GEOLOGY OF THE ALSEK–TATSHENSHINI RIVERS AREA (114P)

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INTRODUCTION

Geological studies of the Falconbridge Nickel Mines Limited–Geddes Resources Limited's Windy-Craggy deposit began in 1982 (MacIntyre, 1983). An additional 10 days were spent mapping in the vicinity of the deposit during the 1983 field season. A total of 86 geologic stations were established in the map-area, which covered approximately 300 square kilometres (Fig. 66). The primary purposes of this project were to define the stratigraphic and structural setting of the Windy-Craggy deposit and to assess the mineral resource potential of the surrounding area. This report summarizes the preliminary results of this work.

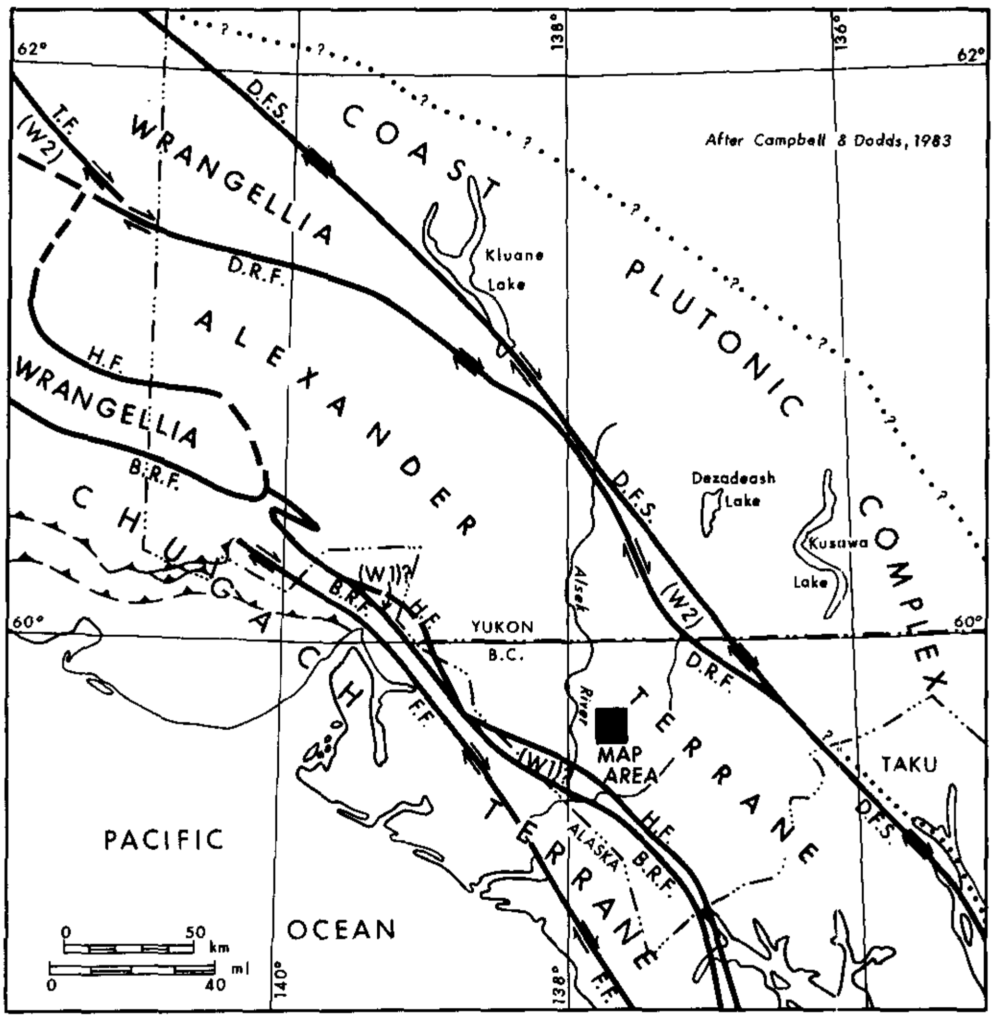
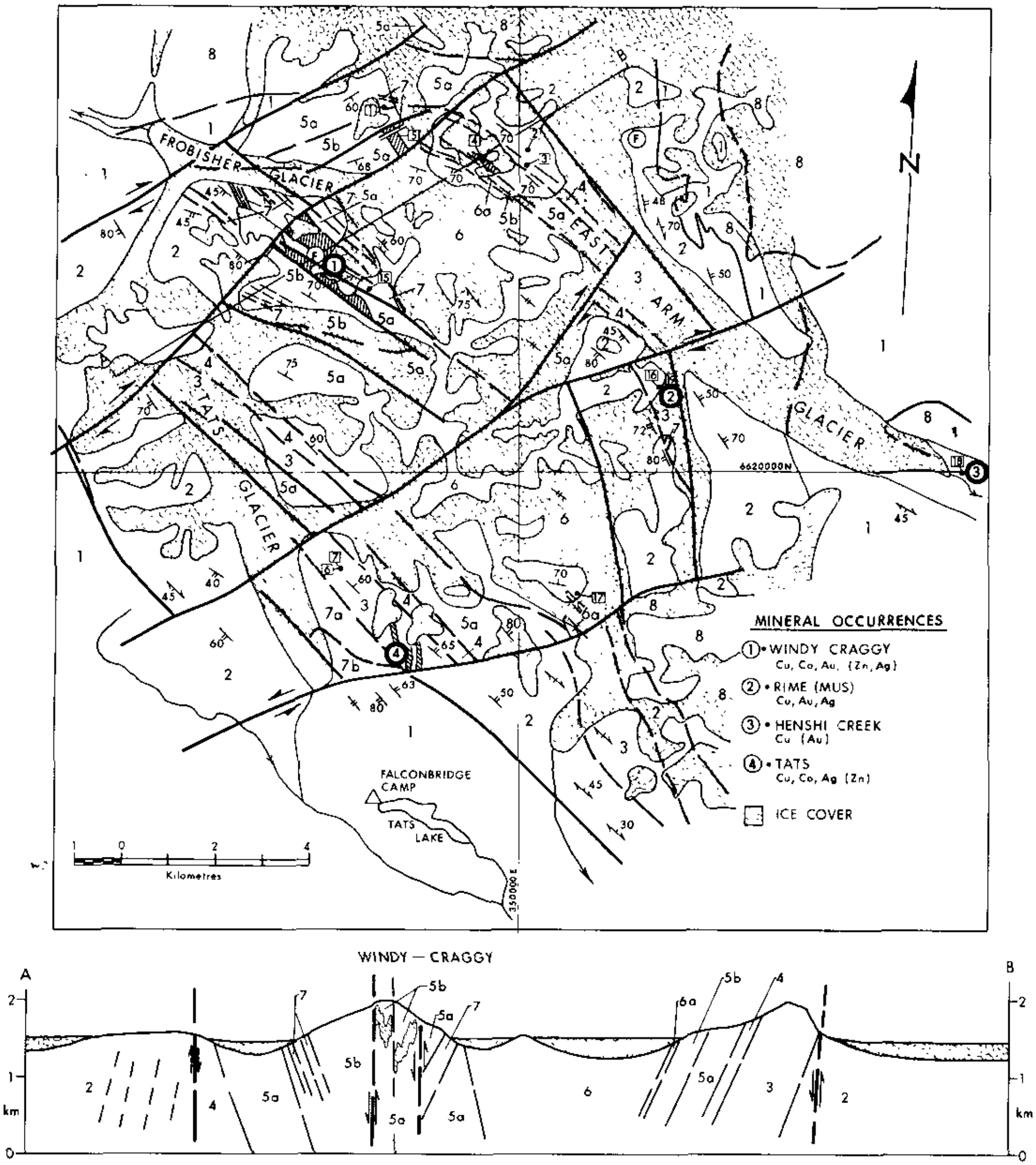


Figure 66. Location of the Alsek-Tatshenshini map-area relative to major tectonic elements as defined by Campbell and Dodds, 1983. B.R.F. = Border Ranges fault; F.F. = Fairweather fault; H.F. = Hubbard fault; D.R.F. = Duke River fault; D.F.S. = Denali fault system; T.F. = Totschunda fault; W1 = Wrangellia.



LEGEND

JURASSIC – CRETACEOUS

8 GRANITIC INTRUSIONS

TRIASSIC OR YOUNGER

7 DIORITIC INTRUSIONS 7a – DIORITE VOLCANIC COMPLEX
7b – DIORITE, QUARTZ DIORITE

LATE TRIASSIC AND (?) YOUNGER

6 MAFIC PILLOW LAVA, 6a - AGGLOMERATE
5b LIMY SILTSTONE ARGILLITE, TUFF FLOWS MINOR LIMESTONE
5a MAFIC PILLOW LAVA, MINOR LIMY ARGILLITE, CHERT
4 FELSIC PILLOW LAVA, PORPHYRITIC FLOWS
3 AMYGDALOIDAL FLOWS, MINOR LIMY ARGILLITE, LIMESTONE

LATE PALEOZOIC (?) TO LATE TRIASSIC

2 LIMY ARGILLITE SILTSTONE, MINOR TUFF

ORDOVICIAN - DEVONIAN

1 LIMESTONE, LIMY MUDSTONE, CALCARENITE, MARBLE, MINOR ARGILLITE

LEGEND

BEDDING
TOPS KNOWN, ASSUMED
FOLIATION
FAULT
SAMPLE SITE (TABLE 1)
GOSSAN

Figure 67. Preliminary geology of the Alsek-Tatshenshini map-area.

The map-area is part of the Alsek Ranges of the St. Elias Mountains; it is characterized by jagged ridges and peaks rising to 2 200 metres above a base elevation of 800 to 1 000 metres. Almost all the cirques and valleys in the area are occupied by glaciers. Outcrop is limited by the extent of ice cover. The steep and unstable nature of much of the outcrop in the area made mapping difficult; many areas could not be sampled for safety reasons. Marginal weather conditions also restricted access to higher elevations during the mapping project. Consequently much of the area has been mapped from a distance or via helicopter with geologic contacts inferred rather than defined. Figure 67 summarizes the geology as it is known to date.

GEOLOGIC SETTING

The Alsek-Tatshenshini map-area is part of the Alexander and St. Elias terrane of the Insular Tectonic Belt (Fig. 66). Recent geologic mapping by Campbell and Dodds (1983) showed this area to be underlain by complexly deformed Paleozoic clastic and carbonate rocks of relatively low metamorphic grade. Mafic volcanic units, lithologically similar to those exposed in the vicinity of the Windy-Craggy deposit, were known to occur in the Early Paleozoic part of the stratigraphic succession; for this reason the deposit was believed to be Paleozoic in age. However, limy beds in the stratigraphic hangingwall of the deposit have consistently yielded Late Triassic conodonts (MacIntyre, 1983). The age of the footwall rocks is, however, unknown.

GEOLOGY

The map-area is underlain by intermediate to mafic submarine volcanic units with variable amounts of interbedded limy argillaceous sedimentary rocks. These rocks are believed to be predominantly Late Triassic or younger in age and to overlie an Early to Middle Paleozoic clastic and carbonate sequence (unit 1). The stratigraphic succession described in this report is based mainly on traverses completed north of the East Arm glacier where a relatively complete southwest-dipping section is exposed and accessible. It is assumed that this section is both representative for the area as a whole and that it is not complicated by major faults.

STRATIGRAPHY

The stratigraphy (Fig. 68) has been divided into map units on a lithological basis. The oldest known part of the section (unit 1) is represented by a thick sequence of laminated carbonate, limy mudstone-siltstone, and massive limestone (upper part). Apparently overlying this unit, but generally in fault contact, is a thick sequence of limy argillaceous rocks (unit 2). These rocks are overlain by andesitic flows with minor intercalations of limy argillite and limestone (unit 3). A thin unit of felsic and mafic pillow lavas and porphyritic flows (unit 4) locally separates these rocks from overlying pillowed and non-pillowed intermediate to mafic flows and tuffs with interbedded limy argillite, siltstone, and minor amounts of chert and limestone (unit 5). Overlying unit 5 is a thick (>1 500 metres ?) pile of mafic pillow lava (unit 6) that has no appreciable amount of interbedded sedimentary rock. Fine to medium-grained dioritic sills and dykes (unit 7) occur throughout the Triassic succession and Jurassic/Cretaceous age plutons (unit 8) occur on the northwest and east edges of the map-area.

UNIT 1: Map unit 1 consists of medium to thin-bedded, grey, cream, and orange-brown-weathering limestone or marble with interbedded calcarenite and limy argillaceous siltstone. These rocks are well exposed in the creek valley south of the Tats showing, where highly contorted bands of marble and calcarenite crop out on the north-facing slope. A major fault occupies the valley bottom and separates these calcareous rocks from massive volcanic rocks and diorite north of the creek.

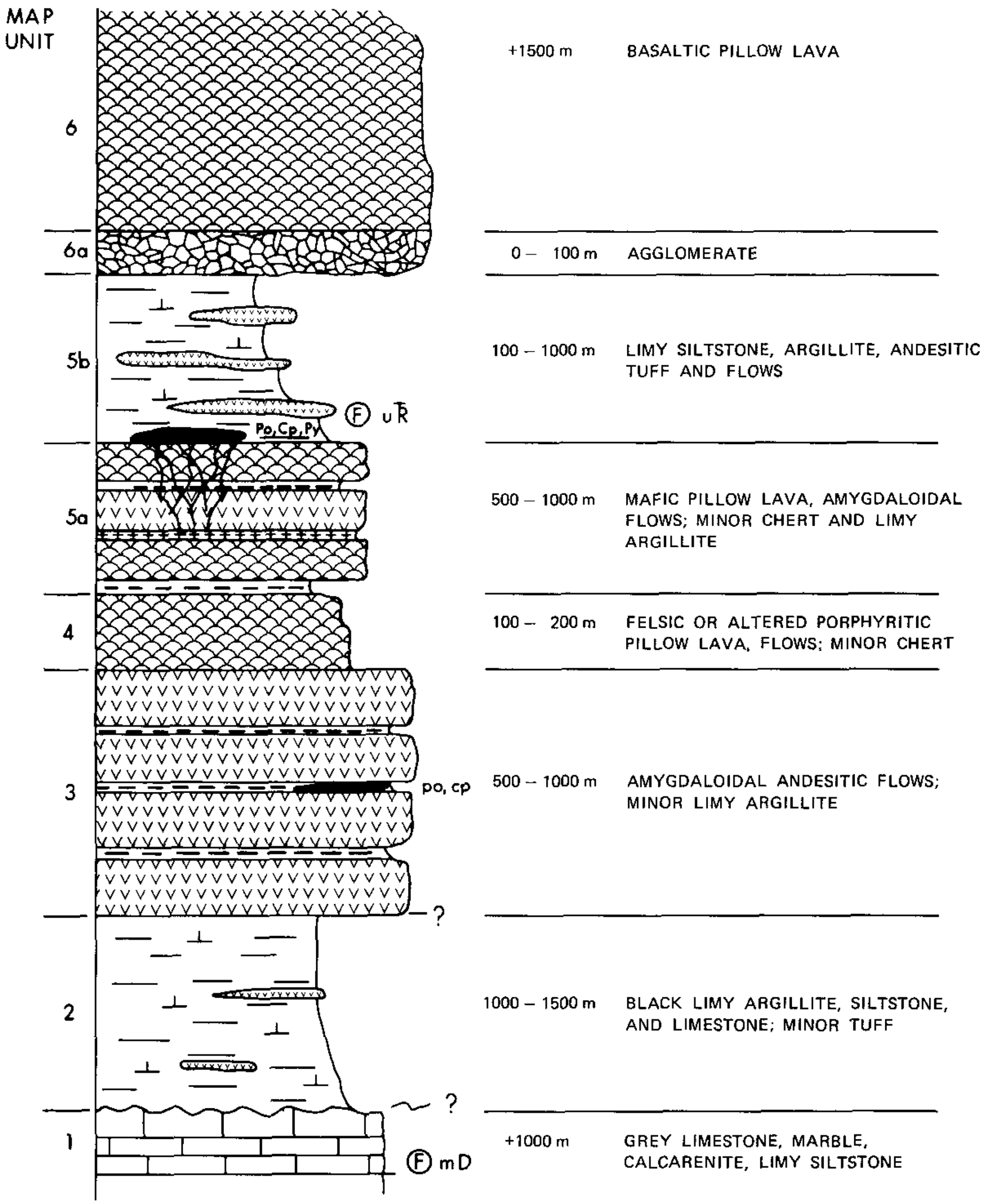


Figure 68. Preliminary stratigraphic column for the Alsek-Tatshenshini map-area.

Grey-weathering limestone also crops out northeast of the East Arm glacier along the crest of a northwest-trending ridge. Apparently this unit has yielded Devonian macrofossils (Knopf and Valle, 1981) and underlying black limy argillites contain Late Eifelian to Early Givetian conodonts (R. B. Campbell, personal communication). The lower half of the ridge is underlain by black-weathering shales which apparently dip northeastward underneath the limestone unit. It is not certain whether these rocks stratigraphically underlie the Devonian limestone or are part of the Triassic succession (unit 2) that is in fault contact with the limestone.

UNIT 2: Black to dark grey-weathering limy argillaceous siltstone and shale are the predominant lithologies in map unit 2. Thin beds of tuff also occur locally within this unit, which for the most part is recessive in nature. This unit is well exposed west of the Tats glacier, northeast of the East Arm glacier, and on the east side of the south-trending glacier that forms the eastern margin of the map-area. Tuff bands within this unit help outline northwest-verging isoclinal folds.

Stratigraphic relationships between unit 2 and units 1 and 3 are not well established. Norian (early Late Triassic) age conodonts have been extracted from samples of lithologically similar rocks exposed on the ridge west and north of the Tats glacier (C. J. Dodds, personal communication), but it is not certain if these limy argillaceous rocks are part of unit 2 or are a volcanic-deficient facies equivalent of unit 5b. Hopefully samples collected from unit 2 elsewhere in the map-area will yield diagnostic conodont fauna to help resolve the relative stratigraphic position of these rocks.

UNIT 3: Map unit 3 consists mainly of massive, thick-bedded, locally amygdaloidal, grey to orangy brown-weathering, intermediate volcanic flows and tuff beds separated by thin beds of limy siltstone and banded limestone. Microdioritic sills and dykes are also common within this unit. These rocks are well exposed north of the East Arm glacier where they dip steeply to the southwest and outcrop as a prominent northwest-trending ridge. The general lack of pillowed flows distinguishes this unit from compositionally similar units which are believed to be higher up in the Triassic succession. This criteria may not be valid and the unit may be a non-pillowed facies equivalent of unit 5a.

UNIT 4: A distinctive unit of felsic pillow lava crops out on the west-facing slope of the ridge east of the Tats glacier. The pillow lava is typically porphyritic with a dark cherty rind outlining pillows. Non-pillowed porphyritic flows and felsic crystal and ash tuff are also included with this unit. Similar rocks crop out at the same stratigraphic position on the south-facing slope of the ridge north of the East Arm glacier. This unit may prove to be an important marker unit within this sequence of predominantly intermediate to mafic volcanic rocks.

The original chemical composition of unit 4 rocks is not certain. Although the porphyritic pillow lavas are relatively siliceous and light coloured these characteristics may be due to superimposed hydrothermal alteration that may be genetically related to massive sulphide deposits that apprently occur higher up in the stratigraphic sequence.

UNIT 5: Map unit 5 can be subdivided into a lower unit (5a) which consists of pillow lava and amygdaloidal flows with minor intercalations of limy argillite, siltstone, and chert and an upper unit (5b) which is predominantly limy siltstone and argillite interbedded with andesitic tuffs and flows. The volcanic flows of unit 5a appear to be somewhat more basaltic and pervasively altered to a chlorite-carbonate assemblage than the predominantly unaltered to weakly altered tuffaceous rocks of unit 5b. Zones of disseminated and stringer pyrite both crosscut and parallel bedding within unit 5a. Rocks of this unit are believed to form the stratigraphic footwall of the Windy-Craggy deposit.

The thickness and percentage of intercalated volcanic rocks are quite variable in unit 5b. Immediately southwest of Windy-Craggy this unit appears to be over 1 000 metres thick and is predominantly limy

Plate VIII. View southwest toward Windy-Craggy. Arrows point to drill locations on ridge. Rocks in foreground are amygdaloidal flows of unit 3. Peak on the left is capped by a southwest-dipping dioritic sill that intrudes pillow lava of unit 6.

siltstone; north of the East Arm glacier volcanic rocks predominate and the unit is probably less than 200 metres thick. Assuming there are no major faults that cut out or repeat parts of these sections (a dangerous assumption!), a local thickening of this unit in the vicinity of the Windy-Craggy deposit is inferred. Perhaps a structurally controlled sedimentary trough was present in Late Triassic time, with limy detritus and rift-related flows and tuffs accumulating within the trough.

UNIT 6: Map unit 6 is almost entirely massive mafic pillow lava; there is little or no intercalated sedimentary rock. This unit is very resistant and forms jagged ridges and near-vertical cliff faces in the area east and southeast of the Windy-Craggy deposit. Here the unit appears to exceed 1 500 metres in thickness; its top has not yet been recognized. Agglomerate consisting of drawn out clasts of lava suspended in a muddy or tuffaceous matrix (unit 6a) occurs at the base of the pillow lava sequence. These rocks are very distinctive and may prove to be a useful marker horizon for the map-area.

The great thickness of mafic pillow lava represented by unit 6 implies that a prolonged period of submarine extrusive activity followed formation of the Windy-Craggy deposit and deposition of turbiditic sediments of unit 5b. The pillow lavas apparently occupy the core of a northwest-trending synclinorium which also coincides with the greatest thickness of unit 5b as mentioned previously. These observations are compatible with a depositional model in which sediments and submarine volcanic rocks accumulated within a trough centred on a submarine rift system located within a back arc sedimentary basin.

UNIT 7: Numerous dykes and sills of grey-weathering medium to fine-grained dioritic rock occur within map units 2 through 5, particularly in the vicinity of the Windy-Craggy deposit. These intrusive rocks are texturally and probably compositionally identical to flows within units 3 and 5b and they are assumed to be the subvolcanic equivalents of these rocks. The sills are difficult to recognize unless contacts are well-exposed and they may be more abundant than presently recognized. Isotopic age dating and petrographic and geochemical studies will be undertaken to help define the volcanic-plutonic relationships.

A diorite-volcanic complex (unit 7a) is exposed along the bottom half of the ridge east of the Tats glacier. This complex is characterized by very coarse-grained hornblende-rich diorite and partly to totally recrystallized mafic volcanic flows. The diorite in places appears to have formed as a result of recrystallization of the mafic volcanic rocks. Segregations of mafic-rich diorite are also present and locally crosscut the volcanic stratigraphy. Hornblende-rich dykes cut rocks in the vicinity of the complex; they may be genetically related to the core of the complex. In one locality a breccia dyke was observed with clasts of volcanic rock that are partially to totally replaced by hornblende and suspended in a finer grained hornblende diorite matrix.

Medium to coarse-grained diorite to quartz diorite (unit 7b) crops out in the lower part of the creek draining the Tats showing and in the major creek valley southwest of the showing. This intrusive body appears to form the core of the diorite-volcanic complex; perhaps the complex represents a transitional zone between the intrusive and overlying volcanic strata.

UNIT 8: Map unit 8 includes granitic rocks of probable Jurassic/Cretaceous age. These rocks are part of a series of intrusive bodies that crop out in the Alsek-Tatshenshini area. Potassium-argon isotopic ages of 156±19, 136±5, and 141±8 Ma were determined by the Geological Survey of Canada on hornblende and biotite-hornblende pairs extracted from intrusive bodies east and southwest of the map-area (C. J. Dodds, personal communication).

STRUCTURE

Major northeast and northwest-trending faults that offset steeply tilted fault blocks dominate the structure of the map-area. Isoclinal folds with northeast-dipping axial planes and northwest plunges occur within

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Au	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	<0.3	0.3	<0.3	<0.3	<0.3	0.3	0.3	<0.3	84	<0.3	0.7	54
Ag	<10	<10	<10	<10	<10	<10	<10	<10	22	<10	<10	<10	29	<10	<10	42	<10	<10	18
Cu	49	76	89	108	110	370	320	140	19.0%	400	600	0.37%	13.5 %	1.19%	230	0.86%	160	0.38%	0.25%
Pb	9	21	19	43	7	10	6	11	9	3	8	15	8	7	18	104	25	370	77
Zn	175	350	370	178	64	74	111	51	226	59	93	40	0.18%	204	73	318	208	310	82
Co	20	4	45	19	21	94	51	62	88	42	17	0.14%	0.12%	580	34	5	42	6	750
Ni	33	31	400	67	93	52	34	42	<2	18	20	3	57	105	103	6	143	6	7
Mo	3	<3	30	6	11	8	3	<3	5	6	5	57	57	<3	36	26	14	5	26
Sb	<3	<3	<3	<3	<3	<3	<3	<3	3	<3	<3	<3	<3	<3	<3	16	<3	<25	<25
Ba	130	<20	855	2663	108	21	<20	97	<20	<20	1548	<20	<20	<20	411	<20	86	—	—
Hg (ppb)	<15	32	232	35	19	26	28	<15	17	19	28	31	71	25	15	235	<15	216	102

NOTE: Values in ppm unless otherwise indicated.

SAMPLE DESCRIPTIONS

1 – Altered pillow lava with disseminated pyrite, unit 5a.
2 – Limestone with pyrite laminae, unit 3.
3 – Pyritic shear zone within brecciated flows, unit 5a.
4 – Pyritic zone within massive flows, unit 5a (distal exhalite ?)
5 – Pyritic zone in massive pillow lava, unit 5a.
6 – Sheared pyritic zone in limy argillite, unit 3.
7 – Sheared pyritic zone in limy argillite, unit 3.
8 – Pyritic chloritized volcanic flow, TATS property, unit 3.
9 – Massive chalcopyrite from thin shear zone cutting massive flows, TATS property, unit 3.
10 – Massive pyritic flow, TATS property, unit 3.
11 – Feldspar porphyry dyke upstream from TATS showing, unit 8.
12 – Massive granular pyrrhotite, minor chalcopyrite, magnetite, TATS showing above creek bed, unit 3.
13 – Massive chalcopyrite and pyrrhotite in creek bed, TATS showing.
14 – Pyritic shear zone down stream from TATS showing.
15 – Pyritic zone cutting altered pillow lava, east of Windy-Craggy, unit 5a.
16 – Banded calcite, pyrrhotite, pyrite, and minor chalcopyrite in limy argillite, RIME property (X-showing of former MUS claims).
17 – Pyritic zone in pillow lava, unit 6.
18 – Massive pyrrhotite, chalcopyrite boulder, HENSHI Creek.
19 – Banded calcite, pyrrhotite, pyrite, and minor chalcopyrite in limy argillite, RIME property (X-showing of former MUS claims).

incompetent limy argillaceous beds and in the massive sulphide zone at the Windy-Craggy property. Elsewhere massive volcanic units do not appear to be significantly deformed, although interbeds of limy argillaceous rocks are often sheared and tightly folded, suggesting movement was concentrated along these less competent beds. A broad syncline is defined by stratigraphic tops as deduced from pillow orientations and the areal distribution of unit 6 (Fig. 67), which is assumed to occur high in the Triassic stratigraphic succession.

MINERAL OCCURRENCES

WINDY—CRAGGY (Mineral Inventory 114P-2): Exploration work continued on the Falconbridge Nickel Mines Limited—Geddes Resurces Limited's Windy-Craggy deposit during the 1983 field season. A total of 4 141 metres of drilling was completed in nine drill holes. This work confirmed the northwest extension of the massive sulphide deposit. Drill hole 83-14, which tested the ground between drill holes 82-11 and 82-12 (MacIntyre, 1983) intersected 61.23 metres averaging 1.21 per cent copper, 11 grams per tonne (0.32 ounce per ton) gold, and 11.6 grams per tonne (0.34 ounce per ton) silver (George Cross Newsletter, No. 197, October 12, 1983). This intersection included a 23.7-metre section averaging 19.9 grams per tonne (0.58 ounce per ton) gold. These results indicate that the Windy-Craggy deposit may also have very significant concentrations of gold. Final results of the 1983 drilling program have not yet been made public.

One of the primary objectives of this project was to define the stratigraphic position of the Windy-Craggy deposit. On the basis of mapping completed to date it appears that the mineralized zone occurs at the transition between units 5a and 5b. That is, the stratigraphic footwall consists of pillow lava with minor intercalations of chert and limy argillite; the stratigraphic hangingwall consists of limy siltstone and argillite with interbedded andesitic tuff and flows. These stratigraphic units are offset by high-angle reverse and normal faults (*see* cross section, Fig. 67).

A similar stratigraphic succession to that hosting the Windy-Craggy deposit is exposed on the north side of the East Arm glacier. Zones of pervasive chlorite and sericite alteration with disseminated and stringer pyrite mineralization do occur in this part of the volcanic sequence, typically producing prominent gossans. So far no stratabound massive sulphide mineralization has been discovered. Analyses of samples from these zones (samples 4 and 5, accompanying table) indicate relatively low base and precious metal contents. There may be an enrichment of barium in sample 4.

TATS: In addition to Windy-Craggy there are two other massive sulphide occurrences in the map-area, namely the Tats and Rime (Mus). The Tats showing, which is also held by Falconbridge Nickel Mines Limited, is located in a south-flowing creek gully just below a small cirque glacier in the first major valley north of Tats Lake (Fig. 69). The showing occurs within a broad, north-trending pyritic zone within massive amygdaloidal flows. These rocks are tentatively assigned to map unit 3.

A thin (less than 2 metres) band of massive chalcopyrite and pyrrhotite exposed in the creek bed comprises the Tats showing. A sample of massive sulphide from this showing contained 13.5 per cent copper, 0.12 per cent cobalt, 0.18 per cent zinc, and 29 ppm silver (sample 13, accompanying table). Small elongate crystals of black actinolite (X-ray diffraction identification) occur within the massive chalcopyrite along with minor amounts of chlorite, epidote, and quartz.

Outcrops of pyritic volcanic flows immediately above the creek bed showing contain bands of coarse-grained pyrrhotite and magnetite with only minor chalcopyrite. Cobalt is also enriched in this sulphide zone with one sample averaging 0.14 per cent (sample 12, accompanying table). Zinc and silver were low, however, in contrast to the creek bed showing. Upstream, a thin dyke of feldspar porphyry cuts the pyritic zone. This dyke is also mineralized with small flecks of malachite and disseminated pyrite (sample 11, accompanying table).

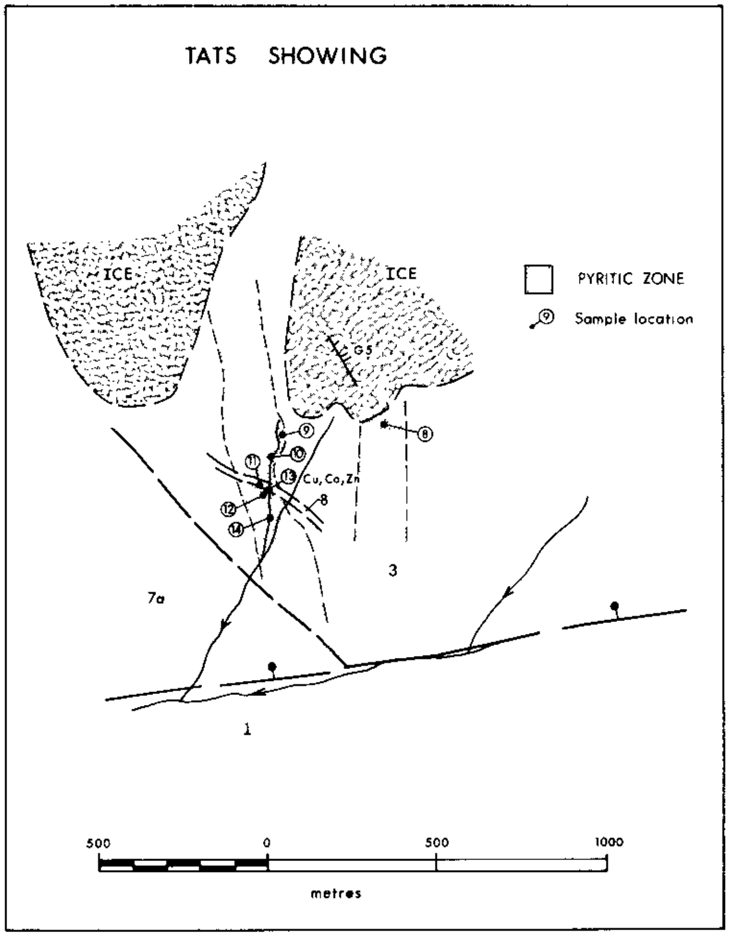


Figure 69. General geology and sample locations, Tats showing.
See Figure 67 for explanation of map symbols.

RIME: The Rime claims straddle the East Arm glacier. The area was formerly held by Swiss Aluminium Company of Canada Ltd. (Mus claims); the main showing was known as the 'X-showing' (Knopf and Valle, 1981). The area has recently been restaked by St. Joe Canada Inc. and airborne geophysical surveys were conducted over the property during the 1983 field season. One of the main targets is a large magnetic anomaly that occurs under the East Arm glacier at the junction of the north and west branches.

The main showing on the Rime claims (X-showing) is a thin zone of banded pyrrhotite, chalcopyrite, and calcite in tightly folded limy argillites. The limy argillite occurs within a sequence of massive amygdaloidal flows that are assigned to map unit 3. Two samples from the showing were analysed for trace and precious metal content (samples 16 and 19, accompanying table) and were found to contain 84 and 54 grams per tonne gold and 42 and 18 grams per tonne silver respectively. Antimony was also slightly enriched whereas cobalt content was very low relative to the anomalous concentrations at the Tats and Windy-Craggy deposits. Additional work is required to evaluate the overall significance of very high gold values in what appears to be stratiform sulphide mineralization.

Thin laminae of pyrrhotite also occur in limy argillite interbeds in exposures of unit 3 north of the East Arm glacier. A sample of massive pyrrhotite from this occurrence (sample 2, accompanying table) contained only a slight enrichment in zinc.

HENSHI CREEK: Boulders of massive pyrrhotite with variable amounts of intergrown chalcopyrite have been deposited at the toe of the East Arm glacier (Henshi Creek showing, No. 3, Fig. 67). The source of these boulders is still uncertain. It is most likely that they are derived from bedrock under the glacier rather than from medial and lateral moraines on the ice surface. Chemical analysis of a sample of one of the boulders indicates an anomalous gold concentration (sample 18, accompanying table), but values are much lower than those obtained at the X-showing.

CONCLUSIONS

Fieldwork in the Alsek-Tatshenshini Rivers area indicates that a thick (>3 000 metres ?) section of Late Triassic andesitic to basaltic flows and limy argillaceous sedimentary rocks is preserved within a roughly rectangular, fault-bounded area. Stratabound massive sulphide deposits occur at several different stratigraphic levels within the Triassic succession; broad zones of disseminated stringer sulphides both crosscut and parallel the stratigraphy. These sulphide zones appear to be spatially associated with fine-grained dioritic sills and dykes in underlying rocks. These intrusive rocks are lithologically and probably compositionally similar to flows within the succession. The presence of a structurally controlled trough is inferred by anomalous thickening of sedimentary and volcanic units in the vicinity of the Windy-Craggy deposit.

The modern day Guaymas Basin in the Gulf of California (for example, Scott, *et al.,* 1983) is favoured as the type of environment in which the mineral deposits of the area formed. That is, hydrothermal vents are inferred to have occurred within a rift trough localized on a spreading centre within a sedimentary basin. The inferred trough was the site of rapid accumulation of submarine flows and clastic and carbonate detritus and injection of subvolcanic dioritic intrusions both before and after the main mineralizing events. No ophiolite sequence has yet been observed in the area, although the diorite-volcanic complex exposed near the Tats showing may have formed in a manner analogous to that proposed for ophiolite complexes. The lack of well-developed ophiolite complexes suggests that the inferred spreading centre was short lived and did not evolve past the earliest stages of crustal spreading.

One of the most significant results of work done in the Alsek-Tatshenshini Rivers area during 1983 is recognition that the deposits of the area may contain significant amounts of gold. Undoubtedly this will have a profound influence on future exploration, not only at Windy-Craggy but also at other prospects in the area.

ACKNOWLEDGMENTS

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