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Summary of Field Work, 1981

by the
Ontario Geological Survey

edited by
John Wood, O.L. White, R.B.Barlow, and A.C. Colvine
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Wilson, B.C.
Foreword

During 1981, the Geological Survey carried out a large number of independent geological, geophysical, geochemical, geochronological, and mineral deposit studies. In addition, studies were undertaken in cooperation with the ministry’s regional geological staff, the University of Manitoba, and several private consulting firms. Funding for a number of regional stimulation projects was provided by the Ontario Ministry of Northern Affairs and the Federal Department of Regional Economic Expansion, and for environmental projects by the Provincial Lottery Fund and the Ministry of the Environment. Project involvement is summarized in the section introductions which follow, and funding acknowledgments are given in the individual summaries.

The locations of the areas investigated are shown on two maps of the Province at the beginning of this report. The preliminary results of the work are outlined in this summary, which contains reports prepared by leaders of each of the projects. In these reports, some emphasis has been placed on the economic aspects of the different investigations. It is the hope of the Ontario Geological Survey that the information thus provided will help in the mineral resource evaluation of these areas, and so will be a valuable aid to mineral prospecting and resource planning in the Province. Also, as a direct result of this summer’s work, research was undertaken on a number of theses at the B.Sc. and graduate level.

Coloured maps and final detailed reports covering most of the field projects are being prepared for publication. In the interim, uncoloured preliminary geoscience maps with comprehensive marginal notes will be released for distribution, mainly during the winter of 1980-81. Notices of the releases will be mailed to all persons or organizations on the Mineral Resources Group notification list, and will be published in the technical journals and other media.

E.G. Pye
Director
Ontario Geological Survey
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LOCATION OF FIELD PARTIES, 1981
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During the 1981 field season, the Precambrian Geology Section continued its research on the distribution and genesis of the Precambrian rocks of Ontario. The objectives of the Base Program of the Section are to provide geologic data, geologic interpretation and concepts which will increase the effectiveness of mineral exploration, and mineral resource potential evaluation and management throughout the 650,000 km² of Ontario underlain by Precambrian bedrock. Additional projects typically directed towards a specific geologic problem, or community were funded:

a) By the Ontario Ministry of Northern Affairs (NOGS);

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c) Jointly by the Federal Department of Regional Economic Expansion and the Ontario Ministry of Natural Resources under the Eastern Ontario Subsidiary Agreement (SOGS).

The source of funding other than from the Base budget is shown on the individual summaries. Of a total of 23 projects undertaken, 12 were directed by Section staff, nine by contract project leaders, and two by Resident Geologists. On the Base Program, some 2,200 km² were mapped at a scale of 1:15,840, and six special or synoptic projects were undertaken. Another 800 km² were mapped at a scale of 1:15,840, and four special or synoptic projects were carried out on additional funding.

Because of the size of the area underlain by Precambrian bedrock, Base Program projects for 1981 were directed at the high to moderate mineral potential sectors of six major geologic domains. These are: the northwest part of the Sachigo Sub-province; the Uchi Sub-province west of Pickle Lake; the eastern and western parts of the Wabigoon Sub-province; the Wawa part of the Abitibi Sub-province adjacent to Lake Superior; the Abitibi Sub-province; and the Cobalt Embayment.

In the Sachigo Sub-province, detailed mapping (at a scale of 1:15,840) of the Lingman Lake area by B.C. Wilson has outlined the metavolcanic-metasedimentary assemblages there, with the suggestion that the search for gold might best be concentrated in silicified zones close to the granite-"greenstone" contact.

In the Uchi Sub-province, detailed mapping in Bowerman and Belanger Townships by T.L. Muir, allied with synoptic work by P.C. Thurston, has shown that the northern belt of metavolcanics in these townships is equivalent to Cycle III in the Confederation Lake area (Thurston and Jackson 1978), and thereby has good potential for massive sulphide mineralization. Muir noted that rocks previously described as quartz porphyry and sericite-quartz or mica-quartz schists are felsic and intermediate metavolcanics. The correlation made by Thurston is that the central part of the Red Lake metavolcanic-metasedimentary belt may be equivalent to Cycle II of Confederation Lake.

In the Red Lake area, Henry Wallace in the second year of a synoptic project mapped Baird Township in detail. He points out (this volume) that there is substantial potential for gold mineralization along strike from the Madsen and Starrat-Olsen Mines, and also that if his structural interpretation is correct, the stratigraphic equivalents of the mine sequence occur in the northern part of the area.

Within the Wabigoon Sub-province, detailed mapping was carried out in the Lake of the Woods (G.W. Johns), Kawashegamuk Lake (C.E. Blackburn and D.U. Kresz), Sioux Lookout (R. Huggins), and O’Sullivan Lake (J. Inasi) areas. Special projects concentrated

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1Chief Geologist, Ontario Geological Survey, Toronto.
on the Wabigoon-Quetico Sub-provincial boundary and the Nipigon Plate (R.H. Sutcliffe); and lithophile mineralization in the Zigzag Lake area (F.W. Breaks). Of the detailed projects, only the O'Sullivan Lake project was not part of a continuing program (see 1980 Summary). Blackburn and Kresz outline favourable areas for gold and copper-nickel gold mineralization in the O'Sullivan Lake area, significant base-metal occurrences are lacking; however gold is present, associated with arsenopyrite and other sulphide mineralization in quartz veins. A previously unknown showing, 1 m thick, of disseminated arsenopyrite in lapilli-tuff, may have potential for gold mineralization. In the Lake Nipigon area, Sutcliffe has shown that Sibley Group sedimentary rocks are more extensive than previously recognized. Sutcliffe has also outlined four heretofore unreported ultramafic intrusions that appear to post-date the Sibley sedimentary rocks, but predate the diabase sheets. The area has potential for gold, base-metals, and uranium.

In the Wawa part of the Abitibi Subprovince, mapping continued in the Heron Bay-Schreiber Belt (M.W. Carter) and in the Wawa-Renabie Belt (R.P. Sage). As a result of his continuing work in the Wawa area, Sage presents a preliminary interpretation of the stratigraphy of the volcanic rocks, and relates that to economic mineralization; an interesting and valuable assessment.

In the Abitibi Subprovince, detailed mapping continued in the Gogama area (G.M. Siragusa), was initiated in Keefer, Denton, and Thornloe Townships (A. Choudhry), and a synoptic project was initiated in the Batchawana area (E.C. Grunsky). The objectives of these projects is to: provide basic data for unmapped portions of the belt; extend and improve stratigraphic and mineralization concepts; and develop and test methods for storage and retrieval of field data.

In the Southern Province, a detailed sedimentological and stratigraphic study of the Gowganda Formation in the Cobalt area (A.E. Legun) is part of a continuing program to study the stratigraphy, structure, and sedimentology of the Embayment (Wood 1980). This program is complemented by the work of the Mineral Deposits Section (A.C. Colvine, this volume; D.F. Long, this volume) and the Geophysics-Geochemistry Section (see V.K. Gupta 1980).

Under the Northern Ontario Geological Survey Program, mapping was completed in the Sudbury area (J. Lafleur), and special studies of the Sudbury Irruptive Footwall (B.O. Dressler) and alteration in the Abitibi Subprovince near Kirkland Lake (E.C. Grunsky) were continued.

Under the Kirkland Lake Initiatives Program (KLIP) the Precambrian Section completed a three-year, detailed stratigraphic mapping project (L.S. Jensen, and N.F. Trowell) initiated in 1979. The relationships of gold mineralization to two distinctly different groups of rocks is emphasized, the distinction in origin and style of mineralization being an important factor in gold exploration.

Under the Southern Ontario Geological Survey (SOGS) program, two detailed mapping projects were completed, one in the Marmora region (J.R. Bartlett and J.M. Moore), and one in the north Frontenac region (L. Pauk). A special study on the stratigraphy and sedimentation of Grenville Supergroup carbonate rocks was initiated (M. Bourque). Bartlett and Moore outline the stratigraphy and structure of Belmont, Marmora, and southern Methuen Townships, and place the mineral deposit type in the regional setting.

The summaries contained in this volume represent a first appraisal of raw geological field data, as do the preliminary maps which are in preparation for publication during the 1981-82 winter period. These summaries and maps were designed as a means to rapidly disseminate “highlights” and to present general outlines of new information. Extended analysis of field data, in conjunction with detailed office and laboratory research for final report and map publication, can be expected to result in changes to the field terminology, interpretations, and concepts expressed in this summary.
References

Gupta, V.K.

Thurston, P.C. and Jackson, M.C.

Wood, John
No. 1 Lingman Lake Area

B.C. Wilson

Introduction

The Lingman Lake area, 325 km north of Red Lake, is bounded by Latitudes 53°45' and 53°55'N and Longitudes 93°00' and 93°15'W. Access to the map-area is by aircraft. Small boats allow travel throughout the area, however, because of numerous rapids, repeated use of interconnecting waterways is impractical. A winter road joins Lingman Lake to Red Sucker Lake, Island Lake, and eventually to all-weather roads in Manitoba.

Mineral Exploration

Prospecting was reported from the Lingman Lake area as early as 1936. Claim staking began in 1938, reached a peak in 1942 following the discovery of gold, and has continued intermittantly to the present time. Claims held in September, 1981, are mostly centred on the gold property north and northwest of Lingman Lake.

The oldest assessment work consists of reports on the gold property now held by Twin Gold Mines Limited (originally Lingman Lake Mines Limited). Activities have included geological mapping in 1938 and 1939, and surface diamond drilling in 1945, 1973, and 1975 totalling a length of about 12 400 m in 83 holes. Between 1946 and 1949, a total of 1383 m of drifting, cross-cutting, and raising was carried out from a 126 m deep shaft on that property. Underground diamond drilling totalled 2 988 m from levels established at depths of 46, 84, and 139 m.


Geology

The entire map-area was most recently surveyed by Gerald Bennett and R.A. Riley (1969) in 1967 as part of a much larger mapping project, Operation Lingman Lake. Relevant geological data is presented on two preliminary maps (Bennett and Riley 1967a, 1967b) and a coloured compilation map (Bennett et al. 1969). The present study concentrated on the supracrustal rocks of the Lingman Lake Belt and did not involve a detailed examination of the surrounding granitic rocks. The contact between the supracrustal and granitic rocks was found by the author to be essentially as shown in the previous mapping.

Metavolcanic lithologies comprised mainly mafic massive and pillowled flows, mafic tuff, and (or) relatively immature arenite and minor volumes of felsic flows, tuffs, crystal tuffs, and possibly lapilli-tuffs. Clastic metasediments included relatively mature wacke and mudstone
and minor volumes of arenite and conglomerate. Chemical metasediments consisted of interbedded chert with magnetite and iron silicate-bearing ironstone which in some places contains graphite or garnets.

Most mafic flows are massive and a few are porphyritic, but pillowified flows which are commonly variolitic or highly fractured are abundant. Some pillows contain large gas cavities filled with quartz and feldspar. Thinly laminated to very thinly bedded dark green clastic rocks are interbedded with the mafic flows. These clastics, which may be pyroclastic or epiblastic in origin, are transitional to more mature metasediments. These rocks form thick successions near Seeber and Durrel Lakes where they are apparently stratigraphically equivalent to mafic flows occurring along strike.

White to buff, light green and grey felsic metavolcanics occur around the southeast corner of Seeber Lake and along the south shore of the large lake 6 km southeast of Durrel Lake, locally known as Tequila Lake. On the small islands and nearby shore of Seeber Lake are feldspar- or rarely quartz-phyric flows. Crystal tuff, the pyroclastic equivalent of the flows, is found interbedded with grey, thinly laminated metasediments to the west and northeast of the flows at Seeber Lake and along the southwest shore of Lingman Lake. These rocks probably all lie at the same stratigraphic position. Medium grey and grey-green crystal tuff and lapilli-tuff found southwest of Lingman Lake appear more distal with large proportions of light-coloured metasediments and are not likely to be on strike with the flows at Seeber Lake. At Tequila Lake, there are interbedded felsic flows, mostly quartz-phyric, and quartz crystal tuff with and without associated metasediments.

Clastic metasediments derived from the metavolcanics within the belt are commonly interbedded with and transitional to those metavolcanics. Such rocks, found in units rarely exceeding 3 m in thickness throughout the belt, are difficult to distinguish from the metavolcanics. More mature, easily recognizable wacke and mudstone occur in much thicker units along the south shore of Lingman Lake, along the west shore of the small lake just southwest of Lingman Lake, and across the centre of Seeber Lake to the western contact. These rocks are medium to dark grey, fissile to slaty, and commonly are graded in beds that are thinly laminated to medium bedded. Polymictic matrix-and clast-supported conglomerates were found at only three locations, one close to the southeast corner of Seeber Lake and two near its northwest shore.

Thin units of chemical metasediments found near Lingman and Lawson Lakes consist of thinly laminated to very thinly bedded chert and magnetite ironstone, commonly interbedded with iron silicate layers now composed of chlorite or amphibole. At the west end of Lingman Lake, some of the chert is highly graphic. A few outcrops of chert interbedded with iron silicate were found southwest of Seeber Lake. South of Tequila Lake similar beds of iron-bearing, commonly garnetiferous metasediments are more abundant and thicker.

A few, very minor metagabbro bodies and at least two varieties of mafic dikes of as yet undetermined composition intrude the local supracrustal rocks.

The supracrustal rocks are surrounded by, and close to the greenstone-granite contact, are included by felsic to intermediate intrusive rocks mapped by Bennett and Riley (1967a; 1967b; Bennett et al. 1969) as granite, quartz monzonite, granodiorite, trondhjemite, quartz diorite, and migmatite. Along the northern edge of the belt and around Pullen Lake, the contact appears to be conformable with supracrustal trends, but along much of the southern edge, the contact appears to be discordant.

Cutting the interior of the greenstone belt are dikes and sills up to 5 m wide composed of felsic to intermediate feldspar and quartz porphyry. These intrusions which are very similar to the local felsic metavolcanics, are found at Seeber, Durrel, Lingman, and Tequila Lakes.

A north-trending 50 m wide post-Archean diabase dike is easily traced in outcrop and by its aeromagnetic expression across the centre of the belt. A few much narrower dikes were observed in mapping, and aeromagnetic data suggest the presence of several more.

### Structural Geology

On the basis of numerous top determinations, the traces of axial planes of two synclines have been interpreted to exist by the author. One syncline extends from just west of the Twin Gold Mines Limited property across the central part of Seeber Lake to the far western end of the belt. The other syncline is centred in Durrel Lake and may extend to Tequila Lake. The axial trace of an anticline which parallels the south shore of Lawson Lake continues to the west and southwest across the western end of Durrel Lake. Many smaller scale folds were observed, especially within the mature metasediments in Seeber Lake and close to the greenstone-granite contact along the southern edge of the belt.

During the formation of these large-scale folds, two sets of vertical cleavages developed axial planar to S and Z shaped minor folds. Cleavages are best developed in metasediments along Lingman Lake and across Seeber Lake. In these rocks S folds and the associated southeast trending cleavage predominate.

Right-handed, nearly vertical faults cross-cut all of the lithologies, including the diabase dikes, within the map-area. The faults are mostly parallel to regional supracrustal trends and slickensides are horizontal or plunge gently eastward. A few relatively minor faults, also right-handed, parallel the southeast trending cleavage. Cataclastic textures are common and were found in all rock types.

### Economic Geology

So far, the only deposit of economic significance known...
in the area is the gold occurrence of Twin Gold Mines Limited. There, mafic flows and minor metasediments have been cut by feldspar and quartz porphyry dikes which are probably related to the main body of granitic rocks just to the north. All of the rock types were subsequently cut by post-Archean, roughly layer-parallel, strike-slip faults. Good gold values are reported to be associated with three faulted, silicified, and carbonatized zones, which are especially close to mylonitized quartz porphyry. Proven and estimated ore totals 296 000 tons at 0.41 ounce of gold per ton and 130 000 tons at 0.21 ounce of gold per ton. This information was obtained from assessment records on file at the Assessment Files Research Office, Ontario Geological Survey, Toronto, and at the Resident Geologist's Office, Ontario Ministry of Natural Resources, Red Lake. The association of gold with the intruding quartz porphyry and the proximity of the granite-greenstone contact suggest that the search for gold might best be concentrated near silicified zones close to this contact.

Molybdenite has been reported at two locations along the northern edge of the belt (Bennett and Riley 1967a). In the present study, molybdenite was observed along fractures in porphyritic flows along the northeast edge of the belt and in narrow granitic dikes close to the granite-greenstone contact near both the northern and southern edges of the belt. More occurrences may be discovered in these contact zones.

Exploration for volcanogenic stratabound massive sulphide deposits would best be concentrated in the southeast corner of Seeber Lake and along Tequila and possibly Durrel Lakes where there are known or suspected occurrences of felsic metavolcanics. No concentrations of metallic minerals which could be contemporaneous with volcanism were observed in the present study.

Many fault zones in the local suracrustal and intrusive rocks have been strongly silicified. Some rocks have been altered to contain ankerite, chlorite, tremolite, sericite, fuchsite, and serpentine. Metallic minerals, mostly pyrite with minor pyrrhotite, chalcopyrite, arsenopyrite, sphalerite, galena, molybdenite, silver, and gold are found in these alteration zones.

References

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1967a: Operation Lingman Lake, Finger Lake Sheet, District of Kenora (Patricia Portion); Ontario Department of Mines, Preliminary Map P.431, scale 1:126 720.

1967b: Operation Lingman Lake, Rottenfish River Sheet, District of Kenora (Patricia Portion); Ontario Department of Mines, Preliminary Map P.432, scale 1:126 720.


Bennett, G., Riley, R.A., and Davies, J.C.
1969: Stull Lake - Sandy Lake Sheet, Kenora District; Ontario Department of Mines, Map 2178, Compilation Series, scale 1:253 440.
Introduction

The objective of this project is to produce a stratigraphic synthesis of the Uchi-Confederation Metavolcanic-Metasedimentary Belt and its relationship to the Red Lake Metavolcanic-Metasedimentary Belt. The area (see location diagram) includes the western part of the Uchi Subprovince (Ayres et al. 1971) and parts of the English River Subprovince, and lies south and east of Red Lake. Access is via Highway 105 which connects Red Lake and Ear Falls to the Trans-Canada Highway at Vermilion Bay east of Kenora. Branching off Highway 105 at Ear Falls is an 80 km long road trending northeast to the South Bay Mine of Selco Mining Corporation on Confederation Lake. Forty km west of Ear Falls, a network of subsidiary gravel roads trend northeast from Snake Falls at the north end of Pakwash Lake. This road network provides good access to the area.

The Uchi-Confederation Metavolcanic-Metasedimentary Belt was divided into three mafic to felsic cycles by A.P. Pryslak (1970). P.C. Thurston and M.C. Jackson (1978) have shown the areal extent of each of the cycles, named from oldest to youngest, I, II, and III. Cycle III at Confederation Lake has a volcanogenic Cu-Zn-Ag massive sulphide ore-deposit in pyroclastic rocks associated with an endogenous dome of quartz-feldspar porphyry.

James Pirie (1980) described the Red Lake Metavolcanic-Metasedimentary Belt as a lower tholeiitic mafic sequence forming the centre of the belt, and an upper sequence of calc-alkaline intermediate and felsic volcanic rocks exposed on the flanks of the belt in the Ball Township, Heyson Township, and Graves Township areas. The Red Lake area contains major gold producers located mainly in the lower mafic sequence. Until recently, there has been no known direct physical connection of the two metavolcanic-metasedimentary belts to permit correlation (Davies and Pryslak 1970). F.W. Breaks et al. (1976), on the basis of reconnaissance mapping, suggested a connection between the Bluffy Lake area, south of Confederation Lake, and an area of mantled gneiss domes south of Red Lake. Recent geophysical interpretation, geological mapping, and diamond drilling by Selco Incorporated and Hudson Bay Mining and Smelting Limited has suggested a direct link between the metavolcanics exposed in Belanger Township, south of Confederation Lake, and the eastern part of Ranger and Willans Townships. Selco Exploration Limited provided access to geological data (personal communication, A.P. Pryslak, 1981) permitting rapid access to available outcrops in the area of the Pakwash Lake 1:50 000 map sheet, an area of poor outcrop. This aid made this project possible in such a short field season.
General Geology

The map-area is underlain by two generally east-trending belts of Early Precambrian (Archean) late granitic intrusions. The northern belt extends from Belanger Township through Fredart Lake, and Troutlake River to the east shore of Gullrock Lake. From north to south, the belt is pillowed mafic flows with discontinuous units of felsic tuff and oxide facies iron formation at Gerry Lake and spherulitic felsic flows and tuffs 21 km to the east in the area of the 18 deposit (see section on “Economic Geology”). This sequence is overlain by mafic flows with minor intercalated felsic tuffs. The southern belt extends from the Fearaver Lake area to the north shore of Pakwash Lake and westward to the Rice Lake and Dixie Lake area. The sequence is composed of pillowed mafic flows with minor intercalated felsic air-fall tuff units 2 to 5 m thick. A local accumulation of felsic metavolcanics occurs north of Bruce Lake where 2 to 5 m thick graded beds of felsic lapillistone and tuff of air-fall origin are overlain by a few hundred metres of felsic lapillistone and tuff-breccia which fines upward over 100 m. This is assumed to be a debris flow deposit, based upon the lack of sorting, lack of fine scale grading, and lack of fine-grained interbedded units. Above this is felsic flow-breccia succeeded by felsic, fine-grained, graded, air-fall tuff and pillowed mafic flows. The area immediately north of Bluffy Lake is underlain by an area 16 km by 2.5 km of massive mafic flows.

Stratigraphic Interpretation

The east-facing part of the basalts of Cycle III in the Confederation Lake area can be traced from southern Confederation Lake in Mitchell Township southwest to northern Belanger Township through to the Fredart Lake area. As well as the physical continuity of the unit, the variolitic sub-unit of the Cycle III basalts (Thurston and Jackson 1978) is found south of Snakeweed Lake. Therefore, all of the northern belt in the present area is interpreted to be of Cycle III age.

The southern volcanic belt is of uncertain age. The style of volcanism in the area of Ten Mile Creek east of Bruce Lake, where mafic flows 3 to 30 m thick alternate with 1 to 3 m thick units of felsic air-fall tuff, suggests the unit may be of Cycle II age and equivalent to the mini-cycles found east of Lost Bay of Confederation Lake (Thurston et al. 1978). Facing criteria suggest the unit faces north. The westward extension of the unit in the Rice Lake area is overlain by a thick unit of mafic flows. These criteria suggest the unit may be correlative with Cycle II, with the overlying basalt in the Rice Lake area of Cycle III age. Reinforcing this interpretation is the presence of oxide facies ironstone in the lower basalt in the Rice Lake area. This ironstone is perhaps equivalent to the mixed oxide-sulphide facies ironstone found on the west limb of the synclinorium at Woman Lake (Thurston and Jackson 1978). If this interpretation is valid, a strike-slip fault exists in the southern belt, separating Cycle II from Cycle III, or drastic thinning or non-deposition of Cycle III has occurred in the upper part of the southern belt.

Implied in the above scheme of stratigraphic correlation is the notion that the south-facing basalts and overlying felsic metavolcanics on Gullrock Lake (Pirie 1980) are of Cycle III age. This in turn suggests that the central part of the Red Lake Metavolcanic-Metasedimentary Belt may be of Cycle II age. This interpretation is also suggested by the presence of marble units along the north shore of McKenzie Island.

Smith and Bailey (1968) described a caldera cycle in which ash-flow magmatism, resulting in the violent emptying of the magma chamber, is followed by collapse of the volcanic edifice, producing a caldera. This can be followed by resurgent volcanism near the caldera margin, consisting of flows and pyroclastic rocks related to domes along the caldera margin. The intermediate to felsic sequence between the North Bay of Confederation Lake and Found Lake in Agnew Township is now interpreted to be a large-scale ash flow. Cycle III felsic volcanic rocks and the hypabyssal suite on Map P1975 (Thurston and Jackson 1978) are considered to represent resurgent caldera-related volcanism, given the spatial and stratigraphic relationship to ash-flow material.

Structural Geology

Trend of foliation and bedding in the project area is approximately east. Facing direction indicators include graded bedding in air-fall tuffs, reverse size grading produced by concentration of pumice at the tops of pyroclastic units, and pillow shape and packing in pillowed flows. These facing criteria, while difficult to observe in amphibolite facies terrain, suggest that the major structure of the area is a synclinorium. The northern belt is the northern limb of the synclinorium, and the southern belt is the southern limb. The axial zone of the synclinorium is intruded by stocks of granitoid rocks.

The east- to northeast-trending faults represent branches of the Sydney Lake Cataclastic Zone, a major fault with dextral offset separating the low grade rocks of the Uchi subprovince from the higher grade rocks of the English River Subprovince. Movement on the north-trending faults is later, that is, after the formation of the mantled gneiss domes south of Red Lake (cf. Breaks and Bond 1978).

Economic Geology

Selco Exploration Limited has delineated three small Cu-Zn-Ag deposits in the northern volcanic belt. Based on an association with spherulitic felsic flows, felsic tuffs, and minor hypabyssal intrusions and the massive nature of the sulphide mineralization, the occurrences represent volcanogenic massive sulphide deposits.

There are three deposits: the one designated 150-18
Figure 1—Geologic sketch map of the area between Red Lake and Confederation Lake.
amounting to about 200 000 tons (A.P. Pryslak, personal communication, 1981) of Cu-Zn.

Based on the stratigraphic association of massive sulphide mineralization with Cycle III in the Confederation Lake area (Thurston et al. 1978) the northern belt has good potential for further occurrences.

Conversely, massive sulphide potential for Cycle II felsic metavolcanics has not been demonstrated. However, minor occurrences are found in the area of the Jig Deposit on Confederation Lake (Pryslak 1971, occurrence Number 7).

References


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Thurston, P.C., and Jackson, M.C. 1978: Confederation Lake Area, District of Kenora (Patricia Portion); Ontario Geological Survey, Preliminary Map P.1975. Scale 1:63 360 or 1 inch to 1 mile.

No. 3 Red Lake Synoptic Project, District of Kenora

Henry Wallace

Introduction

In the summer of 1981, a field party under the direction of the author mapped Baird Township, west of Red Lake, at a scale of 1:10 480. This work was done in conjunction with a continuing project to develop a regional tectono-stratigraphic synthesis of the Red Lake belt (Pirie 1978, 1979; and Wallace 1980). Previous geological surveys of the township were made by H.C. Horwood (1945) in his regional study of the belt, and by S.A. Ferguson (1965) who mapped only the eastern part of Baird Township. Major discrepancies in lithologic terminology between those two reports, and between them and more recent maps covering adjacent townships (Riley 1978; James Pirie, Esso Minerals Canada, 1981, personal communication) prompted the remapping program detailed below.

Access

Within Baird Township, the townsites of Madsen and Star-rat are 9 and 11 km respectively southwest of the town of Red Lake along Highway 618. The southwestern part of the area is accessible along the Suffel Lake Road, a gravel highway which extends westward across the town-ship from south of Madsen. The northern part of the area is most easily reached by boat from St. Paul Bay of Red Lake or from Parker Lake. Numerous trails, bush roads, and grid-line systems, which at one time or another ac-cessed mine workings and exploration sites, criss-cross eastern and northern Baird Township.

Mining and Mineral Exploration

Mineral exploration in Baird Township began in the mid 1920s during the Red Lake "gold rush". Several notable occurrences were found at that time and two of those be-came major gold producers. The Madsen Mine produced 2 416 609 ounces between 1938 and 1976 and had an average grade of 0.29 ounce of gold per ton. At the Star-rat-Olsen Mine, 163 990 ounces were recovered between 1948 and 1956 at an average grade of 0.18 ounce of gold per ton.
In 1937, mine shafts and underground workings were established at two other sites, on the Redaurum Red Lake Gold Mines Limited property north of Russet Lake, and on the Faulkenham Lake Gold Mines Limited property south of Starrat, however neither of these reached gold production.

Several other gold occurrences in the township such as those on the Parvus Mines Limited, Redruth Gold Mines Limited, and Aiken-Russet Red Lake Mines Limited properties have been intensively investigated by trenching and diamond drilling. For details on the history of exploration at these and other occurrences the reader is referred to descriptions by Ferguson (1965) and to the Resident Geologist’s Files, Ontario Ministry of Natural Resources, Red Lake.

Nearly all of the ground in Baird Township underlain by supracrustal rocks is included in blocks of currently-owned patented mining claims.

Exploration activities in the area during the 1981 field season included geological mapping on the Madsen Red Lake Gold Mines Limited and Starrat Nickel Mines Limited properties by Noranda Mines Limited, geophysical surveys in northern Baird Township, east of Parker Lake by Selco Exploration Company Limited, and geological mapping and prospecting southwest of Flat Lake by Cominco Limited.

**General Geology**

All rock-types in the Red Lake Belt appear to be of Early Precambrian age. The eastern and northern parts of Baird Township are underlain by two distinct, predominantly metavolcanic, sequences. The older and more extensive of the two consists mostly of mafic pillow flows rarely intercalated with thin units of magnetite-quartz ironstone and chert. The flows are now fine- to medium-grained actinolitic amphibolites. Some are variolitic, but such units are difficult to trace as markers. Commonly the mafic metavolcanics are carbonatized and/or silicified, and in some places in northern Baird Township pods of massive ankerite and calcite up to several metres wide cross-cut the stratigraphy. Interflow pyroclastic rocks and clastic metasediments are rare. Serpentinite units, which have been interpreted to be komatiitic flows based on well developed spinifex texture and polysutured jointing, occur within this mafic sequence south of Flat Lake and along Russet Lake. Numerous mafic and ultramafic bodies of varying size and orientation intrude all of the lithologies mentioned.

The younger of the two main metavolcanic sequences is made up of felsic to intermediate flows and pyroclastic units which occur between Beaverdam and Faulkenham Lakes. These include the so-called Austin and McVeigh Tuffs which appear to control gold mineralization in the Madsen and Starrat-Olsen Mines. Many of the flows in the sequence are pillowed andesites, and both flows and pyroclastic units are commonly highly variolitic and plagioclase-phyric. Particularly in the vicinity of the two mines these rocks are highly altered. Porphyroblasts of garnet, actinolite, staurolite, and andalusite occur in micaceous schists interpreted to be metasomatized intermediate pyroclastic rocks. Where these rocks are better preserved, they appear to be mostly monolithic lapillituff and lapillistone units. Coarser pyroclastic units are rare in this vicinity. Several coarse-grained metagabbro sills, some plagioclase-phyric, intrude this sequence.

Across the southern part of the township, there is a succession of felsic pyroclastic rocks with some notable intercalations of mafic metavolcanics and clastic metasediments. These pyroclastic rocks are monolithic, rhyolitic to dacitic, and typically highly quartz- and/or plagioclase-phyric. Most of these crystal-rich tuff to lapillistone units are highly recrystallized and schistose, and in many places it is difficult to distinguish these rocks from sheared felsic intrusive phases nearby.

Clastic metasediments found in this predominantly pyroclastic sequence include wacke-mudstones and polymictic orthoconglomerates. In some places, sedimentary structures are still discernable in the fine beds, and top determinations can be made.

Mafic flows, generally pillowformed metabasalts, form relatively thin accumulations at intervals within the clastic sequence.

Numerous minor granitic to granodioritic dikes and sills intrude these supracrustal rocks particularly near the southern boundary of the township, and around the Faulkenham Lake Stock (Ferguson 1965), a body of massive granodiorite and quartz monzonite in the southeastern corner of the township.

The western part of Baird Township, which was not intensively traversed during the present survey, is underlain by parts of the Killala-Baird Batholith (Ferguson 1965), a relatively homogeneous mass of biotite-hornblende granodiorite. The contact between the batholith and the metavolcanics it intrudes is quite irregular, but sharp in most places.

**Structural Geology**

The major structural feature in Baird Township is a triangular fold system or dome centred north of Russet Lake. The northern limb, which strikes roughly east, appears to face northward on the basis of numerous pillow tops. The occurrence of a few opposing tops in the mafic sequence there, may indicate some smaller scale folding with axes sub-parallel to the strike of this limb.

The southeastern limb extends from the southern part of Flat Lake northeastward toward Snib Lake in Heyson Township. From pillow packing and a few top determinations made from tephra size gradation in pyroclastic units, this sequence faces uniformly toward the southeast.
Between Russet and Parker Lakes, the third limb of the main fold is relatively poorly exposed. From tops obtained from pillowed units near Parker Lake, this sequence probably faces southwestward, but evidence is admittedly poor.

Tops in the southern part of the township, determined from pillowed flows and clast metasediments, are consistently to the south.

Nearly all supracrustal rock types and most intrusive phases exhibit secondary planar fabrics parallel or subparallel to the local strike of strata. Pillows, tephra, clasts, varioles, and so on are flattened to varying degrees. Mineral foliations are generally pronounced, and parallel the megascopic planar features. Rocks of the felsic to intermediate metavolcanic sequence exhibit strong schistosity which deflects around porphyroblasts of garnet, andalusite, and staurolite. In the southern felsic metavolcanic sequence, rocks are commonly highly foliated and in places appear gneissic.

Economic Geology

Gold is the only mineral commodity of economic significance found so far in Baird Township. The known occurrences in this area fall into three main categories.

The first includes the Madsen and Starrat-Olsen Mines in which gold occurs in stratabound silicified and carbonatized lenses within pyroclastic units near the base of the predominantly felsic to intermediate metavolcanic sequence in southeastern Baird Township. The gold in such deposits is generally concentrated in the more highly silicified sections of the tuffs where the mineralized tuff beds are thickest. Pyrite, pyrrhotite, arsenopyrite, and magnetite are common in the ore zones, but most of the recoverable gold occurs free, as coarse blebs and flakes.

The second type of gold deposit includes occurrences associated with carbonatized and silicified mafic metavolcanics, for example the Redaurum Red Lake Mine and the Redruth Gold Mines showings. In these occurrences, gold is typically rather erratically distributed in quartz vein systems and/or in irregular lenses of ankeritic carbonate within altered and commonly sheared metabasalt or units of interflow banded magnetite ironstone and chert. Pyrite and arsenopyrite occur with the gold as well as minor amounts of chalcopyrite, pyrrhotite, sphalerite, and galena.

The third category consists of gold deposits hosted by felsic metavolcanics, commonly in close proximity to felsic intrusive bodies. A notable example is the Faulkenham Lake Gold Mines Deposit. Gold occurs in narrow quartz veins containing minor pyrite and traces of other sulphide species. In the example cited, the mineralization occurs in a discontinuous vein system which follows a shear zone in metavolcanics adjacent to a large granitic dike some 30 to 50 m wide. Numerous dikelets of granitic material intruding the metavolcanics are also cut by the auriferous veins.

Potential for the development of gold producing mines in this area remains substantial. Continued exploration along strike with the Madsen and Starrat-Olsen Mines may prove successful. If the structural situation in Baird Township is indeed as suggested above, the stratigraphic equivalents of the mine sequence may be found across the northern part of the area on the northern side of the dome. Geological and geochemical mapping of alteration zones in that area will help to focus exploration efforts.

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Wallace, H.
No. 4 Bowerman-Belanger Township Area, District of Kenora (Patricia Portion)

T.L. Muir¹

Introduction

This map-area, composed of Bowerman and Belanger Townships, is centred about 73 km east of Red Lake and covers approximately 187 km². The project summarized below involved geological mapping of the two townships at a scale of 1:15 840 (1 inch to 1/4 mile). Access to the region is mainly by float-equipped aircraft, although a road leading to the South Bay Mine, northeast of the map-area, passes through the extreme northwest corner of Belanger Township.

Mineral Exploration

Information on mineral exploration reported here was condensed from data series maps (Panagapko and Valliant 1980a and b), and from the Assessment Files Research Office and the Source Mineral Deposit Record Files, Ontario Geological Survey, Toronto. This information, except for the Source Mineral Deposit Record Files may also be found at the office of the Resident Geologist, Ontario Ministry of Natural Resources, Red Lake, Ontario.

Most of the mineral exploration activity in the map-area has been for base metals. The earliest recorded activity took place in 1951; the most recent was in 1980. Ten companies are on record as having completed work in Bowerman Township and 13 have completed work in Belanger Township. Much of the activity took place in 1969 in Bowerman Township, and from 1969 to 1972 in Belanger Township. This was initiated after the discovery, in 1968, of a major Cu-Zn-Ag massive sulphide deposit (South Bay Mine) in a subvolcanic porphyry located about 13 km to the northeast of the map-area.

The mapping for this project has resulted in the recognition of felsic and intermediate metavolcanics previously interpreted as quartz porphyry, sericite-quartz schist, and mica-quartz schist (Fenwick 1966a, b).

This reinterpretation should be of interest to exploration companies, given the proximity of the South Bay Mine and its similar geological setting.

¹ Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.
General Geology

Geological mapping of the entire map-area has been done by K.G. Fenwick (1966a, b). Part of the map-area was also surveyed by J.D. Bateman (1939). Adjacent townships to the north were mapped by A.P. Pryslak (1970, 1971). The area to the west was mapped by Fenwick (1966c), and that to the east by R.P. Bowen (1981). Regional compilations which include Bowerman and Belanger Townships were produced by J.C. Davies and A.P. Pryslak (1967), and P.C. Thurston and J.R. Bartlett (1981).

The map-area is underlain by rocks of Early Precambrian age which are locally covered by glacial deposits. Figure 1 shows a generalized geological map of the area.

The central part of the map-area is underlain by a granodioritic pluton which is largely juxtaposed in a sequence of moderately foliated to schistose, felsic and intermediate metavolcanics containing quartz and (or) plagioclase phenocrysts.

![General geology of the Bowerman-Belanger Township Area.](image)
Locally, flow-banded rhyolite and lapilli-tuff were identified. To the southeast of Fly Lake, intermediate pyroclastic rocks (generally lapilli-tuff) are characterized by highly stretched felsic fragments in an intermediate matrix. Both the fragments and the matrix contain metamorphic amphibole. Locally, within these pyroclastic rocks and extending southward, there are mafic flows and pillowd lavas with minor interflow units of banded amphibole-magnetite ironstone. Gabbro sills and dikes have intruded the mafic metavolcanics in southeast-central Bowerman Township. The southeast part of the map area, in the vicinity of Ben Lake, is underlain by metasediments and (or) tuffs exhibiting pronounced slaty cleavage.

The geological configuration in Belanger Township is relatively complex. Northeast-trending felsic to mafic metavolcanics locally bifurcate around granitic bodies consisting of massive and foliated granitic rocks. The mafic metavolcanics consist predominantly of massive flows; but pillowd flows, and units of chemical metasediments consisting of bands of amphibolite, magnetite ironstone, and chert are locally present. Granitized felsic tuff lies to the northwest of the mafic metavolcanics. The central portion of Belanger Township is underlain by intermediate to felsic tuff and lapilli-tuff. In the southwest part of the township, these rocks have been metamorphosed to porphyroblastic schists and granoblastic rocks that contain combinations of garnet, staurolite, biotite, and feldspar porphyroblasts. Unconformable, irregularly shaped bodies of gabbro have intruded the volcanic and granitic rocks. Biotite and chlorite-bearing, fine-grained trondhjemite rocks trend northeasterly and lie along the north and south shores of Tote Road and Fredart Lake respectively. Locally, on Fredart Lake, these rocks contain garnet or actinolite; this suggests that these rocks may have had an anatectic origin.

**Structural Geology**

Virtually all of the metavolcanics and metasediments have a penetrative fabric which ranges from a lineation of mafic minerals (commonly amphibole) in mafic rocks, to a weak mineral foliation (commonly biotite), and a schistosity (commonly sericite, chlorite, and (or) biotite) in intermediate to felsic rocks respectively. Metasediments and some felsic to intermediate metavolcanics are commonly phylilitic and (or) exhibit well-developed slaty cleavage.

Little structural information could be obtained from the rocks of this area, other than attitudes of types of foliation. Pillows are locally recognizable, but commonly gave unreliable facing information. Bedding, although locally identified, did not allow top determinations to be made because of extensive recrystallization. No lateral offset of units was identified, but shearing was noted along the shores of Fredart, Tote Road, Ben, and Fly Lakes, as well as on some smaller lakes, and may represent some strike-slip faulting.

The author’s preliminary interpretation of the overall structural and stratigraphic relationship holds that the felsic to intermediate metavolcanic rocks are draped around the granodiorite pluton in west-central Bowerman Township. The pluton appears to occupy the axial zone of a northeast-trending, shallowly plunging anticline. The two southwest-trending sequences of intermediate to felsic metavolcanics in southwestern Belanger Township (see Figure 1) are interpreted to be thin, folded units occupying ‘troughs’ in the roof of the pluton.

**Economic Geology**

Sulphide mineralization has been found in several localities throughout the map-area. The most notable is the Copper Lode Occurrence southeast of Fredart Lake. There, in the main showing, occur massive and disseminated pyrrhotite, pyrite, chalcopyrite, and sphalerite hosted by what are interpreted by the author to be moderately metamorphosed intermediate to felsic metavolcanics and lesser amounts of metasediments. Minor specks of chalcopyrite, and in one place molybdenite, were also found by the field party in the narrow belt of metavolcanics extending southwest from the Copper Lode Occurrence. In the belt of mafic metavolcanics at and near the northeast-end of Fredart Lake, minor mineralization occurs that consists of chalcocite, pyrite, and in one case, molybdenite (see Figure 1).

Minor chalcopyrite was found in at least three places within the granitic rocks to the north-northwest of Fredart Lake. A trench west-northwest of Fredart Lake contains massive and stringer pyrite and chalcopyrite within granitized felsic metavolcanics (see Figure 1).

The presence of these sulphide occurrences, most of which are associated with felsic to intermediate rocks, is considered by the author to indicate significant base-metal potential for the area, especially given the proximity of the South Bay Mine. A sample of schistose porphyritic rock of intermediate composition, found in northwest-central Bowerman Township, is similar to porphyritic rocks in the alteration zone at the South Bay Mine (M. Durocher, Resident Geologist, Ministry of Natural Resources, Red Lake, personal communication, 1981; A. Pryslak, Selco Exploration Company Limited, personal communication, 1981), which may further attest to this area’s potential as a source of base-metal deposits similar to that of the South Bay Mine.

Quartz-tourmaline veins were found at several localities, particularly within the felsic pyroclastic units in central and north-central Bowerman Township. No results for gold and silver assays are yet available, but the presence of the quartz-tourmaline veins may be significant given the importance of similar veins in localizing gold mineralization, as in the Red Lake Camp for example.
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No. 5 Lithophile Mineralization in Northwestern Ontario: Rare Metal Granitoid Pegmatites

F.W. Breaks

Introduction

The final phase of the field examination of the rare-metal pegmatites of Northwestern Ontario involved a two-week investigation of the tantalum potential of spodumene pegmatites in the Zig Zag Lake area, 56 km northeast of Armstrong. Economic evaluation of these dykes and other mineralization types in this area is clearly imperative in view of the eventual inundation of the area by Ontario Hydro which is in the process of harnessing the energy potential of the Little Jackfish River System.

Previous Work

The Zig Zag Lake area has previously been mapped in detail by E.G. Pye (1968). Spodumene-bearing pegmatic dykes were discovered in this area in 1956 by F. Tebishogeshik, and were subsequently acquired and evaluated for their lithium potential by Dempster Explorations Limited (Pye 1968, p.56). These pegmatites were mapped in detail by this firm, and enumeration of the various pegmatitic lenses in Figure 8 of Pye (1968) has been maintained in this report. In 1979, J.A. Donner sampled the Tebishogeshik deposits for tantalum and had results varying from 0.02 percent Ta over 15.0 feet to 0.35 percent Ta over 3 feet 6 inches. (Regional Geologist’s Files, Ontario Ministry of Natural Resources, Thunder Bay).

Geology

Rare-metal pegmatites of the Zig Zag Lake area occur in low to medium grade mafic metavolcanics and metamorphosed foliated biotite trondhjemite of the Wabigoon Subprovince situated between 3.5 and 5 km south of the boundary with the English River Subprovince. These pegmatites comprise the western part of a 4 by 16 mile zone termed the Falcon Lake-Zig Zag Lake Field (Mulligan 1965, p.61-63). An increase in metamorphic grade is evident in traversing northwards into the English River Sub-
province. This increase is not as striking in diversity of metamorphic assemblages as is found in the Dryden-Eagle River area (Breaks et al. 1978). Adjacent to the boundary, as exposed on Zig Zag Lake, the English River Subprovince is composed of medium grade biotite meta-wacke and sillimanite-muscovite-biotite metapelite. Further north along this lake and Moule Lake, there are homogeneous diatexites with subordinate inhomogeneous diatexitic and metatexitic metasedimentary migmatite. The diatexites consist of biotite > muscovite white pegmatite with occasional interbanded aplite. Ovoid biotite-quartz symplectites are locally conspicuous in these rocks, and much of the biotite appears to have evolved from the replacement of cordierite, as is suggested by surviving rectangular forms and relics of blue cordierite. Dykes of leuosome originating from these higher grade zones are locally evident in medium grade metasediments, and exhibit the effects of cataclasis in the form of augen-shaped, graphic to homogeneous potassic-feldspar porphyroblasts, and pinch and swell dyke structures.

Numerous anastomosing shears which transect and follow the boundaries of boudinaged dykes are notable by the presence of medium- to coarse-grained, flat sheet-like aggregates of fibrolitic sillimanite. Accessory minerals in the leuosome dykes include garnet, apatite, black tourmaline, and cordierite. The latter mineral is largely altered to reddish brown pits. No connection between the S-type granitoids in the Moule-Upper Zig Zag Lakes area and the rare-metal pegmatitic dikes 5.6 km south could be made with certainty.

Several spodumene dykes in the Zig Zag-Seymour Lakes area are hosted by the marginal part of a regionally extensive granitoid mass (Dempster L-28, L-40, L-61, Chappais Lake Li, and Syemour Lake Li Deposits of Pye 1968, Map 2100). The granitoid mass, however, does not appear to have petrological characteristics that would suggest a genetic connection with these spodumene dykes. This granitoid mass consists of a multi-phase trondhjemitic batholithic complex which is intensely foliated and becomes more massive towards the south.

The diatexites consist of biotite > muscovite white pegmatite with occasional interbanded aplite. Ovoid biotite-quartz symplectites are locally conspicuous in these rocks, and much of the biotite appears to have evolved from the replacement of cordierite, as is suggested by surviving rectangular forms and relics of blue cordierite. Dykes of leuosome originating from these higher grade zones are locally evident in medium grade metasediments, and exhibit the effects of cataclasis in the form of augen-shaped, graphic to homogeneous potassic-feldspar porphyroblasts, and pinch and swell dyke structures.

In the Tebishogeshik spodumene dykes, the degree of albitization increases from east to west. Lens 1 is the most thoroughly replaced pegmatite with no unaltered spodumene discernible. Two types of albitized pegmatite are evident; although age relations could not be verified. These are: 1) fine-grained massive pods of saccharoidal sodic-biotite; 2) medium- to coarse-grained, inequigranular cleavelandite-quartz-green muscovite-beryl ± pink garnet ± potassic-feldspar megacrystal remnants.

Columbite-tantalite occurs mainly as thin diminutive plates up to 1.5 by 4 mm and more rarely as rectangular crystals (maximum size 6 by 7 mm), embedded in the inequigranular cleavelandite-green muscovite replacement complex. In particular, it appears to favour localization along contacts of either incompletely replaced ragged blocky potassic-feldspar megacrysts and/or spodumene altered to fine-grained green muscovite. Columbite-tantalite is relatively scarce in Dempster spodumene dykes L-28, L-40, L-61, and Chappais Lake spodumene dyke.

Holmquistite, not previously reported from this region, occurs in a fine-grained, massive amphibolite adjacent to the southern contact of albitized spodumene pegmatite in Lens 3. It is mainly developed in thin veins up to 1 cm wide and 70 cm in length.

Beryl occurs sporadically in all four of the Tebishogeshik spodumene pegmatic lenses as well as in Dempster L-28, L-40, and Chappais Lake spodumene dykes. It is most abundant in Lens 1 where it locally makes up 1 to 2 percent. The beryl occurs as white irregular crystals varying in diameter between 8 mm and 1.5 cm and is strictly associated with inequigranular cleavelandite-green muscovite replacement complex. In the Chappais Lake spodumene dyke, primary light green beryl was noted to paragenetically succeed spodumene, filling interstices between this mineral, in addition to containing fine-grained spodumene inclusions.
Albitized pegmatitic dikes exhibiting the best tantalum potential would appear to be Lens 1, 2, 3 of the Tebisheshik spodumene deposits. Other lithium dykes examined were characterized by much narrower widths, sporadic albitized zones, and relatively rare columbite-tantalite. Further economic evaluation must await mineral and petrochemical data.

References


**Introduction**

A 174 km² area lying between Long Bay on the Lake of the Woods to the south and Latitude 49°35′N to the north; and between Longitudes 94°04′W and 94°15′W was mapped at a scale of 1:15,840. This area consists of parts of the townships of Manross, Code, Work, MacQuarrie, and Devonshire. Access to the east and central parts of the map-area is from an all-weather secondary road and from dry-weather bush roads that run west from Highway 71 to the north-south Ontario Hydro powerline that bisects the map-area. The area is also accessible from Black Lake. The south and southwest parts of the area may be reached from Long Bay, Yellow Girl Bay, and Adams Creek Bay of the Lake of the Woods. The north and northwest parts of the area may be reached by using the Witch Bay Road, which intersects the aforementioned powerline, and by canoe from Witch Bay on the Lake of the Woods.

**Mineral Exploration**

Gold has been the focus for exploration in the Lake of the Woods region since the turn of the century and many mines and prospects have been found; none are located in the present map-area (Beard and Garratt 1976; Thomson 1935). Exploration for gold and base-metals has been carried out within the map-area, and assessment work on file with the Resident Geologist’s Office, Ontario Ministry of Natural Resources, Kenora, has been compiled and is available as Data Series Maps (Rivett and MacTavish 1980a and b). Currently there is no known exploration activity.

**General Geology**

N.H.C. Fraser (1943) mapped the Whitefish Bay Area, Lake of the Woods, in 1937, this included much of the present map-area. The northwest corner of the map-area was examined by G.G. Suffel (1931) as part of the Bigstone Bay Area, Lake of the Woods. The present geological survey adjoins the Gibi Lake Area to the north which was mapped by N.F. Trowell in 1979 and 1980 (Trowell 1979; Trowell et al. 1980).

Except for a Late Precambrian, northwest-trending diabase dike in Work Township, the rocks exposed in the map-area are Early Precambrian in age. Two cycles of volcanism exist; each cycle consists of mafic metavolcanics overlain by intermediate metavolcanics with inter-
digitated metasediments. The age relationship of the two cycles to one another has not been determined. The metavolcanic-metasediment assemblage has been intruded by the flanking, multiphase Aulneau Batholith and Dryberry Batholith (Blackburn 1981), as well as by internal, single phase stocks; the Viola Lake Stock and the Bunion Lake Stock (Figure 1). One of the volcanic cycles is found in southern Code Township and MacQuarrie Township. The base of this cycle, consisting of fine- to medium-grained massive, porphyritic and pillowed mafic flows, mafic tuff, lapilli-breccia and interflow argillite is found on Long Point Island (Blackburn 1981) and between Yellow Girl Bay and Black Lake (Figure 1). Intermediate to felsic metavolcanics called the Berry Complex (Garth Edwards, Graduate Student, University of Western Ontario, personal communication, 1981) are centred on Mist Inlet, and overly the mafic metavolcanics on Long Point Island. The Berry Complex, dated using the U/Pb zircon method at 2711 m.a. (D.W. Davis, Geochronologist, Royal Ontario Museum, personal communication, 1981) consists of coarse-grained, normally graded metavolcanic debris flows and massive to bedded quartz-rich tuffs with interbedded horizons of quartz-feldspar wackes. The metavolcanic material decreases laterally and vertically until
the thick to thinly bedded, fine-grained quartz-feldspar wacke and argillite predominate. The provenance of these wackes is the quartz-rich intermediate to felsic volcanic material. To a lesser degree, finer grained, darker grey feldspathic wackes are found interbedded with the lighter grey quartz-feldspar wackes near the mafic metavolcanics. The provenance of these wackes is the mafic flows. In the vicinity of Rattrap Lake in northern MacQuarrie Township, a similar intermediate to felsic metavolcanic complex is found overlying the mafic metavolcanics. A similar relationship with the wackes is found here as well. Cherty, garnetiferous, thinly bedded ironstone is found on the Yellow Girl Bay Indian Reservation (IR 32B) down strike from the Berry Complex metavolcanics. Ironstone with a similar appearance is found between Bug Lake and Bunion Lake down strike from the intermediate to felsic metavolcanics at Rattrap Lake.

The second volcanic cycle occurs north and north-east of Viola Lake. This cycle is presumed to be the Dogtooth Lake sequence and the Gibi Lake sequence of Trowell (1979) and Trowell et al. (1980). Only the upper part of this cycle is exposed in the map-area. Interbedded intermediate to felsic quartz-feldspar tuff, lapilli-tuff and mafic flows and tuffs are overlain by thinly bedded light grey, fine-grained to very fine grained, feldspathic arenite and quartzose arenite and siltstone with minor interbedded intermediate to felsic tuffs and mafic flows. These well-sorted sedimentary rocks are capped by intermediate to felsic tuff and lapilli-tuff which wedge out to the northeast.

Minor intrusions of medium-grained gabbro and diorite as well as thin sills of very fine grained mafic rock are found throughout the metavolcanics and metasediments. Pods of pyroxenite and peridotite are occasionally present. Thin sills and dikes of feldspar porphyry are found in the metasediments northeast of Mist Inlet.

Intruding the metavolcanic-metasedimentary assemblage on the east is the multiphase Dryberry Batholith. Within the map-area, the Dryberry Batholith consists of, from oldest to youngest, magnetite-bearing tonalite, trondhjemite, granodiorite, aplite, and felsite dikes and syenodiorite dikes. Several phases of tonalite intrude each other with massive tonalite intruding foliated and clotty tonalite. On the west side of the map-area, the Viola Lake Stock, composed of medium-grained porphyritic, biotite granodiorite, intrudes both the volcanic cycles. The Bunion Lake Stock is composed of pinkish, massive, fine-grained, equigranular hornblende granodiorite. Both the Viola Lake Stock and the Bunion Lake Stock are similar in setting to the internal stocks dated, using the Rb/Sr method, by Dieter Birk and R.H. McNutt (1981). These have an average age of 2555±41 m.a.

The metavolcanic-metasedimentary sequence has been regionally metamorphosed to almandine-amphibolite facies rank. Garnet, andalusite, staurolite, and possibly cordierite are found within the metasediments to a distance of 1.6 km from the contact with the Dryberry Batholith.

**Structural Geology**

The strike of the metavolcanic-metasedimentary assemblage is variable throughout the map-area as the bedding has been deformed around the Aulneau Batholith (Blackburn 1981), the Dryberry Batholith, the Viola Lake Stock, and the Bunion Lake Stock (Figure 1).

Brown (1974, 1975, 1976), who has completed a structural analysis of rocks in the eastern part of the Lake of the Woods, has postulated, at least two phases of folding. The first phase of folding, consisting of major anticlines and synclines with peripheral parasitic folds is regional in extent, and can be traced in a westerly direction beyond the map-area. The second phase of folding is the result of the intrusion of the Dryberry Batholith, the Viola Lake Stock, and the Bunion Lake Stock. The compressive force generated by these intrusions caused northerly trending cross folds found east of Viola Lake and west of Black Lake.

Intense shearing occurs in the rocks adjacent to Long Bay due to the regional west-northwest trending Pipestone Cameron Fault (Blackburn 1981). Although this fault separates distinct geologic terrains in the Kakagi Lake area (Blackburn 1981), it does not appear to do so in the present area, and tentative correlations may be made across it.

**Economic Geology**

Although there are no mines or past producers within the present map-area, there are two past gold producers adjacent to the map-area. The Regina Mine east of Sioux Narrows and the Wendigo Mine just north of Witch Bay on Lake of the Woods have been described by J.E. Thompson (1935, p.30-39).

The field party selected grab samples from mineralized quartz veins, mineralized shear zones, and graphitic interflow sedimentary rocks, and shear zones found within both the metavolcanics and metasediments. Some of the samples have been analysed by the Geoscience Laboratories, Ontario Geological Survey, Toronto, and generally contain 0.01 or less ounce of gold per ton. One exception to this was a mineralized graphitic shaley interflow sedimentary rock in the mafic metavolcanics that contained 0.03 ounce of gold per ton. The rest of the samples are in the process of being analysed for gold and are presently undergoing a thirty element spectrographic analysis.

Numerous electromagnetic conductors have been outlined in the map-area (Rivett and McTavish 1980a and b). These occur within both the metasediments and metavolcanics. Diamond drilling on some of these anomalies has intersected pyrrhotite-bearing graphitic horizons containing traces of sphalerite and chalcopyrite (Rivett and MacTavish 1980a and b). The highly sheared and altered zone associated with the Pipestone Cameron Fault...
has gold associated with it in the Dogpaw-Flint Lakes area to the east, and in the Yellow Girl Bay area to the west (Blackburn 1981). The present map-area also contains highly sheared and altered metavolcanics along the Pipestone Cameran Fault in Long Bay and should be examined for its gold potential.

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Introduction

This project is an investigation of Late Precambrian rocks of the Nipigon Plate and Early Precambrian rocks of the Wabigoon and Quetico Subprovinces in the vicinity of Lake Nipigon. The project has two aims: a) to determine the nature of the Wabigoon-Quetico Subprovince boundary in this area; and b) to investigate the origin of the Nipigon Plate. Determining the extent and nature of the Early Precambrian rocks is particularly important due to the association of gold mineralization with the subprovince boundary zone to the east of Lake Nipigon (Mackasey et al. 1974).

During the 1981 field season an area bounded by Latitudes 49°15' to 49°45'N and Longitudes 88°00' to 89°00'W was mapped at a scale of 1:50 000. Additional areas of specific interest to the south and southwest were also investigated.

Mineral Exploration

Within the map-area, mineral exploration has been primarily focussed on the Early Precambrian rocks. The area east of Lake Nipigon in the Wabigoon-Quetico boundary area has been extensively explored for gold. Exploration work prior to the 1970s has been reported by W.O. Mackasey (1970, 1975). One past producing mine, the Leitch gold Mine, is within the map-area. Sustained high gold prices have resulted in considerable recent exploration activity in this region.

The Quetico Subprovince east of Lake Nipigon contains extensive rare-element pegmatites. The area was explored for spodumene in the 1950s (Pye 1965), but recent activity has been minimal (Breaks 1980).

West of Lake Nipigon, Early Precambrian rocks have been prospected for gold and base metals (Pye 1968; Kaye 1969).

Relatively minor exploration has been directed towards the Late Precambrian rocks of the Nipigon Plate. Recently, however, there has been considerable interest...
in uranium within the Sibley Group metasediments to the south of the map-area. Base-metal exploration has delineated minor occurrences of copper near the diabase-sediment interface such as the Disraeli Lake Occurrences (Coates 1972).

General Geology

The map-area (see location diagram) includes Early Precambrian supracrustal and plutonic rocks of the Wabigoon and Quetico Subprovinces and Late Precambrian sedimentary and intrusive rocks of the Nipigon Plate. Previous mapping of Lake Nipigon is reported by A.W.G. Wilson (1910). M.E. Coates (1972) mapped the area to the south containing Late Precambrian sedimentary rocks explored between Lake Nipigon and Lake Superior. E.G. Pye (1965, 1968), L. Kaye (1969) and W.O. Mackasey (1970, 1975) have mapped Early Precambrian rocks around the margin of the plate in the vicinity of the Subprovince boundary.

Early Precambrian

Early Precambrian rocks occur around the margin of the Nipigon Plate and within the Plate as uplifted fault blocks and outliers overlying the Late Precambrian igneous rocks. During the present survey, previously unreported Early Precambrian metavolcanics were found on Hat Mountain Island and Red Willow Island in Lake Nipigon.

The stratigraphy of Early Precambrian rocks is similar on either side of the Nipigon Plate. The components are: 1) a northern metavolcanic sequence consisting of predominantly mafic metavolcanics and lesser intermediate fragmental rocks; 2) a metasedimentary unit 1 to 2 km wide consisting of polymictic conglomerate, quartz wacke, lithic wacke, and argillite; 3) a thin, 1 km wide unit of mafic metavolcanics, and 4) a southern metasedimentary sequence. The southern metasedimentary sequence increases in metamorphic grade to the south and eventually becomes migmatized.

Mackasey et al. (1974) consider the subprovince boundary to be stratigraphic and to occur over a diffuse zone representing a facies change from predominantly volcanic to predominantly sedimentary assemblages. According to their definition, the northern metavolcanic sequence is considered to be part of the Wabigoon Subprovince and the southern metasedimentary sequence, part of the Quetico Suprovince. In the transitional zone between these facies, the sedimentary rocks show a progressive decrease in grain size to the south suggesting the conglomerate represents a proximal facies of the Quetico Subprovince.

Late Precambrian

In the map-area, Late Precambrian rocks of the Nipigon Plate consist of: 1) Sibley Group sedimentary rocks which unconformably overlie the Early Precambrian rocks; 2) a suite of predominantly ultramafic intrusions, and 3) extensive diabase sheets.

The Sibley Group sedimentary rocks within the area are more extensive than previously recognized. New areas found to be underlain by Sibley Group rocks occur south of Lake Nipigon between Black Sturgeon and Forgan Lakes. The sedimentary rocks are predominantly white calcareous mudstone and carbonate, and are probably part of the Rossport Formation (Franklin et al. 1980). Red mudstone, quartz arenite, and locally conglomerate are also present within the sequence.

Four ultramafic intrusions, which have not been reported in the previous mapping, have been delineated in the map-area and in the area to the south. The intrusions are interpreted to be younger than the Sibley sedimentary rocks since they outcrop at higher elevations than the sedimentary rocks, and they appear to be older than the diabase sheets. The ultramafic intrusions occur on the east shore of Disraeli Lake, according to J.M. Franklin (1970), 1.5 km southeast of Leckie Lake, on the east shore of Lake Nipigon in Eva Township; and in northeast Hele Township as was reported by J. Scott (Resource Geologist, Ontario Ministry of Natural Resources, Thunder Bay, personal communication, 1981). The Disraeli Lake and Leckie Lake intrusions occur as elliptical to circular plugs 1 to 2 km in diameter which range in composition from mica-peridotite to metagabbro and locally syenite. The Eva Township intrusion is a circular ring dike with an outside diameter of approximately 6 km and ranges in composition from peridotite to metagabbro.

Olivine diabase sheets are the most extensive rock type in the area. Two sheets are present in the map-area. The lower sheet has a thickness of approximately 200 m and grades, from base to top, as follows: coarse ophitic diabase to medium-grained diabase to diabase with coarse pegmatic patches containing quartz. The upper 2 m of the sheet is fine grained to aphanitic with polygonal fractures. A zone of amygdaloidal diabase 10 to 20 cm below the chill zone is locally present. Alteration veins containing pectolite, carbonate, epidote, amphibole, tourmaline, and analcime are abundant near the top of the sheet. Overlying calcareous sedimentary rocks of the Sibley Group exhibit contact metamorphic effects including the development of skarns and the growth of metamorphic epidote, amphibole, talc, and serpentine. Remnants of Early Precambrian rocks also overlie the lower diabase.

The upper diabase sheet is the highest stratigraphic unit of the Nipigon Plate within the map-area. The upper contact of this sheet was not observed, and therefore the original thickness of the sheet is not known. The sheet has a minimum thickness of approximately 100 m and ranges from ophitic to medium grained.

Structure

Early Precambrian

In the Nipigon area, the Wabigoon-Quetico Subprovince boundary appears to be stratigraphic, and no evidence is
present to indicate a major structural break between the Subprovinces. Reversals in top directions in both metavolcanics and metasediments indicate complex isoclinal folding in the boundary zone. West of Lake Nipigon, however, metaconglomerate and wacke associated with the Quetico Subprovince appear to overlie metavolcanics of the Wabigoon Subprovince in the vicinity of Max Creek on Highway 527.

Insufficient outcrop of Early Precambrian rock occurs within the Nipigon Plate to trace the boundary zone through Lake Nipigon. A pronounced magnetic high (Ontario Department of Mines-Geological Survey of Canada 1962) associated with iron formation in the boundary zone indicates that the boundary passes through McIntyre Bay and is offset sinistrally by the Black Sturgeon Fault Zone.

**Nipigon Plate**

Observations of the present survey support the hypothesis of Franklin *et al.* (1980) that the Nipigon Plate occupies a failed arm which extends north from a major flexure in the Keweenawan Lake Superior rift. The Black Sturgeon Fault and the Nipigon River Fault were the loci of tectonism in the Nipigon Plate during this event. Both faults are associated with vertical displacement in which the east block has moved up. Vertical displacement is greatest on the Black Sturgeon Fault, and appears to have been contemporaneous with sedimentation. This has resulted in thickening of Sibley sedimentary rocks toward the fault and exposure of Early Precambrian rocks along the east side of the structure (Coates 1972).

The Black Sturgeon and Nipigon River Faults have northern terminations which resemble small scale or second-order triple junctions. These terminations may have been feeder zones for the diabase sheets.

Over most of the map-area, the diabase sheets, and sedimentary rocks form a series of shallow basins and arches with dips ranging from sub-horizontal to less than 15°. The sheets are broadly conformable to the Sibley sedimentary rocks, but are markedly discordant to Early Precambrian rocks. Steep dips of 40° to 80° occur in Sibley sedimentary rocks and diabase sheets associated with the northerly terminations of the Black Sturgeon and Nipigon River Faults.

**Economic Geology**

**Gold**

Early Precambrian metavolcanics and metasediments southwest of Lake Nipigon are correlated with the supracrustal rocks containing gold mineralization east of the lake. Both sequences are similar in lithology, metamorphic grade, alteration, and tectonic environment. This suggests that the sequence southeast of the lake should be favourable for gold mineralization as indicated by Pye (1968). In this zone, numerous quartz veins are present, associated with the carbonatization of the mafic metavolcanics. This alteration is commonly associated with northeast-trending sheared zones.

Archean supracrustal rocks east of Black Sturgeon Lake contain numerous quartz veins and pods, but these rocks are of higher metamorphic grade than those on either side of the Nipigon Plate.

**Base Metals**

Copper occurrences at Disraeli Lake are associated with Late Precambrian diabase sheets and underlying Sibley Group stromatolitic carbonates. Coates (1972) considered these occurrences to be due to metasomatism related to diabase intrusion or to later supergene processes.

The intrusion of large amounts of tholeiitic magma into the sulphate rich Sibley sedimentary rocks suggests an environment favourable for copper and nickel mineralization. Prospecting within the diabase for this type of mineralization should be concentrated on the basal parts of the sheets.

Ultramafic rocks within the area are largely untested and warrant investigation for copper, nickel, and possibly chrome and platinum group elements. The presence of a major ultramafic ring dike in Eva Township indicates a tectonic environment favourable for kimberlites, but none have been detected in this zone to date.

**Uranium**

Uranium mineralization in the Sibley basin has been documented by Franklin (1970) and is associated with northwest-trending fractures in Early Precambrian rocks near the Early Precambrian/Late Precambrian unconformity. Early Precambrian rocks in the vicinity of the Black Sturgeon Fault warrant investigation for this type of mineralization. In this zone, radioactive fractures were discovered by the field party approximately 1 km east of the south end of Black Sturgeon Lake.

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Location and Access

The map-area, centred on O'Sullivan Lake, is bound approximately by Latitudes 50°30' and 50°22'30"N and Longitudes 86°55' and 87°15'W.

Paved and gravel roads lead from Geraldton to the project area. Numerous bush-roads occur within the northwestern part of the project area. Another form of access is by boat from a landing on Kawashkagama River.

Outcrop is abundant and approximately 75 percent exposure occurs. The exposure is particularly good on the lakeshore along the Northeast and Wander Arms where it is virtually 100 percent. The only relatively inaccessible area is between the Northeast Arm in the south and Superb Lake in north.

Mineral Exploration

Mineral exploration has concentrated mainly on gold and base metals. The commencement of production at the gold mine owned by Consolidated Louanna Gold Mines Limited on O'Sulake peninsula has also drawn renewed attention to this area. Overall, small amounts of work have been done every few years on existing prospects known from at least since the mid 1950s. Since then, the only new targets have been geophysically indicated, and overall, only Consolidated Louanna Mines has achieved any measureable success.

The above company has reopened the old mine workings (closed since September 1950) and is constructing a decline to the second level at 90 m. The first level at 45 m has already been reached. Mine planning is based so far on the old geological sections. The mineralization occurs in quartz veins and tuffs adjacent to quartz porphyritic intrusive rocks. Grades below the second (90 m) level and above the first level (45 m) are unknown in detail, and the mineralized zone is described by company personnel as open-ended. Underground drilling from the first level is now in progress. Mine life based on present known reserves is expected to be 3 to 5 years.

Since the early 1970s, all new targets in this area have been defined by geophysical prospecting, and these have been followed up with minor drilling. Matta-
2Regional Geologist's Files, Ontario Ministry of Natural Resources, Thunder Bay.

trudes fine-grained massive metavolcanics. Pyrite, pyrrhotite, chalcopyrite, and malachite occur in veins. Both contacts of the porphyry (< 3 m thick) are mineralized, but the bulk of the mineralization occurs on the east contact zone. Pyrite also replaces the mafic minerals in the porphyry. The best mineralized zone is less than 0.9 m wide.

General Geology

The map-area comprises three geologically distinct sub-areas:

1) The central greenstone pile mainly composed of greenschist facies pillowed and massive lavas and chemical sedimentary rocks overlain by intermediate to felsic tuffs and rhyolites of locally higher metamorphic grade and which have been intruded by quartz-feldspar porphyries and diabase-gabbro dikes;

2) The southern and southeastern trondhjemite-gabbro diabase intrusive complex;

3) The northwestern granitoid-pegmatite area which is adjacent to and intrusive into high grade metamorphosed dominantly arenaceous sedimentary rocks along the northern fringe of the metavolcanic belt.

The central greenstone area strikes northeast to east-northeast and extends from the south shore of Superb Lake to the north shore of the Northeast Arm of O'Sullivan Lake, a distance of 8 km. The southern part of the section is northwest facing and comprises pillowed, vesicular, and massive mafic volcanics, pillow breccia, and hyaloclastite interbedded with intermediate greyish to light green pillowed and massive andesitic flows. Locally, porphyritic types of flow with phenocrysts of plagioclase and amphibole occur, but the mafic to intermediate rocks are on the whole non porphyritic and vary from fine-grained to massive coarse-grained gabbroic flow centres indistinguishable from similar coarse-grained intrusive rocks. Chemical sediments are rusty carbonate rocks composed of very fine grained and massive coarsely recrystallized types. These rocks are confined to pillowed units and are rarely ever more than 0.3 m thick. Boudinage structures are revealed by local thickening and pinching.

Green chloritic and quartzitic tuffs are also interbedded with locally occurring felsic tuffs and intermediate pillowed and massive volcanic rocks. The tuffaceous units are generally not very thick, but are fairly continuous along strike although again boudinage structures have affected the continuity locally. Intense chloritization of these tuffs suggests that chloritization is the main alteration type and that carbonization is more local. Infrequently, leucocratic sheared intermediate to felsic tuffs are also interbedded.

The bulk of the intermediate to felsic extrusive rocks are composed of ashy and crystal tuff, and lapilli-tuff which are commonly deformed, but occasionally are well
The local northeast striping of the rock types suggests that the main fracture direction was northeast to east-northeast in the mafic intrusion, and that only minor unroofing of the granitoid has occurred.

On the north shore of O'Sullivan lake (north of Peter Island) medium-grained granite-granodiorite occurs with coarse granitoid pink pegmatites. Further to the north and northwest, on Superb Lake, Odman Lake, and on the road, outcrops of muscovite albite pegmatites, commonly white, are found.

Fresh late diabase dikes trend north and northwest. Some quartz diabases trend northeast. The quartz content of these rocks exceeds ten percent locally. This may be due to the assimilation of quartzitic tuffs with which these rocks are often seen to be in contact, as on Springpole and Harlow Islands.

Structural Geology

The pillowed and massive volcanic rocks between the south shore of Superb Lake and the mafic shore of the Northeast Arm are essentially monoclinal and face northwest. The felsic volcanic rocks against which these rocks are juxtaposed, however, face south, and this suggests a faulted contact. The arenaceous and less argillic sedimentary rocks to the north also face south and are in faulted contact with the felsic volcanic rocks.

Intermediate to felsic rocks on Cryderman peninsula are tightly folded and are in sheared contact to the north with intermediate north-facing pillowed volcanic rocks. Minor folds on this peninsula consistently plunge west-southwest.

O'Sulake peninsula represents a syncline with intermediate pillowed rocks on the north shore facing south and similar rocks on the island to the east and along the south shore of the peninsula facing north.

The mafic intrusion north of Kawaskagama River also occurs roughly along a synclinal axis defined by pillowed volcanic rocks and felsic tuff north and south of the river.

In all cases, strikes are uniform and dips consistently are steep, except where local block faulting occurs. Locally, some pillowed units suffer minor overturning.

An extensive shear-zone runs from Harlow Island, and along the south shore of the Northeast Arm. A similar shear zone is seen in the northeast side of Conlon Bay.

Economic Geology and Suggestions for Exploration

On the Consolidated Louanna Mines property, chalcopyrite-pyrethrite and pyrite-arsenopyrite occur in quartz veins and disseminations in tuff. This is the typical mineralization type across the whole area where quartz porphyritic intrusive rocks form narrow dykes generally less...
than 3 m wide, which crosscut pillowed metavolcanics and felsic tuffs. The chalcopyrite-pyrrhotite mineralization is typically joint controlled and some calcite and calcite-actinolite aggregates are often present. Gold and silver showings seem to be dominated by the presence of arsenopyrite, although on Farley Island a minor amount of galena also occurs with the chalcopyrite.

The arsenopyrite association with gold is particularly interesting in the previously unknown showing in the bay north of Thompson Bay and southwest of Peter Island.

In almost all cases to date, significant base-metal occurrences are lacking, but the quoted fair grades given in this report obtained from random grab samples continue to be promising. One of the notable features of this area is that the mineralization is always spatially related to quartz porphyritic intrusions emplaced into intermediate volcanics. Mineralization in association with mafic (dark) volcanics is not known. No showings have been recorded in association with the subvolcanic granitoid intrusion parallel to strike and north of Merle Lake; there, the host rocks are dark mafic volcanic rocks. Nevertheless, this belt in particular, is fair ground worth prospecting.

The spodumene showing on the north shore of Superb Lake is the only known one in this area, but white pegmatites are abundant on the road to the northwest and hold promise for similar and more continuous occurrences. A zoned pegmatite outcrops on the road 1 km north of Odman Lake; this also indicates the possibility of the occurrence of columbite-tantalite.

References

Moorhouse, W.W.
No. 9 Terrace Bay Area, District of Thunder Bay

M.W. Carter

Location and Access

The map-area covers about 282 km², is bounded by Latitudes 48°54'00"N and 49°03'00"N and Longitudes 87°01'37"W and 87°15'00"W, and includes parts of the Upper and Lower Aguasabon Lakes areas. The area is the northern part of the Terrace Bay area, and is the second part of a two-year project.

Most of the northeastern and eastern parts of the area are readily accessible by the Kimberly-Clark of Canada Limited logging road which extends across the area and connects Terrace Bay to the south with Geraldton and Longlac to the north. The southwestern and extreme northeastern parts of the map-area are best reached by helicopter, and float-equipped, fixed-wing aircraft.

Mineral Exploration

Exploration in the map-area was carried out intermittently from 1937 to the present time. Exploration has been undertaken primarily for massive-sulphide, base-metal mineralization. This was done mainly by geophysical means in the felsic part of the Wawa volcanic assemblage, and within the Quetico metasediments along the boundary of the Quetico and Wawa Subprovinces. Prospecting activity was also carried out for molybdenum mineralization in granitic rocks.

Molybdenum Mineralization

The following account is based on material in the Regional Geologist’s Files, Ontario Ministry of Natural Resources, Thunder Bay.

In about 1937, a molybdenite occurrence, located approximately 0.8 km southwest of the southern end of Owl Lake, was explored by trenching, pitting, and diamond drilling. The total length of diamond-drill core is unknown. In 1966, four diamond-drill holes were put down on the occurrences for a total length of 159.7 m, and a detailed geological map was made by Halet, Broadhurst, and Ogden Associates for Zenmac Metal Mines Limited. Molybdenite, chalcopyrite, pyrite, and pyrrhotite mineralization was observed during the diamond drilling. In 1969, a magnetometer and soil geochemical survey were carried out at the occurrence by Halet, Broadhurst, and Ogden Engineering Limited for Zenmac Metal Mines Limited. Magnetic anomalies were found, the main one of which was parallel to the trend of the veins, but did not extend outwards from them. Only one geochemical ano-
maly was located, and this occurred in the vicinity of the showings. Anomalous molybdenum results were found parallel to the trend of the showings, extending beyond them into area covered by overburden. In 1972, a detailed geological map of the property was prepared by Halet, Broadhurst, and Ogden Engineering Limited for Zenmac Metal Mines Limited and Pipawa Explorations Limited.

Base-Metal Mineralization
The following account is based on material in the Regional Geologist’s Files, Ontario Ministry of Natural Resources, Thunder Bay.

In 1954, United Montauban Mines Limited had a ground electromagnetic survey carried out on their property at Big Duck Lake in the northwestern part of the map-area by Sharpe Geophysical Surveys Limited. Twelve conductors were found and were considered to be due to disseminated sulphide mineralization in shear or contact zones parallel to the regional geological strike.

In 1957, McPhar Geophysics Limited carried out a ground electromagnetic follow-up survey to an airborne electromagnetic survey done in 1956 by Aerophysics Limited, at Heron Lake in the northwestern part of the map-area for Canabel Syndicate. Geological mapping and exploration activity were also done. Three main, sub-parallel, east-trending conductive zones were located and sulphide mineralization consisting of pyrite, pyrrhotite, sphalerite, and galena, locally massive, was associated with one of them. This was followed by diamond drilling of the anomalies in 1958 when four holes totalling 305.1 m in length were drilled for Valmont Mining Exploration Limited by Boyles Brothers.

In 1959 Burrex ’59 Syndicate carried out ground self-potential and dip-needle magnetic surveys and prospecting in the northwestern part of the map-area, 4.8 km east of Heron Lake. A number of east-trending anomalies were found along with associated pyrite, pyrrhotite, graphite, and molybdenite mineralization.

In 1969, Sol Cowan carried out exploration work near the western shore of the middle part of Owl Lake in the northeastern part of the map-area. No results of the work were recorded.

Early in 1971, Kennco Explorations (Canada) Limited had Lockwood Survey Corporation Limited carry out combined airborne electromagnetic and aeromagnetic surveys in various parts of the map-area to locate economic deposits of massive-sulphide mineralization. Later in the year, ground electromagnetic and ground magnetic follow-up surveys were carried by Geosearch Consultants Limited for Kennco Explorations (Canada) Limited. These located the anomalies discovered by the aerial surveys. The conductors were believed to be formed by pyrite and/or graphite associated with iron formation.

In 1973, Hudson Bay Exploration and Development Company Limited had two diamond-drill holes drilled on their property in the southeastern corner of the map-area for a total of 80.5 m. This was followed by one hole in 1974 for a total of 42.4 m. Mineralization consisting of pyrite and pyrrhotite was encountered in the drilling.

In 1976, a VLF geophysical survey was carried out by Noranda Exploration Company Limited on their property in the southeastern part of the map-area. Several east-trending conductors were located parallel to the geological trend. This was followed by a geological survey in 1977 by the same company on a westerly extension of the property, which was found to be underlain by basalt and rhyolite.

Early in 1979, Selco Mining Corporation Limited carried out ground electromagnetic and ground magnetic surveys on their property in the northwestern corner of the map-area. East-southeasterly-trending conductive and magnetic zones were located. The company had one of these conductive zones diamond drilled later in the year, one diamond-drill hole being sunk for 111.86 m. Pyrite and graphitic argillite were encountered in the hole.

General Geology
The map-area is underlain by Early to Late Precambrian rocks mantled by Pleistocene and Recent deposits.

The Precambrian rocks comprise metavolcanics and metasediments, metagabbro intrusions, granitic and syenitic intrusions, and diabase dikes. The metavolcanics and metasediments occur in two separate contiguous domains: metavolcanics underlie the southern two-thirds of the map-area, metasediments the northern third.

The metavolcanics belong to the Wawa Subprovince and comprise dark-green to black mafic flows and tuffs, the former showing pillowed, amygdaloidal, and vesicular structures. They account for about 80 percent of the volcanic rocks. Intermediate metavolcanics comprise fine tuffs. Felsic metavolcanics are the least voluminous, are light grey in colour, and comprise tuffs, lapilli-tuff and tuff-breccia, and are confined to the southeastern part of the map-area.

The metasediments are fine- to medium-grained, dark to light-grey rocks comprising wacke with minor amounts of arkose, and belong to the Quetico Subprovince. These sedimentary rocks are interlayered with granitic and pegmatitic rocks to form injection migmatites. The Quetico-Wawa boundary trends easterly, south-easterly, and finally northeasterly when traced from west to east across the northern part of the map-area. The supracrustal rocks have been metamorphosed to the amphibolite facies rank of regional metamorphism, and have been intruded by coarse-grained metadiorite and medium- to coarse-grained biotite and hornblende-biotite granitic and syenitic rocks.

Black, rusty-weathering magnetic diabase dikes about 60 to 90 m wide, trend west-northwest, north-northeast, and cut all the rocks previously described. These diabase dikes may be of Late Precambrian age.
The Precambrian rocks are unconformably overlain by Pleistocene and Recent deposits. The most extensive of these deposits consists of glaciofluvial sand and gravel along the Aguasabon River-Aguasabon Lake system within the eastern part of the map-area (Gartner 1979). Thin patches of sand and gravel occur locally along the northwestern branch of the Kimberly-Clark of Canada Limited logging road.

**Structural Geology**

The metavolcanic-metasedimentary rocks have a pervasive foliation which trends east in the western half of the map-area, swings to the southeast in the eastern half of the area, and finally trends northeasterly in the extreme easterly part of the area. The foliation dips steeply, 65° to 85°, to the north throughout most of the southern two-thirds of the map-area, but dips predominantly south in the northern part of the area. Primary bedding and pillow structures parallel the foliation trends, and it is therefore suggested that a major synclinal axis trends easterly along the northern margin of the area.

Numerous photo-lineaments, some with a northwesterly trend and some with a northeasterly trend, are present within the area; the northwesterly ones are the more prominent. Shearing and the off-setting of lithological units indicates that some of these are faults, the most important of which are the Harvie Creek Fault and the Aguasabon River Fault, both of which trend northwesterly.

**Economic Geology**

**Molybdenum**

Molybdenum mineralization occurs at the contact of granitic and mafic rocks near the central part of the eastern boundary of the map-area at Owl Lake. A grab sample taken by M.W. Bartley in 1937 (Bartley 1937, p.40) returned an assay of 1.68 percent molybdenum and 0.03 ounce of gold per ton as determined by the Provincial Assay Office. No assay results from the diamond drilling done in 1937 and 1966 were recorded.

This contact zone represents the best indication of potential for further molybdenum mineralization.

**Base-metal Mineralization**

Assay results from diamond drilling done in 1958 by Valmont Mining Exploration Limited in Quetico metasediments in the northwestern part of the map-area returned best assays of 0.67 percent zinc over 0.55 m and 0.20 percent Ag over 0.48 m (Regional Geologist's Files, Ontario Ministry of Natural Resources, Thunder Bay). During the current survey an occurrence of massive, banded, pyrite-pyrrhotite in basalt was located in a creek bed on the eastern side of the Kimberly-Clark of Canada Limited road half-way between mile eight and mile nine. The sulphide mineralization is accompanied by chert which shows microfolding. A grab sample collected by field party personnel and analyzed by the Geoscience Laboratories, Ontario Geological Survey, Toronto, contained 50 ppm Cu, 135 ppm Zn, trace Pb, 28 ppm Ni, and 45 ppb Au. The showing represents a new occurrence in the area.

Two parts of the map-area are recommended for exploration for this type of mineralization: the southeastern part of the map-area about Rhumly Lake, where there are coarse felsic pyroclastic rocks, and in the northern part of the map-area along the contact zone between the Quetico and Wawa Subprovinces.

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1939: The Northeastern Part of the Schreiber Area; Ontario Department of Mines, Vol.47, Part 9, 1938, p.29-40. Accompanied by Map 47j, scale 1:31 680 or 1 inch to ½ mile.

Gartner, J.F.
1979: Schreiber Area (NTS 42 D/NW), District of Thunder Bay; Ontario Geological Survey, Northern Ontario Engineering Geology Terrain Study 59, 15p. Accompanied by Map 5092, scale 1:100 000.
No. 10 Josephine Area, District of Algoma

R.P. Sage

Introduction

The map-area is bounded by Latitudes 48°6'30" to 48°12'00"N and Longitudes 84°40' to 84°48'W. It includes the Townships of Musquash and Corbiere. This year’s mapping is a continuation of the long-range mapping program of the Wawa area (Sage 1979, 1980). Mapping in Musquash Township is nearly complete, but only 50 percent of Corbiere Township has been covered.

Musquash Township contains only one lake accessible by fixed-wing aircraft. A rough road, barely passable by 4-wheel drive vehicles, extends into the northeast corner of the township. The Magpie River permits only limited access to the township since steep hills and cliffs often border the river. Access to the township is largely by helicopter.

Along the southern boundary of Corbiere Township access is by the Algoma Central Railway. A logging road projects into the extreme southeastern corner of the township. Four lakes provide suitable fixed-wing landing sites. The western and northern portions of the township are easily accessible only by helicopter.

Mineral Exploration

Little record of exploration activity exists for Musquash Township and no current or past producing mines are present. Few mineral occurrences are known. A small segment of the Reynolds iron range passes through the township since steep hills and cliffs often border the river. Access to the township is largely by helicopter.

Corbiere Township has had extensive exploration activity. It contains a past producer, the Josephine Iron Mine, and several iron formations found within the township have been examined for their iron potential. Several gold showings are also present.

The Josephine Iron Mine produced direct shipping hematite ore from the western end of the Josephine-Bartlett iron range. This iron range is the faulted eastern extension of the Michipicoten iron formation which has been broken up by faulting into many segments. The western segments, Helen, Eleanor, Lucy, and Ruth have been previously described (Sage 1980). Iron production from the other fault blocks has consisted of siderite ore. The hematite found at the Josephine Mine is likely from the breakdown of siderite.

The Josephine Iron Mine produced 191,293 long tons of ore and contains reserves of 3,965,000 tons grading 51.65 percent Fe, 14.92 percent SiO2 and 1.88 percent S (Statistical Files Mineral Resources Group, Ontario Ministry of Natural Resources, Toronto). Production ceased in 1946 after a cave-in.

The best known gold showings are the Soocana-Holdsworth and the Edwards showings. The gold occurs in quartz veins. The Soocana-Holdsworth showing is reported to have produced 10 ounces Au and 5 ounces Ag, and the Edwards 28 ounces Au (Statistical Files, Mineral Resources Group, Ontario Ministry of Natural Resources, Toronto).

A massive sulphide (pyrite) zone is present in the southern part of the township. This zone has been diamond drilled and examined as a potential source of sulphur. Table 1 is a list of exploration activity in Musquash and Corbiere Townships.
## TABLE 1
TABULATED EXPLORATION DATA, MUSQUASH AND CORBIERE TOWNSHIPS (AOP – ALGOMA ORE PROPERTIES, ACR – ALGOMA CENTRAL RAILROAD).

<table>
<thead>
<tr>
<th>Company</th>
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<tr>
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<td>Hollinger Consolidated Gold Mines Limited</td>
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Figure 1—Schematic diagram of lithologic distribution in Musquash and Corbiere Townships.
General Geology

Musquash Township is underlain by dominantly massive and pillowed mafic metavolcanics. Felsic metavolcanics intercalated with metasediments are present in the southwest corner of the township. Chert-magnetite iron formation (Reynolds range) is present in the northeast corner of the township. A band of clastic metasediments 400 to 500 m wide strikes northwest through the centre of the township. Numerous occurrences of medium-grained massive mafic rock have been interpreted by the author and his assistants to be intrusions.

Corbiere Township is also dominantly underlain by massive and pillowed mafic volcanics. Felsic tuffs and breccia in the northwest corner of the township may be the southern extension of a larger accumulation of felsic metavolcanics to the north. A northwest-striking band of felsic breccia up to 300 m thick is present approximately 1 km north of West Andre Lake, and a unit of felsic tuffs and breccia occurs in the Reua-Mary Lakes area. This latter unit has not been completely delineated. Felsic tuffs and breccias also form a major stratigraphic horizon beneath the Josephine-Bartlett iron range.

Clastic metasediments found southwest of East Andre Lake are continuous with metasediments found at West Andre Lake. Clastic metasediments are locally present above the Josephine-Bartlett iron range and extend eastward to at least the Marsdan Fault. The metasediments lying above the Josephine-Bartlett iron range were probably faulted into their present position. Numerous small mafic intrusions cut the volcanics.

Extensive areas of the Township display pervasive carbonate alteration and five new chloritoid-bearing zones have been delineated.

Proterozoic diabase dikes cut the rocks of both Musquash and Corbiere Townships. These dikes dominantly have a northwest strike but northeast striking dikes do occur. These dikes commonly occupy faults and shear zones.

Structural Geology

The rocks found in Musquash Township strike northwest, dip 40 to 60 degrees northeast and face southwest. The section is monoclinal and overturned. No folds have been outlined.

The rocks found in the mapped part of Corbiere face southwest and strike west to northeast. Attitudes are steep and commonly overturned. The rocks below the Josephine-Bartlett iron range strike northeast to east, dip subvertically, and face north.

Faulting is present in Musquash Township where the Mildred Lake Fault (Sage 1980) extends northwest through the township. Faulting in Corbiere Township is pervasive, particularly in the vicinity of the Josephine Mine. Faulting in Corbiere Township has not been completely delineated. Local repetition of sections and tectonic thinning and thickening have probably occurred.

Recommendations for the Prospector

Mapping in Musquash Township has indicated the presence of a relatively monotonous sequence of mafic rocks. Sulphide mineralization and quartz veining are not common. Prospecting in this township may best be directed to the location of disseminated sulphide mineralization in association with the mafic intrusions. No record exists of base-metal exploration in proximity to the Reynolds iron range, and this area should be checked.

The rocks of Corbiere Township are highly favourable for base-metal and gold mineralization in addition to the known iron occurrences. Extensive and pervasive carbonate alteration, and numerous chloritoid zones, indicate considerable movement of mineralizing fluids. South and west of West Andre Lake, numerous areas of carbonate-bearing pillow lava display extensive development of a black radiating mineral tentatively identified as tourmaline. The black mineral occurs in crystals up to several centimetres in length, and preferentially occurs in pillow selvages and fractures. No mineralization of economic interest has yet been identified in association with the tourmaline.

Base-metal showings are scarce, even though the rocks and their alteration would have to be considered highly favourable for base-metal concentrations. Zinc is reported (in the records of Getty Mines Limited) to occur in the Big Lake iron formation (not examined this season, see Figure 1), but not in economic quantities.

All of the gold showings in Corbiere Township have not yet been examined by the author. Those that have been examined, consist of quartz veins in mafic metavolcanics. Carbonate alteration in the volcanic rocks and minor sulphide mineralization occur within the metavolcanics enclosing the gold-bearing veins. Assays by the Geoscience Laboratories, Ontario Geological Survey, Toronto, of grab samples collected by members of this field party represent a wide range of gold values. Gold values in excess of 0.1 ounce per ton are common over short strike length and narrow widths.

References

Sage, R.D.

No. 11 Preliminary Interpretation of the Relationship Between Economic Mineralization and Volcanic Stratigraphy in the Wawa Area

R.P. Sage

Introduction

The Ontario Geological Survey is in the third season of a long range program to map and document the economic potential of the supracrustal rocks of the Wawa area. The ideas presented here are tentative, based solely on field observations, and are being outlined at present for the benefit of the many individuals currently working in the area. As chemical data becomes available and mapping proceeds north and east of the current limit of mapping, major modifications of the following ideas may result. Faulting and overturned stratigraphy have complicated stratigraphic interpretation of the area, and subsequent work may result in a stratigraphic reclassification of some sections.

Volcanism

Lower Cycle

Three volcanic cycles have been tentatively recognized.

Middle Cycle

Mafic metavolcanics of the middle cycle which overlie the iron formation are best exposed above the Eleanor and Lucy Iron Ranges and locally above the Helen Iron Range. At the Lucy Iron Range, the mafic metavolcanics of the middle cycle are overlain by clastic metasediments. Extensive felsic tuffs and breccias that occur north of the Magpie River in Chabanel Township are tentatively considered by the author to represent the upper felsic part of the middle cycle. Immediately north of the Magpie River in Chabanel Township, well-developed felsic breccias can be traced laterally, with little interruption, into thinly bedded, immature sedimentary rocks displaying graded bedding, cross bedding, and flame structures. The clastic metasediments found in the upper part of the middle cycle are composed of detritus eroded from felsic centres of the middle cycle. The sedimentary rocks are therefore essentially contemporaneous with the felsic phase of volcanism of the middle cycle. Gold, base-metal and iron formation occurrences in this cycle are rare even though the rock types appear to be similar if not identical to rocks of the lower cycle.
Figure 1—Schematic diagram illustrating three possible volcanic cycles and related mineralization in the Wawa area. Geology simplified, mineral occurrences approximate, (see Sage 1979 and 1980 for additional data).
Upper Cycle

Volcanism of the uppermost cycle was centred south of Wawa Lake in McMurray Township. These metavolcanics consist of tuffs, feldspar crystal tuffs, and a limited amount of felsic flows. The tuffs and feldspar crystal tuffs appear to be intermediate in composition (andesite-dacite) and may be the effusive products of the Jubilee Stock. These tuffs have locally been extensively reworked. Primary bedding observed in the tuffs and flow banding in the felsic flows displays dips from 20 to 50 degrees away from the Jubilee Stock. Enclosing the stock to the east and to a lesser extent to the south is an outer ring of quartz-feldspar porphyry. The author has previously interpreted this ring to occupy a ring fracture enclosing the Jubilee Stock. The Jubilee Stock is a high level intrusion that contains numerous blocks of volcanics. It locally consists of up to 50 percent volcanic rock inclusions at the current level of exposure. The author has previously interpreted the Jubilee Stock to be a subvolcanic intrusion emplaced within a caldera structure (Sage 1979).

The mineral potential of the upper cycle metavolcanics appears to be restricted to gold. Within the interpreted caldera structure neither base metals or iron formation have been found. Carbonate alteration and minor disseminated sulphide mineralization commonly accompanies the gold. The Jubilee shear and its appendages which cut the Jubilee Stock, host several past producing gold mines. Other favourable sites for gold are quartz veins in the margins of the stock or quartz veins cutting the tuffs close to the contact of the tuffs with the Jubilee Stock. The better gold values occur in veins of quartz that are saccharoidal in appearance.

Alteration

Carbonate alteration is so pervasive in the Wawa area that it is of little value for specific target identification of potentially mineralized areas. Carbonate alteration occurs in rocks of all volcanic cycles, however, the most extensive carbonate alteration appears to have developed in the upper portion of the lower cycle.

The presence of chloritoid is a better target indicator since it is far more restricted in distribution than is the carbonate alteration. Chloritoid is locally present in rocks of all compositions from pillowowed mafic metavolcanics to felsic tuffs and breccias. One possible occurrence in conglomerate was located this past field season. Chloritoid occurs only in rocks that also exhibit pervasive carbonate alteration, but rocks that have undergone pervasive carbonate alteration do not necessarily contain chloritoid. Chloritoid that has selectively replaced fragments in a felsic breccia was observed by the field party. Outcrops displaying chloritoid development in fractures have been noted, as was a preference for chloritoid to develop in pillow rims. Generally the chloritoid displays a distribution pattern that is independent of primary structure and is relatively equally disseminated throughout the rock.

Chloritoid may occur both above and below a mineralized zone. Chloritoid zones occur in association with both Michipicoten-type iron formation and massive sulphide zones. The chloritoid zones may have strike lengths of several thousand metres and widths of several hundred metres. While commonly conformable to stratigraphy, the chloritoid zones may encompass several units. In the case of the Helen Iron Range, the chloritoid zone is in excess of 300 m wide and approaches 1500 m in length.

The chloritoid crystals reach 5 mm in size, but most are 1 to 2 mm. The crystals display a random orientation to the schistosity indicating post-kinematic formation.

Mineralization has not been found in association with all of the chloritoid zones so far identified, however, the location of such a zone must be considered a favourable site for massive sulphide and siderite iron formation, since chloritoid is commonly associated with massive sulphide mineralization and siderite iron formation in the Wawa area.

Tourmaline alteration of mafic pillow lavas was located this past season south of West Andre Lake. Mineralization of economic interest is not known to occur with this variety of alteration.

Recommendations to the Prospector

Gold

Promising gold mineralization is present in the lower part of the lower cycle volcanics. Gold mineralization displays a spatial distribution to the margins of the Hawk Lake granitic complex and its associated quartz and quartz-feldspar porphyry intrusions. Shearing, carbonate alteration, minor disseminated pyrite mineralization and locally, minor silification are commonly associated with gold mineralization. Where mineralization is associated with quartz veins, that part of the quartz vein where minor sulphide mineralization is present generally contains better values than where mineralization is absent. More than one age of quartz veining is present in some showings, and the better values appear to be restricted to the older more deformed veins.

Gold mineralization in upper cycle volcanics is associated with the Jubilee shear and quartz veins found within the contact area of the Jubilee Stock with the enclosing volcanics. Carbonate alteration, local silification, and minor disseminated pyrite mineralization occur with the gold.

Base Metals

Base metal mineralization appears restricted to volcanics of the lowermost cycle; most showings are situated in mafic metavolcanics and intrusive rocks.
General Comments

The Wawa area has been extensively prospected for iron, gold, and base metals. Gold and iron were prospected for around 1900 and gold was prospected for again in the 1930s. Gold is currently receiving interest in the area. Over the last 20 years, the area has been subjected to repeated airborne geophysical surveys and follow-up programs. It can be assumed that most promising surface showings have been located and that most geophysically indicated targets have been examined. In spite of these efforts, the author considers the area to have considerable potential. Future work for base metals in the area must be based on a long-term commitment which emphasizes the development of models and concepts to identify target areas. Detailed geologic mapping should precede, not follow contemplated geophysical surveys. The area has long been known to contain large, barren, massive sulphide deposits in association with altered metavolcanics. The number and size of these deposits would make the area of major economic importance if base metals were present in the sulphide zones. Since the area is favourable for sulphide deposition, the problem is one of locating base-metal concentrations.

Gold mineralization in the area is widespread. Over the past five years, the author has examined available data on the gold showings in the area mapped. Most, if not all of these showings warrant re-examination. Early data indicates only limited efforts to do detailed rock identification, to unravel the age relations of the various quartz veins, and to unravel structural complexities. The author would suggest that gold mineralization is better developed in older quartz veins and that ore zones in the vein structures may likely be rod-like, of limited cross-sectional area with a plunging long axis. Such gold-bearing structures are likely to be of relatively high grade, but of low tonnage. These ore zones will likely be difficult drill targets, requiring extensive gathering of geological data to optimize the chance for a successful drill program.

References


No. 12 Keefer, Denton, and Thorneloe Townships Area

A.G. Choudhry

Introduction

The map-area is bounded by Latitudes 48°16'30" and 48°22'00" and Longitudes 81°28'00" and 81°51'25"W and covers an area of approximately 280 km². It includes the townships of Keefer, Denton, and Thorneloe. The town of Timmins is about 25 km to the northeast and Foledeyt is about 75 km to the west. Highways 101 and 144 both pass through the area. Additional access is provided by the gravel roads that extend off the highways and were built for logging haulage purposes.

Mineral Exploration

The information on exploration activities reported here was taken from the Regional Geologist's Files, Ontario Ministry of Natural Resources, Timmins.

Since the discovery of gold at Porcupine in 1909, mineral exploration in the area has been sporadic. A number of old patented claims are located within the area.

Denton Township

In Denton Township, considerable exploration for gold was done in the early parts of the 19th century. Aumo Porcupine Mines Limited did trenching, pitting, and diamond drilling from 1910 to 1925 near the northern boundary of the township. Further diamond drilling of 60 holes was completed in 1945 and 1946. Current exploration work by the company includes 13 diamond-drill holes completed in the summer of 1981.

From 1910 to the 1930s, Jowsey Denton Gold Mines Limited carried out exploration work, including diamond drilling, immediately to the west of the Aumo Porcupine Claims.

In 1945, Wakemac Denton Gold Mines Limited, who held some claims south of Highway 101 near the western
boundary of Denton Township, carried out extensive trenching and put down 12 diamond-drill holes totalling about 1,202 m in length. Apart from a few interesting values, nothing of economic importance was discovered.

From 1945 to 1947 A. Phillips trenched and diamond drilled a sericite-carbonate schist zone located 1 km southwest of Godon Lake. Results were negative.

In 1950, Dominion Gulf Company owned a group of 24 claims in the vicinity of Cripple Creek, south of Highway 101. The company conducted a magnetometer survey over the entire property. Except for a few trenches blasted in scattered outcrops, no other exploration work was done.

In 1955, Hollinger Consolidated Gold Mines Limited diamond drilled 15 holes on, and around, a gold showing (Galata gold showing) on the east side of Mahoney Creek, about 3 km south of Highway 101. In 1958, Hollinger conducted electromagnetic and magnetometer surveys in east central Denton Township and a part of Thorneloe Township. Subsequently, seven diamond-drill holes with an aggregate length of 891 m were put down in the area.

In 1961, Paymaster Consolidated Mines Limited conducted magnetometer and electromagnetic surveys covering an area southwest from Godon Lake to the Keefer Township line. Three weak conductors were delineated, but apparently none were worth testing by diamond drilling.

From 1960 to 1962, Hollinger Consolidated Gold Mines Limited conducted an horizontal loop electromagnetic survey about 1 km west of Mahoney Creek. It detected an easterly-trending anomaly, about 480 m long, into which four holes were diamond drilled. From 1962 to 1967, the company completed magnetometer and electromagnetic surveys together with seven diamond-drill holes, totalling about 1,160 m in length, near the northern part of Denton and Thorneloe Townships boundary.

In 1972, Falconbridge Nickel Mines Limited ran a magnetometer survey of the area west of Godon Lake. The same year, Meridian Mining and Exploration Company Limited carried out electromagnetic and magnetic surveys in the northern part of Denton Township. The company subsequently diamond drilled 13 holes on the east shore of Mahoney Creek (Galata gold showing). Economically interesting values were encountered.

In 1977, Gambit Consolidated Explorations Limited carried out an electromagnetic survey in the northeast sector of Denton Township.

In 1979, the Canadian Nickel Company Limited performed magnetometer, vertical loop electromagnetic, and geological surveys in north central Denton Township. The company subsequently diamond drilled five holes with the aggregate length of approximately 450 m. Only low values of copper-zinc-gold were discovered.

In 1980, Brown-McDade Mines Limited carried out stripping and diamond drilling of eight holes in an area south of Denton Lake. Subsequently, a shaft more than 6 m deep was sunk on a shear zone showing sulphide mineralization. The same year, Gowest Gold Resources Limited staked eleven claims on both sides of Mahoney Creek about 3 km south of the highway. In 1981 the company stripped an area about 17 by 115 m on the east side of the creek (Galata gold showing). Channel sampling across the mineralized zones gave economically interesting (from 0.01 to 0.38 ounce gold per ton) values. Two grab samples of the mineralized zone, collected by the author, were found to contain 0.01 and 0.12 ounce gold per ton (analyses by the Geoscience Laboratories, Ontario Geological Survey, Toronto). The company plans to conduct a diamond drilling program on the property in the near future (Ron Bradshaw, Shield Geophysics, Timmins, Personal communication, 1981).

Thorneloe Township

In Thorneloe Township, the area immediately to the west of Wawayatin Falls was the scene of active exploration before 1940. Gold was discovered on the Thibault claims. Hollinger Consolidated Gold Mines Limited optioned the claims in 1933 and diamond drilled 14 holes with the aggregate length of more than 900 m. In the early 1940s, Maryland Porcupine Gold Mines Limited put down five diamond-drill holes in the area.

In 1948, Garfield Gold Syndicate carried out a magnetometer survey in north central Thorneloe Township, along the Tatachichapika River, and put down eight diamond-drill holes, with negative results.

From 1961 to 1963, Hollinger Consolidated Gold Mines Limited conducted magnetometer and electromagnetic surveys of 28 claims south of Tatachichapika River, and subsequently diamond drilled seven holes totalling about 750 m in length.

During 1950 to 1951, Dominion Gulf Company carried out a ground magnetometer survey south of the river, and put down four diamond drill holes with an aggregate length of 570 m.

In 1966, ACME Gas and Oil Company Limited conducted an airborne electromagnetic survey between Kenogamissi Lake and Tatachichapika River. No significant results were obtained.

In 1974, Jacomo Mines Limited conducted magnetic and electromagnetic surveys west of Wawayatin Falls. As a result, a total of about 610 m of diamond drilling was recommended, but there are no records to indicate whether the drilling was done.

Keefer Township

In Keefer Township, Goldale Mines Limited carried out stripping and diamond drilling in the southwest corner near Opishing Lake.

During 1947 to 1948, Nixon-Bartleman optioned the above property and carried out trenching, pitting, and sampling. Assays gave encouraging gold values.
During 1961 to 1962, Hollinger Consolidated Gold Mines Limited put down seven diamond-drill holes in and around the above area, totalling 1,000 m in length.

In 1971, Texas Gulf Sulphur Company Incorporated and Conwest Exploration Company Limited conducted an airborne magnetic survey on their claims in the southeast quarter of Keefer Township.

In the same year, Cominco Limited did an airborne electromagnetic survey of the northeast quarter of Keefer Township. No significant electromagnetic anomalies were located.

General Geology

W.R. Rogers and E.L. Bruce (1912) mapped parts of Keefer and Denton Townships. E.W. Todd (1924) delineated the greenstone belt in the map area. W.D. Harding and L.G. Berry (1939) mapped the area at 1 inch to 1 mile scale.

The bedrock in the map area consists of an Early Precambrian metavolcanic-metasedimentary sequence of the Abitibi Greenstone Belt of the Superior Province. The supracrustal rocks have been intruded by Early Precambrian granitic rocks, which occupy approximately more than half of the project area.

The northern and central parts of Denton and Thornewe Township are underlain primarily by supracrustal rocks which strike northeast to east and extend into Keefer Township.

The oldest rocks in the area are light grey ultramafic flows, some of which are polysutured pillows and are intercalated with locally derived metasediments. Occasionally, these rocks grade into massive thick flows of serpentinite-bearing peridotite.

Field relations suggest that basaltic komatiite and/or Mg-tholeiite overlies the ultramafic flows. These rocks are succeeded upwards by Fe-tholeiite flows. A thick sequence of calc-alkaline basalt, intermediate to felsic metavolcanics, and clastic metasediments overlie the tholeiitic rocks. The basaltic rocks are mostly amygdaloidal to variolitic pillowed and massive flows, and also include minor tuffs, breccia, and subvolcanic intrusions.

The intermediate to felsic metavolcanics consist of tuff, lapilli-tuff, breccia and foliated to massive porphyritic flows. The pyroclastic rocks show crude to well-defined bedding. Along strike these rocks grade into laminated to subfissile tuffaceous wacke, argillaceous wacke, and clastic metasediments.

The clastic metasediments consist of polymictic boulder-cobble to pebble-granule conglomerate in an arkosic to wacke matrix; fine to medium-grained wackes; arkose and arenite; and pale to dark coloured siltstone and mudstone. These metasediments are thinly bedded and occasionally display crossbedding and grain gradation. A zone of chemical metasediments, consisting of chert, magnetite and/or pyrite occurs interbedded with the intermediate to felsic rocks, as well as clastic metasediments.

Medium- to coarse-grained mafic rocks of gabbroic to dioritic composition intrude the metavolcanic-metasedimentary sequence.

Metamorphism throughout the area is generally of the greenschist facies level. Metavolcanics and metasediments near the late intrusive rocks, however, are in the epidote-amphibolite to amphibolite facies.

Felsic intrusive rocks are probably of three different ages. The oldest is pink to grey granite, granodiorite, and equivalent gneisses which occupy north and northwestern Denton and Thornewe Townships. A pink porphyritic granite, with up to 3 cm long orthoclase crystals, underlies parts of southern Denton and Thornewe Townships. A pink coloured medium-grained granite intrudes the porphyritic granite.

Massive medium-grained rocks of granodiorite to quartz diorite composition intrude the supracrustal and granite contact in Keefer Township.

Aplite dikes and porphyries intrude both supracrustal and felsic intrusive rocks.

Roughly north-trending diabase dikes intrude all other rock units.

Structural Geology

Structural determinations suggest that folding in the supracrustal rocks has produced a series of roughly east-trending isoclinal folds with steeply dipping axial planes and easterly plunge directions. A younger north-trending synclinal fold axis is located on the east side of Mahoney Creek.

A number of shears and faults occur in the area. Three northwest-trending transverse faults cut the area, displacing fold axes and lithological units. A series of easterly-trending shears, carbonatized zones, and minor drag folds were located in the supracrustal rocks.

Economic Geology

Gold

Aumo Porcupine Mines Limited, outlined 45,000 tons of ore grading 0.22 ounce gold per ton in Denton Township. The gold, with minor silver and copper, occurs in: (a) northerly-trending shear zones, within granite that contains pyrite, carbonate and quartz veins. (b) easterly-trending shear zones containing pyrite, chalcopyrite, and minor quartz, (c) and sulphide-bearing graphite zones within felsic pyroclastic rocks.

2 Regional Geologists Files, Ministry of Natural Resources, Timmins.
PRECAMBRIAN — SUPERIOR PROVINCE

In 1972, economically interesting gold values were reported on Mahoney Creek by Meridian Mining and Exploration Company Limited. The average value varies from 0.18 to 0.39 ounce gold per ton over 1 to 1.5 m, for a length of approximately 180 m. The property is now owned by Gowest Gold Resources Limited. The gold occurs along with pyrite and arsenopyrite in metasediments intercalated with ultramafic metavolcanics.

In 1972, a sample of drill core from the Wakemac workings produced 0.7 ounce gold per ton over 0.85 m. The showing in which mineralization occurs strikes N70°E and has been traced over 300 m.

Gold-Zinc-Copper

Low values of gold, zinc, and copper are reported in massive to gneissic andesite by the Canadian Nickel Company Limited, north of Cripple Creek, and south of Aumo Porcupine Mines Limited claims.

Asbestos

The peridotite outcrops south of Tatachikapika River on Highway 144 contain up to 16 cm wide and 1 to 3 m long veins of picolite, an amphibole asbestos belonging to the tremolite-actinolite series. Fibres up to 40 cm long occur in these veins.

References

Harding, W.D., and Berry, L.G.

Rogers, W.R., and Bruce, E.L.

Todd, E.W.
Location and Access

The Parnes Lake map-area is bounded by Latitudes 49°50’ and 49°58’30”N and Longitudes 91°45’ and 92°00’W. It includes most of NTS Sheet 52 G/13 and covers an area of approximately 280 km². The town of Sioux Lookout is 16 km north of the centre of the map-area.

The northern part of the map-area is accessible mainly by water. At the present time, the southern and central parts of the area can be reached by float plane or canoe portaging, and by a gravel logging road (Basket Lake Road-Bark Road extension) which provides access to the southwest of the map-area to join Highway 17 in the south. Access to the central part can also be made along this extension, however, at present the Bark Road extension is under construction and is expected to be completed by the spring of 1982.

History of Mineral Exploration

A description of exploration activity dating back to the 1890s for gold, iron ore, and base metals has been given previously (Speed 1980).

Additional exploration activity in 1981 was carried out by Denison Mines Limited on gold prospects on Neepawa Island and areas to the northwest of the map-area. This program included trenching, geochemical rock sampling, and diamond drilling.

Sulpetro Minerals Limited (during 1980 and 1981; Resident Geologist’s Files, Ontario Ministry of Natural Resources, Sioux Lookout) conducted exploration in the Southeast Bay, Minnitaki Lake, and Twin Bays area.

General Geology

The Parnes Lake area forms part of the Wabigoon Belt (Trowell et al. 1980); it is underlain by metasediments and metavolcanics of Archean age which are in contact to the south with the Basket Lake Granodioritic Batholith.

Approximately half the map-area (Figure 1) is underlain by mafic, intermediate, and felsic metavolcanics, one quarter of the area consists of metasediments, and the remainder consists of granitoid rocks.

Rocks of the Wabigoon Belt in the map-area can be subdivided into three groups (Turner et al. 1973) as follows: Central Volcanic Group; Minnitaki Lake Group; and the Southern Volcanic Group.
Figure 1—Geological map of part of the Parnes Lake Area.
Central Volcanic Group
The Central Volcanic Group is composed of mafic and felsic volcanic rocks which are mainly autoclastic and pyroclastic fragmental rocks.

Minnitaki Lake Group
The Minnitaki Lake Group (Walker and Pettijohn 1971) consists mainly of greywacke and slate. Also, minor amounts of arkose and feldspathic quartzite (with very local conglomerate lenses) and chert and hematite-quartz-magnetite iron formation are present. This zone of chemical sedimentary rocks extends from the western part of the map-area through to the west shore of the Southeast Bay of Minnitaki Lake and lies near the contact with the Southern Volcanic Group.

Southern Volcanic Group
The Southern Volcanic Group is composed of massive mafic volcanic rocks with pillowed, amygdaloidal/vesicular and rarely, porphyritic flows. Intermediate to felsic tuffs and tuff-breccia occurs in the northeast part of Southeast Bay.

The southern part of the map-area is overlain by foliated biotite-granodiorite. A gabbro plug outcrops in the southwestern corner of the map-area.

Economic Geology
As reported by A.A. Speed (1980), and as observed by the author, the gold mineralization in the map-area and adjoining areas appears to be controlled by shear in the mafic rocks. Visible gold has been found on Neepawa Island, and this property is at present under evaluation by Denison Mines Limited. During the summer of 1981, trenching, channel sampling, geological mapping, and diamond drilling were done by or for this company on the Neepawa Island property.

Kelore Mines Limited (1951; Resident Geologist’s Files, Ontario Ministry of Natural Resources, Sioux Lookout) reported visible gold in a shear zone south of the Sykes Mine shaft on patented claim SV 105.

The area around Little Goose Lake, Twin Bay, and the Southeast Bay of Minnitaki Lake has the structural setting and quartz veining associated with gold mineralization in this area. Coltrin-Dole claims (1934; Resident Geologist’s Files, Ontario Ministry of Natural Resources, Sioux Lookout) reported a gold showing in the Southeast Bay area. A part of this area was evaluated over the fall of 1980 and summer of 1981 by Sulpetro Minerals Limited, who used geophysical and geological surveys to evaluate the area for potential gold and base-metal deposits.

The base-metal mineralization in the map-area occurs within thin massive pyrite and/or pyrrhotite and/or graphite layers with small pods of chalcopyrite and sphalerite. There are two iron properties within the map-area. No recent work has been reported on either properties; the last reported work was diamond drilling (1965; Resident Geologist’s Files, Ontario Ministry of Natural Resources, Sioux Lookout) on the property north of Little Goose Lake which was reported by F.J. Johnston (1969).

In the southwest part of the map-area, a gabbro intrusive was observed which contained sparse sulphide mineralization. Insufficient work has been done to fully evaluate the area. The contact with the granodiorite in the south is covered by thick glacial and lacustrine deposits.

Structural Geology
N.F. Trowell et al. (1980), F.J. Pettijohn (1936), R.G. Walker and F.G. Pettijohn (1971), Johnston (1972), and Page et al. (1977) have studied the structure of the map-area. These authors agree that the contacts of the different groups are faults trending in a northeast-southwest direction.

In the centre of Southeast Bay, there is a north-south fault which cuts the east-trending faults (Trowell et al. 1980).

Two cataclastic zones outcrop in the Little Goose Lake, Purity Lake, and Grassly River areas. These zones strike northeast to east and are interpreted as continuations of the Twinflower Lake Fault (Trowell et al. 1980).

Recommendations for Exploration
The untested geophysical conductors in Southeast Bay are considered to be good drill targets because of favourable geology, as recommended by Speed (1980) and from evidence supported by further field work.

The newly discovered porphyritic gabbro should be evaluated for copper-nickel potential.

Shear-hosted quartz veins within the Minnitaki Lake area are considered to have excellent gold potential, but are difficult targets because most of the shear zones are under water.

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No. 14 Pensyl Lake Area, District of Sudbury

G.M. Siragusa

Introduction

The Pensyl Lake Area is east of, and adjacent to the Jerome area mapped by the author in the summer of 1980 (Siragusa 1980). The northwest and southwest corners of the Pensyl Lake Area have Latitudes of 47°36' and 47°32'N, respectively, and lie on Longitudes 81°50'30"W; the northeast and southeast corners have Latitudes of 47°39' and 47°34'30"N, respectively, and lie on Longitude 81°30'W. The area includes northern parts of Benneweis and Champagne Townships and southern parts of St. Louis and Groves Townships for a total of about 180 km². Highway 144 gives access to the western margin of the area, and the Canadian National Railway line crosses the central part of the area a short distance from the eastern shore of Minisinakwa Lake. The town of Gogama is located on the north side of a deep and wide segment of Minisinakwa River, and is approximately 11 km by water from the centre of the map-area. A good bush road, which connects with Highway 144, gives access to the southern part of southern Benneweis Township, and to the Mollie River in the south-central part of the map-area. In addition, most of the lakes in eastern and central Groves and Champagne Townships are accessible by bush plane. Air service is available in Gogama.

Mineral Exploration

In 1922, gold was discovered near the railway bridge at Makwa, and in 1933 it was found also at another locality in Champagne Township near the northwest corner of what was then claim S 24 527 (Laird 1934). Since these early discoveries in the present map-area, and in nearby Chester Township (Siragusa 1980), the area has recurrently attracted exploration activity.

The current high price of gold has led to the staking and exploration of known gold occurrences and adjacent areas within the map-area. As of mid-July, 1981, claims staked in St. Louis, Groves, Champagne, and Benneweis Townships were 53, 236, 128, and 406, respectively.

1 Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.
General Geology

The map-area is underlain by a narrow belt of Archean metavolcanics and metasediments which trend generally east and dip vertically to steeply north or south. The northern section of the belt consists of a monotonous sequence of metabasalt in which primary features have been obliterated by greenschist facies rank metamorphism. This sequence has a minimum and maximum width of about 300 m and 900 m, respectively. The southern section of the belt consists of an accumulation of metasediments that varies in width from 550 to 1800 m, and widens to the east. At Minisinakwa Lake, in the very centre of the map-area, the belt is displaced by a major fault which post-dated the emplacement of late potassic granitic rocks. A north-trending segment of this fault is covered by the water of the narrow southern segment of Minisinakwa Lake. About 3700 m north of the southern tip of the lake, the trend of the fault changes to a northwesterly direction, and the fault itself lies slightly inland of the western shore of the lake. The rocks composing the eastern half of the belt have been displaced along this fault 1860 m north of the western half of the belt. To the west of the fault in southern St. Louis Township, the belt has an essentially westerly trend and extends beyond the western boundary of the present map-area (Siragusa 1980). East of the fault the belt trends east-northeast, and the metavolcanics on the north side of the belt extend to the western shore of the narrows of Groves Lake which is in the eastern part of Groves Township. Grooves Lake is also the locus of a fault trending north-northwest, though the effects of this fault on the belt are uncertain. Aside from the belt just mentioned, supracrustal rocks are locally present in many parts of the map-area as xenoliths of various sizes within the granitic rocks marginal to the belt. Large xenoliths occur in the Benneweis Lake area and the Tate-Piggott Lakes area.

With the exception of minor occurrences of magnetite-keriionite ironstone found at Pensyl Lake, the metasediments are epiclastic and include conglomerate and pebbly sandstone; the conglomeratic nature of these rocks may be difficult to recognize where deformation is intense. Variations in the depositional environment and source of the metasediments are evident along and across the strike of these rocks. For instance, some prominent outcrops of metaconglomerate on the south bank of Benneweis Creek consist of abundant and dominantly granitic boulders up to about 1 m in size embedded in a coarse-grained quartzofeldspathic matrix which contains accessory amounts of biotite and chlorite. Conglomerate found on the south side of Payette Island along strike and east of these outcrops, contains a few small granitic clasts embedded in a fine-grained matrix which is essentially chloritic. Dominantly sericitic schists are exposed at the following places: 137 m across strike from the chlorite-rich metaconglomerate on the north side Payette Island; on Gervais Island (600 m north of Payette Island), and at several localities on the eastern shore of Minisinakwa Lake east and north of Gervais Island. In some of these outcrops, and particularly at the westernmost tip of Gervais Island, the sericitic schists are seen to be sheared derivatives of a conglomerate consisting of small lenticular or ovoid clasts of greenish, tan, and reddish chert set within a matrix of thinly bedded mudstone. This rock, as well as the schist derived from it, are characterized by local reddish-brown stains or mottlings resulting from oxidation of minute disseminations of iron sulphides. Isolated schist outcroppings containing variable proportions of sericite and chlorite, were interpreted by the author to be sheared metasediments on the basis of the outcrops examined on the eastern shore of Minisinakwa Lake.

The granitic rocks include dominant potassic types, subordinate migmatitic rocks, and concordant intrusive sheets or dikes of local occurrence. The latter are commonly fine-grained or apatitic, and some of them are porphyritic due to the presence of rounded quartz crystals a few millimetres in size. Potassic rocks are largely massive, and occur as texturally homogeneous extensive intrusions in areas far from the belt, and as late intrusive phases in the magmatic rocks marginal to the belt. The migmatitic rocks are found at, or close to contacts of granitic and supracrustal rocks, and consist of variable proportions of; a) variably recrystallized and/or assimilated xenoliths of supracrustal rocks, and b) sodic granitic rocks. The migmatitic rocks are in many cases intruded by one or more phases of younger potassic rocks. These rocks commonly show a wide variety of textural and compositional features even within closely spaced areas of the same outcrop. In most cases, however, these rocks can be ascribed to either of two general types. The first type of migmatites are those in which the xenoliths of supracrustal rocks underwent relatively little recrystallization or assimilation, and therefore retain their identity and can be traced laterally over a significant distance. This type of migmatite predominates adjacent to the southern boundary of the belt, east of the Minisinakwa Lake Fault. The second type of migmatites are those in which formerly fine-grained mafic metavolcanics have been subjected to widespread recrystallization and/or assimilation. This second type is also characterized by the small amount of granitic rock present. These rocks are with few exceptions massive, are coarse-grained, and have a dioritic or gabbroic composition. These rocks are commonly heterogeneous in texture because of the uneven distribution of mafic components and variations in grain-size, but texturally homogeneous domains are locally present and resemble coarse diabase. This type of migmatite is predominant west of the Minisinakwa Lake Fault where it forms a large southwest-trending body extending from northeastern to central Benneweis Township. The presence of higher rank magmatic rocks west of the Minisinakwa Fault indicate that the west side has moved up relative to the east side.

Diabase dikes which trend dominantly north-northwest are widespread throughout the map-area, and cut all the previously mentioned rocks.
Economic Geology

Gold

With reference to the discovery of gold close to Kakwa (see section on Mineral Exploration) H.C. Laird (1934) stated: "A sparsely mineralized quartz vein, ranging from 2 to 4 feet in width, has been traced for 300 feet; it strikes N81°E and dips steeply to the south. The country rock is granite or granodiorite. A 5-foot test pit a few feet to the east on the strike of the vein shows a heavy gossan in a strongly jointed and fractured zone having a width of from 6 to 10 feet. The zone is heavily mineralized with fine sulphides, consisting of pyrrhotite, chalcopryite, and pyrite. Samples of the auriferous gossan from this showing are reported to have yielded high values in gold, and particles of native gold as large as wheat grains were obtained".

Both this occurrence and the 1933 gold discovery (see section on Mineral Exploration), are in the Moly-Mollie River area of west-central Champagne Township which is underlain by migmatitic granitic rocks in which the xenoliths of supracrustal rocks are generally traceable laterally over some distance. The site of the 1933 gold discovery is described by H.C. Laird (1934) as follows:

"...the main showing was the discovery vein near the northwest corner of claim S.24,567. It consists of two parallel quartz lenses separated by a horse of granodiorite, the strike being about N35°E, and the dip slightly west. The east lens is 2 feet wide, and the west one 3 feet wide; the total exposed length is about 30 feet. At the west end of the exposure the lenses meet and pinch out, and at the east end they are apparently terminated by a fault. The quartz is a rather white glassy variety containing pyrite, chalcopyrite, and visible specks of very pale yellow gold".

Presumably before 1933 gold was found on property 12 claims centered about Pensyl Lake (Groves Township) held by the Tasmijopen Mining Company Limited. With reference to this discovery, Laird (1934) stated: "The main showings occur at the east end of Pensyl lake in the northwest corner of claim S.24,319. On the lake shore stripping has exposed a rudely banded sugary or cherty quartz vein for a length of 25 feet and a width of 9 feet. It strikes N86°E and is in contact with greywacke on the north. Locally the quartz is strongly impregnated with very fine sulphides. A picked sample of the drill-core material from a depth of 20 feet is reported to have assayed 0.15 ounce gold and 0.15 ounce silver per ton.

Eight chains east of the above showing, a 6-foot test pit has been sunk in a band of cherty iron formation associated with highly contorted beds of greywacke. The iron formation strikes N85°E and dips steeply to the north. The band has been exposed for a length of 30 feet, and heavy gossan occurs over a width of 25 feet or more. The mineralized portion of the band is about 5 feet in width and consists of narrow layers of dark cherty material alternating with layers of sulphides. The sulphides consist of pyrite, pyrrhotite, chalcopryite, mispickel, and sphalerite in about the same order of decreasing abundance. Some of the magnetite present has been replaced by pyrrhotite, and this in turn has been partly replaced by chalcopyrite. Grab samples of the mispickel, which occurs rather sparsely in the bottom of the test pit, are reported by O.H. Smith to have yielded from 0.25 ounces gold per ton and notable quantities of silver. About 100 feet north of this point is a mineralized quartz vein in greywacke. It is one foot wide, strikes S81°E and dips 80°N. It has been opened up for a length of 40 feet, along parts of which there is a heavy ankerite and pyrite gossan. A grab sample taken by O.H. Smith is reported to have yielded 0.50 ounce gold and 2.5 ounces silver per ton".

Pensyl Lake is underlain dominantly by clastic metasediments which are part of the southern section of the belt (see section on General Geology).

West of the present map-area, gold has been found, thus far, essentially within the migmatitic granitic rocks bordering the epiclastic rocks of the southern section of the belt (Siragusa 1980). Within the present map-area, the Makwa-Mollie River area is also underlain by migmatitic granitic rocks. The Pensyl Lake gold occurrence, however, is well within the epiclastic section of the belt. Thus, gossan zones located within the migmatitic zone south of the belt, or within the epiclastic section of the belt, are good targets to prospect for gold. Two types of gossan occur in the metasediments of the map-area. One is associated with local occurrences of minor chert-magnetite ironstone, the other results from oxidation of widespread, but minute sulphides disseminations, or massive stringers in the epiclastic rocks and the schists derived from them.

Base Metals

Copper and nickel mineralization have been reported in diamond-drill logs (Assessment Files Research Office, Ontario Geological Survey, Toronto) from holes drilled in gabbroic and dioritic rocks in eastern Groves Township. A large body of these rocks underlies other parts of the map-area (see section on General Geology), and may be worth some consideration in relation to copper and nickel potential.

References

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Siragusa, G.M.
Introduction

The Batchawana Area (see location map) is currently being examined to integrate and summarize existing geological information. Additional mapping will be undertaken in areas that were previously unmapped and where discrepancies occur between existing maps. Geological maps at a scale of 1:50 000 and a computerized database of geological information will be produced. The database will be created to integrate and archive geological information from several sources, namely field data, thin section data, laboratory data, and mineral deposit data.

The Batchawana Area has previously been mapped by several people. Table 1 provides a summary list of reports and maps for the area.

The Batchawana Area is divided into three major geological domains:

i) Archean metavolcanic-metasedimentary supracrustal domain.
ii) Archean felsic plutonic, (including gneissic and migmatitic) domains.
iii) Keweenawan volcanic, sedimentary, felsite, and mafic intrusive domain.

The synoptic study will focus on the stratigraphy, chemistry, and structure of the Archean supracrustal assemblage, and the structure and tectonic framework of supracrustal-felsic plutonic boundaries. The types, and structures of the felsic plutonic rocks will also be examined. Though an extensive report on the Keweenawan volcanics in the Mamainse Point area has been done by R.N. Annells (1972), little attention has been paid in the past to the Keweenawan dike swarm in the Batchawana Area. The synoptic study will sample and attempt to determine the distinguishing features of these intrusions. A review of known mineral occurrences, deposits, and mines will be carried out to aid in future mineral assessment and mineral exploration of the area.
General Geology

The Archean metavolcanic-metasedimentary assemblage has been deformed, metamorphosed, and faulted, and has been intruded by felsic plutonic rocks. The area was at least partly covered by sedimentary rocks of the Huronian Supergroup. The western part of the Batchawana Area is underlain by mafic metavolcanic flows with interflow metasediments, and is intruded by felsic dikes and bodies of Keweenawan age. The Archean supracrustal rocks have been metamorphosed generally to low to middle amphibolite rank near the felsic plutonic boundaries, and commonly to middle to upper greenschist rank throughout the central part of the belt.

The Archean metavolcanic-metasedimentary rocks form an east-trending belt as seen in Figure 1. The west (Mamainse Lake) and northeast parts (Cowie River) of the belt are composed predominantly of pillowed mafic metavolcanic flows with minor amounts of interflow metasediments. Both areas contain banded magnetite-chert ironstone near the base of the sequence which may serve as a marker horizon throughout the supracrustal assemblage. The east (Dismal Lake) and southeast (Cowie Lake) parts of the belt are composed of a lower mafic metavolcanic sequence, capped by magnetite-chert ironstone, and overlain by intermediate to felsic metavolcanics intercalated with mafic metavolcanics. The southeast part (Cowie Lake) of the belt is overturned and isoclinally dips to the north. The central part of the map-area (Wart, Mongoose Lakes) is composed mainly of metasediments. Bedding appears to be irregular and the structure of the area is unclear at this time. Textural and structural features of the metavolcanics in the west and northeast parts of the belt indicate that these rocks were deposited in a submarine environment. Tuff-breccias were deposited in the area just west of Cowie Lake and were most likely formed proximal to a volcanic centre. Northward, along strike, fine-grained metasediments and tuffs are likely to be the distal equivalents of these coarse breccias.

The felsic plutonic rocks occur as massive to foliated intrusions and migmatitic to gneissic rocks.

### TABLE 1 GEOLOGICAL REPORTS AND MAPS OF THE BATCHAWANA AREA.

<table>
<thead>
<tr>
<th>YEAR</th>
<th>AUTHOR</th>
<th>AREA</th>
<th>PUBLISHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>1925</td>
<td>E.S. Moore.</td>
<td>East Part of Batchawana Belt.</td>
<td>ODM Vol 34 Pt.4.</td>
</tr>
<tr>
<td>1926</td>
<td>E.S. Moore.</td>
<td>West Part of Batchawana Belt.</td>
<td>ODM Vol 35 Pt.2.</td>
</tr>
<tr>
<td>1936</td>
<td>N.B. Keevil.</td>
<td>Northeast Part of Batchawana Belt.</td>
<td>GSC Map 366A.</td>
</tr>
</tbody>
</table>

Abbreviations
- ODM — Ontario Department of Mines.
- P — Preliminary Map.
- OFR — Open File Report.
Figure 1—Regional Geology of the Batchawana Area.
quartz monzonite and granodiorite stocks occur in the Grey Owl Lake Area. Larger plutons of trondhjemite, granodiorite, and tonalite surround the supracrustal rocks to the north and east. These plutonic domains are commonly foliated and have varying amounts of assimilated supracrustal rocks. An extensive zone of migmatite occurs at the southeast part of the belt and extends eastward. Isolated xenoliths of banded chert and magnetite ironstone occur in several places within the migmatitic domain. More detailed mapping within the felsic plutonic and migmatitic domains will help to outline the migmatite zones of individual plutons, and large scale regional domains that exist in the felsic plutonic rocks as shown by K.D. Card (1979), and G.F.D. McCrank et al. (1981).

West of Cowie Lake, a small outlier of conglomerate and arkose that appears to have been faulted into place was assigned to the Gowganda Formation of the Huronian Supergroup (Grunsky and Arenyi 1978). A conglomerate in a granitic rock crevice along the north bank of the Montreal River reported by B.C. Wilson (1980) has been tentatively assigned to the Huronian Supergroup.

The Batchawana Area has been intruded by a diabase dike swarm that strikes most commonly northwest and less commonly northeast. Little information exists about this dike swarm.

As Card et al. (1981) pointed out, the orientation of dikes in this area is not always a reliable criterion to use for age classification. The dominant diabase type has a tholeiitic composition. Olivine diabase has been noted (Grunsky 1980; Wilson 1980; and Siragusa 1981), but is not common in the Batchawana Area. Many of the dikes are probably Keweenawan in age, and may have been feeders to the Keweenawan volcanics.

The Keweenawan volcanic rocks occur in the Mainse Point and Alona Bay areas. These rocks have been described in detail by J.E. Thomson (1953) and R.N. Annells (1972).

**Structural Geology**

The overall structure of the Batchawana Belt is synclinal with a northeast-trending axis extending from the Mainse Lake area to the Cow River. The southeastern part of the belt is a large overturned isoclinal sequence (Figure 1). Two large faults, the Montreal River Fault, and the Goulais River Fault intersect the area. Both faults strike northeasterly and may be part of a fracture system related to the Kapuskasing Subprovince zone. The Montreal River Fault separates the Batchawana supracrustal rocks from the felsic plutonic-gneissic-migmatite domain of the Kapuskasing zone (Card 1979). Little horizontal displacement is indicated by either fault, nor is the amount of vertical displacement known. A significant north-northwesterly trending fault with considerable horizontal displacement cuts across the Grey Owl Lake Stock. Other north-northwest trending faults have probably been obscured by the dike swarm which occurs parallel to these features.

The rocks of the southeast part of the belt were isoclinally folded and overturned, possibly due to the action of diapirism from intruding plutons to the east and northeast.

**Economic Geology**

The Batchawana Area has had two significant copper producers, the Tribag and Coppercorp Mines, both post-Keweenawan deposits. Known base and precious metal deposits and occurrences within the Archean supracrustal assemblages are small and currently subeconomic. One exception to this is the Goulais River Iron Range, east of Cowie Lake. The current reserves of iron are 30 480 000 tonnes (Canadian Mines Handbook 1975-76); however, the presence of numerous diabase dikes intruding the iron range makes it subeconomic at this time. No major base or precious metal exploration program has been done in the Archean supracrustal rocks since 1976.

The Coppercorp Mine is situated within a quartz-carbonate fissure-vein deposit containing chalcocite-bornite, chalcopyrite, specularite, and some native copper. The ore zone consists of mineralized fractures and shears within the Keweenawan basaltic flows. Four main zones have been delineated, the "C" zone and the Silver Creek zones being mined by Coppercorp Limited. The mine opened in October 1965 and closed in November 1972. A shaft 168 m deep with three levels was put down during production. The mine milled 1 294 247 tons of ore grading approximately 2.1 percent copper (Canadian Mines Handbook, 1981).

The Tribag Mine is a post-Keweenawan copper-lead-zinc deposit that occurs within a breccia pipe (Breton Pipe) composed of vuggy quartz and carbonate that contains Archean metavolcanic and granitic rock fragments. The chief minerals are chalcopyrite and pyrite, with minor galena, sphalerite, chalcolite, and scheelite.

Smaller breccia pipes, known as the east and west breccias, are located east and west of the Tribag Mine. The main central Breton breccia pipe produced 37 257 993 pounds of copper and 246 054 ounces of silver. Production started in May 1967 and finished in July 1974. Ore reserve estimates of the mine indicated 40 000 000 tons of 0.2 percent copper. Extensive exploration has been carried out in both the east and west breccia zones by the D.K. Syndicate (Dekalb Mining Corporation) during the past two years. A decline into the west breccia to allow for bulk sampling for tungsten (scheellite) has been done by the D.K. Syndicate. The results are currently not available. Additional percussion drilling into the east breccia zone has also been carried out with no results currently available. The Tribag Mine has been classified as a porphyry type deposit by W.N. Pearson (1979) and the smaller Jogràn Deposit has been grouped within this category by G.A. Armbrurst (1980).

Several anomalous radioactive zones occur in the felsic plutonic rocks north of the Montreal River and in
areas south of the greenstone belt. Uranium is known to occur in sub-economic deposits in the Montreal River area (Nuffield 1955).

In the area west of Cowie Lake and northwestward to Wart Lake, the favourable features of felsic pyroclastic metavolcanics and mafic metavolcanic contacts in an area of proximal volcanic rocks should warrant further base-metal exploration in the area. Neither the Tribag nor the Coppercorp Mines have exhausted their ore supplies. Reassessment of reserves and favourable market conditions could make these mines operable in the future.

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Thomson, J.E.

Wilson, B.C.
No. 16 An Algorithm for the Classification of Subalkalic Volcanic Rocks Using the Jensen Cation Plot

E.C. Grunsky

Introduction

The Jensen Cation Plot enables classification of subalkalic volcanic rocks into komatiitic, tholeiitic, and calc-alkaline chemical affinities. Linear and non-linear equations together with a classification algorithm have been developed by the author. The algorithm and equations will enable users of the Jensen Cation Plot to apply the classification in a computer program.

The Jensen Cation Plot was developed by L.S. Jensen (1976) to classify a variety of subalkalic volcanic rock types from the Abitibi Greenstone Belt in Ontario. The classification is based upon the relative abundance of aluminum, iron (ferric and ferrous), manganese, titanium, and magnesium cations and has many advantages over other types of classification schemes of volcanic rock as discussed by Jensen (1976). Volcanic rock types can be assigned names from their position on the plot (Figure 1) and the plot enables the user to determine whether the rocks are of komatiitic, tholeiitic, or calc-alkaline chemical affinity. The tholeiitic and calc-alkaline fields can be subdivided into basalt, andesite, dacite, and rhyolite on the basis of aluminum content.

The classification boundary curves are numbered and shown in Figure 2. The linear curves (1, 2, 4, 6, 7) were determined by using a method of least squares linear regression and the higher order curves were deter-

![Jensen Cation Plot](image-url)

Figure 1—An Algorithm for the Classification of Subalkaline Volcanic Rocks using the Jensen Cation Plot.
ALGORITHM

For each chemical analysis:

1) Determine the cation percentages (volatile free).

2) Set $FeO = FeO + MnO$

3) Assign the following variables:

   $\text{Sum} = AIO_{1\frac{1}{2}} + FeO + FeO_{1\frac{1}{2}} + TiO_2 + MgO$

   $Al = (AIO_{1\frac{1}{2}} / \text{Sum}) \times 100.0$

   $Fe = ((FeO + FeO_{1\frac{1}{2}} + TiO_2) / \text{Sum}) \times 100.0$

   $Mg = (MgO / \text{Sum}) \times 100.0$

4) $Y = 50.0 - 0.5 \times Fe$ [Curve 1]

   IF (Mg $\leq Y$) Then go to Step 5

   IF (Mg $> Y$) Then the rock is KOMATIITIC

     IF (Mg $> 60$) Then the rock is an ULTRAMAFIC KOMATIITE

     IF (Mg $\leq 60$) Then the rock is a BASALTIC KOMATIITE

   Classification Complete

5) IF (Al $< 54.43$) Then go to Step 6

   IF (Al $\geq 54.43$)

     $Y = 10.0 + 1.05882 \times Mg$ [Curve 2]

     IF (Fe $\leq Y$) Then the rock is CALC-ALKALINE — Go to Step 11

     IF (Fe $> Y$) Then the rock is THOLEIITIC — Go to Step 12
6) IF \( (Fe < 13.80) \) Then the rock is an ABNORMAL BASALT

\[
y = 3.2734755 \times 10^{-5} \cdot Mg^5 - 4.5791246 \times 10^{-3} \cdot Mg^4 + 2.5506266 \times 10^{-1} \cdot Mg^3 \\
-7.0820015 \cdot Mg^2 + 9.7119349 \times 10^1 \cdot Mg - 493.47897 \ [\text{Curve 3}]
\]

IF \( (Fe \leq Y) \) Then the rock is a CALC-ALKALINE BASALT

Classification Complete

IF \( (Fe > Y) \) Then the rock is THOLEIITIC – Go to Step 7

7) \( Y = -10.1 + 1.0556 \cdot Mg \ [\text{Curve 7}] \)

IF \( (Fe \leq Y) \) Then the rock is a HIGH MAGNESIUM THOLEIITIC BASALT

Classification Complete

IF \( (Fe > Y) \) Go to Step 8

8) \( Y = 7.8889 + 1.0556 \cdot Mg \ [\text{Curve 6}] \)

IF \( (Fe \leq Y) \) Then the rock is a THOLEIITIC BASALT

Classification Complete

IF \( (Fe > Y) \) Go to Step 9
PRECAMBRIAN — SUPERIOR PROVINCE

ALGORITHM - continued

9) IF (Mg>15) Go to Step 10
   IF (Mg<=15)
      \[ Y = 50.0 - 1.0 \times Mg \text{ [Curve 4]} \]
      IF (Fe<=Y) Then the rock is a THOLEIITIC ANDESITE
         Classification Complete
      IF (Fe>Y) Then the rock is a HIGH IRON THOLEIITIC BASALT
         Classification Complete

10) \[ Y = -0.06 \times Mg^2 + 0.84 \times Mg + 35.9 \text{ [Curve 5]} \]
   IF (Fe<=Y) Then the rock is a THOLEIITIC ANDESITE
      Classification Complete
   IF (Fe>=Y) Then the rock is a HIGH IRON THOLEIITIC BASALT
      Classification Complete

11) CALC-ALKALINE ROCK TYPES
   IF (Al>80) Then the rock is a RHYOLITE
   IF (Al<=80 and Al>70) Then the rock is a DACITE
   IF (Al<=70 and Al>60) Then the rock is an ANDESITE
   IF (Al<=60 and Fe>13.8) Then the rock is a BASALT
   IF (Al<=60 and Fe<13.8) Then the rock is an ABNORMAL BASALT
      Classification Complete

12) THOLEIITIC ROCK TYPES
   IF (Al>70) Then the rock is a RHYOLITE
   IF (Al<=70 and Al>60) Then the rock is a DACITE
   IF (Al<=60) Then the rock is an ANDESITE
      Classification Complete
mined using the Lagrange interpolation polynomial method of regression over critical points occurring on the curves.

A modification made by Jensen (personal communication, 1980) allows for the distinction between high-iron tholeiitic basalts and high-magnesium tholeiitic basalts. The area between curves 6 and 7 represents tholeiitic basalts that are neither iron nor magnesium enriched.

This note provides the necessary equations required to computerize the classification of the rock types on the Jensen Cation Plot. The algorithm is presented in Table 1. This algorithm was developed for use as a subroutine for large mainframe computers and microcomputers. Copies of a FORTRAN IV subroutine listing for a mainframe computer and a BASIC listing for a microcomputer can be obtained from the author on request.

References

Jensen, L.S.
No. 17 Kawashegamuk Lake Area, District of Kenora

C.E. Blackburn¹ and D.U. Kresz²

Location

Kawashegamuk Lake lies about 30 km southeast of Dryden (see location map). The map-area is bounded by Latitudes 49°22'30" and 49°33'N, and Longitudes 92°15' and 92°30'W, and covers 300 km².

A lumber road commences from Highway 17 at Jackfish Lake, 10 km east of Dinorwic. This road gives access to the western part of the map-area and to Stormy Lake. A township road that commences at Borup's Corner on Highway 17, gives access to the eastern part of the map-area, and to Kawashegamuk Lake. A third road in the north central part of the map-area links these two roads.

Mineral Exploration

The Kawashegamuk Lake area was the scene of gold prospecting and mining activity during the period 1890 to 1912, and again in the 1930s (Thomson 1933). The only deposit to attain significant production in the eastern area was the Sakoose Mine, which produced 3,669 ounces gold and 145 ounces silver (Beard and Garratt 1976). The Tabor Lake prospect reportedly produced 36 ounces gold and 4 ounces silver in 1935 (Beard and Garratt 1976).

The Canadian Nickel Company Limited and Falconbridge Nickel Mines Limited conducted geophysical surveys and diamond-drilling programmes in the map-area, the former company in 1952 on a gabbro-diorite body on the northeast shore of Kawashegamuk Lake, and the latter company in 1957 at Church Lake, and near the gabbro-diorite body previously investigated by the Canadian Nickel Company Limited (Assessment Files Research Office, Ontario Geological Survey, Toronto).

In 1965 and 1966, Dome Exploration (Canada) Limited carried out geochemical soil sampling, trenching, and 1,710 feet of diamond drilling on a molybdenite prospect between Mennin and Oldberg Lakes (Assessment Files Research Office, Ontario Geological Survey, Toronto).

Following discovery of the Cu-Zn-Ag deposits at Sturgeon Lake in 1969, a number of companies flew airborne geophysical surveys over the general Manitou-Stormy Lakes area. Two parts of the map-area received considerable ground follow up. Northeast of the east end

¹Resident Geologist, Ontario Ministry of Natural Resources, Kenora.
²Graduate Student, Brock University, St. Catharines, Ontario.
0 2 km

C.E. BLACKBURN AND D.U. KRESZ

LEGEND

1 Mafic metavolcanics
2 Intermediate and felsic metavolcanics
3 Polymictic conglomerate
4 Volcanic clast conglomerate — intermediate composition.
4a Felsic composition
5 Sandstones and mudstones
6 Gabbros (6a Diorite)
7 Felsic hypabyssal rocks
8 Granitoid rocks

PROPERTIES

(1) Sakoose Mine, Av
(2) Tabor Lake prospect, Av
(3) Oldberg Lake occurrence, Mo

SYMBOLS

Selected pillows to illustrate structure
Bedding, top indicated by arrow
Area of Pervasive carbonization and silification.
Roads

Figure 1—Geology of the Kawashegamuk Lake Area.
of Boyer Lake, Asarco Exploration Company of Canada Limited (during 1970 and 1971), Newmont Mining Corporation of Canada Limited (in 1975), and Selco Mining Corporation Limited (in 1976), reported a total of four diamond-drill holes (Assessment Files Research Office, Ontario Geological Survey, Toronto). In the north central part of the map-area, between Church Lake and the south boundary of Melgund Township, Lynx Exploration Limited-Dejour Mines Limited (in 1970), Newmont Mining Corporation of Canada Limited (in 1974), Hudson Bay Exploration and Development Company Limited (about 1974), and Selco Mining Corporation Limited (during 1977 and 1978) are known to have drilled a total of nine diamond-drill holes (Assessment Files Research Office, Ontario Geological Survey, Toronto).

The Kawashegamuk Lake area has undergone a further round of exploration, following release of an airborne electromagnetic survey in the spring of 1980 (Ontario Geological Survey 1980).

During the winter of 1979 and 1980, Sulpetro Minerals Limited (formerly St. Joseph Exploration Limited) conducted ground geophysical surveys and diamond drilled four holes on the gold property at Tabor Lake, and did geological mapping and geochemical sampling for gold mineralization during the 1980 field season. Work continued in 1981 with dewatering of the shaft for sampling.

In 1980, as follow-up to a regional exploration programme in the general Kawashegamuk Lake area commenced in 1979, Falconbridge Nickel Mines Limited carried out a detailed geochemical sampling programme for gold mineralization on property adjoining St. Joseph Exploration Limited west of Tabor Lake. No further field work has been done to date.

Stripping and trenching has been done at the former Sakoose Mine by J. Redden intermittently over the last few years.

Sulpetro Minerals Limited, in addition to work on its Tabor Lake property, has conducted ground follow-up to both its own and Ontario Geological Survey airborne electromagnetic surveys in the general Manitou-Stormy Lakes area.

Other companies have been active in the map-area during the 1981 field season in response to the Ontario Geological Survey airborne electromagnetic survey.

General Geology

The Kawashegamuk Lake area was mapped as part of a reconnaissance survey extending from Lower Manitou to Stormy Lake by J.E. Thomson (1933). The present map-area was also investigated, as part of a regional study (Trowell et al. 1977; Trowell et al. 1980), and resulting modifications to Thomson's interpretation are included in the current Kenora-Fort Frances compilation map (Blackburn et al. 1981). The present survey is part of a programme of 1 inch to ¼ mile mapping of the Manitou-Stormy Lake belt (Blackburn 1976, 1979a, 1979b), and also adjoins on its north side detailed mapping by J. Satterly (1960).

Mapping west of the current map-area (Blackburn 1980a) has established three stratigraphic groups of supracrustal rocks: the Wapageisi Lake Group, the Stormy Lake Group, and the Boyer Lake Group, that have been traced into this area.

The Wapageisi Lake Group of tholeiitic affinity, underlies the Stormy Lake Group, and faces homoclinal north-northeast. Within the map-area, it consists of pillowed mafic flows, intruded by gabbroic sills, and an overlying sequence of intermediate and felsic pyroclastic rocks. A sub-volcanic felsic porphyry which intrudes this latter sequence is the source of felsic flows at Gawaiwa Lake. Numerous felsic dikes intrude the Wapageisi Lake Group.

The unconformably overlying Stormy Lake Group faces predominantly north. In the west, its basal part is characteristically a polymictic conglomerate with felsic to mafic volcanic clasts, granitoid clasts, and clasts of mafic and granitoid ironstone, and chert. Overlying volcanic clast conglomerates are mostly devoid of granitoid and chemical sedimentary clasts. These rocks represent shallow subaqueous slumping as indicated by intercalated minor highly amygdaloidal pillowed flows.

The Stormy Lake Group consists of sandstones and siltstones of turbidite facies east of Stormy Lake probably transitional from the conglomeratic facies to the west, and is transitional eastward into more distal turbidites at Bending Lake with abundant intercalated magnetite ironstone beds (Trowell et al. 1980).

The tholeiitic Boyer Lake Group is younger with respect to the Wapageisi Lake Group. The group is folded about the Kamanatogama Syncline and is composed of a thick sequence of pillowed mafic volcanic rocks, intruded by gabbroic sills. The Stormy Lake Group is (Blackburn 1979b, 1980a, 1980b) in fault contact with the Boyer Lake Group. It is likely that faulting occurred along an unconformity.

A sequence of calc-alkaline metavolcanics northeast of Kawashegamuk Lake, the Kawashegamuk Lake Group, faces homoclinal southwest. Its contact with the overlying Boyer Lake Group is conformable, and marked by transition from calc-alkaline to tholeiitic volcanism. Basal mafic metavolcanics in the northeast are intruded by granitic rocks of the Revell Batholith (Satterly 1960). Overlying felsic pyroclastics vary from coarse, monolithic breccias in the north, to tuffs in the southeast with interbeds of minor clastic and chemical sedimentary rocks.

Overlying the felsic pyroclastic sequence are andesitic pillowed flows. At Kawashegamuk Lake, along the northeastern shore, these rocks are interbedded with coarse intermediate pyroclastics that become increasingly abundant toward the southeast. The top of the Kawashegamuk Lake Group is defined by a narrow unit composed of felsic to intermediate tuff, that follows the southwest shore of the lake, and widens in the northwest corner of the map-area.
Structural Geology

The east-trending Kamanatogama Syncline is the only major fold in the map-area.

The Mosher Bay-Washeibemaga Lake Fault (Blackburn 1979b, 1980a, 1980b), that defines the contact between the Stormy Lake and Boyer Lake Groups appears to be a hinge fault, that diminishes in displacement eastward, and cannot be recognized east of the northern bay of Stormy Lake.

Economic Geology

Gold

The present mapping has shown that in the vicinity and west of Tabor Lake, mafic and felsic volcanics have been pervasively carbonatized and silicified. The authors of this report suggest hydrothermal alteration associated with felsic porphyry has leached gold, and possibly silver, copper, zinc, and lead, from metavolcanics over a broad area. Prospecting and exploration should therefore be directed toward favourable structural traps (shear zones, faults) and associated porphyry.

Copper-Nickel

The present survey has delineated at least three gabbro-diorite bodies intruding the Kawashegamuk Lake Group that have been exploration targets in the 1950s for Canadian Nickel Company Limited and Falconbridge Nickel Mines Limited, and more recently by Selco Mining Corporation Limited. Copper and nickel have been described in a report for the Canadian Pacific Railway Company (Assessment Files Research Office, Ontario Geological Survey, Toronto) in the diorite body on the northeastern shore of Kawashegamuk Lake. Further prospecting and exploration is warranted in these mafic intrusions, and also in gabbros that intrude the Boyer Lake Group.

Molybdenum

Investigation by Dome Exploration (Canada) Limited of a molybdenite occurrence southwest of Mennin Lake indicated ppm values of molybdenum in soil samples over a wide area of well-exposed granodiorite at the edge of the Revell Batholith. The source of molybdenum at the metavolcanic-granite contacts warrants investigation, as does the rest of the contact zone of the batholith.

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Trowell, N.F., Blackburn, C.E., and Edwards, G.R.
No. S1 Dalhousie Lake Area, Frontenac and Lanark Counties

Liba Pauk

THE WORK REPORTED HERE IS PART OF THE SOUTHERN ONTARIO GEOLOGICAL SURVEY (SOGS) PROGRAM WHICH IS JOINTLY FUNDED BY THE ONTARIO MINISTRY OF NATURAL RESOURCES AND THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION UNDER THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

Introduction

The Dalhousie Lake area is located about 19 km west of the town of Perth and includes parts of Dalhousie, Palmerston, North Sherbrooke, Oso, and Bathurst Townships. The area covers about 250 km², and is bounded by Longitudes 76°30'W and 76°45'W, and by Latitudes 44°52'30"N and 45°00'N. The map-area is accessible by Hwy 509 from the southwest and by Lanark County Road 12 from the east. A large number of township, concession, and cottage roads provide good access to all parts of the map-area. The Mississippi River, which traverses the map-area from west to east, is navigable across the map-area. A large part of the map-area was mapped at a scale of 1:63 360 by B.L. Smith (1958).

Mineral Exploration

Mineral exploration within the map-area dates back to 1880s and is closely related to the construction of the Kingston and Pembroke railway. The Mississippi (Robertsville) Mine is one of many iron ore deposits which have been discovered along this railway route.

In the late 1940s and mid 1950s, there was exploration for base metals. A talc-tremolite deposit located 3.5 km west of the village of Robertsville is being quarried by Ram Petroleums Limited; exploration of this deposit dates back to the late 1930s.

Since the early 1960s, the exploration activity in the map-area has centred on the uranium-bearing pegmatites in the west and southwest part of the map-area. About 10 km² of the ground were covered by airborne radiometric survey, and about 103 diamond-drill holes totalling 5625 m in length were sunk in the most prospective areas. The most recent exploration in this area was conducted in 1980s by AJM Exploration Limited and by Groundstar Resources Limited (Assessment Files Research Office, Ontario Geological Survey, Toronto).

General Geology

The Dalhousie Lake area lies within segments IVb and IVc, that is the Hastings Basin, and Frontenac Axes of the Central Metasedimentary Belt of the Grenville Province (Wynne-Edwards 1972). The bedrock of the map-area consists of Late Precambrian supracrustal rocks, carbonate rocks and metavolcanics, and a variety of syntectonic to late tectonic mafic to felsic intrusives.

The supracrustal rocks are exposed in three main northeasterly-trending belts. The carbonates are dominant in the southeastern belt; carbonates intercalated with metavolcanics and minor clastic metasediments are...
dominant in the central and the northwestern belt. The metavolcanics are represented by hornblende plagioclase + biotite gneisses, and the range of their colour indices suggests that they are of the mafic to intermediate affinities. The central belt of supracrustal rocks contains only narrow, discontinuous layers of metavolcanics. Their composition is difficult to detect, since they are strongly mylonitized and altered.

The clastic metasediments are represented by biotite quartz plagioclase gneiss and by rusty pyrite-bearing metasediments in the northwestern belt, by minor wacke and calcareous mudstone in the central belt, and by narrow layers of biotite hornblende schist in the southeastern predominantly carbonate belt.

An early stage of plutonism in the map-area is represented by the Cross Lake Pluton, which is composed of gneisses of granodioritic-trondhjemitic compositions. Only a small part of this large, northeasterly-trending body extends into the western part of the map-area. The Addington Complex (Lavant gneiss in the report by Smith 1958), comprising gneisses of predominantly granite, quartz monzonite, and granodiorite compositions, extends in a 3 km wide belt from the southwest corner of the map-area to the north-central part of the map-area.

In contrast to the Cross Lake gneiss, the gneisses of the Addington Complex are strongly foliated and are stratified, consisting of alternating layers of differing compositions and textures. The Addington Complex encloses some continuous conformable layers of supracrustal rocks. The textural and compositional characteristics and the field relations suggest that the Addington Complex is the result of the metasomatism of pre-existing lithologies.

The central part of the map-area is occupied by the Lavant Gabbro Complex. Although most of the rocks are massive, the body itself stretches northeasterly, subparallel to the regional trend.

The Lavant Gabbro Complex is extremely inhomogeneous in both composition (the rocks range from gabbro, diorite to granodiorite) and texture (fine, medium, coarse to very coarse grained).

Invariably, patches of several textural and compositional varieties, showing non-gradational contacts, are found within one outcrop area. Some of the fine-grained, foliated phases in the Lavant gabbro may represent roof pendants. The compositional and textural characteristics suggest that several subsequent intrusive stages are responsible for the heterogeneity of this complex.

The late stage felsic intrusion in the map-area is considered to be the Elphin-type "granite" (Smith 1958) which intrudes the Lavant Gabbro Complex in the vicinity of the village of Elphin. The Elphin-type "granite" is represented by unfoliated to poorly foliated medium-grained leucocratic pink biotite granite, quartz monzonite, and syenite. A large number of hybrid rock types and inclusions of the Lavant gabbro are incorporated within this intrusion. A lens-shaped body, texturally and compositionally similar to the Elphin-type "granite" intruded the supracrustal rocks and the ultramafic to intermediate intrusive rocks in the southeast part of the map-area. In the southwest, southeast, and the northeast, the granite body is fringed by a sequence of mafic gneisses, schists, and amphibolites with pyroxenites. These in part may be mafic metavolcanics, but most are metamorphosed ultramafic to intermediate intrusive rocks.

A narrow unit, comprising coarse-grained coarsebly banded gneisses of a variable mineral composition (for example pyroxene-hornblende-plagioclase quartz; quartz-potassic feldspar-plagioclase-biotite; quartz-plagioclase-muscovite ± biotite) outcrops in the southwest corner of the map-area. Its strike contact with the neighbouring lithologies (Cross Lake Pluton, metavolcanics, carbonate metasediments) is conformable, however, along its northern contact, this unit cuts abruptly across the strike of the neighboring lithologies. Detailed examination of the outcrop area revealed the conglomeratic nature of these gneisses. A large number of pegmatite dykes intruding this unit limits the surface exposure of the unit. This band of gneisses was traced southeasterly in the direction of decreasing metamorphic grade (outside of the map-area) where the conglomeratic texture of these rocks is better preserved. The author of this report correlates these rocks, which incidentally lie on the strike extension of the Flinton Synclinorium, with the Bishop Corners Formation of the Flinton Group.

Small late stage felsic intrusions are represented by granite and granodiorite pegmatite dykes and sills that cut the older lithologies throughout the map-area.

The mineral assemblages in the supracrustal rocks indicate, that the rocks in the area have been metamorphosed to middle to upper almandine amphibolite facies rank.

**Structural Geology**

The structural pattern of the map-area is dominated by the northeasterly-trending zones of supracrustal rocks. Their general strike trend is N200° to N400° with shallow to moderate dips (20° to 40°) predominantly to the south. The supracrustal rocks were isoclinally folded and their foliation is essentially parallel to the bedding planes. Shallow, east-north-easterly plunges, as indicated by the quartz, hornblende roddings, and by the minor fold axes, are dominant in the map-area. In the southeast corner of the map-area the older lithologies (carbonate metasediments and amphibolites) are warped by the late stage felsic intrusions. The northwest corner of the map-area contains the closure of the D2 Cross Lake Antiform. The Addington Complex hosted talc-tremolite deposit lies in a northeast-plunging synclinal structure defined by the outcrop pattern of talc-tremolite and the enveloping supracrustal rocks.

Several more or less subparallel approximately east-trending linear depressions cut across the southwest and central-west part of the map-area. One of these lineaments was interpreted as a possible branch of the Plevna Fault (Smith 1958). Present mapping documented the ex-
istence of a system of subparallel approximately east-trending faults in this area.

A major northeast shear zone transects the map-area. The shear zone contains mylonitized metavolcanics, carbonate metasediments, gneisses of the Addington Complex, and Lavant gabbro rocks. The shear zone strikes N150°E and dips 30° to 60°E. It is a normal dip-slip fault. The late stage mafic and felsic intrusions occurring east of the shear zone are the Lavant Gabbro Complex and the Elphin-type "granite". Even these intrusions, which on a small scale are practically structureless, show the regional northeast-trending structural control.

The joints most easily observable in the intrusive rocks trend northwest (N40°W to N50°W) with essentially vertical dips. Second, less prominent system of joints strikes N90°E and dips vertically.

**Economic Geology**

**Base Metals**

The major base-metal showing in the map-area occurs in a system of northeast-striking (N300°E) subparallel quartz veins hosted by the Lavant Gabbro Complex. The thickness of the quartz veins ranges from 12 to 35 cm. The longest, along strike continuous exposure exposed by trenching was 115 m long (Assessment Files Research Office, Ontario Geological Survey, Toronto). The samples examined by the field party in the ore dump contained up to 20 percent of sulphide minerals (pyrite and subordinate chalcopyrite) in a patchy accumulation. This showing is located 800 m southeast of the village of Robertsville.

The shear zone, mainly in the vicinity of the village of Robertsville, contains pyrite mineralization. Pyrite occurs in veinlets, patches, stringers, and as irregular disseminations. No analytical data on presence of other base metals from the shear zone showings are as yet available.

Field party personnel located a small pit 750 m southwest of Otter Lake, containing lenses of calcite-hematite-pyroxene with minor disseminations of chalcopyrite. This showing is hosted by the Addington Complex and occurs near the contact of the Addington Complex and marble.

**Magnetite**

Old reports on the production and exploration of the Mississippi Mine indicate good quality iron ore and the extension of the ore body to depth (Report of the Royal Commission on the Mineral Resources of Ontario 1890).

**Uranium Mineralization**

A large number of pegmatite dykes and sills intrudes most of the lithological units in the map-area. Although many pegmatites yield background radioactivity, the most promising pegmatites are those concentrated in the Cross Lake Pluton, the Addington Complex, and the metavolcanics and metasediments in the southwest and central west part of the map-area. The correlation of highly anomalous uranium zones (Ford and Charbonneau 1979) shows that they coincide with zones of metavolcanics and metasediments in this area.

**Non-Metallic Deposits**

A talc-tremolite deposit is presently being worked by open pit 3.5 km west of the village of Robertsville. Good purity calcitic marble occurs in the southeast corner of the map-area.

**References**


No. S2 Marmora, Belmont and Southern Methuen Townships, Peterborough and Hastings Counties

J.R. Bartlett\(^1\) and J.M. Moore\(^2\)

Introduction

Field work in 1981 was concentrated in Marmora Township; one week of follow-up work was carried out in Belmont and Methuen Townships (see Bartlett et al. 1980).

Marmora Township

Location and Access

Highway 7 crosses the southern part of Marmora Township, passing through the principal settlement, Marmora. The town of Deloro is situated in the southeastern part of the township. Access to the central and northern parts is provided by country roads 3 and 11, an abandoned Canadian National right-of-way, and numerous minor gravel roads of good quality. Crowe Lake, Thompson Lake, Jarvis Lake, Twin Sister Lakes, and parts of the Moira River and Beaver Creek provide shoreline access. Only the northeast corner of the township, east of Beaver Creek, is poorly served by roads.

Mineral Exploration and Production

Marmora Township has a long history of mineral production, dating from the establishment of the Marmora Iron Works in the 1820s. Small deposits of iron, gold, and arsenic, principally associated with the Cordova and Deloro Plutons, were worked mainly around the turn of the century. The Marmoraton open-pit iron mine was active from 1952 to 1978, producing approximately 30 million tons of magnetite ore. W.F. Bonter and Company quarried and milled marble from six small quarries east of Malone before 1971. The only current mineral production is of marble from a few small quarries, and crushed limestone from the Marmoraton waste dumps.

General Geology

Flat-lying Ordovician limestone with minor red mudstone, sandstone, and conglomerate at the base, cover the Precambrian succession in southwestern Marmora Township and occupy several outliers further north. These rocks were not mapped in this study, except near their contacts with Precambrian rocks. The remainder of the township is underlain by Late Precambrian volcanic, volcaniclastic, and carbonate rocks which have been intruded by gabbro, diorite, syenite, and granite plutons. The stratified rocks face southerly to easterly in general, and are described in the order corresponding to their probable stratigraphic succession.
Fine-grained amphibolite in northern Marmora Township is derived from submarine basalt, is pillowed in part, and is similar to flows in central Belmont Township. This amphibolite is enclosed by, and in part interbedded with, rusty-weathering, partly pyritic, fine-grained schist derived from wacke and mudstone. Impure carbonate metasediments derived from thin-bedded limestone, muddy limestone, calcareous wacke, and interlayered limestone and wacke with minor dolostone, become dominant upper section, and occupy most of central and southeastern Marmora Township. East of Cordova Mines, minor felsic metatuff (ash flow?) is also interbedded with marble. The carbonate succession is being studied in detail by Bourque (this volume). Relatively pure calcitic marbles occur in the eastern part of the township, around the periphery of the Deloro Pluton.

The principal igneous bodies are the Cordova metagabbro, which straddles the Belmont-Marmora Township boundary, and the Deloro Pluton, which extends from eastern Marmora Township into Madoc Township. The Cordova Pluton is mainly coarse-grained leucogabbro, is locally layered, and ranges from an anorhotic to an ultramafic composition. Primary textures are preserved except in local shear zones, but primary pyroxene has been replaced by amphibole. The Deloro Pluton exhibits an heterogeneous border zone, varying from leucogabbro at the contact, inward through diorite and syenite, to homogeneous massive perthitic granite typical of much of the pluton. Both igneous bodies have clearly intruded their surroundings, and the carbonate rocks are locally converted to garnet-pyroxyene skarns with associated iron oxide and sulphide minerals. In the area of the Deloro Mine, the peripheral diorite of the pluton is extensively altered, being replaced by potassic feldspar and iron-bearing carbonate, and acts as host to gold-arsenic vein mineralization. The granite, like the gabbro, has undergone regional metamorphism, but with very limited strain. The Gawley Creek Hornblende Syenite, exposed in a small area at the northeast corner of the township, is also coarse-grained and undeformed; smaller plutons to the west are mainly composed of gabbro, diorite and granodiorite, are heterogeneous throughout, and exhibit more deformation. Near Twin Sister Lakes, a small body of meta-pyroxenite about 150 m in diameter hosts copper-nickel mineralization.

The Marmoraton open pit exposes the contact zone of a metadiorite intrusion. This intrusion has a discontinuous syenitic border against carbonate metasediments, which are extensively replaced by magnetite-garnet-pyroxene skarn. This intrusive body, formerly covered by limestone, is separate and distinct from the Cordova and Deloro Plutons. It lies on the trace of an arcuate aeromagnetic anomaly which also includes small exposures of diorite or leucogabbro at Marmora and south of Crowe Lake; these rocks may represent the northern periphery of a large intrusive mass beneath Paleozoic cover.

Satellitic to the Deloro Pluton are granitic to granodioritic plugs of various sizes, and narrow (ring?) dykes which occur both as felsites and quartz-and/or feldspar porphyry rocks.

Structure

As in Belmont Township (Bartlett et al. 1980), two main fold phases are evident throughout the stratified rocks. The first, \( D_1 \), yielded mesoscopic isoclines, typically with attenuated or dislocated limbs and, in mica- or amphibole-bearing rocks, axial-plane cleavage (\( S_1 \)). Where such folds are not evident, there is only a penetrative cleavage subparallel to bedding (\( S_0 \)) in rocks of suitable composition. Bedding and \( S_1 \) are in turn deformed about open to tight \( D_2 \) folds, with northeasterly-striking axial surfaces and an easterly plunge; in micaceous rocks, crenulation is parallel to the \( D_2 \) fold axes. The \( D_1 \) axes, expressed locally by \( S_2/S_1 \) intersection (“streak”) lineation, are subparallel to \( D_2 \) axes. The \( D_2 \) folds have highly variable plunges in some outcrops; their pattern indicates inhomogeneous development rather than a third phase of deformation. Some of the variation in \( D_2 \) fold attitudes, however, may result from an open \( D_3 \) folding.

Graded bedding and convolute in metawacke beds consistently indicate a general southerly-younging direction across much of Marmora Township. Accordingly, it does not appear that major macroscopic \( D_1 \) or \( D_2 \) folds repeat the succession. The \( D_2 \) folds with amplitudes and wavelengths up to 2 to 3 km do occur, however, in the northwest and west-central parts of the township.

All of the larger plutons transect \( D_1 \) fabrics; the timing of their emplacement with respect to \( D_2 \) is less certain. Plutons containing fabric, such as the diorite east of Beaver Creek, are certainly pre-\( D_2 \) in age. The Cordova, Gawley Creek, and Deloro Intrusions may be relatively undeformed because their wallrocks took up \( D_2 \) strain, and not because they postdate that event.

Although faults of up to a few tens of cm displacement are evident in outcrop, few larger faults can be demonstrated with certainty. At map scale, truncated contacts and contrasts in lithologic assemblage and structural style suggest that a major early fault (pre- or syn-\( D_1 \)), perhaps a thrust, passes from Lake Township (Laakso 1968) through the very northwest corner of Marmora Township, and thence south through Cordova and Belmont Lakes (see Bartlett et al. 1980) and under Paleozoic cover. Straight boundaries on some Paleozoic exposures may denote control by later faults. The relatively homogeneous nature of the impure carbonate rocks in central Marmora Township precludes easy recognition of faults.

Metamorphism

Regional metamorphic grade is low, probably of green-schist facies rank, throughout Marmora Township, as evidenced by the fine grain size of metasediments, preservation of primary texture, and a general lack of higher-grade index minerals (although tremolite occurs with calcite at several localities). High grade assemblages do occur in contact zones to intrusions. For example, close to the Cordova metagabbro, wollastonite forms reaction
zones between quartz and calcite, and adjacent to the Deloro Pluton, garnet-clinopyroxene skarn and brucite (after periclase?)-calcite marble are developed. Both plutons have undergone regional metamorphism. Chlorite, actinolite, epidote, and sodic plagioclase replace original clinopyroxene and labradorite of the metagabbro. The Deloro perthitic granite shows marginal recrystallization of alkali feldspar, and coarse alkali amphiboles are replaced by clots of fine riebeckite and biotite. Also, mafic dykes within the granite have been converted to schistose amphibolite. The contact metamorphic rocks are thus probably relics which have survived low-grade regional metamorphism.

Regional metamorphism thus commenced before or during $D_2$, and remained near its maximum grade through $D_3$, judging by the lack of cataclasis and retrograde metamorphism. It also persisted throughout the period of plutonic emplacement, or there was a separate, post-plutonic metamorphism.

Stratigraphy

Although possibly bounded by a major fault, the protolith assemblage of submarine basalt-pyritic mudstone-wacke in northern Marmora Township is very similar to that of Cycle III in Belmont Township (Bartlett et al. 1980). The succeeding wacke-carbonate succession appears to correspond to the uppermost part of this depositional cycle, and is much thicker in Marmora Township than in Belmont Township, where it is truncated by the Cordova gabbro and overlain unconformably by the Belmont clastic metasediments and the emergent to subaerial basalts of Cycle IV. These latter rocks do not occur east of the Cordova gabbro, and may thus have occupied a very local basin of deposition. The Cordova Intrusion may be the subvolcanic counterpart of Cycle IV, and the Deloro plutonic rocks may be similarly related to extrusive ryolites occurring east of the map-area, in Madoc Township (Hewitt 1968).

Economic Geology

Metallic mineral deposit types comprise:

a) Stratiform Zn-Cu-Ag sulphide mineralization in volcanogenic metasediments;

b) Magnetite ironstone;

c) Disseminated Cu-Ni sulphide minerals in ultramafic intrusive rocks;

d) Contact-metasomatic Fe (and/or Fe-Ti) oxides in altered carbonate and gabbroic rocks;

e) Au-As and/or Ag-bearing quartz veins in altered intermediate and felsic intrusive rocks;

f) Contact-metasomatic arsenopyrite and/or magnetite and/or pyrite in altered carbonate (and granitic?) rocks.

The “Deer Lake rusty schists” extend eastward from Belmont Township (Bartlett et al. 1980). East of Cordova (“Deer”) Lake, two properties have been drilled in Marmora Township, revealing sections at least 120 m long, which are continuously mineralized with sphalerite and chalcopyrite, together with significant silver values. These rocks are derived from pyrite-pyrrhotite-bearing mudstones which immediately overlie mafic volcanics and are in turn overlain by volcanic wackes, locally sulphidic. Similar, but less strongly mineralized rocks extend easterly at least to the Twin Sister Lakes area.

Layered quartz-carbonate-magnetite ironstone occurs on the south shore of Thompson Lake and probably, based on a strong ground magnetic anomaly, east of Twin Sister Lakes as well, in the same rock succession.

The Bonter copper-nickel occurrence is in a small metapyroxenite body within siliceous clastic metasedimentary rocks, southeast of Twin Sister Lakes. Past drilling and sampling revealed sections which assayed as much as 2.39 percent Cu and 0.48 percent Ni (Assessment Files Research Office, Ontario Geological Survey, Toronto). Massive magnetite is found, associated with syenite, diorite, and gabbro, in contact skarns at Marmaton Mine and around the Cordova and Deloro Plutons, replacing carbonate rocks and, east of Cordova Mines, the gabbro itself. A sample of the latter type assayed up to 17 percent Ti (C.R. Young, personal communication 1981). The associated igneous rocks also contain disseminated magnetite.

All documented gold mineralization is in quartz-carbonate veins associated with the western border of the Deloro granite. Most of these veins are hosted by highly altered metadiorite or syenite converted to a light grey pyrite- and carbonate-bearing mica schist in the immediate vicinity of the veins. Farther from the veins the wall-rock is massive, but is impregnated with pyrite, biotite, and carbonate. Arsenopyrite is abundant in most veins; pyrite is also present, but in smaller amounts. Some deposits have abundant arsenic, but are low in gold; silver is typically very low, for example, a grab sample collected by field party personnel from the dump at a shaft of questionable identity in the Deloro camp, contained 0.98 oz per ton Au and less than 0.01 oz per ton Ag on assay by the Geoscience Laboratories, Ontario Geological Survey. A grab sample collected by field party personnel from the dump of the Gatlin shaft and assayed by the same laboratory contained 0.41 oz per ton Au and 0.12 oz per ton Ag. Arsenopyrite is also found disseminated in the altered plutonic rocks. Some vein deposits have anomalous silver, but low gold. Two small quartz veins hosted by a muscovite granodiorite plug northwest of the Deloro Pluton were sampled by field party personnel and on analysis by the Geoscience Laboratory, Ontario Geological Survey, returned values of 1.24 and 0.38 oz per ton Ag and less than 0.10 oz per ton Au. As a group, the vein deposits appear to have been precipitated in an extensive hydrothermal system generated by the high-level Deloro Pluton, which leached metals from the marginal plutonic rocks. As the original plutonic rocks were relatively anhydrous (containing alkali amphibole in lieu of biotite), much of the water involved may have been of meteoric origin.

Contact-metasomatic deposits having arsenopyrite,
magnetite and/or pyrite mineralization commonly occur in calcite-diopside ± garnet skarn rocks in the contact zone of the Deloro Pluton, particularly south of Highway 7. These deposits bear up to 25 percent arsenopyrite, 20 percent magnetite, and 10 percent pyrite by visual estimation; minor pyrrhotite is present in some deposits. Further assay work on samples from these deposits is being undertaken.

The non-metallic deposits comprise:

a) Calcitic marble.

b) Paleozoic limestone.

Quarries, mainly located in relatively pure, white calcite marbles near the Deloro Pluton, have produced both dimension stone, and crushed stone for terrazzo and other industrial uses. Associated with these marbles, in places, are brucite (?), tremolite, and serpentine. One of the quarries is presently under active development. The only significant mineral production is of limestone aggregate from the waste piles at the Marmoraton Mine.

Belmont and Methuen Townships

Re-examination of several localities originally mapped in 1980 (Bartlett et al. 1980) has improved our understanding of the stratigraphy in several respects, including:

a) Rhyolite tuff is interbedded with the upper part of the Belmont Lake clastic metasediments;
b) The plagioclase porphyry metabasalts of Cycle IV lie with apparent conformity on the Belmont Lake clastic metasediments.

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No. S3 Stratigraphy and Sedimentation of Carbonate Metasediments Within the Grenville Supergroup

M.S. Bourque¹

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Introduction

Field work carried out during the summer of 1981 is the first phase of a project which will entail a complete analysis of the marine system responsible for the deposition of carbonate and related sedimentary rocks. Included within the study are stratigraphy, depositional environmental analysis, facies models, paleontology, and paleoecology.

The primary purpose of the 1981 field work was to gain a general regional overview of the supracrustal rocks, especially the carbonates and related sedimentary rocks in Marmora Township and the surrounding townships. Detailed study of specific localities within the Marmora area indicate that rock units can be traced for at least 3 to 4 km, and are therefore conducive to stratigraphic subdivisions.

General Geology

Extensive carbonate and clastic metasediments are preserved in Marmora Township and the surrounding region. Very little detailed work has been done on the metasediments. Among the earliest workers were F.D. Adams and A.E. Barlow (1910), who recognized amphibolite layers in

¹ Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.
marble as metasediments. Other work by S.B. Lumbers (1964), and D.F. Hewitt (1968), amongst others, give an overview of the geology of this part of the Grenville Province.

Good exposure and low grade regional metamorphism make the Marmora Township and surrounding area an ideal starting point for detailed work. Detailed mapping of specific areas in Marmora Township indicate that rock units can be traced for distances of 3 to 4 km, and facies assemblages reflecting certain conditions of sedimentation, and particular environmental processes can be separated out. The carbonates and other metasediments exhibit a variety of primary sedimentary features such as graded beds, ripple marks (best seen on exposed bedding planes), cross beds, and soft-sediment deformation structures. Within the carbonates a variety of environments are indicated, and range from shallow intertidal environments typified by dolomite with preserved organosedimentary structures (stromatolites), to deeper water environments typified by fine-grained metasediments, cherty beds, calcareous metasiltstones, well segregated beds, slump structures, and regularly bedded repetitive rock sequences.

In Marmora Township, most of the carbonate metasediments consist of poorly foliated light grey to dark grey fine- to medium-grained marble, with impurities such as tremolite, phlogopite, pyrite, quartz, and graphite. The marbles are generally finely laminated to thinly bedded. Medium- to coarse-grained calcite patches are abundant in the marbles, and are generally at an angle to the bedding. Calcareous metasandstones and metasiltstones are interbedded at places with carbonate metasediments, and form a facies transition between clastic siliceous and carbonate metasediments. Rhythmic bedding is exhibited by clastic siliceous metasediments and calcareous metasiltstones, of which there are two major types: 1) graded bedding where sandy detrital material grades upwards to silty material, and exhibits a sharp boundary contact with the next graded bed, 2) alternating interbeds (2 to 3 cm each in thickness) of calcitic and siliceous metasediments, displaying sharp boundaries between the layers of sediment. Fine-grained metasiltstones and mudstones with stratification parallel to bedding reflect quiet water conditions, where the sediment settled out of suspension; however, in other areas, traction transport showing ripple marks and flaser bedding, and episodic sedimentation is indicated by sharp boundaries between the layers of sediment. Numerous penecontemporaneous soft-sediment deformation features such as load structures, ball and pillow structures are present and are confined to a particular bed. These are not specific to any special environment, but do indicate rapid sedimentation of a particular unit.

Organosedimentary Structures

In the Belmont Lake area, extensive dolomitic units have stratiform organosedimentary structures (stromatolites), reaching up to 2 m in length, and up to 0.5 m in thickness. Stromatolites or algal mats have been mentioned only a few times in the literature concerning the Grenville Province of Ontario (Wilson 1957).

Stromatolites are among the most common and long ranging fossils in the geologic record. Their widespread occurrence in the Precambrian, their geographic distribution, and the existence of a variety of living modern analogues make them extremely attractive for geochemistry, stratigraphy, environmental analysis, mineral exploration, and so on.

The microstructure of most of the recent and ancient algal laminates, and stromatolites, including the ones at Belmont Lake, show an alternation of light (usually sediment rich) and dark (usually organic rich) laminae, as a result of periodic fluctuation in the rates of mat growth and sediment deposition (McKirdy 1976). The sediment trapping and binding and/or mineral precipitation takes place within microbial communities generally termed algal mats. At some of the study localities, the stromatolites show columnar features, but at most places stratiform or hemispherical shapes predominate. The structures are siliceous with preserved laminations.

Structural Cavities

Within the dolomitic units around Belmont Lake, there are large (5 to 15 cm high and 2 to 10 cm wide) partly sediment-infilled cavities. The infilling sediments show graded beds, the cavity walls display solution features, and in some cases, a black, possibly organic coating, is present on the roofs of these structures. The cavities have undergone similar structural deformation as the surrounding rocks. The originally open parts of the cavities above the sediment accumulation have been infilled with two generations of calcite. Several episodes of fracturing, solutional modification, and infilling with calcite precipitate are indicated.

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No. S4 Cascaden, Dowling and Trill Townships; District of Sudbury

Jean Lafleur¹

Introduction

The eastern extremity of the map-area which covers approximately 276 km², comprising Cascaden, Dowling, and Trill Townships, is located about 23 km west of Sudbury. The town of Dowling lies in the east central part of Dowling Township. Mapping was done at a scale of 1:15 840 (1 inch to ¼ mile), with more detailed examinations in areas of extensive bedrock exposure. Accessibility into the area in the form of: major and secondary roads such as Highway 144, Fox Lake, and Ministic Lake roads, logging roads; power lines; the Canadian Trans-Canada railway track (in Dowling Township); lakes (Windy, Ministic, Cascaden, Armstrong, Mosquito, Fairbank and Vermillion Lakes); rivers (Onaping and Vermillion Rivers); and trails provided access to all parts of the map-area.

Mineral Exploration

Extensive prospecting and mineral exploration in the Sudbury area began following the discovery of the Murray Orebody, north of Sudbury, in 1883 (Stevenson 1979). Mineral exploration in the Windy Lake - Cameron Lake area, during the latter part of the last century, led to the discovery of two major showings in Trill Township, along what is now known as the ore-bearing sublayer zone of the Sudbury Irruptive Complex.

Since the turn of the century, a number of companies have actively explored the area for copper, lead, zinc, silver, gold, and nickel.

Most of the recorded base-metal exploration in the map-area was done in the 1950s and 1960s by Falconbridge Nickel Mines Limited and Inco Limited, although several smaller companies and individuals did submit results from diamond drilling and geophysical and/or geological surveys.

The most significant amount of exploration work has been undertaken by Falconbridge Nickel Mines Limited and Inco Limited. Their programs have incorporated ex-

¹Graduate Student, University of Ottawa, Ottawa.
tensive geophysical and geological surveys and diamond drilling, in all three townships, in both the Sudbury Irruptive Complex and the Onaping Formation.

General Geology


The rocks are subdivided into four main groups, these are: the Early Precambrian Levack Gneiss Complex; the Cartier "Granite"; the Proterozoic Whitewater Group; and the Sudbury Irruptive Complex of the Sudbury Basin Structure.

The Levack Gneiss Complex is exposed in Dowling and Trill Townships, and occupies a 4500 m wide band in Cascaden Township, surrounding the Sudbury Irruptive Complex. It consists of highly deformed and metamorphosed granodiorite-tonalite gneisses, of migmatitic supracrustal rocks (commonly garnet- and pyroxene-bearing) with leucosome fractions composed of coarse-grained dioritic to tonalitic material, and of weakly foliated granodiorite - tonalite containing xenoliths of the latter, which occurs in Dowling and in northeastern Cascaden Townships. In addition, massive to weakly foliated potassic feldspar porphyritic quartz monzonite - granite containing xenoliths of supracrustal rocks such as metasediments and amphibolites. Dykes of similar composition to the Cartier intrusive crosscut the Levack Gneiss Complex.

The Whitewater Group is located entirely within the Sudbury Basin and consists of a lower volcanic or meteorite fall-back breccia unit termed the Onaping Formation, grading upwards into a black, finely laminated shale, with a well-developed subvertical cleavage, which is in turn overlain by the thinly-to thickly-bedded turbidites and argillaceous rocks of the Chelmsford Formation.

Of interest is the Onaping Formation, since its nature (volcanic or meteorite fall-back breccia) has been, and still is, controversial. For reviews of this controversy, see J.S. Stevenson (1979), and J.S. Stevenson and L.S. Stevenson (1980). T.L. Muir (1981), in mapping along the North Range of the Basin, distinguished four phases of mostly pyroclastic breccias within the formation, these are the basalt, grey, green, and black members. The volcanic classification was adopted here because it can best describe the nature of the rocks, and for correlation purposes with Muir's North Range mapping, since there is continuity of the major phases across the present map-area. Thus, the Onaping Formation can be divided into:

a) — A Basal Member (lowermost phase), averaging less than 200 m in width, consisting of coarse pyroclastic breccias with variations in fragment/matrix proportion across, and along strike of, the phase. The fragments are mostly granitoid in origin, although quartzite (bedded), gabbro, and minor rhyolite (flow banded) varieties are also present. The matrix is in part composed of fine-grained, pulverized breccia material from the larger fragments, and of igneous-appearing equigranular and fine-grained amphibole-rich material, possibly representing granophyre from the main Irruptive mass, or products of recrystallization (by metamorphism) of the pulverized portion of the matrix.

b) — A Grey Member, varying in width from tens of metres to approximately 500 m in places. Based on the fragment/matrix composition, there are at least two varieties of this phase. The first consists of an igneous-textured, fine-grained, homogeneous siliceous grey matrix containing mostly whiteish sandstone fragments (from cm to more than 30 m in diameter), whereas the second variety is classified as a lapilli-tuff, with minor coarse breccias, containing irregularly shaped aphanitic volcanic glass (?) fragments, shards, cored bombs, accretionary lapilli, and a mixture of accidental fragmentary material ranging in rock type from quartz-rich sandstone to felsic and mafic subvolcanic-volcanic compositions.

c) — A Green Member, averaging less than 1 km in width, and
d) — A Black Member (uppermost phase), averaging between 1.5 to 2.0 km in width. Members c) and d) consist of lapilli-tuffs, lapillistones, and coarse breccias containing simple and complex (multi-penetration) volcanic glass fragments, vesicular pumice, shards, and accidental fragments of different types. The main difference between both phases is the siliceous green to greenish grey matrix of the Green Member, as compared to the carbon-rich black matrix of the Black Member.

The Sudbury Irruptive Complex of Middle Precambrian age intrudes between the Onaping Formation and Levack Gneiss Complex. It is divided into a sublayer zone breccia that is 175 to 1000 m wide, and is at its widest near the Trillabelle showing in Trill Township; a leucocratic, massive, biotite to amphibole, ± pyroxene porphyritic norite (averaging 1200 m in width); and a variable granophyre which averages 2 km in width, but is more than 3 km wide in southern Trill Township. This norite is
assimilated along its contact with the Onaping Formation. The sublayer zone outcrops at the base of the norite in Dowling and Trill Townships, and is subdivided into a leucocratic sublayer and a gabbroic-dioritic sublayer, termed igneous sublayer (Pattison 1979). The leucocratic breccia consists of partly remobilized footwall rock fragments, for example, from the Levack Gneiss Complex, set in a heterogeneous igneous-textured matrix. The igneous sublayer contains inclusions ranging from mafic to ultramafic in compositions, including anorthosite, in a gabbro-diorite matrix. Ni-Cu-Fe sulphide mineralogy is common in both sublayer phases. Inclusions of leucocratic breccia were found within the igneous sublayer in Trill Township, attesting to the younger age of the latter. Age relationships between the sublayer zone and the norite could not be specifically determined in the map-area, although it is believed that the norite is younger than the leucocratic breccia, but older than the igneous sublayer (Muir 1980).

Structural Geology

The gneissic and migmatitic rocks of the Levack Gneiss Complex have been extensively deformed with isoclinal and recurrent fold development, and in places, are overprinted by upper amphibolite - granulite facies metamorphism. The gneissosity is highly irregular, striking northeast to southeast and dipping subhorizontally to vertically. The contact between the Irruptive and the Gneiss Complex is generally considered to dip inwards towards the Basin Structure.

The Onaping Formation possesses a gross lithological layering, and youngs from the Irruptive-Onaping contact inwards into the Basin. Primary depositional attitudes within the pyroclastic breccias cannot be accurately determined because of a lack of local bedding structures.

Bedding attitudes in the sediments of the Chelmsford Formation have been compressed to form open, in places doubly plunging, folds, whose axes approximately parallel the northeast trend of the Sudbury Basin.

Two main faults transect the map-area: the north-trending Fecunis Lake Fault, of the Onaping System, in Dowling Township; and the northeast-trending Cameron Creek Fault, of the Murray System, in Trill Township. Considerable offset has occurred on both faults, in particular along the Cameron Creek Fault, where an observed lateral displacement exceeding 3 km exists, but the vertical component of the offset is not known.

Economic Geology

Nickel-copper and copper-lead-zinc mineralizations have been the target of mineral exploration in the Windy Lake - Cameron Lake Area. All significant showings are associated with the sublayer zone and the Onaping Formation. Common sulphide minerals of the sublayer zone include chalcopyrite, pyrrhotite, pentlandite, and pyrite. Very fine to coarse fragments and patches of sulphide minerals (>0.5 mm to 3 cm) occur in all members of the Onaping Formation, although the Black Member contains a greater abundance (>1 to 5 percent). Identifiable fragment sulphide minerals include the same association as in the sublayer zone.

In addition to easterly-trending mineralized shear zones in the Onaping Formation, there are north-northwest-trending, rather continuous, quartz-carbonate shear zones (some individual zones were traced more than 20 m) exposed in Dowling Township, which contain galena, sphalerite, chalcocite, and pyrite. Five samples collected by field party personnel from one set of veinlets, in the central part of Concession IV, lot 8, and assayed by the Geoscience Laboratory, Ontario Geological Survey, contained trace to 8.88 percent Zn, trace to 11.8 percent Pb, and trace to 0.42 percent Cu.

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No. S5 Footwall of the Sudbury Irruptive, District of Sudbury

Burkhard O. Dressler

Introduction

During the third year of a four year project initiated in 1979 (Dressler 1979, 1980a), the author investigated the footwall and the sublayer of the Sudbury Nickel Irruptive in an area extending from Capre Lake to the Whistle Property along the East Range and in an area from the Lockerby Mine to the Trillabelle Property of the southwestern Irruptive. An offset in Wisner Township (North Range), parts of the Foy Offset (Foy Township, North Range) and the Worthington Offset (South Range) were also investigated.

The aim of the four year study is; to obtain a better understanding of the origin and controls of the environments for mineralization associated with the Sudbury Irruptive, and to make contributions that may lead to a better understanding of the origin of the Sudbury Basin.

The investigation is co-ordinated with a detailed mapping program along the North Range initiated in 1979 (Muir 1979 and 1980) and continued this year (Lafleur, this volume).

1981 Field Investigations

During the 1981 field season, emphasis was placed on the following sub-projects:

1) Completion of a detailed investigation and mapping of the Sultana and Trillabelle properties area in Drury and Trill Townships.
2) Investigation of the footwall rocks and of the sublayer of an area perpendicular to the Irruptive, and the Chicago Mine, and south of the Crean Hill and Victoria Mines, in the South Range of the Irruptive.
3) Investigation of the sublayer and detailed mapping along the East Range Irruptive from Capre Lake to the Whistle Property.
4) Study of the Sudbury-type breccia, its distribution and orientation in sectors south of the South Range of the Irruptive.

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles
1 - Sultana and Trillabelle Properties

The area of the Sultana and Trillabelle Properties is located approximately 9 km northwest of the village of Worthington. Detailed mapping at a scale of 1:8 000 was initiated in 1960 and was completed in 1981. The sublayer and footwall rocks are very well exposed in these properties. Figure 1 shows the geology of the Sultana Property. It is typical of most sublayer-footwall contacts of the North and East Ranges. The typical rock units along the contact consist of the footwall with Sudbury-type breccia and megabreccia, leucocratic breccia and igneous sublayer. These rocks are therefore described in some detail here.

Within the granitic rocks and diabases of the footwall (Figure 1), Sudbury-type breccia bodies are abundant. Near the megabreccia zone (Pattison 1979) where large footwall blocks are intruded by granophyric "leucocratic breccia", the Sudbury-type breccia appears to grade into the leucocratic breccia (Pattison 1979). In this transitional zone, the dark grey Sudbury-type breccia matrix is recrystallized, is light grey to pinkish grey, and in macroscopic appearance is very similar to the leucocratic breccia. A similar transition of Sudbury-type breccia into leucocratic breccia has been observed by the author north of the Coleman Mine in Levack Township (North Range).

The leucocratic breccia, in general, is exposed between the megabreccia and the "igneous sublayer" (Pattison 1979). It consists of footwall rock fragments of various sizes and shapes set in a pulverized and subsequently strongly recrystallized matrix. The colour of the matrix is pink, grey, or dark grey depending on the kind of brecciated rocks. The recrystallization of the breccia matrix and inclusions gives the rock a quasi-igneous appearance. The recrystallization was caused by the intrusion of the Irruptive between the leucocratic breccia and the Onaping Formation. In places, the temperature of the breccia was high enough to cause mobilization of a granophyric melt presently found in the cracks of large fragments within the breccia, or in veinlets or dikes within the footwall megabreccia.

The "igneous sublayer" (Pattison 1979) is characterized by the presence of: xenoliths of footwall rocks, mafic-ultramafic rocks, and sulphide minerals in varying amounts in a gabbro-norite (marginal sublayer) or a hornblende-biotite, quartz dionite (offset sublayer) matrix. According to E.F. Pattison (1979), the quartz dionite represents deuterically altered gabbro-norite. The inclusions within the igneous sublayer observed by the author are the following:

a) Footwall rocks: Mafic metavolcanics, gabbro, diabase, glomeroporphyritic diabase, anorthosite, granitic rocks, gneisses and Huronian arkoses and quartz sandstones. Footwall rock fragments are angular to subrounded and range in size from under 1 cm to several metres.
b) Mafic and ultramafic rocks and massive sulphide mineralization: fragments of these rock types are rounded to spherical, range in size from a few cm to about 2 m, and occur in a gabbro or metagabbro matrix. The matrix is commonly medium-grained and may contain abundant interstitial sulphide minerals. At the Crean Hill Mine, the matrix is very coarse grained. In many places the matrix is strongly sheared, and the silicate minerals are completely altered to chlorite and actinolite. At the South Range occurrences investigated by the author, the mafic and ultramafic inclusions are all altered to chlorite and actinolite, whereas these inclusions are more or less unaltered in the North Range.

It appears that this ore-rich, mafic and ultramafic inclusion-bearing sublayer unit occurs in direct contact with the footwall rocks (Crean Hill Mine, Whistle Property), or forms inclusions within the footwall rock inclusion-bearing "common igneous sublayer" as observed in a small open pit just southeast of the Victoria Mine.

c) Leucocratic breccia clasts within the North Range and East Range igneous sublayer have been observed by the author in many places.
d) Norite fragments from the Irruptive have been observed at the main open pit of the Crean Hill Mine and just north of the Victoria Mine.

2 - Chicago, Crean Hill and Victoria Mines Area, South Range

The author mapped in detail an area extending 1 to 3 km south of the three mines. Many rock specimens were collected for petrographic and geochemical investigations. This South Range sector of the Sudbury Irruptive was chosen as an area in which to study the width and intensity of contact metamorphic footwall alteration and the shock metamorphic deformation of rock forming minerals and compare these with similar features along the North Range. It was also chosen as a suitable area in which to study the South Range sublayer.

The leucocratic breccia appears to be almost completely absent in the South Range. A small occurrence was observed near the Chicago Mine. In the igneous sublayer no leucocratic breccia inclusions have been observed by the author. At the main open pit of the Crean Hill Mine, the igneous sublayer contains many tabular metasedimentary clasts oriented parallel to the footwall-Irruptive contact suggesting flowage parallel to this contact.

3 - East Range Sublayer

The East Range sublayer was studied to compare the inclusions in the "common igneous sublayer" (see under 1 above) and the mafic and ultramafic inclusion-bearing sublayer unit, with the inclusions in other sublayer occurrences around the Irruptive. At the East Range, the igneous sublayer appears to be much wider than previously thought (Dressler 1980b; Muir 1979).
Figure 1—Geology of the Sultana Property, Drury and Trill Townships.
4 - Study of the Sudbury-Type Breccia

The author studied the distribution and orientation of Sudbury-type breccia bodies in an area just south of Kelley Lake (McKim and Broder Townships), south of the South Range Irruptive. About 80 measurements were taken. They will be compared with measurements taken in the North Range footwall rocks (Dressler 1980b). A few Sudbury-type breccia bodies near Ministic Lake (Cascaden Township) were revisited to sample small discontinuous, en echelon-like glassy breccia bodies. Devitrified and vesicular glass also forms the matrix of some breccia bodies near Armstrong Lake in Trill Township.

Many specimens of breccia matrix and of host rocks were taken for geochemical investigations.

Economic Geology

The main aim of the present investigations is to obtain a better understanding of the origin and controls of mineralization environments of the Sudbury Irruptive. No attempt, however, is made here to discuss the voluminous literature on the Sudbury economic geology, to describe the geology of the mines in the areas visited during the 1981 field season, or to give any details on the exploration activities in the Sudbury Mining Camp. For a detailed description of the sublayer, which is the ore-bearing unit around the Irruptive, the reader is referred to Pattison (1979). In this work, references on more recent papers on the Sudbury economic geology can also be found.

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No. S6 Huronian Sedimentation in the Cobalt Area

A.S. Legun

Introduction

Field work carried out during the summer of 1981 comprised detailed stratigraphic and sedimentological studies of the Huronian sediments in the Cobalt area. These studies are an ongoing phase of a program (see Wood 1979, 1980) to study the regional stratigraphy and sedimentology of the Cobalt embayment.

In the Cobalt area Archean volcanics are overlain unconformably by Huronian sediments. The unconformity is an irregular surface with elevated and depressed regions. A map view (Thomson 1964a and 1964b) reveals northeast-trending basement ridges alternating with sediment filled depressions. To the east the basement-sediment configuration is hidden under the cover of an undulating sill-like body of Nipissing diabase. This configuration has been defined in part by drilling for Ag-Co vein mineralization for which the area is historically famous.

There were four essential parts to the summer's activity relating principally to the Coleman member of the Gowganda Formation which rests on the volcanics:
1) Stratigraphic mapping and the identifying of sedimentary facies;
2) Collecting and tabulating drillhole data;
3) Determining the areal distribution of Lorrain granite clasts within Coleman sediments.

These activities are being directed towards the following goals:
1) Determining the environment of deposition of Coleman sediments and the role of the basement as a source of sediment;
2) Producing a computer map of the basement topography based on surface and subsurface data;
3) Determining the relationship between basement topography and stratigraphy;
4) Relating, if possible, topographic elements (basement depressions, diabase bottom surface) to the pattern of distribution of Ag-Co ore veins.
Figure 1—

(a) Surface geology; (b) Geological cross section; (c) Deposition reconstruction of rocks exposed northeast of Nipissing low-grade mill site, Cobalt, Ontario.
General Geology

Depositional Environment

The Coleman Member of the Gowganda Formation is considered by the author to be of glacial origin. K.D. Card et al. (1973) summarize the features indicative of a glacial origin for Gowganda deposits in the region. Additional features were observed during the course of this summer's work and will be described in a later report.

Lithofacies and Stratigraphy

Rocks of the Coleman Member were lithologically subdivided as follows, with percentage clasts of pebble size or larger indicated by numbers in parentheses: wacke conglomerate (>30); conglomeratic wacke (5 to 30); sparsely conglomeratic wacke (<5); conglomeratic sandstones; sandstones and grits; and siltstones and laminites.

A reasonably coherent association of lithologies is commonly the exception rather than the rule. Often a confusing juxtaposition of lithologies is apparent. Features may include vertical contacts, laminate draped depressions of a few metres in extent, variable bedding attitudes, recumbent slump(? ) folds, “lumps” of one lithology in another, sudden changes in clast density and matrix appearance.

Laminites are an integral part of the entire stratigraphic sequence and were observed interbedded with all other lithologies. They conformably drape the irregular top surface of lithologies as coarse as wacke boulder conglomerates. They suggest that subaqueous processes of deposition prevailed even though bedrock was being eroded locally (see section on Provenance).

Sparsely conglomeratic and conglomeratic wackes represent the main lithologies. They are typically unbedded with a random clast distribution, a dark unsorted matrix, and little internal organization. Closely associated, in particular with the sparsely conglomeratic wacke are siltstones and laminites. These form bedded zones, stratigraphically within or bordering massive wackes. Laminites are as Alternating siltstone/sandstone couplets (varves) are a common feature of the laminites. Drainstones and varves indicate subaqueous fresh-water deposition under floating ice. By association the conglomeratic wackes must have a related origin.

Lithologies other than conglomeratic wackes are locally useful as stratigraphic markers. The clast rich wacke conglomerates occur in sharp to erosional contact with underlying siltstones or clast poor wackes. In a traverse from west to east across the north end of Cobalt Lake (Sasaginaga Lake to the Cobalt Lake Fault) three such sharp contacts were encountered. In each case the conglomerates grade upward into grits. Southwards they pinch out and thus seem to represent sedimentary wedges.

Seven of these sedimentary wedges have been identified though their internal geometry is only sketchily known. Wacke conglomerate may occur as a separate sedimentation unit or as part of a coarsening upward or fining upward sequence up to 20 m thick. At least two wedges thin away from basement highs. Three cannot be related to basement topography. One thickens after thinning. One abruptly terminates.

Coarsening Upward and Fining Upward Sequences

Two coarsening upward sequences are well exposed immediately to the northeast and southwest of Nipissing Hill respectively. Laminites (in part varved) at the base are interbedded upward with sandstones exhibiting load casts, ripple drape, and ripple drift. These pass into planar crossbedded sandstones and grits. Overlying rather sharply are clast to matrix supported conglomerates with a wacke matrix. These conglomerates include juxtapositions of lithology mentioned previously. The sequences probably represent glaciolacustrine deltas (Wood, personal communication) or subaqueous outwash (Figure 1). Paleocurrents as well as changes in grain size clearly indicate a northeastern source for the latter sequence.

Fining upward conglomerate-grit sequences may have a concentration of exotic boulders at the base. These sequences overlie by clast poor wackes and laminites are tentatively interpreted as subaqueous moraines.

At the Coniagas pit graded conglomeratic units are interbedded with sandstones. The sandstones then are interbedded with and pass into dropstone laminites. Graded beds here and elsewhere (particularly as graded grits within dropstone laminites) suggest the presence of processes of mass gravity transport.

Drowned Paleovalleys

Sediments filling a paleovalley were examined in the Silverfields Mine. The irregular top surface of a basal breccia is conformably draped by dropstone laminites. The latter are not fluvial, but of subaqueous origin and indicate that the valley was drowned at the time of deposition.

Bedding and Basement Topography

The dips of bedding follow that of basement slopes but at lower values. Stratigraphically lower units appear to rise and pinch out against a rising basement while higher units pass across basement. Where well laminated sediments, undisturbed by slumping rest steeply (60° +) against basement rocks, considerable compaction must have occurred.

Provenance

Clasts within Coleman sediments have their source in: 1) the local volcanic bedrock, 2) the Lorrain granite exposed to the southeast and; 3) granitic, syenitic, gneissic rocks outside the area of study. Clasts of Lorrain granite
are distributed over a wide area to the north and west of present exposures of the granite. Clasts were found as far north as Casey and Harris Townships, where they are intermixed with clasts of syenite derived from locally exposed basement. Within a few kilometres of present exposures of Lorrain granite, boulder conglomerates consisting predominantly of this vibrantly red granite are present. Boulders reach 2 m in diameter and the wacke matrix is rich in angular granitic grit.

The distribution of granite clasts to the north and west of present exposures is in contrast to the southwest paleocurrent flow directions in the vicinity of Cobalt. Similarly east of Cross Lake a Lorrain granite conglomerate wedge (resting on volcanic basement) thins northward in contrast to some of the wedges at Cobalt. At the same location graded beds of Lorrain Formation arenites overlying the conglomerate wedge show a strongly unimodal flow direction to the southwest. These observations support R. Thomson's view (1960, p. 17) that the Lorrain granite was an area of net erosion during deposition of the Coleman member of the Gowganda Formation and was elevated with respect to the surrounding terrain.

**Economic Geology**

**Compaction About Basement Highs**

The occurrence of some Ag-Co vein systems above basement depressions or troughs has been well documented (for example Knight 1924). A slightly different perspective might be taken then from the vantage point of the basement highs. As mentioned previously, considerable compaction of sediments can be shown to have occurred. During this compaction, basement highs probably acted as unyielding knobs about which sediment layers compressed and underwent bedding slip resulting in the general conformability of basement slope and bedding dips. The differential compaction of sediments of varying thickness and lithology sandwiched between basement highs, may be an important component in the generation of fracture patterns in Coleman sediments. Other components include the diabase as a heat source, sources of water, and stresses set up during cooling of the diabase. These components should be taken together in generating new models of ore genesis.

**Base-Metal Sulphides**

Base-metal sulphides (chiefly sphalerite, chalcopyrite, and galena) present as bands within laminites were examined in the fifth level of the Silverfields Mine. In contrast to the views of C. Halls and E.F. Stumpfl (1970, p.256) evidence does not suggest that they are syngentic or that "they were deposited by fairly fast moving waters". Layers of mineralization follow sedimentary structures such as convoluted laminae but layers also split, vary abruptly in concentration, extend along fractures and shears. The layers are associated with bleaching and chlorite spotting. According to W. Petruk (1968, p.523) the distribution of minerals is probably the result of the replacement of chlorite.

Conglomerates commonly host base-metal sulphides. Halls and Stumpfl (1970, p.253) describe sulphide clasts of detrital origin in conglomerate. Petruk (1968, p.523) however gives evidence of a replacement origin for certain massive sulphide pebbles. This author at the Silverfields Mine and elsewhere has noted that both volcanic and granitic clasts occur impregnated with sulphides. Sulphides impregnate altered conglomerates on the fourth level of the Silverfields Mine. Corrosive embayment of clast outlines is evident as well as extensive chloritization of the matrix. In sharp contrast are the adjacent barren and unaltered laminates.

Sulphide bearing conglomerates occur adjacent to former Ag-Co veins and in basal breccias and conglomerates. As some basal breccias and veins are associated with basement depressions the detailed computer paleotopography based on this summer's compilation should clarify known relationships and extrapolate into areas where new exploration work may be warranted.

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1964a: Cobalt Silver Area, Northern Sheet, Timiskaming District, Ontario; Ontario Department of Mines, Map 2050, scale 1 inch to 1000 feet.

1964b: Cobalt Silver Area, Southwestern Sheet, Timiskaming District, Ontario; Ontario Department of Mines, Map 2051, scale 1 inch to 1000 feet.

No. S7 Kirkland Lake Area, Stratigraphic Mapping, District of Timiskaming

L.S. Jensen\textsuperscript{1} and N.F. Trowell\textsuperscript{2}

\textbf{Introduction}

Field work done in 1981 represents the third part of a three-year study, under the Kirkland Lake Incentives Program (KLIP), to carry out stratigraphic mapping of an area straddling the Kirkland Lake-Larder Lake 'Break' from the Quebec border west to Kenogami Lake. In 1979, alkalic volcanic rocks and associated sedimentary rocks to the north and south were studied by M.J. Downes (1979, 1980). In 1980, a limited examination of the various rock-types was carried out by the second author (Trowell 1980). Initiation of this program was an offshoot of regional and stratigraphic mapping of the Kirkland Lake and Larder Lake areas at a scale of 1:63 360 by L.S. Jensen (1978a, 1978b, 1979, 1980a).

\textbf{Economic Geology}

Gold was initially discovered in the vicinity of Larder Lake in 1906 (Thomson 1943, p.40). Shortly thereafter, several gold mines were brought into production near Kirkland Lake, located 24 km west of Larder Lake, and numerous additional mines were brought into production during the period from 1920 to 1940. Much of this early exploration activity is described in geological reports on the area by the Ontario Department of Mines. Between 1950 and 1975, the emphasis has been on the search for base metals, iron, and asbestos to the north and south of the study-area. Recent fluctuations in the value of gold and silver have spurred interest in exploring the area for precious metals, particularly along the Kirkland Lake-Larder Lake 'Break'. For recent mineral exploration in the Kirkland Lake area, see reports of the Kirkland Lake Resident Geologist.

\textsuperscript{1} Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.
\textsuperscript{2} Geologist, Precambrian Geology Section, Ontario Geological Survey, Toronto.
Stratigraphy and Gold Mineralization

**Kerr Addison-Type**

The gold mineralization at the Kerr Addison Mine, and at many of the adjacent former producers and gold prospects between Virginiatown and Larder Lake, is contained in rocks belonging to the Larder Lake Group (Jensen 1980a). This group of rocks butts against the younger Timiskaming Group along the length of the study area and is primarily a komatiitic metavolcanic succession composed of peridotitic komatiite, basaltic komatiite, and Mg-rich tholeiitic basalt. Interlayered with the komatiitic lavas are rhyolitic tuff and tuff-breccia, which had a source area to the south, and metasedimentary rocks. Conglomerate, wacke, and mudstone are composed largely of reworked komatiitic metavolcanic material with some rhyolitic detritus. Associated with them are carbonaceous sediments, chert, ironstone, dolomite, limestone, and minor Fe-carbonate.

Of particular interest with respect to the gold mineralization, are the carbonaceous sedimentary rocks, carbonates, and ‘carbonate-rich’ clastic sedimentary rocks. These sedimentary rocks, although not restricted to the Kirkland Lake-Larder Lake Fault Zone, are best developed toward it before they are abruptly truncated by rocks of the Timiskaming Group. These rocks appear to have been deposited at the edge of a north-sloping pre-existing shelf, the edge of the shelf itself being an early expression of the developing Kirkland Lake-Larder Lake Fault Zone as downward displacement occurred to the north.

At the Kerr Addison Mine, the ‘flow-ore’ is composed of a pyritic graphite unit (foot wall) and a pyritic laminated chert (cherty tuff) unit (hanging-wall), separated by a fuchsite-rich dolomitic unit disrupted by a massive to pillowd tholeiitic lava flow with abundant hyaloclastite. Much of this lava flow is silicified, carbonatized, and pyritic and forms a large part of the ore at the Kerr Addison Mine and adjoining gold properties. The ‘flow-ore’ is enveloped by mass-flow conglomerates composed of carbonatized peridotitic komatiite clasts up to 1 m across, which are cut by quartz-veins carrying free gold.

Critical to the understanding of the gold mineralization is the age of carbonatization and silicification, as well as the formation of fuchsite. Some sections of fuchsite-carbonate-graphite-chert, such as that at the Kerr Addison Mines, are gold-mineralized and others are not. The clastic material of komatititic composition may have been carbonatized and altered by alkaline fluids to form fuchsite by weathering or hydrothermal activity in the source area. Alternatively, the carbonatization, silicification, and formation of fuchsite could have occurred in the basin of deposition, coincidental with the deposition of carbonate and carbonaceous sedimentary rocks. By this means, the gold mineralization formed in an acid-reducing sedimentary environment, or by gold-bearing hydrothermal solutions reaching the surface and precipitating carbonate muds and oozes, and altering the komatiitic detritus.

A third possibility is that carbonatization, silicification, and fuchsite-formation took place following lithification by hydrothermal alteration. In places, the carbonatization and silicification cross-cuts the strata, which suggests either a post-depositional remobilization of pre-existing carbonate and silica, or new additions of carbonate and silica. It is probable that there were two or more phases of carbonate formation, and hence, two or more modes of gold mineralization.

**Timiskaming-Type**

In the Kirkland Lake gold camp, gold mineralization is concentrated in quartz-veins associated with alteration haloes which follow major faults (Kirkland Lake ‘Main Break’) cutting the Timiskaming Group sedimentary rocks, and alkalic volcanic and intrusive rocks (Thomson 1948, Ploeger 1980; see Ploeger, this report). Elsewhere in the Timiskaming rocks, gold (>1000 ppb) associated with disseminated pyrite occurs in many places. These occurrences are neither of sufficient size, nor concentration to warrant development at present. Since these occurrences are not restricted to a particular rock-type or structure, it is difficult to use them as parameters for further exploration.

The Timiskaming Group is composed of conglomerates, sandstones, mudstones deposited in a fluvial environment, and subaerial alkalic and potassium-rich, calc-alkalic, mafic to felsic metavolcanic rocks. R.S. Hyde (1978) divided the Timiskaming Group into alternating formations of sedimentary and volcanic rock, and showed that there was a crude fining-upward in most of the formations, both volcanic and sedimentary.

**Timiskaming Group**

The volcanic flows, flow-breccias, tuff-breccias, and bedded tuffs of each formation of volcanic rocks appear to be genetically related to proximal feeder dikes and sills of mafic to felsic syenite, which cut the Timiskaming rocks in many places. As well, more than 75 percent of the detritus forming the sedimentary formations has been derived from these igneous rocks. The remaining detritus was derived from the older volcanic and sedimentary rocks of the Larder Lake Group to the south. Erosion of the Larder Lake Group was not constant during the deposition of the Timiskaming Group. Consequently, some sedimentary formations, as well as certain members in some formations are richer in carbonate, chlorite, fuchsite, and serpentine particles and have more clasts of chert, komatite (carbonatized and non-carbonatized), and jasper iron formation then others. Of particular note is the basal, carbonate-rich sedimentary formation (Perron Formation of the Timiskaming Group; Hyde 1978), which unconformably overlies the Kenoevis Group on the north, and occurs on the south in contact with the Larder Lake Group, where it is much thicker. This shows that if the two carbonate-rich sedimentary units are correlative, the Timiskam-
ing Group is a synclinal sequence, rather than a monoclinal sequence.

In the syncline, the north limb contains the most complete section of the Timiskaming Group, but it is probable that in the widest parts of the Timiskaming, some of the upper formations have been repeated by faulting, movement along subvertical strike-slip faults similar to the Kirkland Lake Main Break. The narrower south limb section is composed of a series of fault-bounded wedges. Both limbs contain some second-order folds as well.

Gold may have been concentrated in the Timiskaming Group volcanic rocks and intrusive rocks by the partial melting of deeply buried, gold-bearing sedimentary rocks and volcanic rocks, similar to those of the Larder Lake Group (Jensen 1980, 1981). A ten percent partial melting of such rocks would increase the gold content in the resulting igneous rocks by a factor of ten. Alternatively, gold may have been driven off the buried rocks during an early phase of partial melting, and deposited along fractures near the surface by hydrothermal solutions.

Placer gold may be present in the Timiskaming Group sedimentary formations. Crossbedded pyrite was noted in the sandstones. The source of the gold could have been the associated alkalic and intrusive rocks and the gold-bearing sedimentary and volcanic rocks of the Larder Lake Group which are similar to the rocks of the Kerr Addison Mine.

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Trowell, N.F.
No.S8 Abitibi Alteration Study

E.C. Grunsky\(^1\)

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Introduction

The study of altered volcanic rocks in the Ben Nevis Township Area of Ontario (Figure 1) is a three year study funded by the Ministry of Northern Affairs for the Northern Ontario Geological Survey Program. The project is in its third and final year.

It is well documented that many Precambrian metavolcanic belts contain petrographically and chemically anomalous areas in which precious and base-metal deposits occur. Common to many base-metal deposits are the presence of extensive haloes of alteration caused by the circulation of hydrothermal fluids, and these deposits are commonly associated with rhyolite domes, volcanic vents, and exhalative horizons. The Ben Nevis Area exhibits these features, and a detailed examination of lithochemistry and petrography of the metavolcanic rocks forms the basis of this study.

The Ben Nevis Area has been mapped recently by L.S. Jensen (1975). W.J. Wolfe (1977) examined trace metal concentrations in the bedrock and soils of the area, and concluded that the relative distribution of zinc in the bedrock could be used as a good indicator of base-metal mineralization. Zinc exhibits a large dispersion halo around the Canagau Mines Deposit in Eastern Ben Nevis Township. In 1979 and 1980, a sampling project combined with 1:4 800 geological mapping was done to examine the petrographic and chemical features outlined by the anomalous zinc halos published by Wolfe (1977). Approximately 600 samples have been selected for whole rock chemical analysis, and about 300 thin sections were cut for petrographic examination. To date, about 75 percent of the whole rock analyses have been processed and the thin sections have been partly examined. Additional background data to this work occurs in previous Ontario Geological Survey Summaries of Field Work, E.C. Grunsky (1979, 1980).

The volcanic rocks of the Ben Nevis Area are the uppermost part of the Blake River Group in the Abitibi Belt of Ontario. The rocks are flow breccia and tuff-breccia of calc-alkaline basalt, andesite, dacite, and rhyolite composition. The structure of the area is that of a large east-trending synclinorium with local anticlinal features in the Verna Lake area. The rocks appear to have formed in a...
proximal volcanic environment with pillow breccia and flow breccia forming the dominant rock types. The basalt and andesite are highly amygdaloidal, and this feature has probably played a significant role in facilitating the circulation of hydrothermal fluids. Dacite and rhyolite occur commonly as flows, tuff-breccia and breccia dikes. Metamorphic grade is low, with prehnite and pumpellyite as common metamorphic constituents.

Economic interest in the area began during the 1920s when the Canagau Mines Deposit was first discovered. During the late 1920s and early 1930s, a shaft 100 m deep was sunk and several stations and crosscuts were made. Company records indicate that Cu, Pb, Zn, Au, and Ag are present in varying amounts. The highest assay values obtained are 0.84 percent Cu, 30.3 percent Pb, 14.27 percent Zn, 4.6 ounces per ton Au, and 5.6 ounces per ton Ag. The mineralization consists of chalcopyrite, galena, sphalerite, and pyrite in east-trending fractures and shear zones that dip 40 to 60 degrees south. Some fractures that have been intruded by diorite dikes show a concentration of the mineralization along the contacts. The mineralized zones occur as massive stringers and andesite are highly amygdaloidal, and this feature has probably played a significant role in facilitating the circulation of hydrothermal fluids. Dacite and rhyolite occur commonly as flows, tuff-breccia andbreccia dikes. Metamorphic grade is low, with prehnite and pumpellyite as common metamorphic constituents.

The classification of the volcanic rocks in the Ben Nevis Area has been determined by use of the Jensen Cation Plot (Jensen 1976). Petrographic studies suggest that the classification scheme works for almost all of the samples. Mobility of cations in the volcanic rocks is generally limited to the Canagau Mines Deposit area.

MgO and FeO contents indicate a depletion of up to 1.0 percent within a 1 km radius of the deposit; depletion of Fe2O3 up to 1.0 percent occurs in the deposit area, and enrichment of up to 3.0 percent Fe2O3 forms a halo surrounding the deposit.

Aluminum and titanium depletions occur in the deposit area as well; aluminum depletion of up to 4.0 percent and titanium depletion of up to 0.4 percent was noted.

In order to discriminate between chemically anomalous and unaltered areas, the rocks were classified as to rock type and then compared to a normalized composition. This was done by the following method. Using the Jensen Cation Plot, each sample was classified. For each rock type, the mean and standard deviations for major oxides and trace elements were computed from the samples. Each oxide/element of each sample for each rock type was then compared to a normalized composition, or variety of compositions that exist. Alteration is patchy in places, particularly the non-pervasive silicification. As a result, the silicification may not reveal itself when averaging techniques are used to provide computer-generated contour maps.

Hydrothermal alteration as reflected by lithogeochemistry is best indicated by CO2 and lithium (Figure 1). Both of these components exhibit well-defined anomalies that have a north-south trend. These anomalies are coincident with a major north-south fracture that was likely a major hydrothermal vent related to the original fracture system of the main volcanic vent further west. The zinc anomaly is smaller in areal extent than CO2 or Li. Copper and lead are localized, are much smaller, and are limited to actual mineralized occurrences. Tourmaline has been found in quartz veins throughout the silicified zone in the Captain Lake area, and suggests that boron metasomatism has occurred as well.

Other major element oxides also indicate hydrothermal activity, but are less obvious. Sodium displays a general depletion of up to 4.0 percent in the vicinity of the Canagau Mines Deposit, and, a poorly defined halo of enrichment surrounds the zone of depletion. Calcium displays a similar feature; however, the zone of enrichment surrounding the zone of depletion is more clearly defined. An earlier report of this study (Grunsky 1980), suggested that CO2 enrichment and CaO enrichment were coincident; but subsequent investigation has indicated that they are not. More than likely, CO2 has reacted with Mg,
Element Enrichment In The Ben Nevis Area

Figure 1—Computer generated plot illustrating element enrichment in the Ben Nevis Area.
Fe, and Ca to produce carbonate, and excess calcium was carried out of the system and deposited around the main hydrothermal vent. Potassium displays an increase in the immediate vicinity of the deposit.

A study of the mineralogy in the altered zones is currently in progress. Sericite occurs commonly in the rhyolitic rocks both as a metamorphic and as an alteration product. Sericite is also developed in mafic rocks, and its formation appears to be roughly coincident with both the lithium and the potassium anomalies.

Field work was carried out in the area north and west of Verna Lake in the 1981 field season. Disseminated sulphides are common throughout much of the area. In one area, a breccia zone of felsic metavolcanic fragments in a quartz matrix contains up to 10 percent sulphide minerals. Pyrite and chalcopyrite are scattered throughout the quartz matrix and in the volcanic fragments. Quartz-feldspar porphyry occurs to the north of the main showing and contains sericitized feldspar and minor to trace amounts of sulphide minerals. Chemical sampling was carried out in the area and will be incorporated into the final report.

The Ben Nevis Area yields flat electromagnetic and magnetic profiles as indicated by recent airborne surveys. The stratigraphy of the area is gently dipping, thus imposing difficulties on the determination of stratigraphic cross sections and the application of standard geophysical exploration methods. This situation is similar to the Noranda area of Quebec where many base-metal deposits occur well beneath the limits of geophysical detection (Boldy 1979). Success in the Noranda area has been achieved using a combination of geological, geochemical, and geophysical methods. In the Ben Nevis Area, the presence of a large alteration halo composed of several major and trace element anomalies combined with vein-type deposits may indicate that massive sulphides exist in the area. If the Canagau Mines Deposit can be interpreted as an exhalative vent, then it is possible that there may have been a massive sulphide deposit above the present erosional level. This does not preclude the fact that other ore bodies may be present beneath the present surface. Noranda is noted for its stacked ore bodies and the Ben Nevis Area may be similar. Because both the Noranda camp and the Ben Nevis Area are in the Blake River Group, are tectonically similar, and have some similar geochemical signatures, the Ben Nevis Area offers promising prospects. An effective base-metal and precious metal exploration program in the Ben Nevis Area requires a combination of geological/stratigraphical understanding, detailed geochemical sampling, and some strategically placed diamond drilling in order to fully examine the potential of the area.

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Grunsky, E.C.


Jensen, L.


Wolfe, W.J.
Engineering and Terrain Geology Programs
Nine field parties were active in mapping the surficial deposits throughout the Province, six in southern Ontario, and three in northern Ontario. In addition, three field parties were involved with studies of the Paleozoic rocks of Ontario, and nine aggregate study teams were active in both southern and northern Ontario. Many of the field activities were funded by the Ministry of Treasury and Economics, the Ministry of Northern Affairs, and the Federal Department of Regional and Economic Expansion.

E.V. Sado completed the mapping of the Quaternary geology of the Chatham-Wheatley area. Drilling and geophysical methods were used to investigate the subsurface in order to unravel the geological history in a search for buried, potentially viable, aggregate zones within the drift cover.

M.J. Batterson commenced the mapping of the Quaternary deposits in the Penetangishene area, and paid particular attention to the abandoned shorelines of post-glacial lakes, especially those of Lake Algonquin. P.F. Finamore also studied abandoned Algonquin shorelines in the Orillia area, and noted a number of occurrences of deformed shorelines as a result of disturbances of the underlying Paleozoic bedrock. B.S. Goldstein concentrated much of his field efforts on studying the Dummer Moraine in the course of mapping the Quaternary deposits of the Bannockburn area.

J.G. Leyland continued the mapping of the Quaternary deposits in the Tweed-Belleville area, to the east of the areas which were mapped last year. Evidence of a late flow of ice from the Ontario Basin, in a northwesterly direction, was noted in the Tweed area.

R.J. Kodybka commenced the mapping of the surficial deposits of the Algonquin Provincial Park in the Achieby area in response to a request from the regional Parks staff for details of the glacial history of the Park.

C.L. Baker, having completed the basic mapping of the surficial deposits in four map-areas in the Kirkland Lake area, concentrated his efforts in the past year on a detailed sedimentological study of the Munro Esker. Three distinct depositional environments were identified, and are described in his report. Work is proceeding on the mineralogical examination of sediments in each environment.

J.A. Richard mapped the surficial deposits of the Constance Lake-Hanlon Lake areas. These areas include a large esker-kame complex amidst an area otherwise dominated by thin drift and bedrock outcrop. Marine sediments deposited in the Tyrrel Sea are to be found in the northwest corner of the map-area. Aspects of the Cochrane ice readvance were clarified, and potential aggregate resources have been identified. The known southern extent of the discontinuous permafrost zone could possibly be extended with the discovery of summer ground ice in many places throughout the map-areas. A new occurrence of Cretaceous clays was identified at Limestone Rapids on the Kabinakagami River.

M.J. Ford continued surficial mapping studies in the Red Lake-Ear Falls area by extending activities into the Ear Falls and Pakwash map-areas. The dominant physiographic feature is the Lac Seul Moraine, which separates the gently rolling western part of the map-area from the more rugged eastern part with its more numerous bedrock outcrops. Two distinct ice flow units have been identified in the area, suggesting the need for a re-evaluation of the origin of the Snake Falls esker. Extensive deposits of clean sand have been identified, but sources of coarse aggregate are much more limited.

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1Section Chief, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.
In a continuing study of the Paleozoic rocks of southern Ontario, D.M. Carson completed the mapping of the deposits west of the Frontenac Axis, and then commenced mapping the deposits to the east. His examination of many new exposures along the shoreline, and especially those made available as a result of construction activities, has led to a refinement of the boundaries developed from earlier mapping. Carson’s basic mapping should make a significant contribution to the aggregate assessment project, to be initiated by the mineral resources staff of the Eastern Region of the Ministry.

In the past field season, M.D. Johnson completed three years of field studies for the limestone-dolostone assessment of Manitoulin Island. The acquisition of 783 m of core following the 1980 field season, and additional geochemical and engineering testing, will supplement the last season of the field work to permit the completion of the evaluation of the island’s resources.

D.J. Russell commenced a two-year project of the mapping of the Paleozoic outliers on the Canadian Shield, starting with field studies in the Timiskaming and Ottawa Valley areas and with familiarization studies on Manitoulin Island. Detailed logging of Lower Silurian exposures near Lake Timiskaming showed several lithological similarities between those units and time correlatives on Manitoulin Island.

The assessment of the aggregate resources of all designated municipalities in southern Ontario, and of selected urban areas in northern Ontario (Timmins, Smooth Rock Falls, Elliot Lake and Fort Frances), continued over the past year. Field investigations were undertaken to acquire data where little or no information was available to the staff of the Aggregate Assessment Office, or where additional information was required to update available data. Some drilling was undertaken where reliable data was sparse or where geological or other data suggested the presence of potentially useful but buried deposits.
No. 18 Quaternary Geology of the Ear Falls and Pakwash Areas (52 K/11, 52 K/14) District of Kenora (Patricia Portion)

M.J. Ford

Introduction

The Ear Falls-Pakwash area is bounded by Latitudes 50°30'N and 51°00'N and Longitudes 93°00'W and 93°30'W and has an area of about 1970 km². Previous surficial geological work in the area was done by S.C. Zoltai (1965). Preliminary reconnaissance was carried out by V.K. Prest in 1978 and mapping at a 1:50 000 scale was undertaken during the 1981 field season. Access to the map-area is provided by provincial Highway 105, and several logging and mining roads. During the field survey, canoes and power boats were used extensively and remote areas were reached via float-equipped aircraft. Pace-and-compass traverses were carried out over much of the map-area.

Bedrock Geology

The map-area straddles the boundary between Uchi and English River structural subprovinces of the Superior Province. The rocks are all Early Precambrian (Archean) in age. Detailed mapping has been carried out around Bruce Lake by R. Shklanka (1970) and by K.G. Fenwick (1965, 1967) in the Snakeweed Lake and Feaver Lake areas. Reconnaissance mapping and compilation for the entire area has been done by F.W. Breaks et al. (1976). The northern half of the area is underlain by massive to weakly foliated granitoid rocks, intermediate to mafic intrusions, and a west-trending belt of metavolcanics representing at least one mafic to felsic volcanic cycle. Metasedimentary migmatites dominate the southern half of the area. They are mostly wacke-derived metatexites and some coarse-grained homogeneous diatexites. A few small granitoid plutons occur in the southwestern corner of the map-area. The wacke paleosome of the metatex-
ites often displays good glacial polishing and striae yielding most of the ice-flow direction data for the area. Bedrock exposure is limited except in the extreme northeastern and southern parts of the area. On the west side of Bruce Lake, Algoma-type iron formation is mined at the Griffith Mine. The iron formation is intensely folded and is associated with metawacke.

**Physiography**

The north-trending Lac Seul moraine divides the area in two broad physiographic subdivisions. West of the moraine the topography is gently rolling and local relief is generally low but punctuated by sparse bedrock knobs and drift hills of moderate relief. There are three south-west-trending eskers in the northwestern part of the area; the longest is approximately 20 km long. Except for Bruce, Pakwash, and Camping Lakes, lakes are very small and sparse. South and west of the Cedar River the terrain is bedrock controlled. The rock knobs have up to 80 m of local relief with many small intervening lakes elongated parallel to the east-trending structure of the bedrock.

Topography east of the moraine is more varied with many rock knobs and drift ridges and hills. Small lakes are abundant. The Lac Seul moraine itself is a major physiographic element, particularly in the northern part of the area where it is up to 1.5 km wide and its local relief reaches 85 m.

Drainage in the map-area is generally to the south or southwest, and eventually enters the westward flowing English River.

**Quaternary Geology**

Striae measurements indicate that there are two areas with distinctly different Late Wisconsinan ice-flow directions. West of the large esker, which trends northeasterly from Snake Falls, ice flow was about 200° azimuth. This is consistent with ice-flow indicators immediately west of the map-area (Prest, in preparation). There are numerous east-trending minor moraines in the extreme northwestern part of the Pakwash area which are assumed to be roughly transverse to ice flow. In the rest of the map-area ice flow was to 260° to 270° azimuth. The ice-flow data and the streamlined linear morphology suggest that the "Snake Falls" esker may have been formed between two active major ice-flow units.

The oldest Quaternary deposits observed are of stony silty sand to sand till of probable Late Wisconsinan age. Where exposed, the unweathered till varies from massive to fissile and has poor to moderate matrix cohesion. The fresh till is usually olive-grey; where weathered it is brownish grey. In many locations the silt and fine sand have been winnowed out of the upper 30 to 40 cm of the till by the action of Glacial Lake Agassiz. In a 6 to 8 m section at the Griffith Mine the till is substratified and contains horizontal sand stringers, large lenses of cross-bedded sand, and horizons with high boulder contents. This suggests subglacial melt-out as the major mode of deposition. The surficial extent of till over the map-area is limited by the extensive cover of glaciolacustrine clays and silts. Its degree of continuity in the subsurface is unknown.

Glaciofluvial deposits include the three eskers, much of the Lac Seul moraine, and numerous sand bodies scattered about the area. The sands were deposited in Lake Agassiz as "subwash lobes" (Prest 1981) or possibly, in some cases, as ice-marginal deltas. Typically the sands are fine to medium grained, moderately well sorted, and quartz rich. However, locally they may be coarse to very coarse, poorly sorted, and contain abundant angular feldspar and lithic fragments. In section, the sands display: asymmetrical, unidirectional, ripple cross-laminations; climbing-ripple marks with climb angles up to 40°, horizontal laminations; and ripple scale cut-and-fill structures. The fluviatile sands are often transitional upwards into glaciolacustrine siltites, though sharp nongradational contacts were also observed. Many exposures along the shores of Lac Seul and the English River show 1 to 3 m of rythmically stratified silt, clay, and minor sand overlying these fluviatile sands. This suggests that the sands are much more extensive than indicated by their surficial exposure.

Much of the Lac Seul moraine, particularly south of the Trout Lake River, is composed of well-stratified sand and lesser amounts of gravel. A large pit, in the moraine west of Wenesaga Lake, displays 6 to 8 m of fluvial sand and minor gravel over 4 to 6 m of well-sorted pebble and cobble gravels. Only minor deformation structures are present and no till or beds of fine material were observed.

Clays and silts, deposited in Lake Agassiz, mantle much of the map-area. The lake progressively inundated the area as the Late Wisconsinan ice margin receded. The fine-grained deposits vary from massive, compact silt to rythmatically stratified clay and silt. Thicknesses of over 4 m were observed. The maximum elevation of these deposits ranges from 370 m above sea level in the south to 410 m above sea level in the north.

Wave action in Lake Agassiz produced a series of well-developed terraces on the Lac Seul moraine, the "Snake Falls" esker, and several of the higher sand bodies. On the moraine, the terraces are veneered with sand or well-sorted gravels or have lag concentrations of boulders. Only a limited portion of the moraine, in the northern part of the area, stood above the maximum level of the lake which was approximately 480 m above sea level.

Deposits of peat, muck, and organic-rich silts and clays are found in bogs and swamps throughout the area. The peat thickness in many bogs exceeds 1.5 m. Recently deposited alluvial silts and clayey silts are present along parts of the English River and some small streams, but they are generally shallow and of limited areal extent.
Economic Geology

Large supplies of clean sand are available in the map-area. The Lac Seul moraine and the “Snake Falls” esker have been worked for construction material in the past, and still contain immense reserves. Reliable sources of coarse aggregate are much more limited. In the Lac Seul moraine most of the existing pits are primarily sand sources with less than 20 percent gravel. The single major exception is the previously mentioned deep pit, west of Wenesaga Lake, which contains excellent gravel at depth. Power equipment investigation is required to properly assess the coarse aggregate potential of the moraine. The “Snake Falls” esker contains variable amounts of gravel but much of it is oversized. Information is too limited to make reliable reserve estimates for the esker.

Many of the bog deposits consist of uncompacted peat. The low levels of humification in some of these deposits may make them suitable for horticultural use.

References


Fenwick, K.G. 1965: Snakeweed Lake Area, District of Kenora (Patricia Portion); Ontario Department of Mines, Preliminary Map P.349, scale 1:15,840 or 1 inch to ¼ mile. Geology 1964.

1967: Feaver Lake Area, District of Kenora (Particia Portion); Ontario Department of Mines, Preliminary Map P.410, scale 1:15,840 or 1 inch to ¼ mile. Geology 1966.


Zoltai, S.C. 1965: Surficial Geology, Kenora-Rainy River; Ontario Department of Lands and Forests, Map S165, scale 1:506,880 or 1 inch to 8 miles.
Introduction

The Achray map-area (31 F/13) lies almost exclusively within the boundary of Algonquin Provincial Park (Latitudes 45°45' to 46°N, Longitudes 77°30' to 78°W).

This project was initiated at the request of the Regional Parks Co-ordinator, Algonquin Region Office, Ontario Ministry of Natural Resources, Huntsville, and is supported in part by funds provided by the Region. The purpose of the project was to examine and map Quaternary deposits, and to describe features of geological interest in the Achray area. Field activity commenced in mid-May and ended in late August, 1981. Logging roads, in general, permitted excellent access to most areas. Traverses and canoe excursions were necessary to reach more remote areas.

Areas of fairly thin drift cover and extensive rock outcrop were mapped and sampled fairly quickly as compared to areas with relatively thicker drift accumulations.

Bedrock Geology

The bedrock geology of the Achray area is dominated by Late Precambrian rocks of the Algonquin Batholith. Composed of anorthosite suite rocks, predominantly gneissic monzonites and syenites, this batholith was emplaced between 1.5 and 1.4 billion years ago (Lumbers 1980). Coarse clastic metasedimentary rocks characterized by a basal arkose and impure sandstone facies rest unconformably on the flanks of the batholith and occur in isolated outcrops in the Achray map sheet.

Several faults cross the area in an east-southeast direction.

Physiography

The map-area lies in the Laurentian Highland subdivision of the Canadian Shield. The dominant fault which extends along the Grand Lake-Stratton Lake chain of lakes virtually cuts the map-area in half and divides it into two physiographically different areas. North of this fault are relatively flat-lying areas with elevations generally not exceeding 350 m above sea level. Total relief of this area...
is approximately 170 m. South of the fault, the area is generally more hilly. Maximum elevations are in excess of 450 m above sea level and the total relief is approximately 220 m.

Quaternary Geology

The area of the Achray map-sheet exhibits major ice flow directions towards the south-southwest. This is evident from striations on both summit ridges and on rock outcrops of relatively lower elevations, for example, those in valleys. Large-scale erosional forms (whalebacks, roche moutonnées) are also oriented in a general south-southwest direction.

A complex pattern of striations and medium-scale erosional forms, exhibiting a smooth stoss and plucked lee side, radiate out from the highland area, directly south of the Grand Lake Systems. The author considers that these striations and erosional forms are the result of late glacial activity, possibly where remnant ice centred in the highlands was active. Current research (B. Phillips, University of Waterloo, personal communication 1981) is underway to describe and plot the complex ice flows which took place during late glacial times.

Surficial deposits in the map-area are generally of glaciofluvial origin. Deposits are usually discontinuous and thin, and generally restricted to areas between bedrock outcrops. Deltaic deposits dominate the north-northeast part of the map-area. The Petawawa River System, now a mere trickle of the late glacial outflow it once was, eroded much of the deltaic deposits originally in the area.

Extensive aeolian deposits dominate the landscape in the north-northwestern part of the map-area. Dunes of various sizes (generally not exceeding 5 m in height) are interspersed with bedrock outcrops. Few glacial, fluvial, or till deposits are found in this area.

A few isolated pods of glaciofluvial ice-contact deposits are found throughout the northern half of the map-area (generally the north central part). These usually take the form of positive relief features, such as kames or other forms of ice-contact features. The deposits consist of a matrix of clean medium to coarse sand and sub-rounded to rounded cobbles. The depth of these deposits (to bedrock) varies from approximately 5 m up to 30 m in some deposits. These deposits are often laterally bounded by bedrock outcrops where the contact is abrupt, but can exceed the outcrops in elevation.

The southern half of the map sheet, dominated by highlands, is generally a drift-free area. Bedrock outcrops dominate the relief, with only minor sand-gravel deposits interspersed. Boulder-covered areas south of the highlands are found to be isolated, but often extensive. The boulders are of highland provenance, suggesting local plucking and depositing.

The extreme southern part of the map-area contains widespread sand and gravel deposits. In late glacial time, much of this area extending south to Round Lake (Map sheet 31 F/12) probably was an area of shallow water, fluctuating in extent and depth, possibly in response to ice-damming of outlets and meltwater supply. Subsequent deposits of sand dunes are widespread over this area.

Reference

Lumbers, S.B.
No. 20 Quaternary Geology of the Chatham (40 J/8) and Wheatley (40 J/1) Areas, Kent County

E.V. Sado

Introduction

The Chatham-Wheatley area is situated between Latitudes 42°30' and 42°00'N and between Longitudes 82°00' and 82°30'W. Located within this area are portions of Lakes St. Clair and Erie, plus the city of Chatham, and the towns of Tilbury, Blenheim, and Wheatley.

Quaternary geological mapping was completed for this area during the 1981 field season. In addition, data was also gathered regarding the thickness of Quaternary drift cover over bedrock and the topography of the bedrock surface. Particular attention during this survey was given to determining the stratigraphic relationship of the Quaternary deposits and their depositional environments. The use of a trailer-mounted power auger and a Geonics EM-31 geophysical resistivity instrument provided additional valuable data regarding the subsurface geology.

Physiography

The map-area is a flat, modified lacustrine plain with negligible relief. Dover Township and parts of North Tilbury, and East Tilbury Townships, as well as Raleigh Township adjacent to Lake St. Clair, are reclaimed marshland presently used for cropland. This surface is lower than Lake St. Clair and periodically floods. Drainage over the remaining area is imperfect, but is controlled by tile drains and an elaborate system of canals and water pumping stations. Drainage generally is into Lake St. Clair, but in the southernmost part of this area, several deep gullies drain directly into Lake Erie. Virtually every available acre is intensively cultivated for corn, beans, vegetable, and fruit crops.
L.J. Chapman and D.F. Putnam (1966) have divided this area into two physiographic regions, the St. Clair Clay Plains and the Bothwell Sand Plain. Revisions to their work is suggested by findings of this study. The Bothwell Sand Plain previously terminated near Chatham is much more extensive and continues west to Lake St. Clair and south roughly to Highway 401. Lacustrine, alluvial, and deltaic sediments (sands, silts, clays) dominate this physiographic region. The surface of these sediments has been modified by aeolian action. South from Highway 401 to Lake Erie, the surface is a gently undulating clay till plain, part of the St. Clair Clay Plains. Within this zone, Chapman and Putnam (1966) show a narrow, southwest-to northeast-trending end moraine passing through the village of Charing Cross. No evidence for this Charing Cross Moraine was found during this work.

The most prominent physiographic feature in the area is a sand and gravel ridge 1 to 15 m above the clay plain. This ridge underlies Highway 3, following the Lake Erie shore between Blenheim and Wheatley. The ridge formed in glacial Lake Warren as a westerly-growing spit extending from the Blenheim Moraine about 12 500 years before present.

Paleozoic Geology

Middle and Upper Devonian shales and limestones underlie the map-area, but are covered by 15 to 65 m of Quaternary sediments. A small area of Dundee Formation limestone subcrops in the extreme southwest corner near Wheatley and Port Alma. The Dundee Formation is overlain by grey shales interbedded with limestones of the Hamilton Group in the western part of the map-area. These are in turn overlain by black shales of the Kettle Point Formation. The Kettle Point Formation underlies much of the map-area, and though deeply buried, large blocks of the Kettle Point are commonly draglined to the surface at two commercial gravel operations southeast of Chatham (Concession 12 and 13, Harwich Township).

Quaternary Geology

Quaternary deposits in the map-area are Late Wisconsin to Recent in age. Examining Quaternary sediments and their relationships in this area is difficult because of a lack of geomorphic features and of subsurface exposures. In addition, soil-forming processes have also greatly altered primary structures within the parent glacial and postglacial sediments throughout this area.

The oldest glacial sediment in this area is a black, shale rich, clayey silt to sandy silt till. This unit is exposed at the surface over much of map-area south of Highway 401 where it is heavily oxidized and leached of carbonates. This till is best studied along the shorebluffs of Lake Erie where sections of up to 20 m high are well exposed. Boreholes indicate this to be a massive unit resting directly on the bedrock surface. Tracing of this unit eastwards along the Lake Erie shore suggests that it correlates with the Port Stanley Till Sheet deposited about 15 000 year before present during the Port Bruce Stadial. A similar till has been noted in subcrop beneath younger postglacial sediments in the northern part of this area. At present, the stratigraphic significance of this subsurface unit is poorly understood. It shares similar properties with a till described by W.D. Fitzgerald (1979) in the Wallenburg area, but genetically, the author feels these tills are separate stratigraphic units.

Retreat of the glacial ice margin caused proglacial lakes to form and cover much of southwestern Ontario. In the part of the map-area north of Highway 401, glaciolacustrine clays; lacustrine sands, silts, and clays; and alluvial fine sand and silt accumulated. The history of these postglacial lakes is well recorded in adjacent map-areas, but as the Chatham-Wheatley area is relatively low in elevation, only fine-grained sediments accumulated here.

Economic Geology

In this area, oil and gas have been produced continuously for the past century. A resurgence in exploration activity has, however, been noted in the last few years. Several new gas fields have recently been drilled offshore in Lake Erie.

Surface deposits of sand and gravel are meagre and generally of poor quality. The resources remaining are located along a narrow beach ridge following Highway 3. The potential of this area for buried sand and gravel, however, is believed to be high. Two commercial operations at Pinehurst are presently stripping up to 7 m of clay overburden from a thick zone of sand and gravel which continues to the bedrock. Several potentially viable buried aggregate zones were noted during this survey. These will require more detailed work before their economic viability can be determined.

References

Chapman, L.J., and Putnam, D.F.

Fitzgerald, W.D.
No. 21 Quaternary Geology of the Orillia Area (31 D/11), Victoria and Simcoe Counties, Southern Ontario

P.F. Finamore¹

Introduction
The Orillia map-area (NTS 31 D/11) is bounded by Latitudes 44°30' and 44°45'N and Longitudes 79°00' and 79°30'W. The area includes the city of Orillia, the communities of Atherley and Cumberland Beach, and several smaller rural communities. Farming and tourism are the major industries of the area. The present study was undertaken during the summer of 1981 and work was concentrated in the eastern half of the map-area.

Physiography
The Orillia area is in the northern part of the West St. Lawrence Lowland division of the St. Lawrence Lowlands physiographic region (Bostock 1969). The extreme northern fringe of the study area marks the beginning of the Canadian Shield.

¹Graduate Student, Department of Earth Sciences, University of Waterloo, Waterloo.

The Lowlands can be further subdivided into three main physiographic regions, namely the Simcoe Uplands, Simcoe Lowland, and the Carden Plain (Chapman and Putnam 1966).

The Simcoe Uplands are made up of several islands, peninsulas, and headlands of glacial Lake Algonquin (Deane 1950). Consequently, several beach strands and terraces, most of which belong to glacial Lake Algonquin and its successors, are recorded. The Uplands are dominantly composed of till and ice-marginal features. In contrast, the Simcoe Lowlands, which include the basins of Lakes Simcoe and Couchiching, occupy a relatively flat-lying clay plain dotted with drumlins. The Carden Plain region is situated in the northeastern part of the map-area, and is characterized by shallow drift-covered limestone bedrock.

Bedrock Geology
The study area is underlain by Middle Ordovician rocks of the Verulam, Bobcaygeon, Gull River, and Shadow Lake
Glacial deposits in the Orillia area are probably Wisconsinan in age. Ice movement was generally in a south-southwesterly direction, as suggested by various ice flow directional indicators. Crosscutting striae were observed south and north of Canal Lake, in the southeastern corner of the map-area. Both localities exhibit south-southwesterly trending striae with a variance of between 15 and 30 degrees. Although these striae can be explained in terms of a single ice advance, they may represent more than one event, for example, R.E. Dean (1950) believed the Simcoe Moraine to represent a readvance of late Wisconsinan ice.

The texture of the till in the area ranges from stony and gritty, silty, very fine sand to sandy silt. The till is usually compact and fissile and occurs in the form of drumlins, end moraine, and ground moraine. It is usually shallow in the northern and eastern part of the map-area and becomes progressively thicker towards Lake Simcoe and westward. Variations in till texture were observed in several localities, but most notably near the community of Brechin, southwest of the Simcoe Moraine. Here, the "till" consists of clayey silt to silt with a few grits and pebbles. Although the material resembles till, the well-sorted nature of the matrix suggests that it has been water-laid.

Glaciofluvial deposits in the form of esker ridges occur near Dalrymple Lake and northeast of Logan Hill. These deposits are small in size and are in part overlain by lacustrine sands and silts. Both eskers terminate along the ice-marginal position defined by the Simcoe Moraine at Logan Hill and 4.5 km northeast of Udney.

Glaciolacustrine sands, silts, and clays are widespread throughout the map-area. Although the vertical gradation from sand to clay (with depth) is common, there are areas where varved clays are underlain by laminated sands.

Beach deposits of sand and gravel are commonly found to be associated with the abandoned shorelines of glacial Lake Algonquin and its successors. The shorelines are defined by beach ridges, spits, bars, and erosional features. Dean (1950) has documented the levels of glacial Lake Algonquin in considerable detail. Approximately 1 km west of Kirkfield, a beach ridge approximately 18 m above the main Algonquin beach was encountered. Possible beach deposits in the southwest and southeast corners of the map-area appear to be well above the main Algonquin level as well. It is not yet known whether these levels are related to an undefined level higher than the main Algonquin level, or whether they represent a known glacial lake whose extent and size is poorly understood. For example, Chapman and Putnam (1966) have regarded beaches on the slopes west of Lake Simcoe, which are approximately 30 m above the main Algonquin beach, as belonging to a lower stage of Lake Schomberg.

Accumulations of organic matter in the form of peat and muck are widespread throughout the map-area. The thickness of the peat is variable, and it commonly overlies lacustrine sediments.

Economic Geology

Numerous sand and gravel pits which are either inactive or active on demand can be found throughout the map-area. Most of the pits are located in the beach deposits of glacial Lake Algonquin. The large kame moraine deposit at Logan Hill is perhaps the largest source of naturally occurring aggregate in the area. It has been used intermittently since 1945.

Because of the irregular distribution and relative lack of sand and gravel, quarrying of the limestone bedrock is occurring at the present time. Two quarries south of Brechin in Mara Township extract large quantities of crushed stone, some of which is exported to urban centres outside the map-area.

References

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Deane, R.E.
Liberty, B. A.

White, O. L., Karrow, P. F., and Macdonald, J. R.
Introduction

The area under investigation is bounded by Latitudes 44°45' and 45°15'N and Longitudes 79°30' and 80°30'W; a total area of 4320 km². Approximately 40 percent of the area is covered by water. The field work during the summer of 1981 forms the first of a two-year study of this southeastern part of Georgian Bay, and the present report must be considered as tentative. Field mapping was conducted over a three-month period between June and August 1981. The purpose was: 1) to describe the nature and extent of Quaternary deposits, and 2) to identify and measure indicators of ice flow and to determine the glacial history and stratigraphy of the area. Particular attention was paid to the diversity and genesis of till and the sequence of post-glacial lake shorelines, since they have a direct effect on local Quaternary sediments and their characteristics.

Access to the field area varied, from abundant paved, forest access, and recreational roads in the Penetang Peninsula, to the area west of Highway 69 where the lack of roads and preponderance of lakes, inlets, and swamps make access difficult. Investigation in this latter area can only be made effective by boat. The numerous small islands around Georgian Bay also posed problems of accessibility, but in general, these islands are essentially bare rock outcrops.
In addition to the field work, detailed analysis of air-photographs, at scales of 1:15 840 and 1:63 360, well-log data, geophysical reports, soil surveys, and geological reports was also undertaken.

Within the field area, there are several Indian reservations; the Parry Island, Moose Point, Gibson, and Christian Island Indian Reserves. No investigations were carried out within these reservations during the field season.

A general introduction to the area may be found in the works of R.E. Deane (1950), L.J. Chapman and D.F. Putnman (1966), and V.K. Prest (1968).

Bedrock Geology

The field area is underlain by two distinct bedrock regions. The area north and northeast of Severn Sound and Giant Tombs Island is underlain by Precambrian rocks, and forms part of the Muskoka Domain of the Central Gneiss Belt of the Grenville Structural Province (Davidson and Morgan 1980). The Muskoka Domain is characterized by "parallel, northwest-trending belts of relatively straight-layered gneiss in amphibolite facies. separated by terrains with less regular structural trend, higher metamorphic grade, and a higher proportion of orthogneiss, some of which is charnockitic" (Davidson and Morgan 1980, p.294). The major geologic structure within the Muskoka Domain is the Moon River structure, a synform-antiform group, situated west of MacTier.

The remaining area (i.e. Penetang and adjacent Peninsula, and Christian Island Indian Reserve) is underlain by bedrock units of the Middle Ordovician Basal and Simcoe Groups. B.A. Liberty (1969) has described two formations in the area; the Shadow Lake and Gull River Formations. The youngest, the Gull River Formation, which conformably overlies the Shadow Lake Formation varies from a grey and brown, fine-grained limestone and dolomitic limestone to a grey and brown, dense, sublithographic to lithographic limestone. The oldest, the Shadow Lake Formation, is a greenish grey, coarse-grained calcareous arkosic sandstone overlain by red and green arenaceous shale and rests unconformably on the Precambrian surface.

It appears that the presence or absence of Paleozoic rock in a given area is entirely dependant on the relief of the Precambrian bedrock surface. The Paleozoic-Precambrian boundary traverses the map-area; a boundary which is often indistinct. Outliers of Paleozoic rocks are present but rare, such as the one northwest of Lovering, and similarly, inliers of Precambrian rock occur, for example on the northeast side of the Penetang Peninsula.

Physiography

The bedrock, the topography, and the distribution of Quaternary materials give rise to three physiographic units over the field area.

The areas underlain by Paleozoic rocks in the Penetang and adjacent peninsulas, are characterized by an almost complete cover of glacioluvial or lacustrine deposits. Exceptions to this are the bedrock exposures on the Port McNicoll and Victoria Harbour Peninsulas. Drift thickness can exceed 150 m. The highest point within this physiographic region is Lafontaine Hill (328 m). Several small hills also reach above 300 m above sea level. Many of these highland areas are extensively gullied, although much of the Penetang Peninsula has had very little stream dissection because of the sandy nature of the superficial material.

The second major physiographic region lies to the east of Highway 69, and may be described as a mixture of clay plains (notably in the south), glacioluvial, and glaciolacustrine deposits, above which a minor but significant proportion of bare rock ridges is exposed. The proportion of bare bedrock ridges to surficial sediments before present northwards is drift thickness decreases. Elevation generally rises toward the northeast from lake level, approximately 177 m above mean sea level to 320 m above sea level north of High Lake in the Township of Muskoka Lakes. This rise is a gradual one, and local relief is less than 30 m.

The third physiographic region is west of Highway 69. It is characterized by an indented coastline, numerous small rock-knob islands, and a mainland terrain dominated by exposed wave-washed bedrock ridges with organic terrain in intervening depressions. The area is generally low-lying, only reaching above 230 m above sea level in Conger Township to the north. Local relief is low (<20 m).

The map-areas are drained by two major river systems, the Moon and the Severn river systems, both of which trend in an east-southwest direction. Numerous lakes of which Lake Rosseau, Lake Muskoka, and Lake Joseph are the largest, occur within the Precambrian area, and are mostly situated in the northern and eastern parts of the area.

Quaternary Geology

Deposits predating the Late Wisconsinan are not evident in the field area. Morphological indicators indicate that regional ice movement was from the north-northeast. Bedrock control appears to be generally small, although may have been locally significant. The glacial phase ended in this part of Central Ontario about 12 500 years before present (Prest 1968). Ice front recession lead to the creation of a series of large inland lakes; initially Lake Algonquin (approximately 11 000 years before present, Karrow 1980), which was drained through successively lower outlets until the low Lake Hough stage was reached. A rise in lake levels led to the major Lake Nipissing stage approximately 5 000 years before present (Karrow 1980). The whole area shows considerable evidence of washing by lake waters, and thus the sequence of post-glacial lakes are important elements of the area's
Quaternary history. Altitudinal differences in sediment composition are especially apparent.

Investigations revealed that two distinct types of 'till' are exposed within the field area. First, an unmodified, overconsolidated dark-greyish brown (10YR4/2) till with a silty-clay matrix and a clast content of a mixture of carbonate and Precambrian rocks in about equal proportions. Many of the carbonate clasts exhibit the characteristic 'bullet' shape of subglacially transported and deposited material, as well as possessing many fine striations of a chaotic orientation. Secondly, a wave-washed 'till' unit. This unit is normally consolidated with a fine sand matrix, and possesses a clast content low in carbonates (<5 percent). Clasts did not exhibit striations and often had a pitted surface or had undergone disintegration in situ. The existence of lenses of sorted material were also noted in this wave-washed unit, which occurs at all elevations over the map-area. The assignment of the term 'till' in this case is thus only in recognition of its original genesis. Morphological expressions of till are noted in the fluted surfaces of Lake Algonquin 'islands' in Tiny Township and drumlins on the Port McNicoll and Victoria Harbour Peninsulas.

Glaciofluvial and ice contact deposits exist in only localized areas of the field area, and are possibly related to discharge into Glacial Lake Algonquin, which may have been ice marginal. Deposits north of Northwest Basin and north of Lafontaine Hill in Tiny Township, and the kame north of Warbashene in Tay Township are examples. Others occur in the townships of Muskoka Lakes, Georgian Bay, and Conger, and in the township of Gravenhurst near Bala.

Of greatest significance within the study area are the lacustrine deposits. Lake Algonquin covered the whole area, except for some small 'islands' on the Penetang Peninsula. Thus the area below 256 m above mean sea level has been subject to extensive lake action, but over varying time periods. Deposits therefore generally range altitudinally from wave-washed-till through well-sorted lacustrine sands to clays, which are most evident in the south and east parts of the Penetanguishene (31 D/13) Map Sheet. Lake deposits often overlie till. Shorelines associated with the lake sequence described earlier are well preserved on the Penetang Peninsula where many of the type-sectors for the classic post-Algonquin sequence described by G.M. Stanley (1936) were identified. The Algonquin and Nipissing bluffs are by far the most significant; the latter rising to heights of over 45 m above the lake in some locations. Shoreline evidence is not well-preserved on the hard Precambrian terrain.

Organic sediments (peat and muck) cover a large part of the Pentanguishene (31 D/13), Lake Joseph (31 E/4) and San Souci (41 H/1) Map Sheets, often being found within depressions between bedrock ridges. Organic sediments often overlie lacustrine clays.

Economic Geology

The most significant economic minerals in the field area are sand and gravel. On the Penetang Peninsula a large number of pits are present, but many are small and composed entirely of sand. The largest pits are those contained in the deltaic or ice-contact deposits, where a large range of particle sizes exist. These aggregate deposits are used locally for asphalt, concrete, and in construction material.

Sand and gravel pits on the Precambrian Shield are few in number. These deposits result from glaciolacustrine and glaciofluvial environments along the margins of ancestral Lake Algonquin. The large pits are situated near Bala, Ullswater, Cox Bay, and Footes Bay. These deposits yield a lower quality aggregate generally not suited for asphalt or concrete.

Limestone is drilled and crushed for aggregate near Lovering in Tay Township.

References


No. 23 The Geology of the Paleozoic Outliers on the Canadian Shield

D.J. Russell

Introduction

At least five outliers or groups of outliers of Paleozoic rocks occur on the Ontario part of the Canadian Shield, isolated from the main Paleozoic basins of southern Ontario and Hudson Bay. These fault controlled outliers, which were studied during the 1981 field season, are associated with the Ottawa-Bonnechere graben system and its extensions to the west (Lake Nipissing) and north (Lake Timiskaming). The work is aimed at effecting correlations between the outliers and the main basins, as well as determining their areal extent.

Location

The main Paleozoic outlier extends northwest of Lake Timiskaming, and is covered by the following 1:50 000 NTS Sheets: 31 M/5, 31 M/12, and 31 M/13. Fault blocks of Ordovician rocks occur in Renfrew County south of Pembroke, in the area covered by NTS Sheets 31 F/6, 31 F/7, 31 F/10, 31 F/11, 31 F/14, and 31 F/15, (see location diagrams). Small faulted outliers occur at Brent (Longitude 78°29'W, Latitude 46°2'N); on the Ottawa River near Deux Rivieres (Longitude 78°22'W, Latitude 46°16'N); west of the town of Nipissing (Longitude 79°33'W, Latitude 46°16'N); and on the Manitou Islands in Lake Nipissing (Longitude 79°35'W, Latitude 40°16'N). A unit of probable Paleozoic age occurs on Iron Island, Lake Nipissing (Longitude 79°53'N, Latitude 80°1'N).

Lake Timiskaming Outliers

General Geology

The fault block north of Lake Timiskaming is the only outlier in which both Ordovician and Silurian strata are represented. Outcrop in this outlier is fair at the south end, although concentrated in the topmost Silurian formation. Towards the north, outcrop becomes relatively sparse, being covered by clays deposited in glacial Lake Barlow-Öjibway. Table 1 shows the stratigraphy of the Lake Timiskaming Outlier.

The Precambrian-Paleozoic unconformity is exposed in only two locations in the Ontario part of the outlier. The Guiges Formation is the basal unit on the lakeshore exposure at the lumbermill near Haileybury; the Farr Formation overlies Precambrian on the west side of Casey Mountain. This illustrates the significant relief on the Precambrian surface. The Guiges Formation, as determined from limited outcrop and drillcore, consists of terrigenous sediments, mainly sandstones, and conglomerates, but with a 15 m red shale bed at the base in some locations.

The contact with the overlying Bucke Formation is not exposed, but is considered disconformable from faunal evidence (Bolton and Copeland 1972). The Bucke Formation consists of fissile shales, shaly limestone, and nodular limestones with shaly partings. It is exposed in a small overgrown quarry above the lumbermill mentioned above and at the New Liskeard dump.
TABLE 1

<table>
<thead>
<tr>
<th>STRATIGRAPHY OF LAKE TIMISKAMING OUTLIER.</th>
</tr>
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<tbody>
<tr>
<td><strong>MIDDLE SILURIAN</strong></td>
</tr>
<tr>
<td>Thornloe Formation</td>
</tr>
<tr>
<td>Wabi Formation</td>
</tr>
<tr>
<td><strong>MIDDLE AND UPPER ORDOVICIAN</strong></td>
</tr>
<tr>
<td>Dawson Point Formation</td>
</tr>
<tr>
<td>Farr Formation</td>
</tr>
<tr>
<td>Bucke Formation</td>
</tr>
<tr>
<td>Guiges Formation</td>
</tr>
<tr>
<td><strong>PRECAMBRIAN</strong></td>
</tr>
<tr>
<td>Undifferentiated igneous and metamorphic rocks.</td>
</tr>
</tbody>
</table>

The Bucke Formation is overlain by the mottled heavily burrowed fossiliferous limestones of the Farr Formation. This unit outcrops widely in the area west of Haileybury, especially along Highway 11. An abundant fauna of gastropods and strophomenid brachiopods indicate a similar age to the Lindsay Formation of southern Ontario (Sinclair 1965; Liberty 1969).

The uppermost Ordovician unit, the Dawson Point Formation, is only observed in drillcore (Thomson 1965). A sharp lower contact separates the Farr Formation from the soft green and grey shales of the Dawson Point Formation, which contain fauna characteristic of the Whitby Formation in southern Ontario (Sinclair 1965). The four Ordovician formations make up the Liskeard Formation of G.S. Hume (1925) or Liskeard Group of G.W. Sinclair (1965).

Silurian strata are divided into two formations, the Wabi Formation and the Thornloe Formation. The lower, Wabi Formation is exposed along the east side of Dawson Point and along Evanturel Creek near Englehart. It is composed of various coloured finely crystalline, frequently oolitic limestones, with beds of green and grey shale. Sedimentary structures show it to have been deposited in shallow water. Small gastropods and bivalves are common in thinly bedded limestone units of the Wabi Formation, but the ostracod fauna allow correlation with the Manitoulin, Cabot Head, and Dyer Bay Formations of Manitoulin Island (Bolton and Copeland 1972).

The Thornloe Formation is exposed as a 50 m cliff on the east side of Dawson Point as well as extensive bedrock pavements and small quarries. In this cliff section and on Mann Island, Quebec, the lower contact with the Wabi Formation appears unconformable, but at other locations sedimentation appears to have been continuous. The lower part of the Thornloe Formation is a thin bedded finely crystalline bioclastic or fossiliferous limestone. Upper parts of the formation are more massive, sometimes reefy, dolostones. The Thornloe Formation can be correlated with the Mindemoya, Fossil Hill, and Amabel Formations.

**Structural Geology**

H.L. Lovell and T.W. Caine (1970) summarize the evidence for the existence of the Lake Timiskaming Rift Valley. The western edge of the outlier is defined by the Major Mackenzie Fault, although the Lake Timiskaming West Shore Fault, which lies a few hundred metres to the east, is more significant in terms of displacement (approximately 300 m). These shears parallel the trend of many other faults which affect Precambrian rocks only, for example the Montreal River Fault. The regional dip is 3° towards the west, but this increases to up 30° between the faults. There is no exposed evidence for these or any other bedrock faults in the northern part of the outlier. H.L. Lovell (1977) has postulated fault locations in this area using lineaments in drainage courses. The eastern faulted boundary of the outlier is not exposed.

**Economic Geology**

Numerous abandoned quarries exist in the area. High purity lime was extracted from quarries in the Farr Formation. Crushed rock and building stone was produced from many small quarries in the Thornloe Formation.

**Renfrew County Outliers**

**General Geology**

The stratigraphy of the Ordovician rocks of Renfrew County is shown in Table 2. The lowest exposed strata are red and green siltstones with dolostones, ascribed to the Oxford Formation (Wilson 1946). These outcrop at Douglas, on the Bonnechere River, and at the Highway 65 bridge over the Ottawa River. The latter location is the only outcrop where the Precambrian/Paleozoic unconformity is seen in Renfrew County.

Overlying these sediments is the Ottawa Formation, which makes up all other Paleozoic outcrops in the area but one. Outcrop is fair, but concentrated along the Bonnechere River, in quarries, and at the scarps formed by the depositional contact with the Precambrian. This formation is composed of various dark grey and blue-grey limestones. Biomicritic and calcarenitic facies are dominant, but nodular shaly limestones and a massive dolomitic unit are present near the top of the formation. C.R. Barnes (1967) identifies various formations within an Ottawa Limestone “Mega-group”. However, subdivisions of the Ottawa Formation are impossible to map throughout the area due to widespread faulting and flexures. A single outcrop of post-Ottawa Formation rocks exists at Lake Clear. Here, the Mount St. Patrick Fault has preserved alternating fissile black fossiliferous shales and shaly limestones of the Billings Formation.

**Structural Geology**

The outliers of Renfrew County are preserved by down faulting associated with the Ottawa-Bonnechere Graben.
TABLE 2 | STRATIGRAPHY OF THE ORDOVICIAN ROCKS OF RENFREW COUNTY.

<table>
<thead>
<tr>
<th>STRATUM</th>
<th>DESCRIPTION</th>
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<tbody>
<tr>
<td>UPPER ORDOVICIAN</td>
<td></td>
</tr>
<tr>
<td>Billings Formation</td>
<td></td>
</tr>
<tr>
<td>MIDDLE ORDOVICIAN</td>
<td></td>
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<tr>
<td>Ottawa Formation</td>
<td></td>
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<tr>
<td>LOWER ORDOVICIAN</td>
<td></td>
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<tr>
<td>Oxford Formation</td>
<td></td>
</tr>
<tr>
<td>PRECAMBRIAN</td>
<td></td>
</tr>
<tr>
<td>Undifferentiated igneous and metamorphic rocks</td>
<td></td>
</tr>
</tbody>
</table>

The southern boundary of this feature, the Mount St. Patrick Fault, is the only fault which preserves Paleozoic rocks with downthrow to the north. Its greater downthrow enables the preservation of shales of the Billings Formation. All other outliers are preserved by faults with downthrow to the south. Minor faulting within outcrops is common, so correlation between outcrops is tentative. Bedding is virtually horizontal away from major fault zones, but dips increase close to faults.

Economic Geology

Although no active quarrying of Paleozoic bedrock is being carried out at present, there are numerous abandoned quarries in the Ottawa Formation. This unit was a source of both lime and crushed rock.

Ottawa Valley-Lake Nipissing Outliers

Several small outliers are aligned along the west-northwest extension of the Ottawa-Bonnechere system. At Brent, several hundred metres of Paleozoic sediments exist unexposed in the centre of Brent Crater. Paleozoic rock is exposed, however, at Cedar Lake, south of the crater. The sequence there consists of about 3 m of thinly bedded burrowed dark grey limestone and sandy limestone.

A small part of a large fault block, the major part of which is on the Quebec side of the Ottawa River, is present near Deux Rivières. Outcrop is very poor, but the main lithology present is a coarsely crystalline brown bioclastic limestone.

At least 8 m of Paleozoic sediments are associated with the Manitou Islands alkali igneous complex, in Lake Nipissing. The basal unit here consists of a terrigenous sequence dominated by conglomerate, the granitic boulders of which are distinctively different from the underlying Cambrian alkali igneous rocks (Lumbers 1971). Overlying this is a sequence of sandy dolostone, thinly bedded finely crystalline limestone, and massive dolostone. On Iron Island, at the western end of Lake Nipissing,

ing, at least four metres of unfossiliferous, medium and coarse-grained parallel laminated and cross bedded sandstone are exposed. This rock is heavily weathered, but a barite cement is observable in unweathered sections.

Just west of the town of Nipissing, a small fault block of Paleozoic rocks is exposed along the Nipissing Fault, which S.B. Lumbers (1971) regards as representing, in part, the westerly equivalent of the Mount St. Patrick Fault. There is over six metres of massive bedded conglomeratic dolostone, sandy and fossiliferous or bioclastic dolostone with some green silty shale. The Paleozoic unconformity is exposed in the access track to the excavation where the main exposure is seen.

None of these small outliers support any quarrying operations at present.

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No. 24 Aggregate Resources Inventory of Southern Ontario

Staff of the Aggregate Assessment Office

Introduction

Field work was conducted in several areas of southern Ontario during 1981 as part of the Aggregate Resources Inventory Program. Field investigation is an integral step in the preparation of each aggregate report. Results of field activity undertaken in 1981 will be published in several Aggregate Resources Inventory Papers. The main areas involved in field investigations were:

1) The London-Middlesex area;
2) The Regional Municipality of Halton;
3) Grey County;
4) Simcoe County;
5) The Woodstock-Norwich area.

Field investigations consisted of the following activities: examination of existing pits, quarries, and natural and man-made exposures; as well as subsurface drilling. In the field, all active and abandoned pits were investigated. At each site the following observations were made: face height; percentage of gravel and sand; and the presence of deleterious material such as chert, shale, clay, silt, and oversized boulders. Other information gathered during the pit investigation included the intended uses of the granular material, and the presence of stockpiles, water-filled ponds, a crushing plant, and rehabilitation work. Abandoned pits were evaluated as well to provide additional information on resource areas. Estimates of the amount of material previously extracted in these pits were made to enable resource tonnage calculations. Active and abandoned quarries were also visited; at these sites, the height of the face was noted as well as bedrock geology and the presence of deleterious materials. The purpose of the field investigation was to confirm and add to information gathered from various sources such as existing geological reports and maps, data from the files of the Ontario Ministry of Transportation and Communications, and to obtain water well data from the Ministry of the Environment.

In areas where little pre-existing data were available, or where the presence of buried granular material is suspected; drilling was undertaken. In the 1981 field season, drilling was performed in two ways. First, a portable drill operated by the Engineering and Terrain Geology Section was used to perform preliminary drilling and assessment. Secondly, a large rig was contracted to perform drilling and sampling in the most promising areas. Drilling was performed in two major areas in 1981; these were the southern part of Grey County and the Woodstock area. In addition, several test holes were drilled in the vicinity of Kitchener and Brantford.

London-Middlesex Area

Field activity in the London-Middlesex area took place in the townships of Delaware, Westminster, North Dorchester, and West Nissouri. Pits within the City of London were also inspected. Sand and gravel in this area was deposited in large outwash-deltaic complexes which were laid down in glacial lakes Whittlesey and Maumee. In addition, a large buried deposit identified by E.V. Sado (1980) was found in North Dorchester Township.

Regional Municipality of Halton

Three municipalities within the Regional Municipality of Halton were field checked, namely the towns of Halton Hills and Milton and the City of Burlington. Although surficial sand and gravel resources are limited in the region, it contains substantial reserves of bedrock resources. Crushed stone is produced from dolostone of the Amabel Formation. Sandstone from the Whirlpool Formation is suitable for use as building stone. Shale and clay derived from the Queenston Formation constitutes a high-quality resource for the structural clay products industry. Because of intense pressure from urban development, the identification of the best resource areas in the region is very important in order that they are not sterilized for future use.

Grey County

The four townships of Bentinck, Glenelg, Normanby, and Egremont in southern Grey County contain large re-
sources of granular material. These deposits were laid down as a result of the stagnation and retreat of the Huron ice margin in Late Wisconsinan time. In addition to the field checking of pits and other exposures, subsurface drilling was also carried out in 1981. Twenty-eight test holes were sunk in the area in order to assess resources of crushable aggregate. Drilling was carried out to an average depth of 10 m. Many of the test holes revealed the presence of good crushable gravel.

Simcoe County

The townships of Medonte, Tiny, Tay, Matchedash, and Orillia in the northern half of Simcoe County were investigated in 1981. The dominant gravel-bearing feature is the Bass Lake Kame Moraine which skirts the southern boundary of Medonte Township. The sand and gravel resources in the remaining townships are mainly concentrated in glaciolacustrine beach deposits associated with the various elevations of glacial Lake Algonquin. Field investigations were carried out to determine aggregate deposits, pits, and the highest potential aggregate resource areas.

Woodstock-Norwich Area

As a continuation of field work commenced in 1980, subsurface drilling was undertaken around Woodstock in the townships of Southwest Oxford and Norwich. The drilling was undertaken in an interlobate area between the Huron and Erie ice lobes. This area, capped by Tavistock Till, is underlain by granular material. The underlying sand and gravel is exposed on the flanks of the hills and ridges, and in several gravel pits. Drilling was conducted in the central part of the area to determine the extent and quality of the gravel. One test hole revealed crushable gravel, while several others indicated sand with low concentrations of gravel.

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No. S9 Quaternary Geology of the Bannockburn (31 C/12) 1:50 000 Map Sheet, Southeastern Ontario

B.S. Goldstein

THIS PROJECT WAS JOINTLY FUNDED BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUDSIDIARY AGREEMENT.

Introduction

The Bannockburn (31 C/12) map-area is bounded by Latitudes 44°30′N and 44°45′N, and Longitudes 77°30′W and 78°00′W. The area includes portions of Tudor Lake, Marmora, Madoc, and Grimsinorpe Townships in Hastings County, and Methuen, Belmont, Dummer, and Chendos Townships in Peterborough County. Field mapping of the Quaternary surficial deposits of this area was conducted during the summer of 1981. Examination of deposits at natural and man-made exposures and in test pits along highways, logging roads, and ground traverses was supplemented by the use of 1:15 840 scale air photographs. Earlier mapping on a broader scale has been conducted by E.P. Henderson (1972) and L.J. Chapman and D.F. Putnam (1972).

The northern portion of the map-area is located at the southern edge of the Canadian Shield. The Shield rocks consist of a complex of Precambrian granites and granite gneisses, mafic volcanic rocks, intrusive rocks, metamorphosed carbonate, and fine- to coarse-grained clastic metasediments. Deposits of gold are associated with the oval-shaped Cordova gabbro. An elliptical intrusive body of nepheline syenite underlies Blue Mountain. The irregular southern boundary of the Shield is marked by small outliers (averaging 2 to 6 km² in area) of Ordovician carbonates, shales, and basal clastics, and is succeeded to the south by a terrain continuously underlain by these rocks. A bedrock map of the region has been compiled by D.F. Hewitt (1957); and D.M. Carson (1980) has recently mapped the Paleozoic geology of the area.
Physiography

Drainage throughout the region is to the south via the Crowe River and its tributary, Beaver Creek, in the west, and the Moira River in the east. Generally poor surface drainage in the Shield area results in a considerable cover of bogs and swamps in the north. Total relief is more than 180 m. Land exceeding 365 m above sea level in elevation occurs at the fire tower south of Harper Lake, and areas of less than 185 m above sea level are present along the shores of Crowe Lake, in the south. Local relief is up to 80 m along watercourses in the Shield terrain, while a maximum of only 15 m is the rule on the Paleozoic limestone plains. The major geomorphic features are the scattered areas of Dummer hummocky moraine, which merge to the south and southwest with a more continuous cover of Dummer moraine; and the interspersed, broad, high plains underlain by Ordovician limestone bedrock. Precambrian hills covered by thin soils, separated by bogs and swamps, dominate the north.

Quaternary Geology

Only deposits of the last stage of the Wisconsinan Laurentide ice sheet are present in the area, and these are primarily confined to the east-trending belt of Dummer moraine along the south. Except for two large isolated drumlins of till in the north, the exposed Shield area attests to effective glacial scouring during this stage. The drumlins indicate a flow pattern towards S5W in the north, while glacial striae and roche moutonnees farther south range from orientations of S20W to S55W, reflecting bedrock control on local ice flow. The Dummer moraine is composed of a complex of coarse, bouldery, loose deposits arranged in irregularly shaped hummocks less than 15 m high. The easterly trend of this hummocky belt does not necessarily belie the flow direction indicators discussed above, as the distribution of the moraine is strictly controlled by the presence of its primary bedrock source, the Paleozoic outliers and the continuous Paleozoic terrain south of the Shield. Large boulders up to 2.5 m across, plucked along bedding planes, form the major component of any till deposit just south of an outlier. This bouldery till is gradually replaced to the south by a more continuous cover of hummocks composed of a greater proportion of matrix. This relationship between bedrock source and distance of transport of subglacially abraded material explains the mosaic-like distribution of Dummer hummocks, as well as most of the variability in till lithology and texture. In addition, crudely sorted gravel fans occur throughout the Dummer moraine. They are the result of in situ reworking of hummocks by the direct action of melting glacial ice.

Sand and gravel occurs in three distinct geomorphic associations. The most abundant and widespread are loose, mostly massive (non-bedded) deposits of outwash sands draped over local low spots in the underlying bedrock topography. These are generally confined to the region north and northwest of Crowe Lake. Northeast of Crowe Lake, high terrace and bar sands and gravels are arranged primarily along the valleys of the present-day Beaver Creek and Moira River. They are deposits of a more integrated proglacial drainage system. In the vicinity of Malone, they include features formerly mapped as eskers by Chapman and Putnam (1972). Effective meltwater erosion has resulted in the scouring of channels up to 31 m deep into bedrock, in this vicinity, that presently have no streams. Finally, a delta at the northern end of Crowe Lake marks the apparent termination of these two outwash systems in a high (approximately 230 m above sea level) stage of this lake.

Economic Geology

The valley train deposits of Beaver Creek and the Moira River have been exploited for sand and some gravel, with a large part of these deposits still within easy access. The same is true for the coarse-grained gravel found in fans throughout the Dummer complex, and the well-sorted medium-grained sands of the delta north of Crowe Lake. The discontinuous nature and remote locale of the outwash “drape” deposits elsewhere, usually preclude the development of any extensive workings, but locally some pockets up to 5 m thick have provided a good aggregate source, where adjacent to logging or county roads. Quarrying of the limestone bedrock for use in concrete is common along the north-facing escarpment edges of the Paleozoic outliers, while large open-pit mining operations in nepheline syenite are underway at Blue Mountain.

References


J.G. Leyland

Introduction

Mapping of the Tweed, Belleville, and Wellington areas involved re-examination of three map-areas which were initially included in a regional study of Southern Ontario by L.J. Chapman and D.F. Putnam (1966). Preliminary maps prepared later by E. Mirynech were placed on open file by the Geological Survey of Canada in 1978. The areas are being remapped in view of recent revisions that have been published on the glacial and postglacial history of southern Ontario. Fieldwork for the present study was conducted during the 1981 field season.

1Graduate Student, Brock University, St. Catharines, Ontario.
ENGINEERING AND TERRAIN — SPECIAL PROJECTS

Location

The Tweed, Belleville, and Wellington map-areas lie between Latitude 40°30’N and Lake Ontario to the south and between Longitudes 77°00’ and 77°30’W.

Bedrock

Bedrock in this area consists primarily of middle Ordovician limestones of the Simcoe Group which overlie Precambrian metasediments and metavolcanics of the Grenville Province. Most of the bedrock in the map-area is medium- to thick-bedded limestone, shaly limestone, and bioclastic limestone with some calcarenite (Carson 1981a, 1981b; Liberty 1961, 1963).

Precambrian exposure is limited to the northern part of the Tweed map-area and to several small inliers throughout the remainder of the map-area.

Physiography

Chapman and Putnam (1966) have divided the map-area into three main physiographic regions; the Dummer Moraines, the Napanee Plains, and the Prince Edward Peninsula. The topography of all three regions is controlled primarily by the bedrock, because drift is thin throughout much of these areas. The most notable features of the areas are: 1) the north-facing bedrock escarpments; 2) moderate to weak drumlinization; and 3) the hummocky topography of the northern two-thirds of the Tweed map-area, a part of the Dummer Moraines of Chapman and Putnam (1966) where drift thickness may locally exceed six metres.

Local areas of thick drift (greater than 50 m) exist in the northwest part of the Belleville map-area and the southwest part of the Tweed map-area.

Glacial and Post-Glacial Lakes

The only well-developed raised shoreline in the map-areas is that of Glacial Lake Iroquois. These features are restricted to the thick drift areas north and northwest of Belleville, in the area of Pancake Hill. The remainder of the map-areas is at an elevation below the Iroquois wave base. Shorelines from glacial and post-glacial lake levels below the Iroquois level are poorly developed and sparse, and indicate a short lifetime existed for lower lake levels and possibly reflects the lack of workable materials in many areas.

Quaternary Geology

The oldest identified features of the map-areas are the drumlins which are composed of moderately stony silty-sand to sandy-silt till. Drumlin orientation indicates strong ice flow occurred towards the south to southwest and that it curved to the west-southwest in Prince Edward County. The drumlins are sparsely distributed throughout the map-areas, but increase in density to the north and northwest of Belleville where drift thickens. Water well data from these drumlinized areas of thicker drift indicate the existence of a thin mantle of till over stratified sediments. The origin of the underlying stratified sediments has not yet been determined, but they may be part of the Oak Ridges Moraine.

Economic Geology

Aggregates are extracted mainly from esker deposits in the Tweed and Wellington map-areas and from Glacial Lake Iroquois shore deposits in the vicinity of Pancake Hill. Numerous small quarries are present in the map-areas, but most of these are either abandoned or intermittently active. Two large cement plant quarries are presently operating in the Belleville map-area, one at Point Anne operated by Point Anne Quarry Company, and one north of Picton operated by Lake Ontario Cement Limited.
References

Carson, D.M.


Chapman, L.J., and Putnam, D.F.

Liberty, B.A.


Mirynech, E.
No. S11 Stratigraphy and Sedimentation in the Munro Esker, East of Kirkland Lake, Districts of Cochrane and Timiskaming

C.L. Baker

THE WORK REPORTED HEREIN IS PART OF THE KIRKLAND LAKE AREA GEOSCIENTIFIC SURVEYS. IT IS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION AND THE ONTARIO MINISTRY OF NORTHERN AFFAIRS UNDER THE COMMUNITY AND RURAL RESOURCE DEVELOPMENT SUBSIDIARY AGREEMENT.

Introduction

Detailed investigations of the Munro Esker were carried out by the Engineering and Terrain Geology Section in the fourth year of the Kirkland Lake Incentives Program (KLIP), a joint Federal-Provincial project. The desire to utilize all prospecting tools in an attempt to detect high potential ore zones has led to increasing interest in esker sampling. Further progress and widespread acceptance of esker prospecting, however, suffers from a lack of basic knowledge and understanding of esker sedimentology.

The Munro Esker has been previously studied by H.A. Lee (1965, 1966, 1968) who investigated the potential of using this glaciofluvial feature for prospecting. Lee’s work provided encouraging results in that it demonstrated the presence of economically important mineral grains (i.e. gold) and the kimberlite indicator minerals (chrome diopside and pyrope garnet). The present study attempts to carry previous work a step further and define what parameters control the concentration of heavy minerals in the various facies of the esker, and how this can be related to transport distance and dispersion patterns.

The Munro Esker, between Catharine and Garrison Townships, was judged suitable for the study for several reasons:

1) The esker trends north and is perpendicular to the regional strike of the bedrock units, thereby incorporating all lithologies;
2) The esker is continuous for several tens of kilometres;
3) Numerous depositional environments are present and available for sampling along the esker’s course;
4) Exposures in the form of road cuts and gravel pits are plentiful, allowing large sections to be viewed and detailed stratigraphy to be recorded;

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles

1 Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.
The principal objectives of the study are to:

1) Identify the sedimentological facies present in the esker and determine the ice position and shape which controlled the deposition of the facies;
2) Record facies composition, distribution, and stratigraphic relationships;
3) Select representative samples of each facies type;
4) Study the incorporation rates and transport distances;
5) Determine how transport distance is reflected by size of material with regard to each litho-unit;
6) Identify ore zone and rock type indicator minerals; and,
7) Identify potential source areas for mineral anomalies resulting from geochemical and visual analysis.

In order to simplify the sampling of the remainder of the esker which is morphologically complex, sampling was restricted to the crests (distinct linear ridges running parallel to the orientation of the esker). As all eskers of various sizes possess well developed crests, results and sedimentological data obtained in this study can be a guide in the exploration of other eskers.

Sampling was completed by trenching using a backhoe mounted on a John Deere 540 skidder. Use of such equipment allowed off-road travel to sample points and access via overgrown forestry roads. Sampling depth (between 2 and 3 m) was dependent on the material encountered. Over a distance of 50 km, 49 samples were collected in 53 hours of equipment time. Routes and sampling points were selected after studying the aerial photographs and existing Quaternary maps.

Sample Collection and Processing
The number of samples obtained in each gravel pit was dependent on the type, size, and variation of the units present. Only one sample was collected per backhoe trench. Gravel units were field split using a 4 mesh (4 mm) sieve. Two bags of samples resulted: one of gravel, which ranged in size up to 8 cm; and one of the fine-grained fraction, predominantly sand, which weighed 7 to 8 kg. Only one sample was taken from sandy units or units containing a minor amount of gravel.

The gravel fraction was later washed and 100 clasts greater than 1.5 cm in length were split and identified. The 126 sand samples have been sent for processing to Overburden Drilling Management Limited Ottawa, where heavy and mid-density mineral assemblages will be separated and prepared for geochemical and visual examination.

Preliminary Results
The study of the stratigraphy and sedimentation of the Munro Esker has shown three distinct depositional environments, each with a unique morphology and sedimentological sequence. The most easily recognizable is the esker crest or ridge which rises as much as 50 m above the surrounding land surface. The crest of the Munro Esker is segmented, with individual portions ranging in length from 1 to 3 km. A composite section, pieced together from trenches dug in the crest, indicates that the crest is composed of a series of stacked sequences. The base of a sequence consists of coarse gravel, occurring as foresets, massive, or multi-storied assemblages, which fine upward. This is overlain by parallel-bedded sand and gravel capped by either trough cross-stratified material or sand waves. In rare instances the section is topped by a thin ripple-drift unit. All units dip southward, making the occurrence of sand as the surface material much more likely at the southern end of the ridges.

The second depositional environment is hummocky plains, located on either side of and between the esker.
crests. The material in this environment was deposited in a re-entrant in the glacier, which followed the esker back. The sides of this "fiord" were ice supported, and deposition occurred subaerially, at least in the upper portion, making this type of deposit the equivalent of outwash. Upward-fining stacked sequences occur here also. The basal unit is a fan-shaped gravel layer up to 10 m thick on the proximal side and thins to the south. Structures indicate that movement of material was by "sheet" flow and migrating gravel bars. The gravel grades upward into layers of parallel-bedded and tabular cross-stratified sand to pebbly sand. These deposits are in turn overlain by large-scale trough cross-stratification (migrating dunes) which may achieve a thickness of several metres. Intermittently the stream deposits are capped by ripple-drift or parallel-bedded sands.

The third major depositional environment is the flat-topped deltas marking the highest level of Lake Barlow-Ojibway which was ponded in front of the glacier as it receded. The deltas are sedimentologically simple, consisting of well sorted sand foresets overlain by 1 to 1.5 m thick topsets. Occasionally, braided stream deposits are encountered on the delta top. These streams transported material to the front of the delta slope during the final stage of delta deposition.

Continuing Work

Work in progress includes the identification of the gravel samples, and separation and analyses of the heavy mineral fraction of the sand samples. The following preliminary field observations are presently being investigated:

1) The material in the esker crest is closer to its bedrock source than sediments in the other two depositional environments;
2) The percentage of a lithology present in a gravelly unit is a function of that rock type (i.e. some rock types remain as large pebbles and therefore occur preferentially in coarse gravels);
3) A finer unit yields a greater weight percent of heavy minerals as compared to a coarser unit;
4) Free gold grains are concentrated in the gravel units.

References

Lee, H.A.

1966: Glaciolocus; Queen’s Printer, Ottawa.

Introduction

The Constance-Hanlon Lakes map-area is bounded by Latitudes 49°45' and 50°00'N and by Longitudes 83°30' and 84°30'W. The town of Hearst is located immediately to the south-southeast of the map-area, while the community of Calstock is centred in Studholme Township. Detailed field mapping (1:50 000 scale) and stratigraphic investigations were carried out during the summer of 1981. Delineation of surficial units was accomplished through airphotograph interpretation at scales of 1:50 840 and 1:63 360. Geotechnical borings provided data on subsurface conditions. Data were also obtained through the examination of natural and man-made exposures on ground and water traverses, and through the use of soil probing equipment. Helicopter support aided in sampling otherwise inaccessible areas. Selected stratigraphic sections beyond the limits of the map-areas were also examined.


Bedrock Geology

Bedrock geology of the Constance Lake Sheet (42 F/16) has been compiled by D.G. Innes and L.D. Ayres (1969), while the Hanlon Lake Sheet (42 G/13) has been mapped in a reconnaissance manner by Bennett et al. (1967).

Early Precambrian (Archean) gneiss complexes and migmatites of the Quetico Belt within the Superior pro-
vence underlie most of the study area and form northeast-southwesterly structural trends. These rocks are in metamorphic contact with adjacent belts of metagreywacke, iron formation, and mafic metavolcanic rocks. Granitic intrusions occur throughout the study area, and form batholiths, stocks, and lat-par-lit injections. Middle to late Precambrian diabase dikes occur along northeast-southwesterly structural trends. A carbonate intrusion of similar age is located on the Nagagami River west bank, north of Auden Township.

Paleozoic rocks of the Ekwan and Kenogami River Formations (Middle to Upper Silurian) form embayments in the northern part of Fushimi and Rogers Townships. A noteworthy 12 m section of Cretaceous varicoloured clays intercalated with silica sand was discovered at Limestone Rapids (50°02'N, 84°02'W) along the Kabinakagami River, a tributary of the Kenogami-Albany River system.

**Physiography**

The Constance-Hanlon Lake area is subdivided into four physiographic zones:

1. An area characterized by a bedrock-drift complex in the southeast quadrant of the Constance Lake Sheet and all but the northwest part of the Hanlon Lake Sheet. Till-capped rock bosses and domes punctuate the terrain, separated by flat to undulating lowlands underlain by glaciolacustrine sediments. Local relief is generally less than 15 m.

2. An area dominated by a large esker-kame complex in south-central Rogers and western Studholme Townships. Relief changes of 30 m are typical here, and range as high as 60 m on the heavily pitted and dissected upland. A similar feature is located in northeast Fushimi Township.

3. A level to slightly undulating till plain, frequently underlain by bedrock at shallow depth that is comprised of the remainder of the study area. Topographic gradients here drop steadily northwards over the Precambrian-Phanerozoic contact and into the James Bay Lowlands.

4. A small embayment of level marine sediments which overlies the till plain in the northwest corner of the Constance Lake Sheet.

Elevations in the study area range from 137 m to 320 m above sea level, but are generally confined to elevations between 228 m to 258 m above sea level. Several rivers, notably the Magagami, Kabinakagami, and Pvbiska Rivers drain the study area, and are well-incised as they approach the Precambrian-Phanerozoic contact.

**Quaternary Geology**

Late Wisconsinan glacial deposits and features in the Constance-Hanlon Lakes area record the waning of the Laurentide ice, the subsequent readvance/retreat of Cochrane ice, and the post-glacial marine incursion of the Tyrell Sea.

Two, possibly three separate ice movements across the study area are indicated by striae and grooving sets. The oldest striae trend southwards (174° to 190° azimuth), and correspond to trends of the main Laurentide ice advance as observed south of the Cochrane readvance limit. A weak and variable striae set trends 115° to 140° azimuth, and appears to cross-cut the previous set, indicating some limited ice movement that is considered by Boissonneau (1966) to be an early limited Cochrane readvance phase. Well-developed southwesterly (220° azimuth) striae cross-cut all others, corresponding to the main Cochrane readvance, which is further evidenced by drumlinoid ridges, flutings, and till macrofabric data.

Esker and kame complexes related to Laurentide deglaciation traverse the map-area, and display southerly paleocurrents. The Ritchie-Casgrain, Hanlon, Fushimi, Stoddart, Nagagami, and Nassau-Rogers eskers are normally capped by 1 to 2 m of Cochrane till. The latter system extends 31 km across the Constance Lake Sheet into Studholme Township where it is associated with a large kame complex. A similar feature is superimposed over the Fushimi esker in northeast Fushimi Township. A coarse gravel esker core observed at the surface in northern areas became buried in southern zones; but up to 10 m of channel-fill fine-grained sands and silts deposited by conduit meltwaters debouched into proglacial Lake Ojibway during deglaciation.

A pebbly and highly calcareous clayey silt till deposited by the Cochrane readvance forms a variable reddish-brown mantle throughout the study area. Basal melt-out till containing lenses of deformed fluvial sand is a common facies 1 to 3 m in thickness, and is often underlain by a thin layer of overconsolidated lodgement till. Waterlain Cochrane till transitional to glaciolacustrine sediments has been observed in the eastern and southern quadrants of the map-areas. The ubiquitous occurrence of basal till facies across the northern portion of the map-areas below 152 m above sea level, and the occurrence of waterlain till facies transitional to glaciolacustrine sediments at 243 m above sea level in southern zones, suggests the existence of a partly floating ice margin peripheral to a grounded Cochrane ice mass readvancing from the northeast. No stratigraphic evidence has been found for an early southeasterly readvance. Subcrop of a grey, sandy silt till has been examined along the Nagagami River, and is thought to represent the main Wisconsinan Matheson Till (Hughes 1959) or Adam Till (Skinner 1973).

Fine-grained blankets of post-Cochrane glaciolacustrine sediments form a continuous cover in southeast Hanlon Lake Sheet at elevations below 243 m above sea level. Isolated pockets of similar sediments occur sporadically throughout the map-areas.

Post-glacial marine limits of the Tyrell Sea incursion have been observed in an ancient estuary of the Nag-
gami River, north of Auden Township. Despite its unaccessibility to examination due to low river levels during the field season, the marine limit is estimated to be 140 m above sea level.

Organic deposits, which are extensive in northeast Hanlon Lake area, occur frequently, but seldom exceed 1 to 2 m in depth. Peat and black muck are the common constituents.

**Economic Geology**

Aggregate extraction is currently concentrated in southern parts of the map-areas, close to Highway 11. Major operations in Casgrain Township, 6 km north of Hearst and in Stoddart Township, 32 km west of Hearst, currently supply much of the local need. Because of present surface operations, reserves of crushable material, however, are low due to coarser gravel being buried at depth beneath finer grained deltaic sediments. Dragline operations will be necessary for deeper extraction beneath the water table. Numerous active and abandoned pits utilized by timber operations are located in the Hanlon, Fushimi, and Nassau-Rogers eskers. Large potential resources still exist, particularly in the Studholme Township kame complex, and beneath an isolated kame moraine located in northeast Fushimi Township, where waterwell records indicate a 76 m thickness of sand and gravel. High chert content is a quality constraint to utilization. Ubiquitous Cochrane till and glaciolacustrine capping is a hindrance to locating new reserves.

**Engineering Geology**

Sub-surface ground ice noted throughout the summer and low inherent bearing and shear strengths in the melt-out till facies and glaciolacustrine deposits, suggest that attention be given to construction design in the surficial deposits susceptible to frost penetration. Slope stability and erosion pose problems in areas underlain by deep-water glaciolacustrine sediments. Development of waste disposal sites, both municipal and private, should consider the local nature of Cochrane till that demonstrates significant permeability in basal facies due to pervasive sub-horizontal and vertical joint systems.

**References**


Dean, W.G. 1956: Glacial Features of the Hearst-Cochrane Map-Sheet Area; Canadian Geographer, Number 8, p.35-45.


No. S13 Paleozoic Geology of the Kingston Area, Southern Ontario

D.M. Carson¹

INTRODUCTION

Geological mapping of the Kingston area involved the re-examination of three map-areas previously mapped by B.A. Liberty for the Geological Survey of Canada (Liberty 1971). The several systems of lithostratigraphic nomenclature applied to the Cambrian and Ordovician succession in southern Ontario and upper New York State were summarized by Liberty (1969). The terminology used in the present report follows that proposed by Liberty (1969).

LOCATION

During the summer of 1981, geological mapping was completed for the Bath (31C/2), Gananoque (31C/8), and Wolfe Island (31C/1) map-areas. The western part of this region is bounded by Latitudes 44°00'N and 44°15'N, and Longitudes 76°30'W and 77°00'W. The eastern part of the region is bounded by Latitudes 44°00'N and 44°15'N, and Longitudes 76°30'W and 77°00'W. The present report follows the proposed by Liberty (1969).

¹Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.
and 44°30'N, and Longitudes 76°00'W and 76°30'W. Adjoining map-areas to the north and west of the Bath map-area were mapped by the author during the 1980 field season (Carson 1980, 1981a, 1981b). The Yorkshire Island map-area to the south was mapped at the same time, but is included with the map-areas discussed in the present report.

**General Geology**

Paleozoic bedrock outcrop is abundant throughout the Bath map-area on the north side of Cressy Point in the Yorkshire Island map-area throughout the western part of the Gananoque map-area, and along the shores of Wolfe Island. Paleozoic outcrop is sporadic in the eastern part of the Gananoque map-area and occurs only as small, discrete outliers. The Paleozoic stratigraphy of the Kingston area is summarized in Table 1.

<table>
<thead>
<tr>
<th>Precambrian</th>
<th>Undifferentiated Igneous and Metamorphic Rocks.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cambrian?</td>
<td>Potsdam Formation (Sandstone)</td>
</tr>
<tr>
<td>– Unconformity –</td>
<td></td>
</tr>
<tr>
<td>Basal Group</td>
<td>Shadow Lake Formation (Siltstone, Shale, Arkose)</td>
</tr>
<tr>
<td>– Unconformity –</td>
<td></td>
</tr>
<tr>
<td>Middle Ordovician</td>
<td>Simcoe Group</td>
</tr>
<tr>
<td>Lindsay Formation (Limestone)</td>
<td></td>
</tr>
<tr>
<td>Verulam Formation (Limestone &amp; Shale)</td>
<td></td>
</tr>
<tr>
<td>Bobcaygeon Formation (Limestone)</td>
<td></td>
</tr>
<tr>
<td>Gull River Formation (Limestone)</td>
<td></td>
</tr>
</tbody>
</table>

Precambrian rocks outcrop predominantly in the northern and eastern parts of the Gananoque map-area, and to a much lesser extent on Cartwright Point, near the city of Kingston, in the Wolfe Island map-area. The actual contact between the Precambrian rocks of the Canadian Shield and the Paleozoic rocks to the south is drift covered, and thus not sharply defined.

The Potsdam Formation is the oldest Paleozoic rock unit in the report area. It is composed of fine- to medium-grained, well sorted and rounded, red, pink, orange, buff, and brown sandstone, and unconformably overlies the Precambrian basement. Locally, the Potsdam Formation displays crossbedding. The formation outcrops primarily in the central northwestern part of the Gananoque map-area, and to a lesser extent, as outliers in the eastern part of the same map-area. Although no fossils have been recovered from the Potsdam Formation, it is considered to have a Cambrian age (Liberty 1971).

The Shadow Lake Formation unconformably overlies the Potsdam Formation, and consists of generally recessive red and green arkosic sandstones, siltstones, and shales. Major outcrops of the formation occur near Loughborough Lake and near the hamlet of Inverary in the northeastern part of the Gananoque map-area. A conglomerate, consisting of granite and quartz cobbles up to 20 cm by 4 cm in a matrix of green sandy siltstone, typical of the Shadow Lake Formation, unconformably overlies the Precambrian and occurs near the hamlet of Eastview in the extreme southwest corner of the Gananoque map-area.

The Gull River Formation conformably overlies the Shadow Lake Formation, although in some places it was deposited directly on the Precambrian. It is the oldest formation in the Simcoe Group and can be divided into three members. The upper and lower members generally consist of light to dark, brown and grey lithographic to finely crystalline medium-bedded to massive limestone. The middle member of the formation consists of buff and pale to dark grey, fine-grained siltstone and dolomitic siltstone, interbedded with limestone and shaly seams. All three members of the formation outcrop in the western part of the Gananoque map-area. The middle and upper members are present in the northern parts of the Bath map-area. Only the upper member occurs on Wolfe Island. Stromatoporaids, cephalopods, and brachiopods are common fossils in the Gull River Formation.

The Bobcaygeon Formation conformably overlies the Gull River Formation, and can be divided into two members. The lower member consists primarily of brown and grey, sublithographic to finely crystalline limestone, pale brown and grey calcarenite, and brown and grey fossiliferous limestone in beds 10 to 40 cm in thickness. Common fossils found in the lower member of the Bobcaygeon Formation include cephalopods, corals, gastropods and various species of brachiopods. The upper member of the Bobcaygeon Formation is composed of brown, thin bedded, finely crystalline to sublithographic limestone, pale brown fossiliferous and bioclastic limestone, and minor amounts of shale. The Bobcaygeon Formation outcrops in the northwestern part of the Bath map-area, on Simcoe Island in the eastern part of the Bath map-area, and on the southern half of Wolfe Island in the Wolfe Island map-area.
The Verulam Formation conformably overlies the Bobcaygeon Formation, and is somewhat intergrada-
tional with it. It consists of interbedded, brown and grey bioclastic limestone, brown, finely crystalline limestone, and grey shale in subequal amounts and in beds of sube-
qual thickness. The entire formation is thinly bedded and easily eroded. Fossils such as brachiopods, bryozoans, and crinoids are abundant in the formation, while corals and fragments of trilobites are less common. The Verulam Formation outcrops in the western portion of the Bath map-area along the Lake Ontario shoreline, on Cressy Point, and on Amherst Island in the southern part of Wolfe Island map-area. The formation forms the lower part of a 4 to 5 m high cliff on the north shore of Long Point, in the Yorkshire Island map-area.

The youngest formation in the Simcoe Group is the Lindsay Formation, which overlies the Verulam Formation. In the present report area, the formation consists of blue-grey, finely crystalline, pseudonodular, sublitho-
graphic limestone that weathers into thin beds separated by shaly interbeds. The formation outcrops in the central part of Cressy Point in the Bath map-area, and underlies all of Long Point in the Yorkshire Island map-area. An upper member composed of nodular, grey, shaly limestone and calcareous mudstone, which occurs to the west in the Belleville and Wellington map-areas (Carson 1980, 1981b), does not occur in the present report area.

**Economic Geology**

Two formations in the present study-area are currently being quarried for commercial use. The Verulam Forma-
tion is quarried near Bath, by Canada Cement Lafarge Limited for use in the manufacture of cement. The Griffen Brothers Construction Company produces aggregate from quarries in the Gull River Formation at Joyceville, and near Battersea in the Gananoque map-area. Material from the same formation is also quarried near Kingston by Glen Lawrence Quarries, and by McGinnis and O'-Connor Limited for use as crushed stone. More detailed descriptions of the latter four quarries are provided by D.F. Hewitt and M.A. Vos (1972).

**References**

Carson, D.M.  

Hewitt, D.F., and Vos, M.A.  

Liberty, B.A.  


White, O.L., Karrow, P.F., and Macdonald, J.R.  
No. S14 Paleozoic Geology of the Southern Portion of the Ottawa-St. Lawrence Lowlands, Southern Ontario

D.M. Carson

THIS PROJECT IS FUNDED EQUALLY BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION AND THE ONTARIO MINISTRY OF NATURAL RESOURCES UNDER THE MINERALS PROGRAM OF THE EASTERN ONTARIO SUBSIDIARY AGREEMENT.

Introduction

Geological mapping of the Brockville-Cornwall area (the southern portion of the Ottawa-St. Lawrence Lowlands) involved the examination of seven map-areas, six of which were included in the major study of the Ottawa-St. Lawrence Lowlands by A.E. Wilson for the Geological Survey of Canada (Wilson 1946). The terminology used in the present report follows that introduced by A.E. Wilson (1946).

Location

During the summer of 1981, geological mapping was completed for the Mallorytown (31 B/5), Brockville (31 B/12), Merrickville (31 B/13), Kemptville (31 G/4), Morrisburg (31 B/14), Winchester (31 G/3), and Cornwall (31 G/2) map-areas. The report area is bounded by Latitude 45°15'N and the St. Lawrence River and by Longitudes 74°30'W and 76°00'W.

1Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.
TABLE 1
GENERAL PALEOZOIC STRATIGRAPHY OF THE BROCKVILLE-CORNWALL AREA, SOUTHERN ONTARIO.

<table>
<thead>
<tr>
<th>Horizon</th>
<th>Formation (Limestone)</th>
<th>Formation (Shale with Sandstone)</th>
<th>Formation (Dolostone)</th>
<th>Formation (Sandstone)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Middle Ordovician</td>
<td>Ottawa Formation</td>
<td>Chazy Group</td>
<td>Cambro-Ordovician</td>
<td>Nepean Formation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>St. Martin Formation</td>
<td>Beekmantown Group</td>
<td>Oxford Formation</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Rockcliffe Formation</td>
<td></td>
<td>March Formation</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Nepean Formation</td>
</tr>
</tbody>
</table>

General Geology

The Paleozoic stratigraphy of the Brockville-Cornwall area is summarized in Table 1. Paleozoic bedrock outcrop is abundant throughout the Brockville and Merrickville map-areas, and in the western part of the Kemptville map-area. It is moderately abundant in the Winchester map-area, and sparse in the Morrisburg and Cornwall map-areas. Outcrop occurring in the eastern part of the area is generally surficial and poorly exposed. A small number of widely-spaced quarries provides the best exposures in the Cornwall and Morrisburg map-areas.

Precambrian rocks of the Frontenac Axis outcrop throughout the Mallorytown map-area and in the southwestern part of the Brockville map-area. Small outliers of Precambrian rock occur 1.0 and 2.5 km north of Brockville, 3.5 km due east of the hamlet of Bellamys in the Brockville map-area, 6 km south of the village of Spencerville, and 8 km southeast of the town of Kemptville in the Merrickville map-area.

The Nepean Formation is the oldest Paleozoic rock unit in the report-area. It is composed of predominantly white, but also pale orange, pale yellow, and pale buff, fine- to medium-grained quartz sandstone in thin to medium beds. The formation weathers buff, brown, rust, and white, and is locally crossbedded. It unconformably overlies the Precambrian basement. The formation outcrops in an irregular belt across the southern portion of the Brockville map-area, and in two outliers in the Mallorytown map-area. Although no fossils have been recovered, it is generally regarded as Cambro-Ordovician in age (Wilson 1946).

Conformably overlying the Nepean Formation, and frequently gradational with it, is the March Formation. This unit consists of pale to medium grey, pale to medium brown and grey brown, fine to medium crystalline dolostone and sandy dolostone interbedded with brown, grey, and white sandstone. The entire formation weathers grey and brown, shaly interlayers and seams are common throughout. Nodules of white and pink, coarsely crystalline calcite up to 10 cm in diameter, are also common. Outcrops of the formation occur throughout the central and northwestern parts of the Brockville map-area, in the southwestern corner of the Merrickville map-area, and as a large inlier in the northwestern and southwestern corners of the Merrickville and Kemptville map-areas, respectively. No identifiable fossils were recovered from the March Formation, but Wilson (1946) suggested an Ordovician age based upon fossils recovered during that study.

Conformably overlying the March Formation is the Oxford Formation, which consists of pale to medium grey and brown, fine-grained to medium-grained crystalline dolostone, which generally weathers grey and rust, and locally weathers with a green stain. In the central western part of the Kemptville map-area, the upper part of the formation contains a thin sequence of white and pale green, thinly bedded, fine-grained, calcareous sandstone. The formation generally occurs in beds up to 30 cm thick, and commonly contains vugs up to 10 cm in diameter, which are lined with pink and white calcite. Pyrite and chert are also common. Hard, spherical and concentric masses resembling algal growths, up to 10 to 15 cm in diameter, occur in some beds. The Oxford Formation outcrops throughout the Merrickville and Kemptville map-areas, as well as in the western parts of the Winchester and Morrisburg map-areas.

Formations of the Chazy Group do not outcrop in the report area. The Rockcliffe Formation, seen in adjacent map areas, is composed of interbedded olive green shales and grey sandstone, and probably unconformably overlies the Oxford Formation (Wilson 1946). It is, in turn, overlain by the grey limestone of the St. Martin Formation.

The Ottawa Formation unconformably overlies the St. Martin Formation, and is the youngest rock unit in the report area. It consists almost entirely of limestone, and can be divided informally into three lithological units. The lowest unit consists mainly of pale to medium grey, with
lesser amounts of pale to medium brown, sublithographic to finely crystalline limestone, in beds up to 30 cm thick. This material is overlain by a middle unit of pale brown, grey and white bioclastic and calcarenitic material. The upper unit is very similar to the lower unit. The Ottawa Formation outcrops throughout the Cornwall map-area, and the central and eastern portions of the Winchester and Morrisburg map-areas. Outcrop of the formation is generally not extensive, and good exposures are only found in quarries.

**Economic Geology**

Three of the Paleozoic rock units in the report area are currently being quarried for use as crushed stone. The March Formation is quarried by Permanent Concrete Limited at Brockville, and the Oxford Formation is extracted at Fetterly’s Quarry near Iroquois. The Ottawa Formation is quarried at Cornwall by Permanent Concrete Limited and the Cornwall Gravel Company Limited; at Williamsburg by Cruikshank Construction Company; and north-west of the hamlet of Chrysler by A.L. Blair Construction Company Limited. Descriptions of these quarries are provided by D.F. Hewitt and M.A. Vos (1972).

**References**


No. S15 Limestone-Dolostone Assessment Study, Manitoulin Island

M.D. Johnson

THIS PROJECT WAS FUNDED BY THE ONTARIO MINISTRY OF NORTHERN AFFAIRS THROUGH THE NORTHERN ONTARIO GEOLOGICAL SURVEY (NOGS) PROGRAM.

Location

During the 1981 field season, mapping and other data collection was completed for the Paleozoic bedrock survey of Manitoulin Island.

The area is covered by the following 1:50 000 NTS Map Sheets: Providence Bay (41 G/9), Great Duck Island (41 G/10), Manitowaning (41 H/11 and 41 H/12), Little Current (41 H/13), Meldrum Bay (41 G/14), Silver Water (41 G/15), and Kagawong (41 G/16).

The area studied encompasses the mainland mass of Manitoulin Island, and is bounded by the shorelines of North Channel, Georgian Bay, Lake Huron, and Missisagi Strait.

General Geology

Manitoulin Island is abundant in Paleozoic outcrops, particularly in the southern part, where large tracts of bare rock are exposed. The rocks (Table 1) on the island range in age from Lower Ordovician (Verulam Formation) to Middle Silurian (Amabel Formation).

The oldest exposed strata were previously considered to be of the Lindsay Formation; however, detailed study suggests these to be part of the underlying Verulam Formation.

The Verulam Formation consists of a bluish-grey fine to mediocrystalline fossiliferous limestone with minor shales. The unconformably overlying Lindsay Formation consists of grey, fine-grained to sublithographic limestone with minor dolostones. It is overlain by the Whitby Formation, a shaly unit comprising soft brown shales in its upper part, and black fossiliferous shales with minor dolostones in its lower part.

Overlying the Whitby Formation is the Georgian Bay Formation which is composed of lower and upper members; the latter is divided into two submembers. The lower member, the Wekwemikongsing Member, consists of bluish-grey shales. The upper member (lower submember), the Meaford Member, contains bluish-grey fine-grained argillaceous dolostone. The overlying Kagawong (upper submember) is a brown and grey finely crystalline dolostone.

1Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.
## TABLE 1

**PALEOZOIC STRATIGRAPHY OF MANITOULIN ISLAND MAINLAND MASS ONLY.**

<table>
<thead>
<tr>
<th>Layer</th>
<th>Formation</th>
<th>Members</th>
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<tbody>
<tr>
<td><strong>Middle Silurian</strong></td>
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</tr>
<tr>
<td>Amabel Formation</td>
<td>- St. Edmunds Member</td>
<td></td>
</tr>
<tr>
<td>Fossil Hill Formation</td>
<td>- Wingfield Member</td>
<td></td>
</tr>
<tr>
<td>Mindemoya Formation</td>
<td>- Dyer Bay Member</td>
<td></td>
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<tr>
<td>Cabot Head Formation</td>
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<tr>
<td><strong>Lower Silurian</strong></td>
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<td></td>
</tr>
<tr>
<td></td>
<td>- Cabot Head (Restricted) Member</td>
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<tr>
<td><strong>Manitoulin Formation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ordovician</strong></td>
<td></td>
<td></td>
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<tr>
<td>Georgian Bay Formation</td>
<td>- Upper Member</td>
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<td></td>
<td>- Kagawong submember</td>
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<td></td>
<td>- Meaford submember</td>
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<td></td>
<td>- Lower Member</td>
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<td></td>
<td>- Wekwemikongsing submember</td>
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</tr>
<tr>
<td><strong>Whitby Formation</strong></td>
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</tr>
<tr>
<td><strong>Lindsay Formation</strong></td>
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<tr>
<td><strong>Verulam Formation</strong></td>
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</table>

Silurian deposition began with the Manitoulin Formation, a brown to bluish-grey fine-grained to sublithographic dolostone. This formation includes reefal (biothermal) and thin inter-reefal (platform) deposits.

The Manitoulin Formation is overlain by the Cabot Head Formation, which contains four members according to the nomenclature of B.A. Liberty (1968). These are: the Cabot Head (restricted) Member, a green and red shale; the Dyer Bay Member, a bluish finely crystalline dolostone with shales; the Wingfield Member, a brown sub-lithographic dolostone interbedded with green shales; and the uppermost St. Edmunds Member, which is massive brown and grey, fine- to medium-grained crystalline dolostone.

Overlying the Cabot Head Formation is the Mindemoya Formation, a predominantly thin bedded, pale grey to light brown, sublithographic to finely crystalline dolostone. In the mapping and drilling programs of this project, it was not possible to distinguish between the Mindemoya Formation and the supposedly underlying St. Edmunds Member of the Cabot Head Formation. Further work is in progress in an attempt to resolve this problem.

Overlying the Mindemoya Formation is the Fossil Hill Formation, a buff to grey-brown, fine to coarsely crystalline dolostone. This formation is rich in coral, algal, and pentamerid brachiopod remains with beds of chert nodules in the upper part. The contact with the overlying Amabel Formation is frequently gradational.

The Amabel Formation consists of a bluish-grey to buff, fine-grained and evenly crystalline dolostone. Both reefal and inter-reefal beds are present. This formation possesses a number of thin chert-rich zones concentrated in the lower part of the unit. The total thickness of exposed Paleozoic units on Manitoulin is about 280 m.

### Field Work in 1981

The 1981 field studies were a continuation of the work carried out on Manitoulin Island in the previous two field seasons (Johnson 1979, 1980). This program of detailed mapping, combined with geochemical analysis and engineering testing of selected samples, will permit assessment of the limestone-dolostone resources of the main landmass of the Island. The results will be shown as a series of “Rock Quality Maps” with interpretive notes.

Aspects of Manitoulin bedrock geology stressed in the 1981 field season were: unit thickness, lateral and vertical consistency and impurity contents, accuracy of formational contacts, and boundaries between zones of varying rock quality.

As in previous years, less field time was spent on the Ordovician than the Silurian rocks because of the lower economic potential of the Ordovician rocks which results from their lower purity and greater overburden cover.

### 1980 Drilling

During the fall of 1980, 13 diamond-drill holes were completed, thus finishing the drilling program associated with the project. All holes reached their anticipated depth (see Johnson 1980 for locations), although loss of circulation and clay seams caused some problems on the deeper holes. All holes were continuously cored, with HQ size core (6.4 cm diameter) being taken. The geological logs from these cores are to be released in an Open File Report. A total of 783 m of core was obtained from the 13 holes.

### Economic Geology

At present, there are three dolostone quarries on Manitoulin Island. The currently inactive Leason Quarry, near South Baymouth, extracted massive stone from the Amabel Formation to build the dock at South Baymouth. A quarry in the upper Mindemoya Formation, located 4.7 km east of West Bay on Highway 540, provides small block and slabby material for general fill. West of Meldrum Bay, near Mississagi Lighthouse, a new dolostone quarry owned by Seely and Arnill Construction of Ontario
ENGINEERING AND TERRAIN — SPECIAL PROJECTS

is now in production. This operation extracts dolostone from the massive Amabel Formation for crushed stone. A similar operation in eastern Manitoulin Island is also under consideration by other owners.

Petroleum exploration on the island was particularly active during the early part of the century with 104 recorded wells being drilled. These led to at least nine producing oil and gas wells, none of which are presently active.

References

Johnson, M.D.


Liberty, B.A.
No. S16 Aggregate Resources Inventory of Part of Northern Ontario

Staff of the Aggregate Assessment Office

THIS PROJECT WAS FUNDED BY THE ONTARIO MINISTRY OF NORTHERN AFFAIRS THROUGH THE REGIONAL PRIORITY BUDGET PROGRAM.

Introduction

Field mapping of natural aggregate deposits was initiated and completed during the summer of 1981 for the planning areas surrounding four urban centres in northern Ontario. The project was initiated at the request of the concerned municipalities and by District Offices of the Ontario Ministry of Natural Resources.

The Timmins project area consists of seven townships in the central part of the city, and four townships in the eastern part of the city. The central area includes the townships of Wark, Murphy, Tisdale, Deloro, Mountjoy, Ogden, and Price. Evelyn, Matheson, German, and Maclem Townships are situated in the eastern part of the city.

The Smooth Rock Falls project area consists of the geographic townships of Shackleton, Alexandra, Haggart, Sydere, Kendry, Webster, and Colquhoun.

The Elliot Lake project area includes the area of the Corporation of the Town of Elliot Lake and the geographic townships of Beange, Bouck, Buckles, Bolger, Gunterman, Joubin, McGiverin, Esten, and Proctor.

The Fort Frances project area consists of the geographic townships of Crozier, Devlin, Woodyatt, and Roddick.

The objectives of the field component of the program were:

1—To identify and delineate the geological boundaries of all sand and gravel deposits, based on existing geological maps and airphotograph interpretation;

2—To assess the type and quality of the aggregate in these deposits and to sample representative material for grain-size and petrographic analysis;

3—To compile an inventory of all known extractive operations in the deposits;

4—To conduct subsurface examinations (using a backhoe and drill rig) of potential extractive sites.

Smooth Rock Falls

The Smooth Rock Falls project area consists of seven geographic townships, which includes the area immediately surrounding the town as well as that area flanking Highway 11. The local bedrock is dominated by a Precambrian migmatite-metasedimentary-metavolcanic complex with smaller areas of felsic intrusive rocks (Bennett et al. 1966). The bedrock surface is generally of subdued relief, however, there are areas of irregularity. A thick veneer of Quaternary sediments covers the bedrock surface.

The dominant surface material is a compact, low stone, silty clay till deposited during the Cochrane Re-advance, the last major ice movement prior to deglaciation of the area (Boissonneau 1966). The till has no value as aggregate because of its high "fines" content.

Sand and gravel deposits in the area were laid down prior to the Cochrane Re-advance. These deposits were overridden during the re-advance, and were buried by up to 12 m of till. In places, the morphology of the sand and gravel deposits has been well preserved, but because of the thick drift cover, there is generally no surface indication of the existence of buried aggregate. As a result, stripping of the overburden is required to expose the aggregate. In addition to stripping difficulties, extraction is hindered by the high water table. In many cases, large scale extraction requires use of water pumps and dragline equipment.

An esker deposit located in Alexandra, Haggart, and Sydere Townships is the major source of sand and gravel for the study area, but extraction is limited to Haggart Township. The esker material is composed predominantly of sand, however, several of the pits situated near Departure Lake contain large amounts of coarse gravel suitable for a wide range of aggregate products.

Testing performed with a backhoe and drill rig in the Departure Lake area proved inconclusive, but did provide a good indication of the clay thickness and the potential economic problems associated with the clay.

Another esker system located in Colquhoun Township, extends from the southern township boundary, through Greenwater Provincial Park, to the northern township boundary. Although there has been no extraction of aggregate in this portion of the esker
south of the study area contain large amounts of crushable aggregate.

Small fine-grained lacustrine deposits suitable for low-specification uses are also found in Shackleton, Kendrey, and Colquhoun Townships.

Of the 25 sand and gravel pits studied in the Smooth Rock Falls area, only five or six are capable of supplying a range of road-building and construction aggregate. Remaining possible resources, especially of crushable aggregate, are low and a supply problem may exist in the future.

**Timmins Area**

The Timmins project area consists of 11 geographic townships situated within the City of Timmins. It lies within the Abitibi Uplands of the James Bay Region physiographic area and forms part of the Northern Clay Belt. The bedrock consists predominantly of Precambrian age metavolcanic, metasedimentary, and granitic rock. The bedrock surface is irregular, but generally of subdued relief. Drift thickness is variable and in places exceeds 87 m. Previous work by Hunt (in press) has described the aggregate resources in the Pamour Area of the City of Timmins. Hunt's work will be released as an Open File Report in 1981.

The predominant glacial sediments in the area are glaciolacustrine varved clay and shallow-water sands (Tucker and Sharp 1980). Some of the coarser sands, especially when deposited as beach ridges, may be suitable for aggregate use. In places, the lacustrine sands have been reworked by eolian action.

Two tills are exposed in the project area. The oldest till consists of boulders and cobbles in a sand and silt matrix (Hughes 1965). Because of its low 'fines' content, the till may be suitable in places for some low-specification construction aggregate. A younger till is confined to the northern parts of the study area. It was deposited during the Cochrane Re-advance, the last major ice movement prior to deglaciation of the area (Boissonneau 1966). It is a compact, low stone, silty clay till with no value as aggregate because of its high 'fines' content.

Most of the aggregate in the project area was deposited in four north-trending esker complexes. The complexes usually consist of a series of segmented esker ridges flanked by ice-contact deltaic sediments. Pits developed in the ridges expose material ranging in composition from silt to esker core gravel. The esker core material is generally suitable for crushing. The flanking ice-contact deltaic sediments contain large possible resources of sand with irregular pockets of gravel. In places, the esker complexes have been modified by lacustrine action.

The most utilized aggregate source in the Timmins area is the Papakomeka-Pamour esker complex. Over 25 pits have been developed in this deposit which extends from Wark Township in the north, along Highway 655, to Deloro and Mountjoy Townships in the south. The esker complex generally contains sandy aggregate, although esker core gravel is exposed in Murphy Township just south of Bigwater Lake and near Craft Creek.

The Grassy River esker complex is situated along the east bank of the Grassy River in Price Township and extends northward into Ogden and Mountjoy Townships. Extractive development in the esker complex has been
largely confined to Mountjoy Township where pits developed in the ridge expose variable material ranging in size from cobble gravel to silt. The relatively unexploited parts of the deposit in Price and Ogden Townships are potential areas for pit development, and are considered an integral part of the city's resource base.

Large possible resources of sand and gravel are also available from two esker complexes located in Evelyn, German, and Maclem Townships. Both are predominantly sand sources; however, coarse gravel is exposed in an area just east of Roundelay Lake in Maclem Township and within esker segments in German Township. A number of smaller sand and gravel deposits are also located in the Timmins project areas which may be capable of supplying aggregate for local use.

Approximately 100 sand and gravel pits were visited during the study of the Timmins area. Large possible resources of sandy aggregate are currently available, but remaining possible resources of crushable gravel are considered low. Care should be taken to ensure the continuing availability of as much as these resources as possible.

Elliot Lake Area

The Elliot Lake project area consists of nine geographic townships which compose the Corporation of the Town of Elliot Lake. The bedrock consists of early Precambrian felsic intrusive and metavolcanic rocks exposed in the most northern part of the study area and to the south of the town of Elliot Lake. A complex series of folded Middle Precambrian (Huronian) rocks are found in the north central part of the study area. Intrusions of quartz diabase occur throughout the area. The bedrock surface is irregular with low to moderate relief (Van Dine 1980).

Drift in the study area consists of thin till patches with outwash sand and gravel deposits in low lying areas between bedrock outcrops. The till is a compact silty sandy till with boulders. This material is not acceptable for use as a source of sand and gravel because of its high 'fines' content. However, it is used locally for the construction of tailings dams because of its relative impermeability. The sand and gravel outwash deposits are generally clean with varying percentages of gravel. Individual deposits vary throughout, with coarser material being found close to bedrock valley sides and in the upstream part of the deposits.

The most important of the developed resource is that of Summer's Creek, south of Dunlop Lake. There are five active pits in this deposit. All but one of these pits are excellent sources of material for a variety of aggregate products used in road-building and construction. Much of this resource area remains unexploited.

The most extensive undeveloped resource area is in the Gullbeak Lake-Mather Lake area, Bolger Township. Material inspected to the east and to the south of Gullbeak Lake indicates that the deposit is of good quality. Other undeveloped resource areas include an area north of McCabe Lake, the east shore of McCabe Lake to Elephant Lake, and an area west of May Lake.

Most of the sand and gravel pits in the study area are operated on a demand basis. There appears to be adequate sand and gravel to meet community and highway construction needs for the next few years. Conflicting land uses, however, may decrease the amount of readily available aggregate.
Locally, the quartz diabase rocks can be used as a source of aggregate. Other rock types in the area have been eliminated due to their excessive hardness or radioactivity.

**Fort Frances Area**

The Fort Frances project area consists of four geographic townships situated west and southwest of the Town of Fort Frances. The town lies within a low, flat to undulating plain known as the Rainy Lake Lowland with elevations ranging from 335 m to 381 m above sea level.

The bedrock consists of complex, folded felsic intrusive, mafic intrusive, metasedimentary, and metavolcanic rocks of Precambrian age (Davies 1973). Although outcrops representing the highest bedrock peaks do occur, a thick mantle of glacial drift covers the entire study area. Drift thickness is variable and in general exceeds 30 m.

The predominant glacial sediments in the area are: till; glaciolacustrine varved clay, lacustrine beach sand and gravel; and buried glaciofluvial sand and gravel.

The calcareous bluish grey silty clay till found on the surface and in places to a depth of 12 m was deposited by a lobe of the Keewatin glacier advancing from the northwest. It consists of unstratified silty and clayey material consisting of angular, subangular, and subrounded pebbles and occasional cobble-sized stones of Precambrian and later age sedimentary origin (Johnston 1915). The till and the glaciolacustrine varved clay are not suitable for any aggregate use because of their high 'fines' content.

Shallow, wave modified beach ridges of sand and gravel were deposited near topographic highs by the waters of proglacial Lake Agassiz (Johnston 1915). These deposits with thickness ranges of 1 to 3 m have been traditionally used as local sources of aggregate. Because of previous extensive extraction and very limited remaining reserves, these shallow surficial deposits are of local economic significance only.

Previous work (Sado 1976, Roed 1980) suggested the possibility of finding extensive buried channels of glaciofluvial sand and gravel similar to the deposit exposed in the Armstrong Pit near the eastern boundary of the study area, at depths ranging from 1 to 15 m. In order to locate these deposits a detailed subsurface exploration program consisting of geophysics and drilling was initiated.

The geophysical program consisted of the use of an EM-31 portable resistivity unit effective to an approximate depth of 6 m. The survey proved effective in locating shallow beach deposits on top of till and clay.

Fifteen test holes were drilled in the study area to an average depth of 12 m by a CME 45 drilling rig using 3 inch (7.5 cm) inside diameter hollow stem augers. Samples were retrieved by means of a 2 inch (5 cm) standard split spoon sampler.

Drilling data revealed the presence of the glaciofluvial material, similar to that found in the Armstrong Pit, at a depth of 11.5 m, 12.5 m, and 13.0 m at
three different locations. The large thickness of the overburden, as well as the relatively high ground water table throughout the study area, render the extraction of the buried aggregate uneconomical at the present time.

A total of five sand and gravel pits are located in the shallow surficial beach deposits in the study area. These pits are active on a demand basis, and are capable of supplying limited quantities of low-specification use aggregate. The main supplier of high-specification use aggregate for the area is the Armstrong Pit.

To meet future demand for high-quality aggregate the Fort Frances area will have to rely on the Armstrong Pit and will have to import aggregates from townships lying north and northwest of the town.

References


Geophysics/Geochemistry Programs
Geophysical, Geochemical and Geochronological Surveys and Research, 1981

R.B. Barlow¹

Geophysical Program

During the 1980 summer season, a geophysical test range was established by Geophysics/Geochemistry Section staff in the Timmins Area. Several lensoid graphite (with minor sulphide) conductors located beneath approximately 87 m of resistive overburden were surveyed on a controlled grid. Modern multifrequency horizontal loop and time domain equipment was used to investigate the physical characteristics of this area and its suitability as a test range.

A gravity interpretation program began this year based on survey data covering the Cobalt Embayment-Grenville Front Area. The survey data consists of 7 250 gravity stations obtained by section staff and 3 629 gravity stations, previously obtained by the Earth Physics Branch, Energy, Mines, and Resources Canada. In addition, 3 400 rock density measurements were made throughout the 33 000 km² area. Interpretation procedures will consist of pattern recognition studies of the potential fields of both gravity and aeromagnetics and computer modelling in two and three dimensions using the acquired rock density information. These data will be synthesized with the regional geological information wherever possible.

The results of two separate airborne geophysical surveys will be released during the winter of 1982. These surveys are sponsored by the Ontario Ministry of Northern Affairs and are carried out under the direction of the Geophysics/Geochemistry Section.

A total of 6 211 line kilometres of airborne magnetic and electromagnetic data were obtained by Aerodat Limited over the Sioux Lookout Area. Results will be released on photomosaic-based maps at a scale of 1:20 000 and 1:31 680. A total of 7 480 line kilometres of airborne magnetic and electromagnetic data were obtained by Questor Surveys Limited over the Swayze Area. Results will be released on photomosaic-based maps at a scale of 1:2 000 and 1:31 680.

In addition to the airborne survey program, four catalogues of theoretical responses over short-strike-length conductors were prepared to aid users of multi-frequency and time domain airborne electromagnetic systems. Master curves (phasor diagrams) were also constructed for the four airborne systems.

During the summer season, section staff together with aeronautical engineering staff from Aerospace Engineering and Research Consultants Limited (AERCOL) carried out tests on two aircraft structurally modified to carry two vertically displaced high resolution magnetometer sensing heads. A Piper PA-31 Navajo aircraft owned by Kenting Earth Sciences Limited and a Britain-Norman Trislander aircraft owned by Questor Surveys Limited were fitted with a retractable lower boom and a ridged boom assembly, respectively. Airborne tests were carried out by measuring two components of the vibration using three accelerometers mounted in the stingers and near the centre of gravity of both aircraft. The complete vibrational spectra of all accelerometers in both aircraft were calculated and compared. Results obtained under simulated airborne survey conditions will be used to decide which design provides a more optimal housing for the sensing heads.

¹Chief, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.
Geochemistry Program

A third season of a regional basal till survey is in progress in the Kirkland Lake Area. This project is jointly funded by the Federal Department of Regional and Economic Expansion and the Ontario Ministry of Northern Affairs through the Kirkland Lake Initiatives Program (KLIP). Throughout the summer months till samples were obtained in moderate to shallow overburden areas by backhoe sampling. During the winter months, regional sampling using a reverse circulation rotary drill was employed in the area north and west of the town of Kirkland Lake. Samples are being analysed for mineralogical and geochemical elements associated with ore mineral suites commonly found in the area.

Geochemical orientation studies were carried out over the Mcivor property, west of Kirkland Lake, which is owned by Willroy Mines Limited. Various surface geochemical techniques together with shallow percussion drilling and a VLF-EM geophysical survey were employed over the property. An interesting comparison of results should be forthcoming from the survey. In association with the Basal Till survey, a study of the mineralogy of tills was conducted on samples collected during the summer. The results of the mineralogy study were used immediately to provide direction on future sampling locations based on the presence of indicator minerals.

A new regional stream sediment geochemical mapping program was initiated during the summer months over part of southwestern Ontario. This project was funded by the Ontario Lottery Fund and covered an area of 20 000 km² at a sample density of 1 sample per 5 km². It is planned to continue the coverage of this data base for the purpose of mapping the geochemical landscape using a holistic approach. Geochemical information at this scale can be used as a valuable input to the understanding of environmental features, naturally occurring or otherwise, which affect the health and well-being of plants, animals, and man. Future research utilizing this data base will hopefully develop useful correlations between geochemical patterns and trends in agriculture, fish and wildlife, forestry, and epidemiology in areas covered by regional geochemistry.

The second year of an acid rain research program was successfully completed in the area north and east of Lake Superior. Centre lake basin cores are analyzed using techniques developed in limnology, geochemistry, and palynology for the purpose of investigating the historical development of lake acidification in this area. Data on the chemistry of lake waters will be integrated with information obtained on the cores taken from the same lakes. Staircase lake systems were the subject of the sampling program this year. Five lake systems were chosen on the basis of previous lake sediment geochemistry, pH, and bedrock geology so as to represent a wide range of conditions in the area.

Geochronology Program

Geochronology studies are continuing in the Trout Lakes Area, District of Kenora (Patricia Portion) in conjunction with Ontario Geological Survey staff (Precambrian Section) and Dr. L.D. Ayres of the Department of Earth Sciences, University of Manitoba. The study area is located approximately 200 km north of Red Lake, Ontario, and is composed of an east-trending Archean, metavolcanic-metasedimentary supracrustal belt that is bounded by granitic batholiths. The purpose of this work is to determine the age relationship between the granite intrusives and the volcanic rocks, and also to date the time sequence of volcanism as represented by a well-developed stratigraphic sequence thought to contain five volcanic cycles.

Analyses of five rocks from the Kakagi Lake Area have been completed. Four of the rocks have been found to be concordant after using newly-developed techniques involving high gradient magnetic separation and air abrasion. On the basis of geochronology and geological relationships several rocks suites are proposed to have been derived by direct differentiation of the mantle, while others appear to have been derived by partial melting of supercrustal volcanic rocks.
No. 25 Night Hawk Geophysical Test Range Results Using Two Electromagnetic Systems, District of Cochrane

R.B. Barlow

Introduction

During the summer field season, staff of the Geophysics/Geochemistry Section, developed a 1 km² area for the purpose of testing geophysical equipment. A metric grid with lines 100 m, and stations 25 m apart was prepared to survey specifications. Lateral survey precision was controlled using transit and chaining techniques.

The grid system, located in the northeast corner of Thomas Township, covers several lensoid conductive zones in the bedrock which are concealed by approximately 87 m of transported overburden. The overburden in the area of the conductors is largely composed of glaciofluvial outwash sands, and to a lesser extent, gravel and boulders.

In addition to the development of the grid system, several surveys using state-of-the-art electromagnetic prospecting equipment were carried out over the test range. An Apex Parametrics Limited MAXMIN III, frequency-domain, horizontal loop system was employed over nine lines using a coil separation distance of 200 m between the transmitter and receiver. Quadrature and in-phase components of the secondary field were measured at five frequencies ranging from 111 Hz to 1777 Hz.

A Geonics Limited EM-37 time-domain system was employed using a large flat lying fixed transmitter loop (300 m by 600 m), the long axis of which was situated approximately parallel to the southernmost conductor and offset 425 m to the south. The decay of the secondary field in the absence of the primary field was measured using 20 logarithmically spaced gates centered from 89 μs to 7.19 ms after completion of the turn-off time of the primary pulse. Synchronization between the transmitter turn-off time and the receiver gate series was accomplished by referencing a highly accurate crystal-controlled oscillator in the receiver against one in the transmitter. An integration time of approximately 34 seconds was used to permit signal averaging of 1024 samples of secondary field decay by using a fundamental transmitter frequency of 30 Hz. Three orthogonal receiver coil measurements were made of the secondary field decay at each station over five lines.

To date, the closely spaced conductive zones have been tested by Noranda Exploration Limited with one 366 m diamond-drill hole which intersected non-economical graphite shear zones containing minor sulphides.

Location and Access

The test range is located in the northeast quadrant of Thomas Township approximately 12 km south of Highway 101, on the Gibson Lake Road. The Gibson Lake Road turnoff is located approximately 40 km east on Highway 101 from the Empire Hotel in Timmins, a well-known landmark in the area. A diagram (Figure 1) illustrating the grid roads on a detailed scale shows that few areas of the grid

LOCATION MAP

Scale: 1:1 584 000
or 1 inch to 25 miles
Figure 1—Showing grid coverage in relation to the road network.

are without ready access by vehicle. The location of the Noranda drillhole is shown, as is the transmitter base station hook up point to the transmitter loop. It is planned to extend all survey lines southward at least an additional 200 m next season. This will permit more complete coverage of electromagnetic response on the south side of the series of conductors.

Objectives

Over the period of the next several years, the Geophysics/Geochemistry Section will be establishing a number of multipurpose geophysical test ranges having a variety of physical conditions. It is hoped that these sites will serve a number of purposes, namely:

—To permit geophysical instrument manufacturers to test and develop prototype equipment before design criteria are finalized.
—To permit educators of technicians, technologists, engineers, and scientists involved in applied mineral exploration geophysics to utilize a well-documented area for training and experimental use.
—To permit mineral exploration companies access to a few examples of targets having a variety of conditions so that staff operator-training programs can be carried out.

In order to offer the maximum utility, it is possible that some coordination of occupancy time will become necessary. It is proposed that users contact the Geophysics/Geochemistry Section in advance in order to prevent wasted field trips to the area.
Figure 2—Showing MaxMin III results over three lines (In-phase-Dashed lines, Quadrature-Dotted lines).
Survey Methodology

MaxMin III Slingram Survey

The Slingram (horizontal loop) method is currently one of the most popular commercially available methods of detailed electromagnetic prospecting used in Canada. The method offers a practical compromise between ease and speed of surveying and the recording, plotting, and interpretation of diagnostic information on the characteristics of the secondary field in the presence of conductors. Recently, multi-frequency Slingram type instrumentation has been manufactured by Apex Parametrics Limited. This equipment offers a band of frequencies useful for surveying under clay belt conditions where conductive overburden and/or deep overburden are encountered frequently. A variety of coil separations are also possible so that depth and characteristics of the overburden can be taken into account to optimize the response and resolution of targets.

All nine lines were surveyed using a 200 m coil separation and the receiver was kept to the south of the transmitter while surveying along the north-south lines. Minor deviations from the horizontal at the transmitter produced large fluctuations in the in-phase and quadrature measurement made at the receiver and extreme care had to be exercised when measuring low frequency components of the secondary field. This was overcome by optical signal averaging the readout to achieve reliable data. Data was recorded at one-eighth the coil separation or every 25 m. Measurements are plotted for three of the nine lines recorded (Figure 2).

A complete interpretation of the results will be documented in a forthcoming report, however, several observations on the data are possible at this time:

a) By rationing the areas under the shoulders of the in-phase curves at each frequency (a function of dip) it appears that the upper portion of the conductive plate(s) have a northerly dip, remembering that at higher frequencies, the primary field has a more limited depth of penetration, whereas at lower frequencies a larger and deeper primary field is created for a given overburden resistivity. These factors suggest that the deeper parts of the conductive plate(s) have a southerly dip because of the reversal of the ratio.

b) Comparing traverses from west to east, a branching of conductive limbs into two or possibly three separate conductive sheets is apparent. This fact makes this test range valuable for carrying out resolution experiments with different types of EM equipment.

EM-37 Large Loop Survey

This survey illustrates the application of one transient electromagnetic technique for the direct detection of conductive bodies below a thick cover of glacial overburden. A large rectangular loop (300 m by 600 m) was placed in relation to the conductor strike such that the long axis of the loop was parallel to the conductors and offset to the south some 425 m. A peak current of 18 amps at a fundamental frequency of 30 Hz was passed through the loop which had a resistance of approximately 6.5 ohms. Rapid linear ramp termination of the transmitter current pulse induces a rectangular emf in the targets. This in turn produces a secondary field that rapidly decays in the absence of a conductor and decays more slowly in the presence of a conductor. In the presence of a conductor, the decay of the secondary field will usually reach a fixed decay rate \( \tau_0 \), which depends on the conductivity-thickness product and the larger dimensions of the conductor.

In order to respond to a wide range of conductor responses having a variety of conductivity-thickness products, twenty gates with expanding gate widths sample the decay curve as illustrated in Table 1.

At early times the response is largely due to the overburden and the conductor may not be visible. At late times the response of the overburden has decreased and the conductor produces the dominant effect.

Figures 3, 4, and 5 illustrate the EM 37 results over the corresponding lines surveyed by the MAXMIN III (Figure 2). The results of each line are plotted for three components of the secondary field on an expanding, grouped scale with time. The last channel of each group is repeated to show the effect of scale. Results are reported as sampled voltage with time across the traverse line and several pre-modelling observations can be made on these data:

a) An observation of the vertical field (Hz) profiles in Figures 3, 4, and 5 can be made by assuming that currents which are created in the conductor, stabilize at some point in time. Viewing the vertical field

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>GATE WIDTHS AND CENTRES FOR SAMPLING CHANNELS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Channel</td>
<td>Gate Centre (( \mu )s)</td>
</tr>
<tr>
<td>1</td>
<td>89</td>
</tr>
<tr>
<td>2</td>
<td>110</td>
</tr>
<tr>
<td>3</td>
<td>140</td>
</tr>
<tr>
<td>4</td>
<td>177</td>
</tr>
<tr>
<td>5</td>
<td>110</td>
</tr>
<tr>
<td>6</td>
<td>280</td>
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<tr>
<td>7</td>
<td>355</td>
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<td>8</td>
<td>443</td>
</tr>
<tr>
<td>9</td>
<td>564</td>
</tr>
<tr>
<td>10</td>
<td>713</td>
</tr>
<tr>
<td>11</td>
<td>881</td>
</tr>
<tr>
<td>12</td>
<td>1096</td>
</tr>
<tr>
<td>13</td>
<td>1411</td>
</tr>
<tr>
<td>14</td>
<td>1795</td>
</tr>
<tr>
<td>15</td>
<td>2224</td>
</tr>
<tr>
<td>16</td>
<td>2850</td>
</tr>
<tr>
<td>17</td>
<td>3600</td>
</tr>
<tr>
<td>18</td>
<td>4490</td>
</tr>
<tr>
<td>19</td>
<td>5700</td>
</tr>
<tr>
<td>20</td>
<td>7190</td>
</tr>
</tbody>
</table>
Figure 3—Showing EM37 three component measurements over Line 1 West.
Figure 4 - Showing EM37 three component measurement over Line 0.
Figure 5—Showing EM37 three component measurements over Line 1 East.
b) The dip observations made from the MAXMIN III data are confirmed by the EM 37 survey. By inspection of the horizontal field (Hx), we notice that a larger portion of area exists under the curve on the predicted hanging wall side of the conductor at early times, whereas a reverse is noticeable at late times. Modelling of the vertical and horizontal field components will be necessary to derive three dimensional structures. However, from preliminary results, the conductors appear to lie near the nose of a fold, the vertical axis of which appears to be concave to the south, and the east-west axis of which appears also to be concave to the south.
No. 26 A Gravity Study in North Central Ontario, Districts of Sudbury, Nipissing and Timiskaming

V.K. Gupta¹, F.S. Grant², and A. Boud³

Introduction

The Ontario Geological Survey has carried out semi-detailed gravity surveys in Ontario since 1973. As a part of this program over a period of three field seasons, 7250 gravity stations have been established, covering an area in excess of 33,000 km². The area is approximately bounded by Latitudes 46°15' and 48°00'N and by Longitudes 79°00'W, the Ontario - Quebec boundary and 82°00'W. Over 3400 rock density measurements on fresh rock samples have also been obtained by the Ontario Geological Survey, simultaneous to the gravity field work. As part of the National Gravity Survey, the Department of Energy, Mines, and Resources of Canada has also estab-
lished 3,629 gravity stations in the area. Thus, the total number of gravity stations in the survey area is 10,879. The Ontario Geological Survey has so far published two Bouguer Gravity Maps (Gupta and Wadge 1980a, 1980b). The final two Bouguer Gravity maps (scale 1:100,000) are nearing publication.

The geology of the map-area involves three major tectonic subdivisions of the Canadian Shield: the Superior, Grenville, and Southern Provinces. The map-area is quite complex and varied, consisting of numerous major metamorphic, plutonic, and structural events. The geology maps published by K.D. Card (1980) and K.D. Card and S.B. Lumbers (1977) have been compiled to produce composite maps at 1:100,000 and 1:250,000 scale and will be used extensively in the gravity interpretation.

**Objectives**

The aim of the gravity study is to develop in the survey area a geological interpretation of the gravity data. The interpretation is being primarily directed at solving problems associated with regional geology, and will be a useful aid for mineral exploration programs in the area of study. During the study, extensive use will also be made of the existing (Ontario Department of Mines-Geological Survey of Canada) aeromagnetic maps to provide adequate geological details and to remove gravity interpretation ambiguities. With this general framework, five specific geologic problems to be studied are:

1. **Cobalt Embayment:**
   - Determination of the thickness of the Huronian metasediments.
   - Determination of the structure and lithology of the basement rocks underlying the Huronian metasediments.

2. **Nipissing Diabase:**
   - Determination of shapes, volumes, attitudes, and burial depths of the Nipissing Diabase intrusions that occur within or adjacent to Huronian metasediments.
   - Spatial relationships of the gravity signatures of the Nipissing Diabases to known mineralization.

3. **“Greenstone” Belts:**
   - Determination of the cross-section forms, volumes, and lithostratigraphy of the known “greenstone” belts, and the identification of buried or unmapped metavolcanic remnants.

4. **Major Faults:**
   - To study the relationship between gravity anomalies and known major faults.

5. **Grenville Front:**
   - To determine the nature and location of the actual density boundary relating to the Grenville/ Superior contact.

**The Study**

Three Lacoste-Romberg gravimeters were used to establish gravity stations. The gravity observations were tied to the control stations of the National Gravity Network of Canada. A crustal density of 2.67 g/cm³ has been used in the Bouguer correction. The randomly-spaced observed gravity data were interpolated to a 1.5 km grid-cell size, which was convolved with a digital operator to remove data noise. Some smoothing on the final Bouguer contours was also applied. The resultant Bouguer anomaly map contoured at 20 gravity units (2 mgal) is shown in Figure 1.

Interactive two and three-dimensional computer modeling studies will be carried out on a number of well-defined gravity and aeromagnetic anomalies to provide depths, volumes, and attitudes of the causative bodies. The Bouguer gravity field will be separated into its regional and residual components using manual, upward continuation, and spectrum analysis techniques. The regional gravity map will be analysed to develop a crustal model of the Grenville Superior boundary. The residual gravity map will be studied to yield qualitative and quantitative structural information which will be of importance in developing exploration strategies for base and precious metals.

It has been revealed from density measurements on rock samples that there is very little mean density contrast between the Huronian metasediments (ρ = 2.70 g/cm³) and the underlying basement rocks consisting of trondhjemites and granites (ρ = 2.72 g/cm³). This has resulted in a lack of gravity anomalies associated with the metasediments in the Cobalt Embayment. Thus, it seems quite possible that the gravity field may not provide direct information on the thickness of the metasediments in the Cobalt Embayment. It can, however, provide indirect information which is based upon calculated depths to inhomogeneities within the basement, for example, metavolcanics and mafic intrusions.

In order to obtain reliable estimates on the thickness of the Huronian metasediments, we are planning to digitize 18 Ontario Department of Mines-Geological Survey of Canada aeromagnetic maps. This digitized information will be used to compute depths to the top of the causative bodies in order to prepare basement elevation contours. Digital processing (e.g. pseudo-susceptibility mapping, vertical differentiation, continuation, and so on) on the digitized aeromagnetic data will be carried out for the purpose of determining the internal lithostratigraphy of the various “greenstone” belts, and to study their relationship with known mineral deposits.

The density data collected during the gravity surveys have been stored in a System 2000 data base management system. This gives a readily available storage and retrieval capability that is helpful during the Bouguer gravity interpretation. The accompanying density table (Table 1) shows an example in which the density data can be utilized from the database. Bulk densities have been calculated for the rock units as given by the Ontario.
Figure 1 — Bouguer Anomaly Map. Contour interval is 20 gravity units (= 2 mgal).
TABLE 1

DENSITY MEASUREMENTS.
(The Map Unit Refers to Ontario Geological Survey Sudbury-Cobalt Compilation Map 2361)

<table>
<thead>
<tr>
<th>MAP UNIT</th>
<th>ROCK TYPE</th>
<th>N</th>
<th>R</th>
<th>( \bar{\rho} \pm s )</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>SUPERIOR and SOUTHERN PROVINCES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PALEOZOIC</td>
<td>Limestones and dolomite sediments</td>
<td>34</td>
<td>2.46-2.76</td>
<td>2.67±0.06</td>
</tr>
<tr>
<td></td>
<td>LATE PRECAMBRIAN</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAFIC INTRUSIVE ROCKS</td>
<td>All Samples (not weighted)</td>
<td>20</td>
<td>2.79-3.14</td>
<td>2.95±0.11</td>
</tr>
<tr>
<td></td>
<td>Olivine diabase and diabase dikes</td>
<td>11</td>
<td>2.90-3.04</td>
<td>3.00±0.07</td>
</tr>
<tr>
<td></td>
<td>GRENVILLE PROVINCE</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LATE PRECAMBRIAN</td>
<td>ANORTHOSITE SUITE INTRUSIVE ROCKS</td>
<td>6</td>
<td>2.74-3.05</td>
<td>2.86±0.12</td>
</tr>
<tr>
<td>MIDDLE PRECAMBRIAN</td>
<td>FELSIC INTRUSIVE ROCKS</td>
<td>59</td>
<td>2.58-2.79</td>
<td>2.67±0.05</td>
</tr>
<tr>
<td>METASEDIMENTS</td>
<td>All Samples (not weighted)</td>
<td>233</td>
<td>2.43-3.09</td>
<td>2.70±0.09</td>
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<tr>
<td></td>
<td>Biotite gneiss</td>
<td>147</td>
<td>2.43-3.09</td>
<td>2.70±0.09</td>
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<tr>
<td></td>
<td>Gneiss</td>
<td>13</td>
<td>2.59-3.06</td>
<td>2.69±0.05</td>
</tr>
<tr>
<td></td>
<td>Gneissic metasediments</td>
<td>73</td>
<td>2.60-2.99</td>
<td>2.71±0.06</td>
</tr>
<tr>
<td></td>
<td>SUPERIOR and SOUTHERN PROVINCES</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MIDDLE PRECAMBRIAN</td>
<td>FELSIC INTRUSIVE ROCKS</td>
<td>10</td>
<td>2.64-2.77</td>
<td>2.68±0.04</td>
</tr>
<tr>
<td></td>
<td>NIPISSING INTRUSIVE ROCKS</td>
<td>360</td>
<td>2.64-3.17</td>
<td>2.95±0.07</td>
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<tr>
<td>HURONIAN SUPERGROUP</td>
<td>COBALT GROUP</td>
<td>1066</td>
<td>2.53-2.95</td>
<td>2.70±0.06</td>
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<tr>
<td></td>
<td>HOUGH LAKE GROUP</td>
<td>11</td>
<td>2.61-2.75</td>
<td>2.69±0.05</td>
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<tr>
<td></td>
<td>MAFIC INTRUSIVE ROCKS</td>
<td>28</td>
<td>2.78-3.09</td>
<td>2.99±0.06</td>
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<tr>
<td></td>
<td>Gabbro Anorthosite Complexes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>EARLY PRECAMBRIAN</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>FELSIC TO INTERMEDIATE INTRUSIVE AND GNEISSIC ROCKS</td>
<td>402</td>
<td>2.47-2.89</td>
<td>2.67±0.05</td>
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</tr>
<tr>
<td>MAFIC AND ULTRAMAFIC INTRUSIVE ROCKS</td>
<td>51</td>
<td>2.76-3.23</td>
<td>2.92±0.10</td>
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<tr>
<td>METASEDIMENTS</td>
<td>40</td>
<td>2.57-2.92</td>
<td>2.72±0.08</td>
<td></td>
</tr>
<tr>
<td>METAVOLCANIC ROCKS</td>
<td>2</td>
<td>255</td>
<td>2.56-2.85</td>
<td>2.72±0.05</td>
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<td></td>
<td>1</td>
<td>144</td>
<td>2.76-3.22</td>
<td>2.93±0.09</td>
</tr>
<tr>
<td></td>
<td>IRON FORMATION</td>
<td>4</td>
<td>3.26-3.5</td>
<td>3.34±0.01</td>
</tr>
</tbody>
</table>

NOTE: N = Number of samples; R = Density range in g/cm³; \( \bar{\rho} \) = Mean density in g/cm³; s = Standard deviation in g/cm³.

Geological Survey Sudbury-Cobalt Compilation Map Number 2361. Various other density interpretations have been compiled to correlate geological hypotheses with gravity data. The randomly collected densities in the survey area have been gridded at a uniform spacing of 3 km and contoured at 0.1 g/cm³. The density contour maps will be studied for any possible correlation between the densities, Bouguer anomalies, and topography.

Using geological maps published by Card (1980) and Card and Lumbers (1977), it has been planimetrically determined that in the map-area, the intrusive rocks constitute 42 percent of the surface rocks, metavolcanics 10 percent, and the remaining 48 percent of the area is composed of metasediments. Mafic volcanic rocks to felsic volcanic rocks are in the proportion of 4:1. For accuracy and objectiveness, the percentages of the various rock types in the region were determined, and these were multiplied by the mean densities of each rock type to give a total weighted background density of 2.73 g/cm³. These results compare favourably to similar areas in other regions of Canada, and to shield areas in other parts of the world.

The interpretation, which is being carried out from maps at a scale of 1:100 000, is now in an advanced stage of preparation. It is expected that the results of this work will be available early next year.
References

Card, K.D.
1980: Preliminary Maps, Central Superior Province Compilation - Sudbury (411), Blind River (41 J), Gogama (41 P), Chapleau (41O); Geological Survey of Canada, Open File 690.

Card, K.D., and Lumbers, S.B.

Gupta, V.K. and Wadge, D.R.

No. 27 Regional Geochemical Mapping in Southwestern Ontario

Ian Thomson ¹ and E.A. Boni ²

FUNDS FOR THIS STUDY WERE MADE AVAILABLE FROM THE PROCEEDS OF "THE PROVINCIAL" LOTTERY.

Introduction

Systematic regional geochemical mapping of southwestern Ontario began in July, 1981 with a pilot phase, funded by the Ontario Lottery Corporation, covering some 20,000 km² about London, Hamilton, and the Niagara Peninsula. The program is based on sampling and analysis of stream sediment from tributary drainages at a reconnaissance density of 1 sample per 5 km².

General Background

Exploration geologists are familiar with the use of stream sediment geochemistry in the search for mineral deposits. The approach is based on the fact that, correctly taken, a sample of stream sediment is a natural composite of all material entering the stream from the catchment area upstream from the sampling point. Thus, systematic sampling and analysis of stream sediments permits identification of sites with abnormally high concentrations of trace elements (such as Cu or Zn) suggesting proximity to weathering mineralization. The technique was originally developed in the New England states and the Maritime provinces of Canada in the early 1950s, and since then has been used successfully in mineral exploration throughout the world (Meyer, Theobold, and Bloom 1979). After the first application of the technique, however, it was realized that the broad distribution patterns of the trace and major elements revealed by these surveys are primarily related to the composition of the various rock types and glacial deposits in the area under study. The surveys, therefore, not only aid in locating mineralization, but also compliment and qualify regional geological

¹Geochemist, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.
²Geological Assistant, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.
mapping by revealing cryptic chemical variations in the bedrock and surficial deposits.

Although dominantly a reflection of geological sources, the composition of stream sediment is also influenced by local surface conditions such as soil types and vegetation cover. Further, in some areas these natural patterns are modified or obscured by pollution or contamination from a variety of man-made sources.

In summary, therefore, regional geochemical mapping reveals complex patterns of element abundance related primarily to geology and modified by natural surface processes. It is upon this already complex natural geochemical landscape that the actions of man take place.

J.S. Webb (1964) proposed that the naturally occurring geochemical patterns revealed by stream sediment surveys could be of consequence to environmental studies. The term environment is here used in the broadest sense as all features which affect the well being of plants, animals, and man. Initial investigations demonstrated a positive relationship between areas with low levels of cobalt in stream sediments and cobalt deficiency in sheep (Webb 1964). Similar studies elsewhere in Great Britain and Ireland proved that abnormally high concentrations of selenium and molybdenum found in stream sediments were derived from black shales rich in these elements and were related to the incidence of selenosis and molybdenum induced copper deficiency in cattle (Webb 1974). Subsequently, the approach has been used successfully in numerous other studies, including a series of pioneering investigation in Ontario carried out over parts of the Niagara Peninsula (Fortescue 1972; Fortescue et al. 1976).

The Southwest Ontario Survey Program

Rational

Natural variations in the trace and major element content of bedrock are passed on to soils and made available to plants by the weathering processes. The variations influence the composition of ground and surface waters and also the entire food chain. Hence, the geochemistry of a region is of definite consequence to agriculture, fisheries, forestry, and epidemiology as well as mineral exploration, resource development, land use planning, and environmental monitoring. However, to date, there is no systematic data base showing regional variations in the natural abundance of trace and major elements across Ontario.

The character of regional geochemical data and their application in the various studies listed above are described by J.A.C. Fortescue, Ian Thomson, and R.B. Barlow (1980) who give particular attention to Ontario requirements.

Objectives

The Southwest Ontario Survey Program has been designed to fulfill the following objectives:

(a)—Determine the naturally occurring concentrations of trace and major elements across the survey area and so define the natural geochemical landscape in which we live and upon which the activities of man take place;

(b)—Determine the natural distribution patterns of essential and potentially toxic trace elements which might affect the nutrition, well being, and productivity of animals and crops;

(c)—Determine areas of mineral potential within the region;

(d)—Determine the natural distribution of elements of consequence to epidemiology.

Methodology

Project design and specifications were drawn up by the staff of the Geophysics/Geochemistry Section and J.A.C. Fortescue (environmental geochemical consultant). Every effort was made to incorporate experience gained from similar surveys elsewhere in the world. Particular attention is given to quality control of the sampling and analysis to ensure that the resulting data are suitable for rigorous use in a variety of scientific investigations.

Samples of active stream sediment are collected upstream from road/stream crossings at a density of one sample per 5 km². Sample sites are selected in streams with catchment areas of from 1 to 25 km², averaging 5 km², to ensure continuity and spatial relevence. The samples are air dried, sieved to minus 80 mesh, and subjected to extensive chemical analysis. A duplicate sample is collected at each site for permanent storage in an archive as a record of conditions at the time of the survey. Comprehensive field observations are made at each sample site and a photograph taken of every sample location. The samples will be analysed for 28 elements (total contained metal) and loss on ignition. Maps showing the regional distribution and concentration of these elements will be prepared from the resulting data and published as the work is completed.

Progress in 1981

Approximately 20 000 km² of regional geochemical mapping was completed in July and August, 1981. Sample collection and preparation were completed under contracts administered by the Geophysics/Geochemistry Section. Work in the western half of the area, centred on London, Ontario, was carried out by Dominion Soil Investigations Incorporated of Toronto. Work in the eastern section, covering Hamilton and the Niagara Peninsula, was completed by Gartner Lee and Associates of Toronto. Both contractors employed two, two-man sample collection teams each made up of a professional geologist/
geotechnician and a student assistant. Subcompact cars were used for transport with navigation achieved using 1:50 000 scale NTS maps on which all sample sites were preselected. Sampling proceeded systematically across the survey area with individual collection teams averaging 28 samples per day, depending on local access conditions. Analysis of the samples will be completed under contract by a commercial laboratory during the fall of 1981. Data compilation, initial appraisal, and map preparation will continue through the winter. Preliminary maps will be published as soon as they are available in 1982.

References


No. 28 Geochemical Evolution of Lake Systems Northeast of Lake Superior: Integrated Studies in the Wawa Area, District of Algoma

Ian Thomson¹

Introduction

General Background

Comprehensive investigations completed in 1980 (Thomson 1980; Fortescue et al. 1981) revealed the strong influence of geological substrate on the chemistry of lake waters; in particular, the buffering capacity and hence pH, in an area west of Wawa, District of Algoma. The lowest pH values occur in dilute, poorly buffered soft water lakes with extremely low alkalinites developed on granitic bedrock. The highest pH values occur in well buffered, hard water lakes with extremely high alkalinites developed on a substrate of calcareous drift.

Within these broad classifications, a number of significant local influences were observed. Throughout the area, headwater lakes at high elevations tend to have the lowest pH values. Furthermore, low pH lakes are of two types; brown water humic lakes and clear water lakes, which have different chemical characteristics, have evolved in different ways and have different susceptibilities to acid precipitation.

Systematic study of lake sediment cores revealed that it is possible to date the sediments using palynological techniques, and from this base examine the historical characteristics of the lakes. Studies completed in 1980 demonstrated that the diatom population of shield lakes is pH sensitive. Hence examination of populations preserved in the sediment permits estimation of palaeo pH conditions. Preliminary study indicated that some lakes have had a low pH condition in the past. Similarly, characteristic geochemical distribution patterns for As and Pb in the lake sediment cores, frequently attributed to input from recent pollution, were found to predate the arrival of man in this area. These results suggest that, at least in part, there are natural controls to the occurrence of low pH conditions in shield lakes and the enrichment of As and Pb in the near surface of lake sediments.

The 1981 program of investigation was designed by J.A.C. Fortescue, environmental consultant, together with the author, M.J. Dickman (limnologist) and J. Terasmae (palynologist), both of Brock University, to further investigate the historical development of shield lakes northeast of Lake Superior in an area believed to have recently come under the influence of acid precipitation (acid rain).

Objectives

The principal objective of the study was to examine, by use of geochemical, palynological, and biological techniques, the evolution of selected lake systems developed on known substrates within the principal lake water pH regimes identified by the 1980 study (Fortescue et al. 1981).

Methodology

For the present study, a small team of specialists involved in the 1980 study was reformed under the direction of the author. The team consisted of J.A.C. Fortescue, M.J. Dickman, J. Terasmae, and two Brock University students, Sushil Dixit and Ying-Kit Yung. At Wawa, S. Kerr, Fisheries biologist with the District Office of the Ontario Ministry of Natural Resources, provided active support for the field project. Contact was also made with Environment Canada from whom important supplementary information was obtained.

Five lake systems were selected for study on the basis of data available from earlier regional geochemical surveys (Ontario Geological Survey 1979a, 1979b) and inventory data collected by the Fisheries Branch of the Ontario Ministry of Natural Resources. Each lake system comprised a staircase containing a headwater lake and three further lakes at successively lower elevations. At each lake, water characteristics (pH, conductivity, temperature, dissolved O₂, secchi depth) were determined on site. Water samples were collected for later chemical and biological examination, and at least two 50 cm long sediment cores, representing approximately 500 years of sedimentation, were collected from the principal profundal basin in each lake. Deep sediment cores, up to 7.1 m in length were collected from selected lakes. All cores will be subjected to a comprehensive program of chemical and biological investigations through the fall of 1981.

¹Geochemist, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.
Lake Staircase location

LOCATION MAP

Scale: 1:1 584 000 or 1 inch to 25 miles
Acknowledgments

The Algoma Ore Division of Algoma Steel are thanked for their permission to carry out sampling of lake Series W which lies on private land northeast of Wawa.

Cal Sullivan, of the Great Lakes Forest Research Centre, Sault Ste. Marie, kindly made available cold storage facilities for stabilizing the samples collected in the present project, and provided important background data on other work ongoing in this region.

Steve Kerr, Fisheries biologist with the Wawa District Office of the Ontario Ministry of Natural Resources, is acknowledged for his enthusiastic support of the project, and use of laboratory equipment, data files, and maps. In particular, he was instrumental in selecting lake Series X and Z on the basis of recent Fisheries studies.

Field Program

The field program was completed in ten days during July, 1981. Access to most of the lakes was achieved by helicopter with sampling carried out from the floats of the aircraft. Lakes accessible by road were sampled from an inflatable boat.

The five lake systems selected for study were as follows:

Series U: Neutral-transitional lakes (pH 6.52 - 6.96) located 30 km northwest of Wawa, and underlain by metavolcanic and metasedimentary rocks of the Wawa Greenstone Belt.

Series W: Neutral-transitional lakes (pH 6.7 - 7.34) located 10 km northeast of Wawa within the fume kill from the iron sintering plant, and underlain by carbonate-rich metasedimentary rocks and metavolcanics of the Wawa Greenstone Belt.

Series X: Acid lakes (pH 4.82 - 5.18) situated on gneissic rocks south of the Montreal River, 95 km south of Wawa.

Series Y: Alkaline lakes (pH 7.62 - 8.07) situated close to the White River-Hornpayne Road, 95 km north of Wawa and developed on carbonate-rich calcareous glacial drift.

Series Z: Acid lakes (pH 5.17 - 5.64) situated on gneissic rocks south of the Montreal River, 100 km south of Wawa.

Lake Series X and Z occur adjacent to each other and offer the opportunity to study recent acidification of lake systems. Lakes in Series Z contain fish; although no young fish were observed, which indicates a recent failure of reproductive capability. Lakes in Series X are barren of fish.

Preliminary Results

At this time, limited water chemistry is available for the five lakes systems. Data for surface water pH, alkalinity (total fixed end point), calcium (Ca), and sulphate (SO₄) are presented in Table 1. In each series, lake 1 is the headwater lake, with lakes 2, 3, and 4 occurring at successive levels down the staircase.

The analytical data confirm the general relationships established by the 1980 study. The most acid lakes (Series X and Z) are dilute, poorly buffered systems with very low alkalinitities (0.70 to 2.00 milligrams per litre CaCO₃) developed on gneissic bedrock. The highest pH lakes (Series Y) are well buffered hard water systems with high alkalinitities (63.50 to 113.50 milligrams per litre CaCO₃) developed on calcareous glacial drift. The neutral-transitional lakes (Series U and W) have intermediate pH values and alkalinitities. It is interesting to note that among the neutral lakes the lowest pH (6.52) occurs in a headwater lake, U-1, in which the alkalinity is also depressed (8.75 milligrams per litre CaCO₃). These data suggest that lake U-1 is delicately poised, and is in the process of acidifying.

Lake Series W is of particular interest. The high SO₄ content of these lakes is directly attributable to atmospheric fallout from the Wawa sintering plant (Mclveen, Potvin, and Keller 1979). However, despite many years of constant input of acid material, these lakes remain neutral. The reason for this can be seen in the Ca and alkalinity data. The waters in these lakes are well buffered due to the presence of abundant carbonate material derived from the bedrock. Examination of cores from these lakes will provide information on how a naturally buffered system responds to the introduction of large quantities of acid material.

Lake System U is somewhat different. The slightly elevated sulphate content of the waters may be due to atmospheric input from the Wawa smelter. A natural contribution from the numerous sulphide mineral occurrences in the greenstone bedrock of the catchment areas to these lakes must, however, also be considered. Again, examination of the lake sediment cores will provide historical information which may enable differentiation of natural versus anthropogenic sources.

Lake Series Y is alkaline and also low in sulphate (undetected in the four lakes sampled). Since there are no sulphur sources in the bedrock or drift, these data suggest that the waters are not only well buffered, but are receiving, at most, very small amounts of acid (sulphate rich) precipitation.

Lake Series X and Z, although quite acid, are also low in sulphate. Again, the low abundance of sulphate, the bedrock contains virtually no sulphur compounds, indicates that little or no acid (sulphate rich) precipitation has entered the lakes in the period immediately before sampling was carried out. However, the lakes are acid; why? The area is known to receive acid precipitation (Shaw 1979) but, on the basis of the present data, not in large quantities. The cause of the very low pH status of
TABLE 1  
SURFACE WATER CHEMISTRY OF LAKES SAMPLED IN 1981.

<table>
<thead>
<tr>
<th>SERIES (SUBSTRATE)</th>
<th>LAKE</th>
<th>pH</th>
<th>ALKALINITY mg/CaCO₃</th>
<th>Ca ppm</th>
<th>SO₄ ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>U</td>
<td>1</td>
<td>6.52</td>
<td>8.75</td>
<td>4.2</td>
<td>8.3</td>
</tr>
<tr>
<td>(greenstone)</td>
<td>2</td>
<td>6.90</td>
<td>32.50</td>
<td>12.2</td>
<td>7.9</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>6.96</td>
<td>16.60</td>
<td>7.4</td>
<td>10.6</td>
</tr>
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<td></td>
<td>4</td>
<td>6.94</td>
<td>13.95</td>
<td>6.2</td>
<td>5.0</td>
</tr>
<tr>
<td>W</td>
<td>1</td>
<td>6.70</td>
<td>13.25</td>
<td>21.0</td>
<td>57.0</td>
</tr>
<tr>
<td>(greenstone in smelter plume)</td>
<td>2</td>
<td>6.91</td>
<td>13.50</td>
<td>19.8</td>
<td>50.0</td>
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<td></td>
<td>3</td>
<td>6.92</td>
<td>15.50</td>
<td>20.0</td>
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<td></td>
<td>4</td>
<td>7.34</td>
<td>18.25</td>
<td>21.4</td>
<td>53.0</td>
</tr>
<tr>
<td>X</td>
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<td>5.02</td>
<td>1.20</td>
<td>1.4</td>
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</tr>
<tr>
<td>(gneiss)</td>
<td>2</td>
<td>4.82</td>
<td>0.70</td>
<td>1.2</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>4.95</td>
<td>1.15</td>
<td>1.2</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>5.18</td>
<td>1.15</td>
<td>1.2</td>
<td>5.0</td>
</tr>
<tr>
<td>Y</td>
<td>1</td>
<td>8.07</td>
<td>84.50</td>
<td>21.4</td>
<td>5.0</td>
</tr>
<tr>
<td>(calcareous drift)</td>
<td>2</td>
<td>7.90</td>
<td>113.50</td>
<td>32.6</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>7.62</td>
<td>63.50</td>
<td>18.2</td>
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<td></td>
<td>4</td>
<td>7.97</td>
<td>108.50</td>
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</tr>
<tr>
<td>Z</td>
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<td>1.25</td>
<td>1.4</td>
<td>5.0</td>
</tr>
<tr>
<td>(gneiss)</td>
<td>2</td>
<td>5.59</td>
<td>1.90</td>
<td>1.6</td>
<td>5.0</td>
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<td>5.28</td>
<td>1.30</td>
<td>1.6</td>
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</tr>
<tr>
<td></td>
<td>4</td>
<td>5.64</td>
<td>2.00</td>
<td>1.6</td>
<td>5.0</td>
</tr>
</tbody>
</table>

these lakes is thus not immediately clear. It is expected, however, that systematic examination of the sediment cores taken from these lakes will provide evidence of their geochemical evolution and hence the factors controlling the present pH of the lake waters.

Complete results from this program will be published in 1982.

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Thomson, Ian
No. S17 Mineralogical Field Techniques for Till Prospecting in the Kirkland Lake Area, District of Timiskaming

J.T. Lourim¹ and Ian Thomson²

Introduction

As an extension to the program of geochemical work described by Ian Thomson and D.R. Wadge (this volume), a two week field project was mounted in July, 1981, to further investigate the mineralogy of the lodgment till in selected parts of the Kirkland Lake Area. This work forms part of the Kirkland Lake Initiatives Program (KLIP), a project funded equally by the Federal and Provincial governments and managed by the Ontario Geological Survey.

Systematic examination of the mineralogy of till samples collected during the regional survey program (Averill and Thomson 1981, Thomson and Lourim 1981, Thomson and Wadge 1980) has led to the recognition of a number of mineralogical assemblages characteristic of distinctive geological environments in the Kirkland Lake Area. Particular attention has been given to indicator minerals for potential gold mineralization (Thomson and Lourim 1981). The present work sought to continue these studies in the field and develop procedures appropriate for use in an active exploration program.

Objectives

The objectives of the field program were:

1. To further define, through the use of indicator minerals, areas geologically favourable for gold mineralization as described by Thomson and Lourim (1981).

2. To develop appropriate field methods of sample preparation in order to obtain a mineral concentrate suitable for preliminary mineralogical examination. For this, rapid turnaround and minimal use of mechanical devices and hazardous chemicals were considered prime requirements.

Methodology

Samples of lodgment till were collected at close intervals (200 to 500 m) through the areas of interest from pits excavated by a backhoe or by hand, using the procedures described by Thomson and Wadge (1980).

The bulk samples of till (+10 kg) taken from each location were brought to the field office in Kirkland Lake, where they were processed to yield two separate mineral concentrates. The method of sample preparation developed for this study is summarized in the flow sheet shown in Figure 1. Basically, it comprises a modified "gold panning" technique.

The bulk sample is wet sieved through a 20 mesh screen. The oversize (+20 mesh) fragments were examined and notes taken of the lithologies present; any evidence of mineralization or alteration was noted and these fragments were discarded.

The minus 20 mesh part of the sample was panned to yield the mineral concentrate. Water for the panning process was contained in a 45 gallon drum which had been cut in half and mounted on a frame at bench height for comfort and ease of operation. A continued flow of water was ensured via a hose from the domestic supply system.

An injection moulded thermoplastic "gold pan" with riffle bars was employed, it was very efficient and easy to use. With this type of pan, concentration of the heavy minerals is achieved using an erratic backward and forward motion (jigging), rather than the conventional swirling motion. The light minerals were thus progressively eliminated over the riffle bars and out of the pan.

The bulk sample was processed to yield approximately 300 g (concentration ratio 17:1) of panned concentrate enriched in minerals with a specific gravity greater than 2.5. The lowest riffle in the pan yielded a small (5 to 10 g), very pure concentrate, in which almost all minerals have a specific gravity greater than 3.2 (the "superconcentrate").

Some samples were difficult to process due to a high clay content. Preparation of the concentrate from these samples was aided by use of Calgon in the water, which helped disperse the clay coating from individual grains and fragments.
Figure 1—Flow Chart for mineral concentrate.
The concentrate and superconcentrate were transferred to funnels lined with filter paper and were placed to dry in the sun.

The dry samples were studied under a binocular microscope, using the procedures described by Thomson and Lourim (1981). Results were tabulated and plotted on base maps. Areas of particular interest were identified and additional sample sites selected. Once the field technique was perfected, it was possible for the mineralogist (J.T. Lourim) to work in phase with the sampling team to sustain the active follow-up of target areas.

**Preliminary Results**

Systematic examination of the concentrates has led to the recognition of mineral assemblages indicative of previously unrecognized geological environments in two areas:

**Area 1.** Till samples collected close to the McElroy-Hearst Township line, south of Estrangement Creek, were found to contain apatite, zircon, and tourmaline along with well-formed crystals of gypsum and fuchsite. Also present in trace amounts was a light sea-green coloured form of beryl. The samples were collected south (down-ice) of an area mapped as an easterly apophysis of the McElroy Stock. Samples collected north of this area of intrusive rock do not contain any apatite, tourmaline, or beryl. Apatite is a known accessory in the McElroy Stock (Abrahams 1956). The presence of tourmaline and beryl is, however, not reported in the literature. Microscopic studies, supplemented by preliminary x-ray identification, revealed the presence of both the Mg-rich (dravite-schorlirte) and Li-rich (elbaite-indicolite) forms of tourmaline. The presence of beryl and Li-rich tourmaline in the till is thought to be indicative of extreme magmatic fractionation localized within the apophysis to the main body of the McElroy Stock, or in associated dikes.

A possible potential for pegmatite bodies is inferred from this relationship, which requires further work for verification.

**Area 2.** Study of samples collected west of Kirkland Lake in 1980 (Thomson and Wadge 1980) had earlier revealed a strong mineral dispersion train down-ice from the area of the Kirkland Lake "break". Further sampling in the vicinity of the Macassa Mine in 1981 has confirmed this dispersion train. Of note, is the presence of topaz which can be traced well north of the "break" and was followed north of the railway line, northwest of the Macassa Mine, east of Amikouami Creek. The source has yet to be localized and is assumed to lie to the north-northwest of the last sample point. Topaz is a mineral typical of late stage alkali metasomatism (high fluorine) in granitic environments. Its occurrence in the till strongly suggests that a specialized granite with associated greisenization may exist within the area. Present speculation identifies the Winnie Lake Stock and surrounding ground as an area of particular interest.

Work on all the samples is continuing.

**Acknowledgments**

The authors wish to thank the Macassa Division of Willroy Mines Limited for permission to conduct detailed sampling on their properties. The Geosciences Laboratory of the Ontario Geological Survey provided essential support in the preparations for the field study and in the use of their facilities.

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Thomson, I., and Wadge, D.R.
No. S18 Reconnaissance Basal Till Surveys and Related Detailed Geochemical Research in the Kirkland Lake Area, Districts of Timiskaming and Cochrane

Ian Thomson¹ and D.R. Wadge²

THE WORK REPORTED HERE IS PART OF THE KIRKLAND LAKE AREA GEOSCIENTIFIC SURVEYS. IT IS EQUALLY FUNDED BY THE FEDERAL DEPARTMENT OF REGIONAL ECONOMIC EXPANSION AND THE ONTARIO MINISTRY OF NORTHERN AFFAIRS UNDER THE COMMUNITY AND RURAL RESOURCE DEVELOPMENT SUBSIDIARY AGREEMENT.

Introduction

The Geophysics/Geochemistry Section continued an active program of applied geochemical studies in the Kirkland Lake area throughout 1981. This work forms part of the Kirkland Lake Initiatives Program (KLIP), a joint Federal-Provincial project, designed and managed by the Ontario Geological Survey, which will provide a comprehensive geoscientific data base for the area.

¹Geochemist, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.
²Geochemical Assistant, Geophysics/Geochemistry Section, Ontario Geological Survey, Toronto.

This year's work continued the balanced program of systematic reconnaissance surveying and detailed geochemical investigations begun in 1979. The area of study lies between the little Clay Belt and the greater Abitibi Clay Belt, and was the site of a major lake basin during the retreat stage of the Pleistocene glaciation. Extensive deposits of glaciolacustrine clay and glaciofluvial sand and gravel conceal the bedrock over large areas and preclude the use of conventional geochemical techniques. In this area of complex glacial overburden, specialized geochemical procedures are employed.

Acknowledgments

During the execution of this year's work, considerable support was given by individuals and companies who provided access to properties, maps, reports, and sample material. In particular, Corporation Falconbridge Copper, the Macassa Division of Willroy Mines Limited, and Davey Lowe are thanked for permitting detailed studies on their ground.

The work described below was designed and coordinated by the two authors, and unless otherwise indicated, was completed by them with the aid of Peter de Bastiani, Robert Sutherland, and Bruce MacNair, summer student assistants.

Reconnaissance Survey Program

This year's work was completed in two phases. Systematic sampling in areas of deep overburden was completed through parts of six townships using reverse circulation rotary drilling equipment. In addition, sampling was continued in areas of shallow overburden throughout parts of 14 townships using a backhoe to excavate pits into the lodgment till.

Practical experience has shown that, in areas such as Kirkland Lake the basal or lodgment till is of essentially local origin and that systematic sampling of this material...
is an effective means of evaluating the mineral potential of the drift covered areas (Thompson 1979).

**Reverse Circulation Rotary Drilling**

The one month program of drilling, completed in February and March, marked the third part of a project that will ultimately cover most of the deep overburden terrain in the KLIP area. The work is a continuation of the project initiated in 1979 and employed the same techniques described by Thomson and Guindon (1979) and Averill and Thomson (1981).

The winter program was initiated to drill in remote parts of the KLIP area accessible only when the swamps and muskegs are frozen. The work comprises drilling in areas of deep overburden, continuous profile sampling of the overburden and of the bedrock beneath. Chemical and mineralogical studies are undertaken on the samples obtained, paying particular attention to the composition of glacial till, with a view to assessing the mineral potential of the drift covered areas.

During the winter program, 25 drill holes were completed for a total length of 683 m of drilling. The holes are situated on a 3 km grid modified to account for access and outcrop/overburden relationships. Bad snow and poor ice conditions resulting from an early thaw prevented access to some parts of the intended survey area. Drilling was undertaken by Bradley Brothers of Timmins using a Longyear 38 reverse circulation drill mounted on a Nodwell FN 160 tracked carrier. Derry, Michener, and Booth of Toronto managed the program, and provided a team of three people for on site supervision, logging, and sampling of the drill holes.

Drilling was completed through parts of Arnold, Benoit, Bisley, Eby, Lebel, Melba, and Morissette Townships. North of the present Arctic watershed, a complex glaciofluvial and glaciolacustrine sequence is preserved which displays evidence of deposition close to an oscillating ice margin. A basal lodgment till is often present immediately above the bedrock. Minor readvances of the ice are evidenced by the presence of till horizons within the glaciofluvial and glaciolacustrine sediments.

Chemical and mineralogical studies of the samples collected during the winter are complete at the time of writing and will be published before the end of 1981.

**Back Hoe Pit Sampling**

The six week program of pitting and sampling unoxidized till, completed during the summer of 1981, was a continuation of the work begun in 1980 (Thomson and Wadge 1980). The procedures developed in 1980 have been found effective throughout the central part of the KLIP area. This ground, extending east-west parallel with Highway 66 and following the Arctic watershed, was a positive topographic feature during the retreat stage of the final Pleistocene glaciation. Glaciolacustrine and glaciofluvial deposits are generally thin and intermittently developed with numerous outcrops; till is frequently present at or close to surface. Throughout this area, till is readily sampled by digging shallow pits at points where lodgment or basal till is known to be preferentially developed (Thomson and Wadge 1980).

The procedures employed in 1981 are identical with those described by Thomson and Wadge (1980), except that the machine used was a John Deere tree skidder, with a backhoe attached, rented from Michaud and Sons of Montteith, Ontario. A total of 194 samples were collected from 193 locations in 337 hours of machine time which includes travel time between sites and time taken to backfill all the holes excavated. Some 50 other pits, excavated within this time, failed to intersect till and were thus not sampled. In addition, a further 18 pits were excavated and sampled by hand at locations inaccessible to the skidder-backhoe.

Samples were collected at approximately 1 km intervals along roads, tracks, powerlines, and other access routes in Eby, Otto, Boston, Pacaud, and Gauthier Townships and portions of Maisonville, Grenfell, Teck, Bernhardt, Morissette, Lebel, McEloy, Catharine, Hearst, Kalline, McVittie, and McGarry Townships. Local conditions varied considerably in detail but, for the most part, sample locations conformed to the generalized model described by Thomson and Wadge (1980). In the northern part of the area sampled, close to the Arctic watershed, however, extensive till plains are developed; most prominently in Bernhardt and Maisonville Townships. Here hummocky till, which is often several metres deep and possibly a complex of basal lodgment and upper undifferentiated tills, occurs at surface forming an undulating plateau with frequent large outcrops of bedrock.

Till samples collected in this program will be subjected to the same chemical and mineralogical procedures as samples from the drill project. The resulting data will thus provide continuous high density geochemical/mineralogical coverage for the southern and central parts of the KLIP area; a region of very high mineral potential that remains relatively unknown because of the extensive drift cover.

Results from the back-hoe survey will be published in 1982.

**Detailed Investigations**

During the summer field program, a number of small studies were completed involving strategic sampling to gain information in support of the ongoing reconnaissance project. Two, larger, self contained projects were also undertaken comprising (a) an orientation study to examine the dispersion of gold and associated indicator elements, and (b) a test program with the new Wink Sonic Drill.

**Orientation Studies at the McIvor Gold Property**

A comprehensive program of orientation work was com-
completed over the Mcivor property, a gold occurrence some 6 km west of Kirkland Lake owned by the Macassa Division of Wilroy Mines Limited. The Mcivor property was selected for study because it is generally representative of overburden conditions and the style of mineralization. This style is Au with tellurides and sulphide minerals associated with quartz veins cutting Timiskaming intrusives, sedimentary rocks, and volcanic rocks, and is typical of Kirkland Lake. Careful study had shown that such an orientation could not be carried out in Kirkland Lake itself because of the disturbed character of ground throughout the main area of the mining camp.

The Kirkland Lake style of gold mineralization presents some special problems. The gold orebodies are structurally controlled and were originally discovered by systematic prospecting, trenching, and underground development. Little geophysical data exists. Such information as is available indicates that the gold ore zones are probably not easy to locate with applied geochemical techniques. Gold is undoubtedly the best indication of the mineralization. Molybdenum, lead, and to a lesser extent, copper, are probably indicators; but are at best indirect. Tellurium has been very little studied and appears to be potentially a very useful indicator (Thomson and Wadge 1980). Arsenic is apparently very rare and may indeed be absent, even at geochemical levels, from many of the veins. This is in marked contrast with the Larder Lake (Kerr Addison) style of mineralization which is distinctly arsenical, but does not carry tellurium (Thomson and Lourim 1981). Radon and mercury are also of interest since gaseous leakage of these elements may take place along auriferous fractures and shear zones.

At Mcivor, development work carried out in the 1930s (trenching, a 150-foot shaft, and underground development) proved an auriferous zone comprising a quartz vein stockwork up to 0.5 m wide with sulphide minerals in highly sheared rock within carbonatized Timiskaming conglomerate. At surface, the vein and shear zone outcrop intermittently for some 100 m before plunging beneath a swamp.

Within the area of the orientation study, outcrops of bedrock are quite frequent. Between the outcrops, the overburden comprises a thin, intermittent, lodgment till, sedimentary rocks, and volcanic rocks, and is typical of Kirkland Lake. Careful study had shown that such an orientation could not be carried out in Kirkland Lake itself because of the disturbed character of ground throughout the main area of the mining camp.

The equipment used for the test program was built by Wink, and operated, under licence, by C.W. Archibald Limited of Toronto who provided a crew of three men to operate the drill. The unit was completed successfully. A strong conductor was located, subparallel with the Mcivor vein, and traced for several hundred metres beneath a cover of up to 13 m of silt and sand.

The objectives of the test were to assess the capabilities of the prototype Wink system for deep sampling of lodgment till in the Kirkland Lake area, and also provide the operators of the equipment with an opportunity to gain experience and further develop the drilling technique.

f) Routine organic (leaf litter) sampling to examine the effectiveness of this technique in exploring for Au under shallow (up to 10 m) overburden of various types;

g) Deep overburden sampling across the Mcivor gold zone where it is buried by silt and sand using a flow through bit, percussion sampling system (Thomson and Guindon 1979);
h) Detailed sampling of all parts of four carefully selected trees, and the soil beneath, to examine the mobilization, uptake, translocation, and storage of Au by trees;
i) A Gamma-ray survey to detect any alteration patterns.

A routine VLF-EM survey employing a Crone Radem unit was completed successfully. A strong conductor was located, subparallel with the Mcivor vein, and traced for several hundred metres beneath a cover of up to 13 m of silt and sand.

Analytical and interpretive work will continue through the winter of 1981-1982.

Experimental Work With The Wink Sonic Drill

The Wink Vibra-Corer Sonic Drill was deployed for a short test program during August, 1981. Drilling was undertaken at a series of sites selected, on the basis of previous experience with reverse circulation rotary or percussion drilling, as being representative of the range of overburden conditions present in the Kirkland Lake area. The objectives of the test were to assess the capabilities of the prototype Wink system for deep sampling of lodgment till in the Kirkland Lake area, and also provide the operators of the equipment with an opportunity to gain experience and further develop the drilling technique.

The objectives of the test were to assess the capabilities of the prototype Wink system for deep sampling of lodgment till in the Kirkland Lake area, and also provide the operators of the equipment with an opportunity to gain experience and further develop the drilling technique.

The equipment used for the test program was built by Wink, and operated, under licence, by C.W. Archibald Limited of Toronto who provided a crew of three men to operate the drill. The unit is remarkably simple and the entire inventory, including spares and back-up equipment, is carried in a half ton pick-up. While on site, the equipment can be manhandled between drill sites by the crew. The drill is propelled into the ground by the Wink Vibra-Head which weighs some 12 kg and is driven, via a flexible power take off, by a 4 horsepower gasoline motor. The head engages with the drill rods which are normal 5-ft-long BQ casing. The lead rod carries an open, un-toothed, hardened steel bit. The drill rods are retrieved using an electric winch mounted on a portable gin pole.

In operation, the drill literally vibrates itself into the ground. The drill bit settles into and around the unconsolidated overburden which flows, slightly compacted, into the hollow casing. After penetrating the desired distance, (usually 1.5 m) the rods are lifted and the sample recovered from the casing, virtually undisturbed. This ability to recover a full, continuous, essentially undisturbed sample of unconsolidated overburden is a great advantage to many scientific investigations, not least drift pro-
specting. The unit cannot penetrate fresh bedrock, will
stop against large cobbles or boulders in the overburden,
and has difficulty in very coarse gravel which tends to jam
in the BQ casing.

During the present test program the drill achieved a
maximum depth of 25 m in glaciolacustrine clay over
sands before penetrating 10 cm into the lodgment till
where it stopped. Operationally, penetration rates varied
as a function of overburden composition and moisture
content. Maximum penetration was achieved in sands,
silts, and gravels below the water table where rates up to
8 seconds per metre were observed. Pebble beds in
these sediments were readily penetrated; individual pebbles
were found to have been shattered by the sonic bit.
Dry glaciofluvial and glaciolacustrine sands (typical of
the flanks of esker systems) above the water table were
particularly resistant. It appears that dry sand packs
down under the sonic vibrations and will not "flow" into
the casing. Water poured into the hole was found to pro-
vide the necessary "lubrication" and considerably aided
the progress of the drill without visibly altering the bulk
composition of the sample.

Lodgment till proved particularly intractable, prin-
cipally because of the tough, dense character of this over-
compacted sediment. On encountering till at depth, the
drill behaved as if weathered bedrock had been reached.
Penetration slowed immediately and could be sustained
only with difficulty. The Wink unit progressed slowly when
drilling into a thick till unit exposed at the surface, and
reached a depth of 6 m in about an hour before hitting a
boulder where penetration ceased.

In review, therefore, the prototype Wink Sonic Drill
employed in the present test program can be seen to
have some particular advantages. It is a relatively inex-
ensive, light weight, portable unit that can recover a
continuous bulk sample of essentially undisturbed mate-
rial. It clearly operates best in wet silt, sands, and gravels
and appears to be most efficient in overburden up to 12
m deep. At greater depths, considerable time is spend
pulling and clearing drill casing. Drilling with this equip-
ment below 10 m in deep dry sand sequences, such as
on the flanks of eskers, is likely to be very slow. Till pres-
ents a serious problem because of the overcompacted
nature of this sediment. In the Kirkland Lake area the unit,
as presently operating, is not a cost effective system for
sampling lodgment till at depth.

The Wink Sonic Drill, as presently developed, is
suited for sampling alluvial material such as placer gold
deposits and tailings ponds, and for geotechnical stud-
ies, including appraisal of clay, sand, and gravel depos-
its, where these targets lie close to or below the water ta-
ble.

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Paper 96,201p.
No. S19 Airborne Electromagnetic-Magnetic Surveys in Northern Ontario and Associated Research

R.B. Barlow

This project was funded by the Ontario Ministry of Northern Affairs through the Northern Ontario Geological Survey (NOGS) program.

Introduction

Two airborne electromagnetic-magnetic surveys were flown for the Ontario Geological Survey during the late fall of 1980 and the winter months of 1981. The surveys formed part of a joint program between the Ministry of Northern Affairs and the Ministry of Natural Resources. The general objective of this program is to enhance the geoscience data base in selected areas of the Province which are considered to have high mineral potential. These surveys are planned and coordinated by the staff of the Geophysics/Geochemistry Section.

In addition, a research project was carried out on three multi-frequency airborne electromagnetic systems and one time domain system, for the purpose of constructing interpretational aids to be used with the survey results.

The study presents a series of anomaly responses over several short-strike-length, buried, thin sheet conductors. Also, master curve phasor diagrams, covering a broad band of responses which would be normally obtained over short strike length conductors under survey conditions, are presented. The computer modelling study is based on a digital computer program developed at the University of Toronto, Geophysics Laboratory (Dyck and Bloore 1980).

Sioux Lookout Area - Airborne Electromagnetic Survey

This area was surveyed by Aerodat Limited using a Bell 206B helicopter equipped with the Aerodat HEM Electromagnetic System which measures in-phase and quadrature components at two frequencies (945 Hz and 4175 Hz). A Barringer AM-104 Proton Precession Magnetometer is included in this system.

Mean flight line spacing was set at 200 m and the terrain clearance of the sensor bird was approximately 30 m. A time constant of 0.1 second, and a sampling interval of 0.2 second, allowed post-flight filtering to remove...
atmospherics. The distance between Tx and Rx co-axial coil pairs is 7 m. The quadrature response was calculated to peak at a \((\alpha t)\) equal to 3 for the 4175 Hz channel and at a \((\alpha t)\) equal to 15 for the 945 Hz channel (where \((\alpha t)\) = Conductivity - Thickness Product).

Discrimination of conductors is based on the ratio of the in-phase to quadrature responses, variation of responses with frequency, magnetic correlation and the anomaly shape, together with conductor pattern and topography. Approximately 9993 line km of data were collected over the area, and the results will be released on photomosaic-based maps at a scale of 1:20 000 and 1:31 680.

Swayze Area - Airborne Electromagnetic Survey

This area was surveyed by Questor Surveys Limited using a Briton-Norman Trislander aircraft equipped with a Barringer/Questor Mark VI Input\(^{\text{a}}\) airborne electromagnetic System and a Sonotek PMH 5010 Proton Precession Magnetometer.

Mean flight line spacing was set at 200 m and the terrain clearance of the transmitter was approximately 120 m. The receiver coil is towed approximately 90 m aft of the transmitter and 66 m below it. The primary pulse frequency is fixed at 144 Hz and the pulse duration is 1 millisecond. A listing of gate windows (in ms) is as follows:

Channel 1 - 0.20 to 0.38
Channel 2 - 0.38 to 0.56
Channel 3 - 0.56 to 0.92
Channel 4 - 0.92 to 1.28
Channel 5 - 1.28 to 1.82
Channel 6 - 1.82 to 2.36

The transient response in the presence of a conductor is measured after termination of the primary pulse as voltage representative of the emf induced in the receiver by the decay of the secondary field. The decay spectrum is sampled at the above gates and is expressed as parts per million of the primary pulse amplitude. Modelling studies show that channels 1 through 6 reach their respective response maximums between 10 and 80 mhos for most tabular thin sheets.

Discrimination of conductors is based on the rate of transient decay, magnetic correlation and the anomaly shape, together with the conductor pattern and topography. A total of 12 035 line km of data were collected over the area, and the results will be released on photomosaic-based maps at a scale of 1:20 000 and 1:31 680.

Computer Modelling Study

In order to compare results obtained through computer modelling with those obtained earlier by analogue modelling (Ghosh 1972), a comparison phasor diagram was constructed. A standard vertical co-axial pair of coils with a separation of 9.144 m, moving perpendicularly above a vertically dipping conductor having a strike length of 442 m and a depth extent of 221 m, was chosen for the test.

As shown in Figure 1, close agreement was obtained.
between the analogue and digital methods, with the exception of a family of responses obtained at shallow depth. The problem only becomes serious near the inductive limits and is caused by a limited number of eigen currents allowed in the computer program, and errors involved in numerical integrations involved in computing the coupling factors. A.V. Dyck and M. Bloore (1980) suggest keeping the plate width-strike product less than 100 \( d_R \times d_T \) where \( d_R \) and \( d_T \) are the distances of the receiver and the transmitter, respectively, from the nearest point on the plate. Other limitations involving the accuracy of the high frequency quadrature response are suspected to occur when modelling conductivity-thickness products with values beyond 100 mhos.

With the above limitations in mind, four catalogues of responses were produced by the modelling study over short strike-length, thin sheet conductors. Each catalogue illustrates responses from the following systems:

- **Aerodat HEM**
- **Scintrex HEM-802**
- **Scintrex/Kenting Tridem**
- **Barringer/Questor Mark VI**

**INPUT**

- Two Frequency Helicopter System
- Two Frequency Helicopter System
- Three Frequency Fixed-Wing System
- Six-Channel Time Domain Fixed Wing System

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**Figure 1**—Diagram showing comparison of results obtained by analogue methods (Ghosh 1972) with those obtained by computer simulation (Dyck and Bloore 1980).
Results of this study are available on a limited supply basis from the Geophysics/Geochemistry Section, Ontario Geological Survey.

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Mineral Deposits Programs
During 1981, the Mineral Deposits Section continued and developed its applied research program to investigate the geology of the mineral deposits of Ontario. Despite significant staff changes, the section was able to mount a substantial field program involving 13 independent groups; this included application of university and regional staff expertise through cooperative project work. As part of the base program of the Section, projects were initiated or continued in each of the major geological provinces of the Province, namely, the Superior, Southern, and Grenville Provinces. Several community-based and commodity oriented projects supplementary to the main base program were carried out through funding provided by: the Ontario Ministry of Northern Affairs; jointly by the Ontario Ministry of Northern Affairs and the Department of Regional Economic Expansion, Canada; or jointly by the Ontario Ministry of Natural Resources and the Department of Regional Economic Expansion, Canada. Acknowledgment of the funding source is included in individual summaries.

In the Superior Province, broad coverage of the diverse mineral resources is being maintained while new initiatives are being directed principally toward developing an improved understanding of the geological associations of gold mineralization. A.J. Andrews and M.E. Cherry conducted extensive field examinations of the main gold camps as part of a comprehensive evaluation of the applications of research techniques in exploration presently underway. This work is being done in cooperation with J.S. Springer. As part of this study, a reconnaissance investigation of the North Caribou Lake Greenstone Belt, host of the recently discovered Opapimiskan Lake Gold occurrence, was carried out (Andrews, Sharpe, and Janes, this volume). M.E. Durocher and S. Van Haaften (Resident and Resource Geologist, respectively, Ontario Ministry of Natural Resources, Red Lake) initiated a comprehensive three-year study of the geology and distribution of gold deposits in the Red Lake area. Synthesis of geological data has commenced, and several properties were examined, and sampled for further petrographic and geochemical investigation. F.R. Ploeger (this volume) continued his detailed study of the relationship between gold mineralization and syenitic rocks in the Kirkland Lake Area.

S. Marmont carried out field investigations related to the project started in 1977 by A.C. Colvine to investigate mineralization related to Early Precambrian granitoid stocks as possible porphyry copper deposits. Three deposits were examined in detail (Marmont and Colvine, this volume) and six on a reconnaissance basis (Colvine and Marmont, this volume). This work has demonstrated that granitic intrusion plays a significant role in the concentration of mineralization (Colvine and Marmont, this volume); while this is the final year of this project, further work is planned under the base program to investigate more specifically the relationship between granitoid intrusion and gold deposits.

K.H. Poulsen (this volume) continued a comprehensive study of the mineral deposits and metallogeny of the Fort Frances-Mine Centre area. This project covers the geological association of all metallic mineral deposits; the structural controls on gold mineralization, in particular, were defined.

A limited amount of work continued on the project to investigate the metallogenetic development of the Southern Province (Innes and Colvine 1979). The interdisciplinary program to investigate the geology and mineral deposits of the Cobalt-Temagami-Gowganda area had to be postponed due to unavailability of funding; as a result only three projects in the area could be mounted by the Mineral Deposits Section.

1Chief, Mineral Deposits Section, Ontario Geological Survey, Toronto.
A.C. Colvine (this volume) conducted a reconnaissance survey of Huronian strata as possible hosts for paleoplacer gold concentrations; this work emphasized quartz pebble conglomerate units in the Lorrain Formation in the northern part of the Cobalt Embayment. D.G.F. Long (this volume) initiated a project to examine the sedimentary framework of the Huronian strata in the southern part of the Cobalt Embayment; this work is also intended to help evaluation of the paleoplacer gold potential indicated by the work of H.D. Meyn and M.K. Matthews (1980). L. Owsiacki (this volume) initiated a project to map and examine the mineral deposits of the Lundy Township area, previously unmapped; this area contains both Gowganda and Lorrain Formations and is cut by large diabase sills, with associated vein formation.

Faiely broad coverage of the mineral deposits of the Grenville Province continued during 1981. T.R. Carter (this volume) with J.S. Springer, carried out broad mineral deposits studies, with emphasis on carbonate-hosted zinc deposits, and graphite deposits. A detailed study of the shear-zone-related gold mineralization of the Cordova gabbro was initiated by P. Thomas (Thomas and Cherry, this volume). J.A. Siddiqui (Graduate Student, University of Ottawa) initiated a parallel study to map and sample the area of the Sovereign gold deposit in the Deloro granitic pluton, Marmora and Madoc Townships. At the Sovereign gold deposit, gold occurs in quartz-potassic feldspar-ankerite-biotite-pyrite-arsenopyrite veins in altered sheared granite.

A diverse industrial minerals program was carried out under the direction of M.A. Vos. A large part of the funding for this program was provided by the Ontario Ministry of Northern Affairs under the Northern Industrial Minerals Studies Program:

—A comprehensive catalogue and geological inventory of industrial minerals in northern Ontario is nearing completion.
—The Cargill Complex was examined for its vermiculite potential (Vos, this volume), and a brief visit was made to the Prairie Lake Complex in an attempt to locate a wollastonite occurrence; this work is part of the project to evaluate industrial minerals of the alkalic complexes.
—Three areas were considered for their nepheline syenite and feldspar potential for use as a ceramic raw material. Two nepheline syenite bodies in Bigwood Township are presently being evaluated by Steep Rock Iron Mines Limited. Chip samples were collected from the Buda Feldspar pegmatite dike in Goldie Township. Similarly, the Thunderbrick Feldspar deposit on the Spruce River Road near Thunder Bay, also a pegmatite dike, was examined and sampled.
—A.A. Speed continued the project to evaluate sources of lime in Northern Ontario (Mason and Vos 1980). Field examinations and sampling of several of the deposits was carried out, with emphasis on the marl (travertine/tuff) deposits.

Several of these projects are nearing completion, and along with the lithium geochemical project should be released early in 1982.

Under the base program, M.A. Vos initiated a project to evaluate the building and facing stone potential in Ontario; this project includes crushed stone for terrazzo and landscape aggregates. During 1981 samples were collected from the quarries in the Huntsville-Haliburton area, in Southern Ontario, and from the Port Coldwell Complex in Northern Ontario. Cut and polished specimens are being prepared for display in Toronto and the relevant Regional Offices.

Members of the section continued to monitor the status of mineral reserves and resources in the province. J.A. Robertson continued his work in geological evaluation of uranium resources. Related publications include "The Uranium Deposits of Ontario—Their Distribution and Classification" Robertson (1981), and a compilation of the Uranium and Thorium Deposits of Southern Ontario (Robertson, Gordon, and Rybak 1981) with the Northern Ontario volume to be released shortly. The first sheet of the revised Uranium and Thorium Map of Ontario was released (Robertson, Gordon, and Rybak 1981) with the remainder to be released shortly.

Mineral potential evaluation studies continued to be monitored by J.S. Springer. This resulted in substantial involvement of staff from the section in various areas of lands management including land use planning. During the year, the Mineral Deposits Section and the Parks Branch have jointly produced a set of master cronaflexes from which working
copies can be white-printed. The maps, derived from the 1:250,000 Ontario Mineral Potential Map, show the location, status, and classification of parks and park reserves, current to January 1981. Future parklands will be added to the master sheet, when the proposed extent of the Parks System Plan is known.

References


A.C. Colvine

Introduction

Preliminary metallogenetic work in the eastern Southern Province of Ontario (Innes and Colvine 1979) has demonstrated that the mineral deposits of this area (more than 2000 showings) display well-defined systematic distribution patterns. These patterns can be explained in geological terms, with two principal processes active. Firstly, mineralization within the Huronian metasedimentary rocks was largely sedimentary in origin and reflected the sedimentary provenance, either granite or "greenstone". Secondly, large-scale Nipissing-type diabase intrusions caused local remobilization of mineralization from the rocks which they intrude into quartz and carbonate vein systems.

These observations have many implications when considering the exploration potential of this area; perhaps the most important is a re-evaluation of the paleoplacer gold potential. While early Middle Precambrian sedimentary suites elsewhere in the world (for example, Witwatersrand, South Africa, and Jacobina, Brazil) are proven gold provinces, the Huronian Supergroup has generally been considered a uranium, not a gold province. A re-evaluation of the justification for this assumption shows that it is largely based on the fact that the major economic paleoplacers known in the Huronian, constitute the uranium mines of the Elliot Lake area; these contain very low gold concentrations.

Selection of Study Area

The Huronian Supergroup is an extremely thick (>15 km maximum thickness) and complex sedimentary suite; sedimentologically, it is very poorly understood, and hence it is difficult to define the most favourable area or stratigraphic levels for the formation of alluvial fans which may contain gold. Tectonics also played a role in the sedimentary distribution and style, with rift tectonics clearly active during sedimentation in some areas. Resources have not been adequate to carry out the necessary interpretive sedimentological, tectonic, and metallogenetic studies which should be a preliminary to testing the paleoplacer hypothesis.

Notwithstanding, there are some factors which allow a more rational selection of areas favourable for further study. The principal factors are, that the sedimentary provenance should be "greenstone", and that the main lithologies of the sedimentary formations should be quartzose sandstone, containing coarse conglomeratic units.

These relationships were greatly clarified following field visits to the major gold mining areas of the Witwatersrand Basin in South Africa; some of the more relevant observations are noted below:

—Provenance areas are Archean granites and "greenstones".
—Stream channels constricted between granite domes emerged at "entry points" into fault controlled basins, where composite alluvial fans were formed.
—The majority of the Witwatersrand sequence consists of sandstone and shale.
—Virtually all of the economic gold concentrations observed are localized in quartz pebble conglomerates.
—These concentrations occur at erosion surfaces, as channel infillings, on foresets of trough cross-beds, and even as single lag beds in sandstones.
—The gold-bearing carbonaceous units ("carbon leaders") are also associated with conglomerate beds.
—Buckshot pyrite is virtually ubiquitous in gold-bearing beds.
—Individual alluvial fans are small targets. They are essentially planar features in the thick sedimentary pile. They cover an area often less than 100 km², less than the area of one Ontario township.
—Gold may occur throughout most of the sequence; the Main Reef occurs in the middle of the sequence, and most gold has been recovered from it and units stratigraphically above it.

1Section Chief, Mineral Deposits Section, Ontario Geological Survey, Toronto
Figure 1—Generalized geology of the Cobalt Embayment.
By analogy, the formations considered most favourable in the Huronian are therefore the Livingstone Creek, Matinenda, Mississagi, Serpent and Lorrain. The Livingstone Creek Formation is of relatively limited extent, but close to Sault Ste. Marie it warrants investigation. Similarly the eastern extension of the Matinenda Formation east of Espanola, around the Sudbury Basin, is also another target. The Mississagi and Serpent Formations both have potential in the favourable areas; these have been investigated in the southern half of the Cobalt Embayment by Long (this volume), and H.D. Meyn and M.K. Matthews (1980).

The author therefore chose the Lorrain Formation for field examination during the 1981 field season; coverage was restricted to the northern half of the Cobalt Embayment (Figure 1).

Discussion

Field work carried out on this project during the 1981 field season consisted principally of the examination of as many sections as possible of the Lorrain Formation in the northern half of the Cobalt Embayment (Figure 1). Approximately 300 samples were collected, and have been submitted for chemical analyses. The results from this survey will be reported upon more fully when analytical results are available. Only a brief discussion of the main findings is included below.

The Lorrain Formation in the area appears to consist of a lower arkose, overlain by arkoses and micaceous sandstones, overlain in turn by quartz sandstones. Unfortunately, this represents a lateral section from north to south due to the relatively flat-lying nature of the sedimentary rocks and lack of topography; a vertical stratigraphic succession is not available in this area.

A considerable amount of sedimentological data can be derived from the Lorrain Formation. The adjacent Gowganda Formation can also provide significant sedimentological data about the developing drainage patterns before, but which may have persisted during, the deposition of the Lorrain Formation rocks.

A large number of quartz pebble, and quartz-jasper-cherth pebble conglomerates were observed within the Lorrain Formation. These occur principally as trough and channel fillings and as thin pebble lags; they were sampled whenever possible.

Planar crossbedding is common in sandstone units, with foresets commonly marked by heavy mineral concentrations. Hematite, rather than pyrite, is the principal heavy mineral constituent and is common throughout the area examined, except in the upper (southern) clean quartzose sandstones. Hematite appears to form as a heavy-mineral placer constituent, delineating many of the sedimentary features. Analytical work will determine if it is associated with gold and other heavy minerals. In the Witwatersrand, the association of gold with pyrite is clear; but in the present area, further work is necessary to determine if gold was deposited under the same hydrologic conditions as hematite. Also, if gold is contained within pyrite, and the pyrite subsequently oxidized to hematite, it is not clear if the gold would be released and how it would be transported and concentrated.

The best section observed was on a power line road south from the Gowganda-Shining Tree road through Tyrrell, Leonard, North Williams, Dufferin, Stull, and Valin Townships. Conglomerates were observed virtually throughout the Lorrain sandstone section. The section appeared to be traversing stratigraphically upwards through the Lorrain succession, and hence the conglomerates may represent a series of stacked fans. Clean quartz sandstones were encountered in Stull Township, but conglomeratic units were again encountered in Valin Township, possibly representing a local northward drainage from the granitic body in the south. Pyrite was found in patches within the sedimentary rocks in Valin Township, possibly adjacent to diabase intrusions; this was one of the few locations where pyrite was encountered in the Lorrain Formation.

In summary therefore, many of the features observed in the Lorrain Formation in the northern half of the Cobalt Embayment are indicative of the correct conditions for paleoplacer concentration. Anomalous values of gold in some of the samples collected would indicate the presence of gold in the sedimentary system. Such findings should be followed up with careful geological studies with emphasis on sedimentary patterns and environments. The western margin of the Embayment, which may have the Shining Tree "greenstone" belt as its provenance, is considered the most favourable for further investigation.

References


Introduction

During the 1981 field season, work continued on a multi-year metallogenic study of Archean rocks in the Mine Centre-Fort Frances area. This constitutes the second field season of a project designed to describe, classify, and interpret the depositional environments of the wide variety of mineral occurrences at Rainy Lake. The project entails stratigraphic compilation of previous mapping by the Ontario Geological Survey, new structural and metamorphic mapping at a regional scale, and detailed mapping in the vicinity of known mineral occurrences. This report represents a summary of progress based largely on field data. It is intended to supplement the author’s previous descriptions of the geology and mineralization of the area (Poulsen 1980).

General Geology

Stratigraphy

All significant mineralization in the Rainy Lake area occurs within a 15 km wide wedge of Archean rocks; this wedge is bounded to the north and south by the Quetico and Seine River-Rainy Lake Faults, respectively (Figure 1a). Within this crustal wedge, diverse lithologies have been mapped in detail (Blackburn 1973; Harris 1974; Wood et al. 1980). For the purposes of the present study, the results of this mapping have been compiled into a generalized stratigraphic column (Table 1). The stratigraphic order shown reflects regional relationships as well as specific contact relationships mapped at key localities by the author.

During 1981, new stratigraphic mapping concentrated on the delineation of a unique ultramafic metavolcanic unit in the Rice Bay-Redgut Bay area. This rock type has a distinctive chemical composition and texture. Analyses of 42 percent SiO₂, 6 percent Al₂O₃, and 21 percent MgO have been obtained. The rock consists locally of angular to sub-rounded clasts, up to 5 cm in diameter, set in a fine-grained chloritic matrix. The clasts are also

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1 Graduate Student, Queen’s University, Kingston.
Figure 1—

(a) The distribution of gold properties in the Mine Centre-Fort Frances area relative to metamorphic grade.

(b) Rose diagram illustrating the orientation and sense of displacement of shear zones across the study area.

(c) Schematic diagram of vein systems developed in shear zones in the study area.
placement are equally well developed on northward- and southward-facing sequences, and involve all rock types. The shear zones are interpreted to broadly postdate folding. These zones are consistent with the interpretation that the dominant structure in the area is a right hand wrench zone of which the two boundary faults are merely the most obvious manifestation.

**Metamorphism**

The rocks exposed between the two boundary faults have been metamorphosed to assemblages characteristic of the greenschist and amphibolite facies; during 1981, work continued on mapping the “isograd” between the two (Figure 1a). The transition from greenschist to amphibolite facies metamorphism clearly involves both regional and contact metamorphism: the distribution of index minerals such as staurolite and sillimanite is independent of pluton margins, while cordierite-andalusite schists are most common in the aureoles of plutons of granodiorite to quartz monzonite composition.

The northwestward increase in metamorphic grade is unique to the fault-bounded wedge. Grade increases systematically southward from the Seine River-Rainy Lake Fault, but quite irregular low grade metamorphic patterns are characteristic of the Wabigoon Subprovince to the north of the Quetico Fault.

**Mineralization**

The present study emphasizes documentation of the nature and setting of mineral occurrences in the Rainy Lake area. All significant occurrences of exposed mineralization were visited, and based on a consideration of stratigraphic setting, mineralogy, and deposit morphology, a provisional classification scheme (Poulsen 1980) has been expanded and modified. Table 2 describes the dominant deposit types and indicates the relative abundance of each type.

Individual properties may host more than a single

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>MINERAL DEPOSIT CLASSIFICATION, MINE CENTRE — FORT FRANCIS AREA.</th>
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<tbody>
<tr>
<td><strong>TYPE</strong></td>
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<tr>
<td>1 — <em>Stratabound Mineralization Hosted by Felsic to Mafic Metavolcanics</em></td>
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<tr>
<td>A: Sphalerite-galena-chalcopyrite associated with siliceous volcanic rocks</td>
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<tr>
<td>B: Sphalerite-chalcopyrite associated with intermediate to mafic amygdaloidal volcanic flows, tuffs and breccias</td>
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<tr>
<td>C: Sphalerite-chalcopyrite associated with iron formation</td>
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<tr>
<td>D: Lean iron formation — mainly chert-magnetite and massive pyrite-pyrrhotite, minor chalcopyrite common</td>
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<td>2 — <em>Mineralization Hosted by Layered Gabbroic Intrusions</em></td>
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<tr>
<td>A: Chalcopyrite associated with gabbro and leuco-gabbro near the base of sills</td>
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<tr>
<td>B: Disseminated chalcopyrite associated with siliceous phases of the intrusions</td>
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<tr>
<td>C: Ilmenite-magnetite-apatite-rutile lenses in the upper portions of the intrusions</td>
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<tr>
<td>3 — <em>Vein Mineralization</em></td>
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<tr>
<td>A: Quartz-gold-sulfide veins in shear zones</td>
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<td>B: Quartz-molybdenite-pyrite veins in unmetamorphosed granitoid rocks</td>
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<td>4 — <em>Disseminated Chalcopyrite-Pyrrhotite Mineralization Hosted by Ultramafic Metavolcanics</em></td>
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<td>NUMBER OF PROPERTIES</td>
<td>EXAMPLES</td>
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<td>4</td>
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<td>Reef Point, Nickel Lake, Shoal Lake</td>
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<td>7</td>
<td>Northrock, Island Bay</td>
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<td>1</td>
<td>Miranski</td>
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<td>1</td>
<td>Belacoma</td>
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type of mineralization, and these have been classified with the dominant type. Scattered minor occurrences of mineralization, on which there has been no development, have been noted, but are not included in Table 2. With the exception of Type 4, examples of the main classes have been described previously (Poulson 1980) and the following discussion summarizes the main features of each class based on field work to date.

**Type 1: Metavolcanic-hosted Mineralization**

Zinc-copper mineralization at Rainy Lake occurs in a number of specific volcanic environments. The mineralization at Gagne Lake (Type 1A) is clearly representative of volcanogenic massive sulphides: lenses of pyrite-sphalerite-galena are overlain by chert and underlain by a chalcopyrite-bearing chloritic cordiite + anthophyllite alteration zone in felsic lapilli-tuff. While the mineralogy of Type 1B occurrences is similar to that of massive sulphide deposits (sphalerite, pyrite, pyrrhotite, chalcopyrite, minor galena), they possess a number of distinctive characteristics. The host rock is commonly an amygdaloidal, brecciated, intermediate to mafic metavolcanic rock. The mineralization occurs as discrete seams, 1 to 20 cm wide, which are separated by substantial widths (1 to 20 cm) of barren chloritic host rock and mineralized zones are laterally very extensive, greater than 1 km in length at Wind Bay, and have only local zones of footwall alteration. The nine occurrences of this type occupy a single stratigraphic horizon which is exposed over a strike length exceeding 25 km, and these are thought to represent poorly focussed discharge of metals over a large area. While these deposits collectively represent a substantial accumulation of base metals, no single prospect has been shown to have sufficient metal content or tonnage to be economically viable at this time.

Likewise, mineralization of Type 1C represents substantial dispersion of metal with resulting low grade. Sphalerite, in this case, is hosted by pyritic slate which is intercalated with chert-magnetite iron formation. At the main showing of the Pocket Pond Prospect, a small lens less that 0.5 m wide, containing massive pyrrhotite + sphalerite, occurs within a more extensive zone of barren pyrite + pyrrhotite adjacent to chert-magnetite. Iron formation (Type 1D) is a common constituent of the predominantly mafic volcanic terrain in the western part of the study area. There is a common association of chert-magnetite beds immediately adjacent to a massive pyrite + pyrrhotite zone, which at some localities contains minor chalcopyrite. Total thicknesses of a few metres are rarely exceeded and, while the immediate host is commonly a biotitic metasedimentary rock, the iron formations are broadly associated with sections in which metabasalts are abundant.

**Type 2: Gabbro-hosted Mineralization**

Two large, steeply dipping, layered gabbroic sills, the Grassy Portage and Seine Bay-Bad Vermillion Intrusions, are exposed in the study area. Layering is expressed by modal variations in mineralogy, chemical variations across strike, and rhythmic mineral layering which is well exposed in the Redgut Bay area. Rock compositions range from metagabbro to anorthosite, and internal layering suggests that the Grassy Portage Intrusion faces southward, while the Seine Bay-Bad Vermillion Intrusion faces northward. The basal parts of the latter intrusion are truncated by the Seine River-Rainy Lake Faults. Mineralization occurs at three particular horizons in the intrusions. Basal segregations of chalcopyrite-pyrrhotite-pentlandite (Type 2A) form important occurrences along the northern margin of the Grassy Portage Intrusion. Net and droplet textures suggest a magmatic origin, while sulphide veins and local hydrothermal alteration show evidence of deuteric or metamorphic remobilization. The Island Bay Occurrence at Bad Vermillion Lake appears to be of this latter type. Near the top of the Grassy Portage Intrusion, disseminated pyrrhotite-chalcopyrite mineralization (approximately 0.8 percent Cu) is related to siliceous zones within the Intrusion (Type 2B). While these zones may represent granophyric differentiates, their sharp contacts and generally blocky nature suggests that they are assimi- lated blocks of country rock near the roof of the intrusion. In the central to upper levels of both intrusions, substantial accumulations of iron-titanium mineralization (Type 2C) occur as lenticular zones of disseminated to massive magnetite + ilmenite with local apatite-rutile.

**Type 3: Vein Mineralization**

Quartz veins are common throughout the study area. While most are unmineralized, two particular types host gold and molybdenite mineralization. Gold-bearing veins (Type 3A) in the area have been developed and exploited intermittently since the 1890s. In most cases, the veins may be related to discrete shear zones and commonly occupy a central first-order fissure (Figure 1c). Second order veins are foliation-normal, but third order sets are foliation-parallel. The shear zones are systematically oriented and show senses of displacement consistent with a right-hand wrench zone (Figures 1a,b). The shear zones and their gold-bearing veins are found in most lithologies in the area (Table 3), but there is a clear affinity for a coarse-grained felsic plutonic host of the earlier tonalite + trondhjemite suite. While shear zones are present throughout the study area, only those which occur in rocks of gneisschist facies metamorphism contain gold-bearing vein systems (Figure 1a). The above relationships suggest a late tectonic emplacement of the veins in rocks which readily formed dilatant zones at metamorphic grades suitable for precipitation of gold.

The molybdenite-bearing veins (Type 3B) in the Bear Pass-Rice Bay area show no evidence of shear zone development. These generally show sharp contacts with undeformed granodiorite or quartz monzonite and are spatially associated with contacts with biotite schist. They are thought to represent late plutonic extensional vein filling.
Type 4: Ultramafic-hosted Mineralization

The magnetic clastic ultramafic unit in the Rice Bay-Red-gut Bay area hosts a number of showings of low grade copper-nickel mineralization, referred to as the Belacoma property. Disseminated pyrrhotite with some chalcopyrite occurs as blebs and stringers in narrow zones of foliated ultramafic metavolcanics. Reported grades are variable with best grab samples assaying up to 0.29 percent Cu, 1.23 percent Ni, 0.17 percent Co, and best diamond-drill intersections of 0.45 percent Cu and 0.12 percent Ni over 0.55 m (Resident Geologist's Files, Ontario Ministry of Natural Resources, Kenora). Away from the mineralized areas, the ultramafic metavolcanics contain approximately 1150 ppm Ni (average of 4 samples) indicating that metamorphic remobilization may have produced the low grade sulphide zones.

Recommendations for Exploration

Three of the types of mineralization, noted above, are in the writer's opinion particularly attractive targets for further exploration at the present time:

1. The narrow zone of massive sulphide mineralization near Gagne Lake occurs on a particular stratigraphic horizon which has been traced by reconnaissance mapping and airborne geophysical surveys (Ontario Geological Survey 1980) south-westward along strike for several kilometres. No electromagnetic anomalies correlate directly with the mineralization or its projection along strike, but the presence of "dalmatianite" alteration, a hanging wall chert unit, and footwall felsic pyroclastic rocks make the horizon attractive for deep-ore search. The distinctive cordierite-anthophyllite alteration assemblage may not be expected to persist outside the contact aureole of the Ottertail Intrusion; lithogeochemical methods may assist in recognizing altered rocks away from the pluton.

2. The bulk of known gold mineralization was discovered in the area by conventional prospecting methods in the 1890s. Apparently no exploration programs designed to locate veins in drift-covered terrain have ever been attempted in this area. The direct correlation of known occurrences with shear zones suggests that such topographically recessive areas may prove attractive. Shear zone and vein systems may be expected to strike east or northwest-southeast (Figure 1b). Geophysical surveys (VLF, I.P.) may assist in locating such zones; these commonly contain some disseminated pyrite.

3. The northern margin of the Grassy Portage Intrusion and the southeastern margin of the Seine Bay-Bad Vermillion Intrusion are interpreted as the base of sills along which numerous copper occurrences are known. These occurrences have been developed by surface trenching and shallow diamond drilling. At Northrock, approximately 300 000 tonnes grading 1.69 percent Cu have been outlined above a depth of 140 m. Further exploration at depth along these well-mineralized sill margins is warranted.

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No. 31 Mineral Deposits Studies in the Grenville Province, Southeastern Ontario: Zinc and Graphite

T.R. Carter

Introduction

This year's field studies are a continuation of work by the Mineral Deposits Section (Colvine et al. 1977; Carter and Colvine 1978, 1979; Carter et al. 1980; Carter 1980) to establish the geological setting of metallic and related types of non-metallic mineralization in the Grenville Province of southeastern Ontario and provide guidelines for exploration.

The 1981 program was principally directed towards concentrations of zinc and graphite, particularly in the southeastern part of the area. These concentrations occur separately, but are associated with similar rock types and have similar distributions. There is no current production from deposits of either type in Ontario but both zinc (Long Lake Mine) and flake graphite (Black Donald Mine) have been profitably mined in the past. There has been continuous production of zinc and minor lead in the Balmat-Edwards area of New York State since 1915, from deposits similar to the Long Lake Mine.

The field work consisted of four phases.
1. Mapping at a scale of 1:15 840 (one inch to ¼ mile) in the vicinity of the Kirkham and Bawden graphite deposits in southern Bedford and northern Loughborough Townships.
2. Detailed mapping of the Slave Lake zinc deposit in Sheffield Township. Mapping at a scale of 1:2400 (one inch to 200 feet) using a flagged chain and compass grid to establish outcrop locations.
3. Mapping at a scale of 1:15 840 (one inch to ¼ mile) in the Long Lake area near the former Long Lake zinc mine and other concentrations of zinc mineralization.
4. Detailed sampling of the main tailings pond at the former Deloro gold mine to determine average metal content.

The author also visited several industrial mineral occurrences in the area on a reconnaissance basis, including deposits of graphite, vermiculite, apatite, barite, talc, tremolite, calcite, mica, and brucite.

Kirkham-Bawden Graphite

The Kirkham and Bawden graphite deposits (Figure 1) are located about 35 km north of Kingston and about 10 km east of Godfrey. They are accessible via a network of paved and gravel roads that extends eastward from Highway 38.

Bawden: The Bawden deposit occurs on a ridge on the northwest shore of Birch Lake in Lot 2, Concession VI, Bedford Township. Development work consists of a shaft approximately 7 m deep, a small pit, and several narrow trenches. One hundred barrels of graphite are reported to have been shipped from this deposit to the United States (Royal Commission, 1890).

Mineralization consists of disseminated graphite contained as conformable layers and lenses within calcitic marble. The graphite occurs as fine flakes up to 3 mm in diameter, or more rarely, as small rounded lumps of flake and amorphous graphite up to 20 mm in long dimension. A layer 3 to 6 cm wide and 3 m long containing 20 to 40 percent disseminated flakes of graphite is exposed in the pit south of the shaft. The trenches northeast of the shaft expose a conformable mineralized zone 1 to 3 m in width, traceable over a strike length of at least 40 m. Graphite occurs as disseminated fine flakes and lumps comprising 5 to 35 percent of the rock in this zone.

Kirkham: The Kirkham deposit occurs on a small peninsula projecting into Desert Lake on Lot 4, Concessions IV and V, Bedford Township. Mineralization is exposed in outcrop and several poorly defined pits and open cuts. In 1952 Frolisher Limited examined the deposit, completing 30 diamond-drill holes totalling 9860 feet which outlined two parallel lenses of graphite mineralization in calcitic marbles. Total proven reserves in the two lenses are 206 000 tons grading 10 to 12 percent carbon over a maximum width of 7.6 m. Mill tests indicate that the graphite ore is easily milled with recovery of a large volume of + 80 mesh flake with some 20 to 50 mesh flake. An electromagnetic survey completed in 1953 indicated a "potential mineralized zone over 4000 feet long" (Hewitt 1965, p. 11).

Geology: The two deposits occur about 2.5 km apart within a sequence of tightly folded marble and metasedimentary quartz-feldspathic paragneisses (Figure 1). The marble is a medium-grained (2 mm), white, massive rock with rare, poorly defined layering. It is composed
principally of calcite with variable amounts of dolomite, diopside, serpentine, phlogopite, muscovite, quartz, pyrite, and rare apatite; graphite is ubiquitous throughout these rocks, averaging 1 to 2 percent. Siliceous impurities usually comprise 5 to 10 percent of the rock, with local concentrations of up to 30 percent. Graphite concentrations occur near layers or lenses of calcitic marble containing dispersed coarse (5 to 20 mm) irregular fragments of milky quartz, or along contacts with quartzofeldspathic paragneiss.

The quartzofeldspathic paragneisses consist of alternating white, pink and grey layers representing sedimentary beds of different compositions. Bed thicknesses vary from thin (2 cm to 10 cm) to thick (>1 metre).

The three layers consist principally of: quartzite, with a quartz content of up to 99 percent; feldspathic paragneiss, consisting largely of feldspar; and biotite paragneiss, a grey rock with a mafic mineral content, principally biotite, exceeding 15 percent. Porphyroblasts of garnet are locally abundant in some quartz-rich layers of biotite paragneiss. All three rock types are fine grained (0.5 to 2 mm). The paragneisses probably represent a sequence of intercalated sandstones and siltstones including quartz arenite, and quartzose and feldspathic aren-
ites and wackes as defined by H. Okada (1971). Silts and occasional dikes of massive, coarse-grained (2 to 5 mm) pink granite are locally abundant, especially along the western shores of Desert and Canoe Lakes.

Regionally the rocks have been folded into a pattern of large, upright, dominantly northeast-trending plunging folds (Wynne-Edwards 1965). In the study area the marbles and paragneisses are folded about a synclinal axis plunging shallowly 20 to 30 degrees to the northeast between Eel and Birch Lakes (Figure 1). A parallel anticline was mapped by Wynne-Edwards (1965) east of Kingsford Lake; more resistant beds deformed about the antilinal axis form a prominent sinusoidal lineament observed on aerial photographs. An earlier phase of folding appears to be represented by a syncline that was outlined at the Kirkham deposit as a result of diamond drilling. The core of the syncline is occupied by quartzofeldspathic paragneiss which is underlain by calcitic marble; the graphite concentrations occur along the contact. The syncline plunges north-northeast at 25 degrees and is overturned to the west (Hewitt 1965). Some local irregularities in bedding plane attitudes within the paragneiss units, especially between Birch and Kingsford Lakes, suggest similar structural relationships in the rest of the map-area. Consequently the paragneiss units probably occur in the cores of refolded synclines which lie structurally above and between intervening refolded anticlines occupied by marble. No reliable indications of top directions were noted.

Canoe and Desert Lakes occupy a prominent northeast-trending lineament that has been interpreted as a major fault zone by H.R. Wynne-Edwards (1965). Two other northeast-trending lineaments pass through Birch Lake; extensive brecciation and hematization of calcitic marble occur along the westerly lineament, indicating a fault zone, but no estimate of sense or amount of movement could be made.

Concentrations of graphite mineralization in the area are associated with interbeds of quartzofeldspathic paragneiss or siliceous zones in the calcitic marble, or with the contact between marble and overlying paragneiss. Several features suggest a syn-sedimentary origin for the graphite: the stratiform nature of the mineralized zones; its consistent association with specific sedimentary rock types; lack of associated igneous rocks or fault or fracture zones; and the occurrence of disseminated graphite throughout the marbles. The graphite may represent recrystallized organic debris that was concentrated at clas- tice and pelitic clastic sedimentary rocks. Economic potential: There are numerous graphite deposits in southeastern Ontario geologically similar to the Kirkham-Bawden deposits. Past production from deposits of this type in Ontario from 1896 to 1954 totalled 95 156 tons (Hewitt 1965), mostly from the former Black Donald Mine in Brougham Township. There is no current production of natural graphite in either Canada or the United States. In 1980 imports into Canada of ‘crude graphite’ and ‘graphite and other carbon refractories’ were valued at $1 295 000 and $5 251 100 respectively (Statistics Canada). In the United States, consumption of natural graphite in 1979 totalled 61 000 short tons valued at approximately 28 million dollars. The past history of production, lack of current domestic production, and proximity to potential markets in Canada and the United States indicate that graphite deposits in southeastern Ontario may be of economic interest.

Slave Lake Zinc

The Slave Lake zinc deposit is located immediately south of Slave Lake on Lot 10, Concession XVII, and Lots 10 and 11, Concession XV in Sheffield Township. It is accessible via a gravel road connecting Parham and Enterprise.

Zinc mineralization was first reported at this location in 1916 (Uglow 1916) at which time development work consisted of two shallow pits. Between 1936 and 1939 Lennox Mines Limited and Lennox Mines Company Limited completed a large amount of development work, including approximately 5500 feet of diamond drilling and excavation of numerous pits and trenches, including four shallow shafts 18 to 53 feet deep (Northern Miner Press 1939; Rickaby 1949). The author located a total of 22 pits, trenches, and shallow shafts during the field work.

The zinc deposit occurs within a narrow north-to-northeast-trending belt of marble that is completely contained within the Hinchinbrooke 'Gneiss', a large, circular granitic intrusion. Calcitic and minor dolomitic marble, granite, and amphibole-biotite-plagioclase-gneiss are exposed in the vicinity of the deposit (Figure 2). The calcitic marble is a white, medium-to-coarse-grained (2 to 6 mm) rock composed essentially of calcite with accessory dolomite, graphite, phlogopite, serpentine, and tremolite-actinolite. The marble is massive to poorly layered, the layers being defined by variations in grain size and shades of grey. Dolomitic marble occurs in only a few outcrops and is similar to the calcitic marble in appearance. The granite is a pink, fine- to medium-grained (1 to 3 mm), foliated to massive rock. It is characterized by augens of pink feldspar 15 to 25 mm long. The amphibole-biotite-plagioclase-gneiss is a grey to black, fine-grained (0.5 to 2 mm), massive to poorly foliated rock. The mafic mineral content varies from 15 to 50 percent. It may represent the metamorphosed equivalent of either mafic volcanic rocks or pelitic clastic sedimentary rocks.

The geological relationships of the different rock types are complex (see Figure 2). The marble forms northwest-striking units within granite that are closed around northwest-trending axes. The amphibole biotite-plagioclase gneiss generally occurs as isolated xenoliths within the granite and forms a mappable unit only in the east. Layering in the marbles and foliations in the granite generally dip consistently to the southwest at 20 to 85 degrees, with only local variations. Further structural studies are warranted.

There are six different mineralized zones at the deposit (Figure 2). Mineralization consists of sparsely disse-
minated to nearly massive medium- to coarse-grained (2 to 5 mm), dark brown sphalerite and subordinate pyrite in calcitic marble. The sulphides usually form well-defined conformable layers averaging 10 cm in thickness and containing approximately 30 percent sphalerite. A chip sample across such a layer in Zone 2 contained 19.6 percent Zn, 42 ppm Pb, and less than 0.1 ounce of Ag per ton. A grab sample of massive sulphide mineralization collected from a dump in Zone 2 contained 44.3 percent Zn, 17 ppm Pb, 430 ppm Cu, and 980 ppm Cd. The maximum exposed width of zinc mineralization at the deposit is 2 m, in a pit in Zone 4. Lengths of the mineralized zones are usually not as well defined but in Zone 1 zinc mineralization was observed sporadically over a strike length of at least 100 m.

The numerous occurrences of mineralization observed by the author, and the zinc content may justify re-evaluation of the property. Interpretation of the structural relationships is essential to permit delineation of possible extensions of known mineralized zones. Strike extensions of the marbles and other marble lenses within the Hinchinbrooke 'Gneiss' are considered favourable exploration targets.

Long Lake Zinc

The Long Lake area is located about 55 km north of Kingston and 10 km southwest of Sharbot Lake. It is accessible via a network of paved and gravel roads south from Highway 7 and west from Highway 38. Several zinc showings occur in the area, including the Long Lake Mine. From March 1973 to February 1974 a total of 82,371 tons of ore averaging 11.9 percent Zn were mined from the

Figure 2—Geology of the Slave Lake zinc deposit.
Four major types of marble were identified:

1. Very coarse-grained (>1 cm) calcitic marble;
2. Thinly laminated calcitic marble;
3. Layered siliceous calcitic marble;
4. Dolomitic marble.

The four types are usually gradational into each other. They are not subdivided on the geological map (Figure 3) due to the scale, but locally the different marble types can be traced over considerable distances.

1. The very coarse-grained calcitic marble is typified by its massive nature, very coarse grain size (10 to 80 mm), and lack of impurities. Some of the best exposures occur just east of the Long Lake zinc mine, in the marble belt north of Little Beaver Lake on the Smith Farm, and in a narrow marble belt trending south from the main marble unit through the Hawley and Price Farms.

2. The laminated calcitic marble has very regular alternating white and grey layers varying in thickness from 5 to 50 mm. The grey layers are finer grained (3 to 5 mm) than the white layers (5 to 8 mm) and contain abundant (10 to 20 percent), very fine (< 0.5 mm) disseminated flakes of biotite and phlogopite. Dolomite and tremolite are minor constituents. The best exposures are in road cuts and open fields on the Stinchcombe farm west of the Mountain Grove road.

3. The layered siliceous calcitic marble is gradational into and often interlayered with the first two marble types. It is characterized by the presence of thin (5 mm to 5 cm) lenses and layers of tremolite + calcite, tremolite + diopside + quartz, or quartz interlayered with relatively silicate-free medium- to coarse-grained (5 to 15 mm) calcitic marble. Good exposures occur near the barn and along the road on the Hawley farm (Figure 3, No. 2), near the former Long Lake zinc mine (Figure 3, No. 3), and behind the old farm buildings on the Smith farm southeast of showing Number 1.

4. The dolomitic marble forms a massive to foliated, light grey, fine- to medium-grained (1 to 3 mm) rock. It is composed almost entirely (95 to 100 percent) of dolomite with only minor amounts of disseminated serpentine, tremolite, graphite, and occasional pyrite. Good exposures occur on the Smith farm and on the southwestern limb of the main marble belt.

Sphalerite mineralization was observed in outcrops in 5 different places by the author (Figure 3, Nos. 1 to 5). Zone 5 is a previously undocumented showing; extensions to previously known mineralization were also discovered by the author in zone 1. Disseminated sphalerite was observed in isolated marble boulders at localities 6 and 7. Mineralization generally occurs in conformable layers consisting of variable amounts of disseminated, dark brown to black sphalerite, pyrite, and pyrrhotite, often with abundant associated diopside and/or tremolite. Several associations of zinc mineralization were noted. Mineralization is hosted by calcitic marble at occurrences 1, 2, 3, and 4, usually within or in association with siliceous layers and lenses in the marble. Dolomitic marble occurs close to occurrences 1, 2, and 4, and some minor amounts of zinc mineralization occur within dolomitic marble at showing Number 2. At showing Number 5 the zinc mineralization occurs within a calc-silicate lens contained within well-layered dolomitic marble. The associations are not clear but in general it appears that zinc mineralization in the Long Lake area occurs preferentially in association with siliceous calcitic marble, often near minor layers or lenses of dolomitic marble. It should be noted that no known outcrops of dolomitic marble occur near the Long Lake deposit (No. 3).
Discussion

Mapping in the Long Lake area indicates that the marbles can be subdivided into distinct sub-units that can be traced over significant distances. This may aid exploration for zinc in the area as zinc mineralization was found to be preferentially associated with certain marble types, although the association is only loosely defined. Additional zinc mineralization was discovered by the author during the study, largely as the result of very detailed mapping. Further exploration for zinc should involve very detailed mapping and careful examination of all outcrops. Road-cuts and open fields provide the best exposures.

The Deloro Gold Deposit-Tailings Samples

The Deloro gold deposit is located about 5 km east of Marmora in Marmora Township. Production from the deposit totalled 10,360 ounces of gold between 1897 and 1902. Subsequent to the mine’s closure a custom mill and smelter operated at the site, treating various types of ore from different mines, notably from producers in the Cobalt area of Ontario. A large tailings pond of red ferric arsenate mud and silt remains from these operations on the east side of the Moira River opposite the mill-site. The pond covers an area of approximately 400 m by 300 m to an average depth of 1.2 m, representing an estimated dry weight of 100,000 tons (Resident Geologist’s Files, Ontario Ministry of Natural Resources, Tweed, Ontario). The author collected a total of seven sediment samples from the pond. Six of the samples were taken 30 m apart along a north-south line through the western end of the pond. The samples consisted of a shovelful of reddish-brown sediment taken to a maximum depth of 15 cm. Average metal content of these samples is as follows: 5540 ppm Cu, 1300 ppm Ni, 104 ppm Pb, 153 ppm Zn, 1550 ppm Co, 4.65 percent As, 1030 ppm Sb, 0.83 ounce of silver per ton, and trace amounts of gold. A seventh sample was taken from a layer of yellow sediment 40 cm below the surface of the pond. It contained 2980 ppm Cu, 670 ppm Ni, 54 ppm Pb, 32 ppm Zn, 620 ppm Co, 5.0 percent As, 420 ppm Sb, 1.38 ounces of Ag per ton, and trace amounts of gold. These assay results indicate the presence of a substantial amount of contained metals in the tailings pond.

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No. 32 A Preliminary Reconnaissance of the Weagamow-North Caribou Lake Metavolcanic-Metasedimentary Belt, Including the Opapimiskan Lake (Musselwhite) Gold Occurrence

A.J. Andrews¹, D.R. Sharpe², and D.A. Janes³

Introduction

During June 1981, a brief field inspection was conducted on the Weagamow-North Caribou Lake Metavolcanic-Metasedimentary Belt, located approximately 150 km north of Pickle Lake, Ontario (see location map). Our immediate objectives were; (a) to examine known areas of mineralization in the area, including the newly established Au occurrence (Musselwhite Grubstake) on Opapimiskan Lake; (b) to make a preliminary assessment of the potential of further occurrences within the belt; and (c) to determine the need for further geological work in the area which would aid in exploration. Our inspection consisted of an airborne reconnaissance, followed by detailed examination and sampling of selected outcrop areas in the vicinity of Capella Lake, Castor Lake, Akow Lake, Opapimiskan Lake, Markop Lake, the Teal Cu.Ag.Au showing located just north of Randall Lake, the Au-bearing Number 1 quartz vein on the northwest shore of Opapimiskan Lake, and the Musselwhite gold occurrence on the southeast shore of Opapimiskan Lake (Figure 1). Three days were spent on the reconnaissance of the belt north of Opapimiskan Lake, and five days on examination of the Musselwhite property. One of us (D.R. Sharpe), conducted a preliminary (five day) assessment of the Quaternary geology of the area, with particular attention being given to the immediate vicinity of Opapimiskan Lake.

¹ Geologist, Mineral Deposits Section, Ontario Geological Survey, Toronto.
² Geologist, Engineering and Terrain Geology Section, Ontario Geological Survey, Toronto.
³ Resident Geologist, Ontario Ministry of Natural Resources, Sioux Lookout.
Previous Work

The Weagamow-North Caribou Lake Metavolcanic-Metasedimentary Belt was first mapped by J. Satterly (1939) at a scale of one inch to one mile, and was later included in a regional, one inch to four mile reconnaissance survey (Thurston et al. 1979). The belt has been interpreted as an elongate, synclinal trough extending eastwards from Weagamow Lake for approximately 50 km, and then southwards for about 30 km towards Opapimiskan Lake (Figure 1). Immediately south of Opapimiskan Lake, the belt divides into two limbs, one trending south towards Libert Lake and the other trending southeast through Markop Lake. The area is underlain by mafic metavolcanics (commonly pillowd) with minor intercalations of felsic metavolcanics, overlain by up to 4200 m of metasediments. The metasediments consist of conglomerate, arkose, wackes, argillaceous units, and chemical sediments, including iron formation. The belt is bounded on the north and east by migmatized rocks, mainly metasedimentary in composition, and to the south by felsic intrusive rocks. The previous studies indicated that the volcanic and sedimentary rocks have experienced metamorphism ranging from greenschist to middle amphibolite grade; however, there is little or no information concerning the metamorphic history or the location of isograds. P.C. Thurston et al. (1979) described the belt as being dominated by an isoclinally folded syncline, centred along Eyapamikama Lake. South of Opapimiskan Lake, where the belt divides, these authors suggested that major synclinal axes continue along both the south- and east-trending limbs. Details concerning the structure of this belt are not yet known.

Musselwhite Gold Occurrence—Opapimiskan Lake

Gold mineralization was first discovered on this property (Figure 1) by the Musselwhite brothers in 1962. As a joint venture for development, Kenpat Mines Limited was formed in the same year and during 1962 to 1963 completed a magnetometer survey, a geological survey, diamond drilling, and trenching to establish the Number 1, Number 2, and Everway showings (Figure 2). In 1967, the company was dissolved and the property reverted to the Crown. In 1973, the Musselwhite brothers reactivated interest in the area and formed a grubstake. The participants presently include Dome Mines Limited, Dome Petroleum Limited, Campbell Red Lake Mines Limited, Sigma Mines (Quebec) Limited, Canadian Nickel Company Limited, Esso Minerals Canada, and Lacana Mining Corporation (Northern Miner, October 1, 1981). Since 1973, a total of 180 diamond-drill holes have been put down, following an extensive program of mapping, geophysical work, and soil sampling.

Gold mineralization on the property occurs primarily within contorted iron formation units, and appears to be structurally concentrated within fold culminations, particularly antiforms. The mineralization, as presently outlined, occurs in two main areas, referred to as the Camp Zone and West Anticline Zone. Current ore estimates indicate over a million tons grading approximately 0.20 ounce gold per ton (Northern Miner, March 5, 1981).

Lithology

The Musselwhite property is underlain by a sequence of highly contorted rocks consisting of intercalated mafic metavolcanic flows, oxide and silicate facies iron formation, minor tuffaceous horizons, and cherty chemical sediments. The mafic metavolcanic units have been previously mapped as basalt, potassic-basalt, and Mg (ultramafic?) basalt. This classification was adopted for core-logging purposes and remains to be confirmed by petrographic examination and geochemical analysis.

The mafic metavolcanics occur as fine- to medium-grained, massive, and pillowd units, which for the most part are either strongly foliated or sheared. Small stringers and knots of quartz and tourmaline occur in certain horizons of the volcanic sequence, and possibly form an elongate zone conformable with the local structure. Grab samples from two separate mafic metavolcanic-hosted quartz veins yielded gold values of 45 and 70 ppb (1 and 2, Table 1).

Oxide and silicate facies iron formation occurs as interbeds within the volcanic sequence, ranging from <15 m to about 100 m in width. These units are observed in outcrop and diamond-drill core, but have been defined primarily by detailed magnetic surveys. Oxide facies units are characteristically well-banded, consisting of alternating chert- and magnetite-rich layers, 1 to 3 cm in width, and occasional mafic, possibly tuffaceous, intercalations (from 1 cm to a few metres in thickness). Lean silicate facies iron formation consists of alternating cherty bands (1 to 3 cm in width) and mafic, tuffaceous layers (<1 to 10 cm in width), together with occasional thin (<1 cm) magnetite bearing layers. Geologists for the Musselwhite Grubstake have defined three separate horizons of iron formation, classified as the lower, middle (pregnant), and upper units (the middle unit is host to the gold mineralization in the West Anticline Zone). This subdivision, however, must be considered as highly tentative, in view of the complex structural characteristics of the area, together with the paucity of surface exposure. Detailed structural and stratigraphic examinations will be required to distinguish between stratigraphically separate units, facies changes along the same unit, and units repeated in the sequence due to complex folding.

Metamorphism and Deformation

Hand specimen examination revealed common actinolite-tremolite and occasional chlorite in the mafic volcanic rocks and tuffaceous horizons. Numerous, subhedral to euhedral, garnet porphyroblasts (probable andradite) occur in the iron formation, with modal abundances ranging from <10 to 80 percent (0.2 to 1.0 cm in diameter). The distribution and abundance of this mineral are highly erratic, and appear to be unaffected by the composition
### TABLE 1 | ASSAY RESULTS.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Description</th>
<th>Gold (Au) ppb</th>
<th>Copper (Cu) ppm</th>
<th>Zinc (Zn) ppm</th>
<th>Arsenic (As) ppm</th>
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<td>1</td>
<td>Musselwhite Property</td>
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<tr>
<td>2</td>
<td>Quartz veins in mafic volcanics</td>
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<td>5</td>
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<tr>
<td>3</td>
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<td>&lt;2</td>
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<td>72</td>
<td>13</td>
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<tr>
<td>4</td>
<td>Everway Showing</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>5</td>
<td>Barren iron formation 15 m from pit</td>
<td>&lt;2</td>
<td>15</td>
<td>60</td>
<td>20</td>
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<tr>
<td>6</td>
<td>Oxidized iron formation in pit</td>
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<td>12</td>
<td>Oxidized iron formation in pit</td>
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<td>24</td>
<td>Teal Showing</td>
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<td>Quartz-carbonate vein</td>
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<td>6</td>
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</tr>
<tr>
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<td>Quartz-carbonate vein</td>
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<td>31</td>
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<tr>
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<td>Carbonate-sericite schist</td>
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<td>Silver (Ag) oz per ton</td>
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**NOTE:** In samples 1-20, silver assayed <2 ppm and tungsten <100 ppm: that is, below detectability limits.
Figure 1—The Weagamow-North Caribou Lake Metavolcanic-Metasedimentary Belt. (Modified after Thurston et al. 1979).
Figure 2—Original showings on the Musselwhite Gold Property. (Modified after Thurston et al. 1979).
of individual layers, thus indicating a metasomatic influence. Textural features suggest syn- to post-deformational growth. Satterly (1939) noted the occurrence of tremolite in thin section examination of the cherty layers. The occurrence of these secondary minerals suggests that middle to upper greenschist facies conditions prevailed during the latter stages of metamorphism and deformation.

The rocks underlying the area southeast of Opapimiskan Lake have experienced an intense, multiphase tectonic history. At least two and possibly three stages of deformation are discernible in outcrop. The dominant trend (S<sub>n</sub>) is characterized by a combination of tight, isoclinal folding and disharmonious buckling, plunging northwest at 20° to 40°. Folds of this generation occur as mesofolds of hand-specimen dimensions, to megafolds measuring on the order of 250 m from limb to limb. Marked intra-folding within the iron formation units appears to be of this generation. The development of either disharmonious buckling, or isoclinal folding within these units appears to be a function of the relative quantities of competent, cherty layers. A strong foliation appears to have developed subparallel to the axial plane of these folds; however, it is not certain whether this should be included in S<sub>n</sub> or considered as a separate phase of deformation (possible S<sub>n</sub>-I). A subsequent phase of deformation (S<sub>n</sub>-I) manifests as a gentle refolding of S<sub>n</sub> folds. This is most apparent in the regional pattern of iron formation as delineated by the magnetic survey. The axial planes of S<sub>n</sub>-I folds appear to have a southwesterly trend. A zone of shearing in the central part of the property has a northwesterly trend, and may represent an axial planar fault related to S<sub>n</sub> folds.

**Mineralization**

Details concerning the newly developed West Anticline Zone and Camp Zone are not available for publication. As a result, mineralization on the Musselwhite property is discussed below in the context of the original Everway, Number 1 and Number 2 showings (Figure 2).

The Everway showing occurs within oxide facies iron formation, at the crest of a westly plunging, anticlinal fold (S<sub>n</sub>-I). The iron formation here consists of alternating chert- and magnetite-rich bands and is in contact, on the southwest side of the outcrop area, with a highly sheared mafic unit which could be either metagabbro or a coarse-grained flow. The contact is folded and conforms to the orientation of the iron formation bands (that is, plunging 20° to the west). The zone of mineralization occurs within the iron formation, and appears to be oriented down-plunge along the nose of the fold. It is marked by a small, intense zone of oxidation (about 15 by 1 m surface area). Axial planar quartz veins. The gossan contains about 2 percent sulphide mineralization (mostly pyrite), much of which is highly oxidized, leaving a box-work-like texture of limonite and goethite. The quartz veins exhibit a fine- to medium-grained, sugary texture, giving evidence of cataclasis. No visible gold was observed at this location; however, assays conducted on four grab samples (4 to 7, Table 1) reveal that significant concentrations occur within the highly oxidized pit and the axial plane quartz veins.

The Number 1 showing consists of oxide and silicate facies iron formation in a repeated series of tight, isoclinal folds (S<sub>n</sub>-type). The folds occur with a wavelength of about 2 to 3 m. The iron formation is interrupted in the central part of the outcrop area by a 3 to 5 m wide, mafic, possibly tuffaceous unit. Intense oxidation occurs in many of the fold culminations, particularly the antiforms. The close spacing of folds renders these oxidized zones almost continuous across the southwest side of the outcrop where an elongate pit has been excavated within the oxidized fold culminations. Late quartz veins (<0.5 to 2.0 cm in width) cut across the folded iron formation, oblique to the axial plane direction. Again, while no visible gold was observed at this site, assays conducted on two grab samples revealed that significant concentrations occur within the oxidized fold culminations (samples 8 and 9, Table 1). As illustrated on Figure 2, both the Everway and Number 1 showings occur in what may be interpreted as a deformed, antiformal fold culmination.

The Number 2 showing consists of predominantly silicate facies and lesser oxide facies iron formation, with occasional intercalations of garnetiferous, mafic, possibly tuffaceous units. In contrast to the previous showings, the deformation here takes the form of small, open folds of variable dimension (0.1 to 2.0 m across), best described as disharmonious buckling. The larger-scale folds appear to be coincident with a predominance of thick, cherty layers (up to 10 cm in width) and a concomitant paucity of magnetite. A number of pits have been excavated down-plunge along the axial plane of antiforms (1 to 2 m in width) which are marked by small zones of gossan (about 1 m<sup>2</sup> in surface area). Quartz veins are present here, but are not so prevalent as in the Everway and Number 1 showings. When viewed on a larger scale (Figure 2), the Number 2 showing appears to be located within the crest of a northwest-plunging antiform.

**Weagamow-North Caribou Lake Metavolcanic-Metasedimentary Belt**

For descriptive purposes, the belt has been divided into two parts; the north section, referring to the area between Doubtful Lake and Weagamow Lake, and the south section, indicating the area from Doubtful Lake to Opapimiskan Lake (Figure 1). Some emphasis has been given to the distribution and occurrence of chemical metasedimentary units.

**North Section**

Satterly’s (1939) map shows the north section of the belt, along the length of Eyapamikama Lake, to consist of a thick, central core of clastic metasediments, enclosed on
either side by a relatively thin envelope of mafic metavolcanics. Our examination of the metavolcanic-metasedimentary boundary in the vicinity of Castor Lake revealed a transition from north to south consisting of: (1) massive and pillow-mafic volcanic flows; (2) mafic, tuffaceous horizons; and (3) chemical metasediments, including iron formation. The transition from volcanic flows to chemical metasediments occurs over a width of less than 50 m. Although not observed by us, this succession presumably evolves to clastic metasediments immediately to the south. A similar transition was observed along the metavolcanic-metasedimentary boundary near Capella Lake, although at this location chemical metasediments were not observed (exposure was not adequate to determine if they were absent). Outcrops of iron formation have been observed in the vicinity of the metavolcanic-metasedimentary contact south of McGruer Lake, east of Pollux Lake, and west of Castor Lake (Thurston et al. 1979). These observations, combined with aeromagnetic patterns (Geological Survey of Canada (GSC) map 7013G), suggest that chemical metasedimentary units and iron formation may form a thin, but persistent horizon in the north of the northern metavolcanic-metasedimentary boundary, from McGruer Lake in the east to Capella Lake and beyond in the west (Figure 3). While relatively few outcrops occur south of Eyapamikama Lake, aeromagnetic data and one outcrop at the extreme southwest end of this lake suggest that iron formation units may also characterize the southern metavolcanic-metasedimentary boundary from Doubtful Lake west.

South Section

The geology of the south section of the belt is not well known, particularly in the area between Doubtful Lake and Akow Lake. Our aerial reconnaissance revealed the existence of a significant number of outcrops in this area; however, Satterly (1939) was not able to include these in his survey due to poor access at the time. As a result, his mapping here was necessarily interpretive. On the basis of our preliminary observations, combined with aeromagnetic data, we suggest a reinterpretation of the geology as illustrated on Figure 3. A traverse conducted between Akow Lake and Lundmark Lake revealed the presence of mafic metavolcanics and a thin (20 to 30 m) unit of chemical metasediments and lean iron formation. The transition from mafic metavolcanics to chemical metasediments is relatively abrupt (across 15 to 20 m), and similar to that observed in the vicinity of Castor Lake, as described above. No central unit of clastic metasediments was observed here. The distribution of rock types north of Lundmark Lake towards Doubtful Lake, as illustrated on Figure 3, is interpreted from aeromagnetic data (GSC Map 7013G). This evidence suggests the existence of a major structural feature in this area (which Thurston et al. (1979) have interpreted as a fault), including major folding in metavolcanics and chemical metasediments immediately east of Doubtful Lake. A small, apparently fault-bounded section of highly metamorphosed clastic sediments crop out on the west shore of Akow Lake, immediately on strike with chemical metasedimentary units to the north.

Chemical Metasediments

Chemical sedimentary units range from less than 10 m to greater than 100 m in width and consist, for the most part, of oxide facies iron formation and banded cherts, with the latter seeming to predominate. The iron formation is characteristically well-banded, consisting of alternating chert- and magnetite-rich layers (1 to 5 cm in width), and occasional mafic, tuffaceous intercalations (from centimetres to a few metres in thickness). In general, chert-rich horizons consist of continuous, well-defined chert layers (1 to 5 cm in width), often intercalated with mafic, tuffaceous layers of variable thickness (1 to 10 cm) and, less commonly, with thin (<1 cm), buff-coloured partings containing magnetite in the form of discontinuous seams or disseminated grains. Sulphide mineralization often occurs as a minor component of these units, mainly in the form of pyrite, and more rarely as arsenopyrite. The presence of sulphide mineralization is usually marked by a patchy to rather intense oxidation of the outcrop surface. Sulphide-bearing graphitic schist was observed in close spatial association with cherty chemical metasediments on the south shore of Castor Lake.

At some locations, the chemical metasediments appear relatively undeformed, consisting of uninterrupted layers continuous along strike (for example, Castor Lake area). More typically, however, they exhibit a variety of structures giving evidence of both brittle and ductile stress. Units observed in the vicinity of Lundmark Lake exhibit a rather intense boudinaging on a centimetre scale, together with a low amplitude warping on a metre scale. On the south shore of McGruer Lake and Opapimiskan Lake, the units are highly contorted, exhibiting one, or a combination of, tight isoclinal folding, pytgmatic folding, open, disharmonious buckling, and pull-apart structures. The relationship of these features to the structural pattern and history on a regional scale has yet to be determined.

Outcrops in the vicinity of Castor Lake, which were previously interpreted by Satterly (1939) as banded quartzites, correspond to what the present authors regard as well-banded, cherty chemical metasediments. This observation may also apply to other parts of the belt, particularly along the northern metavolcanic-metasedimentary boundary between McGruer Lake and Capella Lake and the metasediment wedge, immediately to the north of Opapimiskan Lake.
Metamorphism

A synthesis of our observations with those of Satterly (1939) and Thurston et al. (1979) suggests that metamorphism within the belt, ranges from upper greenschist to middle amphibolite grade, within distinct metamorphic subprovinces as illustrated on Figure 3. It is emphasized that the recognition and location of metamorphic boundaries are based on preliminary data only.

The entire north section of the belt along the length of Eyapamikama Lake appears to be of amphibolite grade. We observed hornblende-rich metavolcanics along the northern boundary, and Thurston et al. (1979) reported the presence of andalusite and sillimanite within the metasediments of this area. As yet, there is no indication that this metamorphic grade decreases towards the core of the belt; that is, with increasing distance from the bordering granitic intrusive rocks. Between Eyapamikama Lake and Weagamow Lake, metamorphic assemblages in volcanic rocks are observed to include tremolite, actinolite, and hornblende (Thurston et al. 1979). This suggests a transition between greenschist and amphibolite grade which may reflect a metamorphic upgrading during granitic intrusion.

Volcanic rocks observed near Lundmark Lake and Opapamiskan Lake contain actinolite-tremolite and some chlorite, but little or no obvious hornblende. We interpret this to suggest that most of the eastern section of the belt between Doubtful Lake and Opapamiskan Lake may be of greenschist grade. Given this condition, the small section of clastic metasediments in the immediate vicinity of Akow Lake represents a metamorphic anomaly in this area. These pelitic sediments are of middle amphibolite grade, consisting of quartz-feldspar-biotite schists with large porphyroblasts of andalusite, staurolite, and cordierite (the latter retrograded to mica). Porphyroblasts and bedding are often highly contorted and generally oriented at high angles to the north-northwest-trending foliation. Mafic volcanics exposed on the extreme southwest shore of Akow Lake also appear to be of amphibolite grade.

Greenschist grade metamorphism characterizes the highly deformed volcanic and chemical sedimentary rocks immediately south of Opapamiskan Lake, as already described; however, south of Zeemal Lake, where the belt divides, amphibolite grade metamorphism again appears to predominate in both the south- and east-trending limbs. We observed quartz-feldspar-biotite-muscovite schists in the area of Markop Lake, which according to Thurston et al. (1979) include cordierite and kyanite further to the southeast, towards Forester Lake. Thurston et al. (1979) noted the probable occurrence of sillimanite-cordierite-muscovite-almandine subfacies in arkoses of the Libert Lake area.

Quaternary Geology

The glacially transported materials in this region reflect a well-defined flow direction from the northeast. The strong northeasterly trend is supported by striae, drumlin orientation, oolitic jasper erratics originating from the Belcher Islands, and local boulder trains. Northwesterly oriented striae noted by Satterly (1939) on Opapamiskan Lake were confirmed, and appear to represent a local variation in the main ice flow direction.

Most of the glacial drift in the area is coarse, bouldery, sandy, material found in ground moraine, eskers, and morainal sediments. Till in the area appears to have originated from erosion and deposition of basal material; however, exposures are generally poor so that this observation requires further corroboration. Drift is characterized by a high percentage of granitic rocks. This feature persists even over exposed volcanic terrains where the granitic component of the drift is usually 50 percent or more. This component increases to greater than 80 percent where the underlying volcanic bedrock is relatively deeply buried. Such material may have been transported englacially for considerable distance, to be loosely deposited directly from the surface of the glacier during melting. A lake-cut bluff was noted at an elevation of 15 m above Opapamiskan Lake (310 m above sea level). This short-lived glacial lake appears to have deposited only clays, in scattered areas close to the present day Opapamiskan level.

Various samples of till, sand, and clay were submitted for trace element, heavy mineral, and grain size analyses. All these samples were obtained from weathered, oxidized exposures. None of the samples reacted to HCl, despite the local presence of carbonate rocks and the occurrence of carbonate outcrops 'up-ice' in the Hudson Bay Lowlands. Ponded clay deposits, which occur locally in moraine overlying volcanic bedrock, may be useful for trace element analysis.

Mineralization

A brief examination was conducted of the Number 1 quartz vein located about 90 m off the north shore of Opapamiskan Lake, and the Teal, Cu-Au-Ag showing located north of Randall Lake (Figure 1). Details concerning the Number 1 quartz vein have been compiled by Thurston et al. (1979). This occurrence has been described as a northwesterly trending quartz vein hosted by a thin band of iron formation, and continuous over a length of about 210 m. Twelve diamond-drill holes totalling 773 m were put down along the length of this vein by Kenpat Mines Limited. The best mineralization reported was 0.39 ounce gold per ton over 0.4 m. Our observations suggest that this occurrence is probably best described as a vein system, since at a number of locations along strike, multiple sub-parallel veins are in evidence. No iron formation was observed on the surface exposures we examined, however, the main vein does appear to be hosted by a highly oxidized shear zone, most likely originally mafic metavolcanic material. Two grab samples taken by the authors (11 and 12, Table 1) corroborate the conclusion of Thur-
ston et al. (1979) that the best mineralization occurs in shear zones adjacent to the quartz veins. According to Thurston et al. (1979) the mineralized zones do not appear to be very persistent along strike.

The Teal Cu-Au-Ag showing has been described in some detail by Thurston et al. (1979). It consists of a northeast-trending quartz-carbonate shear zone along the contact between coarse-grained, massive diorite to the north, and mafic metavolcanics to the south. Sulphide mineralization is sporadically distributed within the shear zones and in quartz veins, primarily as pyrite, chalcopyrite with subordinate sphalerite, and tetrahedrite. Grab samples (17 to 21, Table 1), taken from west to east along strike of the “Main Bulldozer Zone” (see Thurston et al. 1979, Figure 4, p.77) support the contention that the main area of mineralization occurs at the extreme east end of this exposure. This mineralization is in close spatial association with quartz veins and sulphide mineralization. In general, mineralization is quite sporadic along the length of the shear zone, and it appears that original Au and Ag values of up to 4.56 and 87.8 ounces per ton respectively (reported by Harris, 1959) occur in zones of rather limited dimensions.

Assays for gold in chemical metasediments sampled near Castor Lake (13 on Table 1) and Lundmark Lake (14 to 16, Table 1), are generally low, however; some analyses are significantly higher than background which is estimated at about 2 ppb (see Samples 3, 4 and 16, Table 1). An assay of a haematite-rich, iron formation float located on the southeast shore of Opapimiskan Lake (2 km south of the Musselwhite property) yielded a gold value of 110 ppb (Sample 10, Table 1). While values for the other metals reported on Table 1 are occasionally high, no systematic correlations are evident from this preliminary data.

**Discussion and Recommendations**

The most obvious geological features which combine to characterize the Musselwhite gold property on Opapimiskan Lake are; (a) the presence of chemical metasediments (which here include oxide facies iron formation); (b) the focus of intense, multiphase deformation; (c) the proximity of granitic intrusions; and (d) a greenschist grade of metamorphism. The fact that this area is surrounded on three sides by granitic intrusions may be significant in terms of a mechanism for deformation, and a source of heat to drive a structurally focussed hydrothermal flow. The preliminary evidence suggests that the chemical metasediments, in their deformed state, served as favourable horizons for entrapment and concentration of gold.

Chemical metasediments and iron formation will be relatively easy targets for exploration due to their apparent continuity along strike, their bold magnetic signature, and the rather simple, regional structure and stratigraphy of the belt. On the basis of these observations and the characteristics of the Weagamow-North Caribou Lake Belt as a whole, we feel that there is a good potential for more gold concentrations elsewhere in the belt. In this respect we recommend the following areas for more detailed examination:

1. Immediately east of Doubtful Lake, along the southern metavolcanic-metasedimentary boundary. Here, aeromagnetic data (GSC Map 7013G) suggest the possibility of major folding in metavolcanics and chemical metasediments. This area also coincides with the interpreted location of major lithological and metamorphic transitions as described above (Figure 3).

2. Immediately north and south of Akow Lake where chemical metasediments are known to exist. The presence of middle amphibolite grade pelitic sediments along the west shore of Akow Lake is anomalous for the area, and suggests the presence of a major structural influence.

3. The McGRuer Lake area where Satterly (1939, p.25) has documented the existence of tight isoclinal folding in banded chemical metasediments.

4. North of the west end of Eyapamikama Lake, where the configuration of the metavolcanic-metasedimentary boundary suggests the possibility of a tight fold structure; Satterly (1939) observed a series of tight, east-plunging drag folds in this area. Outcrop geology and aeromagnetic data (GSC Map 7013G) suggest the occurrence of a persistent horizon of chemical metasediments along this metavolcanic-metasedimentary boundary. Of particular interest is a magnetic high located within the northern limb of this potential fold structure.

The southern metavolcanic-metasedimentary boundary, running west of Doubtful Lake past Seeseep Lake, should not be ignored. While there is relatively little outcrop in this area, magnetic anomalies (GSC Map 7013G and Satterly, 1939) suggest the possibility of iron formation and chemical metasediments along this zone.

Our airborne reconnaissance revealed the existence of a significant number of outcrop areas within the belt which have not been previously mapped, particularly in the vicinity of Doubtful Lake, and south towards Opapimiskan Lake. On the basis of this observation, and the need for reinterpretation of the known geology in terms of modern concepts and techniques, detailed re-mapping of the area is warranted. Remapping would be complemented by a program of drift tracing (especially boulder tracing) techniques. The region is particularly well suited for this, since (a) the glacial deposits relate simply to a well-defined ice flow direction from the northeast, (b) the glacial ice movement was transverse to the strike of the metavolcanic-metasedimentary belt, (c) there is abundant coarse glacial drift exposed at the surface, and (d) the metavolcanic-metasedimentary belt consists of spatially distinct bedrock types, easily recognized. Since distance of transport is systematically related to the size and frequencies of the displaced bedrock fragments, recog-
nition of material derived from the Weagamow-North Caribou Lake belt would not pose a problem.

Numerous boulder fields occur along the north and east shores of North Caribou Lake. Since these deposits occur immediately down-ice from the belt and are highly accessible from the lake, a study of their size and frequency distributions would yield a rapid and inexpensive method of assessing the regional distribution of economically interesting rock types.

Acknowledgments

Our reconnaissance benefited from the observations of Mike Cherry (Mineral Deposits Section, Ontario Geological Survey), Henry Wallace (Precambrian Geology Section, Ontario Geological Survey), and Bruce Gordon (Mineral Resources Branch, Mineral Resources Group), all of whom were present on site. Our appreciation is extended to Lorne Halladay and Dome Exploration Limited for access to their property and use of their camp on Opapimiskan Lake. Our work was greatly facilitated by the cooperation and skill of the Ontario Ministry of Natural Resources pilot, Bob Grant.

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MINERAL DEPOSITS

No. 33 Geology of Lundy Township, District of Timiskaming

Leo Owsiacki

Introduction

Field studies initiated during the summer of 1981 are part of a two year project established to determine the structure, stratigraphy, and mineral potential of this previously unmapped township. This involved detailed mapping, rock sampling, and the undertaking of a reconnaissance radiometric survey covering the southern half of the township. Major and trace element geochemical analyses are presently in progress. This work will assist in determining the potential for three styles of mineralization which may be present in this area; a) paleoplacer gold and/or uranium in sandstones and conglomerates and associated quartz veins, b) sedimentary copper and silver occurrences in metasediments of the Gowganda and Lorrain Formations, and c) silver concentrations in carbonate vein systems associated with the Nipissing Diabase Intrusions.

Location and Access

The centre of the map-area is located at Latitude 47°32’N and Longitude 79°58’W and is approximately 20 km west of the town of New Liskeard.

Access is limited to a sand road along Concession line II in the east which extends westward into the township for a distance of 1.5 km. A number of walkable trails, interrupted by numerous ponds, lead from this road into the centre of the township. The south and west are accessible by boat or float plane from the Montreal River or by helicopter.

(See location diagram on p.213).

Mineral Exploration

There is no record of exploration activity other than prospecting in the southern half of Lundy Township. Assessment records list some unsubstantiated reports of minor mineral occurrences. Five patented claims are presently held in the southern half of the township.

Only one previous published report deals briefly with the general geology (Burrows and Hopkins 1922) and includes the township in a 1 inch to 1 mile reconnaissance geology map of the Blanche River area (Burrows and Hopkins 1922).

General Geology

The area is underlain by Middle Precambrian sedimentary rocks of the Huronian Supergroup which are intruded by large gabbric sill-like bodies of the Nipissing-type diabase swarm (Figure 1a). An irregular cover of Pleistocene sand and gravel, till, peat, and clay mantles the outcrop.

Relief is variable and almost totally controlled by the underlying geology and structure. The diabase commonly stands out in ridges with elevations of 335 m above sea level, but the sedimentary rocks produce flat and rolling hills with elevations of about 290 m above sea level. Vertical relief reaches a maximum of 68.6 m in the southern half of the township.

The oldest rocks exposed are Proterozoic metasediments belonging to the Coleman member of the Gowganda Formation. These rocks compose almost two-thirds of this part of the township. The basal unit (see Figure 1a) consists of a well-laminated siliceous siltstone which characteristically exhibits local slump folding features. Immediately above and in sharp contact with this basal unit are massive siltstones and fine-grained sandstones with thinly developed phyllitic laminae. “Dropstones” are commonly found at the base of this unit. Thinly laminated grey argillites make up the remainder of the Coleman lithologies and compose the greatest thickness of sedimentary rocks. Laminae are characteristically <0.5 mm in thickness, and produce a slaty bedding cleavage.

The Firstbrook member sedimentary rocks consist of thickly laminated (5 mm to 30 mm) maroon and green siltstones and argillites. These sedimentary rocks grade
rapidly into coarser Lorrain Formation sandstone through a thin transition zone of massive and very fine grained maroon sandstone. The base of the Lorrain Formation is composed of massive and slightly coarser grained grey sandstone which commonly exhibits large scale cross-beds. These in turn grade into a more clastic, pink, coarse-grained arkose.

Two separate diabase bodies are exposed in the area. The west body has intruded the Firstbrook and Coleman-Firstbrook contact. It occurs as a differentiated sill with a clearly developed transition from top to bottom (west to east); the upper part of the sill exhibits variable coarse-grained units which are interpreted as pockets of residual melt. These pockets form irregular shapes of pegmatitic material in a finer matrix of similar composition. This grades downward to a massive medium-grained diabase which forms the bulk of the sill. The base of the sill is characterized by a much finer grained and massive quartz diabase. The sill, as a whole, dips between 25° and 35° west and forms the east limb of a diabase basin whose west limb is in the adjoining Auld Township where the sill dips 30° to 45° east (Thomson 1958).

The sill located in the east part is a semi-circular body intruding all of the sedimentary units. The sill is steeply dipping, and although textures and features representative of differentiation are observed, it is not possible to conclusively determine the base and top of the body.

This east sill may represent a separate diabase body from the west sill or the easterly extension of an eroded diabase arch. In the adjoining Henwood Township, two separate diabase sills have been identified (Thomson 1968).

Structure

Lithological distribution in the area appears to be indicative of a fairly uniform stratigraphic succession from the lower Gowganda Formation to the lower Lorrain Formation. The sedimentary rocks are relatively flat lying and dips vary from a maximum of 31°W to 25°E. The major structural feature is a prominent anticline in the east part of the township (Figures 1b and 1c). The axis trends about 045°. Near the trace of the fold axis, in the northeast part of the map-area, Firstbrook Formation argillites have developed a cleavage at a low angle to bedding.

In the southeast part of the township, numerous well defined lineaments trend north and northeast and coincide with stratigraphically conflicting geological information. Sedimentary rocks in the vicinity of the lineaments exhibit features ranging from minor shearing in the conglomerates to isoclinal (drag) folding and intense microfaulting in the softer, laminated argillite and siltstone. These factors seem to indicate the presence of graben-like fault structures.

As discussed earlier in this report, the diabase sill forms a well defined basin structure in the west and possibly an arch over the central parts of the map-area (see Figure 1b).

Economic Geology

A radiometric survey, utilizing a McPhar TV-1 spectrometer, revealed no clear-cut anomalies in the area. Each stratigraphic unit, however, had a well defined radiometric signature. This observation is useful in stratigraphic mapping and can delineate those horizons containing the highest concentrations of radioactive minerals. Interpretation of the data is not complete, but it can be seen that there is a relative increase in total radioactive count, from the lower Coleman member to the upper Firstbrook member. The highest readings found occur in the finely laminated argillites of the Firstbrook member.

Within the Nipissing Diabase, numerous previously unrecorded pits were discovered in addition to a number of quartz-carbonate veins containing varying amounts of mineralization. The most interesting of these is located in the southwest corner of the township. A strong vein structure, trending 083°, dipping vertically, and 5 cm in width was followed a distance of 8 m. On strike and 250 m to the west a similar quartz vein was noted. A grab sample of the vein showed good chalcopyrite mineralization and an assay of trace Ag, 0.026 percent Cu, 0.003 percent Co, and 0.006 percent Ni. One hundred metres south of this vein, a number of narrow calcite veinlets with visible chalcopyrite were also observed in the diabase.

A second mineralized vein was found in the east sill. The vein occurs in thicknesses as large as 15 cm and consists of quartz-carbonate with sporadic concentrations of chalcopyrite and possibly annabergite. The vein strikes 095° and dips 32° south.

The only other metallic mineralization found in the area occurred within the fine-grained grey sandstone of the Lorrain Formation and the pebbly conglomerate of the Coleman member. In the former, a few flecks of chalcopyrite were observed in one location and in the latter a pervasive, fine dissemination of pyrite throughout both matrix and fragments was noted in addition to numerous occurrences of flakes of chalcopyrite in the matrix.

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Figure 1a—General geology of the southern half of Lundy Township. 1b—Profiles along A B and C D illustrate a possible interpretation of the geology and structure in the southern half of Lundy Township.
Figure 1c— Stratigraphic section showing succession and relative thickness of Huronian sedimentary rocks in the southern part of Lundy Township.
Introduction

Investigation of uraniferous sandstones and conglomerates in the basal part of the Huronian Supergroup of the southern Cobalt Embayment by H.D. Meyn and M.K. Matthews (1980) indicated anomalous gold concentrations of up to 800 parts per billion (ppb). Meyn and Matthews (1980) suggested that concentrations of gold in these strata might be attributed to a fluvial, placer mode of origin, in which the gold was initially derived from "greenstones" in the Abitibi Belt to the north. The present study
was initiated to determine if gold content could be related to specific macro-environments in such a way that sedimentary structures or lithological characteristics could be used to predict zones of potential gold enrichment irrespective of the uranium content of the rocks. Placer concentrations of radioactive minerals were sought, using a gamma-ray spectrometer, to determine if this could provide a key to higher gold concentrations.


General Geology

Gold and uranium concentrations have been found in the basal part of the Huronian Supergroup in the southern part of the Cobalt Embayment (see map in Meyn and Matthews 1980). The host strata are predominantly arkose and subarkose sandstones, with lesser amounts of conglomerate and mudstone. The highest uranium concentrations occur in the lower part of the sequence in areas where conglomeratic strata are common. The basal strata of the Huronian Supergroup in the Cobalt Embayment are traditionally ascribed to the “Mississagi Formation” in the sense of W.H. Collins (1925). These strata may, however, include strata correlative with parts of Hough Lake and Elliot Lake Groups, although most of the sequence is probably correlative with the Mississagi Formation, in the more restrictive usage (Table 1). The presence of uraniferous quartz-pebble conglomerates near the base of the sequence has been used to suggest that at least part of the sequence is equivalent to the Matinenda Formation in the Elliot Lake area (Long 1976).

While strata intersected in the subsurface in south-central McNish Township have been identified on lithological grounds as components of the Matinenda, Ramsay Lake, Pecors, and Mississagi Formations, (Dressler 1979, p.11) correlation of sequences to the north and west is more difficult. Fine-grained units, which could be attributed to the Pecors Formation, are not exposed in northeastern McNish Township or in adjacent parts of Pardo and Clement Townships. In these areas, a basal sequence containing two thick pebble and cobble conglomerate horizons, separated by a 24 m thick sandstone unit, is overlain by over 100 m of cross-stratified sandstone. The conglomerates have intact (clast supported), rather than the disrupted (matrix supported) frameworks typical of the Ramsay Lake Formation, but might be correlated with this formation if they represented glacial outwash deposits. Alternately, these conglomerates may be proximal fluviatile or fan deposits and as such may be entirely within the Mississagi Formation.

Disrupted framework conglomerates, containing minor cobbles and boulders set in a matrix of granular, small pebbly, very coarse sandstone (mixtite), are present in the lower, 13 m thick section exposed along the south shore of Stobie Lake in western Stobie Township. The mixtite sequence is overlain by up to 10 m of fine-grained and very fine sandstone with minor dispersed granule and small pebble horizons. This is overlain by 17.4 m of medium-grained and coarse-grained sandstone. The basal mixtite may be of glaciogene origin with the scattered pebble horizons in the overlying unit representing ice rafted material. Alternately, the basal mixtite may be of debris flow origin, with the scattered pebble horizons representing sheet flood deposits. The former interpretation would allow the sequence to be interpreted as the Ramsay Lake, Pecors, and Mississagi Formations respectively; the second interpretation does not allow specific correlation. Thin section analysis of the fine-grained units is needed before a glacial origin can be confirmed or rejected.

<table>
<thead>
<tr>
<th>TABLE 1</th>
<th>HURONIAN FORMATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nipissing Diabase (= 2.1 Ga old)</td>
<td>Intrusive Contact</td>
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<tr>
<td><strong>COBALT GROUP</strong></td>
<td></td>
</tr>
<tr>
<td>Bar River Formation</td>
<td></td>
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<tr>
<td>Gordon Lake Formation</td>
<td></td>
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<tr>
<td>H</td>
<td>Lorrain Formation</td>
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<tr>
<td>Gowganda Formation*</td>
<td></td>
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<tr>
<td>U</td>
<td>unconformable to conformable contact</td>
</tr>
<tr>
<td><strong>QUIRKE LAKE GROUP</strong></td>
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<tr>
<td>Serpent Formation</td>
<td></td>
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<tr>
<td>Espanola Formation</td>
<td></td>
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<tr>
<td>R</td>
<td>Bruce Formation*</td>
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<tr>
<td><strong>HOUGH LAKE GROUP</strong></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>local disconformable contact</td>
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<tr>
<td>I</td>
<td>Mississagi Formation</td>
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<tr>
<td>A</td>
<td>Pecors Formation</td>
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<tr>
<td>Ramsay Lake Formation*</td>
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<tr>
<td><strong>ELLIOT LAKE GROUP</strong></td>
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<tr>
<td>McKim Formation</td>
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<tr>
<td>Matinenda Formation**</td>
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<tr>
<td><strong>FORMATION</strong></td>
<td></td>
</tr>
<tr>
<td>Archean (= 2.5 Ga old)</td>
<td>Unconformity</td>
</tr>
</tbody>
</table>

* contains rocks of glaciogenic origin

D.G.F. LONG
Economic Geology

Uranium mineralization occurs in mudstone, siltstone, sandstone and conglomerate within the lowest part of the sequence in the study area. Details of specific occurrences can be found in geological reports and in papers by J.E. Thomson (1961), Meyn (1973a, 1979), and Meyn and Matthews (1980 and in preparation). Gold distribution within the sedimentary pile is less well documented. Meyn and Matthews (in preparation) found that the highest concentration of uranium, thorium, and gold encountered during their investigation of the more radioactive strata within the sequence. These authors found concentrations of 2 to 800 ppb; the highest values were obtained in samples from strata from Roberts and Grigg Townships. Meyn and Matthews (in preparation) found that the highest concentration of uranium, thorium, and gold encountered during their investigation of the more radioactive rock types was in fine-grained sandstones. J.A. Grant (1964) cited assays of up to 2700 ppb in conglomeratic strata in Vogt Township.

The results of gold analysis of samples collected from both radioactive and non-radioactive strata during the present study are summarized in Table 2. The average gold content appears to be highest (57 ppb) in medium sandstones and in intact framework conglomerates (56 ppb), rather than in fine sandstones. The use of averages is misleading in suggesting the most favourable lithologies for gold mineralization. The average values are severely biased by a few high values. Figure 1 illustrates the data summarized in Table 2. It is clear that gold concentrations of less than 40 ppb are independent of lithology. Of the 71 samples analyzed only seven have gold concentrations in excess of 100 ppb. Five of these are conglomerates whose median grain size is in the large and very large pebble range (1.6 to 6.4 cm), and the other two are plane laminated sandstones characterized by a high pyrite content.

The conglomerate with the highest gold content encountered during this study formed part of a 55 cm thick uraniferous quartz-pebble conglomerate unit encountered in a small test pit in Vogt Township. Maximum intermediate diameter of clasts in this conglomerate was 5.1 cm and the matrix, predominantly of medium sand grade contained visible pyrite. The gold content, at 240 ppb, is significantly lower than the 2700 ppb reported by Grant (1964) and suggests high lateral variability within the conglomerate. Sandstone associated with this conglomerate has a relatively high gold content (60 ppb) suggesting locally high gold concentrations.

Uraniferous, very large pebble conglomerate, containing 180 ppb of gold, from Stobie Township is characterized by subrounded clasts of vein quartz and fine sandstone set in a matrix with abundant pyrite. Associated sandstones have a generally low gold content (11 and 16 ppb), but the underlying sequence of thinly laminated fine-grained and very fine grained sandstone with minor pebble and granule horizons contain as much as 105 ppb gold.

Polymictic, uraniferous large pebble conglomerate from the base of the sequence in Pardo Township contains 165 ppb gold. Clasts (maximum 7 cm, median 2.5 cm) are predominantly of local origin, including well rounded vein quartz and meta-argillite, with lesser amounts of black chert and green and white metavolcanic clasts not seen in the immediate basement. The matrix is of medium to coarse sand grade and contains only minor pyrite. Associated sandstones contain as little as 5 ppb gold.

Conglomerate from the base of a 5 m thick fining up sequence of uraniferous, polymictic cobble and pebble conglomerate in Turner Township contained 170 ppb gold. Clasts at the base of the conglomerate are predominantly subrounded and rounded (maximum 12 cm, median 4.2 cm). These clasts consist mostly of quartz and green metasandstones of local origin, minor chert, black argillite, and felsic volcanic rocks. The conglomerate grades up into granular very coarse sandstones and coarse sandstone containing only 29 ppb gold. In the same area other sandstones contain 60 and 350 ppb gold. Both of these sandstones are flat bedded to finely bedded fine sandstones and siltstones, characterized by graded bedding on a scale of 1 to 1.5 cm, in Fraleck, Grigg, and Stobie Townships. Long (1976) tentatively correlated this with the Pecors Formation. Similar strata which closely resemble the Pecors Formation south and west of the study area were identified during field investigations in southeastern Parkin Township, adjacent parts of Rathburn Township, and along the western shore of Wanapitei Lake. The absence of conglomeratic strata which could be readily ascribed to the Ramsay Lake Formation immediately below these fine-grained units makes correlation with strata in the Elliot Lake area highly tentative.

| TABLE 2 | MINIMUM, AVERAGE, AND MAXIMUM OBSERVED GOLD CONCENTRATIONS (ppb) IN SAMPLES FROM THE LOWER HURONIAN SUPERGROUP OF THE COBALT EMBAYMENT. |
|---|---|---|
| | MINIMUM | AVERAGE | MAXIMUM |
| Conglomerate | 2 | 56 | 240 |
| Mixtite | < 2 | 10 | 14 |
| Very coarse sandstone | < 2 | 30 | 90 |
| Coarse sandstone | < 2 | 14 | 60 |
| Medium sandstone | < 2 | 57 | 350 |
| Fine sandstone | < 2 | 47 | 105 |
| Very fine sandstone | 2 | 13 | 35 |
| Siltstone | 5 | 22 | 95 |
| Claystone | 2 | 17 | 95 |

Figure 1—Plot of gold concentration versus grain size for samples from the southern Cobalt Embayment.

+ = mixtite

* = Bruce Formation
laminated medium sandstone containing a high concentration of pyrite along bedding planes.

**Sedimentary Framework**

Most of the lowermost Huronian succession of the southern Cobalt Embayment has a braided fluvial origin, but some lake and pond deposits can be recognized. Long (1976, 1978) suggested that most of the strata were deposited by Platte-type braided streams (cf. Miall 1980), with low sinuosities, high width to depth ratios, and unstable banks. This present study indicates that while Platte-type braided stream deposits predominate, especially in the upper, and more accessible parts of the formation, more proximal Doneck- and Scott-type are present in the lower parts of the sequence, as are minor examples of flash flood or Bijou Creek-type deposits, debris flows (or glacial units), lake, and pond deposits.

The highest gold concentrations do not occur in the most proximal facies. These occur predominantly in large and very large pebble conglomerates with high uranium concentrations and in most cases high pyrite content. All of these conglomerates are within a few tens of metres of the basal unconformity and may owe their “high” gold concentrations to winnowing (placer development) in mid or distal humid region alluvial fans (cf. Minter 1980). Even though none of the gold concentrations (assays) observed during this study merit immediate development the concentrations should be considered in determining the economic viability of uraniferous conglomerates in this area. Placer concentrations of gold may not be restricted to the lowest part of the Huronian Supergroup in an area north of Lake Wanapitei. Conglomeratic units of fluvial origin in the Gowganda and Lorrain Formations, and sandy beach deposits in the uppermost Lorrain Formation and Bar River Formation, may be favourable targets for future gold exploration.

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No. S20 Industrial Minerals of the Cargill Complex

M.A. Vos¹

This project is funded by the Ontario Ministry of Northern Affairs under the Northern Industrial Minerals Studies (NIMS) Program.

Introduction

The Cargill Complex is listed by J. Satterly (1970) as one of 43 carbonatite-alkalic complexes in Ontario. Initially explored for its copper and iron (titanium) mineralization, the Cargill Complex is now being developed by Sherritt Gordon Mines Limited for its phosphate potential. Other industrial minerals associated with this complex are rare earths, vermiculite, calcium carbonate, and mica. Overlying the carbonatite and phosphate residuum are deposits of quartz sand, kaolinite, organic clay, and glacial clay.

Location and Access

The Cargill Complex is made up of a north, a south, and a west subcomplex. Major mineralization is associated with the south subcomplex in Cargill Township. Access to this complex is gained by Spruce Pulp and Paper Company Limited logging road and connecting mine road. The Eccleston haul road passes within 1.5 km of the body. Mine development plans call for a road directly northward to connect with Highway 11 just east of Opasatika.

The north sub-complex, approximately 4 km to the north and partly located in Cumming Township, can be reached by bush trail on the property. The west subcomplex is known only by its magnetic anomaly centred approximately 4 km west of the south subcomplex.

Exploration History

The earliest recorded work on the Cargill Complex was by Continental Copper Mines Limited in 1955. The area was staked for copper-nickel or other base-metal mineralization and magnetic anomalies were tested by diamond drilling of seven holes totalling 931 m depth (Assessment Files Research Office Ontario Geological Survey, Toronto). This company has maintained basic land holdings in the area which have been ultimately consolidated to 21 mining leases. In 1964, and again in, 1970 Kennco Explorations (Canada) Limited examined the property for copper-nickel base metal mineralization. Six holes totalling 1,089 m in length were diamond drilled (Sage 1976, p.66).

In 1969, claims were staked by Union Carbide Canada Mining Limited west of ground held by Continental Copper Mines Limited. In the above exploration programs, only minor amounts of copper and nickel were found, and although apatite was reported in amounts up to 17 percent in calcitic carbonatite, the significance of the Cargill Complex as a phosphate exploration target was not recognized (Sandvik and Erdosh 1977, p.90). There was no further work undertaken on the complex until in 1974 when the International Minerals and Chemical Corporation (Canada) Limited re-examined all available data in a search for phosphates. Ground held by Continental Copper Mines was optioned and additional claims were staked. After drilling of 190 holes using reverse circulation techniques, a tentative open-pit mine estimated to contain a probable phosphate-bearing deposit of 62.5 million metric tons with an average grade of 19.6 percent P₂O₅ was outlined (Sandvik and Erdosh 1977).

In 1979, the property was optioned by Sherritt Gordon Mines Limited. A diamond drilling program to collect 300 tons of sample for pilot plant tests was completed in March 1980. In 1981 to the present, larger samples of several thousand tons were collected for bulk testing. For this purpose a slot measuring approximately 30 m by 300 m and 8 m deep was cut through overburden in the most accessible part of the south subcomplex ore zone. As well, the area of the future mine site and the path of the proposed mine road have been cleared of timber. A decision on the feasibility of phosphate mining is due in 1982.

Meanwhile, construction of a mine access road east of Marilyn Lake has drawn attention to local supplies of vermiculite. The material was excavated by backhoe from several locations along the road on the pyroxenite ridge bordering the carbonatite (see Figure 1). Used on the surface of the road, vermiculite effectively protects the roadbed from excessive moistening in rainy periods.

Geology

The Cargill carbonatite complex is located in an area of hybrid quartz-diorite gneisses and amphibolites of Ar-
Figure 1—Cargill Complex. Contact of carbonatite and pyroxenite with approximate location of vermiculite trenches.

Emplacement of the Cargill Complex 1.8 billion years ago is dated by J. Gittins et al. (1967). Atypical features of the complex, for example the presence of subcomplexes and the absence of fenitized rocks surrounding the carbonatite, have been ascribed to movement, subsequent to emplacement of the complex, along the northeast-trending faults (Sandvik and Erdosh 1977). The north subcomplex in this interpretation represents the western part of an originally circular body translated northeastward in a right-lateral movement over a distance of approximately 4 km. Quartz-diorite gneisses, where observed, would be in fault contact with the carbonatite, displacing their fenitized counterparts. An exception occurs where “banded gneiss outcrops of quartz diorite composition near the unexposed west subcomplex have distinct fenitization around the magnetic anomaly which defines that subcomplex” (Sandvik and Erdosh 1977, p.94).

In rock outcrops along the Ecclestone haul road 1 to 2 km south of the south subcomplex it was noted that the strike of layering in gneisses is predominantly east-west. Most quartz and carbonate veins follow this trend, although pervasive carbonate veining in many directions was observed in some outcrops. Rock units of the carbonatite complex are distinguished by P.O. Sandvik and G. Erdosh (1977) as follows:

- Glacial Lake Clays (youngest);
- Pre-Glacial Overburden;
- Residuum;
- Leached Carbonatite;
- Carbonatite;
- Contact Zone;
- Pyroxenite-Amphibolite;
- Quartz Diorite Gneiss (oldest).
The carbonatites are further divided on the basis of principal carbonate mineral into calcite-, dolomite-, or siderite-carbonatite. Siderite has not been found in fresh (unleached) carbonatite. The bedrock components of this series are described as follows (Sandvik and Erdosh 1977):

**Carbonatite and Leached Carbonatite**

Fresh carbonatite is a white or light gray, medium-grained, moderately banded rock, composed of 60-80% carbonate, 5-10% white or colorless apatite, 5-10% phlogopite and a few percent of actinolite, magnetite, and pyrrhotite/pyrite. The apatite, phlogopite, and magnetite may be disseminated or concentrated in narrow bands, the latter contributing the banded character to the rock. Magnetite also occurs as very coarse (several cm) subhedral or broken crystals. The carbonate minerals are calcite, dolomite or siderite-ankerite, with zonal distribution as discussed below.

Leached carbonatite is a brown or brownish-gray, earthy, soft, semi-consolidated crumbly rock, derived from the fresh carbonatite by weathering and leaching which has removed most of the easily soluble carbonates. Iron oxide (derived from siderite, ankerite, magnetite, and pyrrhotite) and some carbonate are commonly present in leached material. Apatite and magnetite are resistant to chemical weathering, but magnetite ultimately oxidizes to goethite. Therefore, leached carbonatite is enriched in the highly resistant apatite, in general to a range of 20 to 40 percent.

Leached carbonatite forms a rock unit above the fresh carbonatite, which varies greatly in thickness and distribution. In most places it is a few tens of metres thick, but it may exceed 160 m in thickness. On top of the pre-glacial ridges, it is generally thin.

**Contact Zone**

A contact zone is present between the carbonatite and pyroxenite plus amphibolite intrusions. It is made up of a series of alternating bands of carbonatite and pyroxenite, the width of the bands varying from a few centimetres to several metres. The carbonatite bands, veins, and stringers become less frequent and narrower as the main pyroxenite body is approached. The carbonatite includes pyroxenite xenoliths, indicating that carbonatite intrudes pyroxenite. The contacts between bands are sharp; the only distinct chemical reaction due to the intrusion is expressed by the development of biotite-rich zones.

The contact zone is steep or vertical and probably separates the two rock types along the contact. Its width is not well established, but is on the order of a few tens of metres.

No gradational contact rocks have been found between carbonatite and quartz diorite gneiss, indicating that this contact is sharp.

---

*Figure 2—Bedrock geology, north and south subcomplex, Cargill carbonatite (after Sandvik and Erdosh 1977).*
Pyroxenite-Amphibolite

Only a few holes have been drilled into the pyroxenite-amphibolite unit, mostly near the carbonatite contacts; consequently, the main mass of the unit is not well known. Where it has been drilled, the rock is dark grey to black, medium- to coarse-grained, and strongly magnetic. A study at the University of Toronto (Allen 1972) concludes that the pyroxenite-amphibolite is made up of a differentiated sequence of rocks including olivine pyroxenite, hornblende pyroxenite, and hornblendite.

Quartz Diorite Gneiss

The carbonatite is bounded along the west by rocks of quartz dioritic composition. No drill core of this rock is available; only rock chips have been seen, in which the composition appears generally uniform. It is a pink, medium-grained rock, with altered feldspar (mainly plagioclase) and quartz.

The distribution of bedrock components is shown in Figure 2. The near vertical contacts of these rocks contrast sharply with the irregular contact features of residuum and preglacial overburden (see Figure 3). Presumably, the latter developed under influence of karst topography.

The following is a description by P.O. Sandvik and G. Erdosh (1977, p. 93) of unconsolidated rock units overlying the carbonatite, supplemented with analyses by staff of the Geoscience Laboratories, Ontario Geological Survey, Toronto.

Residuum

Residuum is the ultimate product of chemical weathering of the carbonatite. It is a light to dark grey, sometimes brownish, unconsolidated material of predominantly sand size-range, made up of white or colorlessapatite crystals, crystal fragments or rounded grains. Minor goethite, siderite, magnetite, crandallite, and pyrite are present, but calcite and dolomite are absent. The apatite content ranges up to nearly 100 percent.

In many places, the apatite residuum is diluted by other weathering products such as clay and vermiculite, iron oxide, quartz grains and chlorite. In some places, the residuum contains only minor apatite, the main constituent being goethite. In others, near the pyroxenite contact, the residuum is made up of biotite, chloropyrite, and clay derived from weathering of the pyroxenite, with little or no apatite.

A thin crandallite-rich blanket, in which high rare earth values occur, is present in many places at the top of the apatite residuum unit. Several rare and unusual minerals are also associated with this blanket, but only the rare earths are thought to have economic significance. Concentration of secondary pyrite has been noted near the top of the residuum. The crandallite-rich blanket is the result of secondary weathering processes.

The residuum is extremely variable in thickness. In the preglacial troughs, thickness locally exceeds 170 metres and it thins to a few metres or disappears altogether on the ridges (Figure 5).

The following samples have been analysed for phosphate content, niobium, rare earths, CaO, F, and U:

- Sample 74 — Residual chlorite from core in southern part of south subcomplex;
- Sample 75 — Residual from test pit;
- Sample 76 — Residual from test pit-iron oxide stained;
- Sample 77 — Residuum (high grade) from diamond-drill core;
- Sample 78 — Heavy mineral concentrate of 77;
- Sample 79 — Residuum (high grade) from diamond-drill core;
- Sample 80 — Heavy mineral concentrate of 79.

Results are shown in Table 1.

Sandvik and Erdosh (1977, p. 92):

Glacial Lake Clays

Covering all underlying rocks is stiff, tan to grey, varved clay with an even, almost flat upper surface. The thickness of clay ranges from 1.5 m to 10 m, and averages 6 to 8 m.

Pre Glacial Overburden

A heterogeneous, irregular unit, which is pre-glacial and mostly...
### TABLE 2
ANALYSES OF PREGLACIAL AND GLACIAL SAND AND CLAY OF THE CARGILL COMPLEX.

#### 88 — PREGLACIAL QUARTZ SAND FROM DRILL CORE

<table>
<thead>
<tr>
<th>Chemical analysis</th>
<th>Size analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% SiO₂</td>
</tr>
<tr>
<td></td>
<td>67.6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Mesh</th>
<th>% Passing</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>94.9</td>
</tr>
<tr>
<td>18</td>
<td>85.2</td>
</tr>
<tr>
<td>25</td>
<td>72.4</td>
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<tr>
<td>35</td>
<td>58.4</td>
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<tr>
<td>45</td>
<td>45.4</td>
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<tr>
<td>60</td>
<td>33.9</td>
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<tr>
<td>80</td>
<td>24.1</td>
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<tr>
<td>120</td>
<td>17.8</td>
</tr>
<tr>
<td>170</td>
<td>11.6</td>
</tr>
<tr>
<td>230</td>
<td>9.6</td>
</tr>
</tbody>
</table>

Sand grains are equi-dimensional and angular; value Au <2 ppb

#### 81 — PREGLACIAL ORGANIC CLAY ("LIGNITE") FROM DRILL CORE

<table>
<thead>
<tr>
<th>Fixed carbon</th>
<th>Ash</th>
<th>Calorific value</th>
<th>Au 2 ppb</th>
<th>Ge &lt;100 ppm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.0%</td>
<td>71.1%</td>
<td>870 cal/g</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

#### 85, 86 — GLACIAL CLAY, 87 — PREGLACIAL CLAY

<table>
<thead>
<tr>
<th>Mineralogy</th>
<th>85</th>
<th>86</th>
<th>87</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaolinite</td>
<td>–</td>
<td>–</td>
<td>A</td>
</tr>
<tr>
<td>Chlorite</td>
<td>A</td>
<td>A</td>
<td>–</td>
</tr>
<tr>
<td>Illite</td>
<td>B</td>
<td>B</td>
<td>–</td>
</tr>
<tr>
<td>Quartz</td>
<td>D</td>
<td>D</td>
<td>–</td>
</tr>
<tr>
<td>Feldspar</td>
<td>C</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Calcite</td>
<td>B</td>
<td>C</td>
<td>–</td>
</tr>
<tr>
<td>Dolomite</td>
<td>C</td>
<td>D</td>
<td>–</td>
</tr>
</tbody>
</table>

Identity of kaolinite as opposed to chlorite was determined by additional X-ray after heating to 500°C for 1 hour.

Analyses by Geoscience Laboratories, Ontario Geological Survey

The decision to operate may be influenced furthermore by the ability to market byproducts. The chloride concentration adjacent to the phosphate residuum is sufficiently unique and voluminous, possibly amounting to several million tons, to justify research in order to develop uses for this material. Conceivably it can serve as a filler material in special paints, waxes, or plastics. Calcium carbonate on the property could be developed as a source of agricultural lime. Some of it occurs in outcrop along the east side of Cargill Lake. Uses for vermiculite have already been demonstrated locally. Unquestionably more uses can be developed, but a proper evaluation is necessary to derive the maximum benefit from this resource. A primary concern is to establish whether or not any asbestiform minerals are associated with the occurrence. The presence of asbestos detracts from the value of vermiculite, since the extra precaution against dust necessary in processing plants is costly. The advantage of vermiculite is that much of the material is readily available at or near the surface, and the mining of it can be undertaken independently of phosphate production. A continuous zone of vermiculite mineralization 45 to 60 m wide follows the contact between carbonatite and pyroxenite east of the south subcomplex. Approximate areas of excavation are indicated in Figure 1. Part of this summer’s field work consisted of confirming with a soil probe the continuity of vermiculite mineralization between excavations.

### References


No. 21 The Geology and Mineralization of the Terrace Bay Batholith, Mink Lake Stock, and Cairo Stock

Soussan Marmont1 and A.C. Colvine2

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The Terrace Bay Batholith

Introduction

The Terrace Bay Batholith is situated in the southern parts of Strey, Priske, and Syine Townships in the District of Thunder Bay. The area is readily accessible via Highway 17, which traverses the length of the batholith, and many bush roads branching off this highway. To the south, the batholith borders the north shore of Lake Superior, and can be reached by boat.

There is record of exploration activity in the area since 1896 in search of gold. During the period up to 1939, a number of properties were developed close to the northern contact of the Terrace Bay Batholith with the enclosing mafic volcanic rocks. These include the properties of the Gold Range Mines Limited (Number 1, Figure 1), the Harkness-Hays Gold Mining Company (Number 2, Figure 1), and the Jedder Gold Mines Limited (Number 3, Figure 1, now Hays Lake Mines Limited). Since 1950, there has been intermittent exploration activity.

In 1980, W. Acker of Schreiber, constructed a crusher mill on the east shore of the Hays Lake, to develop a gold-bearing vein extending 150 m and averaging 50 cm in width (originally the Jedder Gold Mines Limited property).

The Pitkanen occurrence (Number 4, Figure 1), was the first discovery of copper and molybdenum in the area. In 1965, Nor-Acme Gold Mines Limited and later in the year, Noranda Mines Limited, examined the property and the latter drilled two diamond-drill holes totalling 163 m in length. The property was further surveyed in 1969 by Univex Exploration and Development Corporation Limited who also drilled five diamond-drill holes totalling 490 m.

Previous geological surveys of the area were carried out by M.W. Bartley (1939), G.A. Harcourt (1939), and M.W. Carter (1981).

General Geology

The Early Precambrian metavolcanic (Figure 1) sequence mostly consists of pillowed, amygdaloidal, and variolitic basalts. These are believed to belong to an iron-rich tholeiitic suite (Carter 1981). They are in general rich in magnetite and pyrite, the latter occurring as finely disseminated cubes, narrow beds, or occupying the pillow selvages.

Intermediate metavolcanics are less abundant, and felsic metavolcanics are observed in only a few localities. Interlayered with the metavolcanic rocks, are medium- to finely-bedded, chert, wacke, coarse fragmental units, as well as beds of massive magnetite and pyrrhotite. This supracrustal sequence is intruded by several mafic and ultramafic bodies, which are mostly coarse- to medium-grained gabbro, diorite, and serpentinite.

The general grade of regional metamorphism of these units is of the greenschist facies; however, in the vicinity of the Terrace Bay Batholith, as a result of contact metamorphism, higher grade, amphibolite facies are present.

The Terrace Bay Batholith intrudes all the aforementioned rock types. It is an elongate body, extending approximately 19 by 5.6 km with long axis generally concordant with the surrounding metavolcanics. The most common rock type of the batholith is a massive, medium-grained, equigranular granodiorite/biotite-granite. Hornblende syenite, hornblende-biotite granite, and hornblende granodiorite are most commonly observed near the contact of the metavolcanic rocks; this enrichment in the mafic minerals content, may be the result of assimilation of the mafic volcanic rocks by the intrusive body. Xenoliths of metavolcanics are abundant in the Terrace Bay Batholith. The most common rock type of the batholith is a massive, medium-grained, equigranular granodiorite/biotite-granite. Hornblende syenite, hornblende-biotite granite, and hornblende granodiorite are most commonly observed near the contact of the metavolcanic rocks; this enrichment in the mafic minerals content, may be the result of assimilation of the mafic volcanic rocks by the intrusive body. Xenoliths of metavolcanics are abundant in the Terrace Bay Batholith. These vary considerably in size and composition, exhibiting partial to virtually complete assimilation. In some of the xenoliths, plagioclase metacrysts are developed, as a result of metasomatism. The xenoliths are most common in the area of the southern and western contacts.

A large xenolithic body, possibly a roof pendant, is exposed north of "90 foot Falls" on the Aguasabon River. It is 4 m in width, its contact striking at 80°; in the west it is cut by the Aguasabon River Fault and its easterly extension is covered by overburden. It consists of chloritic mafic volcanics, within a reddish hornblende-biotite granite; the northern contact is occupied by a brecciated quartz vein approximately 1 m wide.

The batholith is fairly homogeneous and appears to

1 Geologist, Mineral Deposits Section, Ontario Geological Survey, Toronto.
2 Chief, Mineral Deposits Section, Ontario Geological Survey, Toronto.
Figure 1—Geology of Terrace Bay Area (from M.W. Carter 1981).
MINERAL DEPOSITS — SPECIAL PROJECTS

represent a single phase intrusive activity. However, colour variation is common, and the rocks exhibit dark red to pink to greyish varieties. The dark red colour is attributed to the hematite content of the rock; this unit seems to be associated with the areas of intense shearing and fracturing. Some parts of the intrusion contain potassic feldspar phenocrysts in addition to the generally high potassic feldspar content of the body. This produces a distinctive porphyritic texture in the grey granodiorite observed mainly in the south-central part of the body (shaded area, Figure 1); this may be the result of later potassium enrichment, possibly an alteration effect.

The Terrace Bay Batholith is cut by aplitic and pegmatitic dikes which vary in width from a few centimetres to 2 m. These dikes are most commonly observed at or near the margins of the batholith. Off-shoots of the intrusive are present within the metavolcanic-metasedimentary sequence. The offshoots generally consist of pink to light buff, fine-grained to aphanitic quartz-feldspar dikes and stringers representing a rapidly chilled phase of the late magma.

All the above-mentioned rock types are intruded by lamprophyre and diabase dikes of Middle to Late Precambrian age. The diabase dikes are black, magnetic, aphanitic to medium grained, and show columnar jointing. The lamprophyre dikes are less abundant and show a distinct purplish colour.

Structure

The supracrustal rocks in the Terrace Bay area form a syncline, along an east-plunging axis (Carter 1981), and strike southeasterly in the area of the intrusion. Fracturing has occurred in various stages, some of which is later than the intrusion of the batholith and the mineralization process. Within the Terrace Bay Batholith, major lineaments and faults occur along north, northeast, and northerly trends, causing intense fracturing and shearing. The main part of the batholith, however, is generally massive. Foliation is usually absent, and only a weak trend paralleling the regional strike is apparent in the area of the eastern contact.

Three basic types of veins have been recognized in the area, occurring along the fractures and shear zones in the intrusive and/or greenstones:

1. Quartz veins, usually consisting of white, glassy quartz along with hematite, and minor sericite. These veins vary in width from a fraction of a centimetre to a few metres and strike 100°, 50°, 75°, and 15°. They occur as wide-spaced single veins in the granodiorite-hornblende granite or form a stockwork of veinlets and stringers. Within the aplite, these veins occupy the central part of the dikes, as a late sealing agent. Various concentrations of sulphides, chiefly pyrite, pyrrhotite, chalcopyrite, galena, and molybdenite along with graphite, magnetite, gold, and silver occur in the quartz veins.

2. Quartz carbonate (usually calcite) veins, cut the quartz veins and carry some hematite. In a few places these veins have been observed to strike 90°.

3. Carbonate-fluorite veins consisting of calcite, ankerite, and purple fluorite.

Economic Geology

Numerous gold and base-metal showings are present in the area, but for the purpose of this study, only the occurrences that show some association with the Terrace Bay Batholith or its offshoots, have been discussed. The main gold occurrences are as follows.

The currently active property of W. Acker on the east side of the Hays Lake (Number 3, Figure 1, previously the Derraugh vein or the Jedder Gold Mines Limited property) consists of a quartz vein hosted by pyritic, basaltic flows which are intruded by a pink, fine-grained to aphanitic quartz-feldspar dike. The vein strikes 60° and dips 85°N. The average width of the vein is about 50 cm and it has been exposed over a length of approximately 150 m. The vein occupies a shear zone and consists of white, glassy quartz which in places is highly brecciated and carries pyrite, chalcopyrite, galena, gold, and silver. A grab sample taken by M.W. Carter (Carter 1981) and analyzed by the Geoscience Laboratories, Ontario Geological Survey, returned 0.45 ounce of gold per ton. G.A. Harcourt in 1936 (Harcourt 1939, p.23) took one chip and one grab sample which were analyzed by the Provincial Assay Office, and gave 2.19 and 1.31 ounces of gold per ton, respectively.

In 1981, a sample of the mill concentrate (excluding the free gold that had been handpicked) given to the Senior author by W. Acker and analyzed by the Geoscience Laboratories, Ontario Geological Survey, returned 14.15 ounces of gold and 1.10 ounces of silver per ton.

The Gold Range property (Number 1, Figure 1) consists of a set of quartz veins that strike 40° and dip 70° northwest. The veins are hosted by intermediate to mafic metavolcanic rocks which are intruded by a fine-grained quartz-potassium feldspar dike. The veins are in turn cut by a lamprophyre dike, at the contact of which, large euhedral pyrite cubes are concentrated; molybdenite, galena, chalcopyrite, and gold tellurides are also present in the veins. The mineralization, however, is not restricted to the quartz veins, and molybdenite, chalcopyrite, and pyrite were observed in the enclosing metavolcanic rocks.

Sylvanite Gold Mines Limited in 1939 assayed one of the veins and returned an assay value of 0.49 ounce of gold per ton over a width of 27.5 cm and a length of 7.6 m (Regional Geologist's Files, Ontario Ministry of Natural Resources, Thunder Bay). In 1980, a grab sample taken by K.G. Fenwick (then Resident Geologist, Ontario Ministry of Natural Resources, Thunder Bay) and one taken by M.W. Carter, Geologist, Ontario Geological Survey, Toronto, analyzed by the Geoscience Laboratories, Ontario Geological Survey, Toronto, assayed 25.82 and 7.60 ounces of gold per ton, respectively.
Several occurrences of copper-molybdenum have also been explored in the area of Terrace Bay.

The Pitanen occurrence (Number 4, Figure 1) has been exposed by two sub-parallel trenches. The host rock is a hornblende granodiorite, which is in contact with a pyrrhotite-magnetite unit. This unit is in turn interlayered with a chloritic mafic metavolcanic flow unit. The hornblende granodiorite is cut by aplite dikes. All the above-mentioned rock types are cut by a network of quartz veins which carry pyrite, chalcopyrite, molybdenite, and secondary copper, and molybdenum minerals. Molybdenite occurs as rosettes, flakes, and disseminated grains. The mineralization is not limited to the quartz veins, and some disseminated sulphides are also present in the hornblende granodiorite, and the aplite.

Alteration in the wall rock of the vein system is not extensive and limited silicification and sericitization can be seen up to 1 m from the veins.

Nor-Acme Gold Mines Limited assayed the veins in 1965 and obtained 3.26 percent molybdenum and 0.01 percent copper (Regional Geologist’s Files, Ontario Ministry of Natural Resources, Thunder Bay).

Univex Exploration and Development Corporation Limited, who drilled the property in 1969, obtained their best assay of 0.2 percent molybdenum and 0.2 percent copper over 2 feet (Diamond Drill Report No. 14, Assessment Files Research Office, Ontario Geological Survey, Toronto).

A vein approximately 20 cm wide has been exposed over a strike length of about 100 m (No. 5, Figure 1) on the power line south of Highway 17. It strikes 100° and dips 60°S. The hornblende granodiorite which hosts the vein is in contact with a pyrite-bearing intermediate, aphanitic volcanic rock and is cut by numerous aplitic and pegmatitic dikes. Minor copper and molybdenum mineralization is present both in the metavolcanic and intrusive rocks. The vein consists of a massive, white quartz, carrying substantial amounts of pyrite, molybdenite, chalcopyrite, and secondary malachite, azurite, and ferromolybdate. It pinches and swells and shows a layering, along which the sulphide minerals are concentrated.

In the area of the Aguasabon River (Nos 6-9, Figure 1), there are a number of narrow (2 to 4 cm) quartz veins dominantly striking 75°, 150°, and 30°. The density of the veins varies from a stockwork to isolated veins occurring 20 to 30 m apart.

Pyrite is present in most of the veins, and chalcopyrite and molybdenite occur randomly. The biotite-hornblende granodiorite in this area is equigranular, pink and medium grained; it contains several xenoliths of the volcanic rocks. As a result of the “Aguasabon River Fault”, the intrusive is strongly fractured, sheared and chloritized in this area. To date, no assay results of metals are available for these veins.

Discussion

Two mineral assemblages of economic interest are present in the Terrace Bay area:

1. Molybdenum-copper occurrences which in places carry minor amounts of precious metals.
2. Gold occurrences which are usually in quartz veins containing variable amounts of silver, copper, lead, zinc, and molybdenum.

In both of these settings, the intrusion of the Terrace Bay Batholith has played a role.

All occurrences of molybdenum-copper are present in the western and southern parts of the Terrace Bay Batholith; to date, no showings of this type have been found in the eastern and northern parts.

The western and southern parts of the intrusive contain numerous xenoliths and a roof pendant of the country rocks indicating that this area represents a higher level of the batholith during intrusion, whereas the northern and eastern sections, represent deeper levels.

The close spatial association of the molybdenum occurrences with the higher levels of the intrusion (western and southern part) suggests a magmatic source for this type of mineralization. The late stage residual phase of the magma was enriched in molybdenum, which was deposited in fractures at the outer/upper levels. The southern showings are also contained within the area of potassic feldspar enrichment in porphyritic granodiorite, possibly an alteration effect associated with the mineralizing magmatic/hydrothermal event.

The gold mineralization in the Terrace Bay area shows association with the contact zone of the Terrace Bay Batholith and some of its offshoots. A metamorphic/hydrothermal process for the concentration of gold is assumed, whereby the intrusion of the batholith, in providing heat, caused mobilization and reconcentration of the gold already present in the volcanic country rocks. The later intrusion of Proterozoic lamprophyre dikes, may also have remobilized and further concentrated the pre-existing gold in the quartz veins. An example of this may be at the Gold Range property, where the higher concentration of gold, trapped within the large euhedral cubes of pyrite, occurs immediately adjacent to the lamprophyre dike and further from it, the gold values in the vein decrease (personal communication, K.G. Fenwick, Mineral Resources Coordinator, Ontario Ministry of Natural Resources, Thunder Bay).
The Mink Lake Stock

Introduction

The Mink Lake Stock is a small granodiorite body, centred on Mink Lake, about 105 km northeast of Red Lake; access to the area is by float-equipped aircraft.

In 1969, Bralorne Can-Fer Resources Limited staked an area of molybdenum-copper mineralization which occurs in a set of quartz veins hosted in the granodiorite (Number 1, Figure 2). Following geological mapping and trenching, the property was allowed to lapse. It was re-taxed in 1977 by Kostynuik Brothers of Red Lake, who carried out extensive trenching and stripping of the outcrops, over a three year period. In 1980, Noranda Exploration Limited, took an option on the property and carried out an airborne geophysical survey. In 1981, they did extensive line cutting, ground geophysical and geological surveys, and approximately 460 m of diamond drilling over 4 or 5 holes (personal communication, G. Pierce, Noranda Exploration Limited).

General Geology

The Mink Lake area lies within the Birch-Uchi Belt, close to its northwestern margin; mapping of the area has been carried out by Thurston et al. (1981), Harding (1936), and G.D. Furse (1933). The volcanic sequence consists of mafic flows, inter-layered with and overlain by felsic flows and pyroclastics, and is part of Cycle II of the three volcanic cycles defined by Thurston (1977) in the Birch-Uchi Belt. The mafic volcanics consist of pillowed, amygdaloidal, and porphyritic flows and exhibit extensive alteration to chlorite, epidote, and carbonate; on the west central shore of Mink Lake they exhibit a porphyritic texture, containing fine- to medium-grained amphibole phenocrysts. The felsic volcanics consist of flows and lapilli-tuffs, and pyroclastic breccias which display thin to medium bedding (less than 1 cm to 15 cm). Pyrite is ubiquitous in the volcanic rocks and occurs in variable amounts as dissemination, thin beds, and narrow stringers.

A sill-like gabbroic body has intruded the mafic volcanics and has itself been intruded by the southern portion of the Mink Lake Stock.

The Mink Lake Stock is sub-circular in outline with a diameter of approximately 2.5 km. It consists mainly of medium- to coarse-grained, equigranular granodiorite to quartz monzonite. Significant variations in colour and texture of the stock have only been observed in the area where extensive trenching and stripping has taken place. This area coinciding with the main zone of mineralization, is hereafter referred to as "the trenches area" and will be discussed under the "Alteration" Section of this report. No sharp contact of the main body of the stock with the surrounding metavolcanics has been seen. However, offshoots of the stock are present as dikes and dikelettes cutting and interfingering with the metavolcanics; these consist primarily of quartz and feldspar, are fine-grained to aphanitic, and are indicative of rapid chilling of a late magmatic phase of the stock.

Numerous quartz and quartz carbonate veins cut the felsic intrusive rocks in three dominant directions. The veins striking almost east, generally dip steeply to vertically, whereas the two other sets striking 30° and 120° have shallower to sub-horizontal dips.

Alteration

In "the trenches area", colour and textural variations of the stock are more readily recognizable, as large areas have been exposed.

A number of different rock types are present, which are listed as follows:

1. Fresh, equigranular granodiorite-quartz-monzonite which is basically the same rock as the main body of the stock.
2. Coarse-grained biotite-hornblende granodiorite, containing xenoliths of the metavolcanic rocks and showing a distinct increase in the mafic minerals content.
3. Aplite and pegmatite dikes cutting the other rock types and therefore representing a late stage phase of the intrusive.
5. Light green sericitized, chloritized unit.

No specific pattern or zoning as expected in a "porphyry" type of alteration, has been observed in the above-mentioned units. The contact between these rocks is sharp, and transitional stages are lacking. The hydrothermal fluids, resulting from the intrusion of the Mink Lake Stock, caused alteration in these rocks and later introduced the mineralization.

Structure

The metavolcanic rocks trend easterly, dip steeply, and are folded about a synclinal axis, to the north of Mink Lake. Foliation is weak and is most apparent in a few localities near the southwestern contact of the stock. Some of the fragments in the intermediate pyroclastic rocks show an elongation, concordant with the regional trend (93°).

A major fault (Shabumeni Fault) truncates the western part of the sequence; the supracrustals to the west of the fault have a north-northeasterly trend.

Fracturing within the Mink Lake Stock is not extensive and the main body of the intrusive is quite massive indicating that the stock was emplaced after deformation. The joints strike 140°, 80°, and 90° and are best exposed in the annulus of mineralization. Some chloritization and slickensiding is present along the joints, but may not be a deep feature.
Figure 2—Geology of Mink Lake Area (from P.C. Thurston et al. 1981).
Mineralization

The main area of molybdenum mineralization ("the trenches area") occurs in the southeastern part of the stock (Number 1, Figure 2), where it is exposed over an area 600 m by 200 m, elongate in an east-west direction; the stripping and trenching of this area provides much better exposure and access to unrestored samples than is available in the remainder of the stock. Mineralization is most evident in quartz veins but also occurs in the wallrock adjacent to the veins, and in areas of highly altered granodiorite.

The glassy, white quartz veins vary in thickness from 1 cm to 5 cm and occur either as planar veins up to 1 m apart or as a network of stringers. Mineralization consists of molybdenite and pyrite with magnetite, chalcopyrite, scheelite, and secondary copper, and molybdenum minerals, concentrated at or close to the vein margin; pyrite is normally euhedral and molybdenite occurs as rosettes, disseminations, and smears along shear planes. The majority of mineralization was observed in shallow vein sets whereas the more steeply dipping veins were generally barren.

A localized alteration zone was observed within a few centimeters of the mineralized veins; it normally consists of a pinkish zone, possibly potassium enriched, with biotite and amphibolite largely absent, succeeded by a greenish zone containing sericite and chlorite, succeeded by fresh granodiorite-quartz monzonite. The sulphide content of the rock decreases rapidly from the vein margin.

Some mineralization is also present in the pale pink carbonate rich fluorite bearing unit (Unit No.4, discussed under alteration) where molybdenite occurs as fine to medium flakes and grains throughout the rock.

Few gold values have been reported, ranging from 0.04 to 0.15 ounce per ton (Durocher 1980). No assay results from samples collected by the authors are available to date, to substantiate this statement.

A minor showing of molybdenite has been found during this survey, located on the western part of the stock (Number 2, Figure 2). This consists of a series of narrow (1 to 2 cm) quartz, carbonate, hematite veins which strike 75°-95° and dip between 75° to 90°. Few fine grains of molybdenite and some pyrite are found within the coarse grained, equigranular granodiorite which hosts the veins. Alteration is very weak and only slight sericitization can be seen immediately to the wall rock.

No other showings of molybdenite were observed during this survey, this may in part be due to difficulty in adequately sampling smooth glaciated outcrops.

Discussion

The Mink Lake Stock, containing xenoliths of the country rocks, is an epizonal, felsic intrusive body. The enclosing volcanic rocks in the area of Mink Lake, have been deformed and metamorphosed to greenschist facies, but the stock is fairly undeformed and homogeneous. Therefore, the emplacement of the stock took place after the deformation of the supracrustal suite.

Molybdenum mineralization is mostly observed in the southeastern part of the stock, where it has been exposed by extensive trenching. The mineralization occurs in two forms:

1— In gently dipping quartz veins;
2— Disseminated in a carbonate-rich unit;

In the quartz veins, molybdenite occurs as rosettes, flakes, and smears. Usually it occupies the margins of the veins. Other minerals present in the veins are pyrite and minor chalcopyrite. Local potassic and sericitic alteration is associated with each vein.

The disseminated pyrite and molybdenite occur as fine grains in the ground mass of a pink, carbonate-rich, fluorite-bearing unit.

In the same area of mineralization, various types of altered rocks are present. Most of these units have been cut by the mineralized quartz veins, and do not show any pattern or zoning related to the mineralization. It appears, therefore, that the intrusion of the Mink Lake stock, was accompanied by hydrothermal activities which caused extensive alteration (only observed in the trenches area), and mineralization as a late stage of that hydrothermal activity.

The results of drilling carried out by Noranda Exploration Limited in 1981, will be released as an assessment report in the near future (personal communication, G. Pierce, Noranda Exploration Limited).

The Cairo Stock

The area of study comprises the Cairo Stock situated in parts of Cairo, Alma, and Flavelle Townships approximately 5 km north-northeast of the town of Matachewan, as well as a number of small intrusive bodies interpreted as possible off-shoots of the Cairo Stock, which are situated in Powell Township.

Production from the Matachewan Consolidated Mines Limited (Number 1, Figure 3) and the Young-Davidson Mines Limited (Number 2, Figure 3) properties, between 1934 and 1957, amounted to 956 117 ounces of gold and 165 598 ounces of silver.

The Ryan Lake property (Number 3, Figure 3), the site of which is presently being used by Extender Minerals of Canada Limited for a barite mill, produced 1352 pounds of copper, between 1950 and 1964 (Lovell 1967). Prospecting and exploration activities have been carried out by numerous individuals and companies in the Matachewan area since 1906 (Assessment File Research Office, Ontario Geological Survey, Toronto). The more recent works include exploration carried out by Texagulf Incorporated, over claims held on the southern boundary of Cairo and Flavelle Townships. The southwestern part of the Cairo Stock has been explored by
Majestic Wiley Contractors Limited during 1975 and 1976, who carried out a geological and geochemical survey. Newmont Exploration of Canada Limited during 1979 and 1980, did extensive mapping, trenching, and geophysical work over the southern part of the Cairo Stock, where it is in contact with the metavolcanic rocks. At the present time, Pamour Porcupine Mines Limited, having taken the option on both Matachewan Consolidated Mines Limited (1979) and Young Davidson (1980), is producing from an open pit operation on the former, some 3500 tons of ore averaging 0.08 ounce of gold per ton, per month.

Previous geological work in the area consists of a regional geological map produced by A.G. Burrows (1918) and H.C. Cooke (1919). Subsequent mapping and research programs were carried out by W.S. Dyer (1935), H.H. North and C.L. Allen (1948) and D.R. Derry et al. (1948). H.L. Lovell (1967) mapped the Matachewan area and W.J. Wolfe (1972) completed a geochemical survey of the Cairo Stock. More recently, W.D. Sinclair (1979) investigated the copper-molybdenum occurrences of the Matachewan area.

General Geology

The general geology of the Matachewan area is shown in figure 3. The base of the metavolcanic rocks in the Matachewan area consists of ultramafic flows (showing spini-fex texture) to the south-southeast of stock (Assessment File No. 2.3027, Assessment Files Research Office, Ontario Geological Survey, Toronto), and west of Hollinger Lake, approximately 2.5 km northwest of Matachewan (Van Wiechen, 1981) and flow breccia. These rocks have been extensively serpentinized, and have been explored for their asbestos veins.

The mafic metavolcanics overlying the ultramafic rocks are massive and pillowed flows and tuffs; a few exposures of variolitic pillows were observed. The felsic units consist of various tuffs which are usually finely bedded.

A bright green, chrome-mica-rich unit interlayered with mafic metavolcanics was mapped in the area of Matachewan Consolidated Mines Limited, and to the south of the contact of the stock. This rock consists of finely bedded/laminated fuchsite-rich carbonate, mostly ankerite and siderite with lesser amounts of calcite. It has a distinctive texture containing rods of a pink, fine-grained to aphanitic siliceous or carbonaceous cherty material; these rods represent either stretched clasts or boudinaged beds. The tightly folded sedimentary rocks overlying the metavolcanics consist of wacke, arkose, argillite, and poorly sorted conglomerate.

The Cairo Stock intrudes the afore-mentioned rocks and shows a variety of textures and compositions. The dominant rock type of the stock is a medium- to coarse-grained hornblende syenite. Near its contact with the volcanic rocks, the syenite is more mafic and layers of amphibole-rich units have resulted partly from assimilation of the volcanic rocks and partly from differentiation of the magma. Another distinct rock type of the Cairo Stock is a "trachytic" syenite, in which, laths of orthoclase occur in a dark red groundmass; in places these show a conformable orientation with the contact of the stock. The orthoclase can be very coarse, up to 2 to 4 cm in length. A porphyritic syenite is also present in the Cairo Stock consisting of large orthoclase phenocrysts set in a fine- to medium-grained groundmass.

Wide colour variations are present with syenite ranging from a bright cherry red to red-brown to pink. No specific relationship has been determined between the different textures and colours. Wolfe (1972) has pointed out a zonation of the syenite body to grade from a more quartzose syenite in the centre to a more mafic one in the margins.

In the Powell Township west of the Cairo Stock, many bodies of syenite interpreted as offshoots of the main stock occur as small cupolas or dikes; most of the occurrences of mineralization are close to or hosted by these offshoots. They exhibit the same variety of textures and compositions as the main body of the Cairo Stock. The granites to diorites and quartz diorites which occur to the south of the stock (Figure 3), exhibit gneissic textures in places; these have no obvious relationship to the Cairo Stock.

The distinctive north-trending Matachewan diabase dike swarm intrudes the Early Precambrian rocks and has been dated at 2485 million years. The diabase consists of pyroxene and lath-like feldspar crystals, sometimes porphyritic with feldspar phenocrysts up to 10 to 15 cm in length. Pyrite is ubiquitous in this rock.

The flat-lying Gowganda Formation of the Cobalt Group unconformably overlies all the abovementioned rock types; it consists of quartzite, argillite, arkose, and poorly-sorted conglomerate.

The last magmatic activity in the area is the intrusion of Nipissing diabase dikes, with no uniform trend.

Structures

The volcanic rocks show a general northeast trend and dip steeply. Faulting is extensive and occurs in north, northeast, and northwest directions. A major left lateral shear zone trends easterly, close to Highway 66 (Lovell 1967). The metamorphic grade of the volcanic rocks is of greenschist facies, but the intrusion of the Cairo Stock has locally upgraded the metavolcanic rocks to amphibolite facies.

Economic Geology

The main exploration activity in the area of Matachewan has been directed towards numerous gold occurrences, mostly in the Powell Township. There are also a number of molybdenum-copper showings, including the Ryan Lake, past producer.

The Matachewan Consolidated Mines Limited gold property (No. 1, Figure 3), under option to Pamour Porcupine Mines Limited is presently producing from an open pit operation, approximately 3500 tons of ore averaging...
0.08 ounce of gold per ton, per month. The gold, rarely visible, occurs in the pyrite, hosted by various rock types. The dominant host rock in the area of the mine is a dark basaltic flow, in contact with Early Precambrian greywacke, and cut by offshoots of pink to dark red porphyritic and trachytic syenite. A green, chrome mica-rich carbonate unit forms a lens within the mafic metavolcanic rocks, and is also host to a significant portion of the mineralization. A third mineralized rock type is a cherry red trachytic and porphyritic syenite which contains up to 2 percent auriferous pyrite. This rock is fractured and jointed. All these host rocks are cut by numerous sets and generations of quartz and quartz-carbonate veins. Tourmaline, chalcopyrite, minor scheelite, and large euhedral cubes and fine disseminated stringers and beds of auriferous pyrite occur in the veins and in the enclosing rocks.

Gold is concentrated to ore grade along the contacts of some of the pink, fine-grained quartz-feldspar offshoots, with the mafic metavolcanics; this demonstrates that the offshoots have played a role in gold concentration.

The mineralization at the Young-Davidson Mines Limited gold property (No.2, Figure 3), also under option to Pamour Porcupine Mines Limited, occurs entirely within the syenite, in contact with the Early Precambrian sediments. The syenite varies from a cherry red central part to a peripheral brown red. The cherry red syenite shows trachytic texture and is the only ore-bearing phase of the intrusion; gold occurs in auriferous pyrite, disseminated throughout the rock and in microfractures. Many generations of quartz and quartz-carbonate veins cut the syenites and the metasediments. Pyrite, tourmaline, chalcopyrite, magnetite, scheelite, molybdenite, and galena are found in the veins.

The Ryan Lake property (No.3, Figure 3) is located in the contact area of sheared, serpentinitized, volcanic rocks with the Early Precambrian sediments, intruded by a fine- to medium-grained, dark grey biotite syenite. A Matachewan diabase dike cuts the syenite in the area of mineralization. The porphyritic syenite, and the quartz veins dominantly striking north to north-easterly, carry molybdenite, chalcopyrite, bornite, and pyrite as dissemination and patches. A steeply dipping easterly trending shear zone contains high grade molybdenum-copper mineralization and was the main zone from which the production of copper came from (Sinclair 1979).

The copper-molybdenum occurrences on Stancop property (No.4, Figure 3) are present in fractures and quartz veins in a red porphyritic syenite and the adjacent greywacke and conglomerates. Chalcopyrite, molybdenite, pyrite, and lesser amounts of bornite, sphalerite, and galena occur in 2 to 3 generations of quartz veins. Chloritization and silification of the fractures is common. Many xenoliths have been seen in the syenite porphyry, some of which are highly sulphidic.

A number of other copper-molybdenum showings have been explored to various degrees in the Matachewan area, the most important ones being the Hawley Lake (No.5, Figure 3) and the Webb Lake (No.6, Figure 3) properties (see Lovell 1967).

Discussion

The main body of the Cairo Stock is a medium- to coarse-grained equigranular syenite. Smaller bodies of similar syenite occur to the west of the main stock as cupolas and dikes, interpreted as offshoots and possibly highest level phases of the intrusion. Both of the principal mineral assemblages in this area are associated with these offshoots and are given as follows:

1. Gold with minor base metals: This type is hosted by all of the main Early Precambrian units including basaltic flows, fuchsite carbonates, greywackes, various phases of syenite, and several generations of quartz and quartz-carbonate veins.

2. Copper-molybdenum with minor gold and silver. These occur mainly at the contact of the Cairo Stock and its offshoots with their enclosing rocks.

The close spatial association of mineralization with the syenitic stock and offshoots indicates that the intrusion played a significant role in the formation of mineralization. Such a role may have consisted of either introduction of metals in a porphyry-style hydrothermal system, or hydrothermal reconcentration of metals present in the wallrocks of the stock due to the heat of its emplacement. It is difficult to assess the contribution of each process in the case of the Cairo Stock, but both were most probably operative.

W.D. Sinclair (1979) has pointed out several features similar to mesozoic porphyry systems. These include the disseminated and stockwork mineralization and alteration in the form of hematization; these are features related to hydrothermal activity. The regional zonation of metals described by Sinclair (1979) from a base metal to a peripheral auriferous pyrite zone was not recognized.

The enclosing volcanosedimentary package of mafic and ultramafic metavolcanics and clastic metasediments, similar to other Shield gold camps, provides a possible source for gold if reconcentration processes were operative.

One feature not considered above is the close spatial association of Matachewan diabases with all of the showings; this is not surprising considering the high density of the dike intrusions. While this does not imply a genetic link, the Matachewan diabases do represent a major intrusive event. As they clearly intrude mineralized rocks, it is probable that they would cause a degree of hydrothermal reconcentration of pre-existing mineralization as demonstrated for the Nipissing diabases to the South (Innes and Colvine 1979).

Whichever process of concentration predominated, the area presently contains many interesting occurrences of mineralization. Some features of the mineral deposits outlined here and in previous publications may assist in further exploration in this area.
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No. S22 Early Precambrian Porphyry Deposits

A.C. Colvine¹ and Soussan Marmont²

This project was initiated in 1977 to investigate Early Precambrian mineralized granitoid bodies; it had been suggested in several publications that some of these exhibited features analogous to Mesozoic porphyry copper deposits (Kirkham 1972, Cimon 1970, Ayres et al. 1973, Campbell 1973, Friske 1974, Ayres and Findlay 1976, Pedora 1976, Findlay and Ayres 1977). Mesozoic porphyries have become a major worldwide source of copper, molybdenum, and to a lesser extent, gold; but to date there has been no major production from Early Precambrian deposits conclusively identified as being porphyry-type.

The approach to the project has been twofold, data compilation and field investigation. A data compilation of more than 100 granitoid mineral deposits will be published shortly; however, our experience from follow-up field examination of several of these deposits, is that literature surveys are not adequate, and may even be misleading in determining the true nature, extent and geological associations of this type of mineralization.

Detailed field investigations of nine of these deposits have been carried out since 1977 (see Figure 1). In addition, six additional deposits were investigated on a reconnaissance basis during 1981 (see Figure 1); a brief description of each is presented below.

1. Owl Lake Occurrence, District of Thunder Bay

This showing (Number 12, Figure 1) is located approximately 16 km north of the town of Terrace Bay, and is readily accessible via the Kimberly-Clark road. The occurrence had been explored by various individuals and companies intermittently from 1920 until 1969.

The felsic to intermediate metavolcanic sequence in the area of Owl Lake has been intruded by a leucocratic, medium-grained, tonalite-diorite body, which shows gneissic texture. The granitic mass has been cut by several aplite and pegmatitic dikes. A series of quartz veins, ranging in width from a few centimetres to a metre, dominantly striking east and dipping steeply to the south, cut the aplite dikes and the granitic body. The mineralization, consisting mainly of molybdenite, pyrite and minor chalcopyrite, occurs in the aplitic phase of the granitic intrusion, and in the quartz veins. Large flakes and rosettes of molybdenite have been observed at the contact of the quartz vein with an aplitic dike. A grab sample taken by M.W. Bartley (1938) assayed 1.68 percent molybdenum (2.8 percent MoS₂) and 0.03 ounce of gold per ton. The mineralization seems to be directly related to the intrusion of the granitic mass, most probably carried in the late potassium-rich phase (aplite and pegmatite) of the magma.

2. Chemalloy Occurrence, northwest of Elmhirst Township, District of Thunder Bay

This occurrence (Number 13, Figure 1) is accessible via road 801 west of Jellicoe and lumber roads. The showing was discovered by A. Mitto in 1971. Extensive trenching and stripping was done in the area, between 1971 and 1972.

The metavolcanics in this part of Elmhirst Township consist of a thick sequence of intermediate to felsic flows and pyroclastic rocks. Some mafic units are intercalated with the felsic rocks, but the area appears to be close to a felsic volcanic centre.

The Elmhirst Lake Stock intruding the metavolcanics is composed of a homogeneous granodiorite to quartz diorite in its main body, but contains numerous xenoliths near its northern contact. Several pegmatite dikes, up to 3 m wide, cut the stock. Quartz veins, striking 110° to 125° and dipping steeply to the north, cut the granodiorite and the pegmatite dikes.

The mineralization occurs in a sheared, chloritized, and silified granodiorite cut by quartz veins which vary in width from 1 to 3 m. Pyrite, chalcopyrite, and molybdenite occur as fine grains, and thin flakes in the shear fractures in quartz veins, and within the granodiorite. Alteration products such as chlorite, sericite, epidote, and carbonate can be seen within 1 m of the veins. Two dark grey diabase dikes, striking 80° and 110° and containing xenoliths of the granodiorite, are also present in the area of the mineralization. The highest assay obtained by the drilling program carried out in 1971, was 0.20 percent MoS₂ over a width of 1.5 m, but an average grade of 0.1 percent MoS₂ over 7.5 m has been reported (File No.63.3128, Files Assessment Files Research Office Ontario Geological Survey, Toronto).

¹Section Chief, Mineral Deposits Section, Ontario Geological Survey, Toronto
²Geologist, Mineral Deposits Section, Ontario Geological Survey, Toronto
Figure 1—Map showing locations of some Early Precambrian felsic intrusion-related mineral occurrences.
by W.O. Mackasey and H. Wallace (1973), assayed 0.51 percent MoS₂, 0.02 ounce of gold, and 0.36 ounce of silver per ton.

The showing has been referred to as a porphyry-molybdenum deposit (Mackasey and Wallace 1978). The alteration in the vicinity of the veins is the result of a hydrothermal system, and the mineralization shows close relationship to it. The extent of mineralization and alteration, however, appears to be very limited, and the mineralization may be fracture-shear controlled.

3. Dorothea Township (A.P.E. Hopkins) Occurrence; southwest Dorothea Township, District of Thunder Bay

This showing (Number 14, Figure 1) is located approximately 2.5 km east of Bish Bay on Lake Nipigon. Road 580 leads to an overgrown bush trail. In the 1930s gold was discovered in the area and from 1939 until 1971, several individuals and companies carried out exploration intermittently.

Intermediate to felsic tuff-breccias and coarse pyroclastic rocks, overlain by a sequence of polymictic conglomerate, sandstone, siltstone, and minor argillite and iron formation, are intruded by a small body of medium- to fine-grained granodiorite. This rock consists of 30 to 35 percent quartz, less than 5 percent mafic minerals, and altered plagioclase replaced by sericite and epidote (Mackasey 1975). Easterly-trending quartz veins cut the granodiorite.

The mineralization consists of pyrite, chalcopyrite, and molybdenite disseminated in the surrounding metavolcanics, in the granodiorite, in the quartz veins, or as smears along the fractures. Alteration is very limited and only slight hematization and sericitization has been observed. The average grade obtained from 31 samples assayed in 1971 (File Number 21896, Files Assessment Research Office Ontario Geological Survey, Toronto) by Gunnex Limited, is 0.02 percent MoS₂, 0.07 percent Cu, and a trace of gold and silver.

W.O. Mackasey (1975) suggested a "porphyry-copper type" of mineralization in a stockwork of quartz stringers. The mineralization is most probably the result of limited hydrothermal activity, related to the granodiorite. This intrusive body, however, may be a sub-volcanic phase of the felsic volcano.

4. Hardiman Bay (Queensway and Newman) Occurrences, Northeast of Horwood Township, District of Sudbury (No. 15, Figure 1).

The access to this area is via Highway 101 and an all weather road through Kukatush railway station. The original discovery was reported in 1936 and until 1978, exploration had been carried out intermittently.

Massive, dominantly mafic metavolcanics, with minor felsic metavolcanics, are part of the Swayze Belt. They are interbedded with volcanogenic wacke, chert, argillite, and polymictic conglomerate. A syntectonic domal pluton (Hardiman Lake Pluton) has intruded the supracrustal rocks. It consists of a leucocratic, medium-grained biotite trondhjemitic quartz monzonite, containing few xenoliths of the country rock. A number of quartz veins cut the intrusion, and in places form a stockwork of stringers and veinlets.

The mineralization consists of molybdenite, minor pyrite, chalcopyrite, and arsenopyrite, disseminated in the intrusive, and/or along the margins of the quartz veins. The quartz monzonite, in the area of the mineralization, contains augen-shaped phenocrysts of potassium feldspar (Breaks 1978). Grab samples reported by Mr. Newman (Breaks 1978) range from 0.02 to 0.98 percent MoS₂.

The mineralization has possibly resulted from hydrothermal activity subsequent to the intrusion of the Hardiman Lake Pluton. The presence of potassic feldspar phenocrysts in the area of mineralization may represent potassium alteration. The extent of mineralization observed is very limited.

5. McIntyre Mine, Approximately 2 km East of Timmins, District of Timiskaming

A brief visit was made to this deposit by the authors (Number 11, Figure 1), presently being mined by Pamour Porcupine Mines Limited.

The deposit has been the subject of extensive studies, and has been well described in the literature (Davies and Luhta 1978). The fairly extensive disseminated and stringer copper mineralization is contained within the altered parts of a porphyroblastic felsic schist unit (the Pearl Lake Porphyry), and adjacent schistose mafic volcanic rocks. Alteration in both felsic and mafic schists consists of intense albitionization commonly associated with anhydrite (to 50 percent) and hematite.

Based on such a brief visit, it is not valid to discuss this deposit at length, but based on the features observed and those described in the literature, and in comparison with other Early Precambrian mineral deposits, an alternative genesis of the deposits from those previously discussed (Kirkham 1972, Davies and Luhta 1978) warrants consideration. The alteration zones are not disimilar to altered stringer pipes in volcanogenic exhalative systems forming feeders to massive sulphide deposits. Subsequent deformation and metamorphism of the altered rock to the present mineral alteration assemblages could potentially have produced the features presently seen.

6. Setting Net Lake, District of Kenora, Patricia Portion

This occurrence (Number 10, Figure 1) is approximately 195 km north of Red Lake and is accessible by float-equipped aircraft. The mineralization was first mapped in 1930. Numerous workers and companies have studied the area.
The Early Precambrian metavolcanics in the Setting Net Lake area are mostly well-foliated to massive, fine-grained basaltic and andesitic flows (Crawford 1976). These rocks are intercalated with thin bands of wacke, argillite, chert, conglomerate, and iron formation. The supracrustal rocks are isoclinally folded about a northwest-trending axis.

The Setting Net Lake Stock intruding these rocks, is an elliptical, epizonal, porphyritic granodiorite-quartz monzonite body, which has been emplaced before the regional deformation of the enclosing rocks (Ayres and Findlay 1976).

A network of quartz veins, varying from a hairline veinlet to up to 2 m wide, cut the intrusive body in a dominant trend striking 65° and dipping 75°S.

The mineralization is essentially concentrated in the northern part of the stock. L.D. Ayres and D.J. Findlay (1976) report an area of 2500 m by 460 m containing molybdenum mineralization. This extensive mineralization was observed by the authors, and its pervasive nature was of particular interest. Over this large area, at virtually every outcrop, molybdenite could be seen in quartz veins and within the body of the stock. Molybdenite, pyrite, and minor chalcopyrite occur as microfracture filling, in quartz veins, and as disseminated mineralization throughout the porphyritic granodiorite-quartz monzonite. An average grade of 0.06 percent of MoS₂ has been reported from the eastern part of the mineralized zone (Ayres and Findlay 1976).

The alteration noted by Ayres and Findlay (1976) consists of extensive albitionization, sericitization, chloritization, and enrichment in carbonate and epidote. Large phenocrysts of potassium feldspar give rise to a porphyritic texture in the area of mineralization, and may represent a potassic alteration zone. The alteration is absent in the non-mineralized southern part of the stock.

The Setting Net Lake occurrence has been described by Ayres and Findlay (1976) as a “Precambrian porphyry copper and molybdenum deposit”. Many of the features observed during the short visit to this area, show close resemblance to a “porphyry deposit”. The outstanding difference between this occurrence and many of the others studied in this project, is the widespread, pervasive nature of both mineralization and alteration, which would have resulted from a large-scale hydrothermal system.

Discussion

Prior to a discussion of the findings of this study, it might be useful to define a porphyry deposit. Literature definitions tend to consist of listings of geological features expected in a porphyry-type deposit (for example Sutherland-Brown 1976). Some of the main features are listed below:

- The deposit should be intimately associated with a felsic pluton.
- The pluon should display a porphyritic texture to some degree (indicative of an epizonal level of emplacement).
- The deposit should consist of widespread, pervasive primary mineralization, sparsely distributed in fractures, veinlets, stockworks, breccias, or disseminations.
- Mineralization should be associated with an extensive alteration of its wallrocks.
- Both, mineralization and alteration should be distributed in the intrusion and/or host rocks in a systematic zonal pattern about the intrusion. Mineral and alteration zones have been defined for many examples.

A generalization of this is that a porphyry deposit forms as a result of a large-scale hydrothermal system developed about a relatively high-level granitoid intrusion. The hydrothermal system forms widespread, pervasive mineralization and extensive wallrock alteration in definable zones in and about the intrusion.

It became clear from an early stage in this project that economic and genetic considerations must not be confused. In none of the nine bodies examined in detail (Marmont and Colvine, this volume), and in only one of those examined on a reconnaissance basis (Setting Net Lake), were the above features recognized as adequate to allow their classification as true porphyry deposits. Regardless of this, most deposits were seen to contain significant concentrations of mineralization, which, if carefully investigated, may prove to be of economic interest. Most are being actively explored, at least one is being developed (High Lake), and two are being exploited (Cairo and Terrace Bay).

Much of the apparent confusion over Early Precambrian porphyries arises from the fact that they are related genetically to a stock intrusion; all nine deposits studied in detail formed as a result of the heat of the intrusion, concentrating metals from the intrusion and/or from its wallrocks. In either case, hydrothermal processes predominated; the mineralization produced is in the veins, stockworks, and disseminations and is commonly associated with alteration. It then becomes a subjective judgement, dependent largely on the scale of the system, as to whether or not these deposits can be classified as porphyries. In the authors’ opinion, based on comparison with Cordilleran Porphyries, it would be misleading to consider any of these nine deposits equivalent to more recent porphyries. To do so, might, in fact, lead to incorrect approaches to their exploration. Of those Early Precambrian deposits in Ontario visited by the authors to date, only the Setting Net Lake body exhibits adequately the necessary features to justify it being classified as a porphyry.

Considering the large number of Early Precambrian epizonal stocks in Ontario, the question naturally arises as to why there are not more porphyry deposits. In an-
MINERAL DEPOSITS — SPECIAL PROJECTS

answer to this, consideration must be given to the systematics of the mineralizing processes, and Early Precambrian tectonic conditions.

The three additional deposits studied in detail this year substantiate the general observations made previously (Colvin and Sutherland 1979). While each area is unique in form and distribution of mineralization, three general categories can be outlined:

1. Most molybdenum mineralization appears to be the product of a late hydro magmatic phase of an intrusion. It is commonly associated with wallrock alteration, potassic and various other types, which are commonly pre-mineralization, but regular definable alteration zones have not been delineated. Mineralization is not pervasive; it is restricted to discrete quartz, aplite, or pegmatite veins or vein systems. It is this containment, rather than dispersion of the hydrothermal phase of the intrusion that has produced a molybdenum concentration of economic interest; such containment may not take place in higher level intrusions.

2. Gold (±copper) mineralization appears to form largely as a result of hydrothermal reconcentration of wallrock mineralization, this occurs in quartz veins, generally around the margin of the intrusion. The extent of gold and copper concentration is seen as a function of gold and copper content of the wallrocks, and also of the effectiveness of hydrothermal reconcentration processes. In all cases studied of this type, extensive assimilation of wallrock material was observed. This type of mineralization appears to be associated with higher-level intrusions.

3. Copper, gold, and other metals appear to be associated with synvolcanic epizonal intrusions. The resultant mineralization might better be compared with the massive sulphide system; stringer and disseminated mineralization forms, and wallrock alteration occurs in the subsurface feeder pipe to a hydrothermal system which vents on the sea floor, commonly producing a massive sulphide deposit.

Lateral, Bamaji, and Mink Lakes all appear to be Type 1. Terrace Bay and High Lake show features of both Types 1 and 2. The Cairo Stock is probably also a hybrid, but is unusual in its concentration of copper in a fairly massive form, and in its concentration of gold distributed throughout some syenitic offshoots. Canoe Lake is Type 2 and Pickerel Arm and Gutcher Lake of Type 3.

Based on only a reconnaissance survey, the other deposits examined this year appear to fall into these categories also: Owl Lake, Chemalloy and Hardiman Bay as Type 1, Dorothea as Type 2, and McIntyre as Type 3.

The hydrothermal systems associated with Types 1 and 2 appear to have had less extensive effects of mineralization and alteration; the apparently smaller systems may be the result of drier conditions. This could be explained by Early Precambrian thermo-tectonic conditions; a thinner crust with higher heat flow. At the subsurface depths necessary to contain and develop a re-circulating porphyry hydrothermal system in the Mesozoic Crust (3 to 4 km), higher heat flow in the Early Precambrian would produce metamorphic grades approaching amphibolite facies. The water available for a hydrothermal system would therefore be largely restricted to that produced by the magma, and hence mineralization forms in discrete quartz veins and pegmatites.

At higher levels, where water would have been more readily available, an extensive hydrothermal system would be expected to vent. Subvolcanic intrusions may be the focus of the hydrothermal system in many of the Early Precambrian massive sulphide deposits. Perhaps these deposits are the true Early Precambrian analogues of Mesozoic porphyries.

Those intrusions emplaced at higher levels after volcanism, and after deformation, show evidence of extensive remobilization and hydrothermal reconcentration. Unfortunately, the rocks above the intrusion, which might be the most interesting economically, in most instances have been removed by erosion.

Setting Net Lake remains the only example examined to date, in which the hydrothermal system appears to have been sufficiently extensive to produce the widespread mineralization and alteration characteristic of a porphyry deposit. Its existence proves that such processes were operative in the Early Precambrian, and it is unlikely that it is unique. It must have formed as the result of interaction of the correct conditions of level of intrusion and availability of metals and water.

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No. S23 Kirkland Lake Gold Study, District of Timiskaming

F.R. Ploeger

The work reported here is part of the Kirkland Lake area geoscientific surveys. It is equally funded by the Federal Department of Regional Economic Expansion and the Ontario Ministry of Northern Affairs under the Community and Rural Resource Development Subsidiary Agreement.

Introduction

The Kirkland Lake gold study was initiated in 1980 (Ploeger 1980) with the objectives of examining and sampling, in detail, the productive suite of syenitic rocks at Kirkland Lake, comparing this suite with others that have been unproductive, and determining the relationship between the intrusive and extrusive alkalic rocks. To accomplish these objectives, the following are being examined:

1. The major and trace element geochemistry of the alkalic rocks;
2. The distribution of gold in the various syenitic intrusive suites;
3. The rare earth element patterns of the alkalic rocks;
4. The relationship of gold to structural features or specific lithologies.

This study complements other Kirkland Lake Initiative Programs currently being carried out by staff of the Ontario Geological Survey.

The author acknowledges the assistance of J.P. Donald, who acted as assistant in the summers of 1980 and 1981, and wishes to express his appreciation for the cooperation of the staff of Long Lac Mineral Exploration Limited and of numerous local residents. Advice and guidance were also provided by Dr. J.H. Crocket, McMaster University, by H.L. Lovell, Resident Geologist, Ontario Ministry of Natural Resources, Kirkland Lake, and by geologists of the Ontario Geological Survey who were working in the area.

General Geology

The geology of the area of study is summarized in F.R. Ploeger (1980). The rocks are of Timiskaming age and include wackes, conglomerates, trachytic flows and pyroclastic rocks, and syenitic intrusions. These rocks are interpreted to represent episodic trachytic volcanism (MacLean 1956) in a primarily braided river environment (Hyde 1980) with deposition probably occurring in a rifted zone on the southern flank of the volcanic pile composed of the Blake River/Kinojevis Groups.

Field work continued in 1981 in the main study area, the narrow zone of syenitic intrusive rocks that host the major orebodies of the Kirkland Lake area, and was expanded to include sampling of several intrusive and extrusive alkalic units and larger intrusive syenitic bodies in Lebel, Teck, and Otto Townships.

The author has interpreted the Kirkland Lake Main Break, the main ore-bearing feature in the Kirkland Lake mining camp, and its satellite structures to represent a plane of recurrent movement along a deep-seated fault, possibly a pre-Timiskaming rift fault. Sediments and trachytic volcanic rocks were deposited in the rifted zone and intruded by syn- and post-depositional syenitic bodies. Continuing movement on the same deep-seated fault resulted in brittle fracturing of the more competent massive syenitic rocks, forming a "proto-Main Break" which was subsequently mineralized. Several generations of post-ore movement and quartz veins followed.
### TABLE 1

**SUMMARY — WHOLE ROCK ANALYSES OF KIRKLAND LAKE AREA SYENITES.**

<table>
<thead>
<tr>
<th></th>
<th>MAIN K. L. SUITE</th>
<th>NORTHERN SUITE</th>
<th>TECK (MURDOCK CREEK) SUITE</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Syenite</td>
<td>Mass syenite</td>
<td>Syenite porphyry</td>
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<tr>
<td>SiO₂</td>
<td>49.52</td>
<td>56.22</td>
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<tr>
<td>Al₂O₃</td>
<td>13.83</td>
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<td>Fe₂O₃</td>
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<tr>
<td>MgO</td>
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<tr>
<td>CaO</td>
<td>5.99</td>
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<tr>
<td>Na₂O</td>
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<tr>
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<tr>
<td>TiO₂</td>
<td>0.87</td>
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<td>P₂O₅</td>
<td>0.50</td>
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<tr>
<td>MnO</td>
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<td>0.07</td>
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<tr>
<td>CO₂</td>
<td>5.63</td>
<td>2.78</td>
<td>3.52</td>
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<td>S</td>
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<td>0.09</td>
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<tr>
<td>H₂O +</td>
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<td>0.91</td>
<td>0.58</td>
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<tr>
<td>H₂O -</td>
<td>0.44</td>
<td>0.42</td>
<td>0.40</td>
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<tr>
<td>L.O.I.</td>
<td>6.98</td>
<td>3.60</td>
<td>3.90</td>
</tr>
<tr>
<td>TOTAL</td>
<td>99.72</td>
<td>100.01</td>
<td>99.74</td>
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<tr>
<td>S.G.</td>
<td>2.76</td>
<td>2.68</td>
<td>2.68</td>
</tr>
</tbody>
</table>

Number of Samples 32

Ba 2.084 1.631 2.313 2.944 1.941 2.149 2.439
Co 30 10 10 9 28 10 17
Cr 263 52 82 78 295 108 106
Cu 99 56 17 16 94 15 48
Li 34 29 15 16 28 16 15
Ni 60 12 31 28 67 38 34
Pb 30 32 20 24 15 15 31
Zn 118 66 60 53 125 64 109

( Elemental Analyses in ppm )

Number of Samples 32

Au* 2.19 5.10 2.64 4.41 20.90 1.01 0.73
Ag 10.55 4.33 1.09 1.81 4.30 1.23 3.42
Sb 7.49 4.58 1.50 0.85 0.90 0.56 1.41
Sn 1.40 1.78 1.27 0.56 0.71 0.19 0.82

Number of Samples 1

AA#

Au 5 2 2 2 2 2 —
As 3 4 4 2 1 11 —
Sb 2.9 3.0 1.3 2.6 9.7 21.3 —
W 500 500 500 500 500 500 —

Number of Samples 5

* - Neutron Activation Analysis by F. R. Ploeger, McMaster University (Au in ppb, all others ppm).
# - Atomic Absorption (Au in ppb, all others ppm).
NOTE: Chemical Analyses by Geoscience Laboratories, Ontario Geological Survey, Toronto, except as noted.
Geochemistry

Whole rock geochemical data for samples collected in 1980 are summarized in Table 1. It must be emphasized that these data are preliminary, and no attempt has been made as yet to discriminate among samples representing different compositions of massive syenite, different ages or compositions of syenite porphyry dikes, and samples that have been altered.

The samples have been divided into three groups on the basis of geographical distribution:

**Group 1. Main Kirkland Lake Suite**

This group includes the three dominant syenitic intrusive phases that host the gold deposits in Kirkland Lake. The syenite porphyry has been further subdivided to separate samples of the main central plug from those of the auxiliary dikes. Whole rock geochemical data for this group reflect a differentiation trend from mafic to more felsic syenites, which is characterized by increases in SiO₂ and Al₂O₃ with corresponding decreases in total iron, MgO, CaO, TiO₂ and P₂O₅. Total alkalis remain constant (excepting the high K₂O in the massive syenites), although the K₂O:Na₂O ratio increases.

The limited number of rare earth element (REE) patterns seem on preliminary analysis to be compatible with the whole rock data, and indicate that the syenites of this suite are differentiates from the same magma source. Additional data, however, are required to confirm this interpretation.

**Group 2. Northern Suite**

The Northern Suite, which extends parallel the Main Kirkland Lake Suite about 0.5 km to the north, comprises dominantly augite syenite plugs and syenite porphyry dikes. These are identical in appearance with the syenites of the Main Suite and have the same major element compositions and differentiation trends. Rare earth element patterns suggest a common origin for Groups 1 and 2.

**Group 3. Teck (Murdock Creek) Suite**

The Teck Suite comprises a 1.5 by 4.0 km elongate syenitic stock, known as the Teck or Murdock Creek Stock, which is located in south-central Teck Township. The part of the stock west of the Murdock Creek Fault is generally coarse-grained and feldspar-rich; that part east of the fault is medium-grained and ferromagnesian-rich. These mineralogical differences were not considered in the derivation of an average composition of the Teck Stock, although minor distinctions in whole rock geochemistry were evident in individual phases. The distinctions are also reflected in the rare earth element patterns of samples of the Teck Stock.

Economic Geology


Of particular interest to this study are the background gold contents of the various syenites and any changes in gold distribution near gold-bearing veins. Twenty samples have been analyzed for Au, As, Sb, and W by the neutron activation method; and 15 have been analyzed by atomic absorption methods. The results, averaged for the various rock types, are given in Table 1. Atomic absorption analyses yielded a mean gold content of 0.02 ppb for most phases of the syenites, whereas neutron activation analyses gave an average of 3.59 ppb. Concentrations of As, Sb, and W within each lithological group varied by as much as 5 ppm.

A detailed profile was made across the syenite porphyry dike that hosts the No.6 vein (average 2 ounces Au per ton; F. O’Connor, personal communication) on the Toburn property. Analyses revealed no relative gold enrichment or depletion in the dike, unless vein material was sampled directly. These results, combined with those indicating that background gold values are generally low, even within alteration zones adjacent to ore-bearing structures and veins, seem to indicate that the syenites were not original anomalous sources of the gold, but that they acted merely as a repository for the gold.

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Wark, W.J.
No. S24 The Geology of the Cordova Gabbro and its Associated Gold Deposits

P.B. Thomas¹ and M.E. Cherry²

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Introduction

Detailed mapping of the Cordova Pluton in Belmont and Marmora Townships was undertaken in the 1981 field season. The pluton hosts two past-producing gold mines and the objective of the current program is to determine the relationships between this mineralization and mineralogical, geochemical, structural, and textural variations in the pluton. Known gold mineralization in the pluton is confined to shear zones, and emphasis was placed upon delineating and sampling shear zones.

¹Graduate Student, University of Ottawa, Ottawa.
²Geologist, Mineral Deposits Section, Ontario Geological Survey, Toronto.

General Geology

The Cordova Pluton, an oval gabbroic body of approximately 30 km² area, intruded Precambrian marbles and volcanic rocks at the southern exposed margin of the Grenville Province. It is unconformably overlain by Paleozoic limestones to the south (Bartlett et al. 1980 and this volume). Contacts with the country rocks are poorly exposed but, where they are visible, there is little evidence of a chilled margin against the Precambrian rocks. There can be, however, up to 5 m of altered Precambrian carbonate rock, which is a fine-grained and calc-silicate-rich rock.

The gabbro is composed of plagioclase (15 to 50 percent of the rock) and hornblende. Lithologic variations are defined by differences in texture of the gabros, which vary from aphanitic to pegmatitic in grain size, and in some areas have distinct primary layering. Mapping of these textural variants has defined four units (Figure 1):

Unit 1. The most abundant rock type is a fine-grained, occasionally grading to medium-grained, black to dark green gabbro, which occupies the central part of the pluton. This unit generally has a relatively low plagioclase content and is massive and unfoliated.

Unit 2. Unit 1 is surrounded by a medium-grained, well foliated gabbro that forms a 400 to 1500 m wide rim between Unit 1 and the country rocks. This foliation, which is defined by alternating monomineralic layers of hornblende and plagioclase, appears to be a primary layering. Layers range from single crystal up to 2 cm in thickness.

The contact between Units 1 and 2 seems to be gradational. The foliation in Unit 2 defines a bowl shape, and if a primary feature, may indicate that Unit 2 is older than Unit 1.

Unit 3. Pods of pegmatitic gabbro varying from a few m² to greater than 1 km² in size intrude Units 1 and 2. The pegmatite comprises plagioclase and hornblende and is characterized by hornblende crystals often as large as 5 cm, with inclusions of small (1 by 3 mm) plagioclase laths. These hornblende crystals are surrounded by a groundmass of plagioclase and hornblende that varies from very fine grained to 1 cm in grain size.
Figure 1—Geology of the Cordova Gabbro.
Unit 4. Small, rare pods of anorthosite define Unit 4. These pods occur in both Units 1 and 2.

In addition to these four units, many randomly oriented dikes cut the gabbros. Commonly these are composed mostly of orthoclase and are about 10 cm wide. Occasionally, the dike reaches 3 m in width. Some narrow, fine-grained granite dikes, which brecciate both Units 1 and 2, also occur. All of these dikes, as well as the pegmatites and the anorthosites, are interpreted to be late stage differentiates of the gabbro magma.

Shear zones, which cut all units of the pluton, occur throughout, but are more abundant in the northern and eastern parts of the pluton. These strike generally east in the northern tip of the pluton, and and north to northeast elsewhere in the pluton. Most are steeply dipping (70° to 90°). Striae, visible on some shear planes, pitch 45° to 60° to the south or east.

The width of the shear zones varies from 1 m to 50 m. In some of the wider zones, there appears to be a central core of more intensely sheared rock with a well-developed planar fissility that is flanked by very poorly foliated, aphanitic material. The highly sheared rock is composed mostly of chlorite and biotite.

The shear zones, on the surface, are curved to some degree along the strike. This wave-like form can also be seen on an outcrop scale in which the shear planes warp gently, sometimes around masses of a potassic, felsic rock. The wave-like form of the shear zones indicates a predominant dip-slip, rather than strike-slip, movement.

Mineralization

The Cordova Pluton hosts two past-producing gold mines (the Cordova and Ledyard Mines) and a past-producing iron mine (the Belmont Mine). The Cordova Mine produced, from 1890 to 1940, some 22,744 ounces of gold and 687 ounces of silver from 120,670 tons of ore (Assessment Files Research Office, Ontario Geological Survey, Toronto) taken from three large east-trending shear zones near the northern margin of the pluton. Lasir Gold is currently developing the deposit. Data on remaining reserves are given in Carter (1980). The Ledyard deposit, also located on an east-trending shear zone in the northern part of the pluton, produced 13 ounces of gold from 55 tons of ore (Assessment Files Research Office, Ontario Geological Survey, Toronto).

Gold occurs in a gangue of quartz, ankerite and pyrite, reportedly as free gold. No arsenopyrite was found in the present survey. The mode of occurrence of the silver is not known. The gold ore occurs in lenses of quartz and ankerite that are flattened parallel to the shear direction. These lenses, which occur in almost all of the shear zones, vary from 1 cm to 3 m in width. Mine records of the Cordova Deposit indicate that ore lenses up to 12 m wide were not uncommon underground and state that the lenses pinch and swell. This suggests that narrow, quartz-poor shear zones at surface may thicken and contain more quartz at depth.

The Belmont Iron Mine is located in the gabbro some 200 m from its contact with Precambrian marble and has been interpreted as a contact skarn deposit (Carter 1980). Some 20,000 tons of ore were shipped from surface and underground workings between 1906 and 1914. At present, 3500 tons of ore are stockpiled on the surface (R. Young, personal communication, 1981).

The iron mineralization consists of bodies of magnetite in the foliated gabbro. All of these are close to the contact with the Precambrian marbles; this proximity and associated calc-silicate mineralogy, at least at the Belmont Mine (Carter 1980), are suggestive of a skarn deposit. Small pods of magnetite in gabbro with well-developed primary foliation near the eastern contact of the pluton, may, however, be the result of gravity settling during crystallization.

Conclusions

The textural and compositional variations in the gabbros of the Cordova Pluton may be interpreted to result from crystallization processes, that is, fractionation and gravity settling. These processes may have generated small magnetite concentrations previously interpreted as skarn deposits.

Shear zones, which host quartz-ankerite-pyrite-gold veins, pinch and swell along strike, and have steeply pitching striations. These features indicate a largely dip-slip movement.

Quartz-ankerite-gold mineralization has been found only in east-trending shear zones in the northern tip of the pluton. The occurrence of quartz-ankerite lenses in shear zones elsewhere in the pluton and the obvious genetic similarities to the shear zones that carry gold indicate that further exploration for gold is warranted.

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commonly fine grained and chloritic, but a small fraction are amphibolitic. The rock, which is moderately to strongly magnetic, contains up to 10 percent modal magnetite as fine disseminations throughout the clasts and matrix. Where visible fragments are not present, the rock consists of a magnetic chlorite schist. As a whole, this ultramafic unit strongly resembles the “ashrock” unit of the Steeprock Group which overlies the iron-ore horizon at Atikokan, 100 km to the east (Shklanka 1972).

**Structure**

The rocks of the study area record abundant evidence of polyphase deformation. At least three fold sets have been recognized (Poulsen 1980) and one of these, the F2 set, corresponds to a strong axial planar foliation which commonly strikes east-northeast and imparts a marked structural fabric to the rocks of the region. The transition from ductile to brittle deformation is evidenced by the pervasive development of mesoscopic scale shear zones. Two fundamental shear zone orientations exist: one set with right-hand sense of displacement parallels the major faults and strikes approximately east and the other conjugate left-hand set strikes north northwest-south southeast (Figure 1b).

These systematic orientations and senses of dis-

<table>
<thead>
<tr>
<th>LITHOLOGIC UNIT</th>
<th>DESCRIPTION</th>
</tr>
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<tr>
<td>Fault Rocks</td>
<td>Schists, mylonites, cataclastites developed on heterogeneous lithologies.</td>
</tr>
<tr>
<td>Dyke Rocks</td>
<td>Diabase, gabbro, lamprophyre, quartz-feldspar porphyry.</td>
</tr>
<tr>
<td>Unmetamorphosed</td>
<td>Granite, granodiorite, monzonite, monzodiorite, quartz monzonite, quartz monzodiorite</td>
</tr>
<tr>
<td>Grantoid Rocks</td>
<td></td>
</tr>
<tr>
<td>Metamorphosed Conglomerate</td>
<td>Conglomerate, arkose, subarkose, lithic arenite, lithic arkose.</td>
</tr>
<tr>
<td>and Sandstone</td>
<td></td>
</tr>
<tr>
<td>Metamorphosed Grantoid Rocks</td>
<td>Tonalite, trondhjemite, granite gneiss, quartzofeldspathic gneiss***</td>
</tr>
<tr>
<td>Metamorphosed Gabbroic Rocks</td>
<td>Gabbro, megagabbro, leucogabbro, anorthosite, quartz gabbro, quartz diorite, metadiabase, amphibolite.</td>
</tr>
<tr>
<td>Metamorphosed Wackes and Mudstones</td>
<td>Biotite schist, biotitic siltstone, slate, wacke, mudstone, migmatite (biotitic paleosome).</td>
</tr>
<tr>
<td>Metamorphosed Chemical</td>
<td>Chert, chert-magnetite, pyrite-pyrrhotite, pyritic slates, slate, siltstone, wacke.</td>
</tr>
<tr>
<td>Sediments and Related</td>
<td></td>
</tr>
<tr>
<td>Clastic Rocks*</td>
<td></td>
</tr>
<tr>
<td>Ultramafic Metavolcanics</td>
<td>Metamorphosed lapilli-tuff, tuff, magnetic chlorite schist.</td>
</tr>
<tr>
<td>Felsic Metavolcanics</td>
<td>Metamorphosed rhyolite and rhyodacite flows, amygdaloidal flows, tuffs, lapilli-tuffs, lapillistone, agglomerate, and quartz sericite schist.</td>
</tr>
<tr>
<td>Intermediate Metavolcanics*</td>
<td>Metamorphosed andesite to dacite flows, pillowed and amygdaloidal flows, chloritic tuffs, lapilli-tuff, agglomerate, breccia, and quartz-chlorite schist.</td>
</tr>
<tr>
<td>Mafic Metavolcanics*</td>
<td>Metamorphosed basaltic flows, mafic tuffs, amphibolite, chlorite schist, migmatite (amphibolitic paleosome).</td>
</tr>
</tbody>
</table>

**NOTES**

* While the table represents the broad stratigraphic order among these rock types, local intercalation of lithologies is common.
** Sills of this type are common throughout the volcanic succession and constitute a substantial fraction of the total thickness of metavolcanic rock.
*** Not necessarily orthogneiss.
locally derived, is made up of quartz sand, commonly containing wood chips, organic clay, and kaolinite, with minor interbedded gravel and silt. The quartz sand is light gray to white, with the grain size ranging from very fine to coarse, and a quartz content exceeding 95 percent in many sections. The quartz grains are irregular in shape and apparently are unweathered.

The organic clay interbedded with the quartz sand is dark brown to jet black, very soft, and commonly up to a few metres in thickness. Narrow interbedded gravel and silt are ubiquitous. In one place, at the southwest end of the south subcomplex, pure kaolinite having at least a thickness of 22 m underlies the quartz sand.

The sand-clay unit is variable in thickness. It is generally confined to pre-glacial troughs, where it is 130 m thick, and is absent or thin over pre-glacial ridges.

**Vermiculite Analysis**

Three vermiculite samples of approximately 300 grams each and minus 5 mesh size were test fired for 30 seconds at 1800°F. The expandable portion, obtained by flotation, constituted respectively: (1) 1.30 percent; (2) 20.57 percent and; (3) 27.14 percent by weight. The lower grade material (sample 1) represents vermiculite soil, while the other two samples were collected from weathered bedrock.

The bulk of sample 1 was in the -4 + 10 mesh sizes with a specific gravity of 0.20 gram per millilitre.

Sample 2 had equal distribution over -4 to + 10 mesh, -10 to + 16 mesh, and -16 + 35 mesh sizes with specific gravity ranging from 0.22 gram per millilitre to 0.41 gram per millilitre. Smaller sizes were up to 0.59 gram per millilitre.

Sample 3 had a similar size distribution as Sample 2 with specific gravities ranging from 0.17 gram per millilitre to 0.30 gram per millilitre (for -16 + 35 mesh size) for the bulk of the material and up to 0.54 gram per millilitre for material -50 + 100 mesh.

**Discussion**

The history of development of the Cargill deposits exemplifies the growing sophistication attendant upon development of mineral resources. Particularly in the development of industrial minerals, it is not so much a question any more of finding a mine, but of creating one. The example of the Cargill deposits shows that the basis of a production decision may lie in the feasibility of adding a phosphoric acid plant to the operation, and in the determination of whether or not the grade and/or quantity of

**TABLE 1 | Residuum samples, Cargill complex.1**

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>74</th>
<th>75</th>
<th>76</th>
<th>77</th>
<th>78</th>
<th>79</th>
<th>80</th>
</tr>
</thead>
<tbody>
<tr>
<td>% CaO</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>44.3</td>
<td>8.2</td>
</tr>
<tr>
<td>% P₂O₅</td>
<td>10.6</td>
<td>10.4</td>
<td>9.88</td>
<td>9.32</td>
<td>9.48</td>
<td>32.8</td>
<td>56.4</td>
</tr>
<tr>
<td>% F</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.54</td>
<td>0.72</td>
</tr>
<tr>
<td>ppm Nb</td>
<td>350</td>
<td>250</td>
<td>100</td>
<td>300</td>
<td>300</td>
<td>7000</td>
<td>6500</td>
</tr>
<tr>
<td>ppm U</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>75</td>
<td>2300</td>
</tr>
</tbody>
</table>

**RARE EARTHS**

(Quotation values)

<table>
<thead>
<tr>
<th>ppm Sc</th>
<th>40</th>
<th>120</th>
<th>25</th>
<th>45</th>
<th>50</th>
<th>630</th>
<th>140</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>200</td>
<td>1200</td>
<td>3000</td>
<td>1000</td>
<td>900</td>
<td>&gt;1800</td>
<td>&gt;1800</td>
</tr>
<tr>
<td>La</td>
<td>510</td>
<td>3020</td>
<td>620</td>
<td>2580</td>
<td>2700</td>
<td>7700</td>
<td>7500</td>
</tr>
<tr>
<td>Ce</td>
<td>1100</td>
<td>6070</td>
<td>1320</td>
<td>2830</td>
<td>2110</td>
<td>1.77</td>
<td>%1.58%</td>
</tr>
<tr>
<td>Nd</td>
<td>760</td>
<td>3334</td>
<td>730</td>
<td>2710</td>
<td>2920</td>
<td>1.1</td>
<td>%1.0%</td>
</tr>
<tr>
<td>Sm</td>
<td>60</td>
<td>270</td>
<td>70</td>
<td>220</td>
<td>230</td>
<td>690</td>
<td>570</td>
</tr>
<tr>
<td>Eu</td>
<td>20</td>
<td>110</td>
<td>20</td>
<td>90</td>
<td>95</td>
<td>340</td>
<td>300</td>
</tr>
<tr>
<td>Gd</td>
<td>60</td>
<td>240</td>
<td>66</td>
<td>210</td>
<td>230</td>
<td>820</td>
<td>720</td>
</tr>
<tr>
<td>Dy</td>
<td>35</td>
<td>170</td>
<td>45</td>
<td>140</td>
<td>145</td>
<td>600</td>
<td>530</td>
</tr>
<tr>
<td>Yb</td>
<td>11</td>
<td>75</td>
<td>18</td>
<td>55</td>
<td>55</td>
<td>170</td>
<td>165</td>
</tr>
</tbody>
</table>

^1 Analyses by Geoscience Laboratories, Ontario Geological Survey.

A partial analysis of chlorite (sample 74) showed SiO₂, 11.6%; Al₂O₃, 5.5%; Fe₂O₃, 18.4%; MgO, 7.4%; CaO, 21.0%; Total, 63.9% (Analysis by Geoscience Laboratories, Ontario Geological Survey.).