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Volcanic stratigraphy, structural geology, and gold mineralization in the Wolverine-Doris corridor, northern Hope Bay volcanic belt, Nunavut

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Abstract: The northern part of the Hope Bay volcanic belt is a mainly bimodal volcanic assemblage. The mafic suite includes intercalated Mg- and Fe-tholeiitic basalts with textural variations. The felsic suite includes dacitic volcaniclastic rocks and coherent flows or sills, with subvolcanic intrusions. The Windy lake felsic rocks show a gradation to more proximal phases to the north. There is good evidence for a synvolcanic structure that juxtaposed different volcanic suites and is capped by a sedimentary package without any obvious offset. Gold mineralization in the area is variable in terms of alteration and morphology, but all types originated during a progressive D_2 event. Synvolcanic mineralization is also recognized at lithological contacts, mainly within the felsic volcanic suites.

Résumé : La partie nord de la ceinture volcanique de Hope Bay consiste principalement en un assemblage volcanique bimodal. La suite mafique se compose d'une interstratification de basaltes tholéiitiques magnésiens et ferrifères marqués par des variations texturales. La suite felsique comprend des volcanoclastites dacitiques et des unités cohérentes (coulées ou filons-couches), accompagnées d'intrusions subvolcaniques. Les roches felsiques de Windy lake montrent une progression vers des phases davantage proximales en direction du nord. Il y a de bons indices de l'existence d'une structure synvolcanique qui aurait permis la juxtaposition de différentes suites volcaniques et qui serait coiffée par un ensemble sédimentaire dans lequel aucun décalage évident n'est observé. Dans la région, les minéralisations aurifères présentent des variations tant au niveau de l'altération que de la morphologie, mais tous les types sont apparus pendant un épisode de déformation progressive D_2. De la minéralisation synvolcanique est en outre identifiée aux contacts lithologiques, principalement à l'intérieur des suites volcaniques felsiques.

INTRODUCTION

Gold deposits in the Hope Bay belt are among Nunavut's most advanced exploration projects and represent potential for near-term production. Several different deposits have been outlined in the belt since the inception of sustained precious-metal exploration by BHP Minerals Canada Ltd. in the early 1990s. These include Boston, Doris, and the Madrid group of deposits (Naartok, Perrin, and Suluk). Each of these deposits is different in terms of geological setting, alteration characteristics, and local controls on gold distribution. This diversity in gold mineralization, along with the abundant outcrop and drill core, low metamorphic grades, and overall low strain, make the Hope Bay belt an ideal location to characterize mineralizing events in the context of the geological evolution of the host terrane.

This paper reports the results of a detailed (1:10 000-scale) mapping program over the Wolverine-Doris corridor, carried out in conjunction with a detailed core-logging and alteration study of the Doris deposit (Carpenter et al., 2003).

REGIONAL GEOLOGY

The Hope Bay volcanic belt is located in the northeast portion of the Slave Structural Province. The Slave Province is predominantly 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).

About 26 granite-greenstone belts are recognized in the Slave Structural Province; these have been subdivided into mafic volcanic–dominated (Yellowknife-type) and felsic volcanic–dominated (Hackett River–type) by Padgham (1985). Yellowknife-type belts typically comprise 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 about 2715 and 2610 Ma (Mortensen et al., 1988; Isachsen et al., 1991). The volcanic belts are typically isoclinally folded and contain belt-parallel shear zones. A late (circa 2.6 Ga), 'Timiskaming-type' sedimentary assemblage, consisting of conglomerate and sandstone, may overlie the main greenstone belts (Fyson and Helmstaedt, 1988). Villeneuve (1997) subdivided the intrusive rocks into 2.70 to 2.64 Ga predeformation tonalite and diorite, 2.62–2.59 Ga K-feldspar megacrystic granite, and 2.60–2.58 Ga postdeformation two-mica granite. A regional pan-Slave deformation event is recognized between 2.7 and 2.6 Ga; it is characterized by regional compression, plutonism, and late extension (<2.583 Ga).

HOPE BAY BELT

The Bathurst Block (Fig. 1) is the part of the Slave Structural Province northeast of Bathurst Inlet. 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 is within the northern portion of the Bathurst Block (Fig. 1, 2). This belt was first mapped at a reconnaissance scale by Fraser (1964), and later in more detail by Gibbons (1987) and Gebert (1990, 1993), who considered the belt to be analogous to the Yellowknife Supergroup. The Hope Bay belt is dominated by mafic volcanic rocks with felsic volcanic and volcaniclastic products and subordinate ultramafic bodies and metasedimentary rocks. Existing U-Pb geochronology of the belt indicates that felsic volcanism spanned a period of at least 53 Ma (2716–2663 Ma; Hebel, 1999).

To the east, the belt is bordered by felsic intrusions that separate the Hope Bay belt from the Elu Inlet belt (Fig. 1). A granodiorite northeast of the Hope Bay belt gave a U-Pb zircon age of 2672 +4/–1 Ma, suggesting a syn- to late-volcanic age of emplacement (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). The Hope Bay belt is bordered to the west by plutonic rocks that contain foliated mafic fragments dated at 2608 ± 5 Ma, which places a lower limit on deformation and metamorphism (Bevier and Gebert, 1991). The metamorphic grade in the interior of the belt is lower greenschist, with amphibolite grade near the belt margins.

WOLVERINE-DORIS CORRIDOR

The belt of rocks that extends from the south end of Wolverine and Patch lakes (Fig. 2) to the north end of Doris lake was selected for this project because it complements detailed mapping completed in 2001 (Sherlock et al., 2002) and contains several important gold deposits, such as Doris and Naartok. Details of the Doris deposit are found in a companion paper by Carpenter et al. (2003). The belt comprises a bimodal assemblage of mafic and felsic volcanic rocks folded about a large-scale antiform. The antiform fold axis extends south through Doris lake, marking the transition between east-facing strata on the east shore of Doris lake and west-facing strata on the west shore of the lake. This antiform can be traced through to the south of Patch lake.

Mafic volcanic rocks

Several distinct suites of mafic volcanic rocks recognized in the Hope Bay area are broadly divisible into Mg and Fe tholeiites (Fig. 2). The Mg and Fe tholeiite distinction is based on the existing lithogeochemical database (approx. 700 samples over the map area). Typical outcrops of Mg and Fe tholeiite were identified geochemically and then revisited in order to define a set of field criteria that would allow this distinction to be made while mapping.

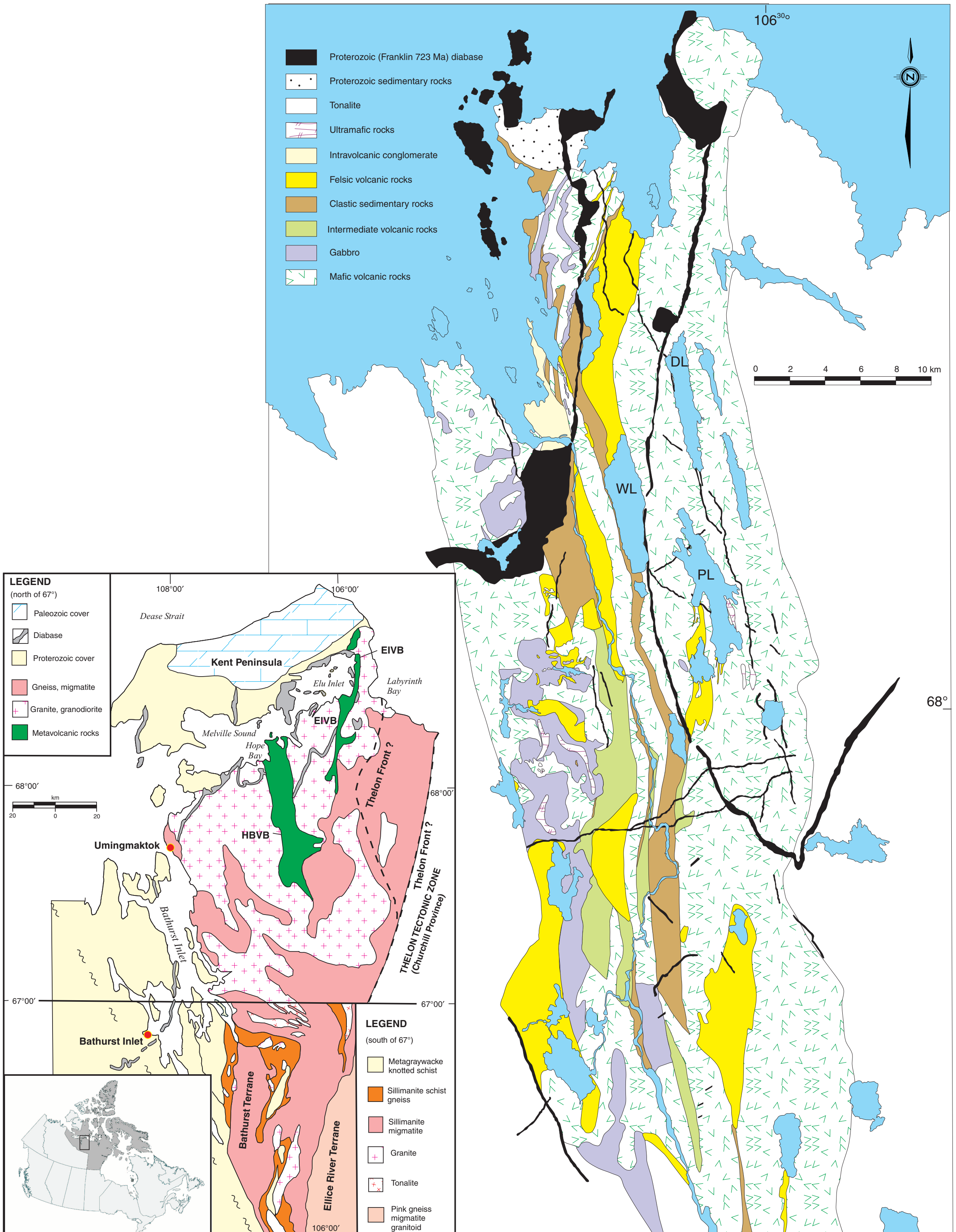


Figure 1. *Regional geology of the Hope Bay volcanic belt (*modified from *Gebert, 1993). Abbreviations: WL, Windy lake; DL, Doris lake; PL, Patch lake. Inset is the generalized geology of the Bathurst Block. Geology north of latitude 67°N* modified from *Fraser (1964); geology south of latitude 67°N* modified from *Thompson et al. (1986) and Gebert (1993). Hope Bay volcanic belt (HBVB) and adjacent Elu Inlet volcanic belt (EIVB) are indicated.*

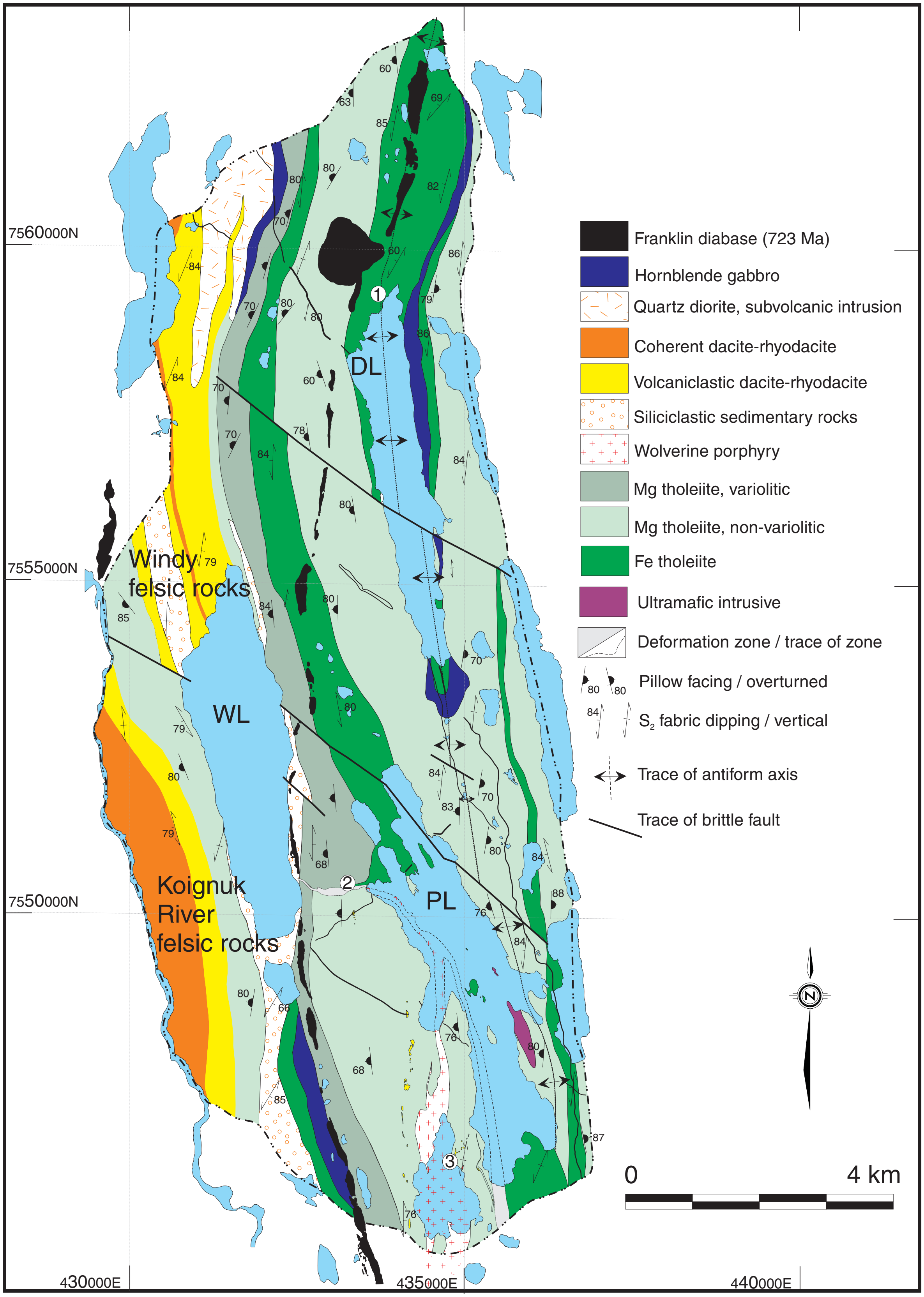


Figure 2. Geology of the Wolverine-Doris corridor. Numbers indicate: 1, Doris deposit; 2, Madrid area; 3, Wolverine showing.

Magnesium tholeiite

The Mg tholeiite is generally characterized by pillowed flows (Fig. 3A, B). The pillows tend to be large (approx. 1 m across) with thin (<2 cm) brown to green selvages. The flows tend to be light in colour, generally pale green. These pillows commonly have large, well preserved and large gas cavities (Fig. 3C) that provide reliable and consistent younging directions. Flow-breccia units are common, as are massive featureless phases interpreted as subvolcanic feeders or thicker, nonpillowed portions of flows. Locally, narrow intervals of interflow chert are recognized.

Two textural subunits are recognized and form consistent map units: variolitic and nonvariolitic types. The nonvariolitic type is the most abundant, forming the bulk of the map package, but a distinct variolitic phase is recognized and can be correlated over the map area (Fig. 3D). In this unit, the varioles are large and mainly developed around pillow selvages, but locally form coalesced varioles that occupy the bulk of a pillow structure.

Iron tholeiite

Iron tholeiite is distinguished from Mg tholeiite by pillow morphology. The pillows are flattened and commonly highly amygdaloidal (weathered out), with narrow, black, chloritic pillow selvages and indistinct pillow shapes (Fig. 3E). The flows are dark, typically dark green to brown. The pillow forms are small (<0.5 m across) and lack gas cavities, making them unsuitable as younging indicators.

As with the Mg tholeiite, there are variolitic and nonvariolitic variants that form consistent map units at 1:10 000 scale. The nonvariolitic type is the most abundant, but a distinct variolitic phase (Fig. 3F) forms relatively thin (approx. 50 m thick) units within the nonvariolitic Fe-tholeiite strata. The variolitic phase is relatively uncommon and makes an excellent marker interval, allowing for high confidence in stratigraphic correlation.

Felsic volcanic rocks

Several felsic successions are recognized in the map area (Fig. 2): the Wolverine, Windy lake and Koignuk River felsic suites.

The Wolverine felsic suite is dominated by the Wolverine porphyry, a quartz-feldspar porphyritic intrusive body centred over Wolverine lake (Fig. 2). In addition to the large intrusive body, there are several narrow but laterally continuous volcaniclastic intervals. These intervals range from fine-grained lithic tuff, to dacite lapilli tuff, to coarse-grained mass-flow deposits (Sherlock et al., 2002). The Wolverine porphyry wraps into the 'deformation zone' (Fig. 2) described below, and is interpreted as a subvolcanic feeder to the Windy lake felsic rocks.

The Windy lake felsic rocks are a diverse suite. They include sedimentary and reworked volcanic rocks (Fig. 3G, H), more proximal volcaniclastic rocks, and massive coherent flows or sills. The basal portion of the succession is dominated by quartz arenite and reworked volcanic rocks. Rock types gradually become more proximal up-section, grading into lapilli tuff (Fig. 3I) and proximal breccia. A second interval of argillite and fine siliciclastic sedimentary rocks is recognized near the top of the succession (Fig. 2). Narrow intervals of massive, fine-grained, coherent rhyolite are recognized in the sequence and interpreted as flows or sills. In the north end of the Windy lake felsic rocks is a massive quartz-diorite unit, hosted within the coarse-grained volcanic conglomerate. This is interpreted as a subvolcanic intrusive, coeval with the Windy felsic rocks. The Windy felsic rocks grade southward into a succession of fine-grained siliciclastic sedimentary rocks (Fig. 2), mainly quartz arenite (Fig. 3J). These sedimentary rocks locally contain clasts of dacite, suggesting that at least some of the sediment was sourced from the more proximal areas of the Windy lake felsic rocks.

The Koignuk River felsic rocks contain a basal conglomerate unit dominated by quartz-feldspar porphyritic volcanic clasts in a sandy matrix (Fig. 2). Detrital material is poorly sorted and coarse grained, lacking sedimentary structures. Overlying the conglomerate is a thick, massive, fine-grained, quartz-feldspar porphyritic coherent flow or sill, which is locally flow banded.

Mafic intrusive rocks

A number of gabbroic bodies have been mapped in the area. These are massive, medium- to coarse-grained, homogeneous units that occur within predominantly pillowed flows. They may represent either thicker portions of flows or feeders to the overlying pillowed flows.

A large ultramafic intrusion crops out on the east side of Patch lake (Fig. 2). This peridotite is enclosed by pillowed flows and is massive with a black knobby texture, presumably the result of olivine weathering. It extends into Patch lake, forming a small island. Initial geochemical work suggests that it may represent the cumulate phase of a differentiated mafic magma.

A coarse-grained, hornblende-bearing leucogabbro forms a late intrusive phase throughout the map area (Fig. 2). This intrusive phase consists of plagioclase and hornblende with rare quartz, and locally crosscuts stratigraphy. North of Doris lake, it grades into a coarse-grained, plagioclase-glomeroporphyritic unit.

Structural geology

The dominant structure in the map area is a tight to isoclinal antiform structure (Fig. 2). The fold axis strikes approximately north and is doubly plunging. The antiform plunges shallowly to the north around the Doris deposit, and shallowly to the south at the south end of Doris lake. The antiform axial plane is slightly inclined with an east vergence. The antiform is mapped based on younging directions from gas cavities in the pillowed Mg-tholeiitic basalt. The Fe tholeiite only rarely contains gas cavities and its younging direction is inferred from adjacent Mg tholeiite.

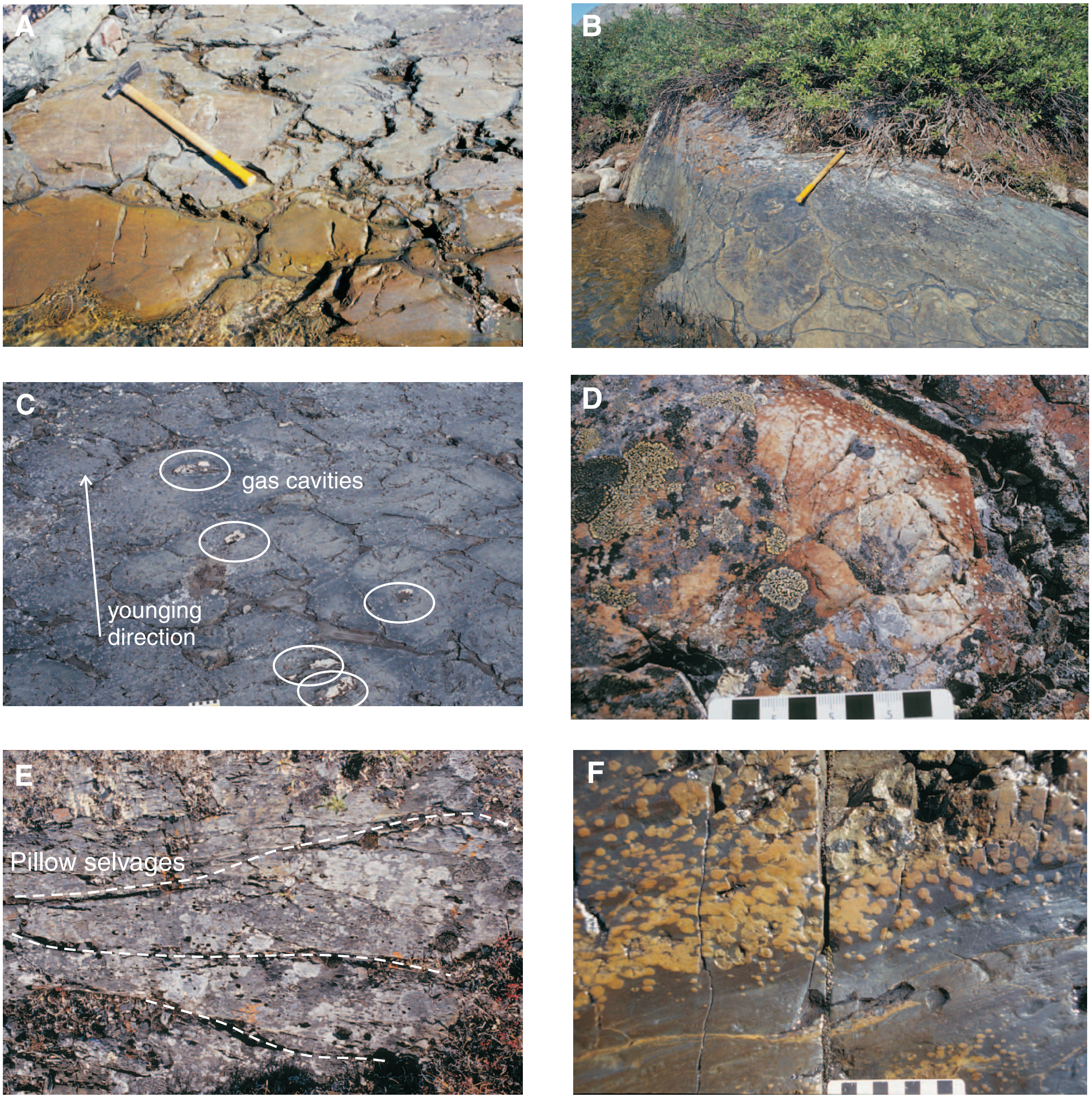
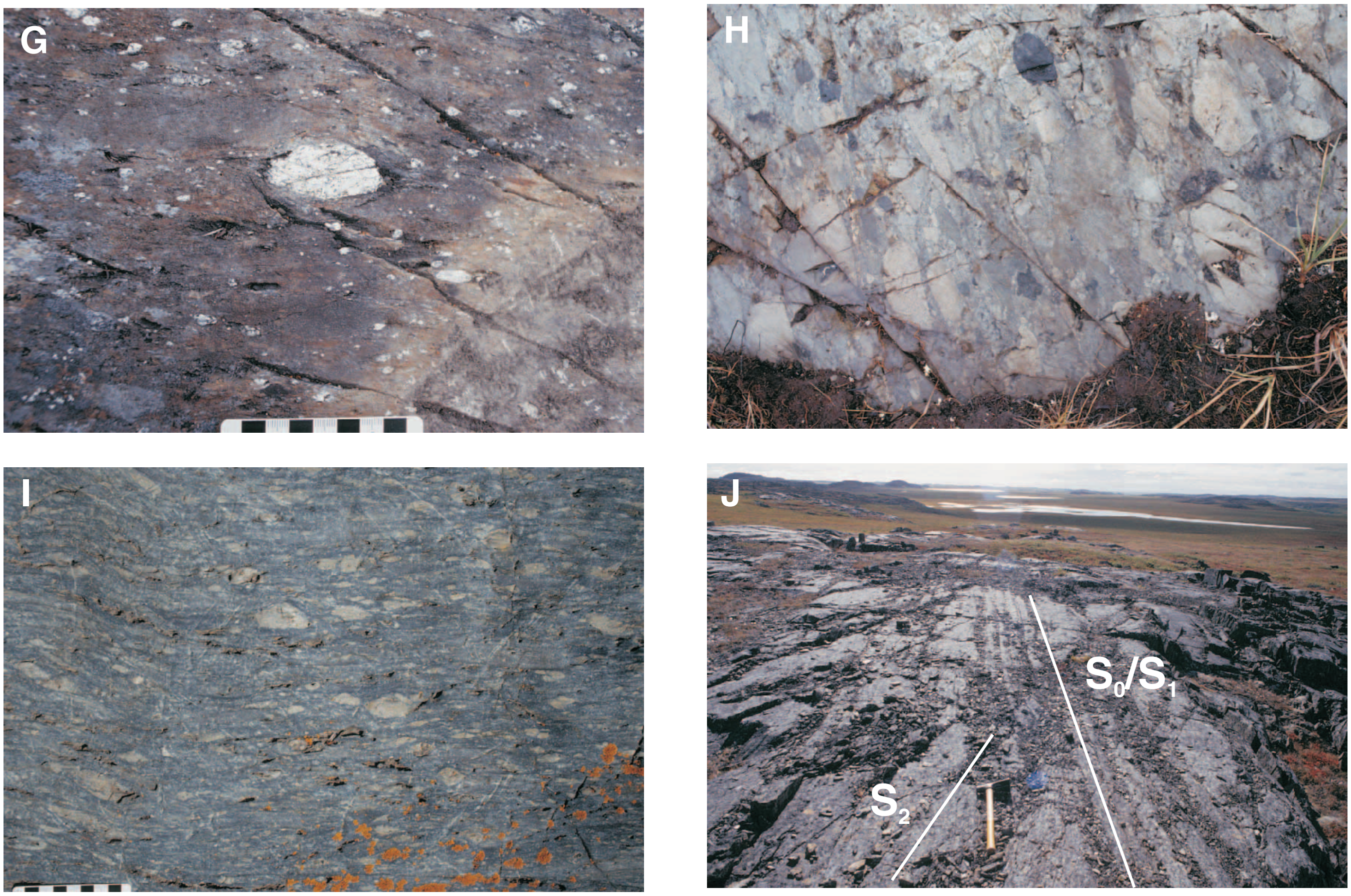


Figure 3. ***A)*** *Well formed pillows, typical of the Mg-tholeiitic basalt suite, east side of Windy lake (UTM 13W, 7553603N, 432266E).* ***B)*** *Mg-tholeiitic pillowed flows, east side of Patch lake (UTM 13W, 7551289N, 434513E).* ***C)*** *Gas cavities in pillowed flows, providing young direction, southeast end of Patch lake (UTM 13W, 7549261N, 435725E).* ***D)*** *Variolitic Mg-tholeiitic pillow basalt with coalesced varioles near the pillow selvage (UTM 13W, 7551059N, 433567E).* ***E)*** *Fe-tholeiitic pillowed flows from the Doris deposit, showing ragged pillow outlines (UTM 13W, 7559269N, 433845E).* ***F)*** *Variolitic Fe-tholeiitic pillowed flows showing coalesced varioles (UTM 13W, 7550870N, 434457E).*



Fiugure 3. ***G)*** *Dacitic volcanic conglomerate with large fragments of quartz-feldspar porphyritic dacite in a sandy matrix, poorly sorted and bedded (UTM 13W, 7551519N, 432601E).* ***H)*** *Heterolithic volcanic conglomerate dominated by dacitic fragments, but also with variolitic basalt and argillite clasts (UTM 13W, 7551852N, 432719E).* ***I)*** *Dacitic lapilli tuff, part of the Windy felsic suite (UTM 13W, 7551735N, 432422E).* ***J)*** *Well bedded and graded quartz arenite, part of the southern extension of the Windy felsic rocks; large dacite fragments are found locally in these sedimentary rocks (UTM 13W, 7546762N, 432447E).*

Based on lithological contacts, interflow sedimentary units, and gas cavities, stratigraphic units strike to the north-northwest in the southern part of the map area and to the northeast in the northern part, north of Doris lake. A spaced fabric, locally developed parallel to lithological contacts, is interpreted as a composite S_0/S_1 transposition fabric (Fig. 3J, 4A).

The main fabric observed in outcrop is a locally penetrative cleavage (S_2). This fabric has a dominantly north-northeast orientation and steep dip. To the north of Doris lake, this fabric swings to the northeast. Commonly, S_2 is well developed and clearly overprints the weakly developed transposition fabric (S_0/S_1). In sedimentary rocks, bedding-cleavage relationships are well preserved (Fig. 4A). Locally, the intersection of these planar fabrics forms a steep north- or south-plunging intersection lineation.

High-strain zones are common throughout the map area and possess a strong penetrative planar fabric. These zones range from less then 1 m wide and several tens of metres long, to more than 10 m wide and several kilometres long. They commonly have a strong Fe-carbonate alteration and may contain auriferous quartz-carbonate veins (Fig. 4B). These zones are parallel to the orientation of local S_2 fabrics and are interpreted as higher strain intervals that developed during D_2, commonly where strain was partitioned at lithological contacts.

The 'deformation zone' is an enigmatic feature encountered only in drill core, in the Patch lake area (Fig. 2, 4C). The 'deformation zone' runs northwest-southeast along the west shore of Patch lake and cuts east-west through the Madrid area. It consists of a contorted quartz–mica–Fe-carbonate schist with disseminated pyrite (Fig. 4C). Straw yellow mica forms semiregular, millimetre-scale laminations that define the schistose fabric. The 'deformation zone' encompasses several rock types and can include both Mg and Fe tholeiites

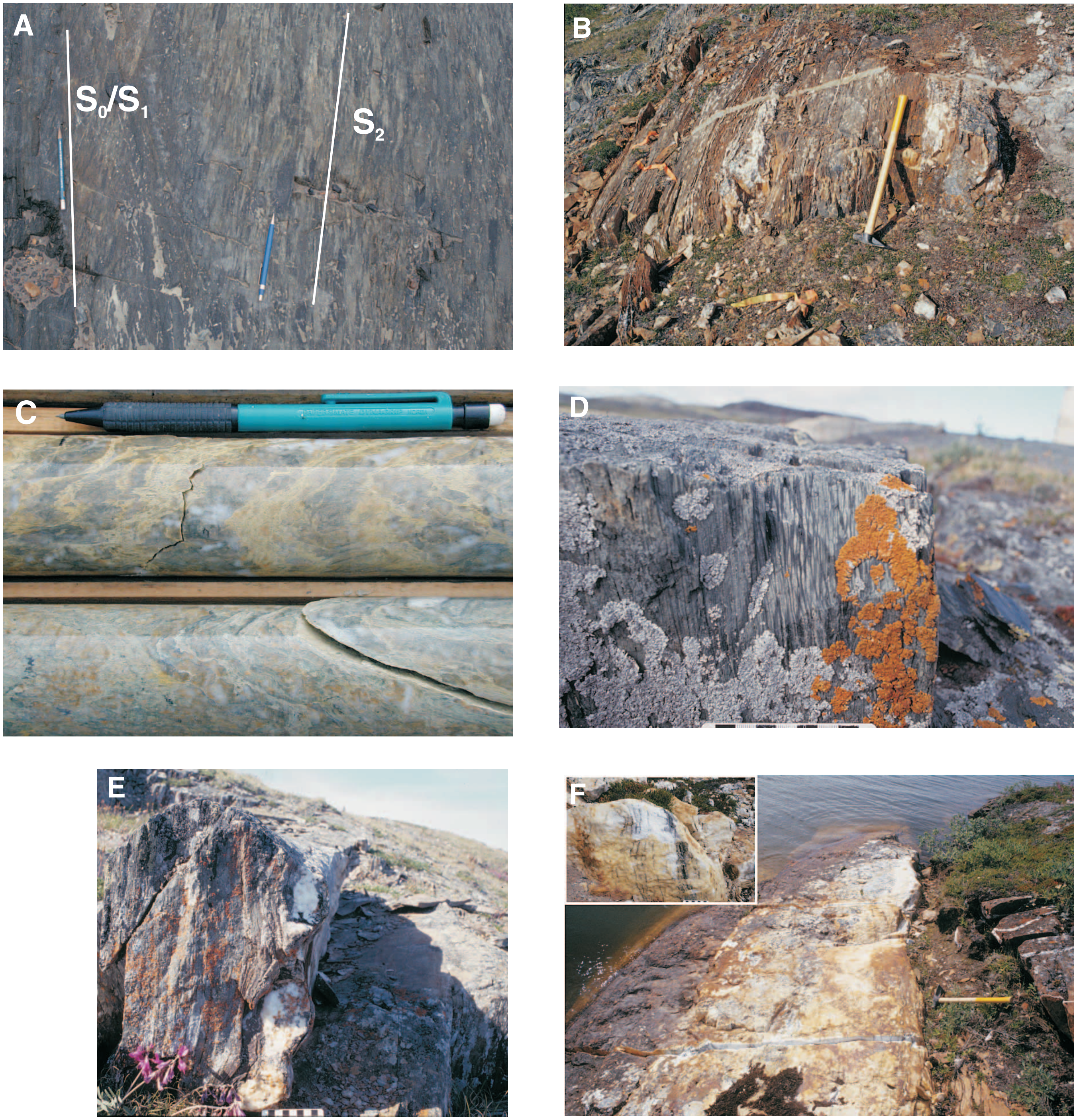


Figure 4. A) *Well developed bedding-cleavage relationships in dacite lapilli tuff, Windy felsic rocks; S_2 trends northeast, whereas S_0/S_1 composite fabric trends north (UTM 13W, 7552717N, 432520E).* ***B)*** *Fe-carbonate–stained high-strain zone with deformed auriferous quartz-carbonate veins, Wolverine showing (UTM 13W, 7546331N, 434994E).* ***C)*** *Deformation zone showing strong alteration and deformation fabrics (drillhole 97PMD77, 130.9 m).* ***D)*** *Strongly stretched varioles in Fe tholeiite from the Doris area. (UTM 13W, 7558435N, 433424E).* ***E)*** *Boudinaged quartz-carbonate veins in an Fe-carbonate high-strain zone, outcrop of the Central vein, Doris deposit (UTM 13W, 7559034N, 433727E).* ***F)*** *Lakeshore vein hosted in an Fe-carbonate–altered high-strain zone, part of the Doris deposit (UTM 13W, 7559009N, 433795E).*

and quartz-feldspar porphyritic rocks (R.L. Carpenter, unpub. geochemical data, 2001). The nature and timing of this structure remain uncertain, but it is spatially related to gold mineralization in the Madrid–South Patch area.

Pronounced stretching lineations are developed mainly in the Fe-tholeiitic basalt that hosts the Doris deposit (Fig. 4D). This is one of the unique characteristics of the Doris area, which distinguishes it regionally. Varioles in the Fe tholeiite have aspect ratios of about 50:3:1, indicating intense elongation and flattening. Quartz-carbonate veins at the Central vein of the Doris deposit are strongly boudinaged in an Fe-carbonate–altered high-strain zone (Fig. 4E). This feature has not been recognized outside of the Doris area.

North of Doris lake, strata and all D_2 structural elements are warped to a northeast orientation. The trace of the Doris antiform also shows a similar deflection to the northeast. Although no evidence for this is found on an outcrop scale, these deflections are interpreted as an overprinting F_3 fold.

Late brittle faults are recognized in outcrop as distinct brittle breaks, which have been preferentially weathered. These are typically less then 1 m across but can be traced for more than 1 km (Fig. 2). In several cases, stratigraphic offsets are recognized across these structures with a consistent apparent sinistral displacement. These faults do not crosscut or offset the Franklin diabase. They are identical in style to the fault at the Robert's bay silver mine, about 5 km north of the map area.

EVIDENCE FOR SYNVOLCANIC STRUCTURES

A schematic stratigraphic section is shown in Figure 5, centred around the Madrid break. The Madrid break is an enigmatic feature forming an east-west linear valley that is almost orthogonal to the general trend of the geology. The south side of the break is dominated by a nonvariolitic Mg tholeiite, whereas the dominant rock type to the north is a variolitic Mg tholeiite (Fig. 2); these rock types cannot be correlated across the break. Similarly, two felsic intervals on the north and south sides of the break cannot be correlated. The westernmost edge of the break is underlain, on both the south and north sides, by variolitic Mg tholeiite, which is overlain by quartz arenite and volcanic conglomerate at the base of the Windy felsic rocks.

Stratigraphically overlying the break is a thick succession of quartz arenite in the south that grades northward into more proximal volcanic conglomerate, breccia, and massive, coherent phases. This sedimentary-volcanic package overlies the break without any obvious offset. In the area closest to the break, the sedimentary package exceeds 400 m in thickness.

The 'deformation zone' underlies the Madrid break, which is spatially related to quartz stockwork mineralization of the Naartok deposit (Sherlock et al., 2002). As described above, it is a deformed and altered assemblage that overprints several

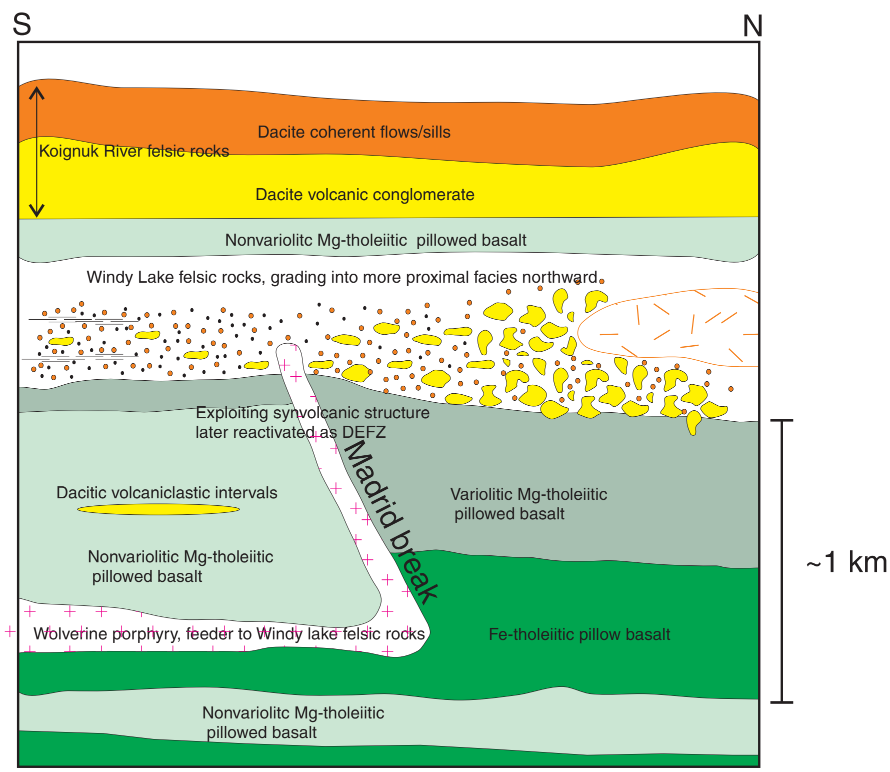


Figure 5.

Schematic stratigraphic section through the northern part of the Hope Bay volcanic belt.

different rock types. Most significantly, this includes altered phases of the Wolverine porphyry (R. Sherlock, unpublished data, 2001).

It is likely that the Madrid break represents a synvolcanic structure that juxtaposed variolitic and nonvariolitic Mg tholeiite. Overlying the structure is a thin interval of variolitic Mg tholeiite and a thick sequence of siliciclastic sedimentary rocks that grade northwards into volcanic conglomerate and more proximal volcaniclastic facies. Occupying the synvolcanic structure are dykes of Wolverine porphyry that intruded into the break and likely fed felsic volcanism higher in the stratigraphic package, possibly the Windy lake felsic rocks. Subsequent deformation (D_2) resulted in minor reactivation of the Madrid break, and mechanical contrasts at lithological contacts caused dilation and hydrothermal alteration, forming what is now seen as the 'deformation zone' and associated mineralization (Sherlock et al., 2002).

STRUCTURAL AND STRATIGRAPHIC RELATIONSHIPS

The stratigraphically lowest rocks in the succession are Fe tholeiite that occupies the core of the Doris antiform. This is generally pillowed, often highly amygdaloidal, and locally variolitic, and reaches a thickness of about 900 m (Carpenter et al., 2003). Overlying this is a thick unit of nonvariolitic Mg tholeiite that reaches a thickness of about 125 m. Cherty interflow sediment is common in this unit. Overlying this is a thick (approx. 100 m) sequence of Fe tholeiite with highly amygdaloidal pillows, similar to the Doris suite of Fe tholeiite. Stratigraphically overlying this is variolitic to nonvariolitic Mg tholeiite juxtaposed along a synvolcanic structure. This unit thickens in the southern part of the map sheet, reaching about 220 m. Intruded into this package is the Wolverine porphyry, which likely fed overlying felsic volcanism. Hebel (1999) obtained a maximum U-Pb age of 2698.7 +6.7/–3.7 Ma for the Wolverine porphyry, on a sample that had inheritance problems. Further U-Pb work is in progress to constrain this age. Also present in this unit are narrow (<20 m) volcaniclastic interbeds, suggesting that effusive felsic volcanism was ongoing at this time. The U-Pb age of these interbeds is 2689.4 +4.0/–3.6 Ma (Sherlock, unpublished data, 2001).

Overlying this dominantly mafic succession is the Windy lake felsic rocks. In the south part of the map sheet, the base of the Windy lake felsic rocks is an approximately 70 m thick interval consisting of quartz arenite and argillite, locally containing large clasts of quartz-feldspar porphyritic dacite. This unit grades northward into a volcanic conglomerate with large felsic fragments in a sandy matrix, which grades into a dacite lapilli tuff. All evidence suggests that the package becomes both thicker (approx. 170 m) and more proximal to the north. Overlying the basal sedimentary sequence is a thick package of dacite lapilli tuff and narrow intervals of coherent lavas or sills. Near the upper portion of the succession is a second interval of fine-grained siliciclastic sedimentary rocks and argillite. Hebel (1999) obtained a U-Pb age of 2685 +3.3/–1.9 Ma from a dacite lapilli tuff in the middle of the Windy lake felsic rocks.

Also exposed in the northern part of the area is a unit of quartz diorite. This unit is contained by a dacitic fragmental unit, is massive and featureless, and is interpreted to be a subvolcanic intrusive. It has a distinct yellow-green colour, caused by pervasive epidote alteration.

Overlying the Windy lake felsic rocks is a 50 m thick interval of pillowed Mg tholeiite. This is indistinguishable from basalt lower down in the stratigraphy with the exception of the upper 20 m of the section, which is highly amygdaloidal and almost scoriaceous.

Capping the stratigraphic succession mapped during this project is the Koignuk River felsic rocks. A 40 m thick volcanic conglomerate, with coarse fragments (up to 30 cm) in a fine-grained sandy matrix, forms the base of this unit. The unit is unbedded and unsorted without any recognized sedimentary structures. Overlying the clastic interval is a 100 m thick interval of coherent feldspar-porphyritic dacite. This interval is fine grained, massive, and locally flow banded. Hebel (1999) obtained a U-Pb age of 2677 +3/–1 Ma from the upper part of this unit.

The entire stratigraphic succession is intruded by hornblende leucogabbro. This intrusive rock tends to be concentrated near the fold axis and is most abundant on the eastern side of the antiform. Franklin diabase dykes and sills intrude the area. They are massive to columnar jointed and have not been offset by late brittle faults.

MINERALIZATION

Mineralization in the area encompasses several different styles of gold and syngenetic base-metal deposits. The main deposit in the area is the Doris deposit (Carpenter et al., 2003), which is an auriferous quartz vein with numerous septa of tourmaline, paragonite, and chlorite (Fig. 4F). Alteration is quite restricted, only really apparent within several metres of the vein system. Textural relationships suggest that the mineralization was introduced during a progressive D_2 event, possibly analogous to a saddle-reef setting (Poulsen et al., 2000). Details of the Doris area can be found in the companion paper (Carpenter et al., 2003).

The Madrid area is described in more detail in Sherlock et al. (2002) and only summarized here. Several gold deposits have been discovered in this area, including the Naartok, Perrin, and Suluk deposits. This zone may be extended to the south Patch area where recent work has intersected similar styles of mineralization. Although quite complex, the Naartok deposit exhibits many of the features typical of these areas. At Naartok, gold occurs within the hanging wall of the 'deformation zone' and may be related to a deflection in the zone. Anomalous gold concentrations at Naartok are related to pervasively altered basaltic, gabbroic, and felsic rocks that now contain Fe carbonate, paragonite, sericite, and pyrite. Texturally overprinting this alteration is a quartz-carbonate stockwork with associated silica flooding, which locally contains coarse visible gold. Different vein types and textures are present, including, Fe-carbonate veinlets, white-quartz+Fe-carbonate veins, quartz±albite veins, and late, fibrous ladder veins of white quartz and carbonate. Crosscutting relations between the vein types suggest a progressive mineralizing event during regional D_2 deformation (Sherlock et al., 2002)

The Wolverine area contains a number of high-grade quartz-vein prospects located outside of the Madrid area. These are all within Fe-carbonate–altered high-strain zones parallel to the local S_2 fabric. Many of these vein systems, and associated high-strain zones, occur at or near lithological boundaries. Within these alteration zones are quartz-carbonate veins, commonly with septa of sheet silicates and/or tourmaline. The septa tend to be parallel to the vein walls, producing a crack-and-seal texture. Vein geometries are generally planar but are locally deformed, with sigmoidal, boudinaged, and locally brecciated veins recognized. The range in deformation fabrics seen in the vein geometries suggests that they formed during a progressive D_2 deformation event, with strain localized at lithological contacts. These geometries and fabrics are typical of fault-fill veins, as described by Robert and Poulsen (2001).

Synvolcanic base metals are recognized in several locations within the Windy lake and Koignuk River felsic rocks. Concentrations of pyrite and base metals are localized at lithological contacts with weak asymmetric alteration halos, suggesting a synvolcanic hydrothermal system. Although not examined in detail, the bimodal nature of the volcanic suite and the identification of several base-metal showings suggests that the district has significant potential for volcanogenic massive-sulphide deposits.

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REFERENCES

Bevier, M.L. and Gebert J.S.
1991: U-Pb geochronology of the Hope Bay–Elu Inlet area, Bathurst Block, northeastern Slave Structural Province, Northwest Territories; Canadian Journal of Earth Sciences, v. 28, p. 1925–1930

Campbell, F.H.A. and Cecile, M.P.
1976: Geology of the Kilohigok Basin, Goulburn Group, Bathurst Inlet, District of Mackenzie, N.W.T. *in* Report of Activities, Part A; Geological Survey of Canada, Paper 76-1A, p. 369–377.

Carpenter, R.L., Sherlock, R.L., Quang, C., Kleespies, P., and McLeod, R.
2003: Geology of the Doris North gold deposits, northern Hope Bay volcanic belt, Slave Structural Province, Nunavut; Geological Survey of Canada, Current Research 2003-C6.

Fraser, J.A.
1964: Geological notes on the northeastern District of Mackenzie, Northwest Territories; Geological Survey of Canada, Paper 63-40, 20 p. plus Map 45-1963 at 1:506 800 scale.

Fyson, W.K. and Helmstaedt, H.
1988: Structural patterns and tectonic evolution in the Archean Slave Province; Canadian Journal of Earth Sciences, v. 25, p. 301–315.

Gebert, J.S.
1990: Geology of the Hope Bay and Elu Inlet metavolcanic belts, Bathurst Block, northeastern Slave Province, Northwest Territories; *in* DIAND Exploration Overview, Northwest Territories; Canada Department of Indian and Northern Affairs, p. 26.
1993: Geology and mineral potential of the Archean Hope Bay and Elu Inlet volcanic belts, northeastern Slave Structural Province, District of Mackenzie, Northwest Territories; Northern Affairs Program, Northwest Territories Geology Division, EGS Paper, 1993-1, 103 p.

Gibbons, W.A.
1987: Preliminary geology of the central Hope Bay volcanic belt, northern portions of NTS 77A/3, /6; Canada Department of Indian Affairs and Northern Development, EGS Paper 1987-12 (map with marginal notes at 1:50 000 scale).

Hebel, M.U.
1999: U-Pb geochronology and lithogeochemistry of the Hope Bay greenstone belt, Slave Structural Province, Northwest Territories, Canada; M.Sc. thesis, University of British Columbia, Vancouver, British Columbia, 96 p.

Hoffman, P.F.
1988: United Plates of America, the birth of a craton: early Proterozoic assembly and growth of Laurentia; Annual Review of Earth and Planetary Science, v. 16, p. 543–603.

Isachsen, C.E., Bowring, S.A., and Padgham, W.A.
1991: U-Pb zircon geochronology of the Yellowknife Volcanic Belt, N.W.T., Canada: new constraints on the timing and duration of greenstone belt magmatism; Journal of Geology, v. 99, p. 55–67.

Mortensen, J.K., Thorp, R.I., Padgham, W.A., King, J.E., and Davis, W.J.
1988: U-Pb zircon ages for volcanism in the Slave, Northwest Territories; *in* Radiogenic Age and Isotopic Studies: Report 2; Geological Survey of Canada, Paper 88-2, p. 85–95.

Padgham, W.A.
1985: Observations and speculations on supracrustal successions in the Slave Structural Province; *in* Evolution of Archean Sequences, (ed.) L.D. Ayres, P.C. Thurston, K.D. Card and W. Weber; Geological Association of Canada, Special Paper 28, p. 133–151.

Poulsen, K.H., Robert, F., and Dubé, B.
2000: Geological classification of Canadian gold deposits; Geological Survey of Canada, Bulletin 540, 106 p.

Robert, F. and Poulsen, K.H.
2001: Vein formation and deformation in greenstone gold deposits; *in* Structural Controls on Ore Genesis, (ed.) J.P. Richards and R.M. Tosdal; Reviews in Economic Geology, Vol. 14, Society of Economic Geologists, p. 111–156.

Sherlock, R.L., Carpenter, R.L., Bardoux, M., Flood, E., and Kleespies, P.
2002: Volcanic relations and gold mineralization in the Wolverine-Madrid corridor, Hope Bay belt, Nunavut; Geological Survey of Canada, Current Research 2002-C9, 11 p.

Thompson, P.H., Culshaw, N, Buchanan, J.R., and Manojlovic, P.
1986: Geology of the Slave Province and Thelon Tectonic Zone in the Tinney Hills–Overby Lake (west half) map area, District of Mackenzie; *in* Current Research Part A; Geological Survey of Canada, Paper 86-1A, p. 275–289

Villeneuve, M.E. Henderson, J.R., Hrabi, R.B., Jackson, V.A., and Relf, C.
1997: 2.70–2.58 Ga plutonism and volcanism in the Slave Province, District of Mackenzie, Northwest Territories; *in* Radiogenic Age and Isotopic Studies: Report 10; Geological Survey of Canada, Current Research 1997-F, p. 37–60.

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