



**A COMPARISON OF THE GEOLOGIC SETTING OF  
STRATIFORM MASSIVE SULPHIDE DEPOSITS OF THE GATAGA DISTRICT  
WITH THE MIDWAY AND WINDY-CRAGGY DEPOSITS,  
NORTHERN BRITISH COLUMBIA  
(94F, L; 1040/16; 114P/12)**

By D. G. MacIntyre

**INTRODUCTION**

A study of the stratigraphic and structural setting of sediment-hosted zinc-lead-barite deposits of the Gataga district of northeastern British Columbia was initiated in 1979 and continued through the 1980 and 1981 field seasons (see MacIntyre, 1980a, 1980b, 1981a, 1981b, 1982a, 1982b, 1982c; MacIntyre and Diakow, 1982). In 1982 further mapping in the Gataga district was curtailed due to budget restraints. However, a short visit to the Driftpile Creek property was made in late June to examine drill core. The scope of the Gataga project has been expanded; it is now a regional study of Paleozoic stratiform massive sulphide deposits in northern British Columbia. During 1982 geologic fieldwork was done on two such deposits, Midway (1040/16) and Windy-Craggy (114P/12E). If budgets allow and suitable logistical support can be obtained, additional work will be done on these deposits during 1983.

Paleozoic and particularly Late Devonian clastic sedimentary strata in northern British Columbia have tremendous resource potential for zinc-lead-barite deposits. Consequently, all areas underlain by these rocks are potentially important and will be studied to assess the potential and to provide a better understanding of the geologic setting and genetic controls for this important class of mineral deposits.

The purpose of this paper is to compare and contrast stratiform massive sulphide±barite deposits of the Gataga district with the Midway and Windy-Craggy deposits. The paper will show that each of the three sedimentary±volcanic terranes discussed host distinct types of stratiform massive sulphide±barite deposits. Those of the Gataga district are barite rich, occur within a linear sedimentary trough, and have a very minor pre-ore volcanic component. Midway is a stratabound silver-rich massive pyrite-sphalerite-galena deposit within transgressive clastic rocks and platformal carbonates. Windy-Craggy is a thick cupriferous massive pyrrhotite±pyrite deposit that is related to altered basaltic volcanic rocks.

**GATAGA DISTRICT**

The history, geology, and mineral deposits of the Gataga district have been discussed in previous reports and papers (for example, MacIntyre, 1982b). Figure 47 shows the setting of the Gataga district with respect

to the Selwyn basin and Kechika Trough and Figure 48 shows locations of mineral deposits and the general geology of the district. An idealized stratigraphic column is shown on Figure 49 along with those for the Midway and Windy-Craggy areas.

Recent work by Gordey (1982), Gordey, et al. (1982), and Dawson and Orchard (1982) has helped to refine the stratigraphy of the Selwyn basin. The informal nomenclature proposed by these authors has been adopted for the Gataga district. That is, all rocks overlying Kechika Group and underlying Middle to Late Devonian siliceous clastic rocks are included with the Road River Group. Overlying Late Devonian to Mississippian transgressive 'black clastics' are included with the Earn Group. It should be noted that microfossil studies are continuing and hopefully

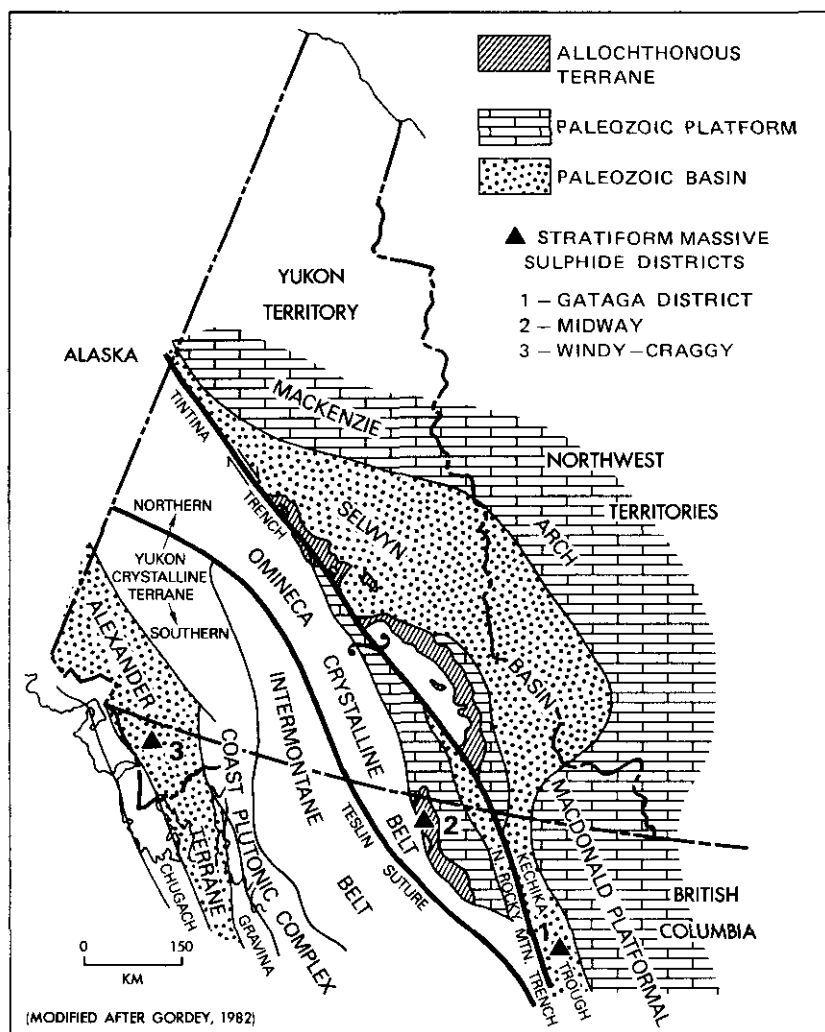


Figure 47. Tectonic subdivisions of the northern cordillera and location of the Gataga district (1), the Midway (2), and Windy-Craggy (3) deposits. Inset shows restoration prior to 450-kilometre right lateral displacement along Tintina and northern Rocky Mountain Trenches.

further refinement of age relationships will be possible when new data become available. Much uncertainty still remains about the exact ages of stratiform barite-sulphide deposits of the district; most ages are inferred by stratigraphic position rather than paleontological data.

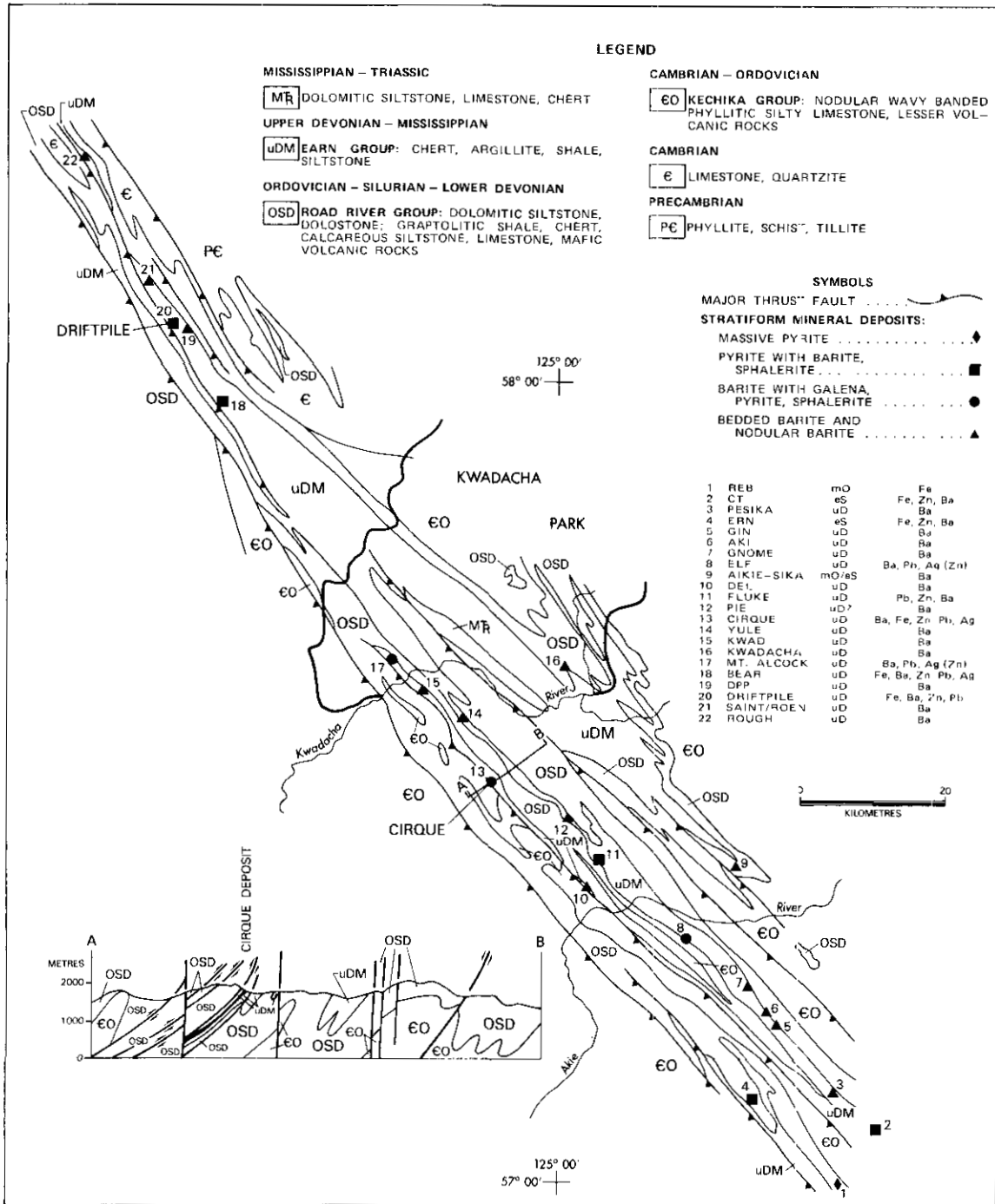


Figure 48. General geology and location of stratiform barite-sulphide deposits of the Gataga district.

As shown on Figure 49, stratiform barite-sulphide beds occur at several different stratigraphic levels within the basinal facies succession of the Gataga district. The oldest known deposits are late Middle to early Late Ordovician age as indicated by graptolite assemblages collected from hangingwall black shales (identification by B. Norford, Institute of Sedimentary and Petroleum Geology, Calgary). Both barren barite (for example, Aikie-Sika) and massive pyrite (for example, Reb) end members are present. The former occurs immediately above a quartz wacke turbidite unit and is located just outboard of the MacDonald platform; the latter occurs within an anomalously thick section of black shales and chert that probably represents a relatively deep water basin. Both deposits are overlain by a transgressive black shale unit. This unit diachronously onlaps platformal carbonates outside the district.

Stratiform barite-sulphide deposits of Early Silurian age have recently been discovered by Cominco Ltd. in the southern part of the Gataga district (for example, CT and ERN prospects). Footwall rocks are shallow water thin-bedded limestones, dolostones, and quartzites that are locally brecciated and mineralized with pyrite. Hangingwall rocks include calcareous siltstone, shale, and cherty mudstone. Mineralization varies up section from predominantly pyrite with variable amounts of sphalerite and minor galena to mainly barite. The stratigraphic succession suggests mineralization occurred during an Early Silurian marine transgression that was terminated by a major regression in Middle Silurian time. This regression resulted in erosion of Early Silurian and older rocks and partial filling of the Kechika Trough with dolomitic detritus. The stratigraphic setting of Early Silurian deposits in the Gataga district is strikingly similar to that of the Howard's Pass area of the Selwyn basin (Morganti, 1981).

The most important stratiform barite-sulphide deposits of the Gataga district occur within a 180-kilometre-long belt of black cherts, cherty mudstones, argillites, and siliceous shales and siltstones of the Middle to Late Devonian Gunsteel 'Formation' of the lower Earn Group. The deposits of the district can be fitted into a Meggan-type zoning model. In this model a central, vent proximal, massive pyrite zone with local high-grade sphalerite and galena concentrations grades outward into massive, barren bedded barite. The Driftpile Creek and Bear deposits would be examples of the massive pyrite zone, the Cirque, Elf, and Mount Alcock deposits appear to be at the transition from massive pyrite to barite and the Kwadacha, Pie, and DPP deposits are examples of the relatively barren bedded barite facies. Beds of nodular and thinly laminated barite at the Rough, Roen, Kwad, Yule, Gnome, Del, Aki, Gin, and Pesika properties may be the distal equivalents of the massive pyrite and bedded barite deposits.

Footwall rocks for the Late Devonian stratiform barite-sulphide deposits of the Gataga district are typically rhythmically bedded black cherts (porcellanites), cherty mudstones and argillites, siliceous shales, and lesser intercalated turbiditic siltstones. These rocks represent a starved basin regime with periodic turbidite sedimentation. Thickness of

the footwall unit varies. It is relatively thin (10 to 20 metres) in the southern and eastern parts of the district where it onlaps slope and shelf carbonates and underlies massive barren bedded barite and laminated nodular barite occurrences (for example, Kwadacha, Pesika, Del, Gin, Aki, Gnome, Pie, Yule, Kwad, DPP). It is relatively thick (100 to 200 metres) with chert-rich sections where it underlies stratiform massive bedded barite-pyrite-sphalerite-galena deposits (for example, Elf, Fluke, Cirque, Mount Alcock) and laminated pyrite-sphalerite±barite deposits (for example, Bear, Driftpile Creek).

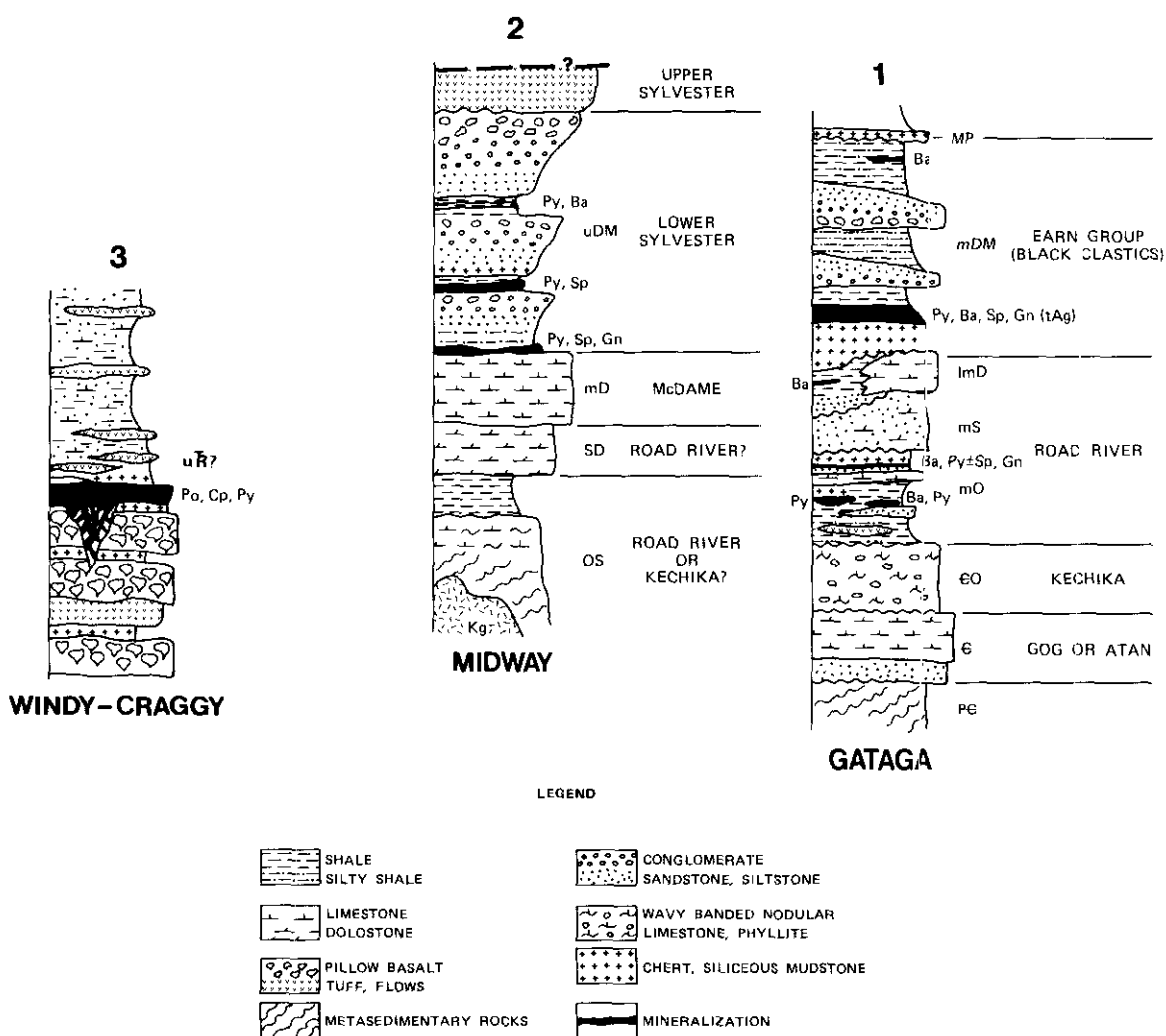


Figure 49. Stratigraphic columns for the Gataga district (1), the Midway (2), and Windy-Craggy (3) areas.

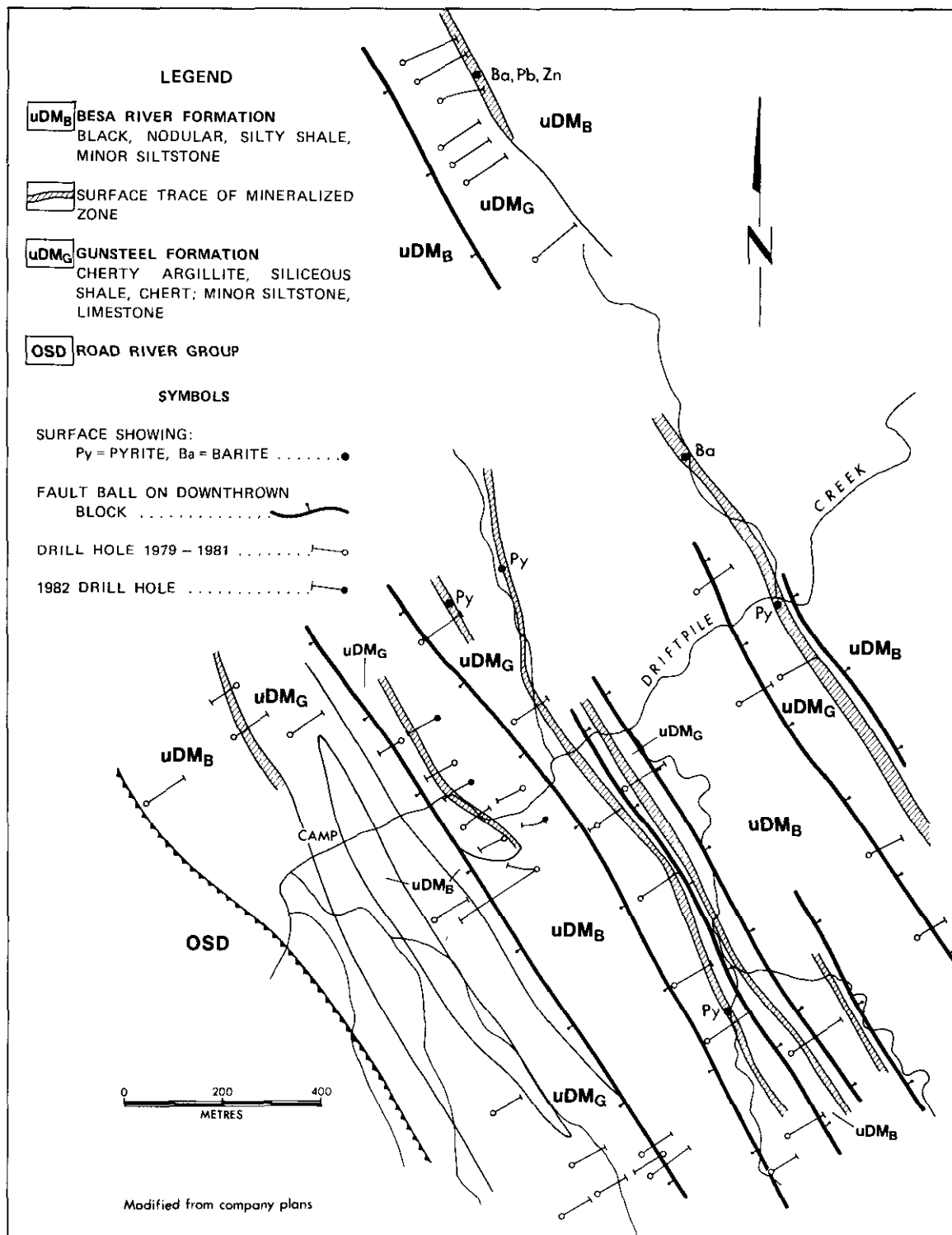


Figure 50. General geology and drill hole locations, Driftpile Creek property.

Siliceous to nonsiliceous pyritic black silty mudstones, argillites, and shales form the immediate hangingwall for the Late Devonian barite-sulphide deposits of the Gataga district. Calcareous 'nodules' and septarian concretions are common in hangingwall rocks at Driftpile Creek and the Bear. Some of the 'nodules' may be limy beds that were pulled apart during compaction. The shales are locally phosphatic and cherty and contain silty interbeds interpreted to be distal turbidites. In general, hangingwall rocks have a relatively high clastic component compared to footwall rocks. This suggests a more open marine environment with higher sedimentation rates followed formation of the deposits. This change coincides with a major eastward advancing Late Devonian marine transgression. Much of the clastic material deposited in the Kechika Trough at this time may have been derived from uplifted fault blocks to the west (Gordey, 1982).

### **DRIFTPILE CREEK**

Driftpile Creek was the only property in the Gataga district that was visited during 1982. The following is a brief summary of the work done on this property to date. From 1978 to 1982 a total of 54 drill holes were completed at Driftpile Creek. Approximate location of these holes relative to the projected and known surface traces of the mineralized zone(s) are shown on Figure 50. The Gataga Joint Venture (Welcome North Mines Ltd., Chevron Canada Limited, Getty Mining Pacific Limited, and Canterra Energy Ltd.) has now earned a 50 per cent equity in the Driftpile property; Placer Development Limited and partners must now match the expenditures of the Gataga Joint Venture in order to retain their 50 per cent interest.

Drilling during 1982 (holes 51 to 54) further delineated a northwest-trending moderately east-dipping zone located approximately 300 metres east of the camp. This zone consists of laminated pyrite with local high-grade concentrations of galena and sphalerite; minor amounts of barite occur at the base of the pyritic interval. The section appears to be upright with stratigraphic tops to the northeast. The mineralized zone is underlain by typical banded cherty black mudstones and siliceous argillite of the Gunsteel Formation (uDM<sub>G</sub>) and is overlain by nodular black silty shales that the author includes with the transgressive shales of the Besa River Formation (uDM<sub>B</sub>). Both hangingwall and footwall rocks are considered part of the Late Devonian to Mississippian Earn Group (black clastics) following the recent usage of Gordey, *et al.* (1982) for the Selwyn basin.

Sparse outcrop and structural complexity have made delineation of mineralized zones difficult, even with relatively close spaced drilling. High-angle normal and reverse (thrust ?) faults are common and typically offset earlier developed fold structures.

It is still uncertain whether the baritic and pyritic mineralization intersected in drilling at Driftpile Creek is part of one laterally





continuous zone repeated by folding and faulting or actually represents several discrete mineralized zones at different stratigraphic levels. Recent biostratigraphic work by Dawson and Orchard (1982) in the Selwyn basin indicates both Middle Devonian and Mississippian (Osagean) barite deposits are present, in addition to the regionally extensive Late Devonian (Frasnian) barite-sulphide horizon. Apparently a similar time-stratigraphic distribution of deposits applies to the Driftpile Creek area (Gordey, 1982). However, the main sulphide-bearing zone at Driftpile Creek is most likely Frasnian in age, as it is in both the southern part of the Gataga district and MacMillan Pass area of Selwyn basin. Thin limestone interbeds collected from drill core at Driftpile Creek are currently being dissolved in the hopes of finding conodonts.

## **MIDWAY**

The Midway deposit, which is situated within a broad synclinorium of Paleozoic platformal carbonates and transgressive clastic rocks immediately east of the Cassiar batholith (Fig. 47), was described in a previous report (MacIntyre, 1982c). Regional stratigraphy is summarized on Figure 49, and Figure 51 shows the geology in the vicinity of the deposit.

Six diamond-drill holes were completed on the Midway property at the end of the 1981 exploration program with encouraging results (Regional Resources News Release, November 23, 1981); 15 additional holes were drilled in 1982 (Fig. 52). The work done to date, which has been funded by Amax of Canada Limited and Procan Exploration Company with Regional Resources Ltd. as operator, has defined a high-grade stratabound zinc-lead-silver deposit in a block of moderately northeast-dipping Devonian to Mississippian carbonate and clastic rocks that are part of the McDame limestone and lower Sylvester Group respectively (Gabrielse, 1969). Massive stratabound pyrite-sphalerite-galena mineralization occurs at three different stratigraphic levels (Fig. 52). These levels are referred to as the Lower, Discovery, and Upper zones (Stollery and Sellmer, 1982). Several pyritic cherty exhalite beds also occur in a 50-metre section of argillites overlying the Upper zone.

The Lower zone occurs at the top of the Middle Devonian McDame limestone (Gabrielse, 1969). The mineralization is mainly hosted by the limestone which is locally strongly brecciated. Drilling indicates that the Lower zone is present in a subcircular area roughly 500 metres by 700 metres in size. The zone, which is locally very high grade, varies in thickness from less than 1 metre in its periphery to approximately 23 metres in diamond-drill hole 82-7 (Fig. 52). Combined lead+zinc grades vary from 2.65 to 32.75 per cent with 42 to 630 grams silver per tonne (George Cross News Letter, No. 188, September 30, 1982). The best intersection to date is in drill hole 82-8 with 2.6 metres averaging 21.61 per cent lead, 14.89 per cent zinc, and 1 371 grams silver per tonne. The lower zone is estimated to contain 2.7 million tonnes with 370 to 435 grams silver per tonne and 18 to 20 per cent combined zinc-lead (J. Stollery,

personal communication). In addition, a weighted average of composite results from eight drill intersections contains 0.65 grams gold per tonne, 0.35 per cent copper, 0.14 per cent titanium, and 0.11 per cent bismuth (George Cross News Letter, November 25, 1982).

The Lower zone is overlain by an upward coarsening clastic sedimentary cycle that is approximately 100 metres thick. The cycle is characterized by increasing frequency, thickness, and coarseness of lithic wacke and pebble conglomerate intercalations up section.

The Discovery zone occurs approximately 100 metres up section from the Lower zone. The zone is well exposed by surface trenching (Fig. 52). The mineralization on surface consists of relatively coarse-grained pyrite intergrown with light-coloured sphalerite and lesser galena. The zone was intersected in all 1981 drill holes. Grades from 1981 drill holes ranged from 4.24 to 9.29 per cent lead-zinc with 62 to 99 grams silver per tonne. The Discovery zone apparently grades eastward into pyritic and baritic cherty exhalite.

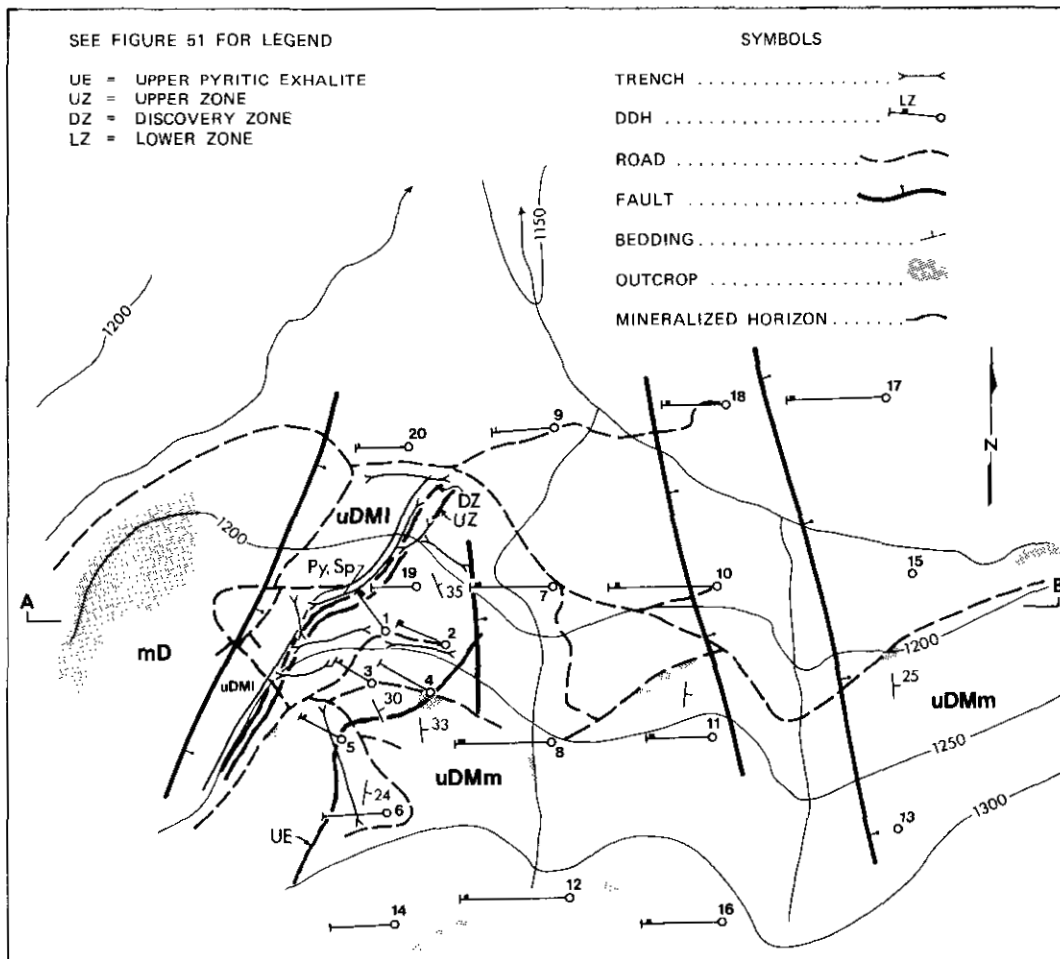


Figure 52. Geology and drill hole locations, Midway property.

The Upper zone occurs 10 to 20 metres above the Discovery zone. This zone, which was intersected in 1981 drill holes, is relatively thin (less than 3 metres) and lower grade than the Discovery and Lower zones.

Host rocks for the Discovery and Upper zones are cherty argillites and silty black shales at the base of the second coarsening-upward sedimentary cycle.

Mapping in the vicinity of the Discovery showing suggests that there are several pale-coloured pyritic cherty exhalite beds in rocks overlying the Upper zone (UE, Fig. 52). South of the Midway deposit cherty exhalite beds occur at a similar stratigraphic position (Fig. 51); these may represent the distal equivalents of the massive sulphide zones. A primary objective of our 1982 work on the Midway property was to collect samples from the exhalite horizons for lithogeochemical studies. Silt samples were also collected from drainages in the vicinity of the deposit, and all limestone and chert units were sampled for micro-paleontological work. Results will be published when analytical work is completed.

The panel of rocks containing the Midway deposits is separated from McDame limestone by a high-angle fault of unknown displacement. The progressive downward displacement toward the east of the Lower zone suggests similar high-angle faults might also be present between drill holes 2 and 7, holes 9 and 18, and holes 18 and 17. Some small bedding plane shear zones were also noted in trenches on the property suggesting that some horizontal movement has also taken place.

The Midway is a new, economically significant example of a stratabound carbonate-hosted massive sulphide deposit that is overlain by clastic rocks containing sedimentary-exhalative-type mineralization. Unlike deposits of Selwyn basin and the Gataga district, which probably formed in starved third order basins, the Midway appears to have formed in a relatively shallow water platformal environment. Sulphide precipitation occurred during short-lived episodes of fine clastic sedimentation that preceded periods of coarse clastic deposition. The significance to exploration is that a starved basin environment is not necessary to form this type of deposit. Probably the most critical factor in determining where deposits of this type are formed is the location of hydrothermal vents, not host rock composition or sedimentary environment. Such vents are probably located along major crustal breaks; these can occur anywhere in a basin, slope, or platform environment. In the case of the Lower zone at Midway, karsting of the McDame limestone prior to clastic sedimentation might have established favourable sites for later sulphide deposition.

#### **WINDY-CRAGGY**

The Windy-Craggy stratiform cupriferous massive sulphide deposit is located in the Alsek-Tatshenshini River area of the St. Elias Mountains

in the extreme northwestern corner of British Columbia. Because of the rugged and inaccessible nature of this area and extensive ice fields and glaciers, little is known about the stratigraphic relationships and mineral resource potential of the various geologic units present.

Regional 1:250 000 scale mapping by Campbell and Dodds (1979) defined several major fault-bounded geologic terranes within the Alexander allochthon (Fig. 47). The Windy-Craggy deposit occurs within a broad belt of volcanic and sedimentary rocks (Fig. 53) assumed to be largely Paleozoic in age. These rocks are intruded by intermediate to felsic plutonic rocks of Late Paleozoic to Tertiary age (unit MT<sub>g</sub>, Fig. 53).

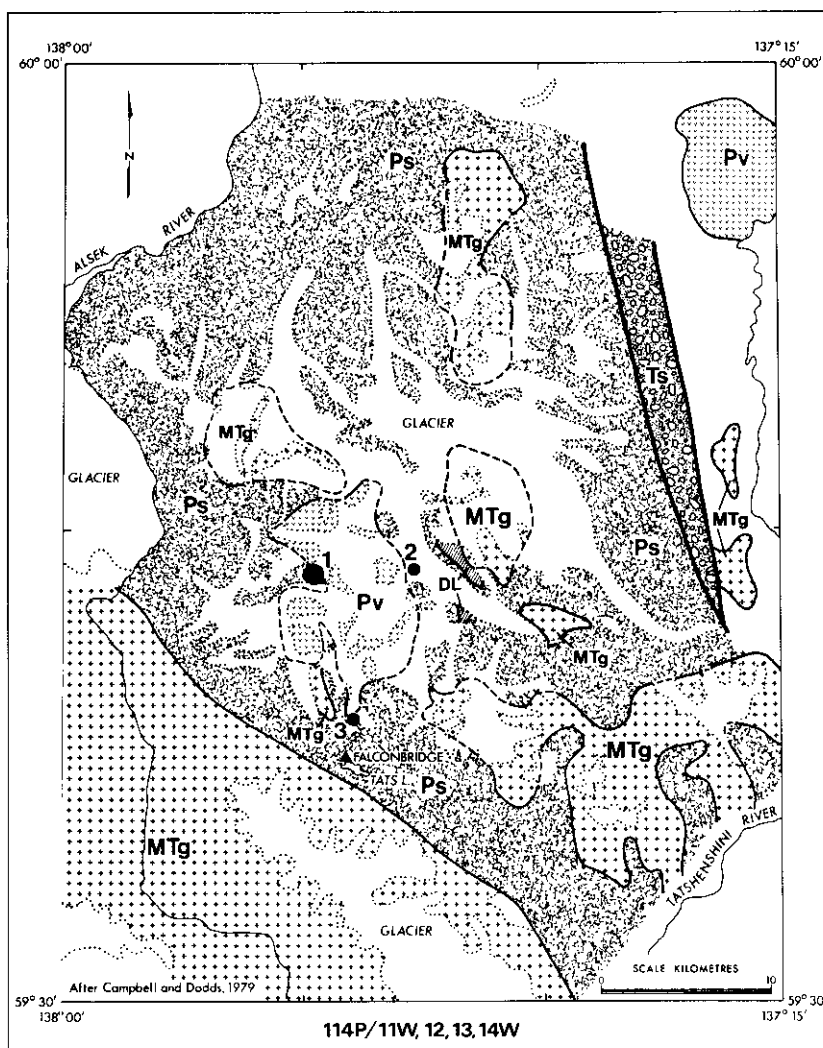


Figure 53. General geology in the vicinity of the Windy-Craggy deposit. Ps = predominantly sedimentary rocks; Pv = predominantly mafic to intermediate volcanic rocks; DL = Devonian limestone; MT<sub>g</sub> = Mesozoic to Tertiary intrusive rocks; Ts = Tertiary clastic rocks; 1 = Windy-Craggy deposit; 2 = Mus showing; 3 = Tats showing.

In the Windy-Craggy area the stratigraphic succession, which is informally called the Kaskawulsh Group (Campbell and Dodds, 1979), consists of a lower unit of intermediate to mafic locally pillowed flows and volcanic breccia of unknown age (unit P<sub>V</sub>, Fig. 53). It is apparently overlain by intercalated calcareous and noncalcareous carbonaceous siltstones, greywackes, carbonates, and andesitic to dacitic tuffs and flows (unit P<sub>S</sub>, Fig. 53). Mike Orchard (Geological Survey of Canada, Vancouver) has recently identified four Upper Triassic (Norian) and one Devonian conodont fauna from a thin limestone debris flow bed that presumably occurs at the base of this unit and in the immediate hangingwall of the Windy-Craggy deposit. The Devonian fauna is interpreted to be from Devonian limestone clasts in the debris flow. A limestone unit is present northeast of Windy-Craggy and contains Devonian macrofossils (unit D<sub>L</sub>, Fig. 53).

The Windy-Craggy deposit and the Alsek (Tats) and Mus showings all occur at or near the contact between an altered pillow basalt unit and overlying interbedded tuff and calcareous siltstone units (Figs. 49 and 53). The mafic volcanic rocks appear to form the core of a major antiform of unknown complexity and attitude.

## HISTORY

The Windy-Craggy gossan was first noted by J. J. McDougall of Falconbridge Limited while doing aerial reconnaissance of the area. A follow-up ground survey in 1958 resulted in discovery of the Windy-Craggy showing. The discovery showing is essentially a narrow gossan along the southern headwall of a cirque glacier. Packsack drilling in 1960 (11 holes totalling 240 metres) by Ventures Ltd. (later absorbed by Falconbridge Limited) intersected a massive sulphide body beneath the surface gossan. Three diamond-drill holes totalling 410 metres were completed in 1965 (65-1, 2, 3; Fig. 54), and an additional 10 holes totalling 2 250 metres were drilled in 1981.

In 1982 hole 1981-9 was extended and two new holes (11 and 12) were completed for a total of 1 364 metres of drilling. This work was financed by Geddes Resources Limited through a drilling fund; work on the property was managed by Falconbridge Limited. By spending \$1 500 000 in 1981 and 1982, Geddes Resources Limited has now earned a 49 per cent undivided interest in the Windy-Craggy property.

## DEPOSIT GEOLOGY

Surface geology and drill hole locations are shown on Figure 54. Drilling to date on the Windy-Craggy property has defined a concordant, tabular, steeply northeast-dipping pyrrhotite-chalcopyrite±pyrite massive sulphide body over 1 000 metres long and averaging approximately 100 metres in thickness. There are unknown extensions along strike and down dip. Copper grades are variable, ranging from less than 1 per cent up to

14 per cent in narrow high-grade supergene enriched intersections. The drill-indicated reserves of the best grade part of the massive sulphide zone are reported to be over 85 million tonnes averaging 3.04 per cent copper and 0.09 per cent cobalt within an overall inferred tonnage for the deposit of 300 million tonnes averaging 1.52 per cent copper and 0.08 per cent cobalt (Northern Miner, January 13, 1983).

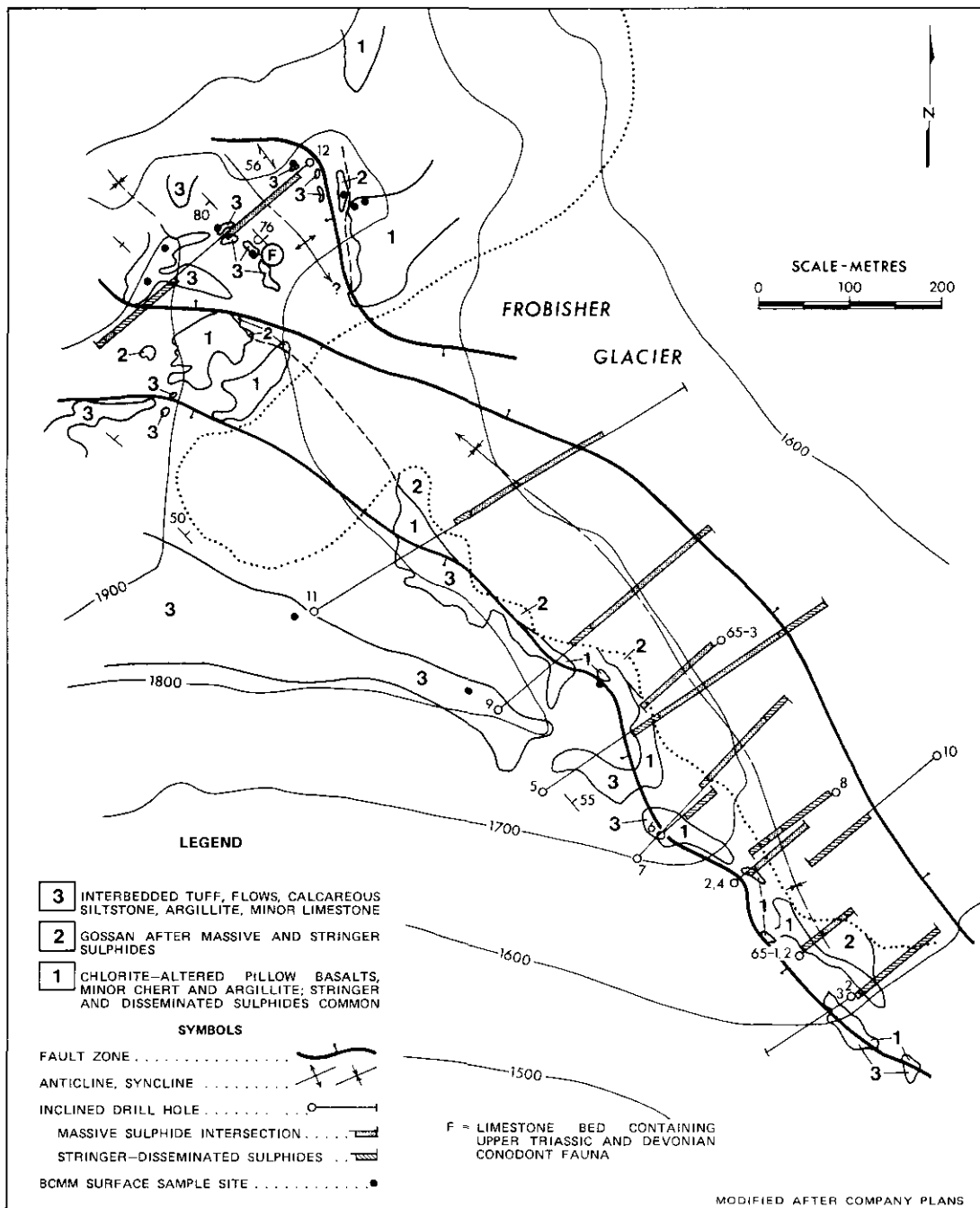


Figure 54. Geology and drill hole locations, Windy-Craggy deposit.

The most northerly drill hole, 82-12, intersected a predominantly massive pyrite zone from 24 to 187 metres that averaged 1.78 per cent copper (includes 53 metres averaging 3.09 per cent copper). The top 12.5 metres of this intersection also averaged 0.58 per cent zinc, 79 grams silver per tonne, and 1.34 grams gold per tonne, and the bottom 38.7 metres averaged 1.75 per cent zinc, 16.25 grams silver per tonne, and 0.47 grams gold per tonne. Concentrations of zinc, silver, and gold appear to increase toward the northern end of the deposit which is predominantly pyrite. Pyritic sections also tend to be coarser and more granular in texture and framboidal texture is locally well developed. Massive pyrrhotite sections are generally much finer grained. Stilpnomelane is a common accessory mineral in the massive sulphide zone, which is also locally magnetite rich. Pyrite and pyrrhotite bands and laminae also occur in argillites and cherts of the immediate hangingwall and footwall of the deposit. Small-scale fold structures are common in the banded and laminated sulphide zones.

One of the most interesting features of the Windy-Craggy deposit is the relatively high concentration of cobalt in massive pyrrhotite sections. Drill intersections averaging greater than 0.1 per cent cobalt are common; some short intersections contain greater than 0.2 per cent. The best cobalt grades do not necessarily correlate with better copper grades as shown on Figure 56. Falconbridge Limited research indicates no discrete cobalt mineral is present; cobalt is probably in solid solution with pyrrhotite and it might not be economically recoverable.

In addition to massive sulphide mineralization, a large zone with stringers and disseminations of pyrrhotite and chalcopyrite occurs in chlorite-epidote-serpentine altered pillow basalts, cherts, and argillites along both sides of the massive sulphide body. The grade of stringer mineralization generally averages 0.5 to 0.8 per cent copper with sporadic intersections up to 2 per cent. The stringer zone has relatively low cobalt, silver, and gold concentrations. A major northwest-trending fault zone separates stringer mineralization from relatively unaltered interbedded calcareous siltstones and andesitic to dacitic tuffs and flows southwest of the deposit. A similar fault may also be present below the glacier on the northeast side of the deposit as indicated by drill hole 81-10 (Fig. 56).

The mixed calcareous siltstone-volcanic unit is probably the stratigraphic hangingwall of the deposit. If altered mafic pillowed basalts and cherts with stringer sulphide mineralization comprise the stratigraphic footwall of the deposit, as they normally do in the classic volcanogenic massive sulphide model (Fig. 55), then drill hole data could be interpreted as shown on Figure 56. In this structural model the massive sulphide body is folded into tight anticline-syncline pairs that are separated and displaced by high-angle normal and reverse faults. In this model the best copper grades are located at the base of the massive sulphide body and in the immediate footwall.

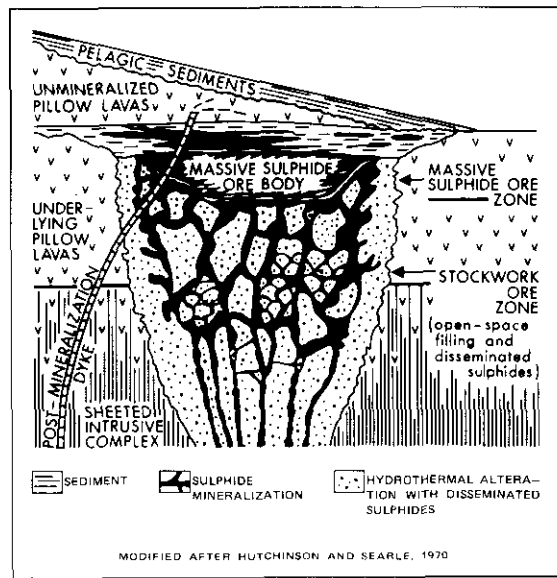


Figure 55. Model for Cyprus-type volcanogenic massive sulphide deposits. Modified after Hutchinson and Searle (1971).

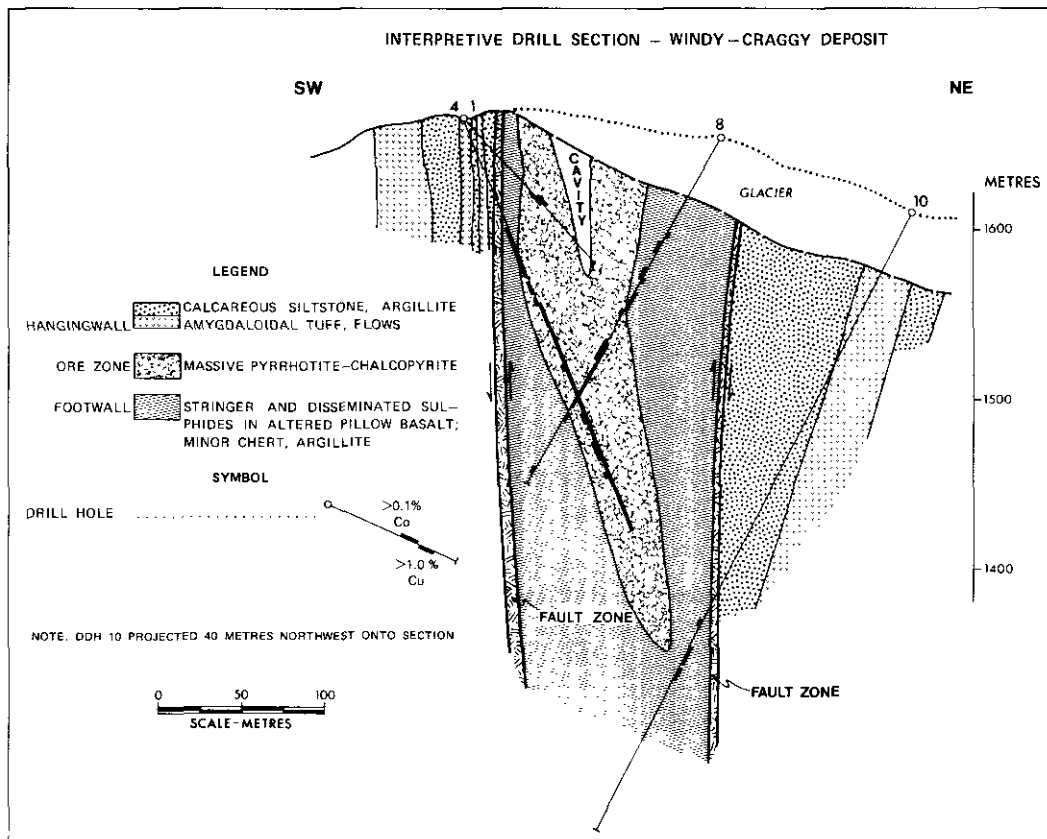


Figure 56. Interpretive drill section, Windy-Craggy deposit.



TABLE 1. COMPARISON OF GATAGA, MIDWAY, AND WINDY-CRAGGY DEPOSITS

	Setting	Pre-ore	Post-ore	Age(s)	Mineralogy
(1) Gataga	Continental margin basin or trough Fault bounded?	Shallow marine shelf and slope to deep marine starved basin; proximal to distal turbidites near shelf; some volcanism (mO)	Transgressive open marine; distal turbidite Subsiding basin? Active growth faults?	(1) uD  (2) eS  (3) mO	Py, Sp → Ba, Py, Sp, Gn → Ba, Gn Ba Regional baritic horizon  Ba, Py, Sp → Ba  Py → Ba
(2) Midway	Shelf or platform along continental margin Fault bounded?	Shallow marine carbonate buildup	Coarsening upward clastic sedimentary cycles; regressive distal to proximal turbidites going to subaerial volcanism Rising platform?	uD-M  M	Py, Sp, Gn → Ba, Py Regional pyritic-baritic exhalite horizons  Ba (Ewen)
(3) Windy-Craggy	Back arc basin? Sedimentary trough centred on spreading rift system?	Submarine volcanic flows and tuffs; minor amounts of chert and clastic sedimentary rocks; pyritic exhalites	Distal turbidites, ash fall tuffs, flows, shallow water carbonate buildup?	uR?	Po, Py, Cp (Sp, Mt) → pyritic exhalite?

Ba - barite; Gn - galena; Po - pyrrotholite; Py - pyrite; Sp - sphalerite; Cp - chalcopyrite; → - lateral trend;  
Mt - magnetite; u - upper; m - middle; e - early; D - Devonian; S - Silurian; O - Ordovician; M - Mississippian;  
P - Triassic

The massive sulphide intersection in drill hole 82-12 is bounded by interbedded volcanic rocks and calcareous siltstones but does not appear to come to surface. Perhaps the intersection is near the top of a tight anticlinal fold structure. As described previously, zinc concentration increases toward the 'upper' and 'lower' contacts of the massive sulphide intersection suggesting that zinc is enriched at the top of the massive sulphide body. This apparent zonation of copper and zinc within the Windy-Craggy deposit is consistent with that normally observed in volcanogenic massive sulphide deposits.

### GENETIC MODELS

The three stratiform massive sulphide deposit types described in this paper have one unifying characteristic; they all formed by *in situ* precipitation of sulphides onto the seafloor, probably in close proximity to a hydrothermal vent. These vents or fumaroles were probably situated along major faults that provided escape conduits for heated formational waters and convectively circulating seawater. Differences in the metal content and mineralogy of the deposits (Table 1) can best be explained in terms of different temperature regimes as suggested by Finlow-Bates (1980), Large (1977), and others (Fig. 58).

Stratiform deposits of the Gataga district formed in a fault-controlled continental margin sedimentary basin or trough and typically have low temperature characteristics. That is, they have very low copper content, high barite content, and no appreciable footwall alteration or veining. The lack of coeval volcanic rocks in the section is consistent with the inferred low temperature environment of formation. In contrast, the Midway deposits formed both within platformal carbonates and in overlying transgressive clastic rocks. Periodic movements along nearby growth faults probably triggered episodes of coarse clastic sedimentation that produced the coarsening upward sedimentary cycles. Unlike deposits of the Gataga district, which grade outward into thin laminae of nodular barite, distal equivalents of the Midway stratiform massive sulphide zone are mainly pyritic cherty exhalites that have only minor amounts of intercalated barite. Mineralization on the Midway property is predominantly massive, locally recrystallized pyrite. It has local high-grade zinc, lead, and silver values but low barite concentrations. The Lower zone also contains copper with some gold, titanium, and bismuth. These features suggest the Midway deposits formed at slightly higher temperatures, and/or closer to hydrothermal vents than deposits of the Gataga district. A major high-angle fault occurs on the west side of Midway deposit; this fault might have been the main conduit for hydrothermal fluids, not only for Midway but also for the nearby Silvertip silver-lead-zinc vein system.

In contrast to the stratiform pyrite sphalerite barite±galena deposits of the Gataga district and the Midway deposit, the cupriferous massive sulphide deposit at Windy-Craggy is much like the Cyprus-type volcanogenic massive sulphide deposits. Cyprus deposits occur in a sequence

of altered pillow basalts of ophiolitic affinity (Hutchinson and Searle, 1971). Typically they have a well-developed underlying stringer and disseminated sulphide zone. The massive cupriferous pyrite body is overlain by unaltered volcanic and pelagic sedimentary rocks (Fig. 55). All these features are present at Windy-Craggy.

The Cyprus deposits occur at the contact of the subcircular Troodos Igneous Complex which consists of an ultramafic base, a sheeted gabbroic dyke swarm, and upper altered pillow basalts. The complex is believed to have formed at a spreading rift system within continental crust. The Windy-Craggy deposit and other nearby stratiform massive sulphide occurrences of unknown significance also occur at the contact of a subcircular mass of mafic volcanic rocks (Fig. 53) and this mass may have an ophiolitic core similar to that of the Troodos Igneous Complex. Therefore a similar environment of formation might apply to the Windy-Craggy area, that is, a spreading rift system within continental crust, perhaps in a back arc basin setting similar to that of the present day Japanese Islands or Gulf of California (Fig. 57). The andesitic to dacitic tuffaceous rocks intercalated with sedimentary strata overlying the Windy-Craggy deposit may, in fact, represent fallout from an active volcanic arc that was located west of the basin. These ideas are speculative and require additional regional mapping to substantiate.

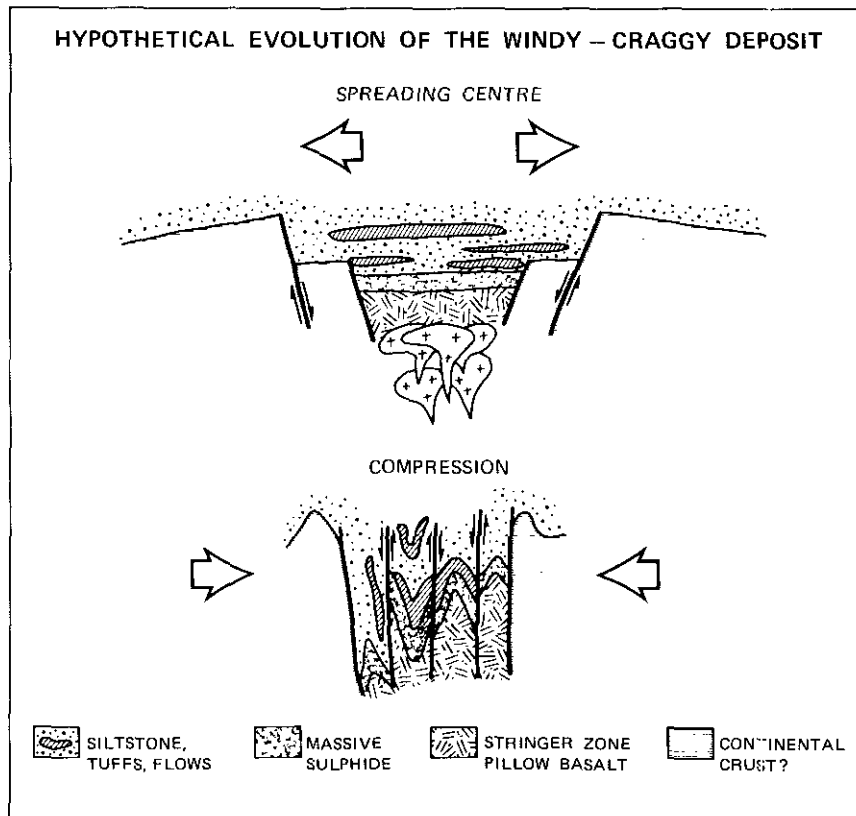
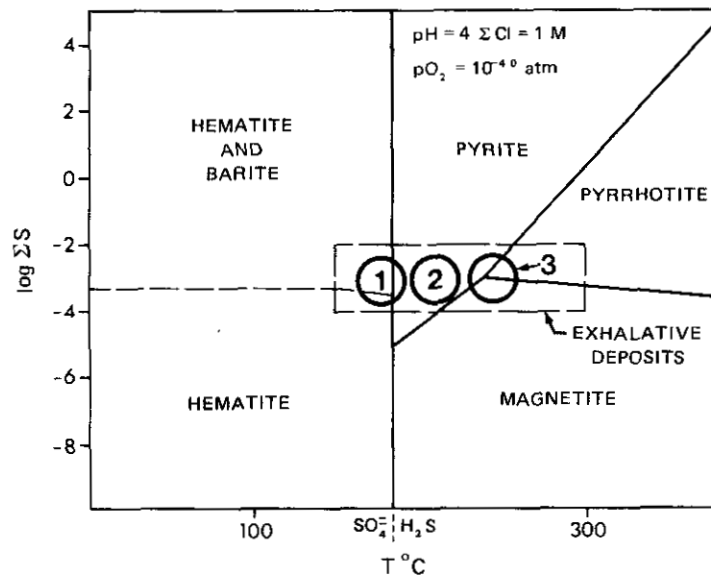
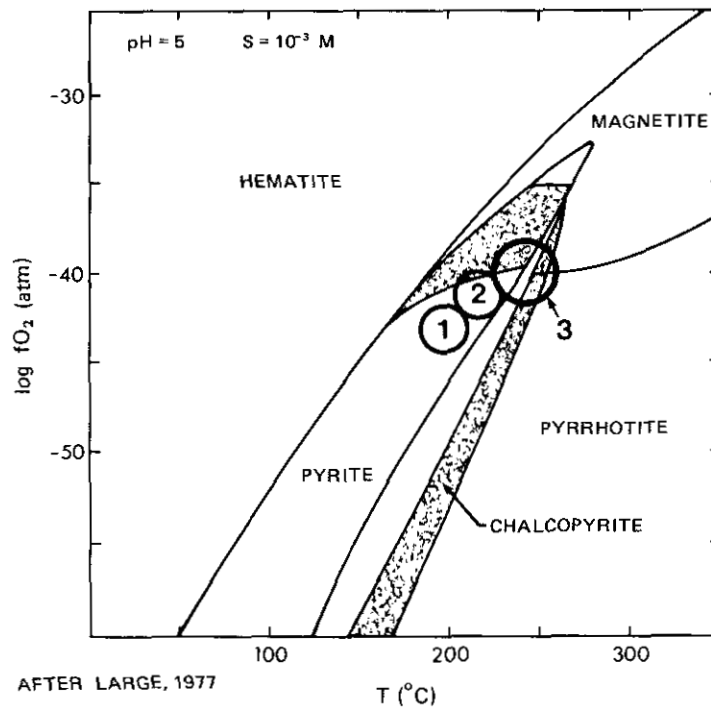


Figure 57. Hypothetical evolution of the Windy-Craggy deposit.



AFTER FINLOW-BATES, 1980



AFTER LARGE, 1977

1 = GATAGA DEPOSITS    2 = MIDWAY    3 = WINDY - CRAGGY

Figure 58. Log total sulphur-temperature and log oxygen fugacity-temperature diagrams and stability fields of phases common to exhalative deposits. Hypothetical fields of formation for deposits of the Gataga district and the Midway and Windy-Craggy deposits are also shown.

The high copper and anomalous cobalt content of the Windy-Craggy ore is consistent with a model of convective downward circulation of seawater and leaching of metals from a mafic to ultramafic volcanic pile in the manner described by Spooner (1980) for formation of the Cyprus deposits. Although Windy-Craggy has almost all the features of the Cyprus model, there is one very important difference -- size. The Windy-Craggy deposit has inferred reserves on the order of 300 million tonnes, which is much larger than the largest of the known Cyprus deposits (15 million tonnes). The discovery of a Cyprus-type deposit of this size and grade in this relatively unexplored area suggests that volcanic-sedimentary rocks of the Alexander terrane have a very high resource potential. In view of the deposit model presented in this paper, the contact between altered mafic volcanic rocks and overlying unaltered volcanic-sedimentary rocks would be a prime exploration target. The apparent Late Triassic age of the hangingwall rocks at Windy-Craggy should also be taken into consideration. If the mafic pillowed volcanic rocks are Paleozoic in age as inferred by the regional mapping of Campbell and Dodds (1979), then a major unconformity or thrust fault may exist between the mafic volcanic rocks and the overlying volcanic-sedimentary unit. Alternatively, the entire package might be Late Triassic in age and therefore correlate with other mafic volcanic units such as the Stuhini Group of the Intermontane Belt and the Karmutsen-Nikolai assemblage of the Insular Belt.

#### ACKNOWLEDGMENTS

The author would like to thank Rob Carne and Mike Philips of Archer, Cathro Holdings Limited, Brian Hall of Cordilleran Engineering Limited, and Terry Chandler and Jim McDougall of Falconbridge Limited for much valuable information and logistical support during visits to their respective properties. Mike Fournier provided able and cheerful assistance in the field.

#### REFERENCES

- Campbell, R. B. and Dodds, C. J. (1979): Operation Saint Elias, British Columbia, in Current Research, Pt. A, *Geol. Surv., Canada*, Paper 79-1A, pp. 17-20.
- Dawson, K. M. and Orchard, M. J. (1982): Regional Metallogeny of the Northern Cordillera: Biostratigraphy, Correlation, and Metallogenic Significance of Bedded Barite Occurrences in Eastern Yukon and Western District of Mackenzie, in Current Research, Pt. C, *Geol. Surv., Canada*, Paper 82-1C, pp. 31-38.
- Finlow-Bates, T. (1980): The Chemical and Physical Controls on the Genesis of Submarine Exhalative Orebodies and their Implications for Formulating Exploration Concepts -- A Review, *Geol. Jb.*, Vol. 40, pp. 131-168.

- Gabrielse, H. (1969): Geology of the Jennings River Map-Area, British Columbia, *Geol. Surv., Canada*, Paper 68-55, 37 pp.
- Gordey, S. P. (1982): Devono-Mississippian ('Black Clastic') Sedimentation and Tectonism in the Northern Cordillera, in Program and Abstracts, *Geol. Assoc. Can., Cordilleran Section, Meeting, Vancouver, B.C., February 1982*.
- Gordey, S. P., Abbott, J. G., and Orchard, M. J. (1982): Devono-Mississippian (Earn Group) and Younger Strata in East-Central Yukon, in Current Research, *Geol. Surv., Canada*, Paper 82-1B, pp. 93-100.
- Hutchinson, R. W. and Searle, D. L. (1971): Stratabound Pyrite Deposits in Cyprus and Relations to Other Sulphide Ores, *Soc. Min. Geol., Japan*, Special Issue No. 3, pp. 198-205.
- Large, R. R. (1977): Chemical Evolution and Zonation of Massive Sulphide Deposits in Volcanic Terrains, *Econ. Geol.*, Vol. 72, pp. 549-572.
- MacIntyre, D. G. (1980a): Driftpile Creek-Akie River Project, B.C. Ministry of Energy, Mines & Pet. Res, Geological Fieldwork, 1979, Paper 1980-1, pp. 55-67.
- ..... (1980b): Cirque Barite-Zinc-Lead-Silver Deposit, B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1979, Paper 1980-1, pp. 69-74.
- ..... (1981a): Akie River Project, B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1980, Paper 1981-1, pp. 32-47.
- ..... (1981b): Geology of the Akie River Barite-Lead-Zinc Mineral District, B.C. Ministry of Energy, Mines & Pet. Res., Prelim. Map 44.
- ..... (1982a): Akie River Project, B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1981, Paper 1982-1, pp. 142-148.
- ..... (1982b): Geologic Setting of Recently Discovered Stratiform Barite-Sulphide Deposits in Northeast British Columbia, *C.I.M.*, Bull., Vol. 75, No. 840, pp. 99-113.
- ..... (1982c): Midway Occurrence, B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1981, Paper 1982-1, pp. 162-166.
- MacIntyre, D. G. and Diakow, L. (1982): Kwadacha Barite Deposit, B.C. Ministry of Energy, Mines & Pet. Res., Geological Fieldwork, 1981, Paper 1982-1, pp. 149-155.
- Morganti, J. M. (1981): Sedimentary-Type Stratiform Ore Deposits: Some Models and a New Classification, *Geoscience Can.*, Vol. 8, No. 2, pp. 65-75.
- Spooner, E.T.C. (1980): Copper-Pyrite Mineralization and Seawater Convection in Oceanic Crust -- The Ophiolitic Ore Deposits of Cyprus in The Continental Crust and Its Mineral Deposits, D. W. Strangway, editor, *Geol. Assoc. Can.*, Special Paper 20, pp. 685-703.
- Stollery, J. W. and Sellmer, W. H. (1982): Midway, An Analysis of a New Massive Sulphide Discovery, *Cdn. Min. Jour.*, Vol. 103, No. 4, pp. 68-71.