineralized zones and nearby host rocks (Fig. 3). Carbonate minerals are as widespread as

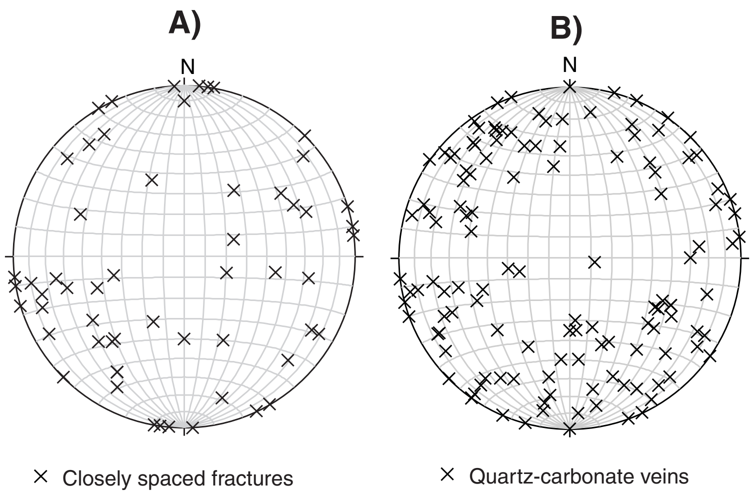

Figure 8.

*Stereonets (lower hemisphere projection) showing poles of **A)** closely spaced fractures, and **B)** quartz-carbonate veins from the Poplar Mountain prospect.*

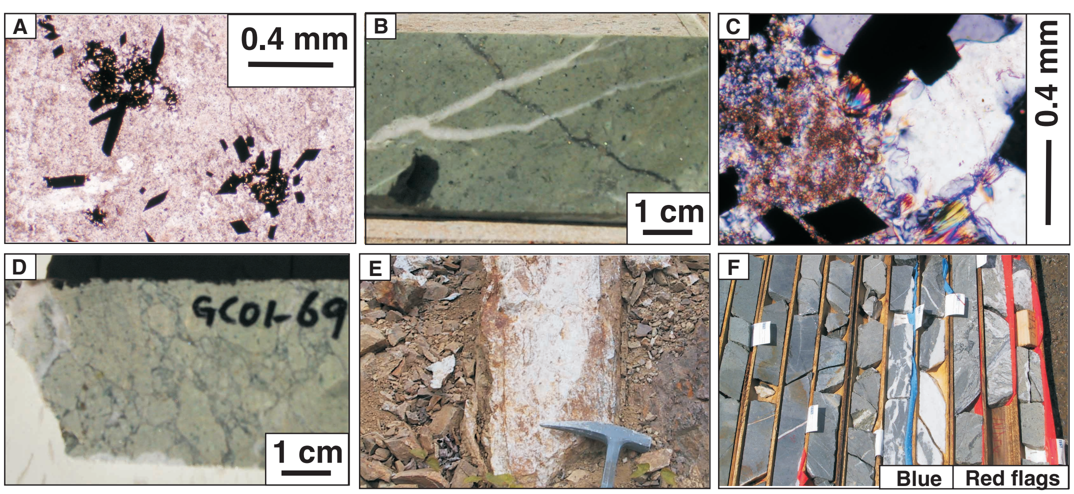

***Figure 9. A**) Disseminated arsenopyrite in porphyritic dacite; note association of asernopyrite with leucoxene (sample 97SW46, from an outcrop near trench 3). **B)** An arsenopyrite veinlet cut by quartz-carbonate veins (sample GC01-61, from drillhole GR99-2). **C)** Arsenopyrite associated with sericite near the wall of a quartz vein (sample 97SW46, from an outcrop near trench 3). **D)** Arsenopyrite in quartz-cemented breccia. **E)** A large quartz-carbonate vein cutting the porphyritic dacite (trench 5). **F)** Drill cores showing that the mineralized zones (red flag: ≥1 ppm Au, blue flag: ≥0.5–1 ppm Au) contain more quartz-carbonate veins than the barren zones.*

chlorite, and can replace any components including phenocrysts of hornblende, feldspars, as well as matrix; however, unlike chlorite, carbonate minerals are better developed in the mineralized zones than in the nonmineralized zones. Illite can be associated with chlorite replacing phenocrysts of hornblende, pyroxene, and plagioclase, or with sericite replacing feldspars. Quartz preferentially occurs in various veins, although its replacement of other minerals is occasionally observed (Fig. 10B). Silicification along fractures has locally produced false volcaniclastic textures.

The combination of chlorite±carbonate±illite±pyrite is comparable to propylitic alteration, and the sericite+carbonate±illite±quartz assemblage may be compared to phyllic alteration. Although some chloritization might be related to regional metamorphism, the occurrence of chlorite veins (next section) favors a hydrothermal origin.

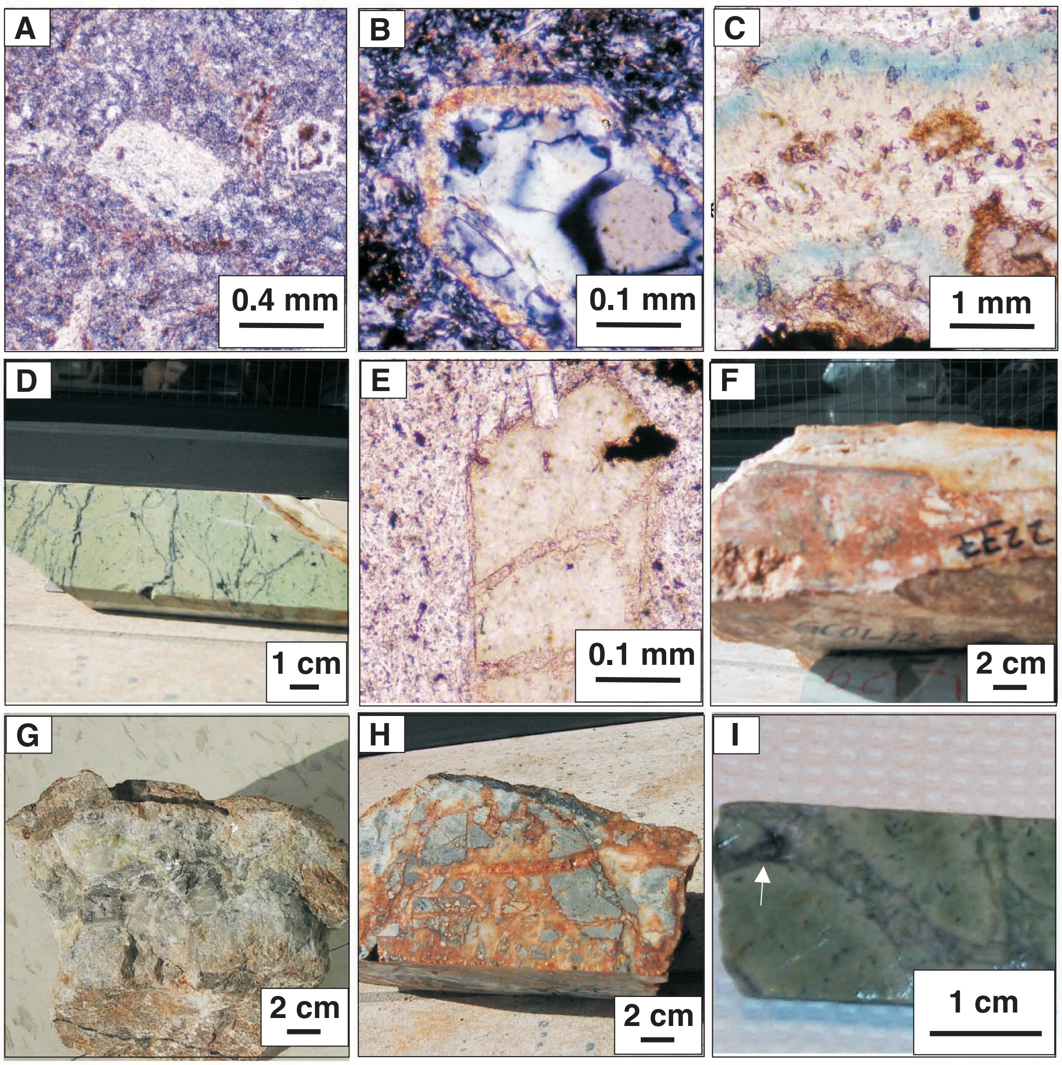

***Figure 10. A**) Feldspar phenocrysts replaced by sericite (sample GC01-80, from drillhole GR99-10). **B**) Hornblende phenocryst replaced by quartz (sample GC01-70, from drillhole GR99-5). **C**) Illite+chlorite+carbonates occurring as cements in hydrothermal breccia of porphyritic dacite; Illite coats the fragments, and is followed by chlorite and carbonate (sample GC01-70, from drillhole GR99-5). **D**) Irregular cracks in porphyritic dacite filled by black material consisting mainly of very fine iron oxide, carbonate, albite, and quartz. **E**) A sericite veinlet cutting through chlorite which replaces a phenocryst in the dacite (sample GC01-79, from drillhole GR99-10). **F**) Cockscomb texture in the centre of a quartz vein. **G**) Large carbonate crystals in vein. **H**) Dacite breccia cemented by quartz-carbonate-sulphides (sample GC01-123, from trench 1). **I**) Dacite breccia cemented by quartz-carbonates-sulphides (sample 01SW32, from drillhole GR99-6). Note the presence of pyrobitumen (arrow).*

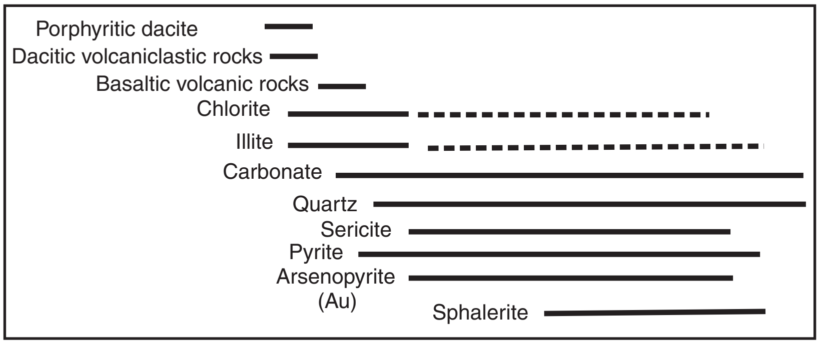

Figure 11.

Paragenesis of principal alteration and ore minerals.

Hydrothermal veins

All the alteration minerals described above also occur in various veins. The crosscutting relationships between these veins offer the opportunity to establish the relative timing of different alterations.

Chlorite+illite±carbonate±pyrite occur as cements in some hydrothermal breccia units in the porphyritic dacite outside the mineralized zones. Illite typically coats the wall of the dacite fragments and is followed by chlorite and carbonate (Fig. 10C). The chlorite and illite in the cements are similar to those replacing hornblende and plagioclase phenocrysts in the dacite fragments, and are considered part of the propylitic alteration.

A set of black veinlets of millimetre to centimetre width and tens of centimetres in length fill highly irregular multidirectional cracks in the porphyritic dacite (Fig. 10D). These black veinlets are composed mainly of iron oxide, carbonate, albite, quartz, and lesser amount of apatite, rutile, sphalerite, and some rare-earth phosphate minerals, all of which are very fine grained and were identified with a scanning electron microscope. These black veinlets cut through chlorite replacing hornblende and plagioclase phenocrysts, and are always cut by various other veins (Fig. 10D).

A set of dark grey veins composed of cherty quartz that are highly irregular in shape, and centimetres to tens of centimetres wide and metres long, were observed in several outcrops within the porphyritic dacite intrusion. They are always cut by quartz-carbonate-sericite veins associated with mineralization.

Multiple quartz-carbonate-sericite±illite±sulphides veins, which mutually cut each other, are developed in the porphyritic dacite, especially in the mineralization zones. These veins are superimposed on chloritization (e.g. Fig. 10F) and earlier veining, and are broadly contemporaneous with sericitization, carbonatization, silicification, and disseminated sulphide mineralization in the host rocks; however, the euhedral quartz with cockscomb textures (Fig. 10F) and some large carbonate crystals occupying the centre of veins (Fig. 10G) may be later than sulphide mineralization. The quartz and carbonate crystals in the veins show no undulatory extinction to strong undulatory extinction, suggesting different degrees of deformation postdating mineralization.

Hydrothermal breccia units, although less abundant than veins, are widespread, and are generally associated with veining. The most common type of breccia consists of porphyritic dacite fragments, generally angular, cemented by quartz and carbonate minerals. Pyrite and arsenopyrite occur in the matrix as well as in the fragments (Fig. 10H, I). In a few cases, some globules of pyrobitumen were observed in the matrix (Fig. 10I).

Paragenesis of mineralization and alteration

Based on the above crosscutting relationships, the paragenetic sequence of mineralization and alteration is summarized in Figure 11. The fact that mineralization occurs both in the porphyritic dacite and basaltic volcanic rocks suggests that mineralization took place after the emplacement of all the volcanic and subvolcanic rocks. Propylitization predates ore deposition, whereas the sericite+carbonates±illite alteration is mainly synchronous with ore deposition. Some carbonate and quartz veins may postdate ore deposition.

DISCUSSION AND CONCLUSIONS

Due to the lack of data and definite relative chronology between volcanism, deformation, and mineralization, the origin of gold mineralization at Poplar Mountain remains uncertain. McLeod and McCutcheon (2000) classified the Poplar Mountain gold occurrence as a porphyry type, based on the fact that it is mainly hosted in a porphyritic intrusion. Freewest Resources Canada Inc. (unpub. report on exploration on Golden Ridge property 1999; unpub. report on 1999 diamond drilling on Golden Ridge property, 1999) emphasized the epithermal features of the mineralization, such as the quartz-cemented brittle breccia and cockscomb textures, and the association of Au with As and Sb. In such a case, these characteristics, combined with the relatively high Zn and low Cu contents (S.E. Watters, unpub. report, 1998) and the abundance of carbonate alteration, would suggest a low-sulphidation affinity.

The propylitic and phyllic alterations are common in epithermal deposits (Henley, 1991; Sillitoe, 1993a), but they can also be the outer zones of a porphyry-type gold system (Sillitoe, 1993b). On the other hand, neither K-silicate alteration, typical of porphyry-type system, nor andularia and bladed calcite and colloform-crustiform textures, diagnostic of a low-sulphidation epithermal system, have been so far identified at Poplar Mountain.

Mineralization within the dacite intrusion is mainly controlled by dense, multidirectional brittle fractures that could have enhanced the permeability of the dacite and promoted mineralization both as veins and as dissemination in the dacite. The age and origin of the fracturing is at present unknown. They could have been related to volcanic activities that formed the volcanic dome, or to the tectonic event that tilted or folded the whole volcanic sequence. The northwest-, north-northwest-, and east-trending faults, which controlled some gold-bearing quartz-carbonate veins, however, are more likely to be related to a tectonic event in a northwest-southeast compressional regime.

The role of the Woodstock Fault in the formation of the ore-controlling fractures is also currently uncertain. From the close spatial relationship between the Poplar Mountain Volcanic Complex and the Woodstock Fault, it is probable that this regional fault played a key role in the emplacement of the volcanic and subvolcanic rocks, and probably also played an important role in the mineralization by enhancing the permeability of the volcanic rocks as well as providing conduits for mineralizing fluids.

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REFERENCES

Bourque, P.-A., Brisebois, D., and Malo, M.
1995: Gaspé Belt; *in* Chapter 4 of Geology of the Appalachian-Caledonian Orogen in Canada and Greenland; (ed.) H. Williams; Geological Survey of Canada, Geology of Canada, no. 6, p. 316–351 (*also* Geological Society of America, The Geology of North America, v. F-1).

Cox, K.G., Bell, J.D., and Pankhurst, R.J.
1979: The Interpretation of Igneous Rocks; Allen and Unwin, London, United Kingdom, 450 p.

Fyffe, L.R.
in press: Stratigraphy and geochemistry of Ordovician volcanic rocks of the Eel River area, west-central New Brunswick; Atlantic Geology.

Fyffe, L.R. and Fricker, A.
1987: Tectonostratigraphic terrane analysis of New Brunswick; Maritime Sediments and Atlantic Geology, v. 23, p. 113–122.

Henley, R.W.
1991: Epithermal gold deposits in volcanic terranes; *in* Gold Metallogeny and Exploration, (ed.) R.P. Foster; Blackie, Glasgow and London, United Kingdom, p. 133–164.

Hopeck, J.
2001: Post-Caradocian, pre-Acadian stratigraphy in eastern Maine: relation of the Aroostook–Matapedia Belt to the Miramichi Anticlinorium and the Central Maine Belt; *in* 93rd Annual Meeting of the New England Intercollegiate Geological Conference, Field Guide Book, p. C4-1–C4-13.

Lutes, G.
1979: Geology of Fosterville-North and Eel lakes map-area G-23 and Canterbury–Skiff Lake map-area H-23, parts of 21G/13 and 21G/14; New Brunswick Department of Natural Resources and Energy, Mineral Resources Branch, Map Report 79-3, 22 p.

McLeod, M.J. and McCutcheon, S.R.
2000: Gold environments in New Brunswick; New Brunswick Department of Natural Resources and Energy, Minerals and Energy Division, Plate 2000-8.

New Brunswick Department of Natural Resources and Energy
2000: Bedrock geology of New Brunswick, Map NR-1 (2000 edition), scale 1:500 000.

Rast, N., Lutes, G.G., and St. Peter, C.
1980: The geology and deformation history of the southern part of the Matapedia Zone and its relationship to the Miramichi Zone and Canterbury Basin; *in* A Guidebook to the Geology of Northeastern Maine and Neighboring New Brunswick, (ed.) D.C. Roy and R.S. Naylor; 72nd Annual Meeting of the New England Intercollegiate Geological Conference, Presque Isle, Maine, p. 191–201.

Sillitoe, R.H.
1993a: Epithermal models: genetic types, geometrical controls and shallow features; *in* Mineral Deposit Modeling, (ed.) R.V. Kirkham, W.D. Sinclair, R.I. Thorpe, and J.M. Duke; Geological Association of Canada, Special Paper 40, p. 403–417.
1993b: Gold-rich porphyry copper deposits: geological model and exploration implications; *in* Mineral Deposit Modeling, (ed.) R.V. Kirkham, W.D. Sinclair, R.I. Thorpe, and J.M. Duke; Geological Association of Canada, Special Paper 40, p. 465–478.

Williams, H.
1995: Temporal and spatial divisions; Chapter 2 *in* Geology of the Appalachian-Caledonian Orogen in Canada and Greenland, (ed.) H. Williams; Geological Survey of Canada, Geology of Canada, no. 6, p. 21–44 (*also* Geological Society of America, The Geology of North America, v. F-1).

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