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Abstract: The QSP area represents a well preserved segment of felsic volcanic stratigraphy within the Hope Bay volcanic belt. The stratigraphy consists of a basal sequence of amygdaloidal intermediate volcanic rocks, overlain by four distinct cycles of coherent to volcaniclastic felsic volcanic rocks. These units are traceable over the area mapped and are truncated to the north and west by monzogranite and to the east by gabbro. No large-scale structural repetitions of stratigraphy were recognized. Locally, the felsic rocks are altered to an assemblage of quartz-sericite and pyrite through which primary volcanic textures may be recognized. These alteration zones are discontinuous, having been disrupted and attenuated during development of the main transposition fabric, which the intensity and style of alteration suggest formed as a synvolcanic alteration. Regional metamorphism of the altered, high-aluminous assemblage produced aluminosilicate porphyroblasts, suggesting localized centres of more intense alteration.

Résumé : Le secteur QSP forme un segment bien conservé de la stratigraphie volcanique de composition felsique au sein de la ceinture volcanique de Hope Bay. La stratigraphie consiste en une séquence basale de roches volcaniques à texture amygdalaire de composition intermédiaire, laquelle est surmontée de quatre cycles bien définis de roches volcaniques felsiques montrant le passage de roches cohésives à des roches volcanoclastiques. Ces unités peuvent être suivies dans la région cartographiée et sont tronquées par du monzogranite au nord et à l'ouest et par du gabbro à l'est. Aucune répétition structurale d'envergure de la stratigraphie n'a été repérée. Par endroits, les roches felsiques ont été transformées par altération en une association à quartz-séricite et pyrite, mais, dans ces roches altérées, les textures volcaniques primaires peuvent néanmoins être reconnues. Ces zones d'altération sont discontinues, ayant été segmentées et amincies par la formation de la fabrique principale de transposition. L'intensité et le style de l'altération indiquent que celle-ci serait de formation synvolcanique. Le métamorphisme régional de l'association d'altération hyperalumineuse a engendré la formation de porphyroblastes d'aluminosilicates, ce qui laisse croire à la présence de zones localisées où l'altération a été plus intense.

INTRODUCTION

Gold deposits in the Hope Bay volcanic belt are among Nunavut's most advanced exploration projects and represent potential for near-term production. Several distinctly different deposits have been outlined in the belt since the inception of sustained precious-metal exploration, initially by BHP in the early 1990s and currently by the Hope Bay Joint Venture. These include the Boston and Doris deposits as well as the Madrid Group of deposits. In addition to the precious-metal deposits, a number of base-metal targets have also been developed over the course of regional exploration. The diversity in mineralization style along with abundant outcrops and drill cores, low metamorphic grades, and overall low strain make the Hope Bay belt an ideal location to characterize the architecture and mineralizing events of the greenstone belt and to place them in the context of the evolving host terrane.

Here we report the results of a detailed (1:5000 scale) mapping program over the QSP area to outline volcanic stratigraphy and associated geochemistry and hydrothermal alteration. The QSP area is a prospect that has some potential for gold-rich synvolcanic mineralization.

REGIONAL GEOLOGY

The Hope Bay volcanic belt is located in the northeast portion of the Slave structural Province, an Archean granite–greenstone–metasedimentary terrane that lies between Great Slave Lake and Coronation Gulf and is bounded to the east by the Thelon Orogen (2020–1910 Ma) and to the west by the Wopmay Orogen (1950–1840 Ma; Hoffman, 1988).

Twenty-six granite–greenstone belts are recognized in the Slave Province and are subdivided into mafic volcanic-dominated (Yellowknife type) and felsic volcanic-dominated (Hackett River type; Padgham, 1985) types. Yellowknife-type belts are typically massive to pillowed tholeiitic flows interbedded with calc-alkaline felsic volcanic and volcaniclastic rocks, clastic sedimentary rocks, and rarely synvolcanic conglomerate and carbonate units. Hackett River-type belts are dominated by calc-alkaline felsic and intermediate rocks intercalated with turbidite. Uranium-lead geochronology brackets volcanism in the Slave Province to between 2715 and 2655 Ma (Mortensen et al., 1988; Isachsen et al., 1991). The volcanic belts are typically isoclinally folded and contain belt-parallel shear zones. A late (< 2.6 Ga) 'Timiskaming-type' sedimentary assemblage consisting of conglomerate and sandstone commonly overlies the main greenstone belts (Fyson and Helmsteadt, 1988). Villeneuve et al. (1997) subdivided the intrusive rocks into 2.70 to 2.64 Ga predeformation tonalite and diorite, 2.62 to 2.59 Ga K-feldspar-megacrystic granite, and 2.60 to 2.58 Ga postdeformation two-mica granite. In general, a regional pan-Slave deformation event is recognized between 2.7 and 2.6 Ga, characterized by regional compression, plutonism, and late extension (<2.583 Ga).

HOPE BAY VOLCANIC BELT

The Bathurst block is the portion of the Slave Province northeast of Bathurst Inlet (Fig. 1); it is isolated from the rest of the Slave by Proterozoic cover of the Kilohigok Basin (Campbell and Cecile, 1976). The Hope Bay volcanic belt (Fig. 1) is within the northern portion of the Bathurst block. It was first mapped at a reconnaissance level by Fraser (1964), Gibbons (1987), and Gebert (1990, 1993), who considered it to be an Archean volcanic terrane belonging to the Yellowknife Supergroup. It is dominated by mafic volcanic rocks with lesser felsic volcanic sequences and subordinate ultramafic bodies and metasedimentary rocks. Existing U-Pb geochronology indicates that felsic volcanism spanned a period of at least 53 Ma (2716–2663 Ma; Hebel 1999; M.U. Hebel and J.K. Mortensen, unpub. data, 2001).

To the east, the Hope Bay belt is bordered by granitoid intrusions that separate it from the Elu Inlet belt (Fig. 1). A granodiorite northeast of the Hope Bay belt gave an U-Pb zircon age of 2672 +4/-1 Ma, suggesting synvolcanic to late volcanic felsic intrusions (Bevier and Gebert, 1991). The southeastern contact of the Hope Bay belt is a heterogeneous gneiss terrane that yielded a U-Pb zircon age of 2649.5 +2.9/-2.5 Ma and a titanite age of 2589 Ma, which may represent a metamorphic age (Hebel 1999; M.U. Hebel and J.K. Mortensen, unpub. data, 2001). The Hope Bay belt is bordered to the west by plutonic rocks that contain foliated mafic fragments at 2608 ± 5 Ma, placing a lower limit on deformation and metamorphism (Bevier and Gebert, 1991). Metamorphism is lower greenschist grade in the interior of the belt and amphiolite grade near the belt margins.

HISTORY

Following the reconnaissance mapping by Fraser (1964), a number of precious-metal-bearing quartz-carbonate veins were staked in the 1960s. In 1972–1974, the Hope Bay Mining Company obtained a four-year lease and in 1973–1974, it initiated small-scale mining activities at the Ida Bay and Roberts Lake silver showings. Less than 100 000 ounces (31 103 000 g) of silver were produced over the two-year period (J.S. Gebert, unpub. rept., 1999).

In 1977, Noranda Ltd. initiated a reconnaissance base-metal exploration program in the belt that continued into the early 1980s with limited success. In 1987 and 1988, Abermin Corporation staked a number of the precious-metal showings. In 1988, BHP Minerals Ltd. conducted a limited reconnaissance program in the belt. Exploration was ramped up to a more comprehensive program following the discovery of the Boston deposit in 1991 and the Doris deposit in 1994. In late 1999, Miramar Mining Corp. and Cambiex Exploration Inc. (Hope Bay Gold) entered into a joint venture to explore and develop deposits in the Hope Bay belt. The current classified resource estimate from several deposits is 2.789 Mt grading 15.7 g/t Au (1.412 million ounces) measured and indicated and 4.588 Mt grading 12.5 g/t Au (1.845 million ounces) as an inferred resource (Miramar Mining Corporation press release, November 23, 2000).

From 1987 to 1993, federal and territorial government geological mapping programs were conducted in the belt (Gibbons, 1987; Gebert, 1993), leading to the production of a geological map at 1:50 000 scale. This was complemented by detailed mapping by BHP throughout the 1990s. Hebel (1999) completed a thesis on the geochronology and geochemistry of the belt, establishing the initial geochronological framework. The current program has focused on understanding the detailed volcanic stratigraphy in several key areas of the Hope Bay belt in order to understand the architecture of the belt and the relationship of stratigraphy and deformation to various styles of mineralization.

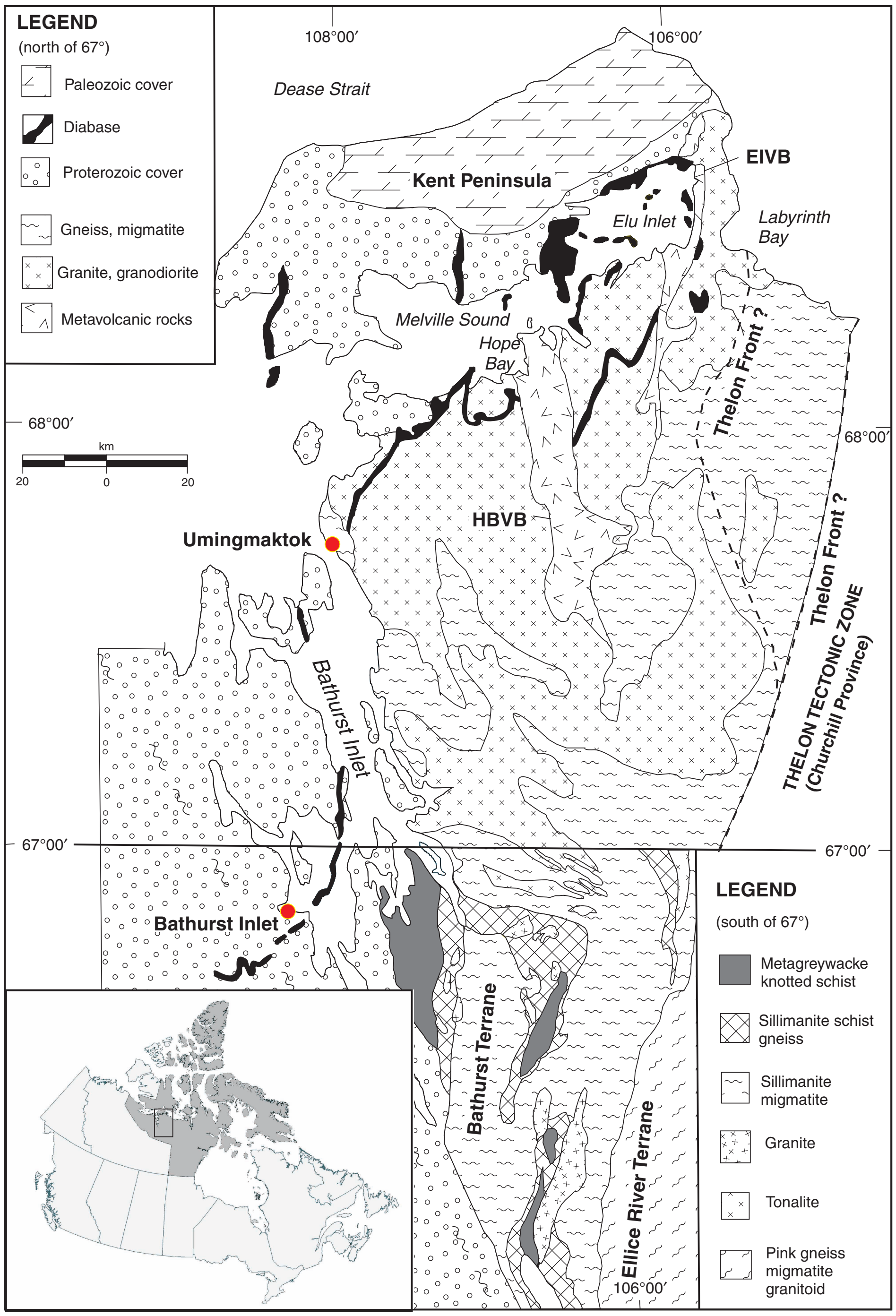

Figure 1. *Generalized geology of the Bathurst Block. North of latitude 67°N (*modified from *Fraser, 1964), south of latitude 67°N (*modified from *Thompson et al., 1986). Modified from Gebert (1993). The Hope Bay volcanic belt (HBVB) and adjacent Elu Inlet volcanic belt (EIVB) are indicated.*

QSP AREA

The QSP area is a sequence of felsic volcanic rocks in the west-central portion of the Hope Bay volcanic belt (Fig. 2, 3). It is immediately south of, and may be similar to, the Quito sequence of felsic volcanic rocks. Hebel (1999) considered the Quito and QSP areas as part of the Square Lake sequence of felsic volcanic rocks, all located in west-central Hope Bay belt. Hebel has a date of 2690 +2.0/-1.5 Ma for a flow and 2690+3.6/-2.8 for a tuffaceous rock from the Square Lake suite. Additional geochronological work is ongoing to further refine the ages on the stratigraphy in the QSP area. Regionally these rocks are metamorphosed to greenschist facies.

Felsic volcanic rocks in the QSP area are commonly altered to an assemblage of quartz-sericite and pyrite. Also locally present are aluminosilicate porphyroblasts and potential subvolcanic intrusions. Three drillholes have been completed in the area, one of which intersected 2 m containing 16.8 g/t Au. Although the drillholes were not available for examination, drill-log data indicate that the auriferous intersection was hosted in a felsic volcaniclastic unit altered to an assemblage of quartz, sericite, and pyrite. This intersection indicated the possibility of gold-rich synvolcanic mineralization analogous to that of Doyon and Bousquet, Quebec (Poulsen et al., 2000). Also intersected was a unit termed 'dalmationite', characterized by dark grey porphyroblasts, logged as andalusite. This is consistent with a metamorphosed zone of stronger alteration.

Volcanic rocks

During this mapping project, the volcanic rocks were subdivided on the basis of their composition, phenocryst content, and primary volcanic facies, i.e. coherent versus volcaniclastic. Younging directions were not established because of a general absence of sedimentary features, but are inferred to face westward, consistent with adjacent portions of the belt.

A volcanic rock of intermediate composition occurs in the northeast portion of the map area (Fig. 3). This amygdaloidal rock weathers medium green to grey and locally blocky red and green. Coherent and brecciated textures are present within this 150 m thick unit, which appears to conformably underlie the felsic volcanic rocks (Fig. 3).

The lowermost interval of felsic volcanic rocks is an aphyric, coherent sequence of pink- to white-weathering dacite–rhyodacite. This flow facies is very thick (>450 m) and is truncated to the east by gabbroic intrusive rocks. Overlying the massive flow is a relatively thin (< 50 m) volcaniclastic facies of similar composition (Fig. 4a).

Overlying the aphyric unit is a massive flow of coherent blue quartz(±feldspar)-porphyritic dacite overlain by compositionally similar volcaniclastic rock. This is followed upsection by a similar sequence of blue quartz- and feldspar-phyric flow–flow breccia units, locally with mafic pumice fragments (Fig. 4b). Coarse volcanic conglomerate is recognized with fragments up to 10 cm across (Fig. 4c).

The uppermost sequence is a thick interval of massive aphyric flows and sills capped by a volcaniclastic interval. It contains feldspar crystal tuff that serves as distinctive marker beds. Mafic beds or dykes of limited lateral extent are also recognized.

The four sequences of felsic flow–flow breccia are layered stratigraphically (Fig. 3) with no evidence of any large-scale structural repetition of stratigraphy. Each interval is distinct, recognizable, and traceable, and all are unlikely to be derived from the same flow sequence. The lithological distribution is interpreted as four discrete couplets of coherent felsic flows (flows and shallow sills), flow breccia, and subsequent volcaniclastic products formed through eruptive or erosional processes.

The lowermost felsic intervals (#1 and #2, Fig. 3) thin and pinch out southward. This may reflect the gabbro intrusion to the east and structural attenuation. Alternatively, it may also reflect some component of primary distribution suggesting a centre of volcanism to the north. In the third felsic interval, vesicular mafic fragments are distributed among the felsic fragments. They may have been eroded from an older mafic source and simply deposited with the felsic fragments. Alternatively, they may have been erupted, transported, and deposited contemporaneously with the felsic volcanism, suggesting the possibility of a bimodal suite of volcanic rocks.

Geochronological, lithogeochemical, and petrographic work is ongoing to address some of these unresolved issues.

Intrusive rocks

Synvolcanic intrusive rocks are unambiguously observed in only a few localities, i.e. where the coherent facies has a different composition (phenocryst abundances) than the associated volcaniclastic rocks. At several localities in the sequence, narrow felsic bodies are recognized that have intruded the felsic volcanic couplets described above. An example of this is seen in the upper felsic unit (UTM ~7,533,000 N, 428,000 E) (Fig. 3) where an aphyric massive unit has crosscut a blue-quartz-phyric volcaniclastic interval.

The thick intervals of massive coherent felsic volcanic rocks are inferred to be flows as they are compositionally similar to the overlying volcaniclastic rocks and compositionally different from the underlying volcaniclastic rocks. This is an interpretation, and relatively thick intervals of subvolcanic intrusive rocks may occur that have not been recognized.

Gabbroic rocks flank the felsic sequence to the east (Fig. 3). They are generally fairly massive, with a weakly developed foliation, and locally have a margin of talcose ultramafic rocks. They may contain quartz. Small gabbro and granodiorite stocks intrude the felsic sequences.

The felsic volcanic rocks are bounded to the west by a biotite-bearing pink monzogranite intrusion that is generally well foliated (defined by the alignment of biotite). A lobate monzogranite body crosscuts and truncates the felsic volcanic sequence in the northern portion of the map area (Fig. 3).

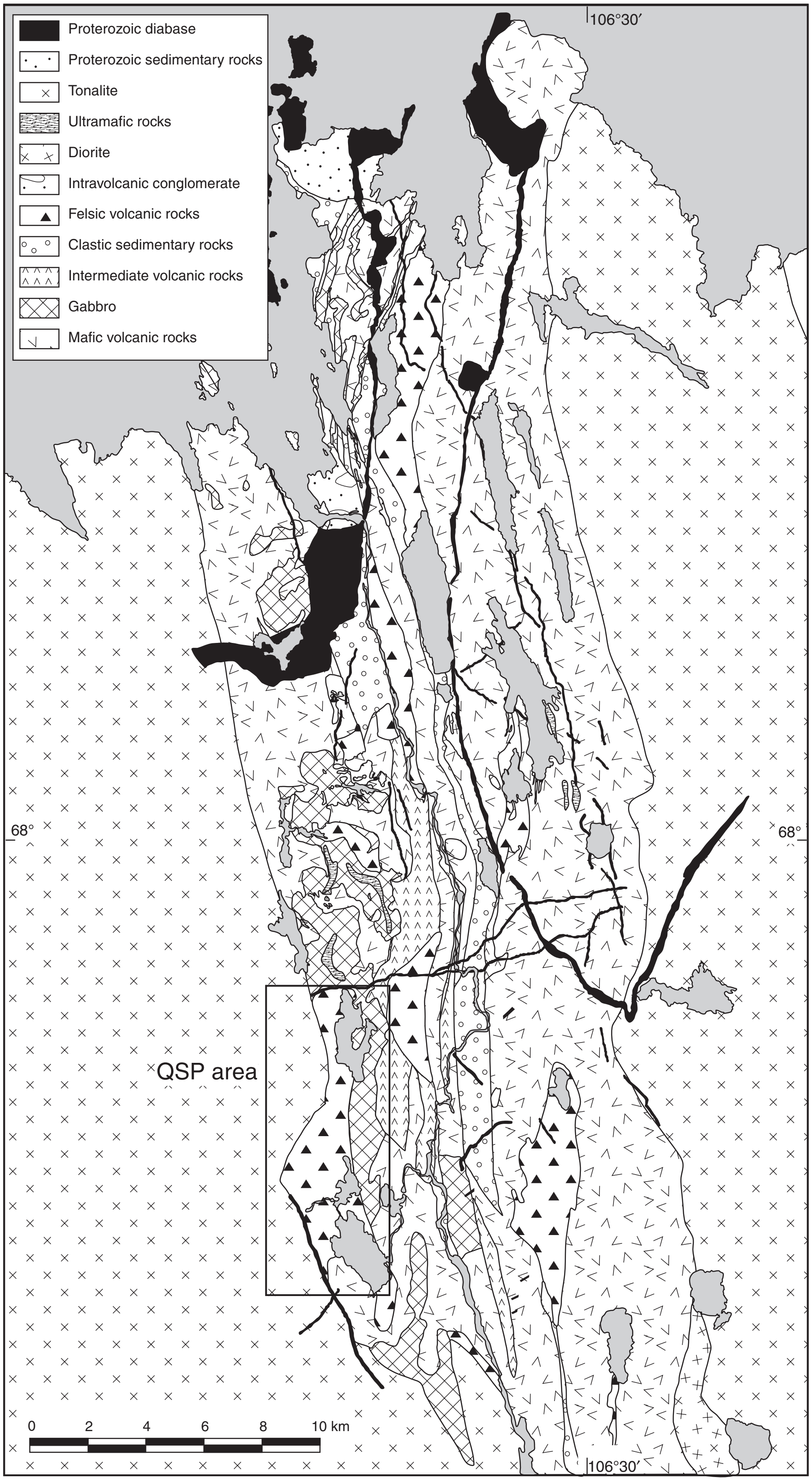

Figure 2. *Generalized geology of the northern portion of the Hope Bay volcanic belt (J.S. Gebert, unpub. rept., 1999). Also indicated is the QSP area.*

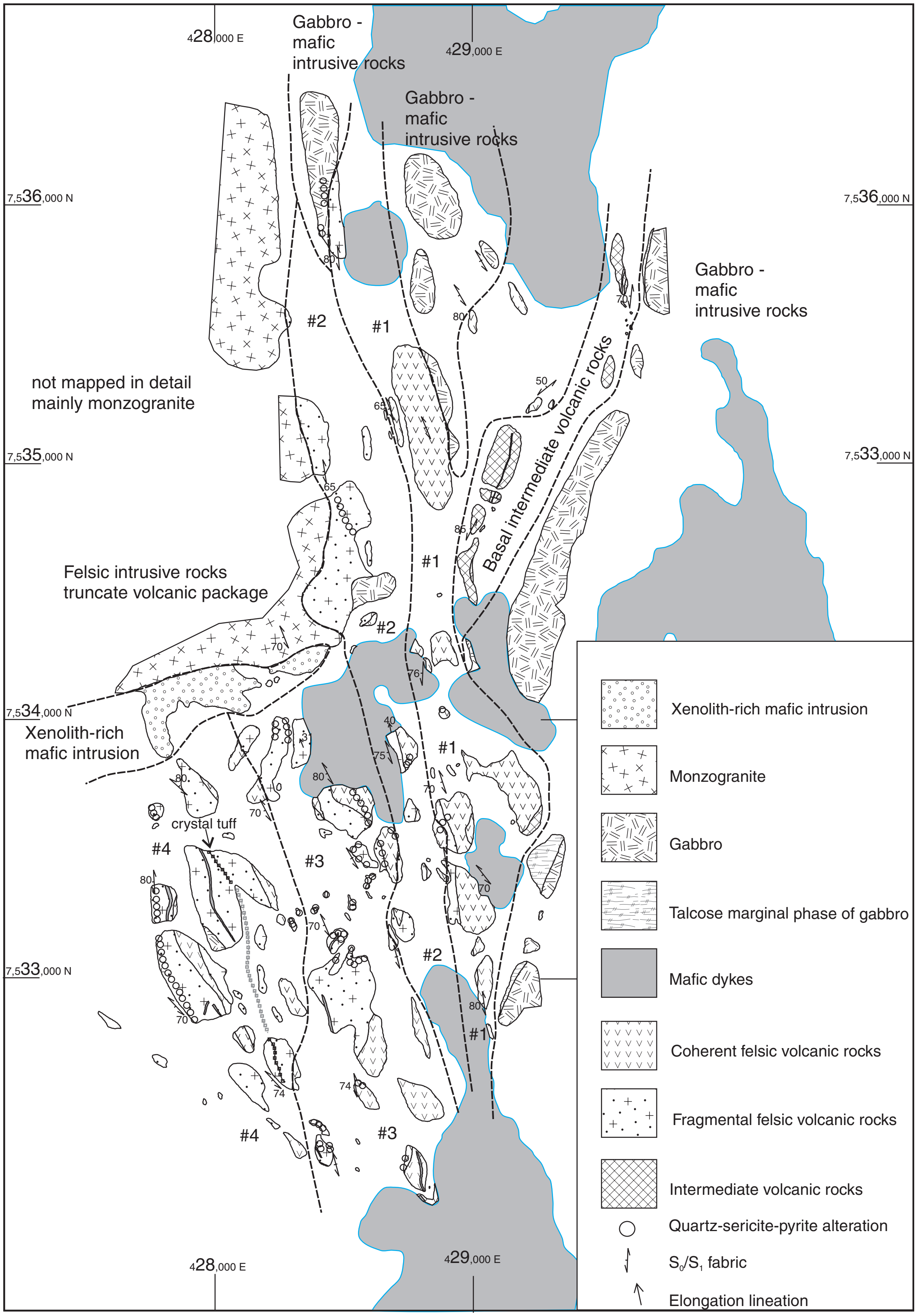

Figure 3. *Geology of the QSP area. Major contacts are emphasized (dashed lines). The felsic units are divided into four sequences with the lowermost designated #1 and the uppermost designated #4.*

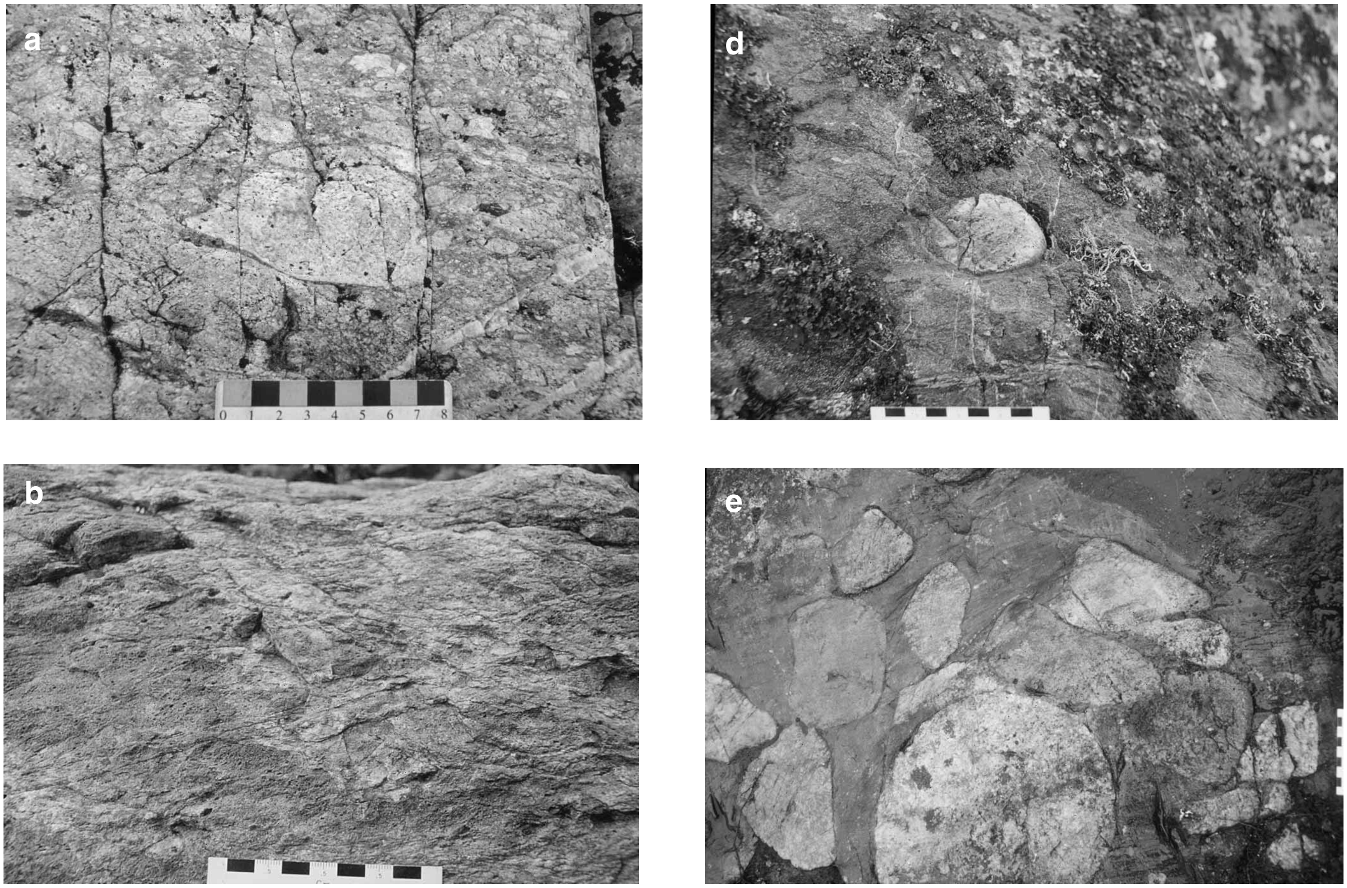

***Figure 4. a**) Felsic volcaniclastic rocks from the lowermost felsic sequence. **b**) Mafic scoriaceous fragments within the felsic volcaniclastic rocks, suggesting two volcanic sources for the fragments. **c**) Flattened felsic volcanic conglomerate with coarse fragments. The combination of coarse grain size and flattening gives the outcrop a stripped look. **d**) Mafic xenoliths within late xenolith-rich intrusion. **e**) An extreme case of large rounded xenoliths of varied rock types. **f**) Cordierite (andalusite) porphyroblasts developed in felsic fragmental rocks, elongated in the strong stretching lineation developed in the plane of the foliation.*

A mafic intrusion with numerous rounded xenoliths occurs in spatial association with the monzogranite body (Fig. 3). It has a chloritic mafic matrix, but contains abundant clasts of various rock types, including monzogranite, felsic and mafic volcanic rocks, quartz ((?)vein), and amphibolite (Fig. 4d). These fragments range from less than 1 cm to over 50 cm across. The unit is relatively massive although locally it contains a weak east-west-oriented fabric. Aside from its spatial association with the granitoid, it forms a dyke crosscutting the foliation and locally containing numerous (>50%) fragments of varied composition and size (up to 40 cm) (Fig. 4e). This rock is interpreted to be a lamprophyre-like rock. The density and diversity of the rounded fragments (including amphibolite fragments) suggest a deep-seated, volatile-rich source. The lack of fabric and the inclusion of foliated monzogranite fragments suggest that it postdates the monzogranite. However, it is crosscut by a fine-grained aplite dyke, indicating that it does not represent the last igneous event to have occurred.

Alteration

Discrete zones of felsic volcanic rocks are altered to an assemblage of quartz, sericite, and pyrite. These areas weather a distinctive yellow-brown. The alteration invariably contains 5% to 10% fine-grained pyrite with sericite and quartz making up the remainder of the material. The alteration is not always texturally destructive as primary textures such as fragment shapes and phenocryst outlines may be preserved. This alteration assemblage may be crosscut by quartz-pyrite veinlets, suggesting a protracted and progressive hydrothermal event. The degree and style of alteration is consistent with a synvolcanic hydrothermal system.

The bulk of the alteration is hosted in the third felsic volcaniclastic unit, described above. Individual alteration zones are lensoidal and discontinuous, generally difficult to trace for more then 100 m (Fig. 3). An exceptional interval on the western margin of the felsic volcanic rocks is a linear zone of altered rock several hundred metres long, in places containing semimassive (~20%) pyrite (Fig. 3). The general lack of continuity in the alteration likely reflects its early synvolcanic formation and the subsequent attenuation of these zones during development of the main transposition fabric.

Cordierite (or andalusite) porphyroblasts are recognized in two outcrops (Fig. 4f) and are locally well developed, constituting up to 10% of the rock by volume. They are likely the product of metamorphism of a rock that was altered to a relatively alumina-rich assemblage and may reflect the development of a localized, more intense alteration system. Similar porphyroblasts have been described from drill cores.

STRUCTURAL GEOLOGY

The dominant fabric observed, a well developed penetrative planar fabric designated 'S_1', is widespread and developed in all rock types, except the possible lamprohyre described above. It generally strikes south-southeast and dips steeply west-southwest. It is locally deformed into small asymmetric folds that trend northwest and dip steeply. These folds do not seem to reflect a larger scale repetition of stratigraphy.

Mineral elongation lineations are locally well developed, particularly on the margins of the felsic sequence near the contacts with the monzogranite intrusions. They tend to be in the plane of S_1 and dip moderately (~45°). Where developed, the cordierite (andalusite) porphyroblasts are elongated in the stretching lineation (Fig. 4f). Amygdales in the basal intermediate volcanic rocks are elongated and plunge northwest.

The youngest deformation feature is a weak buckling of earlier deformation fabrics. These consist of open, northeast-trending folds with steeply plunging fold axes. They have a very minor effect on the overall geometry of the stratigraphic package.

SUMMARY

Geological mapping in the Hope Bay volcanic belt has been undertaken to examine the volcanic stratigraphy in key areas in order to help understand the architecture of the belt and the relationship of stratigraphy and deformation to various styles of mineralization. To that end, detailed mapping in the QSP area examined the felsic stratigraphy and potential for gold-rich synvolcanic mineralization.

Five reasonably distinct units of volcanic rocks were recognized on the QSP property. The lowermost interval is a massive, amygdaloidal, intermediate volcanic sequence. Overlying this are four intervals of massive felsic flows, overlain by their volcaniclastic products, formed either through erosional or eruptive processes. These units are traceable over the mapped area and are truncated to the north and west by monzogranite and the east by gabbro. No large-scale structural repetitions of stratigraphy were recognized. Fragment composition suggests that volcanism may have been bimodal at some levels of the stratigraphy.

Locally, the felsic rocks are altered to an assemblage of quartz-sericite and pyrite through which primary volcanic textures are still recognizable. These alteration zones are concentrated in the third volcaniclastic unit, but are difficult to trace laterally for any distance having been disrupted and attenuated during development of the subsequent transposition fabric. The intensity and style of alteration is consistent with a synvolcanic alteration package. The distribution of aluminosilicate porphyroblasts, interpreted to be metamorphosed domains of alumina-rich alteration, suggests that the intensity of this alteration varies.

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