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THE SEARCH FOR MAGMATIC Ni–Cu–Co MINERALIZATION IN NORTHERN LABRADOR: A SUMMARY OF ACTIVE EXPLORATION PROGRAMS

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ABSTRACT

This article summarizes some of the active exploration properties in northern Labrador that have developed following the Voisey's Bay mineral discoveries. It is compiled mostly from public-domain information contained in press releases and other promotional material, along with preliminary observations from 1996 field work and examination of representative drill-core material. The new Ni–Cu–Co occurrences discovered in 1995 and 1996 show a diversity of mineralization styles, ranging from discordant (epigenetic ?) vein-like massive sulphide (± oxide) zones, to syngenetic sulphides in pyroxenitic and gabbroic dykes, to stratigraphic sulphide accumulations hosted by layered sheet-like intrusions. Although the initial drill results may not have been spectacular, some of these areas have clear potential for longer term exploration programs, and many other projects were only in the early stages of exploration during 1996.

Although the appeal of northern Labrador to junior exploration companies seems to have diminished, it must be remembered that magmatic Ni–Cu–Co sulphide deposits (despite immense potential value) represent small and difficult exploration targets, even in areas where the geology is well understood. This is certainly not the case in Labrador, where most new discoveries are in essentially unmapped areas. It is against this background that the results of two years of mineral exploration should be judged.

INTRODUCTION

OVERVIEW

The world-class Ni–Cu–Co mineral discovery at Voisey's Bay, south of Nain, Labrador, has had an enormous impact on mineral exploration in northern Labrador. The 1995 and 1996 field seasons saw intense exploration activity in a corridor from Harp Lake to Okak Bay (Figure 1), and unusual levels of activity throughout Labrador. Numerous new mineral occurrences have been discovered, many of which are in areas that have never been systematically mapped or prospected. Several of these discoveries have now become the focus of more detailed and extensive exploration programs including diamond drilling. In 1996, the Geological Survey initiated metallogenic studies directed toward magmatic base-metal mineralization in Labrador. The initial field activity was focused in the Nain area, and consisted of field examination, mapping, sampling, and examination of diamond-drill core from a number of projects. Future activities will include more detailed work in this area, expansion into other areas of Labrador having potential for magmatic sulphide mineralization, and also petrological and geochemical studies aimed at more regional problems (e.g., Kerr, *this volume*).

Results and ideas from the 1996 field season are preliminary, and the details of exploration programs remain mostly confidential. This article provides a brief review of some of the more active developing exploration projects in Labrador, by collating public-domain information disseminated through press releases and other promotional materials. It also includes some preliminary general observations on local geology and the character of mineralization. A companion article (Kerr, *this volume*) reviews some essential characteristics of the Voisey's Bay deposit and discusses the controls on the formation of such magmatic sulphide deposits, with application to northern Labrador. Readers are also referred to Ryan *et al.* (*this volume*) for a more detailed discussion of the geology of the Alliger Lake map area (NTS 14E/01), which includes several of the projects discussed here. This report is not a comprehensive review of all active exploration projects in the region, and readers should note that a lack of discussion of a specific exploration property does not indicate a perceived lack of mineral potential, nor does its discussion represent any form of endorsement. In the case of details of grades and drill intersections, information is quoted mainly from press releases. Details and information discussed in this report are current to December, 1996.

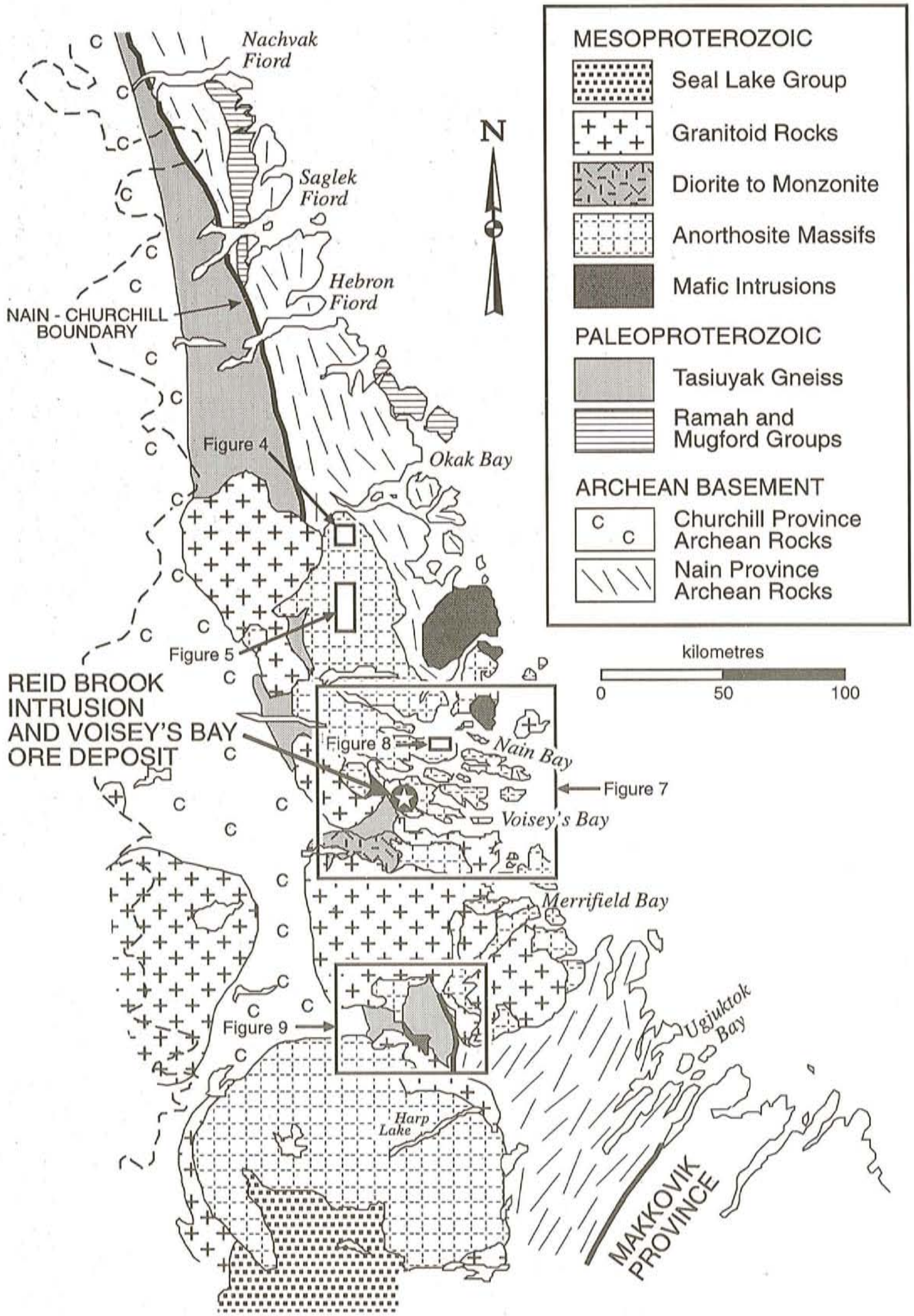

Figure 1. *Generalized geological map of northern Labrador, showing the location of the Voisey's Bay deposit, and the area of most intense exploration activity. The locations of Figures 4, 5, 7, 8 and 9 are also shown.*

REGIONAL GEOLOGY AND SCOPE OF EXPLORATION

The regional geology of northern Labrador, in the context of base-metal exploration, has been summarized elsewhere (Swinden *et al.*, 1991; Ryan *et al.*, 1995; Kerr, *this volume*). The main focus of recent exploration activity has been the Mesoproterozoic plutonic rocks (Figure 1) with the emphasis being on mafic and anorthositic members. This focus reflects the genetic association of the Voisey's Bay ore deposits with the Reid Brook intrusion, a troctolitic (mafic) member of the Nain Plutonic Suite (Naldrett *et al.*, 1996; Ryan, *in press*). However, exploration activity has been determined to a large extent by geography, rather than geology, and large areas underlain by basement gneisses and granites have also been staked and explored. The most intense activity has been between Harp Lake and Okak Bay, along the trace of the Nain–Churchill structural province boundary (Figure 1), which has been suggested to be an important control (Ryan *et al.*, 1995).

Exploration activity has, to date, mostly been of "grass-roots" type, consisting of ground prospecting and mapping, coupled with mainly airborne geophysics (commonly combined EM–magnetometer surveys). Properties that revealed gossan zones or significant geophysical anomalies have commonly progressed to ground geophysics, more detailed prospecting, mapping and diamond drilling. The rugged and well-exposed northern Labrador landscape has aided ground prospecting, but contributes to many logistical and weather problems. The projects summarized in this article lie mostly between Voisey's Bay and Okak Bay, with the exception of the Donner Resources "South Voisey Bay Project", which is located north of the Harp Lake anorthosite complex (Figure 1; *see* inset area for Figure 9). They are all located within, or associated with, Mesoproterozoic plutonic rocks.

ACCURACY AND RELEVANCE OF GRADE DATA

Information on the grades of a particular occurrence generally comes in two stages. Initial information is reported from "grab samples", collected during prospecting. Although this term implies some degree of randomness, such samples are commonly selected because they are well-mineralized and they are rarely representative. Values for Cu should, in particular, be viewed with caution, as chalcopyrite is the mineral most readily identified by prospectors. More systematic information from "channel samples" has been acquired from some properties, but many Labrador projects proceeded directly to diamond drilling. The reporting of drillhole data is a more complex matter, as illustrated by a hypothetical drill intersection that is not atypical of the area (Figure 2). The most rigorous presentation method is to list each assayed section individually, but summary averages are more common. Of these, weighted averages provide the best measure, as they reduce the influence of short high-grade sections, but simple numerical averages are far less representative (in this example, they are 50 percent higher). In many press releases, it is not clear which method has been employed. Drill intersections have also been reported through a combination of

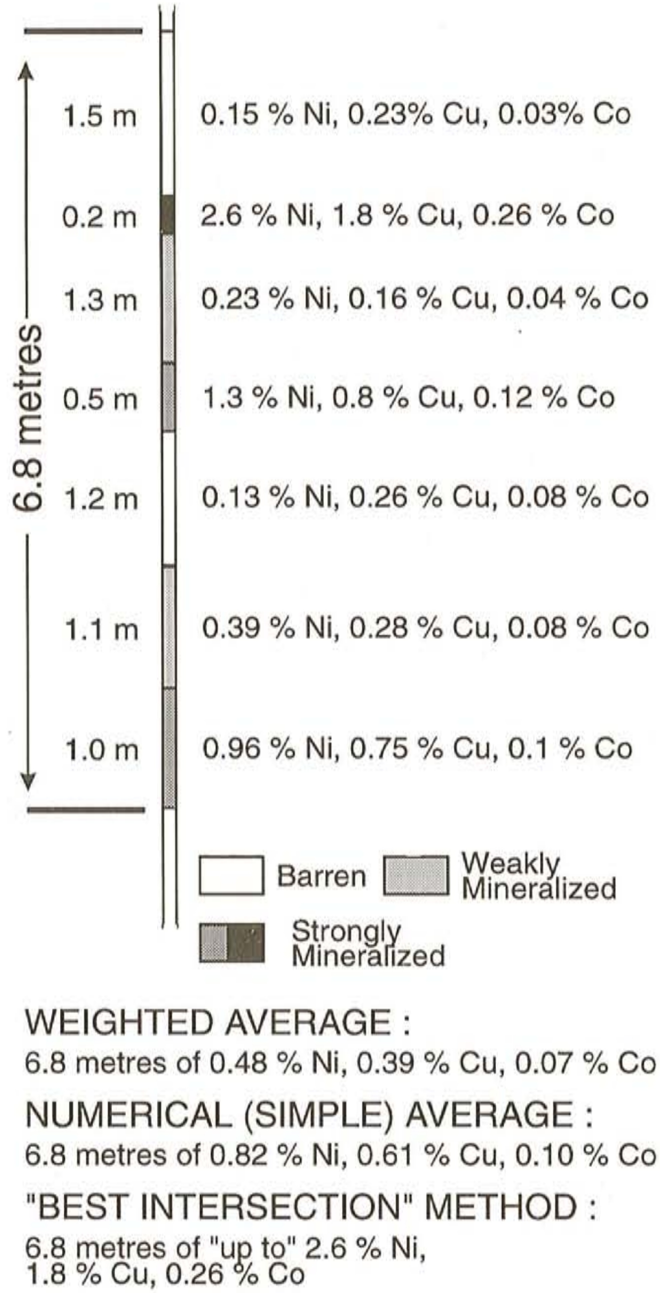

Figure 2. *A hypothetical drill intersection with low- and high-grade sections; results indicated by weighted and unweighted averages of the entire mineralized interval. Note that unweighted averages are 50 percent higher than the more representative weighted result.*

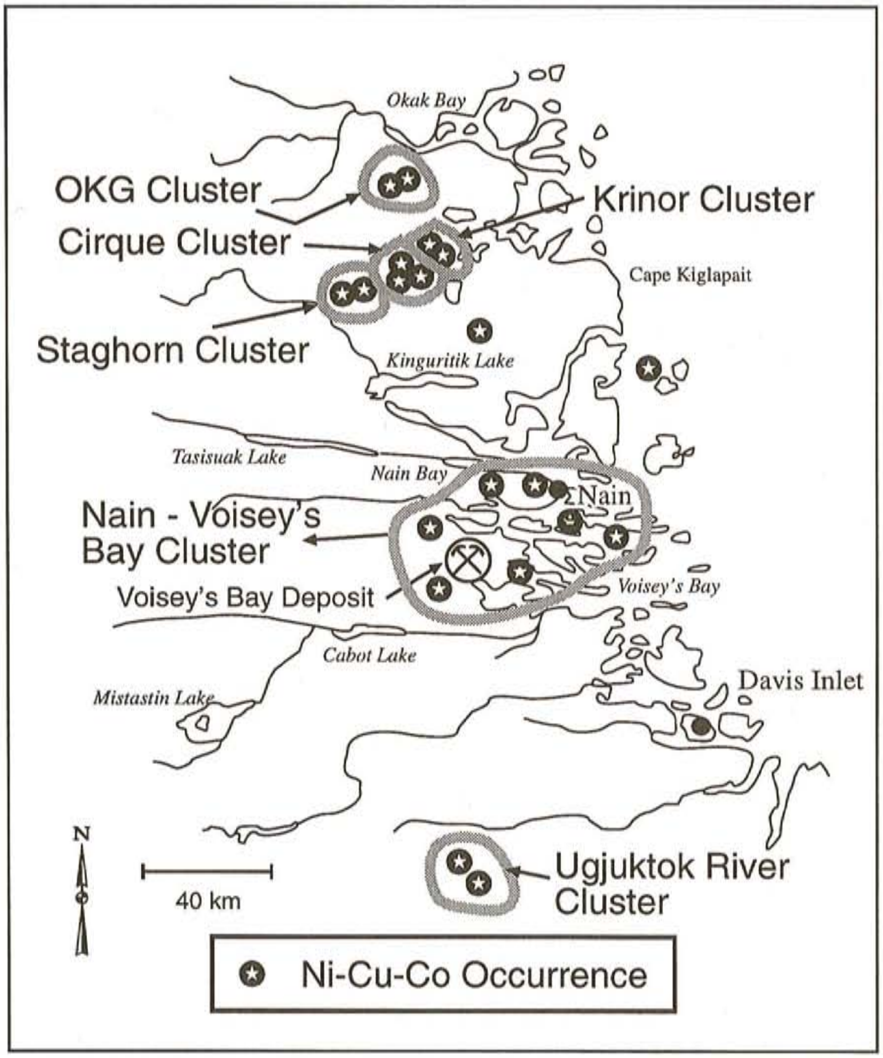

Figure 3. *Sketch map showing the general locations of "clusters" used as a framework for description of individual showings and prospects.*

total length and best assay results, usually in the form of "X metres grading up to Y percent Ni, etc.". This method provides essentially no useful information on the tenor of mineralization. Exploration companies active in northern Labrador have used all of these methods, and readers may in some cases wish to verify the exact wording of the original sources.

SUMMARY OF NEW MINERAL DISCOVERIES

For the sake of convenience, exploration projects have been divided into several "clusters" (Figure 3). These groupings are essentially geographic, but in some cases occurrences within a cluster share common host rocks or geological features. The names chosen for the clusters are drawn from a prominent example, but the choice of a name should not be taken to indicate any sort of pre-eminence. The order of discussion in this report is geographic, from north to south. In most cases, the operator of the project is listed as the mineral rights holder below, together with important joint venture (JV) partners. Individual press releases (PR) are referred to by company name and date.

OKG CLUSTER

The OKG cluster is the most northerly area studied, at the northern extremity of the Nain Plutonic Suite, a few kilometres south of Okak Bay (Figure 3). There are two principal exploration areas (Figure 4); the OKG showing and adjacent areas (license 1539M), held by Castle Rock Exploration Corporation (JV United Compass Resources), and the nearby license 2381M, held by Golden Trump Resources (JV Noront Resources). The two areas are very close together laterally, albeit at significantly different elevations, and likely represent the same mineralizing system.

OKG Prospect and Adjacent Areas

The OKG prospect was discovered in the summer of 1995. The best grab sample assays from the surface showing were 1.78% Ni, 1.44% Cu and 0.21% Co (Castle Rock Exploration, PR, September 21, 1995), and such samples consistently gave greater than 1% Ni. Two diamond-drill holes were completed near the showing in late 1995, in conjunction with a ground geophysical program. Although both holes intersected "multiple stringers of pyrrhotite and chalcopyrite" (Castle Rock Exploration, PR, November 15, 1995), no significant mineralization was encountered. With the acquisition of geophysical data, the focus for exploration shifted toward coincident magnetic–EM anomalies in the valley below, where three more holes were drilled in late 1995. All three holes intersected mineralization, but this differs in appearance from the surface showing. "Disseminated to semimassive to massive sulphides" were reported in distinct "pyroxenitic layers" up to 7.5 m in apparent thickness, situated from 150 to 400 m beneath the valley floor (Castle Rock Exploration, PR, November 28 and December 4, 1995; United Compass Resources, 1995 annual report). Intersections reported in various press releases include 3.2 m with up to 1.1% Ni, 0.93% Cu and 0.1% Co; 7.5 m with up to 0.86% Ni, 0.53% Cu and 0.09% Co, and 7.6 m with up to 0.88% Ni, 0.56% Cu

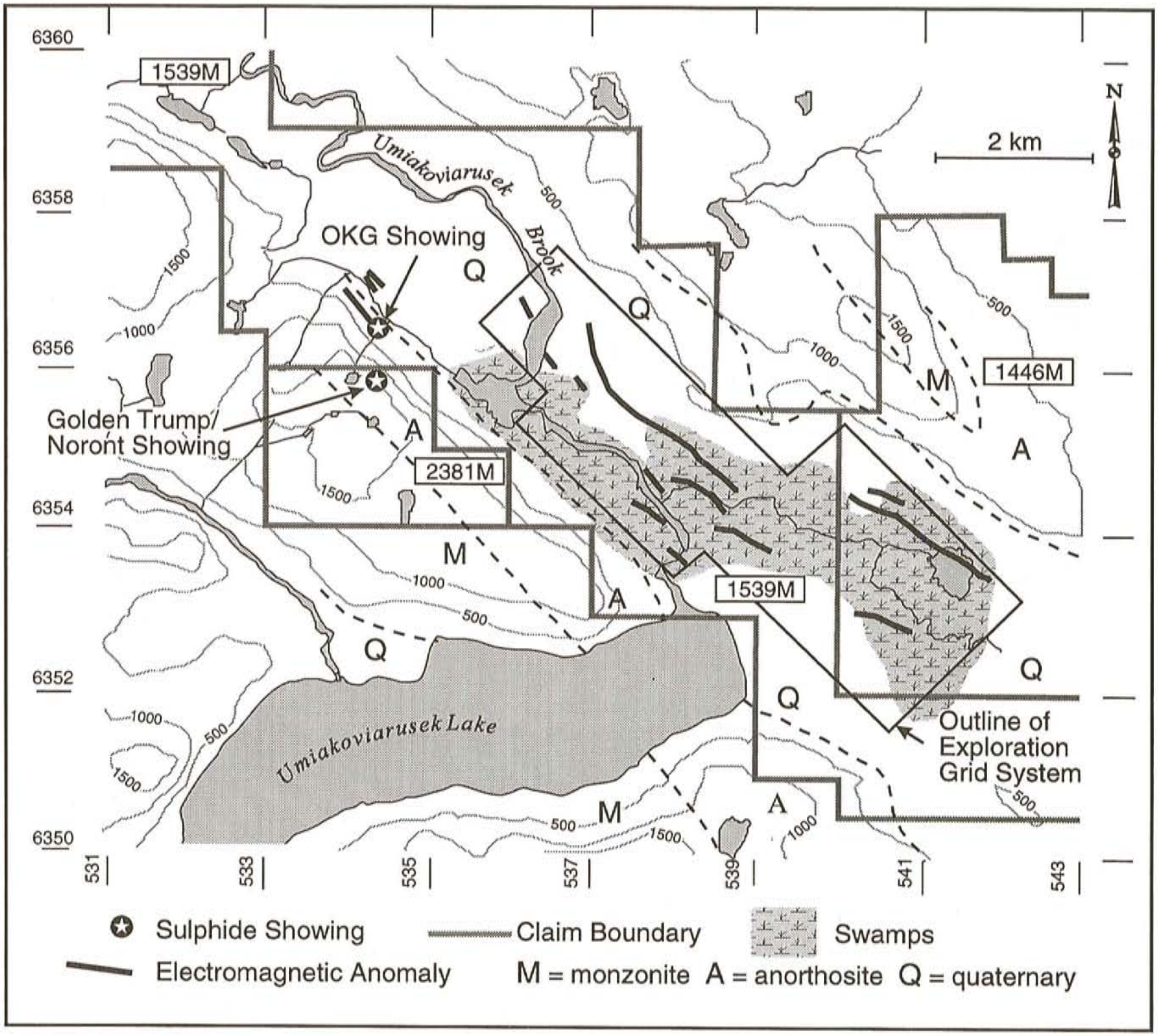

Figure 4. *Location map of the area around the Castle Rock Exploration "OKG" prospect and Golden Trump–Noront Resources area. Details of exploration grid and geophysical anomalies from United Compass Resources annual report, January 1996.*

and 0.05% Co. Additional geophysics was conducted in late winter of 1996, and several coincident magnetic–EM anomalies were defined in the valley. Diamond drilling commenced again in June 1996, but problems were encountered with the extremely thick over burden (up to 167 m) on the valley floor. Additional holes drilled during 1996 have intersected similar mineralized "pyroxenites", with apparent widths up to 14 m. Four discrete 1 m intersections of disseminated sulphides over a total apparent width of 10 m in hole OKG-96-9 gave 0.3 to 0.85% Ni, 0.09 to 0.43% Cu and 0.05 to 0.11% Co (Castle Rock Exploration, PR, July 22, 1996). Drilling continued through the summer and fall, with the deepest hole reaching 736 m.

The surface showing includes a prominent gossan on a near-vertical cliff that forms the southwestern wall of a spectacular U-shaped glacial valley, and some smaller gossan zones 300 to 400 m to the northwest (Figure 4). The showing lies close to a contact between massive anorthositic rocks and brown-weathering iron-rich monzonites, but the gossan zone is within the anorthosite. Reconnaissance examination in conjunction with B. Ryan (of the provincial Geological Survey) suggests that the monzonite–anorthosite contact is at a shallow angle, and that the monzonite forms a "cap" on the anorthosite at higher elevations. At surface, and in drill core, the anorthosite is altered and recrystallized, the primary mafic mineral assemblage has been retrogressed, and it is cut by dykes and veins of felsite and diabase. Similar features led Ryan *et al. (this volume)* to suggest that some anorthositic rocks previously grouped with the Nain Plutonic Suite are of Paleoproterozoic rather than Mesoproterozoic age. The OKG area is along strike from these units to the south, and it is possible that the host anorthosites are not part of the Nain Plutonic Suite.

The precipitous OKG gossan zone is difficult to examine in detail. It contains a mixture of unmineralized anorthosite, anorthosite with patchy disseminated mineralization, and massive sulphides. The massive sulphides consist of pyrrhotite and variable amounts of chalcopyrite, and typically form discontinuous pods having sharp external contacts. The sulphide pods range up to 3 by 2 m, and give the impression of elongation parallel to the cliff faces. Locally, chalcopyrite is concentrated around pod margins, or forms narrow veinlets that appear to crosscut the pyrrhotite. Due to intense weathering, relationships between sulphides and silicates in mineralized anorthosite are unclear. Small pods of a dark, pyroxene-rich rock containing disseminated sulphide occur within the showing area, but their relationship to the anorthosite is unclear. Similar material is abundant in talus downslope from the showing area.

Examination of representative drill core from holes OKG-96-9 and OKG-96-11 indicates that sulphides are essentially confined to a dark pyroxene-rich rock that exhibits sharp contacts against coarse-grained anorthosite. Contact relations are not completely clear in the core, but narrow pyroxenitic intersections resemble veins or dykes, implying that this rock intrudes the anorthosite. The sulphides are dispersed throughout the pyroxene-rich rock and appear to be syngenetic, i.e., they are interstitial and network-textured with respect to associated silicate phases. Downhole increases in the proportion of sulphides, culminating in narrow semi-massive to massive zones, imply some gravitational segregation. The grade of the massive material, and the relationship between grade and the amount of sulphide, is unknown. Based on descriptions in press releases, the attitude of the pyroxene-rich host-rock zones is very varied, and it is difficult to correlate between holes.

Golden Trump – Noront Project Area

The Golden Trump Resources (JV Noront Resources) claim block is immediately adjacent to the OKG exploration area, but is located on the mountaintop, several hundred metres higher (Figure 4). There is a small surface showing, from which grab samples assayed 0.54% Ni, 0.22% Cu and 0.07% Co (Noront Resources, PR, August 13, 1996). Diamond drilling started in mid-August, 1996, and targeted coincident magnetic–EM anomalies. The best results include 6.4 m of 0.82% Ni, 0.48% Cu and 0.06% Co, including a 2.3 m massive intersection of 1.98% Ni, 1.03% Cu and 0.16% Co (Golden Trump Resources, PR, September 9, 1996), and 1.75 m of 1.57% Ni, 1.02% Cu and 0.12% Co (Golden Trump Resources, PR, September 16, 1996). These intersections are all within 30 m of the surface, essentially representing tests of the surface showing, and it is not stated how summary grade results were calculated. Subsequent drilling has yielded narrow intersections, although Ni contents of up to 1.4% were reported (Golden Trump Resources, PR, October 11, 1996).

This property was not examined during the 1996 season, and it is not clear if the mineralization resembles the pod-like massive sulphides in anorthosite (cf., OKG surface showing) or the possibly syngenetic sulphides in pyroxene-rich zones (*cf.*, OKG drill intersections). Press releases contain no information on the geology.

KRINOR CLUSTER

The Krinor Cluster, as defined here, consists of several Ni–Cu sulphide prospects scattered through extremely rugged terrain in the Alliger Lake map area (NTS 14E/01) immediately south of the Puttuaalu Brook valley (Figure 5). These include the Krinor Property itself (license 1848M), held by Castle Rock Exploration (JV Consolidated Magna Ventures; Arc Resource Group), and three zones within license 1506M, held by Columbia Yukon Resources (JV Silverstone Resources). The adjacent "Puttuaalu Staircase" property (license 911M), held by Ace Developments, also hosts several gossan zones.

The geology of the Alliger Lake map area is discussed by Ryan *et al.* (*this volume*). The area of the Krinor cluster is underlain by a series of layered norite and leuconorite interpreted to be part of the Nain Plutonic Suite. The layering in these rocks is spectacularly developed, and dips gently northward. The lower part of the sequence (mostly within the Columbia Yukon Resources area) is typically brown- to red-weathering whereas the upper portion is buff to grey. The layered rocks include foundered house-sized blocks of massive anorthosite, and appear to be intruded from beneath by massive leuconorites (Ryan *et al.*, *this volume*).

Krinor Showing

The Krinor showing, discovered in late summer 1995, consists of an extensive rusty zone through a steep gully on a 300-m-high sheer cliff. Surface samples from the Krinor showing area yielded assays of 0.56 to 0.82% Ni, 0.16 to 0.6% Cu and 0.1 to 0.13% Co. The best assay from the property was 1.31% Ni, 0.52% Cu and 0.21% Co (Castle Rock Exploration, PR, October 4, 1995). Geophysical surveys were conducted during the summer of 1996, and diamond drilling commenced in mid-August 1996. Due to the extreme topography, the drill site was located on the mountaintop, up to 300 m above surface mineralization. No information has been released concerning drilling results, but three holes intersected sulphide mineralization, over widths up to 14 m, but Ni and Cu grades were subeconomic (J. O'Sullivan, personal communication, 1997).

Much of the gossan zone is inaccessible, and it is strongly weathered. However, the geometry and near-vertical attitude of the gossan zone, relative to gently dipping igneous layering, suggest that it is discordant. Surface outcrops at the base of the zone do not reveal any single vein-like sulphide concentration, but consist mostly of unmineralized but heavily stained norite, associated with norite containing "disseminated" pyrrhotite. Massive sulphide is rare in the exposures at the lower end of the zone, but there is abundant massive material in downslope talus. The massive sulphide consists of coarsely crystalline (2 to 5 cm) pyrrhotite and variable amounts of chalcopyrite; no pentlandite was identified in the field. Small zones of massive sulphide in outcrop are similar, and have sharp contacts with the host norite, although locally a "fringe zone" of heavily disseminated pyrrhotite is present. Igneous layering is not well developed in the mineralized outcrops, but there is no sign of a preferred orientation to sulphide zones. Smaller, apparently similar, sulphide zones occur on the opposite side of the valley, and in the northeastern part of the claim block (Figure 5).

License 1506M Showing

License 1506M, held by Columbia Yukon Resources, contains four main gossan zones exposed on steep hillsides and cliffs (Figure 5). The host rocks in this area are red-brown-weathering norite and leuconorite, with well-developed cumulate layering, superbly displayed on sheer cliff faces south of showing #1 (Figure 5). This showing includes an extensive gossaned zone having a geometry similar to that of the Krinor showing, i.e., it appears to be regionally discordant to igneous layering. It is also similar in that massive pyrrhotite (± chalcopyrite) is most abundant in talus, and only locally seen in bedrock, where it has a pod-like form. Much of the showing comprises stained, unmineralized, norite, and material with variably disseminated pyrrhotite. Grab samples assayed up to 0.77% Ni, 0.59% Cu and 0.16% Co (Columbia Yukon Resources, web site, 1996). Showing #2 (Figure 5) is the most interesting geologically, as massive sulphide clearly forms several discontinuous pods (up to 1 m diameter) over an area of 40 m^2. Individual pods are separated by barren or weakly mineralized host rock, and show sharp contacts. Chalcopyrite is more plentiful here than in the other showings, and forms small blebs, and discrete crosscutting veinlets, in coarsely crystalline (2 to 5 cm) pyrrhotite. Grab samples assayed up to 0.53% Ni, 0.82% Cu and 0.16% Co (Columbia Yukon Resources, web site, 1996). Showing #3 is virtually inaccessible as it is located on a vertical, crumbling cliff, but surface outcrops at the top of the zone contain abundant magnetite. B. Ryan (personal communication, 1996 and Ryan *et al.*, *this volume*) suggests that some of the host rocks here may be pyroxenitic. Showing #4, directly across the valley from showing #1, is defined mostly by gossaned talus and minor massive sulphide, but is assciated with a conductor. It produced assays of up to 0.44% Ni, 2.35% Cu and 0.12% Co, but such Cu-rich material was not observed in the field.

Showings #1, 2 and 4 all show evidence of diamond drilling, but the results released are not clearly linked to these locations. The best results include 6.5 m of 0.44% Ni, 0.47% Cu and 0.07% Co (average), including 2.8 m of 0.67% Ni, 0.63% Cu and 0.12% Co (weighted average of highest-grade section) (Columbia Yukon Resources, PR, June 7, 1996), and 5.7 m at 0.64% Ni, 0.38% Cu and 0.09% Co (weighted average; Columbia Yukon Resources, PR, June 20, 1996). The core from these showings has not been examined. The long-range plans for this project include deep drilling (Columbia Yukon Resources, web site, 1996).

Puttuaalu Staircase Property

The "Puttuaalu Staircase" property (license 911M), held by Ace Developments, includes several, mostly small, gossan zones hosted by anorthosite and norite. The most obvious is located in a cirque valley about 2 km southwest of the Columbia Yukon Resources showings (Figure 5). Grab samples from this area contained up to 0.6% Ni, 0.6% Cu and 0.14% Co (Ace Developments, PR, August 21, 1995). The showing is dominated by stained, unmineralized norite, and norite and disseminated pyrrhotite, associated with rare pods of massive pyrrhotite and chalcopyrite. Chalcopyrite has a vein-like habit akin to that seen in other pod-like occurrences. The other gossan zones on the property were examined only briefly.

CIRQUE CLUSTER

The Cirque Cluster is located a few kilometres south of the Krinor Cluster, in an area of even more extreme relief and topography (Figure 5). It includes the Cartaway Resources "Cirque Prospect" (license 1764M), and the adjacent Canadian States Resources project (license 1514M) and the Noranda "Hilltop" property (license 915M). The geology of this region is extremely complex (*see* Ryan *et al.*, *this volume*) and contains several discrete intrusive units, including a layered sequence of mottled leucotroctolite and anorthosite at higher elevations, which sits above more massive norite and anorthosite, but is also intruded by a younger norite to anorthosite pluton.

Cirque Prospect

The spectacular Cirque Prospect consists of an extensive gossan zone exposed in the cliff walls of a glacial cirque

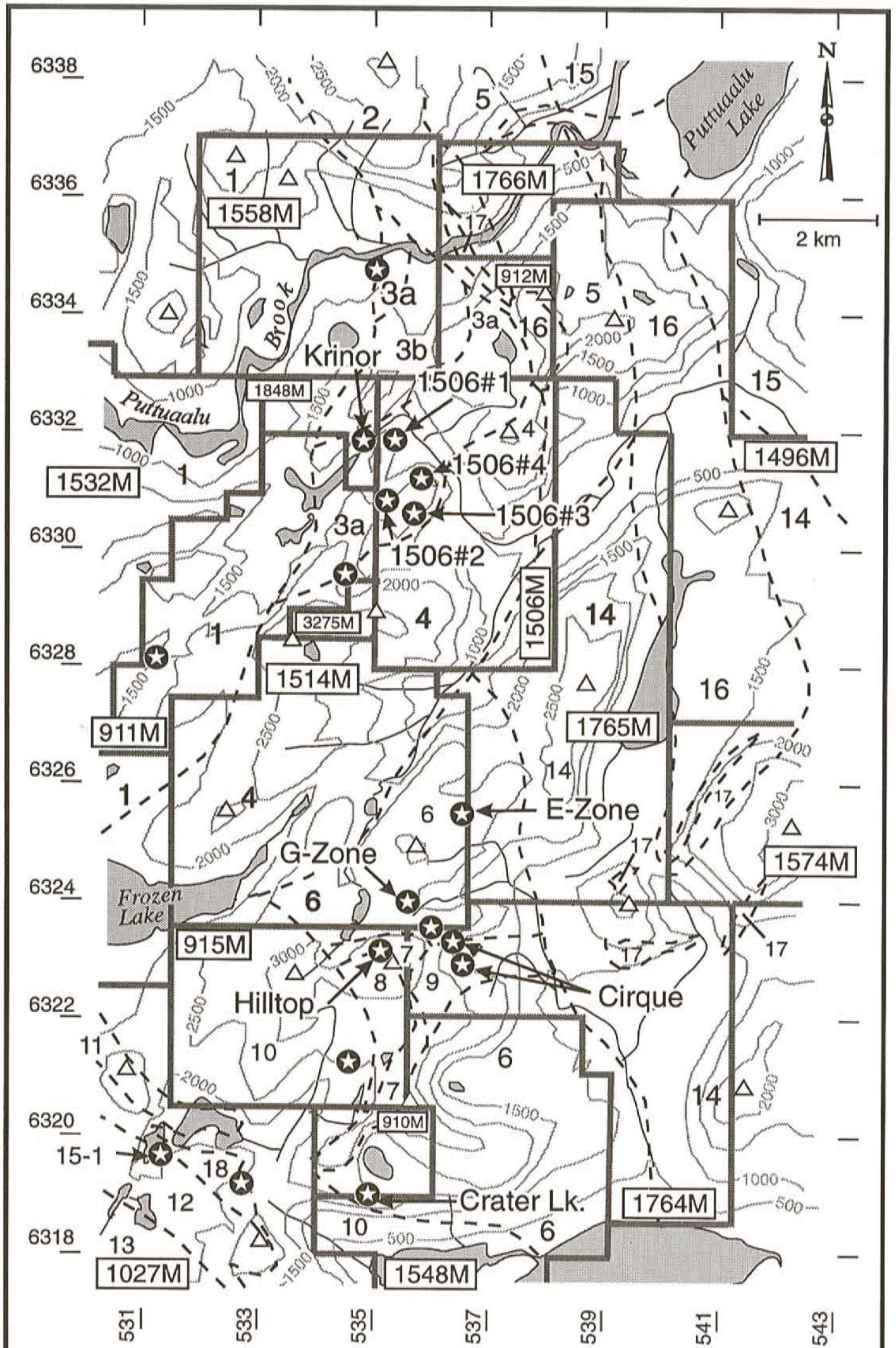

Figure 5. *Location map for showings in the western part of the Alliger Lake (NTS 14E/01) map sheet. Geology from Ryan* et al. (this volume).

LEGEND (for Figure 5)

GEOLOGICAL UNITS (after Ryan et al., 1997)
(Not in any stratigraphic order)

18 Layered mesocratic granulite
17 Diorite dykes and small intrusions
16 Monzonite
15 White anorthosite and leuconorite
14 Massive to layered norite and anorthosite
13 Massive grey anorthosite
12 Foliated leuconorite
11 Grey anorthosite and leucotroctolite
10 Massive norite, leuconorite and anorthosite
9 Pale pink to grey anorthosite
8 Grey olivine - anorthosite
7 Mottled troctolite and leucotroctolite
6 Brown to grey leuconorite and anorthosite
5 Buff leuconorite
4 Grey to green anorthosite and leucotroctolite
3 Leuconorite and norite; 3a - Layered; 3b - Massive
2 Grey to mauve anorthosite
1 Dark grey, labradorite - bearing norite to anorthosite

1000 Topographic Contour (feet)
△ Mountain Peak
Sulphide Showing
1514M Claim Block Boundary and Number

having a relief of about 350 m. The gossan zone is associated with large talus slopes, in which massive sulphide debris is abundant. Mineralization was recognized in late summer 1995, after helicopter prospecting and airborne geophysical surveys showed a series of EM conductors up to 800 m long, spatially associated with the gossan. Grab samples gave assay results of 0.13 to 0.36% Ni, 0.15 to 0.61% Cu and up to 0.12% Co (Cartaway Resources, PR, August 31 and September 7, 1995). A ground geophysical survey was conducted, and results were interpreted in terms of "a pipe-like massive sulphide lens (cylinder) some 250 m in diameter, plunging to the south" (Cartaway Resources, PR, September 7, 1995). Attempts at drilling in late 1995 were unsuccessful, due to the severity of winter conditions.

The gossan zone is only accessible in two separate areas in the southwest and northwest corners of the Cirque respectively, but both locations are exposed and subject to frequent rock falls. The downslope talus provides most of the sulphide material, and also an excellent sampling of the host rocks. The dominant host, in talus and outcrop, is a variably recrystallized, greenish-grey anorthosite, interpreted by Ryan *et al.* (*this volume*) as a large dyke-like body. Locally, this is a medium-grained, granular, saccharoidal rock that does not appear to have a preserved primary texture, but in most cases coarser grey plagioclase is present within the finer material. The anorthosite characteristically contains single large crystals (up to 20 cm long) and coarse aggregates of black, variably iridescent, labradorite, which are presumed to be igneous xenocrysts and disrupted cumulate zones. A magnetite-rich dioritic dyke is visible in the north wall of the cirque, dipping some 45° to the northwest, and a subvertical granitic vein also cuts the anorthosites in this area.

Cliff outcrops at the southwest corner of the Cirque contain the best examples of *in situ* mineralization. Here, there are at least two subparallel massive sulphide lenses, consisting almost entirely of coarse pyrrhotite, which are elongated in a northwest–southeast direction and dip steeply to the northeast, subparallel to the exfoliation surfaces in the cliffs. Although only a small part of the outcrop is safely accessible, the distribution of intensely gossaned areas suggests a series of interconnected, elongated pods having a common *en echelon* orientation. In the outcrops, zones of heavily disseminated sulphide may surround and connect the individual lenses in 3 dimensions. Cliff outcrops in the northwest corner are less informative because the exposure surfaces are subparallel to the mineralized zones. Abundant massive sulphide in downslope talus suggests that much of the mineralization has been eroded here. The mineralization resembles that at the southwest corner, and consists dominantly of coarsely crystalline pyrrhotite and minor chalcopyrite. The gossan zone as a whole strikes at about 130°, but the mineralized outcrops in the southwest corner do not line up precisely with the gossans in the northwest corner. They may be separate zones, or (alternatively) a single zone that has been displaced along a small fault running through the axis of the cirque. A prominent fracture zone in the west wall, striking northeast–southwest, and dipping steeply southeast, may be the expression of such a fault.

Six diamond-drill holes were completed in May 1996, working from the top of the cirque, aimed at the strongest section of the conductor. Holes 1, 2 and 3 form a fan from the same set-up, with inclinations of 50°W, 90° and 50°E respectively (Cartaway Resources, PR, May 8, 1996; Figure 6). The west-dipping and vertical holes intersected several sulphide zones, but were mostly barren below about 125 m. The east-dipping hole intersected the same series of sulphide zones, and also more extensive mineralized intersections to a depth of about 200 m (Cartaway Resources, PR, May 16, 1996). In conjunction with field observations inside the cirque, these results confirm that the mineralized zone as a whole dips to the northeast. A similar fan of 3 holes drilled from a point about 50 m south produced similar results, i.e., the widest mineralized intersections were in east-dipping holes that cut across the zone at a shallow angle (Cartaway Resources, PR, June 20, 1996). The orientation of drillholes

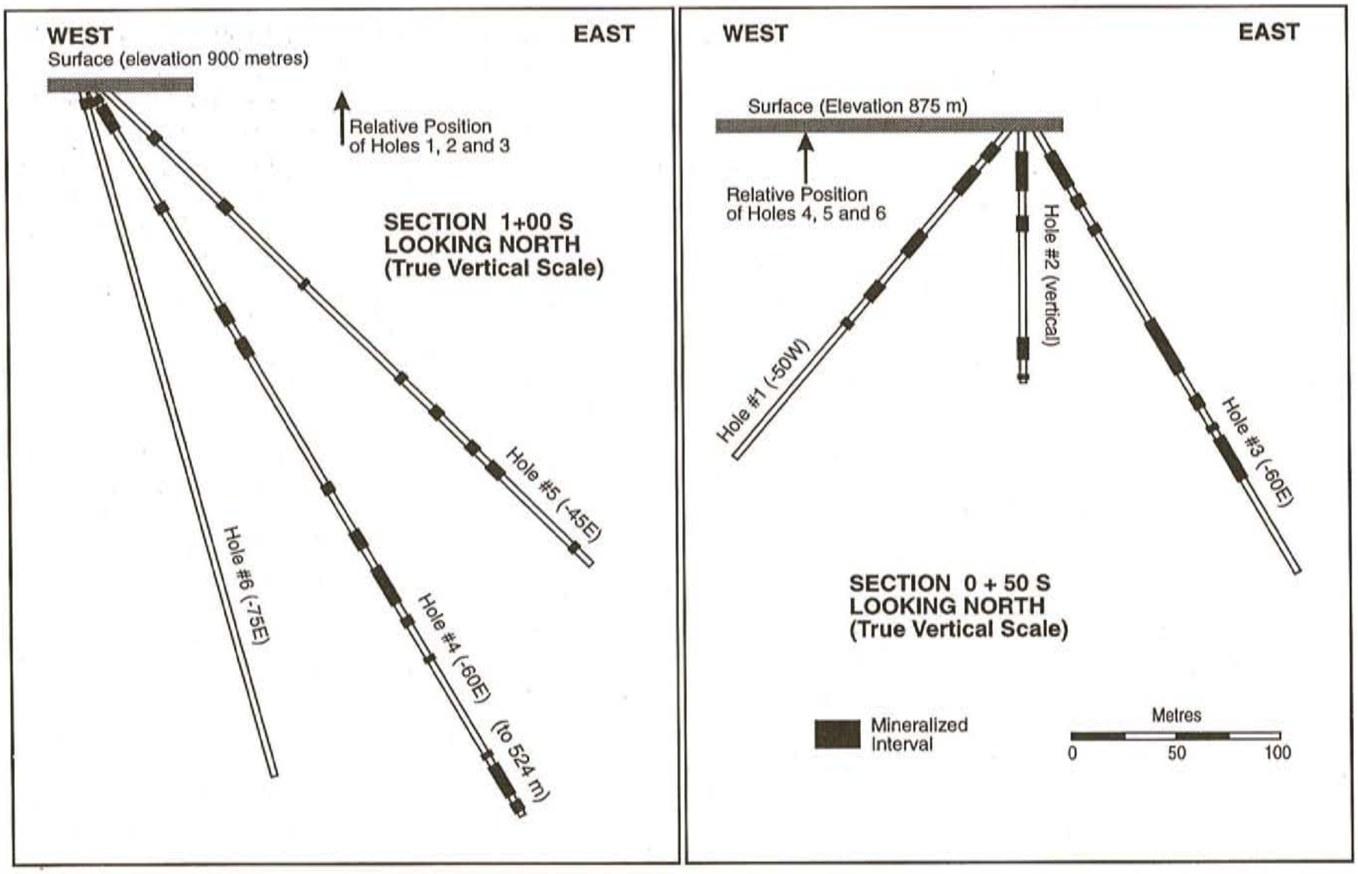

Figure 6. *Summary of drill intersections from holes 1-6 at the Cartaway Resources Cirque prospect, showing the orientation of the sulphide-bearing zone (from Cartaway Resources, PR, May 17, May 21 and June 6, 1996).*

at the top of the Cirque is controlled by the topography, as it is impossible to collar holes farther to the east.

Although initial "visual estimates" had described "net-textured to massive sulphides" and "pyrrhotite, pentlandite and chalcopyrite, having average chalcopyrite mineralization between 5 to 10 percent" (Cartaway Resources, PR, May 16, 1996), these were not corroborated by assay data. The best intersections contained up to 0.44% Ni and 0.27% Cu over short widths (up to 5 m), but most of the assays were significantly lower, generally <0.3% combined Ni and Cu (Cartaway Resources, PR, May 17 and May 21, 1996). Higher Co (locally up to 0.14%) was associated with increased Cu. Subsequently, a 588 m hole was drilled westward from the bottom of the cirque (Figure 6) in an attempt to intersect the downdip extension of the zone, but did not encounter significant mineralization (Cartaway Resources, PR, June 20, 1996). Consultant advice from F. Puskas stated that "exploration to date has been restricted to sulphides representing replacement bodies that have variably detextured the sulphidized anorthositic/gabbro/noritic host rocks", and that the mineralization was of "distal-peripheral or more medial" type (Cartaway Resources, PR, June 20, 1996). Three deep drillholes were completed from the cirque floor during the summer of 1996, seeking a deeper source region for the sulphides, but no significant mineralization was encountered (Cartaway Resources, PR, October 22, 1996).

Diamond-drill core was examined briefly and sampled during the summer of 1996. The distributions of rock types and mineralization is irregular to locally chaotic. The host anorthosite varies considerably in texture, from well-preserved grey material having net-like accumulate growth, to fine-grained, pale-green material that seems entirely recrystallized. The coarse-grained (xenolithic ?) black anorthosite also occurs in the core, where it gives the appearance of discrete units. The sulphide zones are localized and widely varied in width, ranging from net-textured zones a few centimetres wide to essentially massive intersections greater than 1 m wide. Their attitudes, with respect to the core axis, are similarly varied, and their contacts locally seem to run subparallel to the core. The sulphides consist of coarsely crystalline pyrrhotite with minor chalcopyrite concentrations, most commonly at the margins of sulphide zones. It is difficult to correlate mineralized intersections or sulphide zones from hole to hole (Figure 6).

Most massive to semimassive sulphide zones include silicate material, most commonly subhedral plagioclase crystals, although other phases may also be present. Plagioclase crystals commonly show signs of thermal erosion, in the form of rounding and pitting by sulphides. The "network-textured" sulphides appear to represent the percolation of sulphide liquid along grain boundaries, or possibly between crystals in a partially solidified cumulate. All gradations of this texture are seen, from massive sulphide with scattered plagioclase crystals, to half-and-half mixtures, to recognizable anorthosite having intergrain sulphide pockets. As brecciation and penetration of a solid monomineralic wall rock and infiltration of a "wet" cumulate pile would lead to essentially the same texture, it is difficult to interpret these zones; petrographic studies should help to resolve this. However, none of these "network-textured" zones correspond to true "net-textured ore", in which cumulus silicates sink into a massive sulphide layer (Naldrett, 1973). In addition to the coarse-grained pyrrhotite, finer grained pyrrhotite is present in crosscutting veinlets associated with fracture systems, interpreted as later (remobilized ?) mineralization. The drill core examined confirms impressions from surface geology, where massive sulphide lenses appear to be linked in three dimensions by zones of disseminated, network-textured material.

Canadian States Resources Property

License 1514M, held by Canadian States Resources, includes an extension of the same discontinuous series of gossan zones and combined magnetic–EM anomalies observed at the adjacent Cirque Prospect. The local geology is dominated by dark-grey to buff leuconorite, containing black plagioclase xenocrysts. Layered granular gabbronoritic rocks and magnetite-bearing troctolites also occur in the area (Ryan *et al.*, *this volume*). There are two main areas of exploration, which are termed the "E" and "G" zones in company literature; the "G" zone is situated only 1 km northwest of the Cirque Prospect (Figure 5).

Mineralization was initially identified in conjunction with airborne geophysical surveys, and sampling of surface showings in the "G" zone gave encouraging results, with assays up to 1.8% Ni, 0.3% Cu and 0.17% Co, along with up to 0.93% Cr and 0.23% Zn (Canadian States Resources, PR, July 20th, 1995; September 12, 1995). Following ground geophysics, drilling commenced in late September 1995. Two shallow drillholes from the same location at the "G" zone intersected massive sulphides over widths of approximately 10 m, with average assays of 1.73% Ni, 0.52% Cu and 0.1% Co, and 1.77% Ni, 0.81% Cu and 0.12% Co (Canadian States Resources, PR, September 25, 1995). These holes represent closely adjacent tests of a surface showing, in which mineralization is of limited extent. Drilling continued on both the "G" and "E" zones through late 1995, and has continued to encounter sulphide mineralization, although the grades and widths of the initial holes at the surface showing have yet to be matched. The downdip extension of the "G" zone recently provided an intersection of 1.59 m of 1.19% Ni, 0.51% Cu and 0.06% Co, about 43 m below surface (Canadian States Resources, PR, August 21, 1996). In the "E" zone area, wider and deeper intersections of "disseminated to massive sulphide layering" have been reported, including 12.9 m of 0.24% Ni, 0.20% Cu and 0.06% Co, and 54 m of 0.4% Ni, 0.43% Cu and 0.11% Co, although it is not stated if the latter intersection is continuous (Canadian States Resources, PR, August 21, 1996). Generally, the grades are higher than those from the adjacent Cirque Prospect, although such comparisons may be complicated by differences in averaging techniques.

The surface showing at the "G" zone is a vein-like zone of massive sulphide having a true width of 1 to 2 m, which has sharp contacts against unmineralized norite wall rocks, and apparently contains blocks of the wall rock. It consists of massive coarse-grained pyrrhotite and variable amounts of chalcopyrite; coarse pentlandite was not observed in the field, but some untarnished cleavage pits may represent pentlandite exsolution lamellae. The drill core from "G" zone is impressive, and clearly contains fragments of anorthosite and leuconorite, consisting of multiple crystals having variable recrystallization, surrounded by the massive sulphide. These appear to have been solid, relatively cool fragments at the time of incorporation, and are locally rimmed by chalcopyrite concentrations. In addition to the large fragments, individual, variably resorbed, plagioclase crystals occur within the sulphides.

There is very little outcrop in the area of the "E" zone, although gossaned boulder fields contain scattered sulphide-bearing float. Drill core from two holes was examined in 1996, and shows a variety of textures. The distribution of sulphide-rich zones is irregular and unpredictable, as at the Cirque Prospect, and the massive material is similar, albeit richer in chalcopyrite. On the margins of massive zones, network-textured sulphide zones are present, and these are dominated by chalcopyrite, in contrast to the massive sections, which are dominated by pyrrhotite. The textural relationships between sulphides and host rocks strongly suggest that the latter were solid and competent, and there are numerous examples of *in situ* brecciation and of multicrystal rock fragments surrounded by sulphides.

In some sections of core, there is evidence of pervasive recrystallization, grain-size reduction and (possibly) alteration of anorthosite and leuconorite that may be spatially associated with the mineralization. The coarse grey anorthosite is reduced to an essentially featureless pale-green rock, but this remains hard and competent. The nature of this transformation is unknown, but the competency of the product argues against any large-scale sericitization or chloritization related to hydrothermal processes.

Noranda "Hilltop" Property

The "Hilltop" property (license 915M), held by Noranda Mining and Exploration, is located immediately west of the Cirque Prospect, and includes the highest mountain peaks between Nain and the Kaumajet Mountains, with a maximum elevation of over 1000 m (Figure 5). Noranda is a major mining corporation, and no public-domain information is available about the Property. The following summary is published with the permission of Noranda.

The main area of interest lies just below the summit, where a small showing of massive and semimassive sulphide (pyrrhotite ± chalcopyrite) is hosted by grey anorthosite, forming part of the layered anorthosite–leucotroctolite unit that occupies higher elevations (Ryan *et al.*, *this volume*). Disseminated sulphide mineralization also occurs in pods of a granular mafic rock interpreted by Noranda as a dyke (G. Squires, personal communication, 1996). Although the surface mineralization is of limited extent, it is spatially associated with a coincident magnetic– EM anomaly.

Drilling has confirmed the presence of more extensive subsurface mineralization of two types. Massive and semi-massive sulphide (pyrrhotite ± chalcopyrite) is mainly hosted by anorthosite, and shows relationships similar to those described from the nearby Cirque and Canadian States Resources areas, i.e., a sulphide liquid appears to have penetrated and disrupted largely solid wall rocks. Disseminated sulphide mineralization is present in a finer grained, melanocratic mafic rock described by company geologists as a "pyroxenite", and appears to be syngenetic. The massive zones are spatially associated with the marginal contacts of the melanocratic rock type, which has been interpreted as a younger dyke-like body. The presence of clinopyroxene crystals in massive sulphide zones suggests a genetic link to this unit (G. Squires, personal communication, 1996). No information on widths and grades of mineralization has been released, but material of potentially economic grades has not yet been encountered. Pervasive recrystallization and grain-size reduction (± alteration) of anorthosite to a featureless pale-green rock occurs adjacent to sulphide zones, as in the Canadian States Resources area.

In addition to the main area at the summit, there are other gossans on the property, including a prominent cliffside zone about 2 km south of the peak. Brief examination of this during 1996 suggests that sulphides are spatially associated with noritic dykes cutting anorthosite, which may form part of a regional contact zone between the older layered series and subjacent massive norites. G. Squires (personal communication, 1997) suggests that the mineralization may actually predate the noritic dykes.

STAGHORN LAKE CLUSTER

The Staghorn Lake Cluster comprises occurrences in the southwest corner of the Alliger Lake map area (NTS 14E/01) and the adjacent edge of the Staghorn Lake map area (NTS 14E/02). The area is held by a variety of interests, but NDT Ventures is the principal operator of the properties, with joint venture partners, including Aranlee Resources and Layfield Resources. Initial reconnaissance suggests that the geology is similar to the area around the Cirque Cluster, i.e., an older series of variably layered rocks at high elevations, intruded by subjacent noritic rocks. There is also a prominent unit of deformed leuconorite, probably representing the deformed margin of a diapiric pluton, in the southwestern corner of NTS 14E/01 (Ryan *et al.*, *this volume*).

The Staghorn Lake area was explored initially in late summer 1995, and yielded interesting grab samples, containing 0.38 to 0.68% Ni, and 0.26 to 1.16% Cu, with local Cu grades up to 4% (NDT Ventures, PR, August 14, 1995). Sampling of "fresh sulphides beneath gossan" gave grab samples containing up to 1.86% Ni, 0.95% Cu and 0.165% Co (NDT Ventures, PR, September 27, 1995). At least 4 holes, totalling 507 m, were completed in late 1995, and were reported to have intersected sulphides (NDT Ventures, PR, November 16, 1995), but the only released result was 0.8 m of 0.29% Ni, 0.28% Cu and 0.07% Co (Aranlee Resources, PR, May 16, 1996). NDT Ventures had an extensive program of mapping, prospecting and ground geophysics in the 1996 season, and a deep-drilling project is planned for the 1997 season (Aranlee Resources, PR, December 11, 1996).

Two showings were visited during the 1996 season. The Project 10-1 showing (5 km to the southwest of Figure 5) consists of a discontinuous massive sulphide pod hosted by a largely unmineralized anorthosite, and a nearby area that contains numerous small rusty zones and sulphide pods over about 250 m^2. The massive sulphides consist of coarsely crystalline pyrrhotite with lesser chalcopyrite, and include silicate fragments and crystals, mainly plagioclase. The style and appearance of the mineralization suggest that it is pod-like and "discordant". The anorthosite is intruded by dyke-like units of a greenish norite, but this does not contain any obvious sulphide. The Project 15-1 showing (Figure 5) consists of a large (3 by 3 m) massive sulphide pod, and some smaller zones, hosted by the strongly foliated leuconorite noted above. The margins of the sulphide pod are clearly discordant to the foliation in the host rock, indicating that the emplacement of sulphides must postdate the crystallization and solid-state deformation of the host.

NAIN–VOISEY'S BAY CLUSTER

The region between Nain and the Voisey's Bay deposits hosts several active exploration projects located in both the

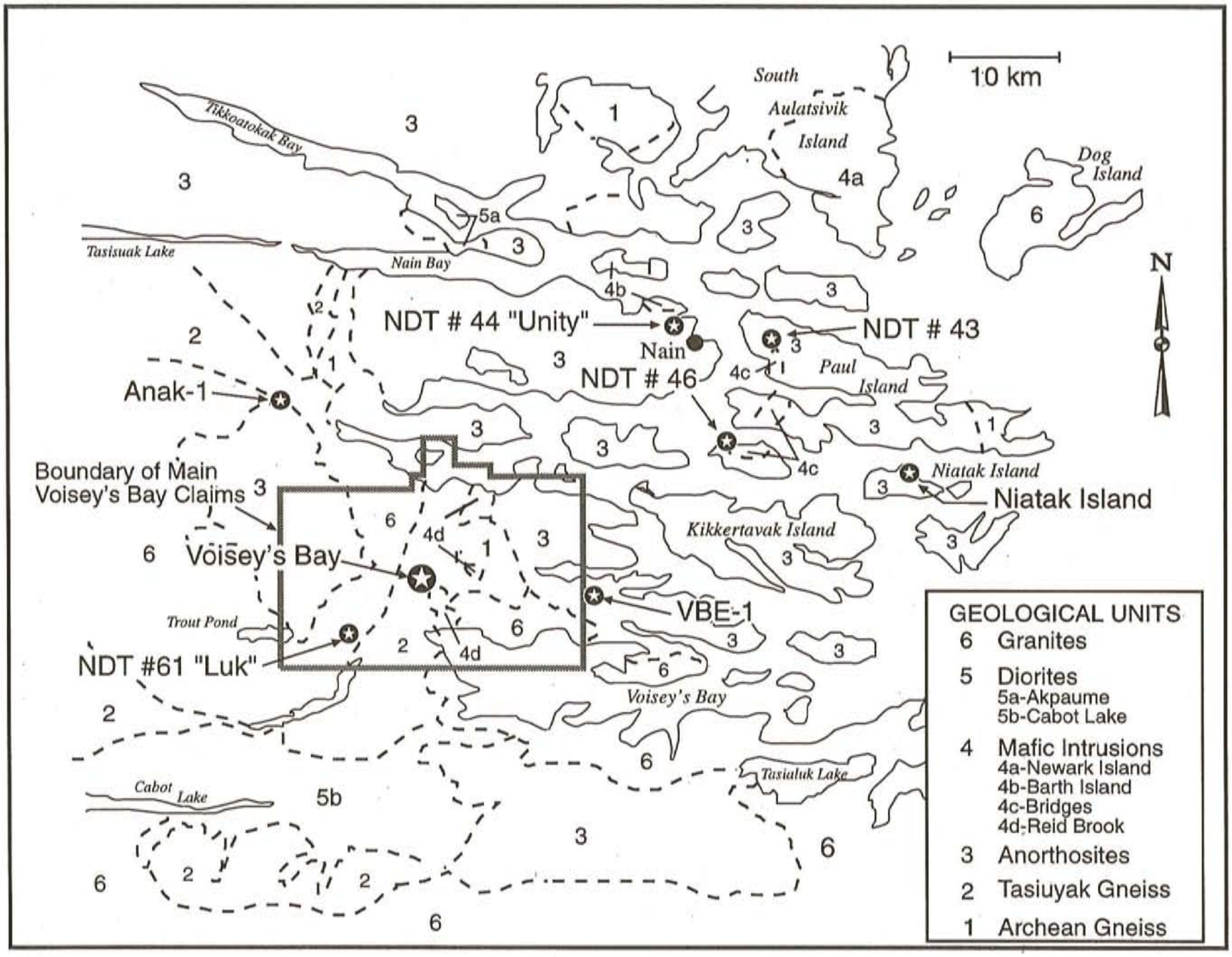

Figure 7. *Location map for showings in the area between Nain and the Voisey's Bay deposits.*

Nain Plutonic Suite and Archean to Paleoproterozoic country rocks (Figure 7). These are scattered over a large area, and have diverse geological settings; in this article, only four areas, associated with Nain Plutonic Suite rocks, are discussed.

NDT Ventures Project 44 (the "Unity Claims")

The NDT Ventures (JV Takla Star Resources) Project 44 (license 756M) is probably the most active of the properties in this cluster, and is located adjacent to the town of Nain (Figure 7). Mineralization was initially recognized in conjunction with airborne geophysical surveys in 1995, and initial weathered grab samples returned values of 0.41% Ni, 0.15% Cu and 0.07% Co. The showings are associated with a 2.4-km-long series of coincident magnetic–EM anomalies (NDT Ventures, PR, July 26, 1995). Later sampling produced assays of 0.5 to 0.6% Ni and 0.46 to 1.0% Cu from two separate zones (NDT Ventures, PR, August 14, 1995), and the best assays showed up to 1.28% Ni, 1.34% Cu and 0.164% Co (NDT Ventures, PR, September 6, 1995). Locally, up to 6.3% Cu and 0.21% Co were reported (NDT Ventures, PR, September 25, 1995). Drilling was delayed until the summer of 1996 because the claim block lies within the Nain municipal watershed, and the approval of the town council was required. A separate zone of mineralization in the southern part of the property (not included in Figure 8) has provided grab samples with assays up to 1.5% Ni and 2.87% Cu (NDT Ventures, PR, September 24, 1996). In addition to press releases, non-technical information about the project has been released through a joint English–Inuktitut newsletter, the "NDT messenger".

Project 44 contains three main zones of surface mineralization (Figure 8). Two of these, collectively called the "unity", and here labelled "Unity East" and "Unity West" zone, lie on the southeastern flank of Nain Hill, overlooking Nain. A third area of surface gossans, termed the "Valley Zone" is located west of Akpiksai Bay, just north of Nain.

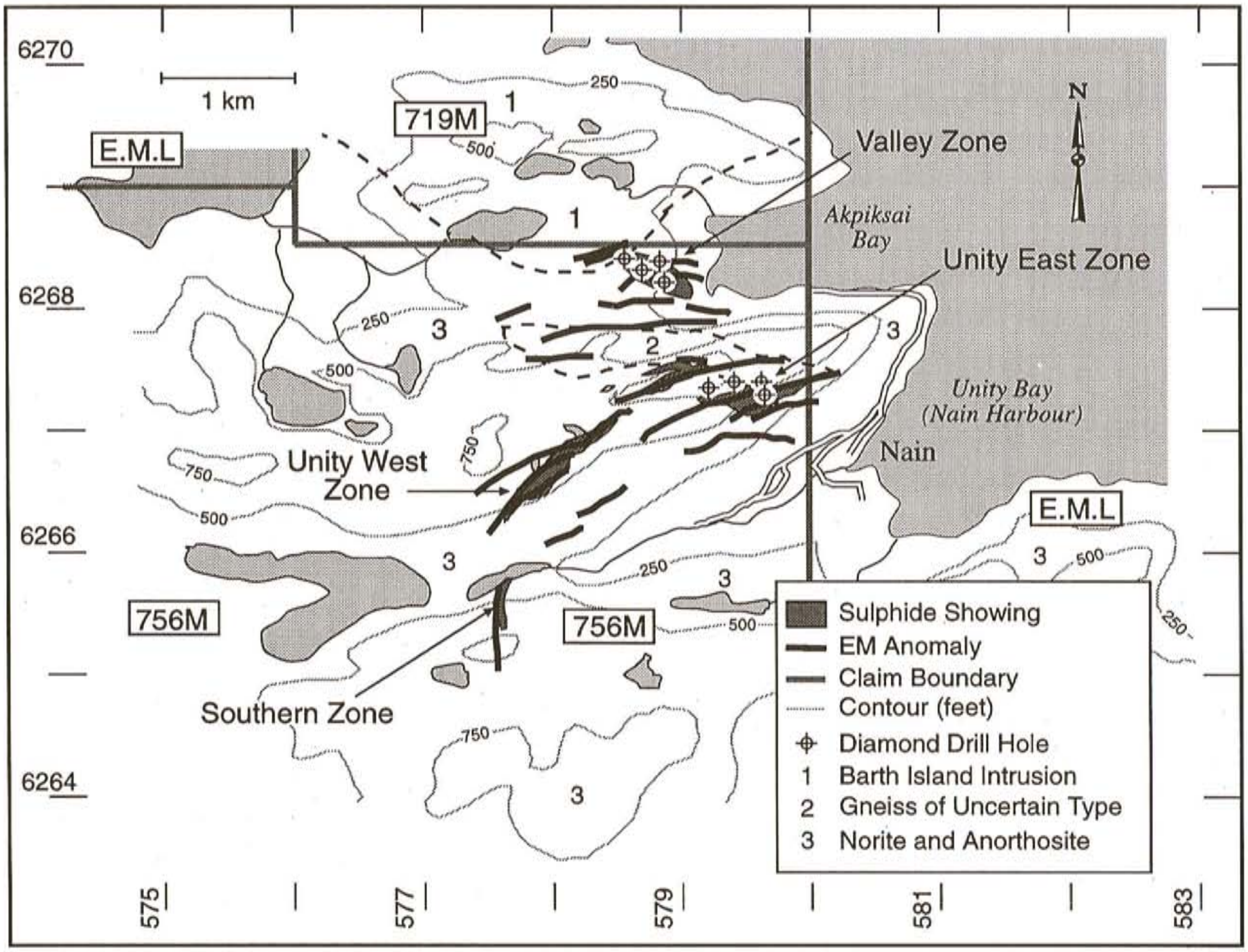

Figure 8. *General map of NDT project 44 area, near Nain, showing the locations of gossan zones, geophysical anomalies and diamond-drill holes (after maps published in the NDT Messenger, August 1996 issue, and NDT Ventures 1996 annual report).*

The predominant rock throughout the area is a variably foliated grey leuconorite to anorthosite, which probably represents the deformed margin of one of the larger diapiric plutons in the Nain area.

The gossans of the Unity Zone are deeply weathered, but sulphide mineralization appears to be present in three forms. The least impressive consists of sporadic disseminated pyrrhotite in the host anorthositic rocks; however, these are more commonly barren, albeit stained with rust. Irregular zones of massive sulphides (pyrrhotite ± chalcopyrite), commonly with abundant magnetite, are also present, but are intensely weathered, and their relationship to the anorthosites is unclear. However, at one location in the Unity East Zone, a prominent cavity probably represents a weathered (and/or excavated) sulphide zone, and has a vein-like geometry, clearly discordant to the fabric in the anorthosites. In the Unity West Zone, disseminated pyrrhotite and minor chalcopyrite is widely present in a finer grained, melanocratic, pyroxene-rich rock that appears to intrude the anorthosites. The contacts between this material and the anorthosite are complex, and in some areas it appears to form subhorizontal, sill-like units; however, elsewhere, contacts appear steep. The pyroxene-rich rock is commonly gossaned, suggesting that disseminated sulphide is widespread. Similar dykes and sills are seen in the Unity East Zone, but may have a more intermediate (dioritic ?) composition in this area. The Valley Zone consists of extensive, but very deeply weathered, gossans that are rich in magnetite, and also appear to be spatially associated with a finer grained, sulphide-bearing, melanocratic rock type. The large surface extent of the gossans suggests that these units are flat lying or gently inclined.

In the summer of 1996, NDT Ventures completed 4 drillholes on the Valley Zone and 4 drillholes on the northeastern end of the Unity East Zone (Figure 8). In the Valley Zone, these intersected multiple sulphide and magnetite-bearing zones in foliated anorthosite and leuconorite having widths ranging from less than 1 m to over 10 m. However, grades were generally low, with less than 0.4% combined Ni and Cu. The best intersection was 6.94 m of 0.51% Ni, 0.37% Cu and 0.04% Co, including 1.4 m of 1.08% Ni, 0.37% Cu and 0.1% Co (NDT Ventures, PR, July 30, 1996). Results from the Unity East Zone were similar, but the mineralized zones appear to be steeply dipping. The best results were 6.3 m of 0.4% Ni, 0.35% Cu and 0.04% Co, including 0.8 m of 1.65% Ni, 0.3% Cu and 0.15% Co. Some other short (<50 cm) intersections returned values of 1% Ni (NDT Ventures, PR, July 30 and August 20, 1996). Drilling was temporarily suspended to permit downhole geophysical surveys, and two holes were subsequently deepened, but did not intercept significant mineralization. Geophysical surveys have located a gravity anomaly between the Unity and Valley zones, which is suggested as a future target (NDT Ventures, PR, September 24, 1996).

Examination of drill core from the Valley and Unity zones, along with surface relationships, suggest that sulphide mineralization postdates the crystallization and solid-state deformation of the host anorthosite– leuconorite. Massive and semimassive sulphide intersections contain single plagioclase crystals, but also contain multicrystal fragments in which primary mafic minerals have been recrystallized and altered. Massive sulphide–oxide units contain rounded xenocrystic plagioclase crystals that are identical to the large crystals in the wall rocks. There appears to a vague spatial association between sulphide-bearing zones and finer grained igneous rock types that range in appearance from dioritic to pyroxenitic and contain disseminated pyrrhotite. These also contain xenocrystic plagioclase crystals, suggesting that they are discrete, younger, intrusions. The Project 44 (Valley and Unity) sulphide zones are very rich in magnetite compared to other areas examined in 1996, and some mineralized intersections contain subequal amounts of sulphide and magnetite. At least one hole from the Unity Zone encountered thick zones of massive magnetite, with interstitial pyrrhotite. This material shows exactly the same textural relationships to the host rocks as the sulphide-rich material, and appears to be an oxide-dominated liquid.

NDT Projects 43 and 46

These two projects are located on Paul Island and Palungitak Island respectively, east and southeast of Nain (Figure 7). The Palungitak Island (Project 46) showing was visited briefly in 1996; it is a gossan in a seacliff that is difficult to gain access to safely. Late in 1996, two 300 m drillholes intersected noritic rocks containing disseminated pyrrhotite and chalcopyrite, including a 1.1 m section assaying 1.64% Ni, 3.50% Cu and 0.09% Co (NDT Ventures, PR, October 21, 1996). Two drillholes on Project 43 intersected sulphide mineralization, including a 1 m section assaying 1.29% Ni, 0.93% Cu and 0.11% Co (NDT Ventures, PR, October 21, 1996). Little is presently known of the geology in either area.

VBE-1 Project

The VBE-1 project area (license 787M), held by International Canalaska Resources (JV Columbia Yukon Resources) is located between Kangeklualuk Bay and Voisey's Bay, about 12 km due east of the Eastern Deeps deposit at Voisey's Bay (Figure 7). The claim block is underlain mainly by anorthosite of the Nain Plutonic Suite, intruded by granitoid rocks, possibly equivalent to those that intrude the Reid Brook troctolite, east of the Voisey's Bay deposit (Ryan, 1990).

Mineralization was initially recognized in the summer of 1995, and was described as "structurally controlled", with grab samples providing results of 0.04 to 0.81% Ni, 0.29 to 0.52% Cu and 0.04 to 0.1% Co (International Canalaska Resources, PR, August 2, 1995). Later releases suggested grab sample assays up to 1.1% Ni and 0.94% Cu (International Canalaska Resources, PR, March 8, 1996). There are no reported geophysical anomalies associated with the surface mineralization. In 1996, a series of ground geophysical surveys were initiated (Columbia Yukon Resources, PR, June 18, 1996) and drilling commenced in late September, 1996. The drill site was selected on a combined positive gravity–magnetic anomaly, and the hole intersected anorthositic and noritic rocks over a depth of 870 m. Minor pyrite and chalcopyrite were reported in the final 100 m or so (International Canalaska Resources and Columbia Yukon Resources, PR, October 15, 1996). A downhole pulse EM survey was conducted, but drilling did not resume.

The VBE-1 project, like several others near the Voisey's Bay deposits, is essentially predicated on deep drilling for a blind Eastern Deeps-type target. Examination of surface occurrences in the northern part of the project area suggests that they are relatively small sulphide concentrations in anorthosite, and that some are associated with the margins of granitic pegmatites, suggesting that they are not strictly associated with mafic plutonic rocks. International Canalaska Resources views the mineralization as "leakages" or "remobilizations" from a suggested deep source, and it is this idea that drives continued exploration.

Niatak Island Showing

The Niatak Island showing (license 923M), held by Goldnev Resources (JV Starcore Resources) is one of the few sulphide showings in Labrador known from earlier exploration work. It was initially discovered by BRINCO in the 1950s, and was described as a prominent gossan in anorthosite containing disseminated pyrrhotite, pyrite and chalcopyrite (Grimley, 1955). The total extent of the zone is some 300 by 50 m (although this is not uniformly gossaned), and grab samples gave assays of 0.16 to 0.32% Ni, 0.37 to 0.65% Cu, and 0.06 to 0.11% Co (Goldnev/Starcore PR, June 6, 1995). The sulphide zone is associated with a coincident magnetic–EM anomaly (Goldnev/Starcore, PR, July 6, 1995). Five diamond-drill holes were completed in late summer 1995, and four were reported to have encountered sulphide mineralization. No systematic results were released, but "significant widths" were reported to contain 0.15 to 0.49% Ni, 0.15 to 0.71% Cu, and 0.05 to 0.16% Co. The widest mineralized intersection contained 0.17% Ni, 0.26% Cu and 0.06% Co over 6.4 m (Goldnev/Starcore, PR, August 8, 1995). Activity on the property in 1996 was limited.

A brief visit to the showing during 1996 confirmed that the gossan zone is extensive, but much of it contains only traces of sulphide, and parts are essentially barren, albeit stained. A few small concentrations of massive pyrrhotite (± chalcopyrite) were observed, but their relationship to the anorthosite is obscured by intense weathering. Finer grained, broadly dioritic, dykes were observed cutting the anorthosite, and seem to be spatially associated with some of the sulphide-bearing zones, a point noted also by Grimley (1955). Drill core from the Goldnev/Starcore program has not yet been examined; given the deep weathering, it is an important requirement for understanding the character of mineralization.

NDT Project 61 (The "Luk Claims")

This consists of a tiny claim block (license 674M), held by NDT Ventures (JV Takla Star Resources) located about 12 km southwest of the Voisey's Bay deposit, and surrounded by claims held by Voisey's Bay Nickel Company (Figure 7). The area of interest is a small pocket of mafic intrusive rocks, correlated with the Reid Brook intrusion, but surrounded by the Makhavinekh Lake granite (Ryan, 1990). Mineralization was originally discovered in conjunction with airborne geophysical surveys, and grab samples yielded assays of up to 0.64% Ni, 0.95% Cu and 0.06% Co, associated with EM anomalies (NDT Ventures, PR, July 4, 1995). Subsequent sampling produced assays of up to 1.86% Ni, 0.95% Cu and 0.16% Co (NDT Ventures, PR, September 6, 1996). Two gossan zones were tested by drilling in late 1995, and one of these returned a near-surface intersection of 7.4 m of 0.45% Ni, 0.18% Cu and 0.03% Co. Two shorter (around 0.7 m) sections within this interval assayed 0.75 to 0.78% Ni and 0.24 to 0.29% Cu. The best assay was 0.6 m containing 60% sulphides, with assays over 1% Ni and 0.35% Cu (NDT Ventures, PR, October 19, 1995). The host rock to mineralization is described as "hybrid gneiss within troctolite". Subsequent drillholes returned less encouraging assays, with less than 0.4% combined Ni and Cu (NDT Ventures, PR, November 10, 1995). Activity in 1996 consisted of ground geophysical surveys and mapping, aimed at the definition of deep drill targets (NDT Ventures, PR, May 9, 1996).

Examination of the area during the 1996 season confirmed the field relationships suggested by Ryan and Lee (1989). The mineralization appears to be confined to paragneiss rafts in an olivine-bearing mafic rock, which itself appears to be a large kilometre-sized raft within homogeneous rapakivi-textured granite. The mafic rocks are in most places extensively veined by granite suggesting that they have been widely disrupted, and are unlikely to have great continuity. No sulphide mineralization was observed in the mafic rocks or the granite, although the digestion of sulphide-bearing country rocks could have created local magmatic sulphide concentrations. Drill core from this project has not yet been examined.

UGJUKTOK RIVER CLUSTER

Although the area between the Voisey's Bay deposit (Figure 1) and the Harp Lake Complex to the south contains several anorthositic units, notably on the coast, there have been few reports of mineral discoveries during 1995 and 1996. The most active project is located just north of the Harp Lake Complex, in an area dominated by Churchill Province gneisses. This includes several contiguous claim blocks for which the operator is Donner Resources, in conjunction with a wide variety of joint venture partners. Although the project has been termed the "South Voisey Bay Project", a geographically more accurate, if less topical name is used here. This area was mapped by Thomas and Morrison (1991), and the main focus of exploration is a mafic unit that has traditionally been grouped separately from other Mesoproterozoic plutonic rocks because it postdates the Harp Lake Intrusive Complex (Wardle, 1993). This forms an elongate, sheet-like, dipping intrusion that may be linked to a larger mafic to anorthositic pluton mapped to the north, and intrudes sulphide-bearing paragneisses, garnet-bearing granitoid rocks and, at its southern extremity, Mesoproterozoic granites of the Harp Lake Complex (Figure 9). The mafic unit is commonly described as a "sill" but it should be noted that it is discordant to regional compositional layering.

Mineralization was initially noted by Thomas and Morrison (1991) at the base of mafic sills, but was not sampled, due to deep weathering. These authors also noted the presence of "fragmental rocks" containing angular fragments of country rocks and, in one area, graphite and sulphides. Sampling of several disseminated sulphide zones in 1995 gave consistent results of 0.05 to 0.30% Ni, 0.05 to 0.30% Cu and 0.01 to 0.03% Co, with values up to 0.45% Ni, 0.52% Cu and 0.04% Co (Donner Resources, PR, September 25, 1995). Subsequent airborne geophysical surveys identified several coincident magnetic–EM anomalies. Some initial drilling was conducted in late 1995, and intersected graphitic gneissic rocks containing variable amounts of pyrrhotite under one of these anomalies; assay results were not released (Donner Resources, PR, December 11, 1995). A larger scale drilling and exploration program began in June 1996. Five holes drilled to test the gabbroic intrusion in two areas intersected sulphide mineralization, consisting of disseminated pyrrhotite and chalcopyrite in the basal section of the body. "Leopard-textured" gabbro containing 10 to 20% sulphide assayed 0.1 to 0.35% Ni, 0.1 to 0.3% Cu and trace

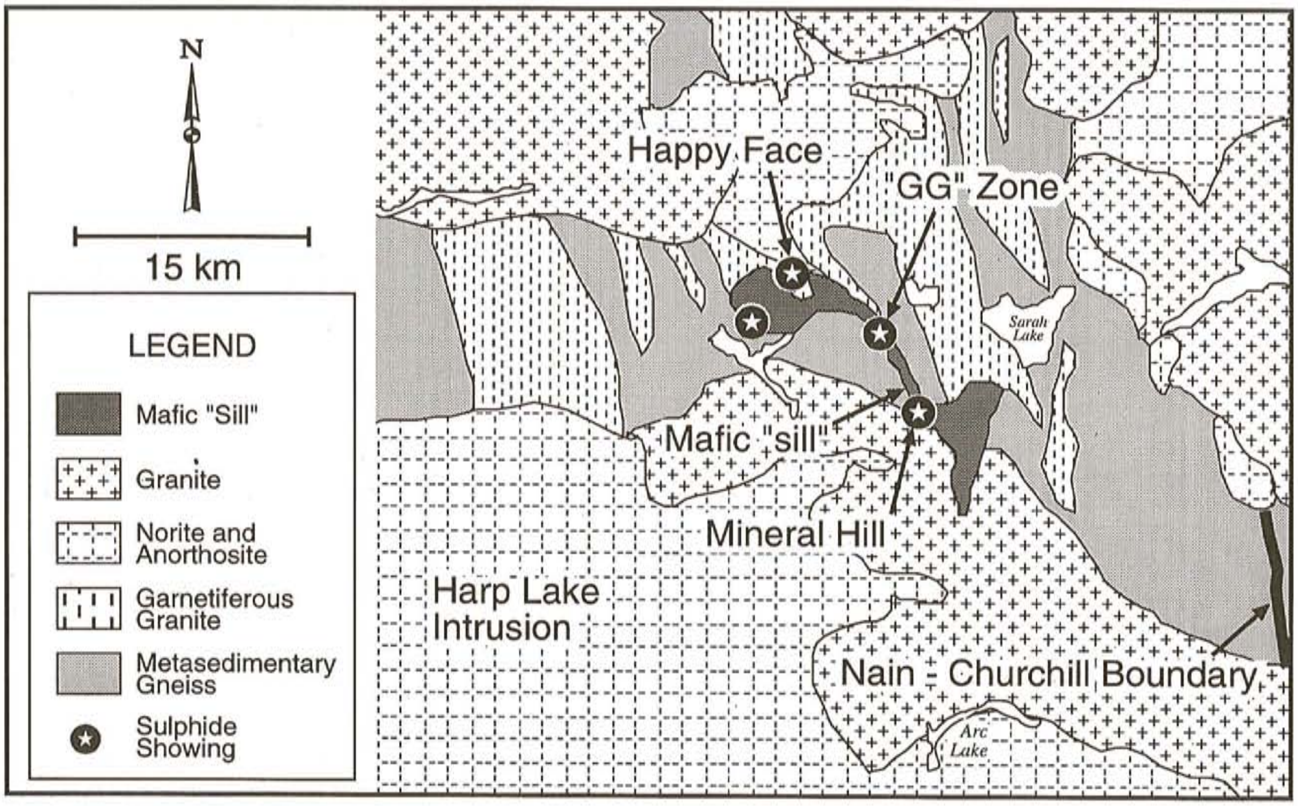

Figure 9. *Generalized geology of the area around the Ugjuktok River cluster (also known as the "South Voisey Bay Project"). Geology after Wardle (1993), and Donner Resources public relations material and press releases.*

Co over widths of 8 to 12 m, close to surface. In one of the holes, sulphides increased to 30 percent or more just above the basal contact (Donner Resources, PR, June 25, 1996). Pentlandite has been identified as a discrete phase in sulphide zones (K. von Einsiedel, personal communication, 1997). By August 1996, a total of 33 shallow holes had been completed over a large area, to test the basal section of the mafic intrusion. Most of these holes intersected disseminated sulphide mineralization, with grades similar to the earlier holes. The best results came from a short 1 m section of semimassive sulphides near the basal contact, which gave 0.55% Ni, 1.39% Cu and 0.02% Co (Donner Resources, PR, August 12, 1996). The widespread disseminated mineralization and distinctive "leopard" textures were interpreted as evidence of a regionally extensive mineralized feeder system akin to the Western Extension and Discovery Hill dyke at Voisey's Bay (Donner Resources, PR, August 12, 1996). In the fall of 1996, ground geophysical surveys, including deep penetrating EM and induced polarization (IP) were conducted, and six additional holes were completed, five of which intersected 10-m-thick zones of disseminated mineralization above the basal contact. The remaining hole was intended to test for the presence of the gabbro sill at depth in the west of the area, and intersected a 100 m thickness of gabbro, but did not penetrate to the basal contact (Donner Resources, PR, November 27, 1996).

A short visit was made to this area in 1996, to visit surface showings and examine representative drill core. Although the showings are distributed over a wide area (Figure 9), they have many features in common. All are associated with the basal section of the intrusion, which displays locally well-developed layering, and is finer grained, compared to the overlying massive coarse-grained gabbro. The country rocks beneath the intrusion are biotite-rich paragneisses having local sulphide concentrations, except at the southern end of the intrusion, where it sits upon quartz monzonite associated with the Harp Lake Complex. The gabbro is described as consisting of plagioclase, clino- and orthopyroxene, and olivine and minor red biotite (Thomas and Morrison, 1991; Donner Resources, PR, August 12, 1996). A thin zone of unmineralized fine-grained gabbro (chilled ?) commonly separates the mineralized section from the country rocks. The mineralized zones are intensely weathered and gossaned, but are regionally extensive, and locally contain relatively fresh sulphide-bearing material. A "knobbly" texture is very common, and appears to be a manifestation of the "leopard-texture" in which large pyroxene oikocrysts are set in a recessive sulphide-bearing matrix. The most impressive surface mineralization is at the "GG" and "Mineral Hill" showings (Figure 9), but air observations indicate that smaller sulphide showings are widespread, suggesting that the zone may originally have been semicontinuous over wide areas. Drill core from the "GG" showing exhibits a well-developed "leopard-texture" that is closely similar to the "leopard troctolites" reported from the Voisey's Bay deposit, notably the Western Extension and Eastern Deeps (Naldrett *et al.*, 1996). Drill core from the Mineral Hill showing exhibits a slightly different texture where the sulphides are concentrated in interstitial clots, but in both cases the sulphides are undoubtedly syngenetic and magmatic. Drillholes that penetrated the underlying country rocks locally intersected vein-like sulphide concentrations suggestive of thermal erosion and brecciation of the gneisses.

The Donner Resources exploration philosophy is based on the perceived similarity to the Voisey's Bay area, and suggests that depressions or other "structural traps" along the base of the intrusion may host massive sulphide accumulations that have settled from the magma. As discussed by Kerr (*this volume*) the production (and preservation) of such deposits requires that several consecutive conditions be met. Although the Ugjuktok River area provides some of the best examples of syngenetic magmatic sulphides yet recognized outside Voisey's Bay, there is at present little information about the nature of the mineralized intrusion and its fractionation history. Five analyses reported by Thomas and Morrison (1991) have SiO_2 contents of 47 to 57 percent, and MgO contents from 1 to 10 percent. The Ni and Cu contents range from 5 to 200 ppm, and 15 to 83 ppm, respectively. These rocks are richer in SiO_2 and poorer in MgO than the layered melatroctolites of the Reid Brook intrusion, but are not dissimilar in composition to the massive leucotroctolites (Emslie, 1996). However, as both are cumulate rocks, direct comparisons of whole-rock data are difficult.

SUMMARY AND DISCUSSION

The purpose of this article is to summarize results from exploration projects, and to offer initial geological observations, rather than any detailed interpretation. The metallogenic studies project is in its early stages, and it would be premature and unwise to build any classification or theory on the present database. Nevertheless, several important points emerge from the preceding descriptions.

First, virtually all of the sulphide occurrences summarized here appear to represent sulphides of broadly magmatic origin. There is no evidence of the alteration that would be expected if these sulphide concentrations resulted from hydrothermal fluid-dominated processes. Second, where examined in drill core, the sulphides are coarse grained and crystalline, and contain silicate inclusions, mostly plagioclase, which show signs of being thermally resorbed by the sulphides. Typical hydrothermal "gangue" minerals such as quartz, calcite and chlorite are absent.

Third, although the magmatic origin of the sulphides appears clear, the relationship of sulphide mineralization to the local host rocks is anything but clear. In the area north of Nain, there is no correlation between mineralization and regional intrusive units mapped by Ryan *et al.* (*this volume*); the hosts include possible Paleoproterozoic anorthosites (OKG), layered norites (e.g., Krinor), variably recrystallized anorthosites (e.g., the Cirque), older layered troctolites and norites (e.g., Canadian States area, Noranda Hilltop), and foliated, deformed leuconorite (e.g., Staghorn Lake). The form of these showings, and the textures observed in drill core, suggest that the sulphides were emplaced into, and disrupted, previously solidified host rocks. The same appears to be true of at least some mineralization in the Nain area (e.g., NDT Project 44). This observation raises several questions, most importantly, where did the sulphides come from, and how far did they travel? It is too early to answer this question, but the progression of projects toward deep drilling clearly indicates the current view of the exploration community.

Fourth, although much of the mineralization appears to be later than the host rocks, and has no direct relationship to the immediate wall rocks, there is good evidence for syngenetic sulphide concentrations in several areas. In the OKG area, mineralization in "pyroxenites" is clearly primary and syngenetic, and the Noranda Hilltop property also contains mineralization of probable syngenetic type in a dyke. J. Archibald (personal communication, 1996) suggests that similar rock types occur in some holes on the nearby Canadian States Resources property. Similarly, there appear to be primary concentrations of sulphides in melanocratic, dyke or sill-like bodies at NDT Project 44, near Nain. It is tempting to suggest a link between "epigenetic" styles in older country rocks and "syngenetic" styles in nearby younger intrusions, but more information is needed to assess this possibility. There is also very good evidence for syngenetic magmatic sulphide development in a mafic intrusion in the Ugjuktok River area, which probably represents the closest geological analogue to the local area around the Voisey's Bay deposits themselves. However, several factors must coalesce to create economic magmatic sulphide mineralization, and there is as yet no indication of massive sulphide deposits in this area.

As a final comment, the results of two seasons of exploration activity in northern Labrador must be judged against the level of background geological knowledge, and also with knowledge of the type of target. As discussed in a companion article (Kerr, *this volume*) magmatic sulphide deposits, despite their immense potential value, represent small and difficult targets, and the discovery of such diverse magmatic sulphide mineralization in an area with essentially no previous history of exploration should be viewed as a positive result.

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