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GEOLOGICAL SURVEY OF CANADA

SHORT PAPERS CONTAINING RESULTS OF ECONOMIC INTEREST DERIVED FROM 1974 FIELD WORK IN THE NORTHWEST TERRITORIES AND YUKON

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CONTENTS

1\. CARMACKS MAP-AREA, YUKON TERRITORY

Project 700025

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Parts of Carmacks map-area (Bostock, 1936) were examined during the first half of the 1974 field season with the object of allowing reinterpretation of the geology in the light of recent studies in adjacent parts of the Yukon Crystalline Platform (Tempelman-Kluit, 1973). Work was done by ground traverses with very limited helicopter support.

For the discussion that follows the reader is referred to Tempelman-Kluit (1974), a preliminary interpretation of Bostock's (1936) work made without the benefit of field work in this area. Although this reinterpretation is generally valid, the distribution of rock units requires revision particularly in the area between the Pelly and Yukon rivers.

Metamorphic rocks including amphibolite, marble and serpentinite found in the northern part of Carmacks map-area (Schist-Gneiss unit) are not equivalent to this unit in Snag map-area. Instead, the schist-gneiss of Carmacks area bears similarities to rocks of the Anvil Range Group (Tempelman-Kluit, 1972), and may be Permian. The unit is continuous with Campbell's (1967) unit 6. No diagnostic fossils were found in the marble associated with the unit although crinoid columnals are found at many localities.

The amphibolite and hornblende gneiss in southern Carmacks map-area and included in the biotite schist is more probably correlative with the amphibolite found in northern Aishihik Lake map-area. The age of this unit is unknown.

Ultramafic rocks although mapped as a single unit belong to three distinct suites. One is serpentinite and serpentinized peridotite interfoliated with the Schist-Gneiss unit and presumably of Permian age. This suite occurs along Pelly River. A second group includes coarsely crystalline magnetite-rich diorite to gabbro found associated with the Triassic massive green volcanics near the mouth of Wolverine Creek. Fresh finely crystalline diabase, a subvolcanic part of the Selkirk Lavas, comprises the third suite included in the ultramafic rocks. They are found mainly near Minto.

The massive green volcanic unit that trends northwest diagonally across Carmacks map-area shows a remarkable variety of textures and includes augite porphyry, fine-grained tuff, tuff breccia and agglomerate (Figs. 1a, b, c, d). The unit ranges from massive greenstone to well foliated amphibolite and rocks in the north are more metamorphosed than those in the south. Because it generally lacks primary layering, the internal structure of the unit has not been worked out, but the rocks are faulted against hornblende granodiorite in the southwest. In the south, this fault is a brittle fracture zone with much shearing in the walls. Farther north its brittle nature is masked and the fault is welded by later metamorphism.

The Pelly Gneiss and hornblende granodiorite (Klotassin Suite) have nebulous migmatitic relations over wide areas in central Carmacks map-area. This fact and the similar composition of the two units suggests strongly that the hornblende granodiorite was derived from the Pelly Gneiss by partial melting during metamorphism at or close to the level presently exposed.

Syenite found in central Carmacks area is gradational with, and apparently a phase of, hornblende granodiorite that constitutes the Klotassin Batholith.

Sandstones of the Lower Jurassic Laberge Group are poorly exposed in most of the area, but the belt of these rocks is cut by steep dipping faults that break relatively open symmetrical folds. A number of new collections of ammonites and pelecypods from old and new fossil localities have been made, but as these have not yet been studied, no account of their stratigraphic implications is given.

Within a radius of ten or fifteen miles of Carmacks, the basal 500 feet or more of the Carmacks Group consists of light coloured tuff, tuff breccia and tuffaceous sediments, overlain by massive brown basalt that is found elsewhere in the Carmacks Group (Fig. 1e). Such extensive and thick development of tuffs does not occur elsewhere within the Carmacks Group.

The Selkirk volcanics are fresh Pleistocene lavas that are spectacularly exposed in stream cuts near the mouth of Pelly River (Fig. 1f). Nodules of pale green olivine enclosed by partly devitrified glassy basaltic rinds were discovered in tuff extruded from the small volcanic centre opposite the mouth of Wolverine Creek (Fig. 1g). A number of these have been collected for study.

No new mineral occurrences were discovered. The writer briefly examined some of the drill core at the United Keno Hill Minto property. The mineralization, host rocks and lack of extensive alteration here are identical to those seen at the Williams Creek and Hoochekoo Bluff properties. Concentrations of mafic minerals within granodiorite of the Klotassin Suite are host to chalcopyrite and bornite at all properties. These schlieren are remnants of poorly digested Pelly Gneiss with the granodiorite. The copper was probably emplaced hydrothermally during late stages in formation of the granodiorite from the Pelly Gneiss.

NOTE

Photographs – Figures 1a to g are not reproduced in this open file due to technical difficulties.

Figure 1

(a) Altered tuff breccia in the massive green volcanic unit (Triassic) near Victoria rock.

(b) Agglomerate with rounded boulders of granodiorite and a variety of volcanic rocks; a part of the massive green volcanic unit. This exposure is just downstream from the mouth of Williams Creek.

(c) Regularly laminated and thin-bedded pale green fine-grained tuff of the massive green volcanic unit. The exposure is near Minto.

(d) Tuff of the massive green volcanic unit just downstream from Minto.

(e) Flat-lying tuff and tuffaceous sandstone that make up the lower 600 feet of the Carmacks Group here. This view westward from Tantalus Butte shows the exposure north of Murray Creek.

(f) Exposures of stream-cut columnar basalt of the Pleistocene Selkirk Lavas along Yukon River. Nine cooling units with varying column characteristics and of different thickness can be seen here.

(g) Olivine nodules in tuff that mantles the small volcanic cone opposite the mouth of Wolverine Creek. One of the nodules is enclosed by partly devitrified glass, the other two are incorporated directly in the tuff and lack such rinds. Note the match for scale.

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1974: Carmacks, Yukon Territory; Geol. Surv. Can., Open File 200.

2. STRATIGRAPHIC AND STRUCTURAL STUDIES IN THE PELLY MOUNTAINS, YUKON TERRITORY

Project 730037

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Quiet Lake and Finlayson Lake map-areas (105F, 105G) are of particular interest because they straddle Tintina Trench, the locus of a major transcurrent fault, whose tectonics are critical to reconstructions of the geology of the northern Cordillera. Field work in parts of these areas during the latter half of the 1974 field season was aimed at gaining a clearer insight into the stratigraphic and structural relations of rock units in and near the fault zone. The work, carried out by ground traverses with limited helicopter support, is the second season in a continuing project to study the region between Tintina and Shakwak trenches. Figure 1, an index of the accompanying cross-sections shows where field work was concentrated. Wheeler *et al.* (1960a and 1960b) have mapped the distribution of rocks in the region at reconnaissance scale and the reader is referred to their maps for the discussion that follows:

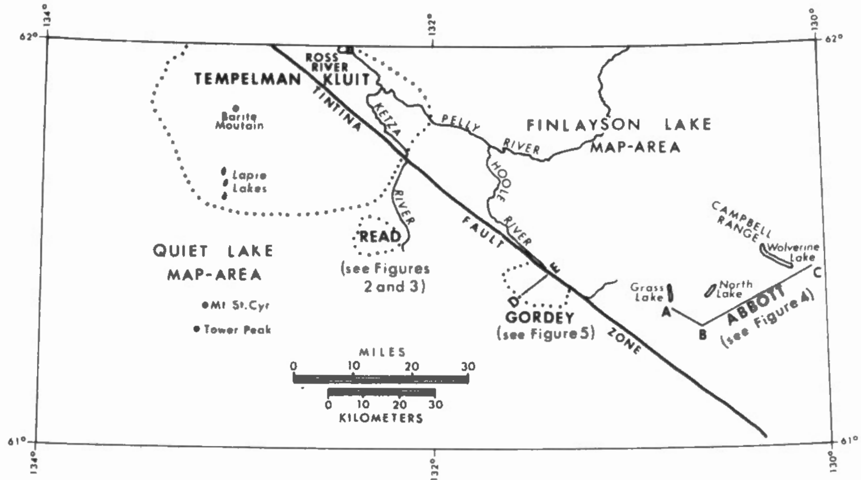

Figure 1. Index map of Quiet Lake and Finlayson Lake map-areas showing where field work was concentrated in 1974.

Green argillite and fine-grained, thin-bedded, crosslaminated, greenish, argillaceous quartzite mapped as units 1b and 1a in east central Quiet Lake map-area lie unconformably below the lower Cambrian carbonate rocks (unit 1c). The argillite and quartzite closely resemble the upper part of the "Grit Unit" northeast of Tintina Trench in Selwyn basin, and these rocks are therefore probably Proterozoic. The same argillite and quartzite is found, with its metamorphosed equivalents, west of Lapie Lakes where it is included with younger strata in unit 2 of Wheeler *et al.* (1960a).

Metamorphic rocks in central Quiet Lake map-area included in units A and C can be traced into the Proterozoic argillite and fine-grained quartzite and into the overlying impure carbonate rocks of Early Cambrian age. The metamorphic complex may also include equivalents of the Cambro-Ordovician phyllite (unit 2), but these rocks have not yet been recognized in the complex. The metamorphic complex in the western part of Quiet Lake map-area probably includes no equivalents of younger strata. Unit B, a marble, may be the metamorphic equivalent of carbonate rocks of Proterozoic age.

Lower Cambrian rocks in the Ketza River area are the subject of detailed study by B. Read. Figure 2 is a generalized section of these rocks. Figure 3 shows the facies relationships within, and the stratigraphic relationships of the Lower Cambrian strata as determined by Read. Several unique features of the succession merit emphasis. The clean orthoquartzite generally found at the base of the Lower Cambrian

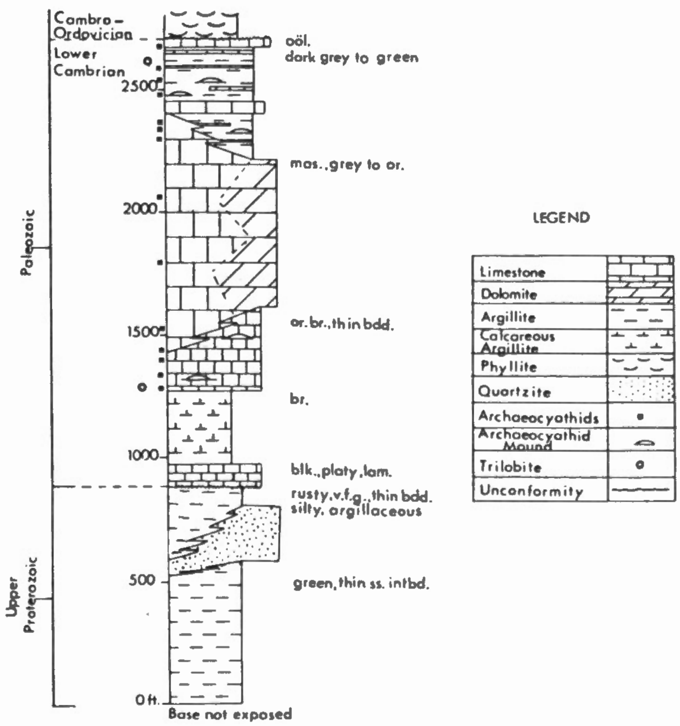

Figure 2. Generalized Lower Cambrian Section in the Ketza River area.

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[2]University of Alberta, Calgary.

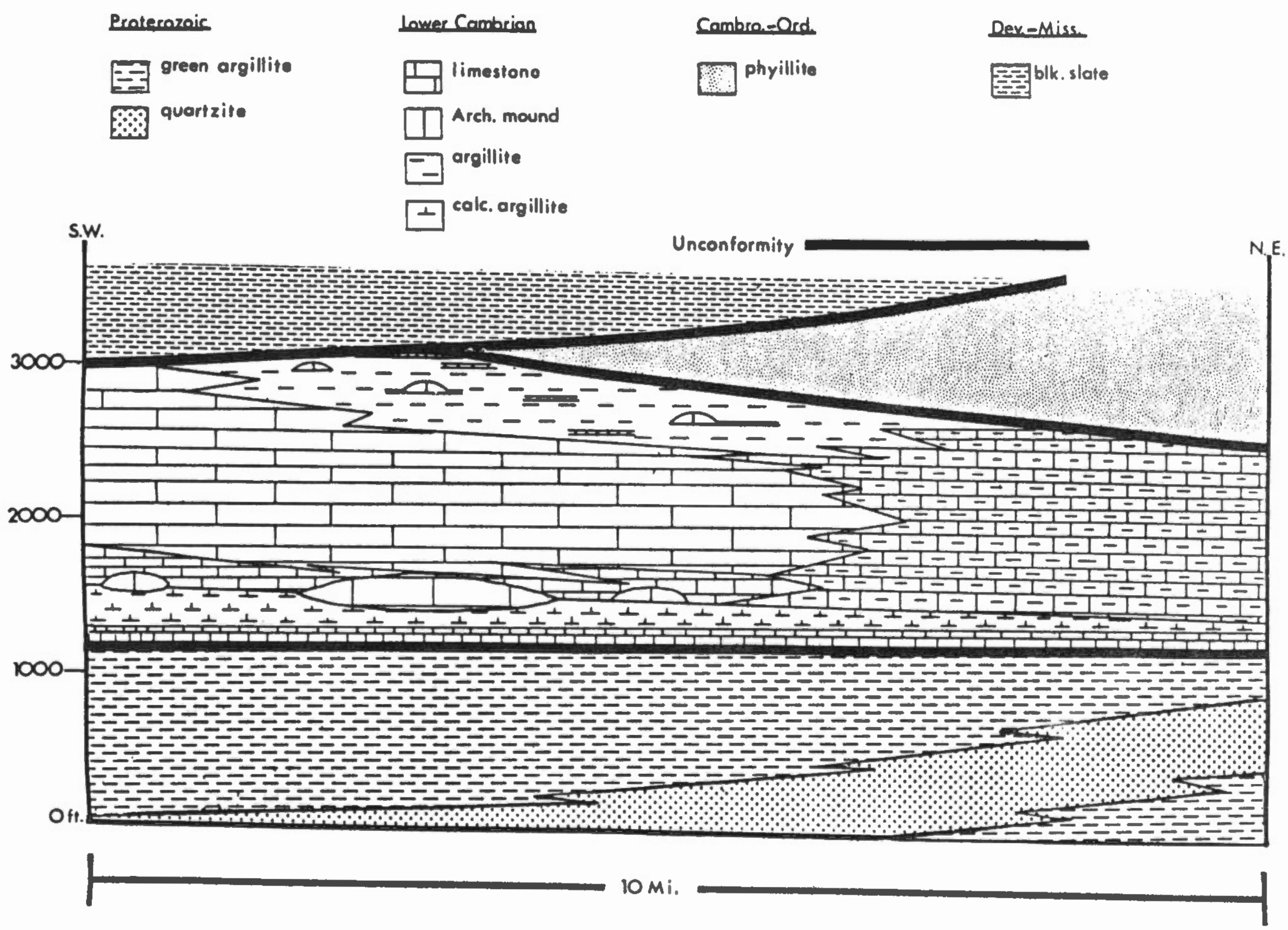

Figure 3. Facies relationships of lower Cambrian rocks in the Ketza River area.

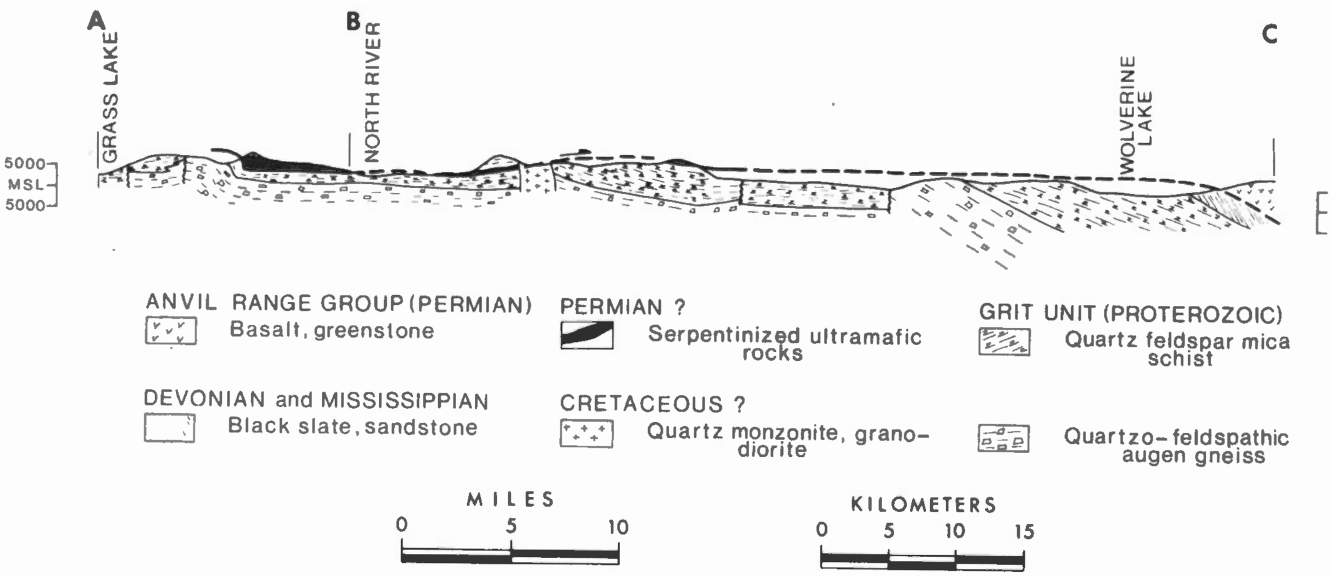

Figure 4. Diagrammatic cross-section of the Finlayson Lake metamorphic complex (*see* Figure 1 for location).

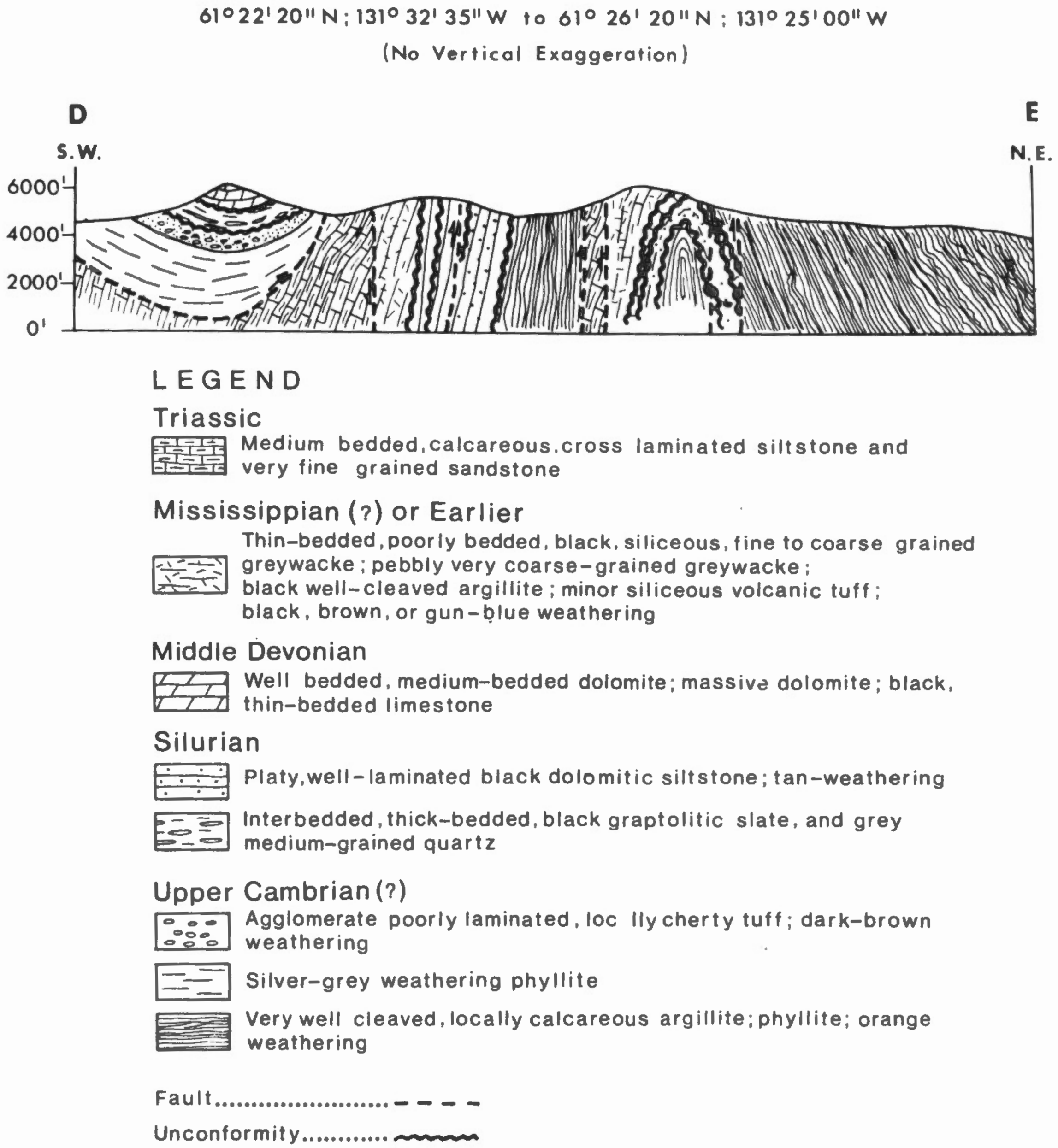

Figure 5. Diagrammatic cross-section.

elsewhere in the Cordillera is absent in Pelly Mountains. Furthermore, although trilobites are rare, those found suggest to W. H. Fritz (*see* this publication, report 144) that only the lower part of the Lower Cambrian is exposed in the Ketza River area and that the upper part, seen in most sections elsewhere, was either not deposited or eroded. The thickness of carbonate rocks over which Archeocyatha are found, nearly 1,500 feet, is considerably more than generally noted elsewhere in the Cordillera.

Although the rocks are strongly deformed and metamorphosed and lack fossils, the Lower Cambrian strata west of Lapie Lakes conform broadly to the scheme outlined in Figure 2. Unit 2 as mapped west of Barite Mountain includes about 2,000 feet of calcareous phyllite and impure limestone that is considered Lower Cambrian. The thin-bedded limestone and limy phyllite that forms the resistant outcrops at the Lapie canyon bridge (also mapped as unit 2) is also thought to be Lower Cambrian.

Volcanic rocks mapped as unit 6 are not all part of one stratigraphic unit. Those near Tower Peak and Mount St. Cry belong, with their associated ultramafic rocks (unit D), to a suite that may be correlated with the Anvil Range Group. Similarly, rocks included in unit 6 in the northeast corner of Quiet Lake map-area are part of the Anvil Range Group. However, the volcanic rocks mapped as unit 6 northeast of the Seagull

Fault are part of a distinctly acid terrestrial suite that appears to be a facies of unit 5 with which the rocks are closely related and homotaxial. The acid suite northeast of Seagull Fault is gradational, and deformed with the strata on which it rests, whereas the basic volcanics near Tower Peak may be allochthonous.

Granitic rocks in western Quiet Lake map-area are intrusive at the level of their present exposure and have sharp contacts and marginal zones up to 2 miles wide where irregular dykes and sills are abundant. The metamorphism of rocks surrounding the plutonic rocks is a relatively high temperature - low pressure type and results from the intrusive episode though it is not thermal metamorphic in the restricted sense. Metamorphic aureoles are narrow and have sharp gradients. Metamorphism has obliterated the minor structural elements of the rocks.

Main structural features of the area mapped are briefly outlined by Wheeler *et al.*, 1960a. The zone of phyllitic rocks southwest of the Tintina, mapped as unit 2, is cut by a number of steep-dipping faults of which the St. Cyr Fault is an example. Thrust faults close to the Tintina Trench, like the Porcupine Thrust had northeast directed movement, but thrusts with movements in the opposite sense are found east of Lapie Lakes. Some of the thrust faults are folded and apparently cut by younger thrust faults.

Abbott examined part of the metamorphic complex in central Finlayson Lake map-area in a traverse from Grass Lake to Wolverine Lake (*see* Fig. 4). Units A and C of Wheeler *et al.*, 1960b, are lithologically like the "Grit Unit". Unit A, comprising brown weathering quartz-feldspar-muscovite-biotite-chlorite schist overlies unit C, a more recessive weathering homogeneous quartzo-feldspathic gneiss. Feldspar augen occur in both units, but are more common in unit C. Their development is a function of the bulk composition and degree of metamorphism. Foliation dips gently and is axial planar to recumbent, small sub-isoclinal folds. Fold axes and mineral lineations trend eastward west of North Lake and southeast of the east of the lake. The orientation of minor structures is consistent over large areas and local abrupt changes reflect young faults. Serpentinized ultramafic rocks form massive to weakly foliated sheets and pods parallel with the regional foliation. Locally these sheets are enclosed by the metamorphic rocks, but more commonly they cap ridges and are overlain by amphibolite and chlorite schist correlated with the Anvil Range Group. The ultramafic bodies southeast of North Lake are the remains of a single flat lying sheet. Along the northeast shore of Wolverine Lake black slate (Devono-Mississippian) overlies the metamorphic rocks and is overlain by basalt of the Anvil Range Group. A large slide, shown in the cross-section (Fig. 4) along the base of the serpentinite sheet is not inconsistent with the data. Such a thrust may have served to bring the Anvil Range Group over the metamorphic complex into the Campbell Range where they now rest.

S. Gordey began a study of the structural style southwest of the Tintina Fault zone near Hoole River. His results are summarized in the diagrammatic cross-section of Figure 5.

Although only small, relatively high grade, showings of transgressive mineralization have so far been discovered in the Pelly Mountains the region holds promise for occurrences of stratabound mineralization. The stratigraphy is grossly like than that of Selwyn basin and specifically strata that are equivalent to those that host the deposits in the Anvil Range are widespread. Because the metamorphic rocks in west-central Quiet Lake map-area are equivalents of the "Grit Unit" and Lower Cambrian they are particularly important in exploration for lead-zinc. The occurrence of metamorphosed impure Lower Cambrian limestone in this metamorphic and intrusive complex, and the presence of tungsten at several localities makes this region important prospecting ground for that metal. Barite occurs in narrow veins within rocks of unit 4 at many localities, but no stratabound barite is known in these rocks. However, an occurrence of bedded barite was discovered in rocks of unit 5 at N60°56'45", W132°58'00". No sulphide minerals were noted at this locality. Many bright orange gossans are seen in the acid volcanic suite (unit 6) northeast of the Seagull Fault. Although pyrite is widespread in these rocks, no valuable mineralization is known.

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N 61

3. OPERATION SAINT ELIAS, YUKON TERRITORY

Project 730035

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Introduction

Following a wide-ranging reconnaissance of the Saint Elias Mountains in 1973 (Campbell and Eisbacher, 1974), a comprehensive geological study was initiated in the summer of 1974. The work, restricted to the mountains in Yukon Territory, involved regional mapping and related specific studies. Stratigraphy and structure of Permo-Triassic rocks, including detailed mapping of the "Mush Lake Group", was investigated by J.W.H. Monger and P.B. Read, the latter under contract to the Geological Survey. G.H. Eisbacher worked on the sedimentology and structure of Jurassic-Cretaceous and Tertiary strata. J.G. Souther studied the stratigraphy, structure and evolution of Tertiary volcanic and related intrusive rocks. This report provides a general introduction for separate discussions of each of these studies. Mapping of the surficial geology and studies of the glacial history were the responsibility of V.N. Rampton.

The efforts of the authors were directed primarily toward mapping regions where the geology was mainly unknown; this included Paleozoic (pre-Permian) sedimentary and volcanic rocks of generally low metamorphic grade and a variety of plutons in the Icefield Ranges. They were concerned, also, with the compilation of data on a scale of 1: 250,000 from the other participating geologists and from all available sources. The accompanying map (Fig. 1) is generalized and shows those regions in which the geology was the particular focus of one or other of the individual studies mentioned above. The map emphasizes, also, the main faults which are important elements of the regional structural setting.

Important revisions have been made in the geology of Dezadeash map-area where Kindle (1953) applied the name Mush Lake Group to rocks he believed to be Triassic, and he indicated, also, that rocks overlying the Mush Lake Group near Alsek River, were part of the Jurassic-Cretaceous Dezadeash Group. The rocks of the Mush Lake Group within Dezadeash map-area are now thought to be early and mid-Paleozoic (Read and Monger, following report), and the overlying rocks near Alsek River are also Paleozoic (*see* below).

Rocks in the Icefield Ranges

Locally, rocks in the Icefield Ranges have been mapped and reported on by previous workers (Kindle, 1953; Wheeler, 1963; Muller, 1967), and results of the earlier work with modifications are incorporated in the accompanying map. The results of the complete examination of fossil collections, and of the determination of the radiogenic age of plutonic rocks are not yet available, and field work is incomplete.

Layered rocks, dominantly sedimentary, are generally metamorphosed to low greenschist facies. Higher grade rocks, containing biotite and less commonly garnet, possibly resulted from contact metamorphism superimposed on the lower-grade, regionally metamorphosed rocks following the final phase of widespread penetrative deformation. The higher grade rocks are mostly restricted to a narrow zone extending northwesterly from near the terminus of the Dusty Glacier to the terminus of the Donjek Glacier (*see* Wheeler, 1963), and to an area northwest and southeast of Mount Alverstone. They can be divided into two sequences as shown by Sharp (1972) and Muller (1967): one characterized, if not dominated by, thick, grey carbonate and argillaceous rocks, and the other made up mainly of metamorphosed greywacke and shale with subordinate thin carbonate beds. The former, partly or entirely Devonian, has yielded fossils listed by Muller (1967, p. 28). The latter may overlie the carbonate unit, perhaps unconformably, and at Alsek River contains fossils tentatively identified as Upper Mississippian (B.E.B. Cameron, pers. comm., 1974).

The carbonate unit outcrops in a narrow band northwest from the mouth of Dusty River, along the southwest side of the Duke River Fault (*see* Wheeler, 1963, and Muller, 1967), and in another band along the southern and western edge of the area mapped, from south of the Fisher Glacier to the Klutlan Glacier. It also underlies a large, unmapped area north of the Walsh Glacier. The metamorphosed greywacke and shale sequence lies between the two bands of the carbonate unit and extends from near Bates Lake to near the Steele Glacier.

The Paleozoic stratified rocks of the Icefield Ranges were folded at least twice, and locally, if not generally, the axes of the later folds are at a high angle to those of the earlier. Although extensive exposures are characteristic of the region, macroscopic folds are uncommon, even where prominent marker beds are present. The reasons for this are not understood. Possibly fold hinges are obscured and dislocated by shearing. If the folds are large, and the axes plunge steeply on a regional scale as they do locally, fold hinges may not be obvious in the steep, mountainous terrain.

Plutonic rocks vary from gabbro and diorite to quartz monzonite and syenite. Most are moderately dark hornblende-biotite quartz diorite and granodiorite, but some are melanocratic gabbro or diorite with syenitic phases, and some are leucocratic, biotite quartz monzonite with large pink potash feldspar phenocrysts. Most granitic plutons have sharp, steeply dipping contacts and rather irregular outlines. The rocks probably range from late Paleozoic to Tertiary in age, but any breakdown by age or composition must await results of laboratory studies.

Major Faults

The mid and lower Paleozoic rocks of the Saint Elias Mountains are separated by major faults from Permo-Triassic and Jurassic-Cretaceous rocks along the northeastern margin of the mountains. The Dalton Fault extends southeastward from Jarvis River and is the direct southeasterly extension of the Shakwak segment of the Denali Fault system (Campbell and Eisbacher, 1974). It separates the Paleozoic rocks from the Jurassic-Cretaceous Dezadeash Group and contains pods of Tertiary coal-bearing conglomerate within the vertical fault zone. Tertiary volcanic rocks, presumably equivalent to the Wrangell Lava of eastern Alaska are cut by the fault.

The Duke River Fault (Muller, 1967) diverges from the Shakwak-Dalton Fault near Jarvis River from where it can be traced northwestward to the Klutlan Glacier. At its southern end the fault dips steeply to moderately southwestward; farther north it is mainly vertical. Throughout its length the fault separates the Paleozoic rocks of the Icefield Ranges from Permo-Triassic strata to the northeast; locally it displaces the basal units of the Wrangell Lava, but does not cut higher flows. North of Steele Glacier the lava is deformed into large overturned folds above the trace of the underlying fault, and other, possibly related faults cut the lava (Souther, this publication). Near Klutlan Glacier Permian rocks are thrust over the Tertiary volcanics. The trace of the Duke River Fault apparently extends beneath the Klutlan Glacier westward into Alaska where it may intersect or interconnect with the Totschunda Fault system (Richter and Matson, 1971).

The type and magnitude of movement on the steeply dipping Dalton and Duke River faults is unknown. Indications of Pleistocene or Recent movement on the faults are lacking, but both the Dalton and Duke River faults cut, or are related to deformation within rocks that may be as young as Pliocene. Most of the movement must predate deposition of the Wrangell Lava.

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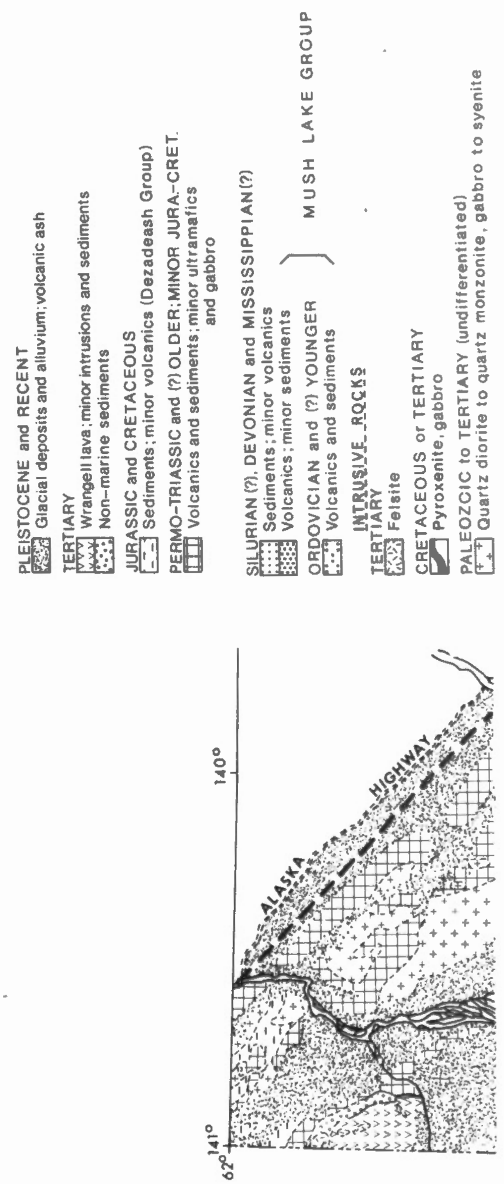
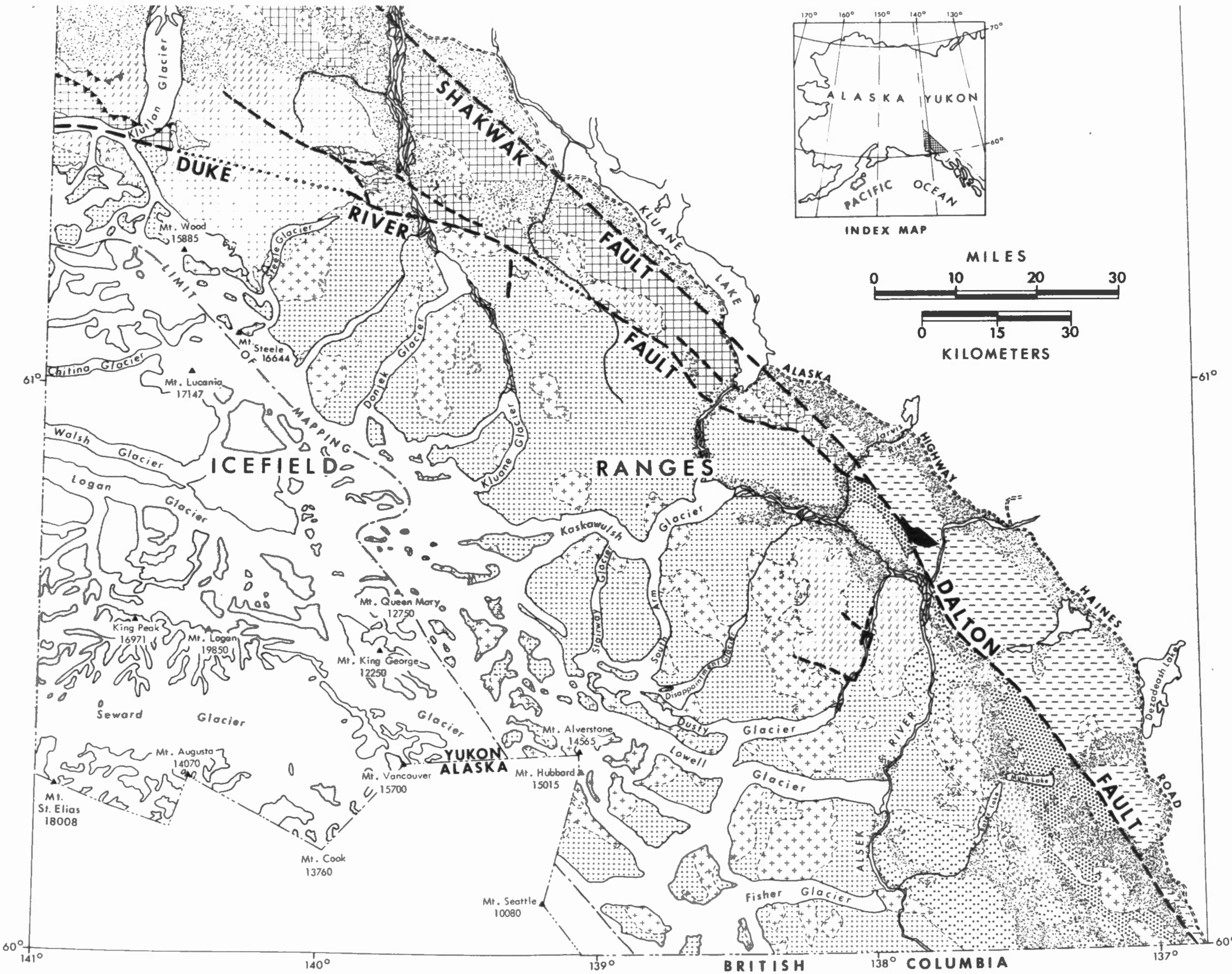
Figure 1

GEOLOGICAL MAP, ST. ELIAS MOUNTAINS, YUKON




SHAKWAK
FAULT
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INDEX MAP
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KILOMETERS
Kluane Glacier
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Chitina Glacier
Mt. Lucania
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Donjek Glacier
Walsh Glacier
Logan Glacier
ICEFIELD
RANGES
ALASKA
Jarvis River
HIGHWAY
Kaskawulsh Glacier
Stairway Glacier
South Arm
Disappointment Glacier
DALTON
FAULT
HAINES
ROAD
Dezadeash Lake
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King Peak
16971
Mt. Logan
19850
Mt. King George
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Seward Glacier
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Mt. Alverstone
14565
Dusty Glacier
Lowell Glacier
YUKON
ALASKA
Mt. Augusta
14070
Mt. Vancouver
15700
Mt. Hubbard
15015
Mt. St. Elias
18008
Mt. Cook
13760
Mt. Seattle
10080
ALSEK RIVER
Fisher Glacier
61°
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BRITISH COLUMBIA

4. OPERATION SAINT ELIAS, YUKON TERRITORY: THE MUSH LAKE GROUP AND PERMO-TRIASSIC ROCKS IN THE KLUANE RANGES

Project 720041

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The project was designed to study the stratigraphy, structure and economic potential of the Triassic and Jurassic (?) Mush Lake Group and underlying Permian rocks, that were thought to form much of the Kluane Ranges in Dezadeash (115A), eastern Mount Saint Elias (Kaskawulsh, 115B), and Kluane Lake (115F - G) map-areas. Field work demonstrated that the distribution of Permo-Triassic rocks in Kluane and Kaskawulsh map-areas is essentially as shown by Muller (1967) and Wheeler (1963). In the type area of the Mush Lake Group, however, rocks mapped by Kindle (1953) as Triassic and Jurassic (?) are of probable Ordovician and Devonian ages. Consequently, separate descriptions are given in this report of the Mush Lake Group of Kindle, here largely restricted to the Dezadeash map-area, and the Permo-Triassic rocks farther north.

Mush Lake Group

The Mush Lake Group (restricted) is separated from younger rocks to the north and northeast by, respectively, the Duke River and Dalton faults (Campbell and Dodds, preceding report, Fig. 1), and extends along strike for at least 70 miles, from Jarvis River in the Kaskawulsh map-area (latitude 60°50') to south of Dezadeash map-area (latitude 60°00').

Stratigraphy

The Mush Lake Group consists of approximately 20,000 feet mainly green, porphyritic and amygdaloidal meta-andesite flows, with intercalated tuff, volcanic breccia, grey phyllite, limestone and chert. Fossils from sediments interbedded with the flows indicate a probable Early to Middle Ordovician age for strata near Field Creek, approximately 12 miles southwest of Mush Lake, and probable Devonian age for rocks north and south of Mush Lake. These rocks underlie massive to thin-bedded limestone and dolomite, grey phyllite and phyllitic greywacke that extend over a vast area of the Icefield Ranges and are at least partly of Devonian age.

Near Field Creek dark green meta-andesite with plagioclase phenocrysts and chlorite amygdules underlie massive light grey limestone (Fig. 1). Towards the southwest, lenses of tuffaceous sediments up to 100 feet thick are intercalated with the flows. Above the limestone is an intensely folded volcanic sequence containing calcareous volcaniclastic rocks.

Between Mush Lake and Beloud Creek, the Mush Lake Group consists mainly of meta-andesite flows with discontinuous pillow lavas and volcaniclastic rocks (Fig. 2). Probable Devonian fossils were obtained from thin, bioclastic limestones low in the section at Sickle Creek, southeast of Mush Lake and 1¼ miles southeast of Johobo Mine. Beneath these limestones are dark grey phyllite and greywacke previously mapped with the Jurassic-Cretaceous Dezadeash Group.

Structure

At least two regionally extensive phases of folding deformed rocks of the Mush Lake Group. Late folds have northwest-striking axial planes with steep dips, and fold axes plunge steeply. Early folds are isoclinal with highly variable attitudes. Near Field Creek, massive grey limestone outlines a large late antiform plunging northwestward and exposing Ordo-

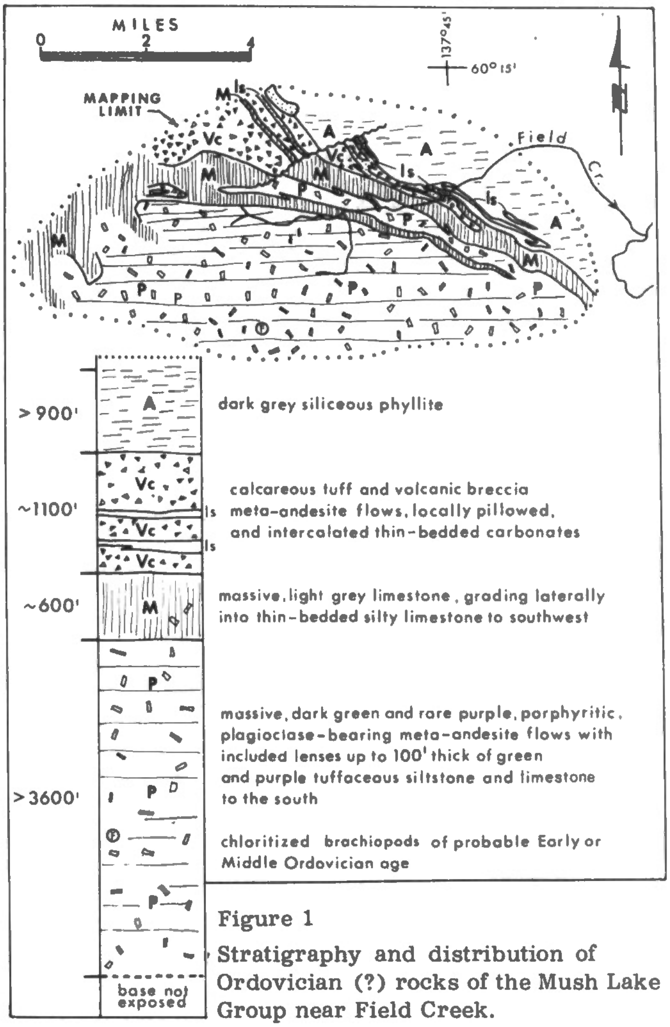


Figure 1
Stratigraphy and distribution of Ordovician (?) rocks of the Mush Lake Group near Field Creek.

[1]Consulting geologist: 4490 Angus Drive, Vancouver, British Columbia.

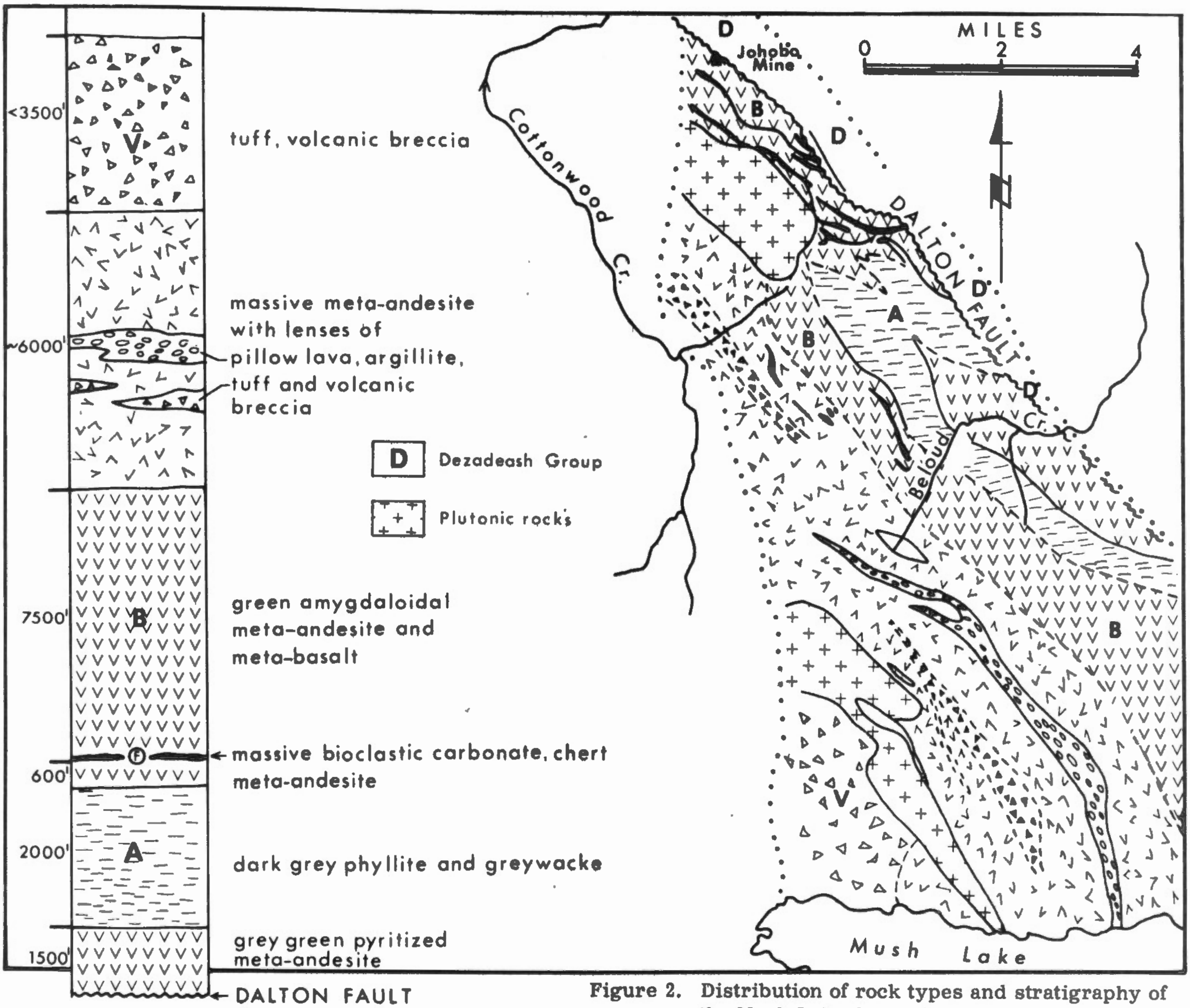


Figure 2. Distribution of rock types and stratigraphy of the Mush Lake Group in the type locality.

vician rocks in the core. Early isoclinal folds in this limestone mostly plunge moderately southeastward. The belt of Mush Lake Group from Jarvis River to Mush Lake forms the northeast limb of a northwest plunging syncline. The anticline exposed at the head of Cottonwood Creek is one of the parasitic folds on the early (?) regional fold.

The folds are cut by northwesterly striking Dalton and Duke River faults, whose latest movements are shown by slickensides to be subhorizontal.

Mineralization

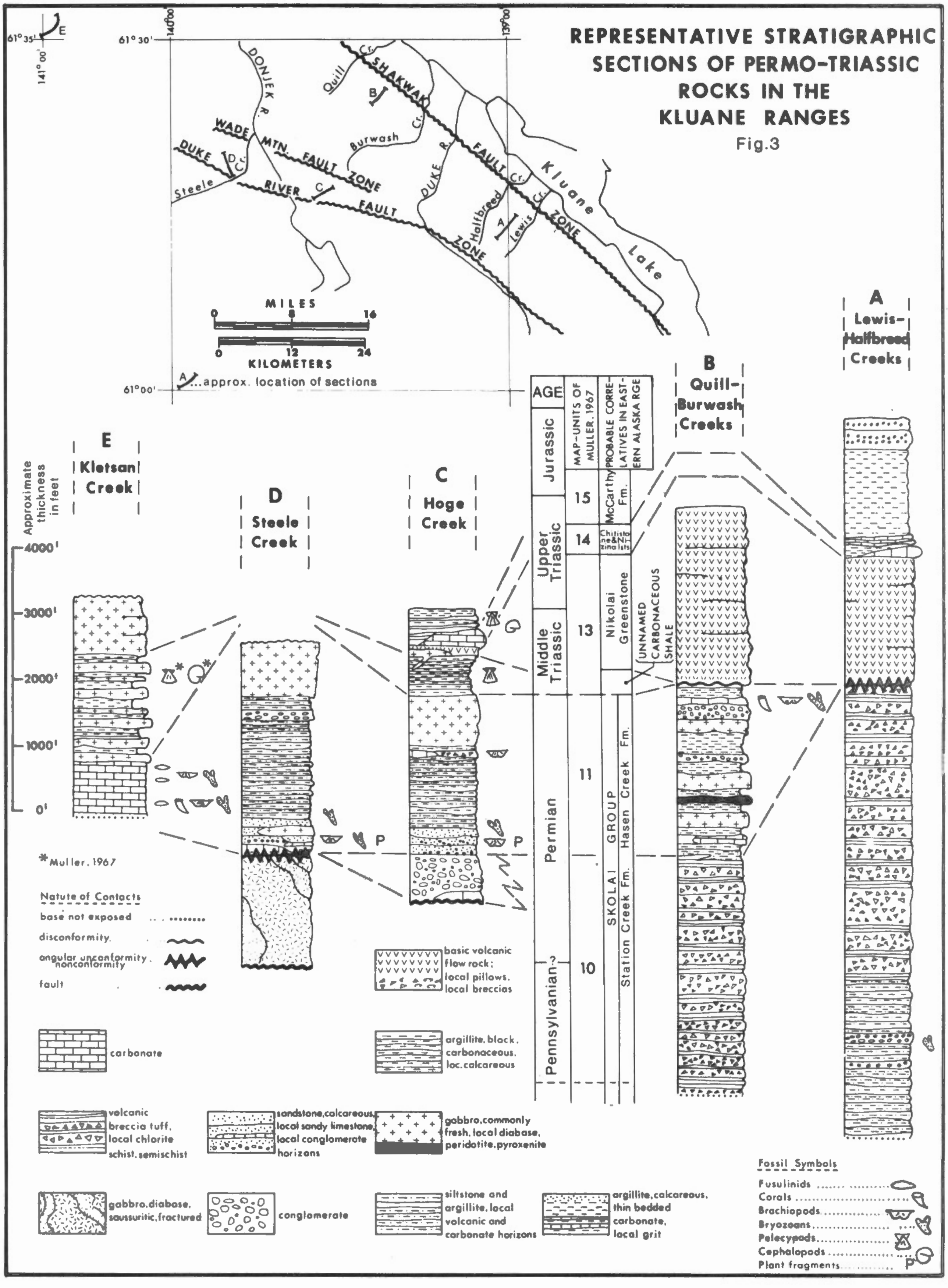
Mineralization is spatially restricted to certain rock types or structures. In the Dezadeash area, most copper showings in the Mush Lake Group lie within 4 miles of the Dalton Fault adjacent to intrusions. The Johobo Mine is within 1,000 feet of the Dalton Fault near the crest of an anticline outlined by sedimentary and volcanic rocks of the group.

Permo-Triassic and (?) older rocks

Permo-Triassic and (?) older rocks in the Kluane Ranges underlie an area extending for 125 miles along strike, from the Alaska boundary in the northwest (latitude 62°05') to Jarvis River in the southeast (latitude 60°50'), (Campbell and Dodds, preceding report, Fig. 1). The area is 35 miles wide in the northwest, and tapers to zero width near Jarvis River. Major faults, the Shakwak-Dalton on the northeast and east, and Duke River to the southwest, separate these rocks from, respectively, metamorphic and granitic rocks of the Yukon Crystalline Platform and Devonian and older (?) strata of the Icefield Ranges.

Stratigraphy

Six main stratified rock units, listed below in order of decreasing age, overlie and are cut by basic intrusive rocks of two and possibly three ages (Fig. 3).



REPRESENTATIVE STRATIGRAPHIC SECTIONS OF PERMO-TRIASSIC ROCKS IN THE KLUANE RANGES

Fig. 3

The stratigraphy correlates well with upper Paleozoic - lower Mesozoic stratigraphy described by Smith and MacKevett (1970), and Richter and Jones (1973) from the eastern Alaska Range.

(1) Permian and (?) older volcanic rocks, exposed extensively in the eastern part of the Kluane Ranges and near the Alaska boundary at latitude 61°30' are grey-green fine-grained, well-bedded, crystal lithic tuff and volcanic breccia containing clasts of saussuritic basalt, pyroxene or hornblende porphyry and feldspar porphyry and rare, locally pillowed, flow rocks. Near the Shakwak and Wade Mountain fault zones, these rocks grade locally into chlorite schists and semischists, and they are probably the primary rock for much of the amphibolite and dioritized 'greenstone' associated with granitic rock in the belt between the Generc River and the easternmost Kluane Ranges (part of map-unit 17 of Muller, 1967). Commonly these are the oldest rocks in the area between the Duke River and Shakwak faults (Fig. 3, Sec. B), but between Halfbreed and Quill Creek (Fig. 3, Sec. A), the volcanic rocks are apparently underlain by a sedimentary sequence.

(2) Permian sedimentary rocks exhibit three main lithofacies. Most abundant, but most deformed and extensively cut by gabbro and peridotite, are argillite, siltstone, less-common chert, graded-bedded sandstone, chert pebble conglomerate and thin limestone in the easternmost Kluane Ranges (Fig. 3, Sec. B). Southwest of the Wade Mountain Fault zone is a well-preserved sequence of basal, locally brown to orange crossbedded calcareous sandstone, sandy limestone and minor chert pebble conglomerate, dominant thin-bedded siltstone and argillite, with lenses of volcanic rock and carbonate near the top (Fig. 3, Secs. C, D). In contrast to the eastern section, which conformably lies on Permian and (?) older volcanic rocks, the sequence near Steele Creek lies nonconformably on gabbro and diabase and near Hoge Creek conformably on maroon to green pebble to boulder conglomerate containing clasts of gabbro, pyroxenite, basic volcanic rocks and chert. Near Kletsan Creek (Fig. 3, Sec. E), the Permian section is represented by thick-bedded, crinoidal calcarenite and calcarenitic limestone.

(3) Middle Triassic argillites, characterized by their black colour and carbonaceous content, are locally calcareous and nodular. These rocks are known from southwest of the Wade Mountain Fault zone and near Kletsan Creek, but have not been positively identified in the eastern Kluane Ranges.

(4) Triassic volcanic rocks are mainly red-brown, massive amygdaloidal basalts with pillow lava and breccia near the base of the sequence. Individual flows can rarely be recognized except south of Kletsan Creek on the Alaska boundary (latitude 61°34') where flow tops are marked by breccias and red horizons. Fine-grained amphibolite and dioritized 'greenstone' immediately northeast of the Wade Mountain Fault zone (part of map-unit 17 of Muller, 1967), is a metamorphosed equivalent of this unit. Southwest of the Wade Mountain Fault zone the Triassic volcanic rocks are thin and discontinuous but elsewhere they are up to 3,000 feet thick.

(5) Upper Triassic limestone is commonly massive but is locally thin bedded near its stratigraphic top. Topographically prominent, it makes a useful marker horizon, but in places is a series of lenses rather than a continuous unit.

(6) Upper Triassic and (?) Jura-Cretaceous clastic rocks are mainly argillite, but have a characteristic basal unit consisting of thin limestone beds in argillite. Upward they contain lenses of grit and, rarely, conglomerate.

Basic intrusive rocks in this area are of two, possibly three ages. Massive, fractured, green gabbro, pegmatitic gabbro and diabase nonconformably underlie Permian strata (Fig. 3, Sec. D) as first suggested by Sharp (1943). Intrusive relationships of this gabbro are not known, as it is apparently in fault contact with Devonian strata across the Duke River Fault. Most common are relatively fresh, grey to grey-green, locally columnar jointed gabbro sills, commonly concordant with bedding. In places peridotite sills associated with the gabbro show ambiguous cross-cutting relationships suggesting they are the same age as the gabbro. As these sills cut all rocks up to and including the Triassic basic volcanic unit, but not younger rocks, they are perhaps genetically related to the volcanics. Finally, rusty weathering, dark grey to black basalt and diabase sills cutting Middle Triassic rocks south of Kletsan Creek are possibly feeders to late Tertiary lavas in the area.

Structure

Permo-Triassic and (?) older strata are folded and faulted. Folds commonly trend northwesterly and may be tight or open, and major folds generally have subhorizontal fold axes. Many fault surfaces carry subhorizontal slickensiding, indicating strike-slip movement, and close to such faults, plunges in mesoscopic folds may be steep. Some faults at least are very young. Near Kletsan Creek, Permian strata are thrust over upper Tertiary volcanics and near Steele Creek and Donjek River, faults cutting Permian strata and pre-Permian gabbro can be traced laterally into folds and faults affecting adjacent upper Tertiary volcanics.

Economic Geology

Small malachite and azurite showings are present in nearly all rock units described above, but are particularly abundant in the Triassic volcanic rocks. On the upper canyon of the White River, recent exploratory adits in the Triassic volcanics reveal scattered occurrences of native copper, chalcocite and rarely, bornite. Nickel-copper deposits near Quill Creek, along the contacts between the Permian sedimentary rocks and gabbroic intrusives, are currently being studied as a University of British Columbia thesis project.

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5\. INTEGRATED STUDIES ON MINERAL RESOURCE APPRAISAL IN THE BEECHEY LAKE BELT OF THE NORTHERN SHIELD

Project 730009

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The appraisal of mineral resources has, for a variety of reasons, become of increasing concern to governments. The concept of the exhaustion of nonrenewable commodities in the not too distant future, most vigorously propounded in the "Club of Rome" report, has attracted criticism from earth scientists. Whatever the merits of this criticism, this work has served as a powerful catalyst to more serious study of the future availability of mineral resources. The "energy crisis" has more recently focussed attention on the gap between anticipated demand and supply of petroleum and also uranium (Nininger, 1974; Darnley, 1974).

Mineral resource appraisal is not, of course, a new field. Indeed, the appraisal of the mineral potential of an area or prospect has always been the essential first stage in exploration. What is novel in some recent studies is that an attempt has been made to quantify the appraisal. This may be called mineral resource estimation. In Canada there has been two principal approaches to mineral resource estimation. In the first, statistical methods have been used to integrate a variety of expert opinion on a region (e.g. Barry and Freyman, 1970). The second has emphasized geomathematical analysis of existing geological data (e.g., Agterberg *et al.*, 1972).

These two approaches have validity for the better explored parts of Canada. For more remote areas, however, there is generally insufficient geoscience information on which to base estimates. For these regions a preliminary requirement is to acquire the necessary data. There is some advantage to this, for the investigator may choose to obtain the data most appropriate to his need. It is inevitable that the methodology used to acquire these data will differ little from those used in mineral exploration, including geological, geophysical and geochemical surveys and even some drilling (Darnley, 1974). There is, however, an important difference between this type of resource estimation and mineral exploration. In the former, the knowledge gained by the detailed investigation of a few anomalies will be used to obtain probabalistic estimates of the mineral potential of many other anomalies in the same region or geological environment. This project was concerned with such a detailed investigation of geochemically anomalous area in northern Canada.

Since 1969 the Geochemistry Section has been developing methods of geochemical reconnaissance for the northern Shield based on lake sediment sampling. In 1972 a full-scale test survey was carried out over 36,000 square miles of the Bear and Slave Provinces of the Shield (Allan *et al.*, 1973). A sample density of one per ten square miles was used. This survey proved the approach to be rapid and economical and the data correlated well with the known distribution of mineralization (Allan *et al.*, 1972; Cameron and Allan, 1973). However, as a relatively new technique, there was some hesitancy in interpreting anomalies not associated with known mineralization. Also there was a need to convert the geochemical data into a form suitable for resource estimation.

To answer the first of these questions, a follow-up study was carried out in the summer of 1973 to investigate anomalies in the eastern part of the Slave Province (Cameron and Durham, 1974a, 1974b). The study showed that an important group of multi-element anomalies (principally Zn-Cu) were associated with previously unmapped volcanic rocks. One interesting target, believed to contain zinc-, copper-, lead-, silver-, and gold-bearing massive sulphides, was identified (the Agricola Lake, or "Y" anomaly).

This anomaly was chosen in 1974 for detailed geological, geophysical and geochemical studies. The principal objective was to investigate the most suitable methods for follow-up and interpretation of lake sediment anomalies. However, the scope of the work was broadened to allow a fairly complete "case history" examination of exploration methods on the permafrost environment of the northern Shield. In addition, the geochemical party took the opportunity to assess the feasibility of operating a sophisticated geochemical laboratory in a quite remote location; to study the extent of present-day oxidation of sulphide bodies; and to investigate hydro-geochemical methods of exploration. During the summer aerial colour photography was obtained for the western margin of the Beechey Lake belt. As well as being of value for studies in the Agricola Lake area, this photography should be most useful for geological mapping and mineral exploration within the metavolcanic terrane of this belt. Further studies were carried out on the Lineament Lake uranium anomaly (Cameron and Durham, 1974b). The Canada Centre for Inland Waters of the Department of the Environment used the base camp for preliminary studies on Arctic limnology.

Subsequent to Open File release of the 1973 field data (Cameron and Durham, 1973), a number of companies staked along the western margin of the Beechey Lake belt. This staking was mainly over metavolcanic rocks. During the 1974 field season, the Yava Syndicate (Conwest Exploration - Brascan Resources Ltd. - S.M. Roscoe) carried out surveys on the Agricola Lake area and drilled five holes into the geochemical target (Fig. 1).

Figure 1 shows the location of the various studies. All were centred on the "B" horizon massive sulphide prospect delineated in 1973. The geochemical soil study, the V.L.F.-resistivity, and the high sensitivity magnetometer surveys were carried out over the same 600 m by 375 m area. These three surveys used a 30 m by 15 m interval grid surveyed by transit and chain. The gravity survey was made over a rather larger area using an independently surveyed grid. Rock samples were collected from a still larger 1,560 m by 780 m area. In addition, water samples were collected from most lakes and streams in the Agricola Lake and Friday Lake drainage systems. Deep lake sediment samples were taken from the lakes to compare with the nearshore sediment samples collected in previous years. During this field season lake waters were collected and

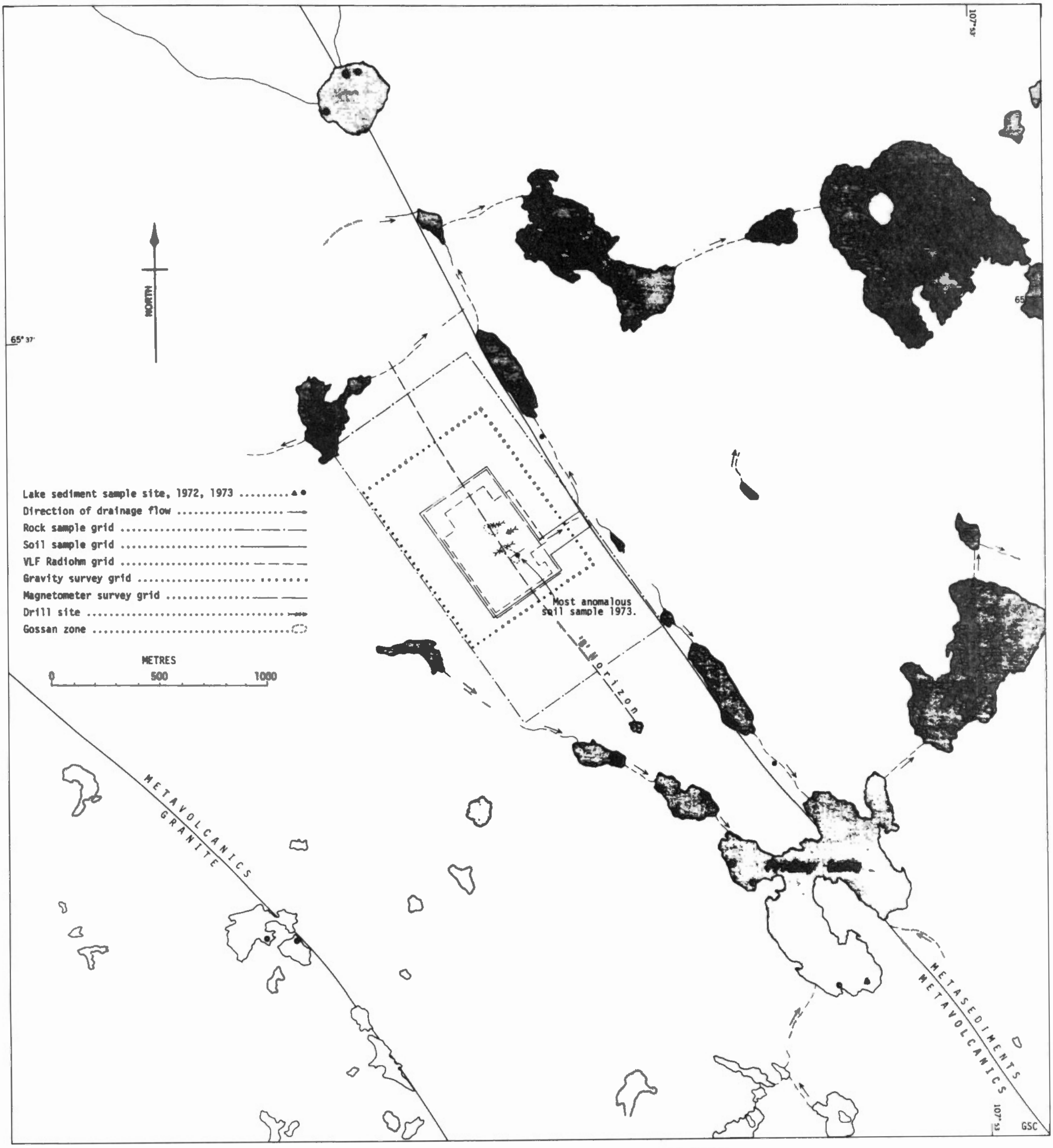

Figure 1. Study area, Agricola Lake, N.W.T.

analyzed from a 900-square-mile region around High Lake, 150 miles north-northwest of Friday Lake; from a 750-square-mile area around Agricola Lake; and from the Hackett River area 26 miles to the north-northwest.

Figure 2 is a geological map of the area of soil, V. L. F., and magnetometer surveys. It was prepared by A. Williams. This is an interim map, based on field information only. The geophysical studies, reported later in this volume, suggest a number of changes, mainly in the less well exposed parts.

Rock exposure is generally excellent in this area, overburden being thin in most places. This is flat country that might, in the absence of lakes, be described as featureless. The volcanic rocks produce the greatest relief, but even this rarely exceeds 30 m. The most obvious features of glaciation are eskers. These trend parallel to the dominant north-northeast strike of the rocks.

The area of soil, V. L. F. and magnetometer surveys is basin-shaped. The low ground in the centre is underlain by hydrothermally altered acidic to intermediate volcanic rocks and by exhalative sulphides of the "B" horizon (Cameron and Durham, 1974a, 1974b). The soils overlying the sulphides are of a buff, gossanous colour. Pyrite is very abundant in this area. Despite intensive search by a number of geologists, only trace quantities of sphalerite, chalcopyrite and galena were found at the surface. Since the drilling by the Yava Syndicate indicates that these minerals exist in quantity at depth, they have clearly been thoroughly oxidized at the surface.

The papers that comprise this section were compiled from data that were obtained in the field or became available shortly thereafter. The various

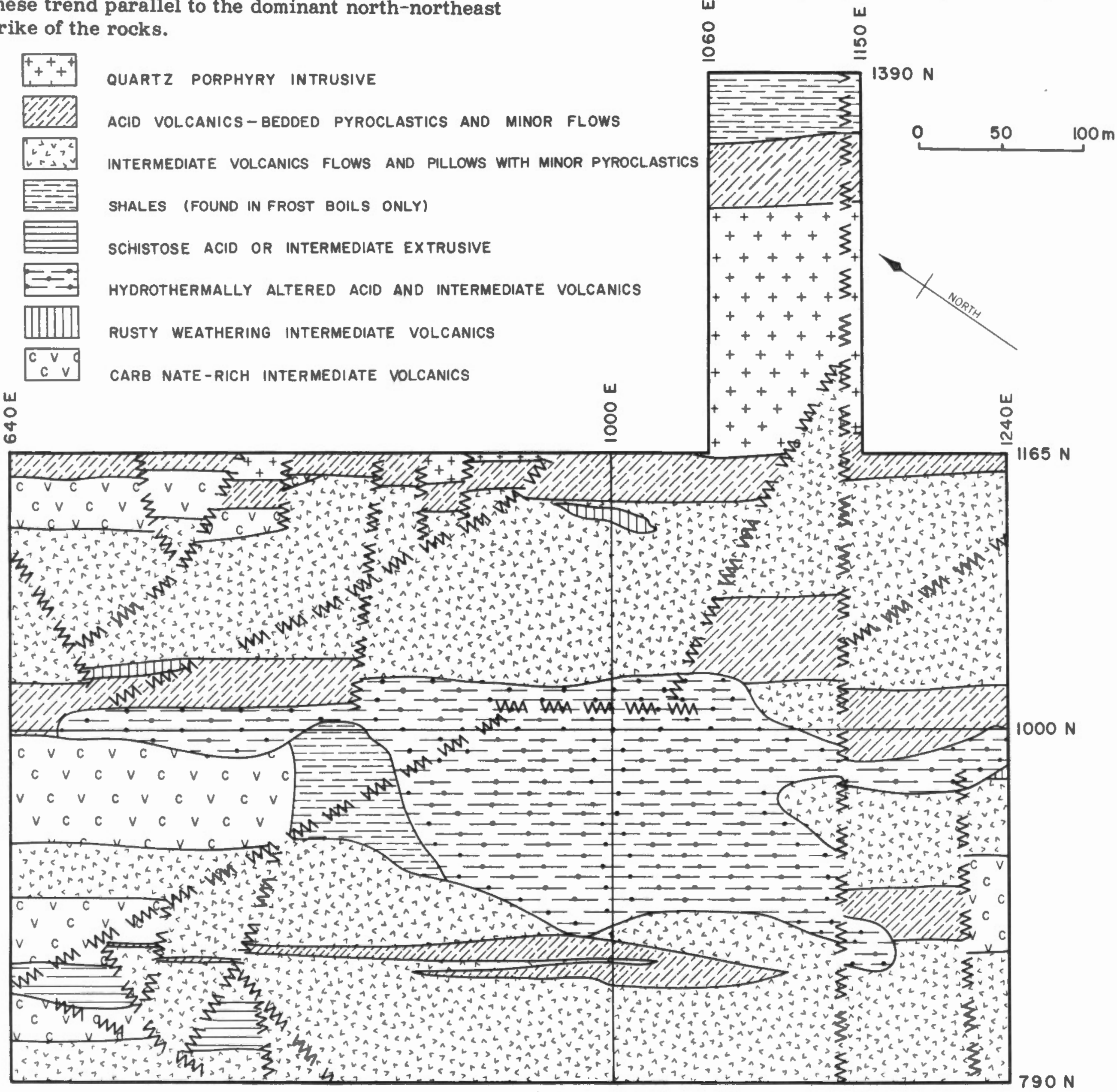

Figure 2. Geological map of the Agricola Lake massive sulphide prospect. Boundaries as for soil sample grid (Fig. 1).

authors have had little chance to compare their data with that of the others. Thus, no attempt has been made to synthesize the results. This will be done at a later date. However, these initial reports show that each method has some unique information to contribute to the understanding of the geological environment. Most important, the studies show that this northern permafrost environment is not as inimical to modern methods of mineral exploration as had previously been feared.

Camp was established on the northeastern shore of Friday Lake (Fig. 1). This is approximately 300 miles northeast of Yellowknife, the supply base. The camp was established after break-up in late June and was occupied by the geochemical staff until the onset of winter conditions in mid-August. The other investigators visited the camp for shorter periods, during breaks in their other field programs.

The main geochemical-geological party comprised:

E.M. Cameron, party chief
C.C. Durham, deputy party chief
R.E. Horton, chief analyst
Miss E. Ruzgaitis and Miss S. Costaschuk, analysts
S.B. Ballantyne, hydrogeochemical sampling
D. Lefebvre (Queen's University), geological mapping
A. Williams, senior assistant, geological mapping and rock sampling
J. Thomas and J. Spence, sampling, sample preparation
Miss M.J. McKay and Miss M. Coutts, cook and cook's helper
R. Watson, helicopter pilot and engineer.

The following persons visited the camp for shorter periods:

J.B. Boyd and E. Garrison (Earth Physics Branch), gravity (July 9-23)
J.B. Henderson and J. Osler, geological studies (July 9-19)
W. Dyck, uranium geochemistry (July 9-23)
I.R. Jonasson and R. Benson, sulphide mineral studies (July 9-23)
W.J. Scott and D. Eberle, V.L.F.-resistivity (July 19-26)
J.D.H. Williams (D.O.E.), limnology (July 19-29)
L.J. Kornik, magnetometry (August 7-11)
V.R. Slaney, aerial colour photography (based at Tundra Mine airstrip).

The author wishes to thank Dr. Arthur Darnley, for stimulating an interest in a multidisciplinary approach to resource evaluation. Mr. Robert Hornal has both encouraged and facilitated the work. Dr. S.M. Roscoe, Mr. K. O'Connor, and Mr. B.K. McKnight have provided useful comments on our interpretations of data obtained on the Yava claims. The field logistics were largely organized by Mr. Chris Durham. Finally, I am greatly indebted to my colleagues from a variety of fields who have so enthusiastically cooperated in this study.

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6. A GRAVITY INVESTIGATION WITHIN THE AGRICOLA LAKE GEOCHEMICAL ANOMALY, DISTRICT OF MACKENZIE

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Introduction

Follow-up studies (Cameron and Durham, 1974a, b) in 1973 of a prominent Cu-Zn geochemical anomaly delineated by a regional lake sediment survey in 1972 (Allan *et al.*, 1973) outlined several targets for more detailed investigation. The targets occur within intermediate to acid volcanic strata of the Archean Beechey Lake sedimentary-volcanic belt which is the main belt in the eastern part of the Slave Province (Cameron and Durham, 1974b). One target in particular, located along a prominent gossan horizon, possessed several characteristics of stratabound, volcanogenic, massive sulphide mineralization. This target was selected for multidisciplinary study using a variety of geochemical and geophysical methods. Detailed geological mapping and airborne colour photography were also carried out. All of these activities were undertaken in the summer of 1974, during which time a massive sulphide body containing copper and zinc together with other metals was proved through drilling by the Yava Syndicate holding extensive claims in the area (Northern Miner, 1974). This report describes the results of the application of one geophysical technique, namely gravity, to the problem of orebody detection and appraisal.

The Gravity Survey

A primary grid for the gravity survey was chosen on the basis of the geochemical and geological findings of the 1973 follow-up studies. Five profiles spaced at 300 m intervals and of 700 m or 750 m lengths were selected normal to the gossan zone and local geological strike. The profiles were connected by an orthogonal base line running more or less along the gossan horizon. Shorter fill-in profiles were traversed in the latter part of the survey after examination of the initial data.

A total of 159 gravity stations were occupied comprising 10 regional stations and 149 traverse stations. The majority of the latter are indicated in Figure 1, but some have been omitted for clarity of presentation. Traverse stations are normally 50 m apart, but as close as 10 m in some cases. A LaCoste and Romberg geodetic gravimeter No. G-88 was used for all the observations, which were tied to a local gravity datum established by helicopter ties to the control stations of the national gravity net.

Stations were positioned along the grid by transit and slope-corrected chainage. Since there were no geodetic control monuments in the vicinity, the horizontal control survey was tied to a point (identified on NTS map-sheet 72G) with geographical coordinates — latitude 65°35.6' and longitude 107°54.2'. Elevations were obtained by spirit level using a local datum tied to a Department of National Defence spirit level line located some 30 km east of the survey area. This tie was obtained by repeated barometer readings; the elevations of the 10 regional stations were also obtained barometrically.

The adjusted observed gravity values for the traverse stations are relatively accurate to ±0.03 mgal, elevations to ±3 cm and horizontal positions to ±2 cm.

The gravity data were reduced to the common datum of sea level using a uniform density of 2.67 g/cm^3. Terrain corrections were not computed, but since the terrain is relatively flat any error from this source is considered negligible. The Bouguer anomalies shown in Figure 1 have an accuracy of ±0.1 mgal; the regional stations which lie outside the area of Figure 1 have an accuracy of ±1 mgal.

Geology and Rock Densities

Geology

A detailed geological account and map of the area is presented elsewhere (Cameron, preceding paper, Fig. 2). In summary, the rocks in the area of the gravity survey comprise a more or less vertically-dipping sequence of intermediate to acid volcanics striking north-northwest, which are believed to become younger towards the northeast (Cameron and Durham, 1974b). They have been metamorphosed to greenschist to low amphibolite facies, and as a result the original mineralogical composition and textural features have been altered, making microscopic identification extremely difficult (Turay, 1974). However, chemical identifications of the rocks indicate compositions ranging from andesitic through dacitic to rhyolitic (op. cit.).

The detailed geological map was incomplete at the time of analyzing the gravity anomalies and only a simplified picture of the geology was available through the descriptions of Cameron and Durham (1974a, b) and from selected rock samples collected by the Geological Survey of Canada in the summer 1974 work.

A simplified geological map based on 97 rock samples is superimposed on Figure 1; the locations of the samples are also indicated. On the basis of hand sample identification the majority (79) of the samples are classified into three main groups indicated as A, B and C on Figure 1. Another 9 samples (group D) appear to be a slightly more acidic variety of B. Brief descriptions of the three main rock-types based on macroscopic and microscopic (one thin section of a representative sample of each group was used) examination follow.

Group A. Dark grey, medium to fine grained in hand specimen. Contains approximately 80% hornblende, apparently of secondary origin. Tentatively identified as an AMPHIBOLITE, probably originally an intermediate to basic intrusion.

Group B. Medium to dark grey, fine grained in hand specimen. Contains abundant sericite, epidote, biotite, quartz and opaques. Feldspar is likely present but is indistinguishable from quartz. Ghost areas of differing texture suggest altered fragments of phenocrysts. Tentatively identified as a recrystallized VOLCANIC TUFF.

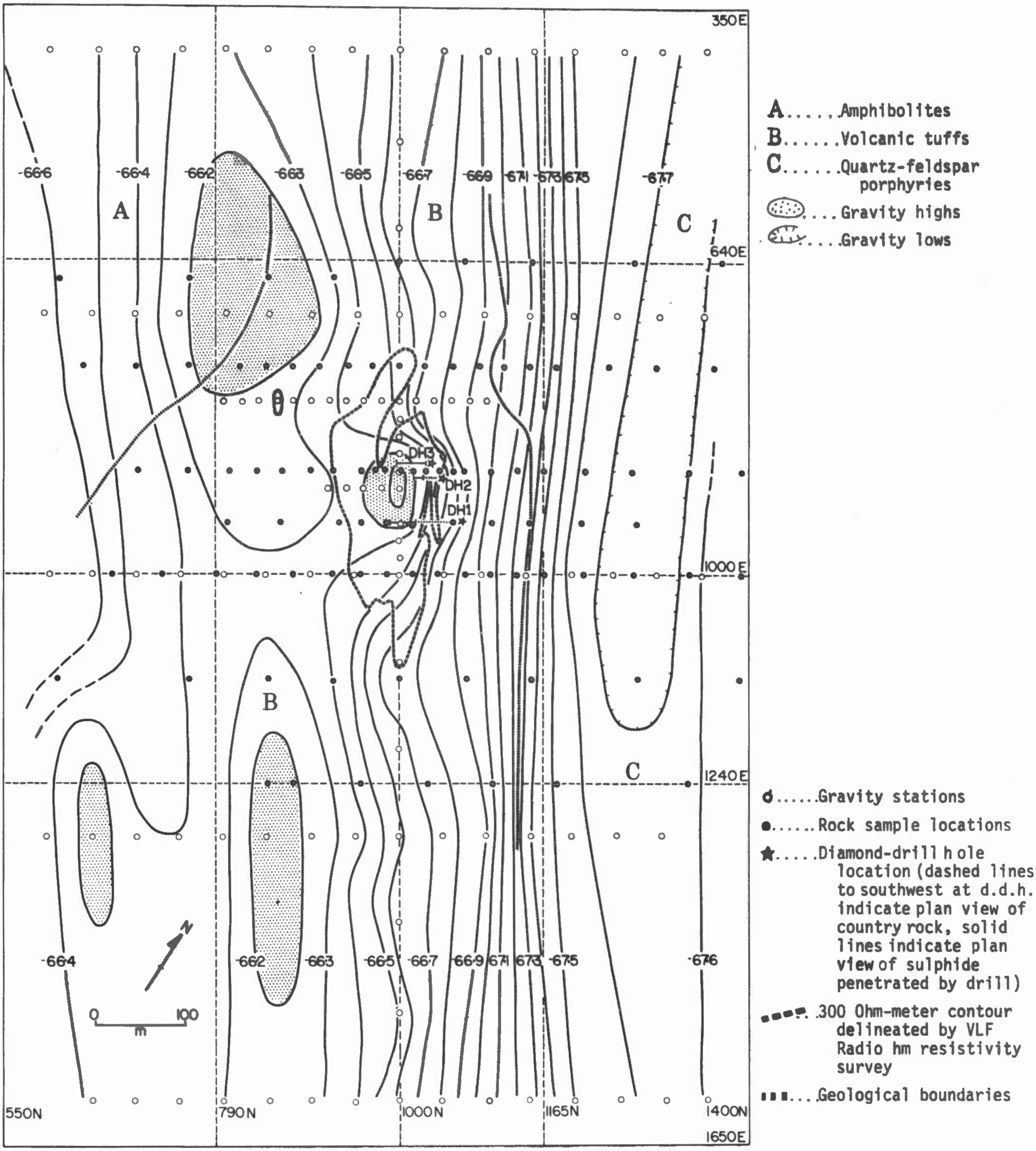

Figure 1. Bouguer anomaly map.

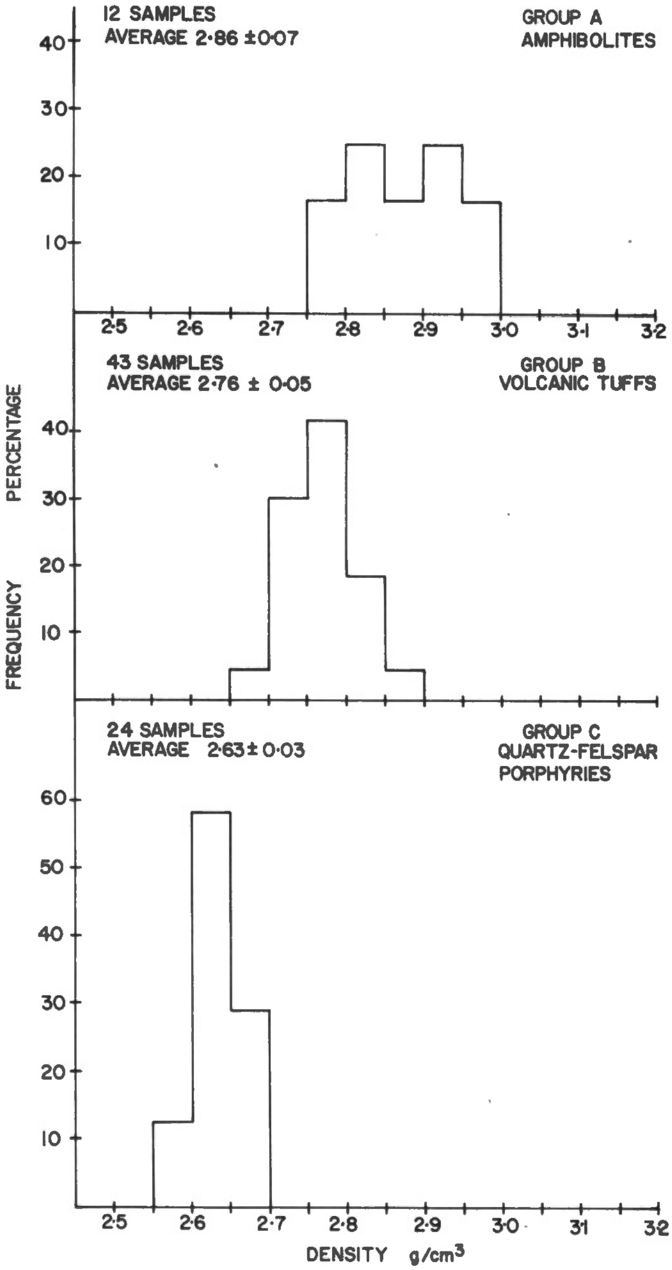

Figure 2. Histograms of rock densities. Average density and standard deviation of each group in g/cm^3 are indicated.

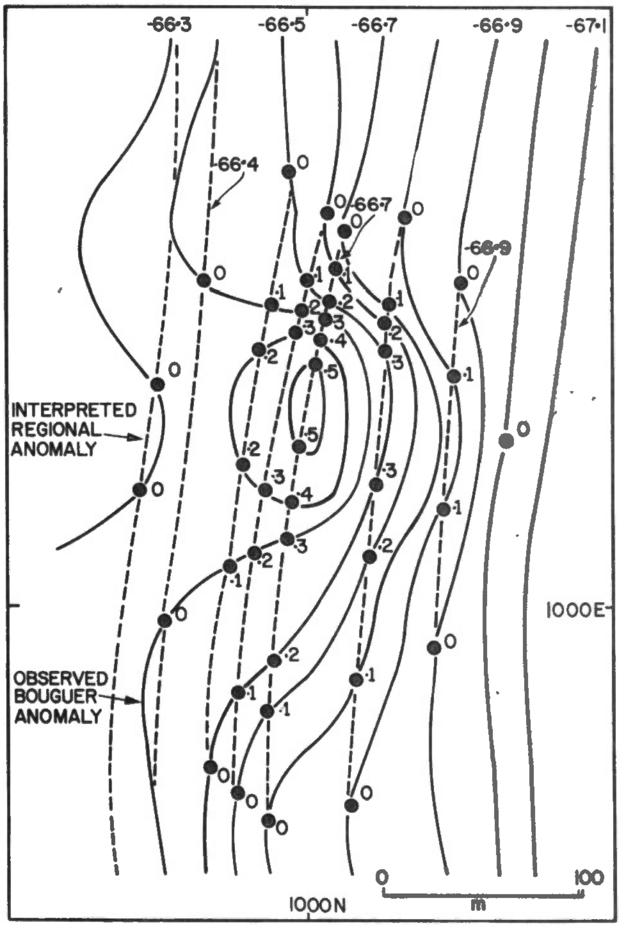

Figure 3. Observed gravity field and interpolated gravity field used to obtain residual gravity anomaly over sulphide body. Solid circles with values (in mgal) indicate point differences between the two gravity fields.

Group C. Light to medium grey, porphyritic texture in hand specimen. Quartz and plagioclase and probable K feldspar phenocrysts; feldspars are cloudy and sericitized. Identified as a QUARTZ-FELDSPAR PORPHYRY.

Rock Densities

A summary of rock density measurements on the samples of groups A, B, C and D, as well as of samples of mineralized material (sulphides) obtained from the Yava Syndicate's diamond drillhole No. 1 (DH1) (*see* Fig. 1 for position) is given in Table 1.

Histograms of densities for groups A, B and C are presented in Figure 2. The normal distributions and small standard deviations of B and C reflect the high degree of homogeneity of the densities of these rock types, and to a certain extent support the identifications and grouping. Certainly, as density groups for gravity interpretations they are well defined. The histogram for A is bimodal and this is believed to result in part from misidentification between the finer grained samples of group A and the samples of group B. The average densities of groups A, B and C are consistent with those expected for basic, intermediate and acidic volcanic rocks respectively. This consistency has been supported by microscopic studies for groups A and C; it seems likely, therefore, that group B is of intermediate composition.

Some mineralogical and density data pertaining to the sulphides are presented in Table 2. The percentages quoted in the table for the various minerals and host rock are based on macroscopic examination of very small (∿25 g) samples.

Table 1

Summary of rock density data

Lithology	No. of Sample	Average Density and Standard Deviation g/cm^3	Range of Densities g/cm^3
A	12	2.86 ± 0.07	2.75 - 2.96
B	43	2.76 ± 0.05	2.68 - 2.88
C	24	2.63 ± 0.03	2.56 - 2.69
D	9	2.69 ± 0.03	2.62 - 2.72
Mineralized Rock	7	3.45 ± 0.26	3.04 - 3.78

Table 2

Characteristics of mineralized rock from DH1

*Depth	Mineralogy	Density (g/cm^3)
72.5	Sp. 55%, Py. Trace, Ho. 45%	3.39
76.5	Sp. 10%, Py. 25%, Ho. 65%	3.45
79.6	Sp. 5%, Ch. 5%, Ho. 90%	3.14
81.2	Ph. 65%, Ho. 35%	3.78
86.9	Sp. 5%, Ho. 95%	3.04
87.8	Sp. 65%, Ch. Trace, Ho. 30%	3.64
114.3	Ph. 60%, Ho. 40%	3.72
	Average Density	3.45 ± 0.26

*Depths are in metres from surface along the length of the drill core which is inclined at 45°.
Ch. - Chalcopyrite, Ho. - Host rock, Ph. - Pyrrhotite, Py. - Pyrite, Sp. - Sphalerite.

Discussion of Gravity Anomalies

A Bouguer anomaly map of the area contoured at 0.1 mgal interval, is presented in Figure 1 superimposed on the simplified geological map based on the rock density samples. The anomalies do not vary by more than 1.5 mgal over the whole area. The gravity contours trend dominantly north-northwestwards reflecting the prevailing geological strike. The general pattern of anomalies is that of a broad gravity high overlying the southwestern two-thirds of the area separated by a narrow belt of steep gradients from a low amplitude gravity low lying along the northeastern margin of the area.

The belt of steep gradients correlates extremely well with the junction between the volcanic tuffs (B) and the quartz-feldspar porphyries (C) and may be directly attributable to the marked density contrast (0.13 g/cm^3) between the two groups; the quartz-feldspar porphyries being the lighter lithology are associated with the lower Bouguer anomalies. An explanation of the broad gravity high in terms of the mapped geology is not as readily apparent, either by comparison of the anomaly with the detailed geological map (Cameron, preceding paper) or the simplified map (Fig. 1). However, there are limited correlations between rock density, geology and gravity anomaly which suggest that amphibolitic rocks (average density 2.86 g/cm^3), possibly together with carbonate rocks, in contact with volcanic tuffs (average density 2.76 g/cm^3) are the main source of the anomaly.

A local gravity high is present within the vicinity of the mineralized zone, and is manifest in the bulging of the gravity contours towards the northeast and in a closure of the contours over the zone. This high corresponds in position with a prominent VLF Radiohm electrical resistivity anomaly (*see* Fig. 1). The results of the VLF Radiohm survey are described elsewhere (*see* Scott, this publication, paper 64). It is important to note that the control for contouring the gravity field in the area immediately northeast of the zone is extremely poor, since gravity observations were not made northeast of grid line 1000N in this vicinity. Contour positions in this area were therefore obtained by interpolating between the -67.0 mgal contour line and the base line station value at the end of the shortest gravity profile.

Because the gravity high associated with the mineralized zone is superimposed on the flank of the

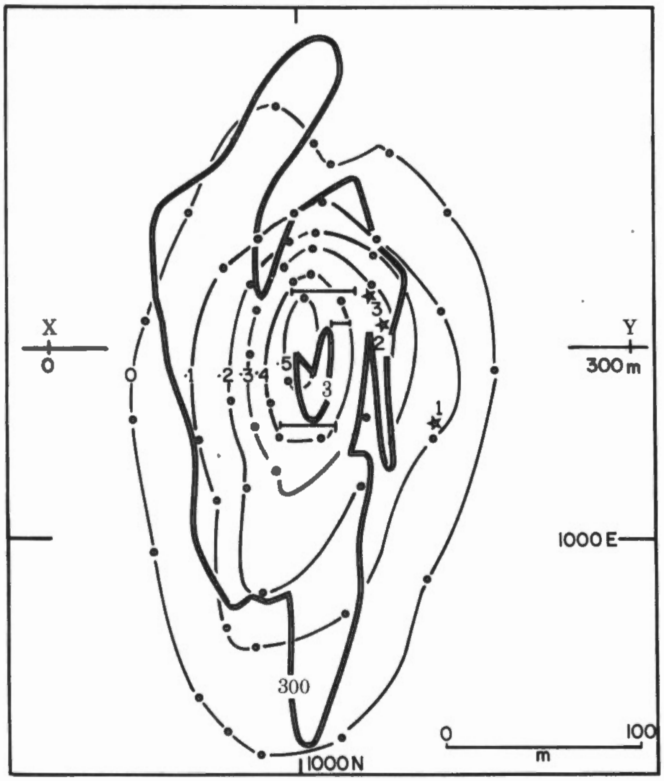

Figure 4. Residual gravity anomaly. Solid circles correspond to solid circles in Figure 3. Contour values are in mgal. Dashed lines represent VLF Radiohm resistivity contours. Stars indicate drill hole positions. Solid bars indicate plan views of sulphides as proved by drilling.

more extensive broad high attributed to amphibolitic rocks an estimation of its amplitude is somewhat difficult. It has been necessary, therefore, to remove a background anomaly, in order to portray more clearly the gravity effect of the mineralization.

A residual gravity anomaly was obtained by removing a background gravity field using a simple graphical method. The method, outlined below, is appropriate in the present case because the gravity contours to either side of the mineralized zone have similar gradients and are essentially linear and on strike with each other. Gravity contours interpolated from the linear belts on either side of the disturbed field were constructed (*see* Fig. 3) and the interpolated field was subtracted from the observed field at the points of mutual intersection of the fields. The point values obtained in this manner were then contoured to produce the positive residual gravity anomaly outlined in Figure 4.

The residual gravity anomaly is approximately elliptical in plan with major axes of lengths 320 m and 180 m, and is symmetrical about the major axis. The maximum values occur over the northwestern half of the anomaly where the 0.5 mgal anomaly defines the peak closure.

The close correlation in position between the gravity anomaly and the electrical resistivity anomaly indicated in Figure 1 is even more clearly demonstrated in Figure 4 where the 300 and 3 ohm-metre contours of the VLF Radiohm survey are outlined. The latter contours define respectively the perimeter and peak of the conductivity anomaly. There is a remarkable correlation between the lengths of the gravity and resistivity anomalies and in the positions of their peak values and axes.

The coincidental positions of the peaks of the anomalies suggest a number of possibilities; the mineralization is more concentrated in this location (gravity and resistivity indications); the mineralized zone is wider (resistivity); the mineralized zone is wider and/or deeper (gravity); or a combination of all these possibilities.

The close association between the gravity and resistivity anomalies taken together with the results from the other surveys (this section) and the drilling (Northern Miner, 1974) is a favourable indicator for the presence of a massive sulphide body. An idea of the minimum horizontal extent of this body may be obtained from the lengths of the anomalies themselves. Evaluation of the subsurface extent of the body may be accomplished by gravity modelling. It is intended to provide gravity model interpretations and estimates of the mass of the body in a future detailed presentation of the results.

Acknowledgments

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The Yava Syndicate is acknowledged for its cooperation in providing the drill core material for density measurements.

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7. SOIL GEOCHEMISTRY OF THE AGRICOLA LAKE MASSIVE SULPHIDE PROSPECT

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The soil sample grid is centred over the "B" horizon massive sulphide prospect. Survey lines, normal to this horizon and to the strike of the volcanics, were established at 30-m intervals. Soil samples were collected at 15-m intervals along these lines. The main part of the soil grid extends from 640 E (metres) to 1240 E and from 790 N to 1165 N (Fig. 1). For the four lines 1060 N to 1150 E, the sampling was extended to 1390 N. This extension is over a stream draining the prospect; these additional soils were sampled to study dispersion along this drainage channel.

The geology of the soil study area is shown elsewhere (Cameron, this section, Fig. 2). It is situated in the upper part of the near vertical-dipping volcanic sequence. The 1165 N boundary is roughly coincident with the lower contact of the quartz porphyry sill. The "B" (exhalative) horizon (Cameron and Durham, 1974a, 1974b) runs parallel and close to the 1000 N base

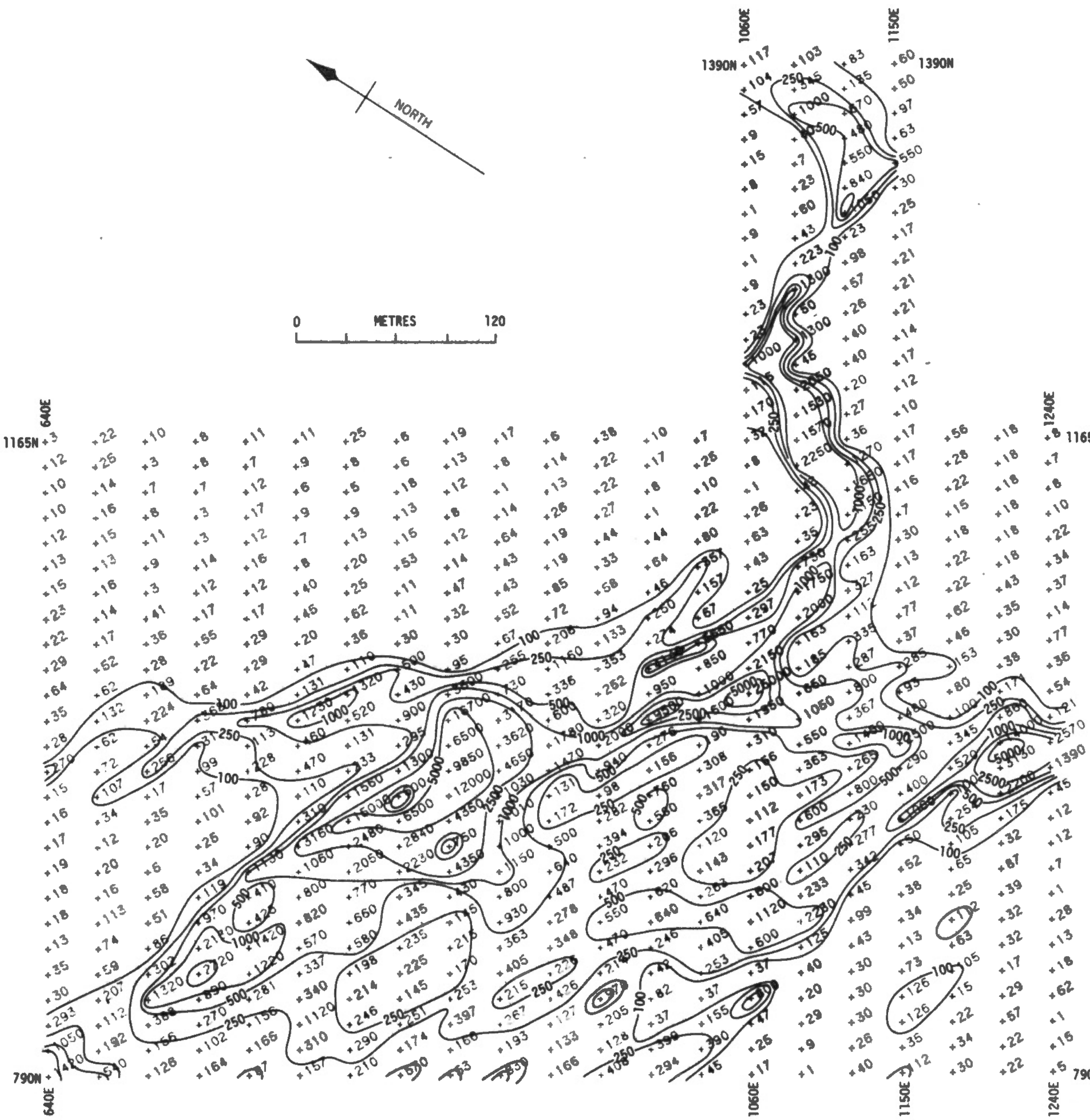

Figure 1. Distribution of lead (as ppm) in soils, Agricola Lake massive sulphide prospect, N.W.T.

line. The sampled area is roughly basin-shaped. The "B" horizon, the underlying hydrothermally altered rocks, and the shales form low, partly swampy ground with poor rock exposure. This is surrounded on all sides by better drained ground of greater relief, within which the rocks are well exposed. As noted above the basin drains (grid) north.

The soils in the central area of low ground are extensively dissected by frost boils. These soils tend to be stony and many are of a buff, gossanous colour. The hanging-wall volcanics are more resistant than the footwall volcanics or "B" horizon exhalite. This has caused the latter to be covered in many places by boulder fields derived from the hanging-wall volcanics.

The soils were sampled at a depth of 6-8 inches. Where possible, organic-rich soils were avoided, but in some places there was no alternative sample type. After drying, the soils were sieved, the minus 80-mesh fraction being used for analysis. Zn, Cu, Pb, and Ag were analyzed in the field by atomic absorption spectrometer. Extraction was with hot HNO_3-HCl. Samples below the detection limit of 2.5 ppm Pb were assigned a value of 1 ppm. Attempts were made in a number of places to sample the soil in profile. However, the highly thixotropic nature of the active layer, accentuated by a wet summer, rendered this impossible.

In Figures 1 and 2 we show the distribution of Pb and Cu in the soils. Figures 3 and 4 illustrate the frequency distribution of these elements in the sample population. We believe that there have been three important processes responsible for the transportation of Pb in the soil study area. This has been shown diagrammatically in Figure 5. Solifluction has dispersed the solid material relatively short distances downslope in the immediate vicinity of the sulphide body. Glaciation is believed to have produced a more extensive dis-

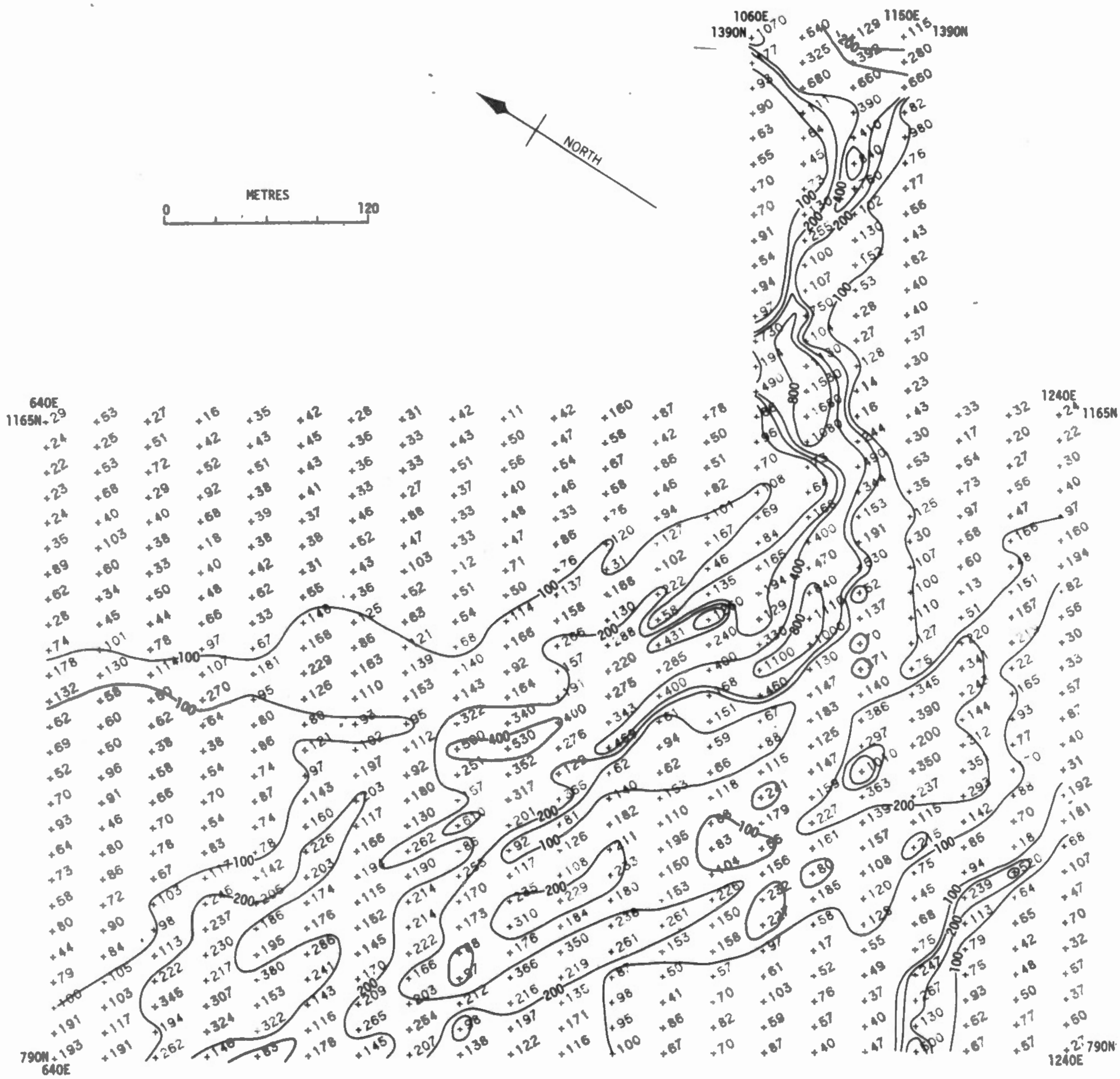

Figure 2. Distribution of copper (as ppm) in soils, Agricola Lake massive sulphide prospect, N.W.T.

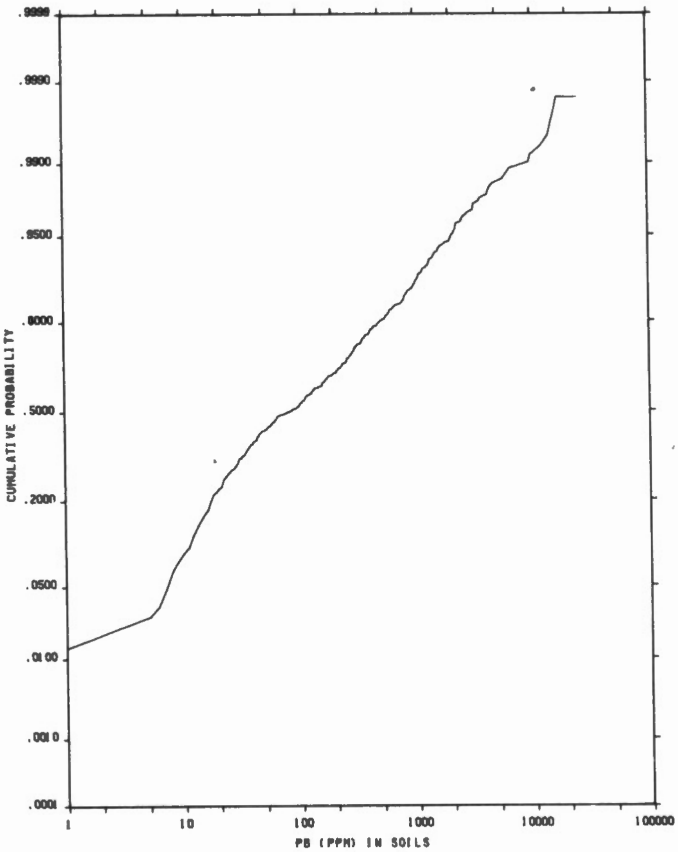

Figure 3. Frequency distribution of lead in soils, Agricola Lake massive sulphide prospect, N.W.T. (606 samples)

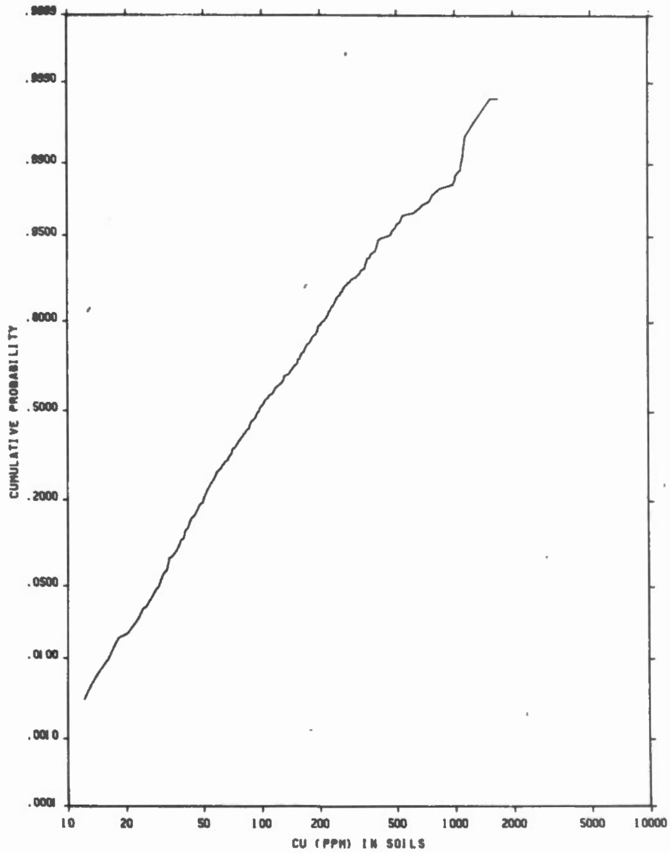

Figure 4. Frequency distribution of copper in soils, Agricola Lake massive sulphide prospect, N.W.T. (606 samples)

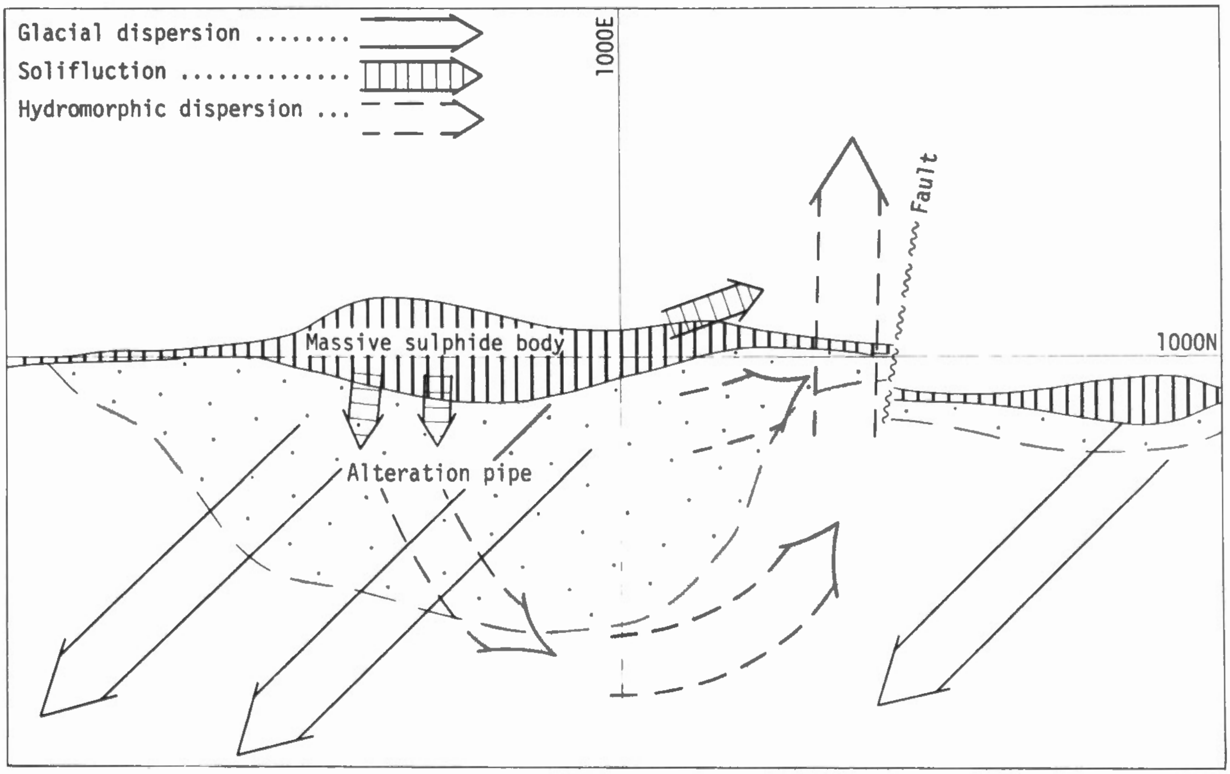

Figure 5. Patterns of secondary base metal dispersion, Agricola Lake massive sulphide prospect, N.W.T.

persion along a bearing of 290° true N from the body. Soils from the (grid) southeast corner of the area shown in Figure 1 contain fragments of shale and hydrothermally altered volcanics. Since no similar lithologies were detected in the bedrock in this area, it is believed that these fragments were transported from the central portion of the soil study area. The topographic gradient is upwards in this direction, so that glacial transport is the only feasible explanation. The indicated direction of transport is similar to the bearing of other glacial features in the region. An esker 5 miles to the west of the study area has a bearing of 320° true N. The third, important mechanism for transport of Pb is by solution. This is believed to have caused some movement of Pb across the central swampy portion of the site, and then out along the stream valley draining the area. The dispersion of Pb along the latter may be readily discerned in Figure 1. The concept of hydromorphic dispersion of Pb is substantiated by the data showing that this element is held in solution in the springs and streams around the prospect (*see* Cameron and Lynch, this section, following report). Lead is a relatively immobile element (Table 1) but it is dissolved in the highly acidic groundwaters in contact with the massive sulphide body. It is then precipitated in the upper reaches of the drainage system. Surface waters in the area are not conducive to the solution of Pb, as is evidenced by the high values for this element obtained by soil analysis. Many soil values close to 1% were obtained over the sulphide body. This is approximately the same abundance as was found in the drill core cutting the sulphide body (0.71% Pb for 134 feet, of which the upper 72 feet averaged 1.18% Pb; Northern Miner, August 15, 1974). Lead is present in the soils as the sulphates, anglesite and plumbojarosite (Cameron and Durham, 1974a).

In the case of Cu the same general pattern of dispersion resembles that for Pb (Fig. 2). There is, however, one striking difference from the Pb data. The soils from the central portion of the study area, above the sulphide body, are only weakly enhanced in Cu compared to background values (although the 134 feet of core noted above averages 1.09% Cu). The highest Cu values were obtained from the stream bed draining the area.

This distribution reflects the greater mobility of Cu. In the central, less well drained portion, underlain by sulphides and hydrothermally altered rock, soils and surface waters are rather acidic. Values for pH in the range 3 to 4 are most common. In the surrounding, better drained terrain the pH is greater, in the range 5 to 6. Cu has been largely removed from the central, more acidic, area to be dispersed in drainage waters. Outside this central area a greater proportion of the Cu derived from the rocks or transported overburden has been retained in the soils.

Table 1.

Solubilities of heavy metal sulphates

Sulphate	Solubility in g/100 ml
$ZnSO_4$	86.5 at 80°C
$ZnSO_4.7H_2O$	96.5 at 20°C
$ZnSO_4.6H_2O$	117.5 at 40°C
$CuSO_4$	14.3 at 0°C
$CuSO_4$	75.4 at 100°C
$CuSO_4.5H_2O$	31.6 at 0°C
Ag_2SO_4	0.57 at 0°C
$AgSO_4$	1.41 at 100°C
$PbSO_4$	0.004 at 25°C

Since all three processes of surficial transport for Cu and Pb tend to disperse these elements across the hydrothermally altered zone, it is difficult to tell whether this zone is also enriched in base metals. In the opposite direction Pb and Cu values in soils overlying the hanging-wall are quite low.

For the other two elements determined, Ag mimics the distribution of Pb. Both are relatively immobile. Zn, on the other hand, shows the same trends as Cu, but more pronounced. As the most mobile element of the four, Zn shows an even greater depletion over the central area.

The soil anomaly in the area of the prospect is very extensive, as a result of glacial transport and hydromorphic dispersion. In a similar environment soils collected at a wider interval would give almost as much information as was obtained from this 30 m x 15 m grid. The distribution of base metals in the soils is largely determined by the individual chemical properties of these elements.

The writers wish to thank Mr. S.B. Ballantyne and Mr. J. Thomas for assistance in sampling; Mr. R. Horton, Miss E. Ruzgaitis and Miss S. Costaschuk for field analyses; Dr. R.G. Garrett for preparation of the cumulative frequency diagrams; and Mr. Denis Lefebvre for laying out the survey grid.

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HYDROGEOCHEMICAL STUDIES IN THE AGRICOLA LAKE AREA, 1974

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In the 1973 field season extensive base metal anomalies were identified in the drainage systems of this area (Cameron and Durham, 1974a, 1974b). These anomalies have their origin in massive sulphide type mineralization in the volcanics of the area. It was apparent from these data that the most mobile elements (e.g. Zn) travelled several miles in the drainage system before being precipitated in lake sediments. The

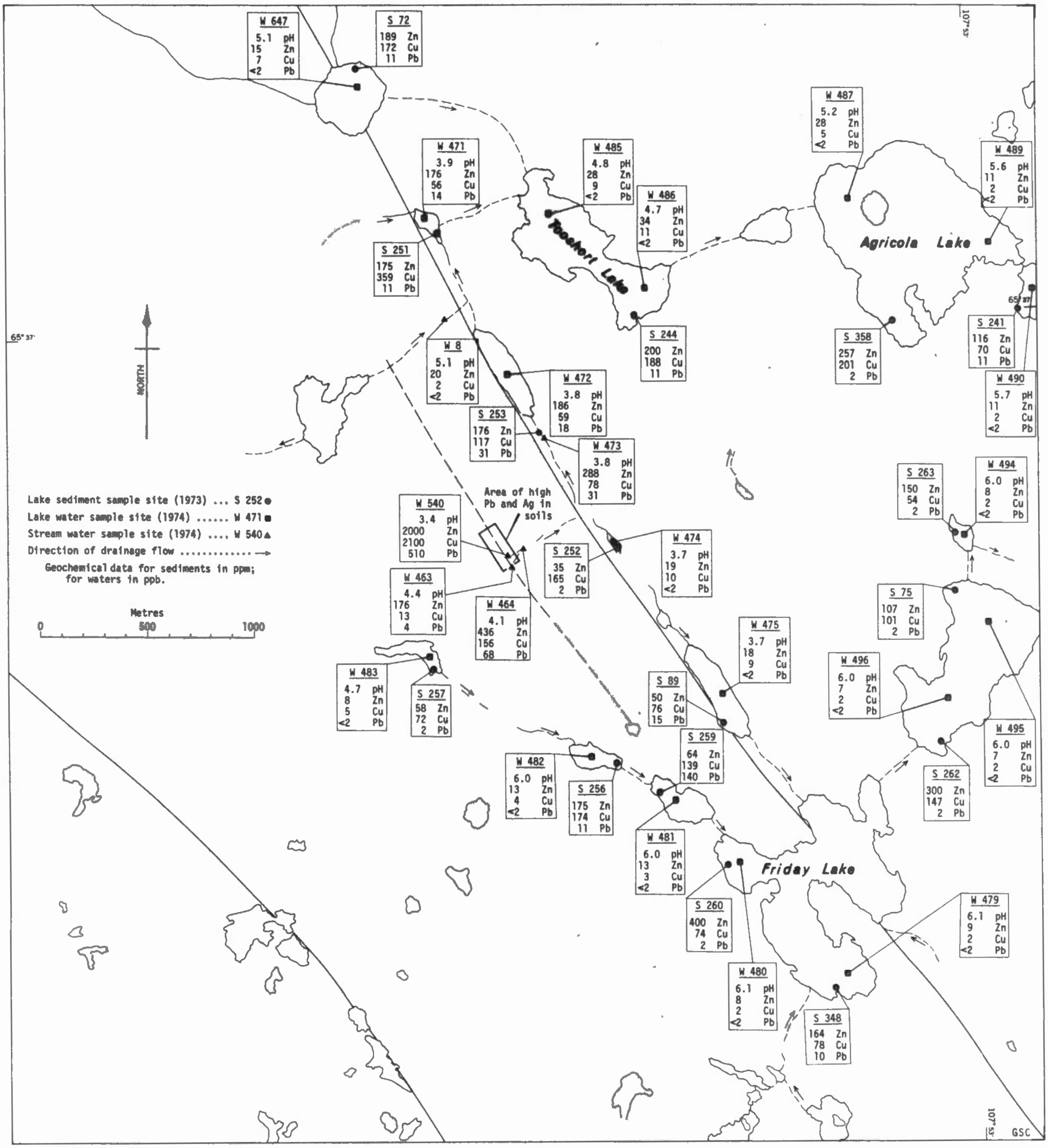

Figure 1. Selected analyses for Zn, Cu and Pb in lake waters and lake sediments, Agricola Lake area, N.W.T.

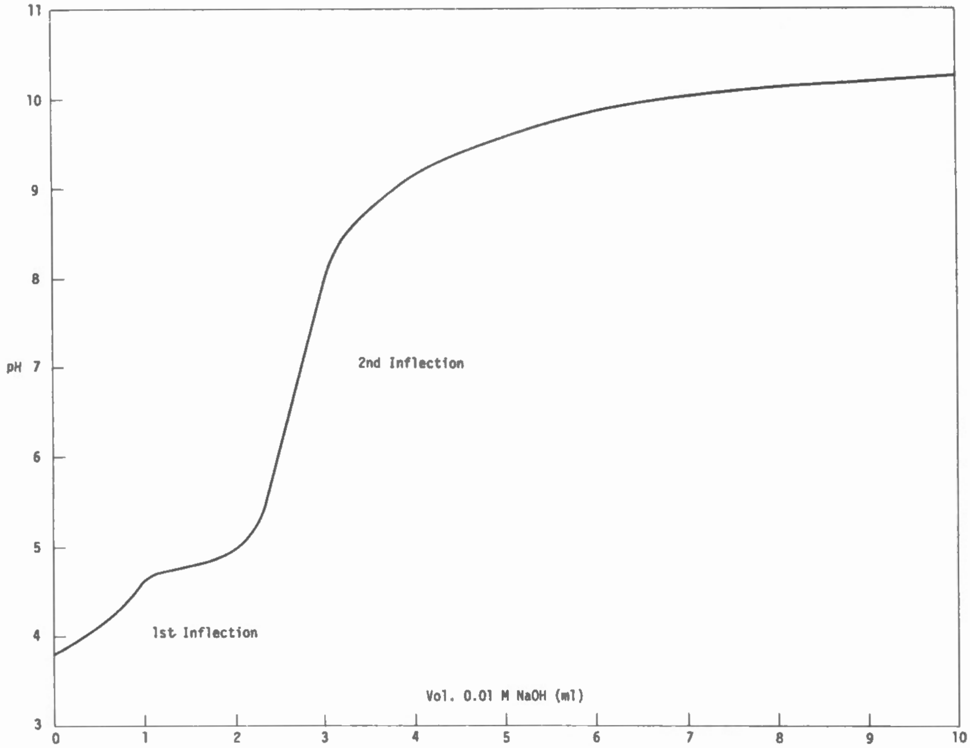

Figure 2.

Titration curve for sample 9 (50 ml sample).

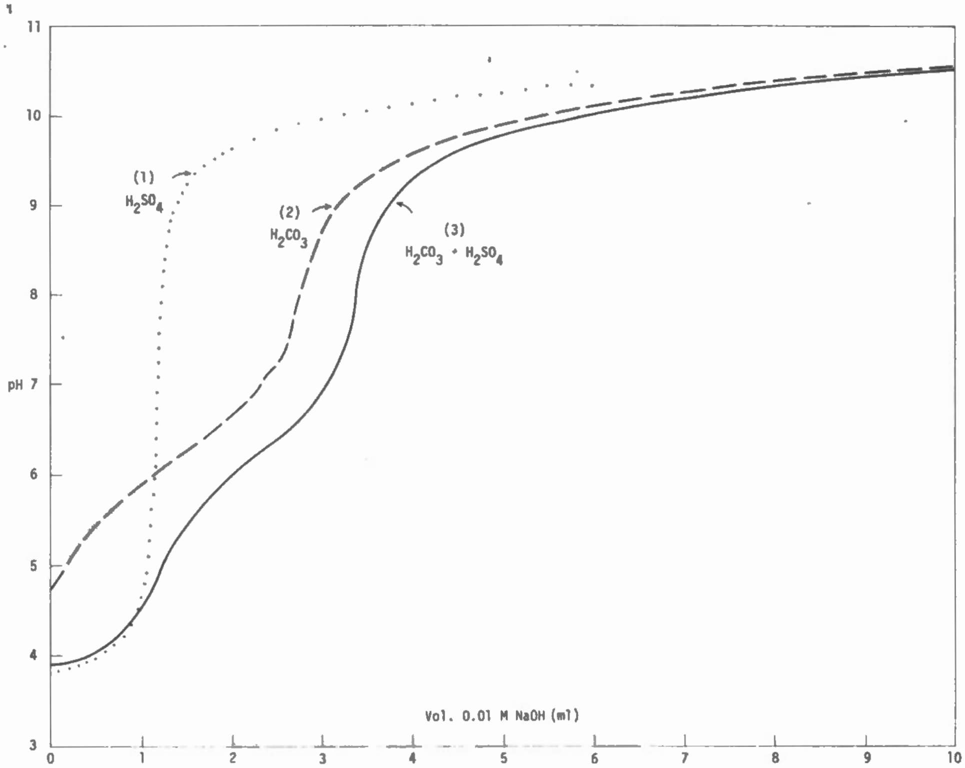

Figure 3.

Titration curves for (1) H_2SO_4, (2) H_2CO_3, (3) mixture of H_2SO_4 and H_2CO_3.

primary object of the 1974 hydrogeochemical studies was to more fully explain these processes of secondary dispersion. However, the results of the work, based on field analyses, were so favourable that the program was enlarged to consider the use of hydrogeochemical methods as a primary exploration method.

Boyle *et al.* (1971) have provided an excellent summary of the application of hydrogeochemical methods of exploration in the Canadian Shield. These methods have been infrequently used for a variety of reasons which they discuss. The features of the Shield that have discouraged such use include the relatively impermeable nature of Shield rocks, the low topographic relief, and the various effects of glaciation. In areas of permafrost, such as at Agricola Lake, the disadvantages may appear to be even more serious. Groundwater circulation and the oxidation of sulphides would, at first sight, appear to be severely restricted in this environment. Present-day oxidation is, of course, essential to any scheme of hydrogeochemical prospecting. Many geologists and geochemists have assumed that present-day oxidation is largely lacking in northern Canada and other permafrost areas. However, Boyle *et al.* (1971) have listed a number of examples of oxidized sulphide bodies in the Shield. While they suggest that this may be largely of Tertiary age, they feel that oxidation has continued in many places to the present. The most extensive work on this problem has been carried out in the Soviet Union. Here modern oxidation of sulphide bodies in permafrost areas has been demonstrated (Shvartsev and Lukin, 1965). Also, the migration of solutions along thin films of water at mineral/ice or ice/air interfaces has been demonstrated (Tyutynova, 1960, 1961). This work has been briefly reviewed by Cameron (1974).

Water samples were collected in 500 ml plastic bottles. They were analyzed in the field within two or three days of collection by procedures described elsewhere (*see* Horton and Lynch, this section). All samples were analyzed for Zn and Cu and some also for Pb. Almost without exception the samples were clear and colourless. They were not filtered prior to analyses. Several hundred samples were returned to Ottawa and analyzed for a more extensive suite of elements approximately two months after collection. No acid or other preservative was added prior to shipping. Contrary to the experience of other workers, there was no decrease in the Zn and Cu content of the waters as a result of this storage. This applied to waters of neutral as well as of acidic pH and of varying trace element composition. However, some samples gave higher Zn and Cu values by later laboratory analyses, compared to the field determinations. This is provisionally explained on the basis of the Zn and Cu of these waters being organically bonded. Organically bonded metals may extract less rapidly into M.I.B.K. when chelated with APDC than these metals in the ionic form. Field extractions were performed by hand shaking; in Ottawa shaking was done by mechanical means for a longer period of time. These various comparative data will be given in a later report.

In Figure 1 a selection of the water data are given for the Agricola Lake area. Sediment, soil and water analyses for the same area are shown in Cameron and Durham (1974b, Fig. 2). By far the highest concentrations of Zn, Cu and Pb are found in ponds, streams, and springs near the massive sulphide prospect (identified as the area of high soil Pb and Ag in Fig. 1). Several water samples were collected near the prospect with pH values in the 3.2 - 4.0 range and with Zn and/or Cu values near 1000 ppb and Pb values near 500 ppb. Samples collected before and after the start of drilling operations showed no marked differences in base metal content.

Downstream these waters are diluted as they mix with waters of lower trace element content. However, they remain noticeably anomalous as far as Agricola Lake. Approximately 1½ miles to the east of Agricola Lake this drainage system enters a large unnamed lake. Here the mean value of three water samples was 3 ppb Zn, 2 ppb Cu and 2 ppb Pb. These may be considered as background values. It is of interest that in the Agricola Lake drainage system the most anomalous lake sediment samples for zinc are from Agricola Lake itself, several miles from the principal source of this metal. By contrast, the content of Zn in the waters of this lake is rather low, as a result of dilution and precipitation. These features will be discussed in detail in a later report, but the significance to geochemical reconnaissance of this observation should be noted. If anomalous levels of indicator elements can be detected at a greater distance from the source for lake sediments than for waters, then the former can be sampled at wider intervals.

The downstream dispersion of Zn, Cu and Pb in this drainage chain may be examined in more detail by reference to Table 1. Near the massive sulphide prospect there are a number of waters of varied metal ratios, reflecting perhaps metal zoning within the sulphide body and variable leaching conditions. Two such waters are samples 540 and 463. After mixing of these and other waters (sample 464) they travel mainly underground (at lease in summer) northeastwards to the main northwest-trending valley. Here they are mixed with waters of low pH and low trace element content (sample 474, Fig. 1). These valley waters may owe their low pH to the oxidation of the pyritic, carbonaceous slates underlying the valley. The changes in Zn/Pb and Cu/Pb between samples 464 and 471 indicate that Pb is fairly rapidly precipitated. The Zn/Cu ratio does not change substantially from samples 464 until Agricola Lake is reached. Zn is clearly the more mobile of the elements.

Table 1

Metal Ratios and pH values for selected waters from the Agricola Lake drainage chain

Sample	Zn/Cu	Zn/Pb	Cu/Pb	pH
540	0.95	3.9	4.1	3.4
463	13.5	19.0	3.2	4.4
464	2.8	6.4	2.3	4.1
473	3.7	9.3	2.5	3.8
472	3.2	10.3	3.3	3.8
471	3.1	12.6	4.0	3.9
485	3.1	>14	>4.5	4.8
486	3.1	>17	>5.5	4.7
487	5.6	>14	>2.5	5.2
489	5.5	-	-	5.6
490	5.5	-	-	5.7

The Friday Lake drainage chain (Fig. 1) presents an entirely different picture. These waters have only weakly anomalous levels of Zn and Cu and no detectable Pb. By contrast, many of the lake sediments of this drainage are noticeably anomalous with respect to

Table 2

Major and Trace Constituents of selected waters, Agricola Lake area

Sample[1]	2	9	6	14	19	M-52
Na, ppm	1.56	1.00	0.52	0.68	0.46	1.4
K, ppm	0.94	0.58	0.68	0.32	0.18	0.7
Mg, ppm	2.38	1.42	0.90	1.26	0.30	1.3
Ca, ppm	5.58	2.50	1.72	1.00	1.44	4.6
Fe, ppb	875	74	<10	80	58	10
Mn, ppb	92	76	25	41	< 5	< 1
Zn, ppb	1080	179	43	22	11	2
Cu, ppb	867	39	8	10	2	< 1
Pb, ppb	341	15	2	< 2	< 2	-
Cl, ppm	0.6	0.3	0.6	0.3	0.4	1.2
SO_4, ppm	76.7	40.6	13.6	41.5	7.3	2.4
Mineral Acidity as ppm $CaCO_3$	22.8	8.5	0.9	16.1	n.d.	-
Total Acidity as ppm $CaCO_3$	48.6	26.5	4.3	33.1	n.d.	-
pH	3.2	3.5	4.1	3.5	5.3	7.2
Conductivity as μ mhos/cm	230	112	31	155	15	<55

[1] Sample Locations: Sample 2 near 540 (Fig. 1); 9 near 472; 6 near 485; 14 near 474; 19 near 480; M-52, Yellowknife River, Reeder *et al.*, 1972.

n.d. = not determined

regional background (for background values *see* Cameron and Durham, 1974b). Our observations have revealed no large, actively oxidizing, base metal sulphide bodies along this chain, hence the low trace element content of the waters. In view of this, the anomalous nature of many of the sediments requires some explanation. Whatever the cause, it provides further evidence that anomalous base metal values are more widely distributed in the lake sediments of mineralized areas than in the waters.

For some other samples from the area the major constituents have been determined (Table 2). The waters shown in Table 2 are relatively pure. Only sulphate is notably abundant. In comparison with the sample from the Yellowknife River (also in the Slave Province), the samples are variably enriched in sulphate, base metals, Fe and Mn. Also these waters are markedly more acidic. It is the excess H ion that enhances the conductivity of the waters from the Agricola Lake drainage chain. The high sulphate, representing free sulphuric acid, is related to the oxidizing sulphides in the area. The source is sulphides enriched in base metals in the case of sample 2 and base metal-poor sulphides in the case of Sample 14. The low salt content of the waters allows the wide dispersion of H_2SO_4 before neutralization. This, in turn, facilitates the dispersion of base metals. The weak solutions of sulphuric acid associated with the massive sulphide body is a potent agent for the leaching of sulphides.

Samples 2, 9, 6 and 14 were titrated with 0.01 M NaOH. These samples showed a pronounced inflection in the titration curve between pH 4 and 5 caused by free sulphuric acid (Fig. 2). A second inflection, believed to be caused by weak acid(s) occurs between pH 7 and 8. Artificial mixtures of sulphuric and carbonic acids gave titration curves similar to Fig. 2 (Fig. 3). In order to determine whether the second (weak acid) was carbonic acid, samples were aerated with CO_2-free air and titrated. Aeration removes any free carbonic acid. In all cases, the aerated sample titration curves were slightly displaced to the left. However, the general shape of the second inflection was not changed, thus indicating the continued presence of a non-volatile weak acid or hydrolysis (e.g. Al).

To summarize the above data, the most significant finding is that the massive sulphide body and other sulphides in this area are undergoing active oxidation at the present day. Oxidation of the sulphides produces groundwater that is a weak solution of sulphuric acid which further leaches the body. The sulphuric acid solution is not quickly neutralized in the drainage system. This has obviously facilitated the wide dispersion of base metals, particularly Zn, in the drainage waters. Anomalous levels of base metals appear to be more broadly dispersed in lake sediments than in waters, with consequent advantages to their utilization in geochemical reconnaissance.

These favourable results for lake waters plus their ease of sampling and analysis suggested that they might be a very useful medium for semi-reconnaissance and detailed exploration in the northern Shield. To test this further, a 750-square-mile area around Agricola Lake was sampled at an approximate density of 1 sample per 3 square miles. An area of approximately 900 square miles was similarly sampled at High Lake, N.W.T. Most lakes in the Hackett River camp that contains a number of massive sulphide bodies were sampled. These data will be published in detail in a later report. The pH of waters from the latter two areas are approximately neutral, in contrast to the acidic waters of the Agricola Lake area. This undoubtedly reflects the abundance of exhalative-type limestones at High Lake and at Hackett River. Lead could not be detected at all in these neutral waters and it is possible that the mobility of Cu is reduced. Highly anomalous values for Zn were, however, found in lake waters from both areas near known massive sulphide mineralization. This very mobile element may be very useful for hydrogeochemical surveys in the northern Shield.

Mr. Bruce Ballantyne was responsible for most of the water sampling; both he and Mr. Robert Benson completed the High Lake regional sampling in the remarkably short time of 2 days. The skill and enthusiasm of our helicopter pilot, Mr. Bob Watson, contributed greatly to the efficiency of the water sampling. Mr. Ronald Horton, Miss Elizabeth Ruzgaitis and Miss Sue Costaschuk analyzed the water samples in the field, and Mr. Gilles Gauthier and Mr. W. Nelson carried out most of the determinations in Ottawa. We are most grateful to all these persons for their hard work and enthusiasm.

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9.

SURFACE LAKE WATER URANIUM-RADON SURVEY OF THE LINEAMENT LAKE AREA, DISTRICT OF MACKENZIE

Project 720067

W. Dyck and E. M. Cameron
Resource Geophysics and Geochemistry Division

Using the facilities and helicopter support of the field camp at Friday Lake (lat. 65°36'N, long. 107°55'W) (*see* Cameron, this section), a uranium-radon survey of surface lake waters of the Lineament Lake area was carried out. The survey was prompted by the lake sediment uranium anomaly discovered during the geochemical reconnaissance in 1972 (Allan and Cameron, 1973). The anomaly is situated about 60 miles south-southeast from Friday Lake at lat. 64°50'N, long. 107°00'W.

The area is covered by massive granitic rocks composed mainly of biotite granite and quartz monzonite of Archean age (Wright, 1967).

Follow-up work in the form of ground scintillometry and rock collection in 1973 (Cameron and Durham,

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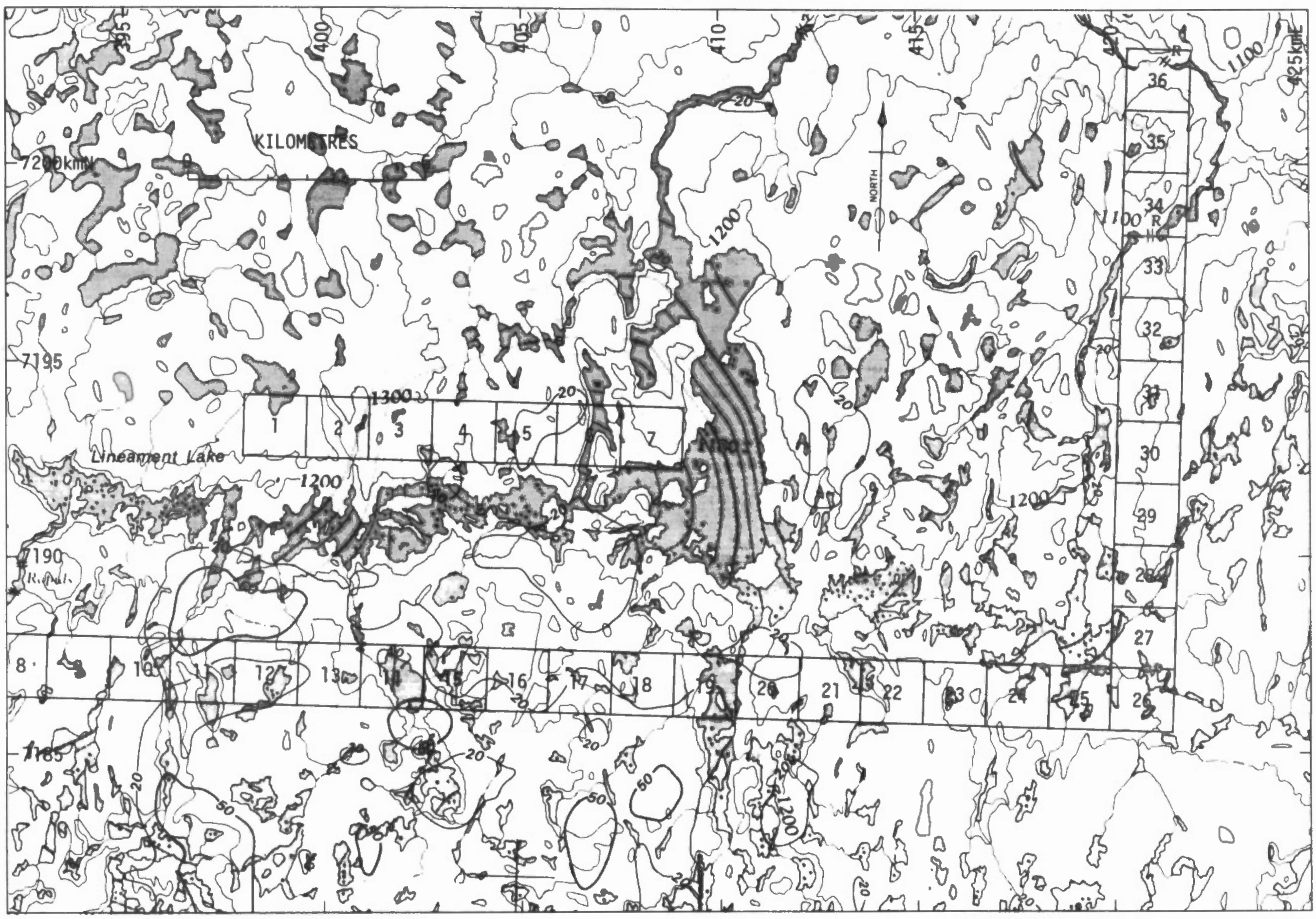


AIRBORNE GAMMA RAY SPECTROMETER COUNTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
346	389	387	383	453	474	465	488	511	484	520	570	516	512	473	637	552	527
38	49	43	64	48	60	50	46	36	59	74	85	97	75	73	73	58	49
75	72	43	52	80	105	174	120	134	120	137	173	246	274	193	182	163	186

19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
712	643	666	665	676	578	408	410	541	447	378	365	435	401	342	382	544	454
49	21	38	24	21	15	28	24	50	39	8	33	30	41	15	51	58	51
127	136	115	114	165	113	53	58	77	80	47	35	32	71	18	72	145	114

Geometric mean + 3S/2 = 50pC/l 50

Geometric mean + S/2 = 20pC/l 20

Uranium in ppm in lake sediments (Map 9-1972 (Sheet 3)) ...

Study area 5

Figure 1. Radon in surface lake waters, Lineament Lake geochemical survey, 1974.

1974) confirmed the enrichment of uranium in the rocks in the anomalous area relative to rocks of Archean age outside the anomaly but revealed no uranium-rich minerals in the rocks.

The 1974 follow-up work consisted of (1) surface lake water sampling of about two thirds of the lake sediment anomaly, (2) airborne gamma-ray spectrometry and ground gamma-ray scintillometry of selected portions, and (3) rock collection from sites that gave highest radon and scintillometer readings.

A total of 307 lake water samples were collected, 257 samples for an initial semi-detailed coverage of the anomaly at a sampling density of 1 sample per 2.6 km^2 (1 sample per sq. mile) and 50 samples for more detailed follow-up in the most promising area as outlined by the radon content of the water samples from the semi-detailed survey. The samples were collected in 260 ml glass bottles at inflow or outflow bays of lakes within 5 m to 10 m from shore. Depth, temperature and conductivity of the water was measured at each site. Radon and pH was determined at the field camp using portable instruments. Uranium determinations were carried out in the Geochemical Laboratories of the Geological Survey of Canada, Ottawa (Smith and Lynch, 1969).

The radon and uranium results of the semi-detailed lake water survey are shown in Figures 1 and 2. The 1972 reconnaissance lake sediment uranium survey results are also shown in these figures. The coincidence of radon in water, uranium in water and uranium in sediments is quite striking but the semi-detailed results focus more sharply in an area just south of Lineament Lake. The slightest displacement of the uranium in the sediments towards the north is probably due to its relatively greater mobility compared to radium (the immediate parent of radon) in the surface environment and the general direction of flow of the water system.

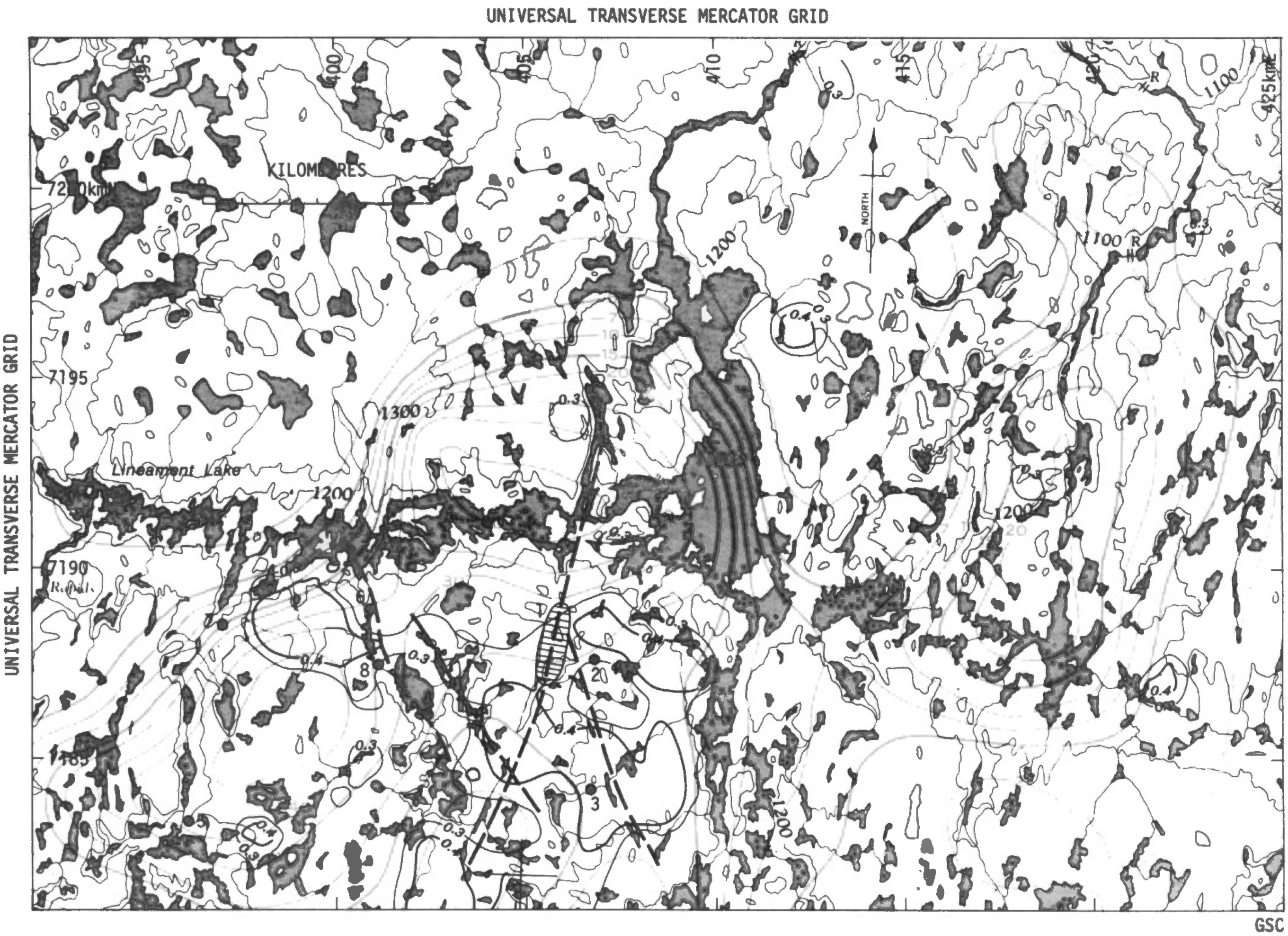
The highest radon and uranium values encountered were 366 pc/1 and 1.9 ppb with background levels (geometric means) of 7 pc/1 and 0.2 ppb, respectively. By comparison the Beaverlodge lake water survey in 1969 gave highs of 60 pc/1 and 2.7 ppb, and backgrounds of 1 pc/1 and 0.4 ppb respectively (Dyck *et al.*, 1971). Obviously environmental factors such as nature of rock, organic matter, size and depth of lakes, temperature variations etc. affect the mobility of these two elements. Hence an area comparison must take these into account. The lake waters in the area are exceptionally pure. This conclusion is based on the low average conductivity of 8 micromhos compared to 112 for Ottawa tap water and the pH measurements which were erratic and difficult to reproduce indicating poor buffering by ionic species. The negative correlation of lake area, depth, and temperatures with radon observed elsewhere in the Shield (Dyck, 1974) was barely significant in the Lineament Lake area probably as a result of general shallowness of lakes and permafrost in the ground. Incidentally, the mean lake area listed in Table 1 refers to an effective area taking into account the maximum range of approximately 1 km for radium and radon in the surficial environment.

To follow up in more detail on the radon highs, 50

TABLE I

GEOMETRIC MEANS, STANDARD DEVIATIONS, AND RANGES OF VARIABLES OF SAMPLES FROM LINEAMENT LAKE, N.W.T.

VARIABLES	SEMI-DETAILED SURVEY No. of Analyses	Mean	Log 10 Stand.Dev.	Range	DETAILED SURVEY No. of Samples	Mean	Log 10 Stand.Dev.	Range
Rn pc/1	257	7.0	0.585	0.2 - 165.0	50	37.6	0.480	0.2 - 366.0
U, ppb	256	0.2	0.235	0.0 - 1.0	50	0.3	0.336	0.0 - 1.9
pH	257	7.6	0.028	6.9 - 8.8	50	7.4	0.015	7.1 - 8.0
Temp, °C	257	13.8	0.035	11 - 16	50	15.2	0.043	11 - 16
Conductivity μ mhos	257	8.1	0.221	3.0 - 13.0	50	6.8	0.082	4.0 - 9.0
Depth, m	257	1.0	0.302	0.1 - 7.0	50	1.2	0.199	0.5 - 3.6
Area, km^2	257	9,2	0.642	0.01- 4.0	50	0.1	0.784	0.01- 2.50



GROUND SCINTILLOMETRY STATIONS AND READINGS
(granite - GRNT, pegmatitic - PGMT, general background - BKG)

1	2	3	4	5	6	7	8
GRNT 10-50 μR	GRNT 10-30 μR	GRNT 15-35 μR	GRNT 15-30 μR	GRNT 10-20 μR	GRNT 10-15 μR	GRNT 10-15 μR	GRNT 15-25 μR
PGMT 10-12 μR	PGMT 10-12 μR	PGMT 10-25 μR	PGMT 10-25 μR	PGMT 10 μR	BKG 10-12 μR	BKG 10-12 μR	BKG 5-20 μR
BKG 10 μR	BKG 10 μR	BKG 12-15 μR	BKG 12-15 μR	BKG 12-15 μR			

Geometric mean + 3S/2 = 0.4 ppb 0.4

Geometric mean + S = 0.3 ppb 0.3

Uranium in ppm in lake sediments (Map 9-1972 (Sheet 3)) ...

Detailed water sample site locations ....

Ground stations....................... ●

Figure 2. Uranium in surface lake waters, Lineament Lake geochemical survey, 1974.

lake water samples from trenches or faults in the anomalous zone were collected and analyzed. The location of these trenches is shown by the dashed lines in Figure 2. As the means in Table 1 indicate several samples contained more Rn and U than did the semi-detailed samples but no values were high enough to suggest ore nearby.

The numbered squares in Figure 1 are the locations over which integral airborne gamma-ray spectrometry was carried out with the aid of a helicopter and a spectrometer system with a 15 cm by 10 cm crystal leased from Exploranium Corporation of Canada. The counts listed under Figure 1 are the net average of two one minute counts in the K, U and Th channels accumulated while flying in a circle inside a 1.6 km square at an elevation of 91 m, avoiding water as much as possible. Background counts were obtained over the largest part of Lineament Lake near the centre of the map-area.

The U and K counts were corrected for Compton Scattering using the following equations (Grasty and Darnley, 1971):

$$U_c = U_u - \alpha . Th$$

$$K_c = K_u - \beta . Th - \gamma . U_c$$

where the subscripts c and u are corrected and uncorrected respectively and $\alpha = 0.43$, $\beta = 0.62$, and $\gamma = 0.91$ for the 6-inch by 4-inch crystal used.

The counts indicate a rise in K, U and Th in the same area as the water Rn and U highs but fail to support ore grade concentrations of U in the surface rocks. Of interest may be the U/Th ratio counts. These are generally lower where the higher net counts occur. However, quantitative determinations of these ratios are required to confirm these field observations before conclusions may be drawn from them.

Groundstation scintillometry was carried out at 8 stations near sites of high R_n in water. These stations are shown in Figure 2 and the total gamma-ray counts of granites, pegmatites and general backgrounds listed in the legend. Total counts for granites ranged from 10 μR/hr to 50 μR/hr and for pegmatites from 10 μR/hr to 25 μR/hr. Background readings with the scintillometer slung over the shoulder were generally around 10 μR but values of 5 and 25 also were encountered. But as with the other tests, no counts were recorded high enough to suggest U mineralization. It should be noted that the pegmatitic rocks in any one area were always lower in total count activity than the adjacent granitic rocks and pegmatites with large mica flakes were more radioactive than those lacking in mica.

From the tests carried out this summer in the Lineament Lake area, one could conclude that the lake sediment U anomaly has resulted from the weathering of granites with above average U content. However, much more work and more detailed work is required to arrive at any firm conclusions on the uranium potential of the area.

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10. A GEOCHEMICAL FIELD LABORATORY FOR THE DETERMINATION OF SOME TRACE ELEMENTS IN SOIL AND WATER SAMPLES

Project 580175

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From July 1 to August 2, 1974, a geochemical field laboratory was in operation at Friday Lake, N. W. T. The laboratory was set up to provide trace element analyses of soil and water samples for a field party headed by Dr. E. M. Cameron of the Geochemistry Section. Since the field area was a considerable distance from the nearest community, Yellowknife (483 km) it was essential that the laboratory operate at the base camp of the field party.

The fact that extremely low levels of Zn and Cu in water samples as well as low levels of Ag in soil samples were required to be determined, made it necessary to utilize atomic absorption spectroscopy as the main analytical tool rather than some of the simpler colorimetric methods used in previous field parties (e.g., Allan *et al.*, 1971).

The remoteness of the area where the laboratory was situated ruled out any technical assistance from service personnel; hence all pieces of equipment which could conceivably break down were duplicated, i.e. two atomic absorption spectrophotometers, two generators, two air compressors, etc. were shipped to the base camp.

All possible preparatory work was done in Ottawa. Standard solutions, buffer solutions and dilute acids were all prepared and purified (where necessary) at the Geological Survey laboratories. Analysts were trained in Ottawa and did test runs on analytical procedures to be used in the field. When all preparations were completed, the laboratory equipment moved to Yellowknife and then flown from there by a Twin Otter to Friday Lake.

Two longhouse tents (12 by 14 feet each) were used to house the analytical laboratories. A third tent (10 by 12 feet) was used for sample drying and sieving. One longhouse tent contained the two atomic absorption spectrophotometers, balances and some office space. The other longhouse tent contained the apparatus for the hot acid decomposition of soils, separatory funnels for preconcentration of water samples, a water reservoir, demineralizers and a small stainless steel sink for the washing of glassware.

Utilizing both laboratory and field staff (total of seven) for two days the tents were put up, the major pieces of equipment were installed and made operational.

Electrical power was supplied by two 3000 watt generators equipped with gasoline engines. The power to the two atomic absorption spectrophotometers stabilized with a 500 watt voltage regulator. One generator was devoted entirely to running the air compressor.

A small electric pump was used to bring water from the lake to a 15 gallon storage vessel which in turn provided raw water for the sink and the demineralizing column by means of a siphon system.

The atomic absorption equipment consisted of two Perkin Elmer instruments, a model 300 and a model 303. The flue gases from these two instruments were vented through 4" aluminum drier ducting which lead to the outside of the tent. Draught was provided by two small electric squirrel cage fans.

The soil samples, in paper bags, were dried on a rack suspended above three catalytic heaters. When dried, approximately 100 grams were sized to -80 mesh using stainless steel sieves. The sieved sample was then stored in a plastic vial. The oversize fraction was discarded.

A 0.50 gram sample of the soil was weighted on a torsion balance and transferred to a 18 by 150 mm test tube. A 3 ml aliquot of an acid leach solution (4M HNO_3-1M HCl) was added and the sample heated in a hot water bath (aluminum roasting pan on a portable propane stove) for 2 hours in batches which usually

Table 1

Atomic Absorption Instrumental Parameters

Element	Lamp Current (mA)	Burner Length	Fuel	Oxidant	Wavelength (nm)	Slit-width (nm)
Zn	15 (a)	10 cm single slot (c)	C_2H_2 (d)	Air	213.8	0.7
Cu	15 (a)	10 cm single slot	C_2H_2 (d)	Air	324.7	0.7
Pb	8 (b)	10 cm single slot	C_2H_2	Air	283.3	0.7
Ag	12 (a)	10 cm single slot	C_2H_2	Air	328.0	0.7

(a) Perkin-Elmer lamp.
(b) Westinghouse lamp.
(c) Rotated to reduce sensitivity for the determination of Zn in soils.
(d) For the determination of Zn and Cu in water, the C_2H_2 flow was substantially reduced.

consisted of 60 samples. Metal-free water was then added to bring the final volume to 10 ml. The samples were mixed, allowed to settle and analyzed by atomic absorption for Zn, Cu, Pb and Ag. The instrumental parameters are listed in Table 1. Pb and Ag were determined on the model 303 which has a built in deuterium arc background corrector. Since Zn and Cu do not normally require background corrections, these two elements were done on the model 300. This instrument does not have background correction facilities.

The water samples were collected in 500 ml plastic bottles. For the determination of Zn and Cu a 50 ml aliquot was transferred to a 125 ml separatory funnel. The water sample was then buffered to pH 4.8 by the addition of 5 ml of a sodium acetate-acetic acid solution. A 1% solution (2.5 ml) of ammonium pyrrolidine dithiocarbamate (APDC) was then added to chelate Zn and Cu. The chelated metals were then extracted into 6 ml of methylisobutylketone (MIBK) by manually shaking the separatory funnels for a period of 1 minute. The solvent and aqueous layers were allowed to separate for 5-10 minutes; the aqueous layer was then drained and discarded; the solvent layer was transferred to a 16 by 100 mm test tube. The concentrations of Zn and Cu were then determined by spraying the MIBK solution into the burner of the model 300 atomic absorption spectrophotometer.

During the month of July, 4400 determinations were performed on 1400 soil and water samples.

Reference

Allan, R.J., Lynch, J.J. and Lund, N.G.
1971: Regional geochemical exploration in the Coppermine River area, District of Mackenzie; A feasibility study in permafrost terrain; Geol. Surv. Can., Paper 71-33, 52 p.

11. GROUND MAGNETOMETER SURVEY IN THE AGRICOLA LAKE AREA, DISTRICT OF MACKENZIE

Project 720080

L.J. Kornik
Resource Geophysics and Geochemistry Division

A ground magnetometer survey was carried out in August 1974 over the geochemical soil survey grid in the Beechey Lake belt of the N.W.T. (*see* Cameron, this section). This grid was positioned to cover the Agricola Lake massive sulphide prospect, and consists of 21 lines spaced 30 metres apart with sample sites every 15 metres along these lines. The sites were occupied with a McPhar GP-70 proton magnetometer.

The total field magnetometer survey results are presented in Figure 1. The contour interval is 10 gammas where the magnetic gradients are gentle and 100 gammas where the magnetic gradients are steeper. The magnetic field values have a range of 6,000 gammas from a low of approximately 57,000 gammas to a high of approximately 63,000 gammas, although most anomalies have less than a 1,500 gamma amplitude. The 10+00 E and 10+00 N lines are marked on the accompanying diagrams. Line 10+00 N was used as the base line to tie in all the lines for levelling with station 7+90 E/10+00 N used as the base station for correcting for diurnal fluctuations. During the survey a range of 325 gammas was recorded in the total magnetic field at the base station. The individual lines were levelled to the base line and the diurnal removed by repeatedly occupying the base station.

Figure 2 is the same contour map with a 100 gamma shading interval. The shading emphasizes the blocky nature of the magnetic anomalies and outlines some of the structural features of the area. The main sulphide body is not defined magnetically but occurs along the axis of a weak magnetic low along line 10+00 N between lines 8+50 E and 10+90 E. This is consistent with the fact that the mineralization consists of Zn-Cu-Pb sulphides and pyrite and apparently does not contain any significant amount of pyrrhotite.

Structural features are well defined magnetically and are shown in Figure 3. In this figure, magnetic discontinuities are depicted as zig-zag lines. These discontinuities in the magnetic anomalies probably represent faults. The trends of the axis of magnetic highs are shown as thick dotted lines. These magnetic trends probably represent the trends of the lithologic units. Structurally, the geology appears blocky with the lithologic units cut and displaced by faults. The mapped geology (*see* Cameron, this section) in general supports this interpretation although in some areas the interpretations conflict; a particularly striking example occurs in the (grid) southeast quarter of the map. In that area, a geological interpretation of the magnetic contours would favour a 30^{o} change in the strike of the lithologic units as indicated in Figure 3, perhaps by fault block rotation. Also the area mapped geologically as shale should probably have a longer strike length on both sides of its mapped position if the area of lower magnetic relief on the magnetic map is related to this shale unit. An unmapped geological feature must also occur along line 10+00 E between 8+50 N and 9+70 N to produce the magnetic anomalies which are evident along this line.

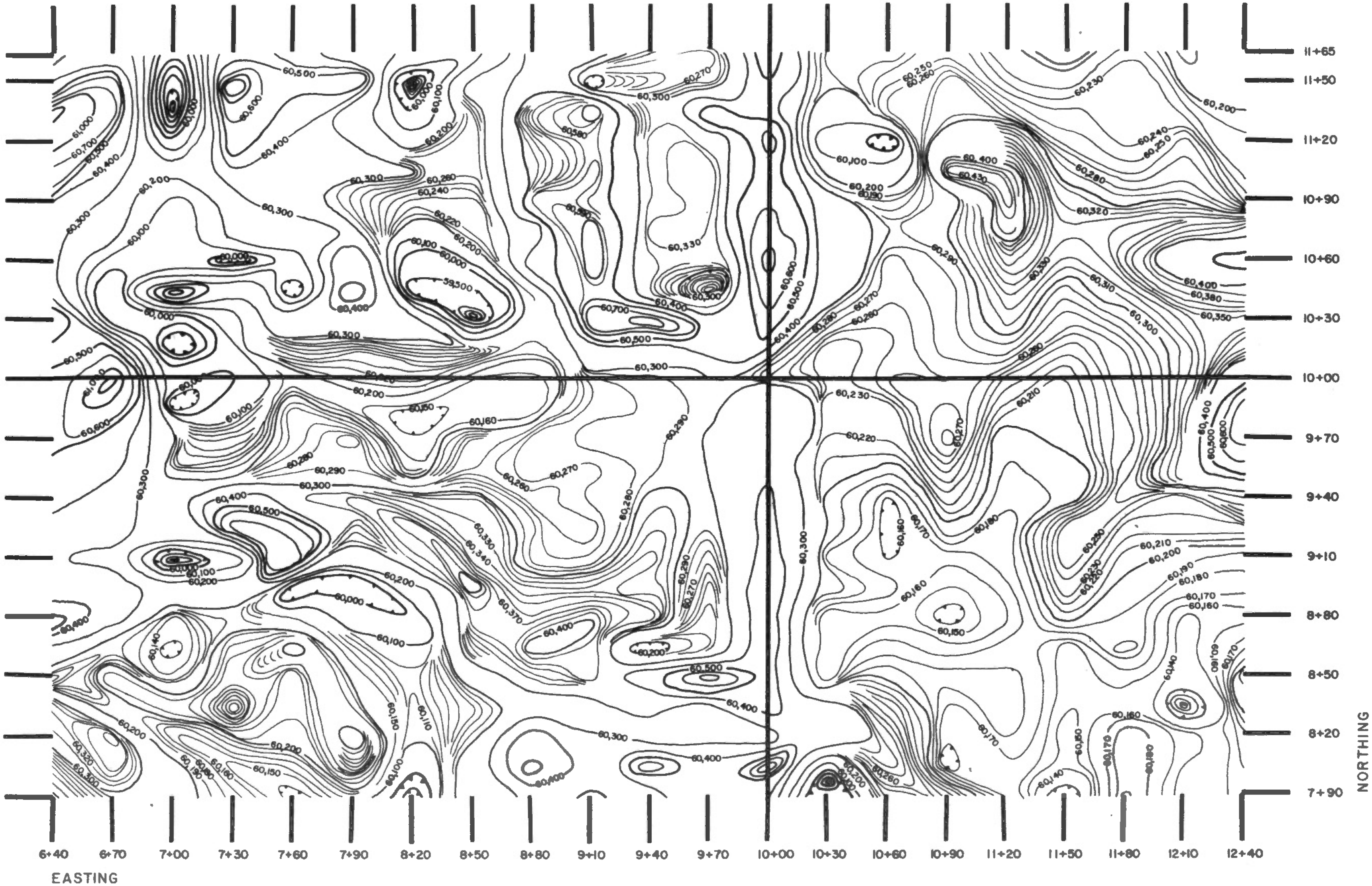

Figure 1. Total field map from ground magnetic survey, Agricola Lake massive sulphide prospect, N.W.T. Contour interval 10 gammas.

L. J. Kornik

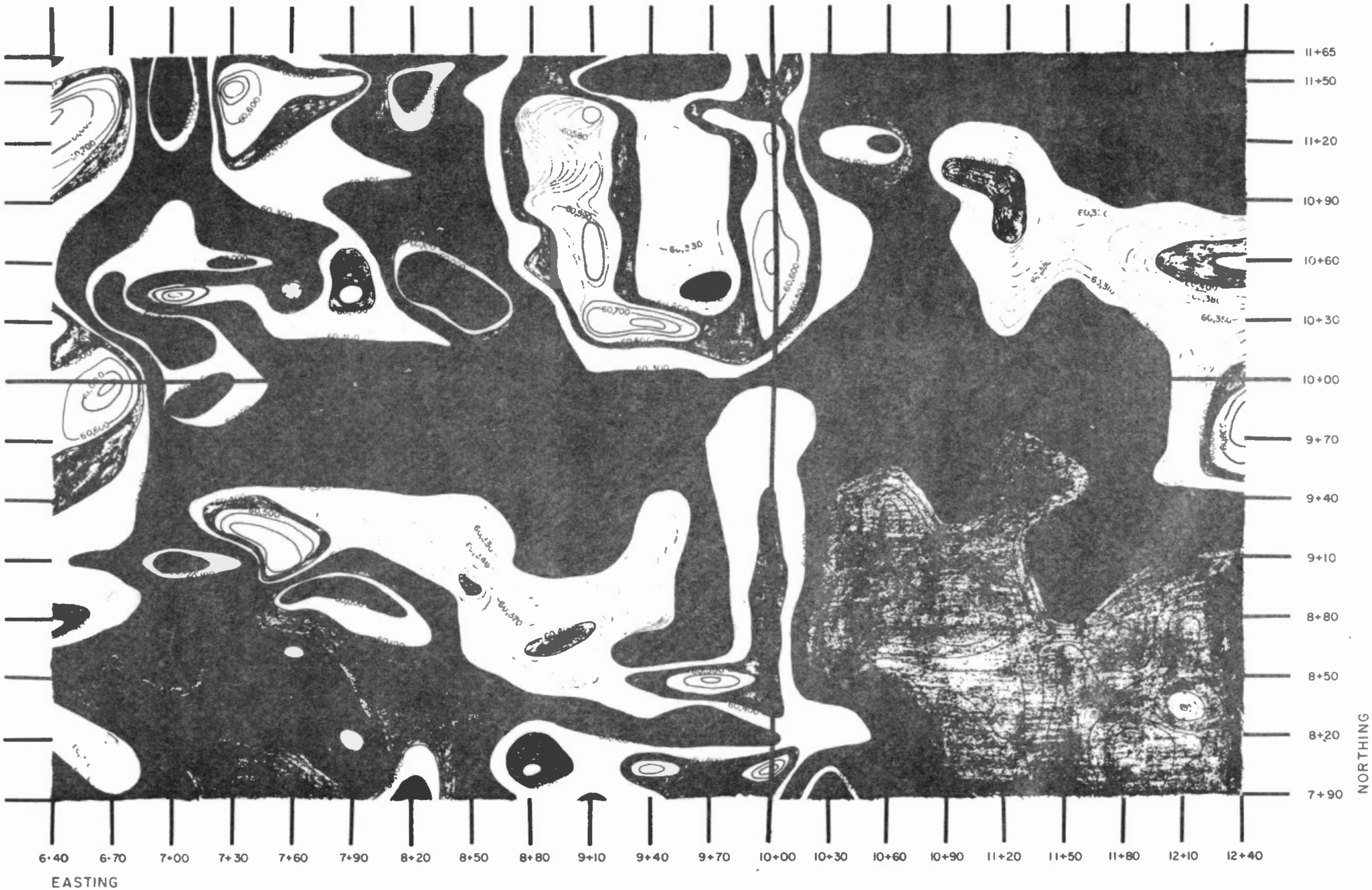

Figure 2. Total field map from ground magnetic survey, Agricola Lake massive sulphide prospect, N.W.T. Contour interval 100 gammas.
L.J. Kornik

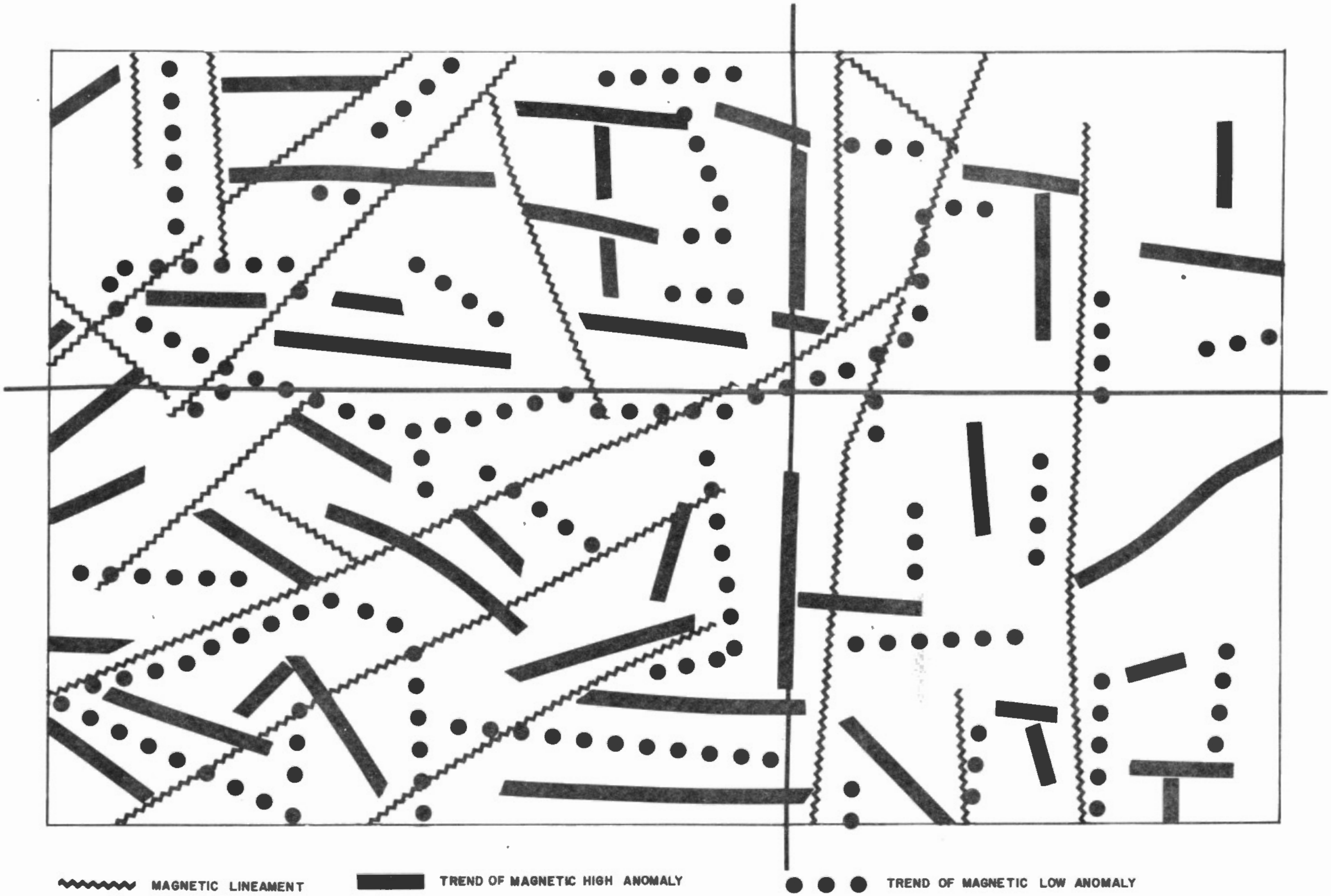

Figure 3. Structural features interpreted from ground magnetic data, Agricola Lake massive sulphide prospect, N.W.T.

L.J. Kornik

GEOLOGY OF THE AGRICOLA LAKE AREA, DISTRICT OF MACKENZIE

T.H. Pearce and Denis Lefebvre
(Queen's University, Kingston, Ontario)

Introduction

During the past years (1972 and 1973), the Geological Survey of Canada conducted an integrated program of geochemical reconnaissance and follow-up in the Bear and Slave Structural Provinces of the Canadian Shield (Allan *et al.*, 1973; Cameron and Durham, 1974; Cameron *et al.*, 1974). This program resulted in the discovery of several geochemical anomalies and especially in the discovery of one anomaly in copper, zinc, arsenic, lead, silver and gold in the Slave Structural Province. This anomaly, the Agricola Lake or "Y" anomaly, is located west of the Beechey Lake in the Northwest Territories, centred on the coordinates 65°36'N and 107°55'W.

The Agricola Lake anomaly is located in a new-found greenstone belt, near the contact of the volcanics and the sediments. This area was previously mapped as a metasedimentary belt (Fraser, 1964; Tremblay, 1971; Wright, 1967) but during the summer of 1973, several volcanic rock occurrences were observed (Cameron *et al.*, 1974).

Due to the lack of geological information on this specific area, mapping was initiated during the summer 1974 by Mr. D. Lefebvre, graduate student, under the supervision of Dr. T.H. Pearce. For this purpose, we benefited from the facilities and the equipment of the Geological Survey field camp. The field season, restricted to seven weeks, began in June and ended in the middle of August. In the field, we profited especially from the advice of Dr. E.M. Cameron (party chief) and C.C. Durham (assistant party chief). The help of Mr. A. Williams (senior assistant) and Mr. J. Spence (junior assistant) was greatly appreciated. Dr. S. Roscoe (Manager, Yava Syndicate) kindly facilitated work in the area.

General Geology

The geology of the Slave Province has been described by McGlynn and Henderson (1970), McGlynn and Fraser (1972) and by McGlynn (1970). The Slave Province underlies 195,000 sq. km of the northwestern part of the Canadian Shield. Mostly Archean in age, the rocks of this province consist also of Aphebian cover to the northwest, the northeast and the southeast. From a visual estimation, 50 per cent of the Archean rocks are sedimentary-volcanic and the rest mostly consist of granite, granodiorite and granitic gneiss. Up to date, around 20 greenstone belts trending north to northeast have been recognized in these Archean rocks and they form the Yellowknife Supergroup.

Commonly, in the Yellowknife Supergroup, a thin sequence of predominantly mafic volcanics, is followed by thick sedimentary series of greywacke and shale. The transition is locally marked by minor amounts of conglomerate, more mature sandstone, limestone and tuffaceous sediments. The volcanics of the Yellowknife Supergroup are generally restricted to the margins of the greenstone belts. Most of the contacts between the granitic rocks and the rocks of the Yellowknife Supergroup appear to be intrusive. However, some evidences of a granitic basement have been observed here and there in the Slave Province and have been described in the literature.

The volcanic rocks of the Yellowknife Supergroup form 5 per cent of the total area of the Slave Province. They mainly consist of mafic lavas with minor proportions of intermediate to acidic lavas and tuffaceous rocks. Sills, dykes and irregular shaped masses of gabbro, diorite and acid porphyry occur in the volcanic rocks and less commonly in the overlying sediments. The thickness of the volcanic piles usually varies between 1 and 3 km.

Among the sediments of the Yellowknife Supergroup, greywacke, mudstone and their metamorphic equivalents are the most abundant rocks. These are usually conformable with the volcanics, their contacts being gradational and consisting of a series of interbedded flows, tuffaceous beds, greywacke and mudstone. The thickness of the sediments average 1 to 5 km or more.

The rocks of the Yellowknife Supergroup have been folded, intruded by granitic bodies and metamorphosed during the Kenorean Orogeny. The metamorphism varies from low greenschist facies to amphibolite facies.

Description of the Work

Before the field season, D. Lefebvre worked at the Geological Survey in Ottawa, doing photo interpretation, literature research and petrographical work on the samples collected by the Dr. E.M. Cameron party during the previous summer.

For the photo interpretation, we used the two following aerial photographs of the Energy, Mines and Resources Department: A16317-102 and A16317-103. These are the usual black and white contacts of the vertical photographs at the scale 1:6,000. The study area is very well exposed and on the aerial photographs, we could recognize several geological features:

- the general trend (northwest-southeast) of the greenstone belt;
- a relatively thin sequence (2000 m) of volcanic rocks, bedded and slightly folded;
- a thick sequence (over 7000 m) of sedimentary and metasedimentary rocks, more finely bedded but largely folded, located to the northeast of the volcanic rocks;
- granitic rocks, with rough topography and concurrent sets of fractures, located to the southwest of the volcanic rocks;

- folds, which cut the different units perpendicular to the general trend or with a 30-40 degrees angle (west-northwest).

A more detailed study under the stereoscope revealed, among the volcanics, the presence of volcanic tuffs, acid intrusive (locally at the contact of the volcanics and the sediments) and a zone of intense weathering and erosion around the massive sulphide prospect.

These features were checked out in the field and re-examined on the aerial photographs to extend their correlation.

The literature research and the photographical work are not original studies. They were done only to become familiar with the geology of the already known of the greenstone belts in the Slave Province and to be able to recognize more easily the several rock types. The papers of Fraser (1964), Tremblay (1971), Wright (1967), Cameron and Durham (1974) and Cameron *et al.* (1974) were mostly consulted.

In the main area of interest, the mapping was done using a grid of 10 lines, 120 or 240 m apart and 800 m long, set across the general strike of the rock units. Almost all outcrops were visited and each rock type was sampled on each line. The grid was centred on the massive sulphide prospect. The mapping was extended over an area of 6 by 6 km. Twelve traverses, from 300 to 800 m apart, were run in the volcanics and extra traverses were run in the more complex areas. Two short traverses in the granite and two short ones in the sediments were also run to check the uniformity of these rock types. Three intrusions in the sediments but outside the working area were sampled: a granitic plug, a stock of diorite, and a mafic dyke with a diabasic texture.

Geology of the Agricola Lake area

The Agricola Lake area is part of a greenstone belt of the Yellowknife Supergroup, nearly 40 km long and probably the same belt in which the Hackett River deposit (Cominco) has been found. This area is excellent for geological work on the Archean rocks of the Slave Province, the exposure being very good. The rocks are only slightly deformed and metamorphosed. The strike of the volcanics in this part of the belt is northwest-southeast, varying between 145° and 160° and the dip is sub-vertical, varying between 85°NE to 85°SW. The thickness of the volcanics is nearly 2 km but the thickness of the sedimentary rocks is much greater. To the northwest and the southeast of the area, the volcanics are more metamorphosed and more folded. It appears that the area surrounding the massive sulphide prospect has been preserved from high metamorphism and deformation, even if the rocks were tilted to the vertical.

Stratigraphy

Due to the subvertical dip of the rock units, a nearly complete stratigraphic section is exposed in the Agricola Lake area. Two kilometres of volcanics, locally intruded by mafic to felsic bodies are overlain conformably by more than 4 km of sediments. In the field, the contact is marked by a valley 10 m deep and 200 m wide caused by the erosion of the soft sediments (slate) in contact with the volcanics. This ridge may also be produced by a fault along the contact (J.B. Henderson, pers. comm., 1974). The volcanics are not folded, but several transverse faults cut the units perpendicular to their strike. In the field, the displacement is usually not considerable, due to the geometry of the faults and the strata. Near the contact with the volcanic rocks, the sediments are mainly composed of slate and greywacke. Commonly, these rock units are interstratified and the thicknesses of the slate and the greywacke beds vary between 1 to 5 cm and 2 to 10 cm respectively. These rocks are highly deformed in open, closed and isoclinal folds and the amplitude of the folds vary from less than 5 cm to several kilometres (visible on the aerial photographs). The metamorphism of the sediments increases away from the volcanics, from the low grade greenschist facies to the staurolite and sillimanite subfacies of the amphibolite facies.

The granite appears to have intruded the volcanics. Near the contact, several narrow dykes of granitic composition cut the intermediate volcanics. Locally, the volcanic outcrops show a pink weathered surface on their joint planes which probably correspond to the filling of the small fractures by the quartzofeldspathic material derived from the granitic intrusion. Usually, near the contact between the granite and the volcanics, we found small bodies of granodiorite to diorite composition which represent probably a contamination of the granite by the intermediate volcanics. A few dykes of intermediate material, similar to the volcanics, have been observed locally in the granite, near the contact of the volcanics. Possibly, they represent the feeder of the intermediate intrusions in the volcanics.

The Volcanic Rocks and their Related Rocks

This group of rocks consists mainly of mafic and intermediate to felsic flows, tuffs and fragmental rocks. Moreover, the limestone beds, the gossan zones, and the alteration zones within these rocks are included in this category. Finally, the mafic and the acid intrusives found within the volcanic rocks will be described under this title.

The mafic and intermediate flows generally exhibit a massive structure and the contacts between the flows are hard to see. However, in the northwest part of the mapped area, we observe good flow contacts, locally less than 1 m apart. These contacts are continuous over several hundred metres. Other flows exhibit pillow structures. These are not well developed, recognizable only here and there and averaging 1 m in diameter. Great thicknesses of pillowed lavas were not observed in the field but the correlation from one line to another permit us to delimit major pillowed lava units.

The massive lavas and the pillowed lavas are greenish grey on weathered and fresh surface, fine to medium grained and locally showing a diabasic texture. Occasionally, they exhibit 2-5 mm black amygdules of chlorite and amphibole, rimmed by white feldspar. These amygdules are rounded or angular. Other flows show the presence of numerous amygdules of calcite, 1-5 mm or more of diameter. The weathered surface of these rocks is sponge-like. Locally, amygdules of quartz were found in the intermediate flows. These structures are usually less than 3 mm.

A calcite-rich flow lies on the northwest part of the central fault, which cut the main gossan of the massive sulphide prospect. The calcite occurs in a few amygdules, infilling of fractures, in dissemination through the rock, or in the matrix of the brecciated rock. This presence of calcite is not restricted to the flows and is probably due to a secondary effect.

The tuffs and the fragmental rocks are uncommonly well bedded. We think they are of a pyroclastic origin because of the rounded and elongated fragments they contain. These lapili vary in size from 1 to 3 cm. Occasionally, the fragments are more angular. The rock exhibits the same greenish colour on the weathered and the fresh surface and the grain size is similar to the mafic to intermediate flows. Northwest of the central fault, the tuffs present also the concentration in calcite as a dissemination through the rock, as a filling of fractures or as the matrix of local breccia.

Acid flows were not positively recognized. This name was given to a rock type according to the massiveness of its outcrops in the field, the homogeneity of the texture, the absence of bedding, banding, etc. Locally, we found some vacuoles in this thick unit, not very widely spread. This rock exhibits also a local brecciation corresponding possibly to a flow breccia. The rock is white on weathered surface. The light greyish fresh surface is glassy to fine grained, hard, siliceous, with conchoidal fractures and textureless. A few phenocrysts of feldspar, less than 1 mm, were locally observed.

The acid tuffs are the most interesting rocks of this area. Usually, they show fresh structures and textures like bedding, banding, crossbedding, graded bedding, flow-like texture, shards, fragment of pumice, microbreccia and agglomerate. The thickness of the individual beds is commonly less than 5 cm. The rock is white to greyish on weathered surface, greyish white on the fresh surface, glassy to fine grained, hard, siliceous, similar to the rock of the acid flow but differing by its bedding and by the presence of small fragments usually less than 1 cm. Agglomerates and microbreccias were locally observed but no widespread units were recognized.

The gossan zones are found mainly in the acid tuffs or at the contact of these rocks with the intermediate rocks. They are produced by the oxidation of the iron sulphide contained in the tuffs. These sulphides are probably derived from the exhalative activities of the volcanoes. In the field, these zones appear rusty and usually the host rock is deeply altered or weathered.

The alteration zone is located on either side of the central fault. In this zone, the rocks are altered to chloritic schist and to sericite schist, probably derived respectively from intermediate and acid rocks. Numerous gossan were found in the alteration zone. In the field, this zone is poorly covered by sheared outcrops. We used principally the material contained in the frost boils to map this area.

The limestone horizons are not extensive. Usually, they are less than 2 m thick and less than 200 m long. They consist of impure carbonate mixed with recrystallized chert. The weathered surface is typically rugged, deeply eroded and rusty brown in colour. The origin of these carbonate horizons is probably a chemical sedimentation of the exhalations of the volcanoes.

The mafic intrusions are a group of massive and structureless mafic rocks. Greenish grey on weathered and fresh surface, they are coarse grained, equidimensional, composed of hypidiomorphic feldspar and ferromagnesian minerals, locally containing blue quartz eyes up to 2 mm. These bodies are commonly conformable but they can end suddenly in the volcanics by faults or their spatial geometry. A few mafic dykes were observed in the mafic, granitic and acid rocks.

One of the most important features of the geology of the Agricola Lake area is the presence of a sill of quartz and feldspar porphyry near the top of the volcanic succession. This body is probably an intrusion due to the nature of its contact with the acid tuffs and the slate. Where the slate is in contact with the porphyry, the matrix of this latter is usually darker and contain angular inclusions of slate, less than 5 cm. The porphyry is massive and randomly jointed. The white weathered surface exhibit euhedral and zoned feldspar phenocrysts up to 3 mm and quartz eyes up to 5 mm. Under the microscope, the quartz phenocrysts appear to be corroded (irregularly shaped). The fresh surface is greyish white and shows a few biotite flakes. This rock is hard, siliceous and porphyritic, the grain size increasing toward the centre of the intrusion.

Small dykes of quartz and feldspar porphyry and small dykes of fine grained acid rock were also found and are probably related to the same period of intrusion.

The Sedimentary Rocks

Generally, the slate found in the valley at the contact between the volcanics and the sediments does not occur in outcrops. Due to its softness, the slate is eroded and the remnants are found in the rubble alongside the gully and in the frost boils. The slate is black, very fine grained, with at least two schistosities well developed and a very good cleavage.

The greywacke found over the thick sequence of slate is usually interbedded with thin layers of slate. The greywacke is well bedded, schistose, greyish green on fresh surface, fine grained and usually showing tiny fragments of quartz and/or feldspar crystals. The alternation of greywacke and slate is well observed due to the difference in hardness of these rocks. Moreover, the slate developed a perfect cleavage compared to the poor schistosity of the greywacke.

The Granitic Rocks

The granite is massive, randomly jointed and occurs as large rounded outcrops partly covered by granitic blocks. The rock is white to pink on the weathered surface. The fresh surface is usually pink, showing a granitic texture composed of an assemblage of quartz, potassium feldspar, plagioclase, muscovite, biotite, hornblende and locally epidote. The grain size increases from 1-3 mm, near the contact with the volcanics, to 3-5 mm, 500-1,000 m away from the contact.

Locally, the granite exhibits partly assimilated inclusions of the volcanic rocks as dark irregular patches of greenish material in the pink matrix. These features are commonly less than 1 cm. Near the contact of the granite with the volcanics, the composition of the granite looks slightly more mafic and usually, several local outcrops exhibit a fine grained rock with a granodioritic to quartz dioritic composition.

Structure and Metamorphism

Beside the transverse faults which cut the formation nearly perpendicular, several other transverse faults, parallel and forming an angle of 30 to 40 degrees with the strike of the rocks, were mapped. Also, a shear zone of the same orientation was found with the help of a resistivity survey in the vicinity of the main "B" horizon gossan (W.J. Scott, 1974, pers. comm.).

Commonly, the volcanic rocks in the central portion of the Agricola Lake area are metamorphosed to the greenschist facies and locally we could observe metamorphic biotite flakes in the intermediate rocks.

Conclusion

The result of this field work is a geological map of the Agricola Lake area, using a 100- by 100-cm base map which is the enlargement to the scale of 1:6,000 of the portion L to R, 4 to 10 of the aerial photograph A16317-103. On this map, the area covered by the volcanics is nearly 2 by 6 km.

The environment in the Agricola Lake area corresponds to the same type of environment found in the Archean volcanogenic massive sulphide deposits as described by Sangster (1972). The initial drillhole put down by the Yava Syndicate cut a section of 134.4 feet (40.99 m) assaying 3.70 per cent of zinc, 0.71 per cent of lead, 1.091 per cent of copper, 2.73 oz/ton of silver and 0.036 oz/ton of gold (Northern Miner, August 15, 1974). This hole was drilled to test the soil geochemical anomaly described by Cameron *et al.* (1974) and further defined by geophysical studies by the Yava Group. This gossan zone is located near the intersection of the shear zone and the central fault, in the middle of the alteration zone.

It is clear that from geological consideration, further mineral prospecting and drilling will be done in this area by the mining companies. It is clear also that, for a better understanding of Archean geology in the Slave Province, laboratory work on the samples and further field work need to be done in this area where the rocks are well exposed, undeformed and not highly metamorphosed. The writers plan to continue study of the petrology and chemistry of the rocks of this area to develop techniques which will be of use in resource evaluation.

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13. VLF RESISTIVITY (RADIOHM) SURVEY, AGRICOLA LAKE AREA, DISTRICT OF MACKENZIE

Project 670041

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Introduction

During the last week of July 1974, a VLF resistivity survey was carried out over the Agricola Lake massive sulphide prospect. Measurements were made along the soil survey lines (Cameron, this publication, report 55, Fig. 1) using the Radiohm technique (Collett and Becker, 1968). In this technique, the apparent resistivity of the earth is determined by a magnetotelluric measurement of the radiated field from a remote radio transmitter.

The quantities measured are the horizontal components of the radial electric field (E_x) and the tangential magnetic field (H_y), and the phase difference between E_x and H_y. A value for apparent resistivity is derived from the approximate expression:

$$\rho a = \frac{1}{\mu \ \omega} \left| \frac{Ex}{Hy} \right|^2$$

ρa = the apparent resistivity in ohm-metres

where μ = the magnetic permeability of the medium (assumed = $4 \pi \times 10^{-7}$ Henrys per metre)

ω = the angular frequency of the signal $2\pi f$, where f is the frequency in h_z

The instrument used in this survey was a Geonics EM16R, which obtains H_y by means of an integral coil and E_x by means of two ground probes spaced 10 m apart. The measurement is made by orienting the instrument so that the coil is maximally coupled to H_y (determined from an audio signal) and inserting the two ground probes along the direction indicated by the

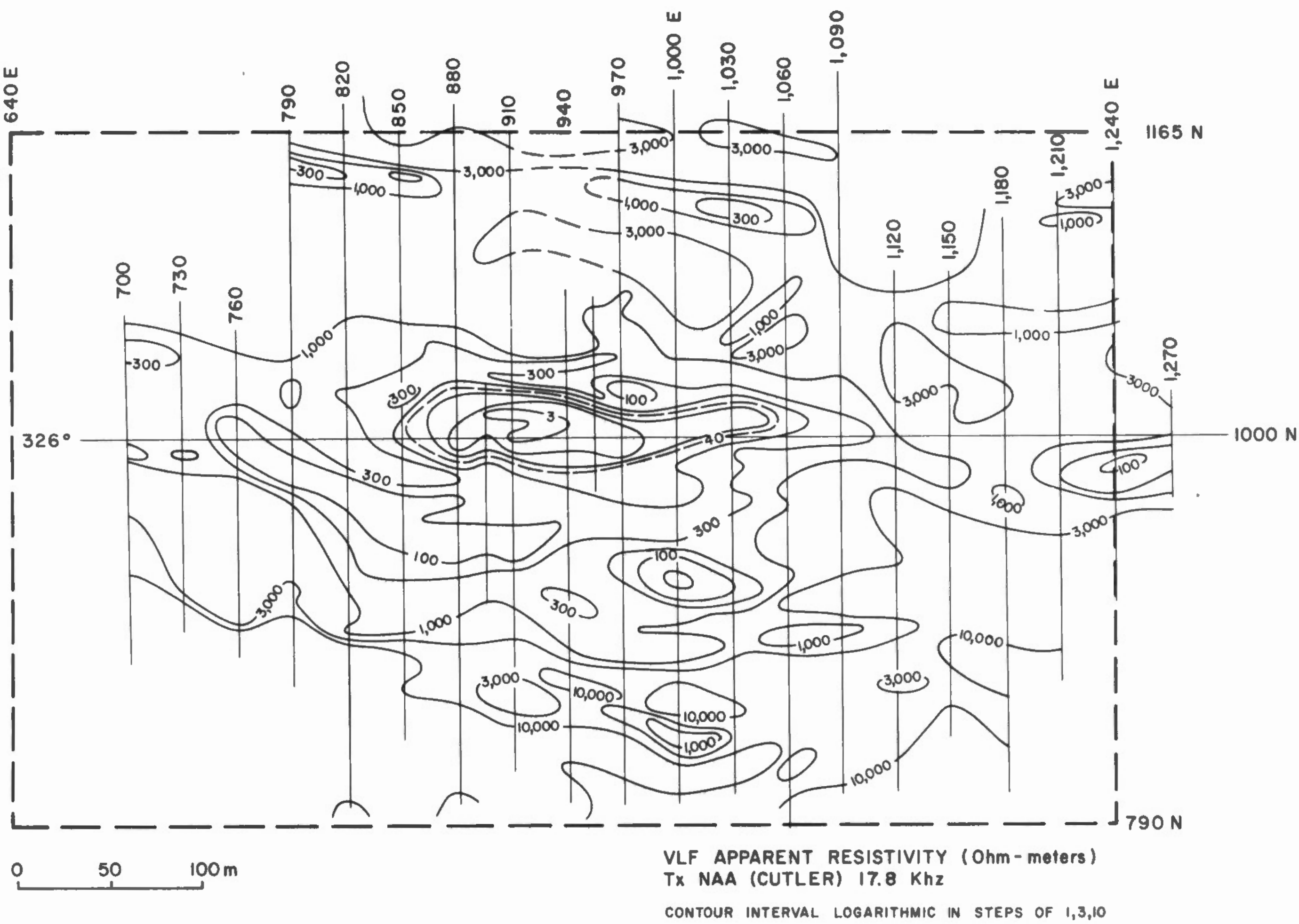

Figure 1. Contour map of VLF apparent resistivity, Agricola Lake massive sulphide prospect, N. W. T.

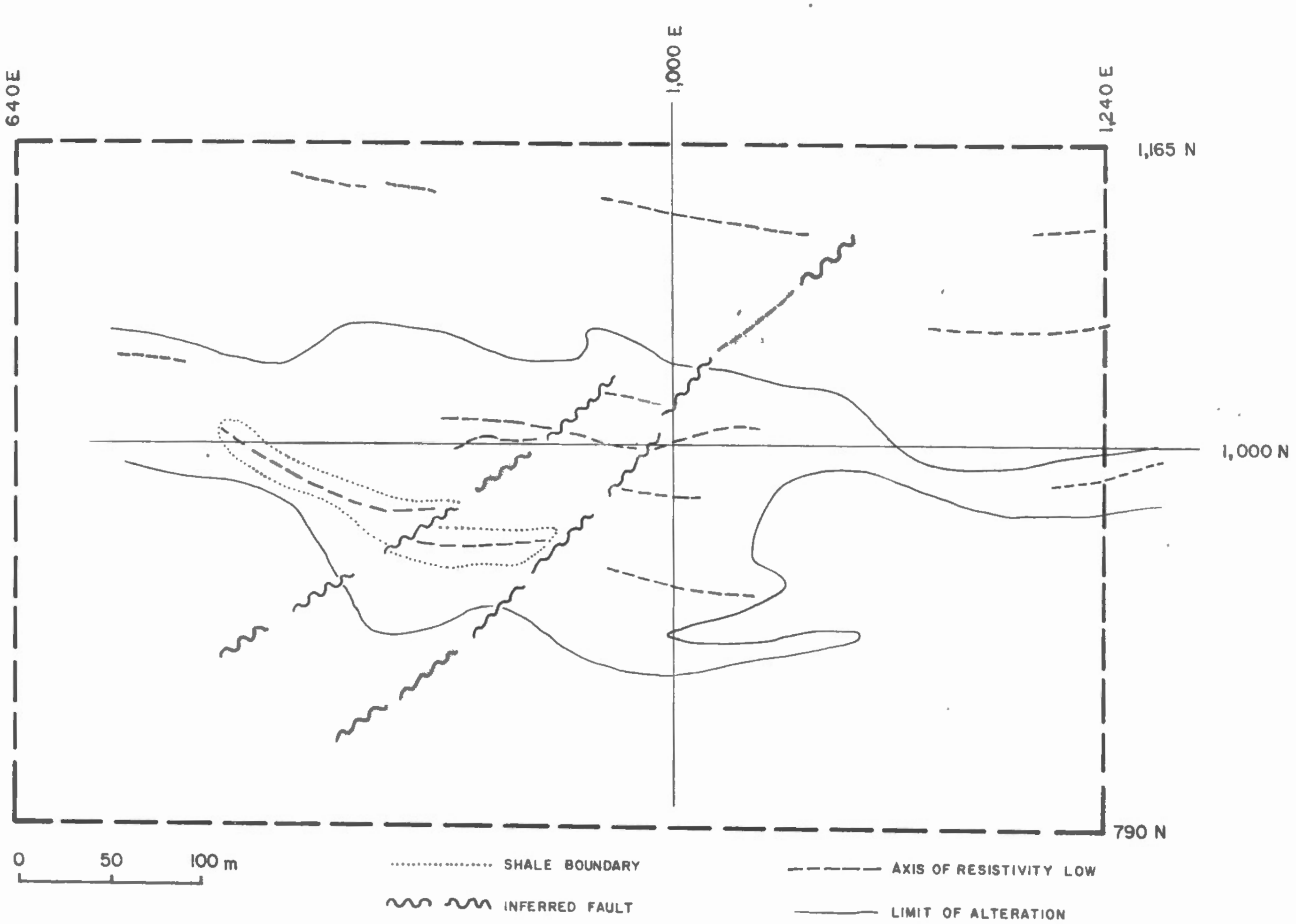

Figure 2. Geological interpretation of VLF apparent resistivity data, Agricola Lake massive sulphide prospect, N.W.T.

instrument orientation. After the audio signal is nulled by means of two controls, the phase angle and apparent resistivity values can be read directly from the instrument. The apparent transmitter azimuth may be determined from the orientation of the instrument.

For the present survey the signal utilized was from NAA, Cutler, Maine, at a frequency of 17.8 Kh_z. The transmitter azimuth was approximately parallel to the base line of the survey grid.

During four and a half field days some 900 measurements of resistivity, phase angle and transmitter azimuth were made by a crew of two, augmented at times by a third man to speed the work on rough ground. The readings were taken at intervals of 15 m on grid lines spaced at 30 m. When adjacent readings varied by a factor of 1.5 or more, intermediate readings were taken.

Results

Figure 1 shows a contour map of apparent resistivities obtained on the grid lines indicated; Figure 2 shows an interpretation based on these data. For purposes of clarity the grid lines are defined to run north-south, and the baseline east-west (true bearings notwithstanding). Directions referred to in this paper are understood to be grid directions.

The observed variation of apparent resistivities agrees in general with the preliminary geological interpretation of (*see* Cameron, op. cit., Fig. 2). In the northern part of the grid, apparent resistivities from 1000 to 4000 ohm-m reflect the presence of acid and intermediate volcanics, whose southern boundary agrees on the whole with the 1000 ohm-m contour.

Rather higher resistivities in the southern part of the grid correlate with a further sequence of acid and intermediate volcanics. In the south-central area, the 1000 ohm-m contour agrees with the northern limit of the volcanics. In the southeast, however, the resistivity data suggest that the unaltered volcanics may extend farther west beneath thin overburden, than indicated by the geological map.

The central area of low resistivity (less than 1000 ohm-m) in general coincides with the area mapped as hydrothermally altered volcanics. Within this zone are several prominent lows. Lying on the baseline from 850 E to 1060 E is a pronounced low, whose outline as shown by the dashed 40-ohm-m contour (Fig. 1) agrees with the part of the boundary of a massive sulphide zone indicated by diamond drilling by the

Yava Syndicate (Northern Miner, August 15, 1974). A small low at 990 N, 1240 E coincides with high metal values in the soil, and may be an extension of the main sulphide body.

The low trending southeast from 760 E on the baseline to 940 N, 940 E crosses a shale unit indicated by the presence of shale fragments in frost boils. In view of the lack of outcrop it is possible that the geology could be re-interpreted to place the shale member under this low as suggested in Figure 2. The results of a magnetic survey on the same grid (Kornik, this publication, report 62) support this interpretation. The low at 925 N, 1000 E appears from the magnetics not to be an extension of this feature, and may indicate a further concentration of sulphides.

The weak east-west low from 960 E to 1080 E at 1120 N coincides with rocks mapped as rusty-weathering intermediate volcanics; it is probable that the westward extension of the feature from 790 E to 870 E indicates the presence of more of this unit. A similar low from 1140 E to 1240 E at about 1060 N may also be associated with such a rock unit.

The traces of two faults trending northeast-southwest (Fig. 2) are picked on the basis of aberrations in the resistivity contours and offsets in the axes of low trends. Further faulting could probably be inferred as well, but would best be done on the basis of a combined interpretation of all the geophysical results. The two faults shown, however, are also indicated by the magnetic data (Kornik, op. cit.).

Discussion and Conclusion

Despite the fact that the area is well within the zone of continuous permafrost (Brown, 1967) there is a wide variation in apparent resistivities. For metallic sulphide mineralization this is to be expected, but it is less obvious that frozen rocks should exhibit such variation. Spot measurements on shale outcrops to the north of the grid give resistivities ranging from 10 to 200 ohm-m, while some measurements on outcrop within the zone of alteration yielded values of a few hundred ohm-m. It is reasonable to suppose that such low resistivities are the result of clay minerals in the rock, with the resultant retention of some pore water in the fluid phase, despite ground temperatures significantly below 0°C.

In the unaltered volcanics, however, particularly to the south, quite wide variations in resistivity did not appear to be related to known rock types, and subdivision of the volcanics on the basis of resistivity would at the present time appear unreliable. It is possible that further work, including laboratory measurements of resistivities at low temperatures, may clarify this problem.

The phase angle and azimuth data taken in this survey have not been shown, because they contain peculiarities which are difficult to interpret. Phase angles are theoretically limited to the range from 0 to 90 degrees, yet at a number of stations, particularly at the west end of the baseline, values much greater than 90 degrees were recorded. Strong variations were observed in the apparent azimuth of the transmitter, as indicated by the direction of H_y. It is probable that these variations are the result of the presence of a strong linear conductor in a region of generally high resistivity. It is hoped that further study will identify the cause of this variation.

The major disadvantage of VLF Radiohm measurements is the lack of penetration through any thickness of conductive overburden. In this study area, however, overburden was generally thin. There appeared to be no significant correlation of resistivity variation with the presence or absence of overburden.

The concept of Radiohm measurements, as embodied in the Geonics EM16R, is extremely useful, particularly in difficult conditions such as experienced at this site. Even in permafrost regions, there appears to be some utility in resistivity mapping as an aid to geological work.

Acknowledgments

The help of D. Eberle (Geological Survey of Germany), A. Williams (GSC), J. Williams (DOE) and Jim Thomas (GSC) in carrying out the field work is gratefully acknowledged.

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14. COLOUR PHOTOGRAPHY IN THE BEECHEY LAKE BELT, DISTRICT OF MACKENZIE

Project 630031

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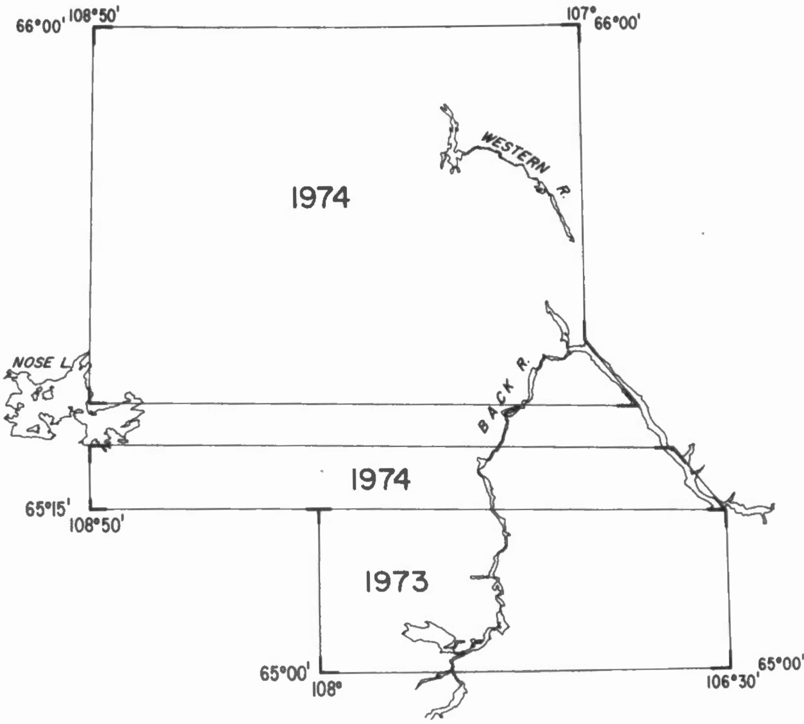
A colour airphoto survey of the Beechey Lake belt was undertaken to provide photogeological support for the interpretation of geochemical data and to assist geological mapping of the volcanics of the Beechey Lake belt. An examination of the 1973 imagery has determined that many if not most of the gossans known to be present will be recognized on colour film.

Some 600 line miles of photography were flown in August 1973 before poor weather conditions halted the project. Flights were continued in July and August 1974, when the whole of the planned area was completed except for a gap 3 lines wide (3 miles) in the southern half of the area.

The area now flown is shown in Figure 1 and totals 3,400 square miles. There are 45 east-west lines spaced at 1.6 mile intervals. The average photoscale is 1:15,000. The negatives acquired in 1973 are held by the National Air Photo Library in Ottawa.



15. LIMNOLOGICAL INVESTIGATIONS IN THE AGRICOLA LAKE AREA

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The feasibility of using present equipment and techniques for locating and sampling sediments in Arctic lakes was investigated. These studies were carried out at the Geological Survey of Canada Friday Lake camp over the period July 18-29, 1974.

A Geological Survey member (Bruce Ballantyne) and I both had the same experience with the Ponar grab sampler - unless the sampling platform was stationary, the sampler rarely brought up any material. Presumably it toppled over on hitting the bottom if the platform was drifting appreciably. The Minishipek was not available for testing, but the sediment was such that I see no reason why it should not have been as effective on these sediments as it has been in the Great Lakes to date. I wonder, however, whether the Minishipek might be vulnerable to damage on striking boulders, due to its protruding knobs. Perhaps the knobs could be partially encased.

A Geological Survey sampler designed for collecting organic-rich samples from lakes in the southern Shield was also used. It is similar to the Phleger corer but slightly heavier. The valve system uses a ball. This corer failed on two drops out of three, and is probably inferior to the Minishipek as a grab sampler.

The Phleger corer in its present form is not a suitable coring instrument for sampling soft sediments. Problems encountered were:

(1) many cores were often far shorter than the depth of immersion of the corer (generally to the fins). Presumably the valve mechanism was closed on entering the sediment, either because the valve was not properly freed before lowering the corer into the water, or because the valve closed as the corer descended.

(2) the liners are open at both ends and, as soon as the barrel was unscrewed, the sediment started sliding out. Attempts to remove the cores by immersing the corer under water were usually not successful, though the job may have been easier with two persons (shoulder length rubber gloves might have helped too). Under these conditions, it was very tricky to slip the present type of cap onto the liners. The problem was not much alleviated by filing the outside edges of the ends of the liners.

(3) some of the liners were too tight to slide out of the barrel easily. While trying to free them, the core was invariably lost.

(4) the cutting edge had to be removed with a vise grip on one occasion.

Owing to the clear water, the descent of the Phleger in free fall could be watched. It kept a good vertical orientation. On impact the disturbed sediment spread out for about 0. 5-1 m around the corer, but did not billow up into the water which remained clear.

It looks as if we need another lightweight system for recovering sediment cores for helicopter sampling. Possibilities are a type of box corer such as the one developed at Brock University. Another possibility is to develop a miniaturized version of the Sphincter corer. Yet another is the Brown and Livingstone corers. It might be possible to convert the Phleger corer into a useful instrument by:

(1) having constructed valves similar to the new Benthos valves which could be taped to the top of the liners. The stop inside the core barrel would then have to be moved upwards.

(2) filling the outside edges of the ends of the liners OR redesigning the caps.

Even then, the narrow barrel of the Phleger means that a disproportionate amount of uppermost 2 cm or so of the sediment column is smeared down the sides of the barrel. This objection may apply to the Brown and Livingstone corers also.

Because of the shallowness and clearness of many Arctic lakes, it might be advantageous to record at each sampling station the Secchi disc reading and/or whether the bottom was visible by viewing tube.

The lakes which I visited all seemed to have rocky "nearshore" areas (occupying at least half the lake) and central depressions partly filled with sediment, with little or no transition. The Kelvin-Hughes MS 39 echo sounder, had no difficulty in differentiating rock from sediment-filled areas. The sediments recovered by Geological Survey sampler were very varied in colour, including light brown, light grey, bright red and dark brown materials with sandy, silty and "soily" appearances. In Friday Lake two distinctive types of sediment were seen, and could be distinguished by the echo sounder. Type I, giving a very "soft" reflection, consisted of a reddish uppermost layer, about 1 cm thick, overlying soupy brownish material down to a depth of at least 30 cm (the maximum length of core recovered by the Phleger corer). The other type, Type II, giving a "harder" reflection, consisted of bright reddish surface material overlying brownish material over bluish-grey sediment. The last material readily oxidized in the core liners on standing after only a couple of days to a deep black material, inducing the speculation that the bluish material contains $Fe(OH)_2$ which readily oxidizes to material of the approximate composition $Fe_4(OH)_{10}$ with possibly serious consequences for paleomagnetic measurements.

In conclusion, Arctic lake sediments are fascinating materials, and should give abundant scope for process studies. There is evidence that the post-depositional changes in these sediments are very different from what we are familiar with in the Great Lakes. The development of adequate dating techniques for these probably pollen-free lakes could lead to studies of the dispersal of man-made pollutants (including radionuclides and exotic organic compounds) in high latitudes.

NICKEL POTENTIAL OF THE PRINCE ALBERT GROUP, N.W.T.

Project 630037

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Previous mapping of the Prince Albert Group (Heywood, 1961, 1967; Campbell, 1974; Frisch, 1974 and Schau, 1974) has revealed the presence of numerous ultramafic bodies, a compilation of which is shown in Figure 1. During the 1974 field season, the writer examined some of these ultramafic rocks in 6 separate areas in order to gain some appreciation of their nickel potential. The writer gratefully acknowledges helicopter support and field guidance supplied by V. and D. Kretschmar, Cominco Ltd., in the Hayes River area, (A and B, figure 1) and the following Geological Survey officers: T. Frisch, in the Mackar Inlet area (C and D), M. Schau, in the Hall Lake area (E and F) and J.E. Reesor, in southern Melville Peninsula.

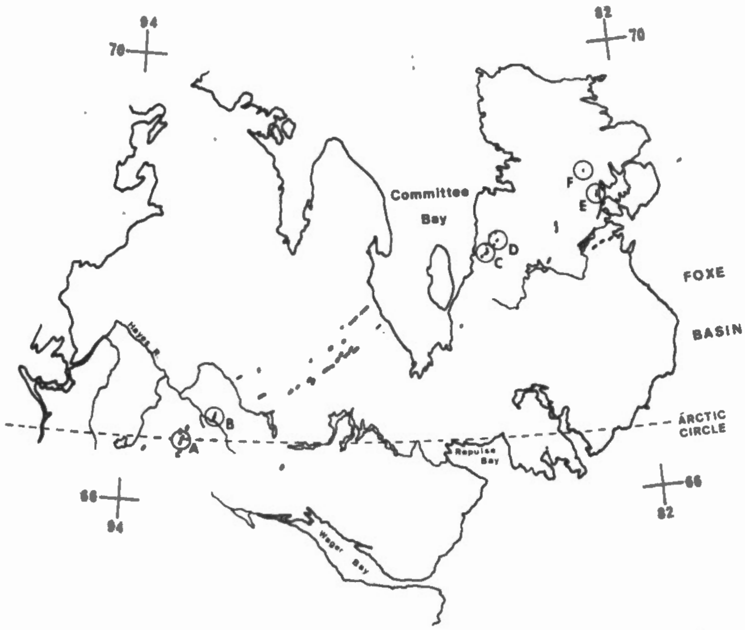

Figure 1. Compilation map of ultramafic bodies in parts of the Districts of Franklin and Keewatin. From data by Heywood (1961, 1967), Campbell (1974), Schau (this publication), J.E. Reesor (pers. comm.) and T. Frisch (pers. comm.). Letters indicate localities visited by the writer during the 1974 field season.

The most noteworthy finding was that a significant proportion of the ultramafic rocks seen are of extrusive origin, closely similar in morphology and primary textures to the ultramafic flows of Munro township (Pyke *et al.*, 1973). Of the six localities shown in Figure 1, two (A and C) contain sequences of clearly identifiable, spinifex-bearing flow units, from which unequivocal facings were determined. In two other localities (B and D), the presence of flows seems likely.

Locality A in Figure 1 is an area with a great concentration of ultramafic rocks (*see* Schau, this publication, reports 94, 95). In one outcrop, 1 to 2 metres thick, ultramafic flow units exhibit well preserved grain-size gradation of the spinifex zones (Fig. 2, 3) all indicating northwest-facing of the flows. Weathering of the flows produces colour bands, the spinifex layers appearing as dull grey-green bands and the cumulate layers (originally more olivine-rich) as brighter reddish-brown bands. Tremolite-actinolite and chlorite are the principal minerals in the spinifex

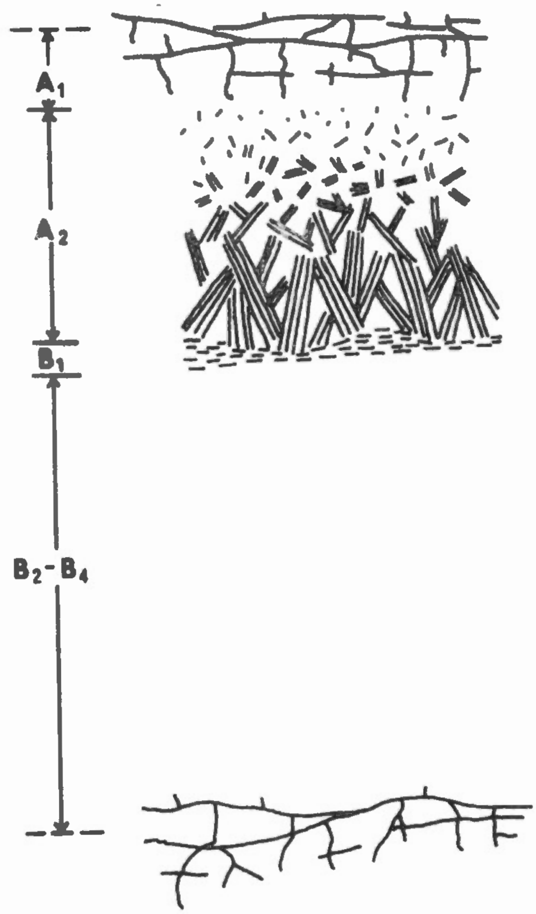

Figure 2. Schematic diagram of layering within one single flow unit at locality A, Figure 1. A_1 = chilled and fractured flow top; A_2 = spinifex zone, showing grain size gradation; B_1 = foliated skeletal olivine layer; B_2–B_4 = massive peridotite (designation of layers as in Figure 8, Pyke *et al.*, 1973). Precise traces of upper and lower contacts are uncertain within a few centimetres. Total thickness of flow unit is about one metre.

layer, but abundant biotite was also noted in the interstices between laths (originally olivine) of coarse spinifex in one flow unit (Schau op. cit.). Other ultramafic rocks also seen at this locality include thicker units, with minor spinifex texture, that are probably flows; two large equant outcrops of massive serpentinized peridotite that are probably parts of intrusions; and a conformable tremolite-talc rock intercalcated with amphibolite, quartzite, and paragneiss. Few sulphides were seen in the ultramafic rocks.

At locality B, conformable ultramafic lenses occur in thin-bedded, mafic and quartzitic metasediments. These sediments contain abundant sulphides, mainly pyrite and pyrrhotite, in many cases immediately adjacent to the ultramafic lenses. These sulphide zones, sampled by King Resources Co., yield assay values up to 0.18% nickel and 0.05% copper (Laporte, 1974, p. 121). Some of the ultramafic rocks contain minor amounts of disseminated sulphides. Deformation, alteration and recrystallization of these ultramafic rocks has been intense, and could account for the lack of recognizable spinifex texture. Nevertheless, the presence of interlayered tremolite-rich and chlorite-rich rocks suggests that they could represent flows of mafic to ultramafic composition. Analyses of such rocks from areas A and B are reported by Schau elsewhere in this publication.

In one outcrop area in locality C, metre-thick ultramafic flows with good "graded" spinifex permit reliable top determinations, apparently the only ones in this area (*see* Frisch, this publication, report 87). Brown and green colour bands in these rocks are even more prominent than at locality A. Identical colour-banded ultramafic rocks at locality D contain no recognizable spinifex, but probably represent spinifex-bearing flows in which primary textures have been destroyed by recrystallization. It is suggested that ultramafic rocks displaying alternating brown and green colour bands of the appropriate width, without spinifex but with obviously recrystallized textures may tentatively be interpreted as sequences of ultramafic flows. Closely associated with the flows and suspected flows in localities C and D, are massive serpentinized peridotites and their talc-carbonate altered equivalents, which seem more likely to be intrusive.

The ultramafic rocks at locality E are sufficiently deformed and recrystallized that their original character remains obscure.

At locality F, a feldspathic meta-pyroxenite stock, about 150 to 300 metres wide, is conspicuous because of the extensive gossanous weathering developed on contained disseminated nickel-copper sulphides. Aquitaine Co. of Canada Ltd. carried out 2000 feet of drilling on this prospect in 1973. (Department of Indian Affairs and Northern Development, 1974, p. 22). The outline of the stock appears to transect layering in the surrounding granitic and migmatitic paragneisses. The texture of the pyroxenite is medium-grained, granular and unfoliated. The sulphides are most abundant at the margins, diminishing in abundance toward the centre of the stock. They are mainly disseminated, but are also found as fracture fillings. It appears that the pyroxenite mass with its attendant magmatic sulphides was intruded into the gneisses after their main period of deformation, but that later shearing and metamorphism have affected the mass.

NOTE: Photograph - Figure 3 is not reproduced in this open file due to technical difficulties.

Figure 3. Photograph of spinifex texture in a polished thin section, specimen from locality A. GSC 202660-B.

Nickel potential

Few nickel sulphide occurrences have been reported in the Prince Albert Group (Laporte, 1974). The only significant occurrence is that of Aquitaine at locality E. However, the nickel potential of the Prince Albert Group must be regarded as significant because of the nature and environment of the contained ultramafic rocks. They bear certain similarities to ultramafics containing nickel and sulphide deposits in a number of Archean terranes including the Abitibi orogenic belt in Ontario and Quebec, the Yilgarn and Pilbara blocks of western Australia, and the Rhodesian Craton. Some of the points of similarity are the following:

1. A large proportion of the ultramafics are conformable lenses, and many of these are demonstrably extrusive.
2. The ultramafics are part of a supracrustal suite of rocks comprising volcanics, and siliceous and other sediments including iron formation (*see* Campbell and Schau, 1974).

3. The ultramafic rocks are commonly found in close spatial association with oxide or sulphide iron formation and sulphide-rich sediments (Campbell, 1974).

Because of these similarities it is reasonable to expect that some nickel sulphide deposits similar to those in the other terranes might also be found in the Prince Albert Group ultramafics. Such deposits could be either of the Kambalda type, associated with flows, or of the Mt. Keith type, associated with sills (Eckstrand, 1973).

Age of the Prince Albert Group

Apart from the Prince Albert Group, all of the presently known spinifex-bearing ultramafic flows whose ages are known with reasonable assurance are Archean in age. Consequently, even though lithology can rarely if ever be used as a sure indicator of age, the presence of such rocks in the Prince Albert Group supports an Archean age interpretation.

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17. VOLCANOGENIC ROCKS OF THE PRINCE ALBERT GROUP, MELVILLE PENINSULA (47 A-D) DISTRICT OF FRANKLIN

Project 720062

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Regional and Economic Geology Division

Mapping volcanogenic rocks of the Prince Albert Group continued this year (Schau, 1973, 1974) along the east coast of Melville Peninsula (47A and D) in an effort to determine the nature and location of volcanic centres and their place within the stratigraphic section and the nature of subsequent deformation affecting the Prince Albert Group in belts recently outlined by Heywood (1967, 1974). J. Maley, L. deBie, A. Béland, K. Arthur and Y. Michie ably assisted the operation, aided on a half time basis by a G47A Bell helicopter piloted by E. Beaumont and serviced by E. Godleski. Base camp, on the Kingora River, approximately 40 miles west of the small community of Hall Beach, in the District of Franklin, was occupied between June 27 and August 21, 1974.

The results of most interest include the finding of more magnetite-bearing iron-formations similar to those previously reported (Heywood, 1967; Wilson and Underhill, 1971). The establishment of a partial section in the Prince Albert Group, the finding of thin ultramafic dykes and sills of the same type as found last year (Schau, 1974), the presence of very coarse grained metre-thick anorthosite layers in a widespread gabbro, the locating of several acid volcanic centres, and the recognition of thick mafic flows above felsic volcanics, constitute the important geological results.

The rocks of the Prince Albert Group are thought to rest upon a basement of diverse character, but nowhere was the unconformity seen. A variety of lithologies are present, ranging from calc-silicate layers to poorly-foliated granite gneisses, but most common is a grey well-layered gneiss. The presence of different structures within th gneiss include large, gently dipping recumbent structures not seen in the nearby steeply-dipping Prince Albert Group. In some instances, undeformed ultramafic dykes cut the gneiss. These dykes are seen in gneisses known to be old in the Hayes River region, and as well, are taken to indicate the extreme age of the enclosing gneisses.

Prince Albert Group

Sinuous belts of the "Archean" Prince Albert Group strike in a northeast direction towards Roche Bay where they swing northward to go along the west shore of Hall Lake. The belts are steeply dipping. In the south, beds and structures are considerably flattened so that primary structures are absent. To the north, however, a few structures, especially pillows, are discernible. Iron-formations are more important to the south, and although all relations are not fully understood in these areas it appears that quartzitic rocks and acid volcanogenic rocks underlie the mafic volcanic rocks.

At the extreme north of Melville Peninsula, on the south shore of Fury-Hecla Strait, a partial section about 6 km thick of the Prince Albert Group is preserved. These rocks have been described by Blackadar (1963) who noted that pillow structures are common here. Acid recrystallized volcanogenic rocks constitute the bottom third of the section. These are overlain by oxide facies iron-formation, quartzites, and quartzose breccias which are in turn overlain by "andesitic" flows, breccias and tuffs, and "topped" by oxide facies iron-formation. Basaltic pillowed and massive flows capped by a quartz-rich breccia-conglomerate overlie the "andesites". At the top of the section is a 1 km thick set of trough-crossbedded immature grits and sandstones in which are thick local flows (?) of basalt. These flows (?) within the grit unit are peculiar in that they consist of a sheared tuffaceous and fragmental base, above which is a layer of very magnesian material, usually a talc and chlorite schist, overlain by medium-grained gabbro, which may be fractured into metre size blocks. These coarse-grained rocks are overlain by true pillowed basalts and a sheared tuffaceous top. The flows (?) vary in thickness from several hundred metres where the complete series is developed, to thin layers of chlorite schist only a few metres thick. Flattened intercalations of medium-grained and fine-grained greenschist and amphibolites are seen north of Hall Lake. Here the sequence is also interpreted to be in the core of a south-plunging syncline.

Felsic volcanic centres were found in the Bouverie Islands (UTME 445000, UTMN 7725000)[1] and near the south end of Hall Lake (UTME 435000, UTMN 760500) with associated iron-formations of oxide facies. Fragmental rocks of the Prince Albert Group in the latter area include breccias with fiamme structures now represented by biotite-rich shapes. These indicate that some of the felsic volcanic units were subaerial, whereas the presence of pillows suggest some of the mafic volcanism was subaqueous. Within the Prince Albert Group, under the mafic rocks near the north end of Hall Lake, is a breccia-conglomerate with dark volcanic clasts and clasts of medium-grained granodiorite. In thin section the plutonic rock appears to have been severely crushed and mineralogically retrograded in comparison to the non-crushed appearance of the dacite. This is indirect evidence for the plutonic basement.

In summary, a mixture of quartzite and other clastic sediments, iron-formation, felsic volcanic rocks and basic to ultrabasic volcanic rocks make up the Prince Albert Group.

[1] All localities within text are all in UTM zone 17W.

Ultramafic layers are locally abundant as chocolate brown to green, thinly layered, ultramafic sheets, described previously (Schau, 1973, 1974; Schau and Campbell, 1974; Schau, this publication, report 95; Eckstrand, this publication, report 76; Frisch, and Goulet, this publication, report 87). In most localities they are sheared and contain local breccia zones. Along the south shore of Fury and Hecla Strait ultramafic units are clearly intrusive as shown by a folded iron-formation of oxide facies complexly intruded and in part assimilated by an ultramafic sill and dyke complex. East of this locality, along the shore thin ultramafic sheets cut more gently dipping quartzite-rich breccia-conglomerates. Elsewhere, ultramafic sheets seem to be part of the basic flows of the Prince Albert Group previously described. In the south, ultramafic units emplaced in "old" gneiss are more massive than their sheared counterparts in the Prince Albert Group. Ultrabasic magmas are interpreted as being emplaced both as flows and as dykes and sills in the Prince Albert Group rocks; they must represent a late igneous phase in the depositional history of the Prince Albert Group.

Gabbro is widespread. On the east coast of Melville Peninsula the gabbro is characterized by large euhedral to rounded plagioclase phenocrysts which may on occasion form layers up to a few metres thick that extend for many hundreds of metres. The phenocrysts decrease in abundance towards the south. They are an easily distinguishable lithology, even in migmatite terrane or in sheared metagabbro units. Because of subsequent deformation the original shape of the gabbro body is not known although it would appear from the parallel orientation of anorthosite layers and bedding that the gabbro was introduced as sills in the still relatively flat-lying Prince Albert Group. One thin lava flow in the Bouverie Islands contains abundant plagioclase phenocrysts of the same aspects as those in the intrusive gabbros suggesting the coeval emplacement of gabbro and the mafic volcanic units.

Although the gabbro and some ultramafic sheets are clearly intrusive, it is thought that they were emplaced during the latter part of the deposition of the Prince Albert Group.

Granitic rocks are very abundant in the region. The western border of the Prince Albert Group near Hall Lake is intruded by a massive medium-grained characteristically porphyritic granite to granodiorite which nearly everywhere separates the gneisses from the Prince Albert Group. It cuts across structures in the Prince Albert Group, especially north of Hall Lake and includes parallel, closely-spaced roof pendants, as well as stoped blocks of recognizable Prince Albert Group or mafic intrusives. Locally, migmatite and gneiss grades into the granitic rock. To the southwest of Roche Bay, this unit is foliated and locally crushed along northeast-trending, steeply-dipping surfaces. In this region gneisses and gneissic granitic rocks are difficult to distinguish.

Metamorphosed diabase dykes which traverse both Prince Albert Group and granitic rocks, are faulted and folded in events thought to be associated with the deformation of the Penrhyn to the south.

Feldspathized zones to small local pods of medium-grained miarolytic granite, cement faults and intrude all units except fresh diabase dykes throughout the mapped region.

Structure

The Prince Albert Group is folded into large, tight-to-upright isoclinal folds which are responsible for the linear outcrop pattern. Because primary structures are rare in most tightly folded regions in the south, it is not known whether complete synclines are still preserved in the southern portion of map-area 47 A. Preliminary work suggests that only portions of the synclines were protected from the encroachment of the granitic intrusions. To the north, gneisses, thought to be old, outcrop both east and west of the belt. North of Hall Lake the Prince Albert Group outcrop area is wider, and in this region local, interior, complicated folds occur. On the Bouverie Islands folding of the Prince Albert Group is relatively simple, with steep western limbs and gently dipping eastern limbs to form asymmetrical folds with a gentle southeast plunge which contrasts sharply with the near horizontal northeast-southwest trend of the folds in the region near Roche Bay.

The difference in structural intensity through the region is due in part to the superposition of the penrhyn deformational event. The domal styles displayed by Aphebian Penrhyn sediments and their basement are not continuous throughout the region, instead they are best displayed in the southeast corner of 47 A, and extend southward into map-sheet 46 (Heywood, 1967; Reesor, 1974; Reesor *et al.*, this publication, report 92) to form the Foxe Fold Belt (Davidson, 1972). As the region of Penrhyn outcrop is approached, the northerly trend of the Prince Albert Group changes to the northeast. The plutons are foliated along the same trend. In "older" gneisses the style of latest folds change from conical, open folds in the north (UTME 413000, UTMN 7655000) through concentric styles (UTME 420000, UTMN 7640000) to similar styles not distinguishable from later or earlier folds near the Penrhyn outcrops. The first appearance of Penrhyn rocks is in a tight northeast-trending syncline with a horizontal plunge and a near vertical axial plane, and not as expected, a thrust fault or recumbent fold with a southwest-dipping axial plane. No outliers of these Aphebian sediments have been found north of the border syncline.

The latest deformational events have been along faults which have bent and displaced Ordovician sediments.

On regional compilation maps the belts of Prince Albert Group are shown as being both Aphebian and Archean (Douglas, 1968). The belts are now known to be structurally, stratigraphically and lithologically continuous (Schau, 1974; Campbell, 1974). The fact that they are cut by granitic plutons that are in turn cut by folded and faulted metadiabase dykes that are seen to underlie the Aphebian Penrhyn Group (Lecheminant, pers. comm.) shows that the Prince

Albert Group is not a lateral equivalent of the Penrhyn. Aphebian (?) quartzites rest upon 1) Prince Albert Group, 2) the granites that cut it, and 3) the metadiabase dykes that cut both at Folster Lake and environs map-area 47 B (Frisch, 1974). Zircons from gneisses, basement to the Penrhyn group, are considered Archean (Reesor, 1974; Wanless, pers. comm.). Further geochronological studies are in progress.

Minerals of economic interest

Iron-formations have been the object of considerable interest (Wilson and Underhill, 1971) in the southern portion of map-area 47 A. These beds sweep northward to form locally thickened sections at least as interesting as those to the south. The beds form local inclusions in ubiquitous gabbro intrusions, but the region near (UTME 424500, UTMN 7649500) is an example of a potentially interesting region. Other elements of interest have also been found, albeit in small concentrations, and are included as a matter of record. Eckstrand (this publiction, report 76) reports on the sulphide concentration in a "young" feldspathic pyroxenite stock, minor copper stains are associated with the older meta-ultramafic units, and as veins in greenstones. Base metals are found in a zone within the quartzose sediments on Cox Island and, finally, molybdenum is found in a vein in granite (Table 1).

TABLE 1

SOME SELECTED OCCURRENCES OF MINERALS ON MELVILLE PENINSULA

UTME (in zone 17W)	UTMN	DESCRIPTION
426800	7656396	Molybdenite in a small local vein in granite.
444600	7714082	Yellow stained radioactive quartz-rich rock associated with granite.
433652	7603417	Small amounts of chalcopyrite associated with fiamme structures in acid volcanic rock.
447500	7725555	Very scarce chalcopyrite and malachite staining in sheared ultramafic layer (several occurrences in this region).
442035	7714180	Malachite stained, chalcopyrite, galena, and sphalerite-bearing quartzose metasedimentary rock forms local small zone in quartzose metasedimentary rocks.

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18. VOLCANISM AND PLUTONISM, SLOAN RIVER MAP-AREA (86K), GREAT BEAR LAKE, DISTRICT OF MACKENZIE

Project 730039

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Three months were spent mapping the south half of Sloan River map-area (Fig. 1). Mapping in the north half was begun in 1973 (*see* Hoffman and Cecile, 1974) and the project is scheduled for completion in 1975.

The most important results of this year's field work concern the relation of mineral deposits at Port Radium to regional volcanic facies changes.

General Geology

The map area straddles the north end of the "Great Bear Batholith" (Fraser *et al.*, 1972), a belt of latest Aphebian volcanic and plutonic rocks in the west half of the Bear Province. The area contains one of the world's great accumulations of intermediate and acidic welded ash-flow tuff. The tuffs are broadly folded about gently-plunging northwest axes, but northeast-dipping limbs predominate such that high stratigraphic levels occur only in the northeast and low ones in the southwest. For this reason, it is uncertain whether the important changes in volcanic facies from east to west across the map-area are related mainly to paleogeography or stratigraphic level.

Throughout most of the area, no basement to the volcanic pile is known. However, at their most easterly extent, the volcanics are intercalated with sedimentary rocks that abut against older granitoid rocks of the "Hepburn Metamorphic-Plutonic Belt" (Fraser *et al.*, 1972). This contact, in part depositional and in part tectonic, results from west-side-down movement during volcanism along a fundamental crustal break, the Wopmay Fault.

The volcanic rocks are intruded by discordant epizonal plutons having narrow contact metamorphic aureoles. The plutons are massive and have sharp contacts. The older ones range from granodiorite to quartz monzonite; the younger ones are granite and quartz diorite, the latter being relatively small. The large post-volcanic plutons do not extend east of the Wopmay Fault, although a single small granite stock of identical type intrudes gneisses of the Hepburn Belt near the southeast corner of the map-area (*see* Fig. 1).

Both the volcanic and plutonic rocks are offset by steeply-dipping, northeast-trending, right-lateral, strike-slip faults. These faults splay and die out approaching the older Wopmay Fault, and have a complementary set of northwest-trending, left-lateral faults in the Hepburn Belt. Strike-slip faulting probably preceded deposition of the Helikian sediments that cover the Great Bear Batholith to the north and west, but dip-slip rejuvenation of the faults persisted through Helikian time. The volcanic and plutonic rocks are deeply weathered beneath the Helikian cover, a fact which may be important in the evolution of their mineral deposits.

Western Volcanic Sequence

The volcanic rocks in Figure 1 are divided into western, central and eastern sequences. The western sequence, stratigraphically the lowest, is exposed along the rugged coast of Great Bear Lake from Echo Bay to Doghead Point (*see* Fig. 2). Earlier maps of this region include Feniak (1952) in the north and Mursky (1973) in the south.

Of fundamental importance is the facies change from south to north (Fig. 3). To the south, a great shield volcano is exposed in cross-section. At its base is a transition upward from subaqueous to subaerial tuff and tuffaceous sediment, intruded by andesitic plagioclase-hornblende porphyry. In detail, the succession is (1) distal deep water facies — fine-grained, laminated, silicified tuff ("banded chert"); (2) proximal deep water facies — tuffaceous mudstone with turbidites and slump breccias of redeposited tuff; (3) shallow water facies — crossbedded tuffaceous sandstone and tuff-pebble conglomerate; and (4) subaerial facies — graded and reverse-graded, crystal and lithic, air-fall tuff. The lowest flows are thin, finely-porphyritic, basaltic (?) andesite, but the bulk of the shield volcano is built of coarsely porphyritic andesite flows and flow breccia, interstratified with thinner units of bedded air-fall tuff. Trachytic alignment of plagioclase phenocrysts is common except in the upper flows, which are expecially altered and contain abundant gossans.

To the north, the andesite thins markedly and is in part overlain by and in part interfingered with dacite-rhyodacite ash-flow tuff and sediment. The lower ash-flows are mostly massive, densely welded, and crystal-rich; the upper ones are strongly eutaxitic, moderately to weakly welded, highly altered, and rich in lithic fragments. The sedimentary units locally contain acid porphyry domes, some probably extrusive, and consist of conglomerate, sandstone and mudstone, derived in part from the andesite shield volcano and in part from the acidic ash-flows and porphyry domes. Crossbedding indicates northward transport, that is, away from the shield volcano.

One conglomerate high in the sequence at Doghead Point contains granodiorite and quartz monzonite pebbles resembling the large pluton on Hogarth and Workman Islands a few kilometres to the south. This pluton intrudes only the lower part of the western sequence and is itself intruded by a feeder to the distinctive plagioclase-quartz porphyry sill that discontinuously

[1]McGill University

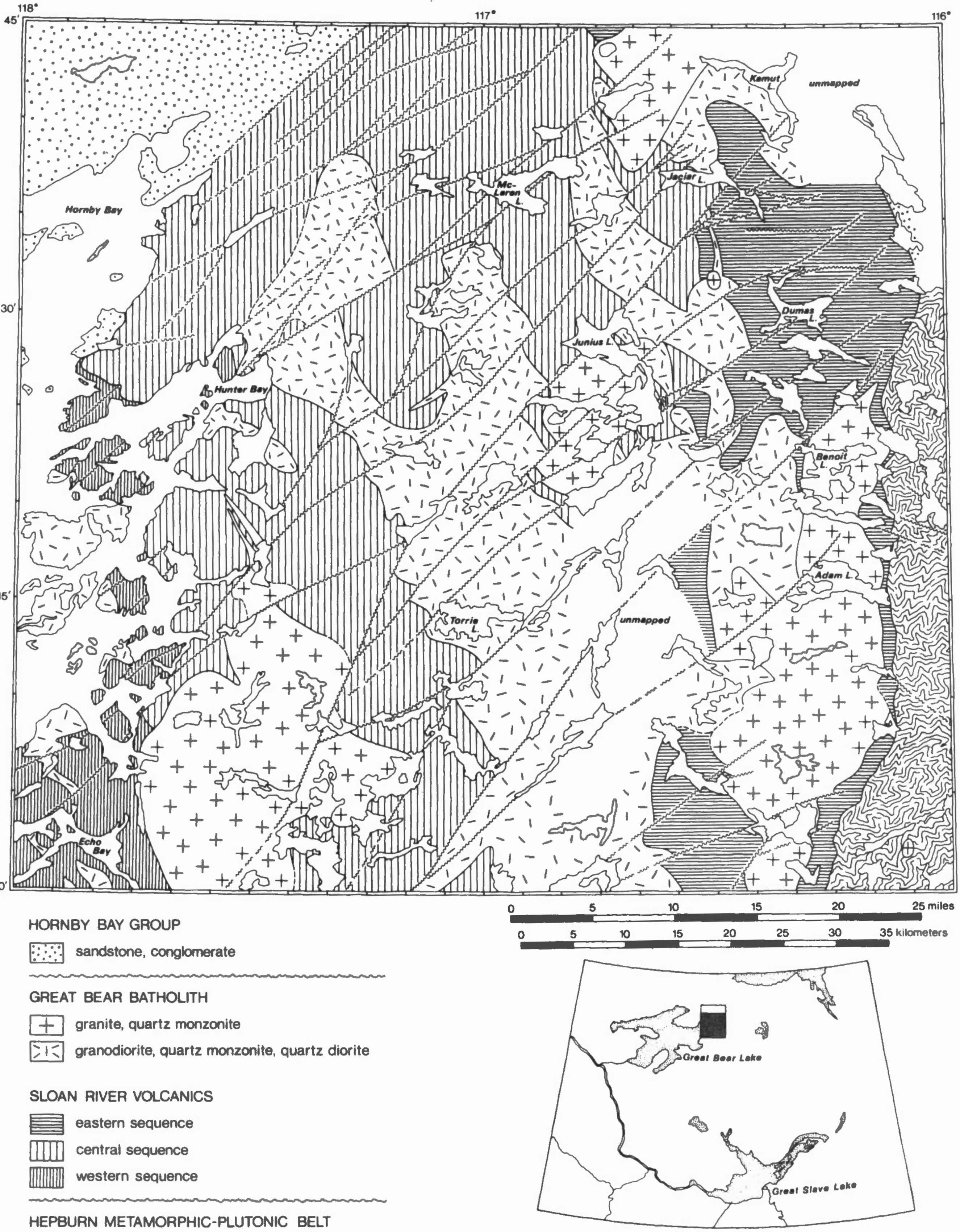


Figure 1. Geology of three-quarters of the Sloan River map-area showing the distributions of the western, central and eastern sequences of volcanic rocks.

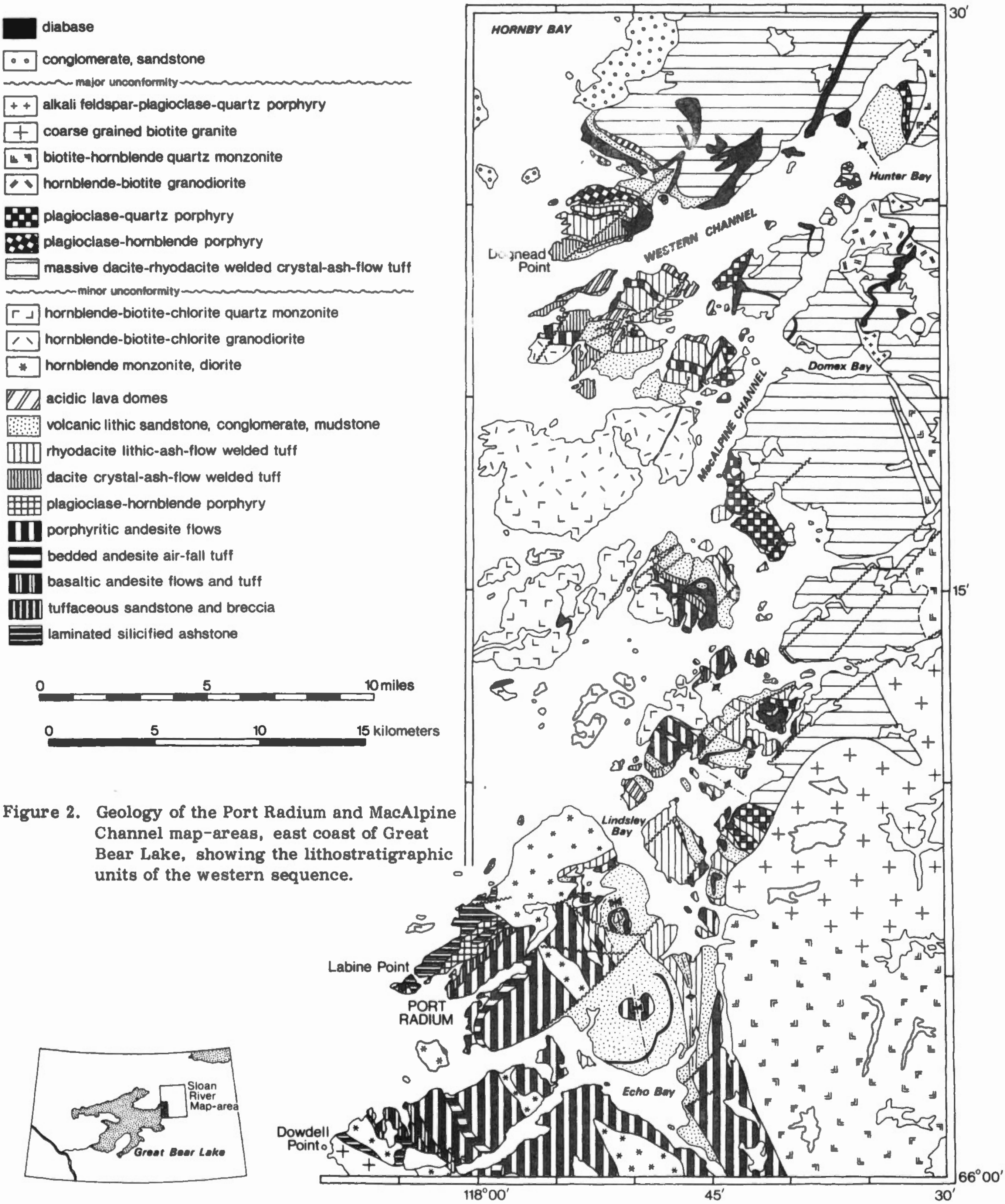


Figure 2. Geology of the Port Radium and MacAlpine Channel map-areas, east coast of Great Bear Lake, showing the lithostratigraphic units of the western sequence.

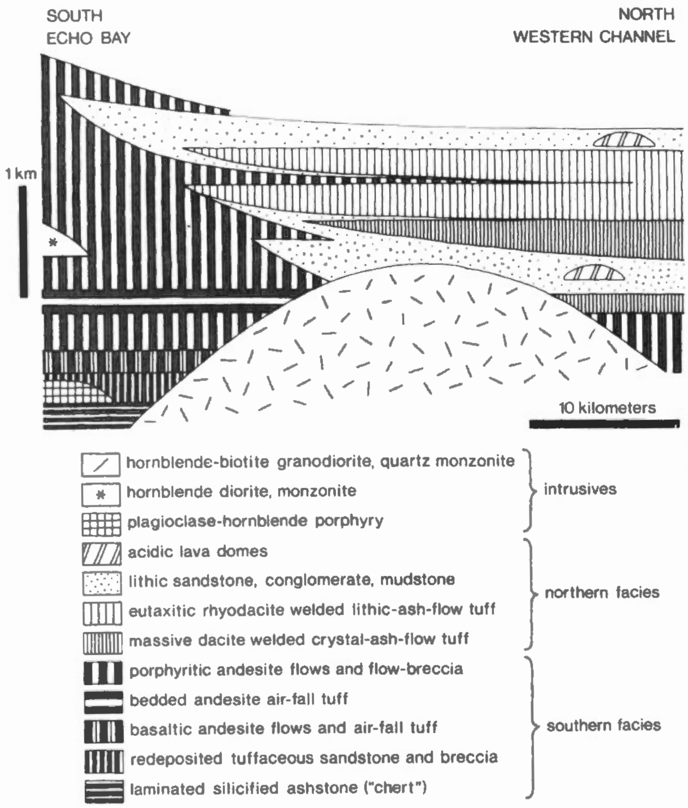


Figure 3. Facies relations in the western sequence from Echo Bay to Doghead Point.

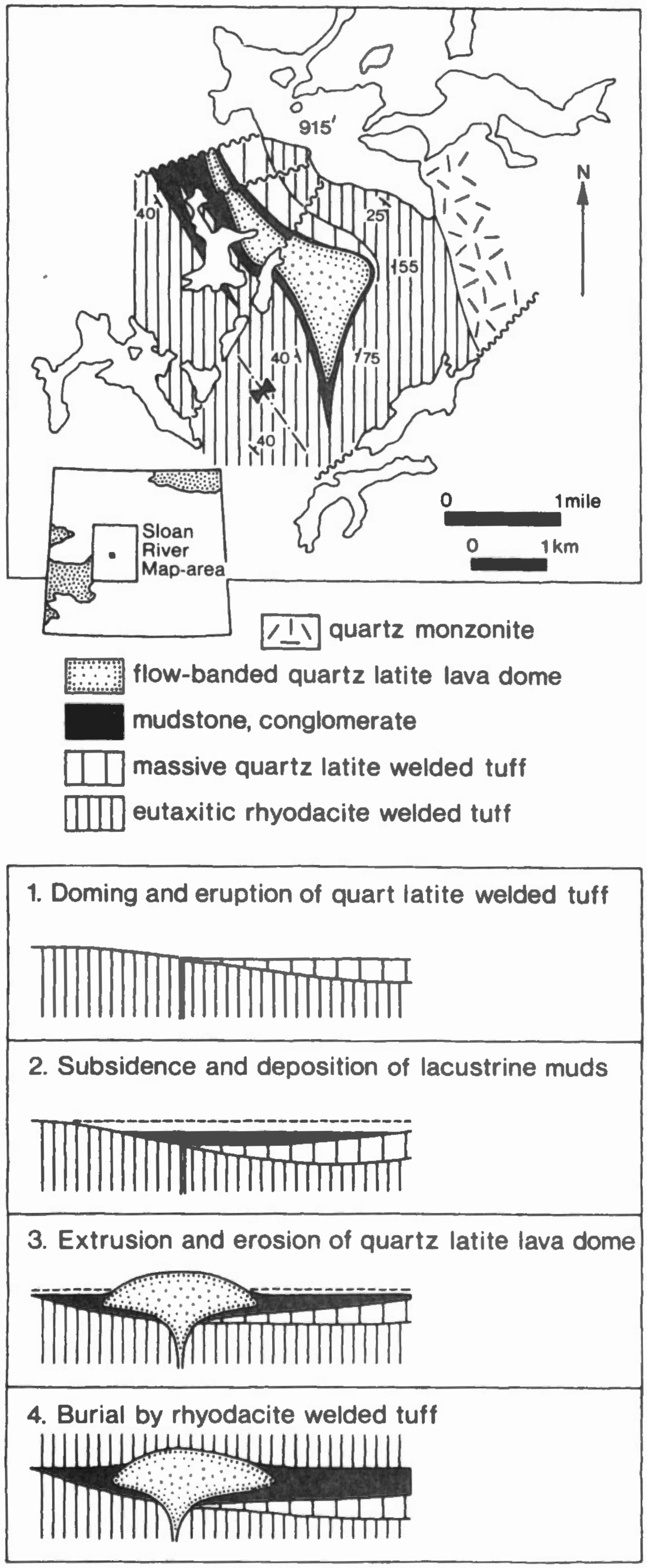


Figure 4. Map and genetic reconstruction of a quartz latite lava dome in the central sequence at 66°28'30"N, 117°07'W.

separates the western and central sequences. Therefore, this pluton must by syn-volcanic and, by extension, so must the family of older, uniquely quartz-poor, monzonite-diorite intrusions around Echo Bay (*see* Fig. 2).

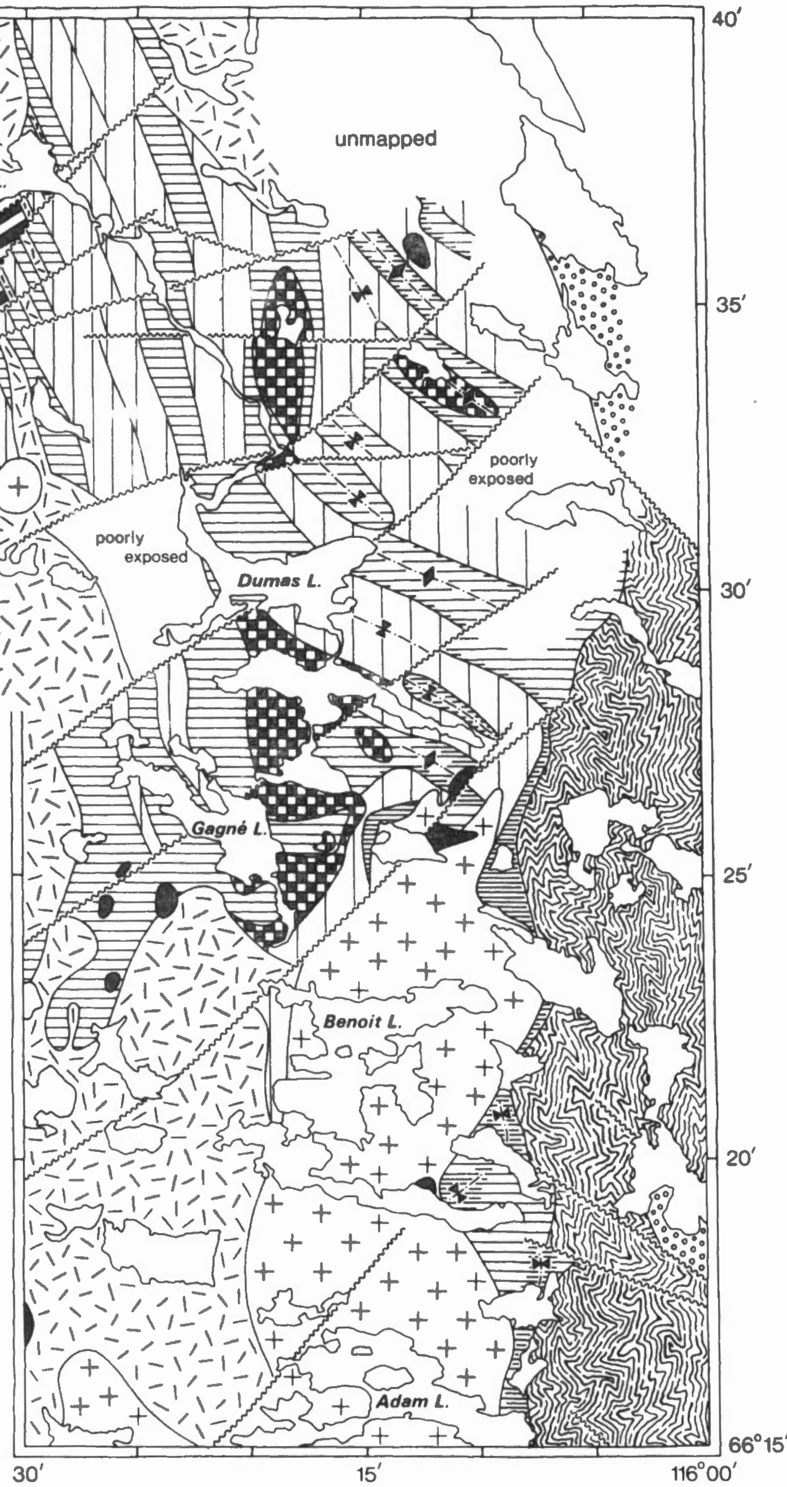
The western sequence was tilted gently to the west, lightly block-faulted, and weathered before deposition of the overlying central sequence.

Central Volcanic Sequence

The central sequence consists of enormously thick piles of densely welded ash-flow tuff rich in broken crystals. Paucity of interstratified sediment distinguishes it from the western and eastern sequences.

The belt extending southeast from Western Channel almost to the south edge of the map-area (*see* Fig. 1) is stratigraphically the lowest part of the sequence. The tuff in this belt is very well exposed, very monotonous, reddish dacite-rhyodacite with prominent columnar jointing. Eutaxitic structure is weakly developed. In its upper part, the tuff is intruded by sills of dacite-rhyodacite porphyry, compositionally identical to the tuff but with unbroken phenocrysts.

More heterogeneous tuff occurs northwest of McLaren Lake and in the pendant-shaped belt between Junius Lake and Hunter Bay (*see* Fig. 1). Massive, coarsely phenoclastic quartz latite is interstratified with strongly eutaxitic rhyodacite. A major flow-banded,



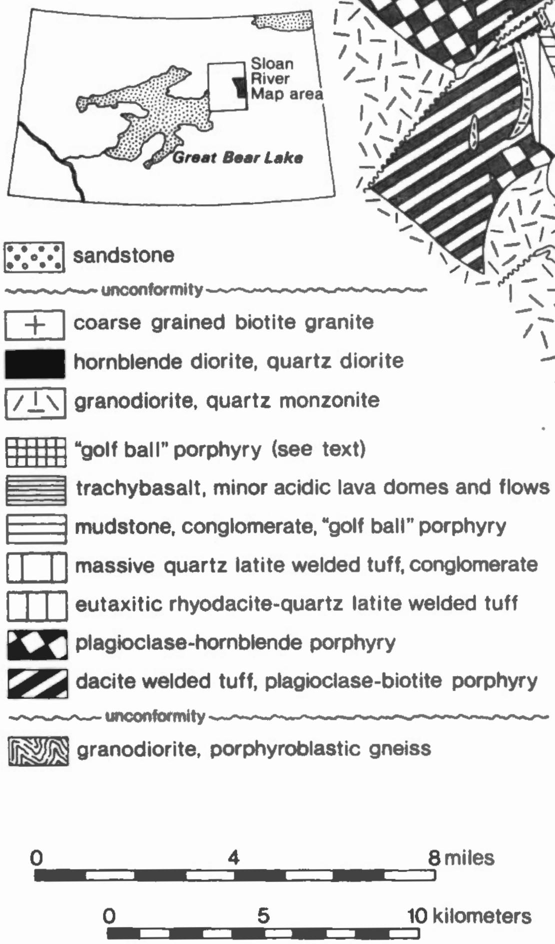
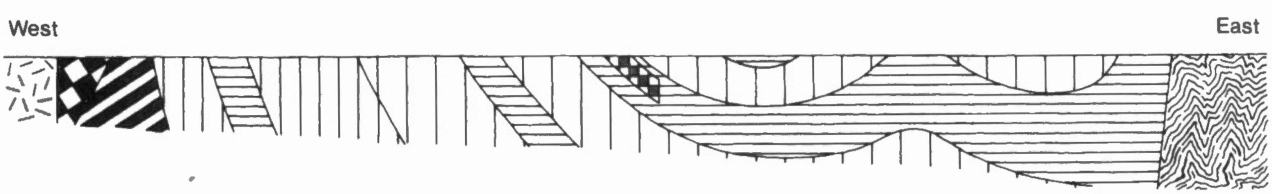


Figure 5. Geology of the region between Jaciar Lake and Adam Lake showing the lithostratigraphic units of the eastern sequence. The idealized cross-section depicts the structure before the late strike-slip faults.



quartz latite, lava dome is located within a lens of lake sediment and probably marks one of the elusive eruptive centres of the ash-flow tuff. A map and interpretation of its origin is shown in Figure 4.

The upper part of the central sequence is exposed in a triangular area between Junius, McLaren and Jaciar lakes (*see* Fig. 1). Extensive lenticular units of dark green, moderately eutaxitic, dacite-rhyodacite, ash-flow tuff are interspersed with thinner brick-red, strongly eutaxitic, ash-flow tuff relatively poor in crystal fragments. The tuff is discordantly intruded by a fine plagioclase-biotite porphyry and a slightly younger rhyodacite porphyry with coarse phenocrysts of plagioclase and hornblende, plus minor alkali feldspar and quartz. The latter also intrudes lower parts of the central sequence to the west.

No plutons are known to have intruded the central sequence before deposition of the conformably overlying eastern sequence.

Eastern Volcanic Sequence

The eastern sequence is best exposed around Dumas Lake (*see* Fig. 5) but a narrow strip against the Hepburn Belt extends to the south edge of the map-area. The "buttress unconformity" between the eastern sequence and Hepburn basement is exposed at latitudes 66°02', 66°05', 66°18'30" and 66°25'30"N.

The sequence is made up of several cycles containing, from the base upward, (1) a thick, densely welded, crystal-rich, rhyodacite-quartz latite, ash-flow tuff; (2) a sedimentary unit ranging laterally and vertically from mudstone with varve-like lamination, to mudstone with turbidites, to crossbedded sandstone, to volcanic-pebble conglomerate; and (3) a relatively thin capping of potash-rich, rarely pillowed, porphyritic, basalt flows, locally with acidic lava domes. The mudstone units contain intrusions of "golf-ball porphyry", a distinctive quartz latite with large rounded phenocrysts of alkali feldspar. At least one such intrusion, east of Gagne Lake, is multilobate in plan view. The quartz latite ash-flow tuffs contain broken "golf-balls", indicating that the tuff and porphyry are extrusive and intrusive equivalents of the same magma.

The sedimentary units and, even more so, the basalts thicken toward the Wopmay Fault. The Hepburn basement near the fault is intruded by swarms of basalt and acidic dykes that can be traced into flows and sills in the eastern sequence. Conglomerates against the fault consist of boulders of Hepburn basement rocks, plus intraformational sediment and basalt clasts. Sedimentation is clearly related to slippage on the Wopmay Fault, perhaps triggered by ash-flow eruptions, in a manner similar to resurgent cauldera (Smith and Bailey, 1968), to produce the observed cyclicity.

Stratigraphic Nomenclature

The only formal stratigraphic nomenclature applied to the volcanic rocks is based on mapping of the western sequence around Echo Bay (*see* Kidd, 1933, an altogether outstanding report). The andesite and underlying tuffaceous sediments were assigned to the "Echo Bay Group", and the overlying conglomerate and sandstone (*see* Fig. 3) to the "Cameron Bay Group". The groups were thought to be separated by an unconformity because the conglomerate contains clasts of andesite. This year's mapping indicates, rather, that there is no angular discordance, that the andesite and sediment interfinger, and that the clasts result from syn-volcanic erosion of the andesite shield volcano. There is therefore, no unconformity.

The facies changes in the western sequence has frustrated attempts (e.g. Mursky, 1973) to extend the two-fold stratigraphic subdivision north of Echo Bay. The ash-flow tuffs, in particular, have been assigned in some places to one group and elsewhere to the other. Furthermore, the two group names have increasingly been applied throughout the Great Bear Batholith to rocks in the central and eastern sequences. By now, their stratigraphic significance, once clearly defined, is lost.

A new stratigraphic nomenclature is in preparation. The three sequences will constitute formations of a single group. The western formation (i.e. western sequence of this report), especially, will contain several members. Discussion of this proposal will be welcomed by the senior author.

Volcanic Facies and Mineral Deposits

The mineral deposits at Port Radium and Terra Mine, 50 km to the south, have a similar and highly specific geologic setting. Both are located in the western sequence, at the base of the andesite volcanic pile, and where the pile is relatively thick. This suggests a spatial, if not genetic, relation to the centre of the andesite shield volcano. In all probability, both are in the same volcano, offset by a major strike-slip fault in the valley of Tilchuse River. In addition, it may be significant that both deposits are close to where a large pluton, mostly underwater at Port Radium, truncates the base of the andesite pile. Perhaps, contact metamorphism concentrates minerals originally of volcanic origin. Regardless of origin, the base of the andesite pile, exposed at the south tip of Stevens Island, near the north tip of Vance Peninsula, east of Dowdell Point, and along the Camsell River south of the map-area, is an attractive exploration target. Exploration should not ignore the possibility of exhalative massive sulphide mineralization in the tuffaceous sediments directly beneath the andesite pile.

The potential of the area for "porphyry copper" mineralization associated with plutonism was viewed pessimistically by Hoffman and Cecile (1974). This view might best be tempered in the case of the intrusives around Echo Bay and on the islands to the north. This is because they are apparently older and more probably syn-volcanic than the large plutons to the east.

Regional Tectonic Setting

Hoffman and Cecile (1974) on the basis of work mainly on the eastern and central sequences, suggested that volcanism occurred in an environment of crustal attenuation analogous to the Basin and Range Province of the western United States and Mexico. However, there is little direct evidence of basin and range faulting and, while an extensional environment is still favoured, slip apparently occurred exclusively on the Wopmay Fault.

Badham (1973), on the basis of the calc-alkaline petrochemistry of the western sequence, favoured a volcano-plutonic arc analogous to the Cenezoic central Andes, generated above an east-dipping subduction zone. However, the rocks are consistently more potassic (Badham, 1973) than is typical of the Andean arc-crest.

Perhaps both models are in part correct, and by combining them the observed change in volcanic facies from west to east may be rationalized. It is suggested that the map-area covers only the back part of the arc, the front parts being covered to the west. Thus, the western sequence — andesite shield volcanos standing high above dacite-rhyodacite ash-flow plateaus — represents the back part of the arc-crest, its high potash content relating to the progressive increase in potash/silica ratio from front to back in arcs generally. The central and, especially, the eastern sequences — containing a bimodal association of acidic ash-flows and lavas, and potassic basalts — represent the fill of an exteme back-arc rift basin, essentially an incipient "marginal basin" (Karig, 1971). Assuming a scale of arc development comparable to the Andes, the front of the arc may be as far west as the Mackenzie Mountains. Thus, the entire arc edifice is the basement on which the Helikian continental terrace wedge was deposited.

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CARBONATE-HOSTED ZINC-LEAD DEPOSITS OF THE NORTHERN CANADIAN CORDILLERA

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The accompanying map shows the distribution of significant recent discoveries of zinc and lead in the Mackenzie Mountains, some two dozen of which were examined in the initial phase of a continuing metallogenic study of the northern Cordillera. All occurrences are in strata older than Upper Devonian, and the majority of significant deposits has been found in dolomites of Lower Cambrian age. The strong affinity of base metal deposits for Lower Cambrian rocks elsewhere in the northern Cordillera was noted by Gabrielse (1969) some three years prior to these discoveries in the Mackenzie Fold Belt.

The base metal deposits, most of which appear to be of classic Mississippi Valley type, bear no apparent spatial or genetic relationship to igneous rocks. In fact, none is less than 20 miles east of a line of Cretaceous plutons peripheral to eastern Selwyn Basin (Fig. 1). Zinc, as pale sphalerite, commonly predominates over lead by about 10:1. Silver and iron content of the deposits are low. Pyrite and pyrobitumen are minor constituents, and gangue minerals include sparry dolomite, calcite, quartz and barite. Secondary Zn-Pb minerals, notably smithsonite, are developed in higher ridge-top occurrences that apparently escaped glaciation (*see* Sangster, this publication, report 69).

The deposits follow the trend of Lower Paleozoic strata for 225 miles along the Mackenzie Fold Belt, but may be considered as constituting three "camps": Godlin Lakes, discovered in 1972; Bonnet Plume River in 1973, and an arcuate belt of deposits in the northern Mackenzies discovered mainly in 1974.

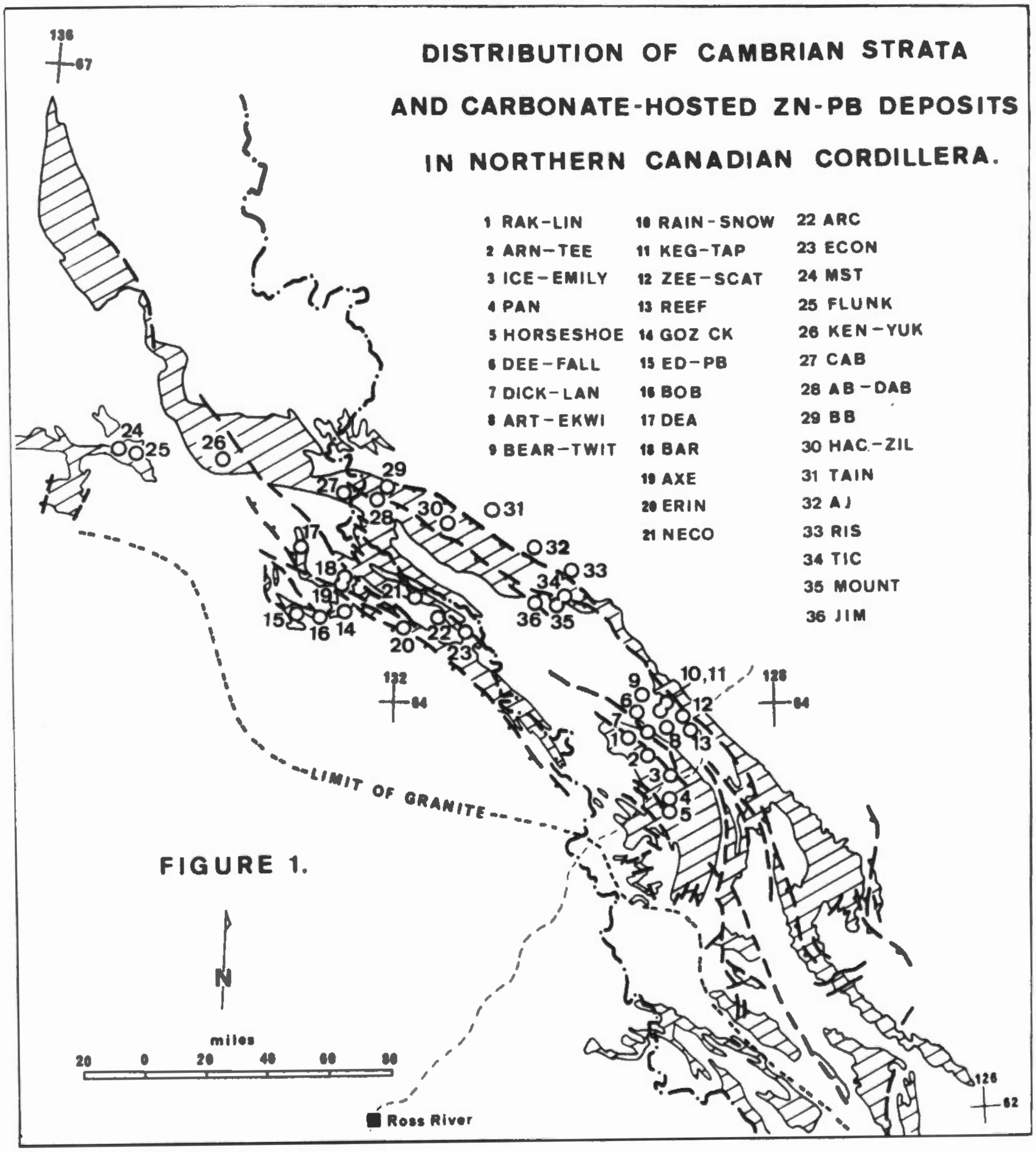

FIGURE 1.

Godlin Lakes

The Godlin deposits are clustered in the Sekwi Mountain map-area (Blusson, 1971) 200 miles northeast of Ross River along the North Canol road. The camp includes 20 zinc-lead prospects that were discovered and/or acquired by Welcome North Mines in 1972-73, and subsequently optioned to other mining companies.

The Sekwi Formation (Handfield, 1968), a porous, orange-weathering Lower Cambrian dolomite, hosts an almost continuous array of stratiform deposits running northwestward from the ICE and EMILY claims of Geomont (63°40'N, 129°05'W) for 16 miles along strike through to the ARN and TEE claims of Bethlehem (63°44'N, 129°15'W). A resistant orthoquartzite bed overlain by red and green shale beds serves as a marker horizon about 1500 feet above the base of the Sekwi Formation. Yellow sphalerite, coarse-grained galena and white dolomite fill open spaces in a very porous, 6-mile-long horizon about 100 feet above the quartzite on the ARN-TEE claims, whereas similar, if not more continuous deposits occur 60 feet below the marker horizon on the ICE-EMILY ground.

On the KEG (Dynasty) and TAP (AMAX) claims ($63^{\circ}58$'N, $129^{\circ}13$'W) northwest of Godlin Lakes, Upper Cambrian to Silurian dolomites of the Sunblood, Road River and Whittaker formations contain zinc-lead deposits of several forms. Pale yellow sphalerite with galena and pyrite occurs as disseminations and pore fillings throughout permeable horizons in the three units, particularly as interstitial fillings of solution and collapse breccias with white dolomite, and as vug and fracture fillings in reefal Whittaker dolomite.

On the BEAR-TWIT property of Cominco on the Twitya River ($64^{\circ}02$'N, $129^{\circ}25$'W), zinc-lead-copper deposits occur mainly in brecciated dolomites of the Upper Silurian to Lower Devonian Whittaker, Delorme and Camsell formations. A window in a southwestward-dipping thrust plate involving the three formations exposes the most intense mineralization in the Delorme Formation. Low-grade stratiform disseminations of fine-grained sphalerite and galena are remobilized and upgraded locally in crackle breccias and fracture zones adjacent to the thrust fault. Fracture-fillings of coarse-grained galena, yellow-green sphalerite, and lesser quartz, calcite, barite and tetrahedrite are irregular in length, width and spacing, but yield highest-grade intersections. Finer-grained (and lower grade) Zn-Pb mineralization, with quartz and calcite, fills the matrix of crackle breccia.

The RAIN-SNOW ($63^{\circ}58$'N, $129^{\circ}16$'W) property of Welcome North is a similar deposit in younger rocks that occurs on strike 5 miles southeast of the BEAR showings. Beds of intraformational breccia within black dolomite of the Middle Devonian Arnica Formation contain interstitial sparry white dolomite and yellow sphalerite (Brock, 1973).

The ART-EKWI ($63^{\circ}51$'N, $129^{\circ}12$'W) property of Atled Explorations contains secondary Zn-Pb minerals in a fault zone subparallel to steeply-dipping, northwesterly-trending dolomites of the Middle Devonian Arnica and Landry formations. Three showings occur along a strike 1000 feet long, the northernmost of which contains the highest grade zinc deposits. Spectacular smithsonite "dry bone ore" occurs with barite, cerussite and hydrozincite where the fault zone crosses an unglaciated ridge at 6500 feet above sea level (*see* Sangster, this publication, report 96).

Bonnet Plume River area

Following the Godlin discoveries, significant base metal deposits of the same type were discovered 120 miles northwest at Goz Creek by personnel of Barrier Reef Resources in early 1973. Subsequent exploration activity by numerous companies and individuals continued through 1973 and 1974, resulting in the staking of at least 8 important Zn-Pb deposits.

The Goz Creek claims of Barrier Reef ($64^{\circ}26$'N, $132^{\circ}31$'W) cover a number of zinc deposits extending more than 2 miles along an east-trending strike of a Lower Cambrian dolomite. The grey, thick-bedded, porous, partly pisolitic and sandy dolostone unit is about 2500 feet thick at Goz Creek, and is overlain by Sekwi dolomite one mile to the east. The principal "A" and "B" zones are characterized by high-grade sphalerite deposits that show both stratigraphic and tectonic controls, within pervasively silicified dolomite. Zinc deposits were controlled initially by primary and secondary porosity; then upgraded by tectonic brecciation along north and northeast-trending faults with concomitant remobilization, and finally modified by supergene alteration.

The striking mineralized breccias at Goz Creek contain sphalerite that varies from white (cleiophane) through pale yellow ("turkey-fat ore") to honey brown and red (ruby zinc). Pyrite and galena are less abundant, and boulangerite ($Pb_5Sb_4S_{11}$), occurs in "B" zone only. Massive smithsonite is common, and cerussite and hydrozincite also occur in the oxidized zone.

Similar Zn-Pb deposits occur on the ED-PB claims of Cypress Resources at $64^{\circ}26$'N, $132^{\circ}55$'W, 15 miles west of Goz Creek on the Bonnet Plume River. About 12 individual deposits occur for 3.5 miles along an east-trending strike of a dolomite unit, immediately below a northerly-dipping contact with overlying brown shale.

The host dolomite resembles that at Goz Creek in most respects, but was considered to be stratigraphically lower by Blusson (1974), and of possible Hadrynian age. Trilobites collected by Blusson and the writer in 1974 from the shale unit on Cypress' claims (G.S.C. Loc. 91689) have been tentatively assigned to the Bonnia-Olenellus zone (Lower Cambrian) by W.H. Fritz (1974, pers. comm.), indicating that the Cypress dolomite may be equivalent in age to the upper, reefoid part of the Sekwi Formation further west (Unit 14A on Sekwi Mountain Map-area, Map 1333A, Blusson, 1971).

Sphalerite deposits occur along an essentially continuous permeable horizon, as disseminations, vug and breccia fillings, and as discordant veins. Pale sphalerite is associated with framboidal pyrite, coarse-grained galena, quartz, sparry dolomite, calcite, barite and pyrobitumen. As at Goz Creek, highest grade deposits of sphalerite-quartz are the result of remobilization within transgressive crackle breccias localized where north- to northeast-trending faults cross the favourable dolomite horizon.

The BOB claims of Barrier Reef Resources ($64^{\circ}24$'N, $132^{\circ}50$'W) are located on Harrison Creek, at the eastern end of Cypress' ground. Disseminated pyrite-sphalerite in dolomite extends westward to the ED-PB claims, where it occupies a horizon several hundred feet below the other showings.

Other significant deposits in the area of similar mineralogy, and within rocks of similar age that were not visited by the writer include the DEA claims of Cominco on Corn Creek ($64^{\circ}45$'N, $133^{\circ}00$'W) and the ECON claims of Noranda ($64^{\circ}20$'N, $131^{\circ}15$'W) 20 miles east of Bonnet Plume Lake.

On the ERIN claims of Clyde Smith ($64^{\circ}23$'N, $131^{\circ}55$'W) 5 miles north of Bonnet Plume Lake, base metal deposits occur at the top of an Ordovician carbonate unit that overlies the Sekwi Formation, and is overlain by Devono-Mississippian Besa River shale. The carbonate is brecciated, dolomitized and silicified for thicknessess up to 100 feet below the shale contact, and is impregnated with sphalerite, galena and traces of pyrite.

Interesting Zn-Pb deposits in Siluro-Devonian limestones occur on the AXE claims of Welcome North (64°35'N, 132°31'W) and BAR claims of Andy Harman (64°37'N, 132°29'W) 6 miles west of Goz Lake. Colloform sphalerite with galena and pyrite fills vugs and breccias, in textures reminiscent of Pine Point ore.

Northern Mackenzie Mountains

The last camp visited during 1974 was the belt of deposits extending from Mountain River on the southeast for 175 miles through the Mackenzie Mountains to the Wind River in the Wernecke Mountains on the west.

At the west end of the belt, the FLUNK (65°06'N, 134°47'W) and MST (65°06'N, 135°03'W) claims of Archer-Cathro are located 18 miles southwest of Margaret Lake. The mineralized Lower Cambrian carbonate on the FLUNK claims resembles the Sekwi dolomite, but lacks the orthoquartzite marker bed. It is a white, thick-bedded micritic reefal dolomite that contains a horizon of disseminations and pore fillings of sparry dolomite, pale sphalerite, clear quartz and coarse-grained galena. Clastic content increases above the mineralized horizon, whereas underlying beds are a grey algal dolomite containing large pisolites and Lower Cambrian trilobites. Like the Bonnet Plume River deposits, the best zinc concentrations occur in two transgressive crackle breccia bodies apparently localized along a cross-cutting northwest-trending fault.

A different type of deposit occurs in rocks of the same age five miles west of FLUNK claims on the MST claims. A coarse clastic, partly conglomeratic member of a grit unit that dips 20 degrees south is impregnated with galena, pyrite and sphalerite along a strike several hundred feet long. An underlying reddish-purple shale contains Olinellid trilobites of mid-Lower Cambrian age (Blusson, pers. comm.).

The AB (64°49'N, 132°17'W) and CAB (65°00'N, 132°35'W) claims of Welcome North Mines are located near Gildersleeve Lake at the headwaters of both the Arctic Red and Snake rivers. The same host rock, grey, wispy-banded dolomite of the Sekwi Formation (Blusson, 1974) hosts similar Zn-Pb deposits at the two localities. On the AB claims, breccias that appear to be of both collapse and tectonic origin contain yellow sphalerite, framboidal pyrite, galena, secondary dolomite and barite. The CAB claims cover 7 or 8 deposits extending 10 miles along the strike of a porous horizon in the Sekwi. As elsewhere pale sphalerite occurs both as stratiform pore fillings and as remobilized breccia and fracture fillings.

Other significant Zn-Pb discoveries in this belt that were not visited include the ZIL-HACK (64°50'N, 131°30'W) and TIC (64°30'N, 130°07'W) claims of Serem Ltd., and the BB of Welcome North (65°02'N, 132°10'W) in the Sekwi Formation; as well as the JIM (64°29'N, 130°28'W), AJ (64°46'N, 130°29'W) and RIS (64°36'N, 130°06'W) of Welcome North in Silurian and Devonian carbonate rocks.

Summary

1. A major new zinc province has been discovered in the Mackenzie Fold Belt of the northern Canadian Cordillera.

2. Numerous deposits of Mississippi Valley type are hosted in Lower Paleozoic rocks, mainly Lower Cambrian carbonates.

3. Low-grade, stratiform sphalerite-galena deposits in porous dolomites are remobilized and upgraded locally mainly by tectonic means.

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