

Twenty Third Annual Meeting

Thunder Bay, Ontario

Institute on Lake



Superior Geology



PROTEROZOIC TRIP

PROTEROZOIC ROCKS OF THE THUNDER BAY AREA
NORTHWESTERN ONTARIO

May 3-4, 1977

FIELD EXCURSION GUIDE

PREPARED BY

C.R. Kustra, Ontario Ministry of Natural Resources
W.H. McIlwaine, Petro-logic Limited, Thunder Bay
K.G. Fenwick, Ontario Ministry of Natural Resources
J. Scott, Ontario Ministry of Natural Resources

Guide to the Proterozoic Rocks of the Thunder Bay Area, Northwestern Ontario

INTRODUCTION:

The Proterozoic rocks of Northwestern Ontario, which form part of the "Animikie" and "Keweenawan" units, represent one of the most complete geological records of Middle and Late Precambrian sedimentation and igneous activity in eastern North America. These rocks are virtually unmetamorphosed and relatively undeformed.

Mineral deposits in the Proterozoic rocks include silver in Keweenawan dikes and the Rove Formation, iron in the Gunflint Formation, nickel in mafic intrusive rocks, copper in various volcanic and sedimentary strata, and lead-zinc-barite, amethyst and uranium associated with the Sibley Group. During the last century, the famous Silver Islet mine produced over 2.8 million ounces of silver.

REGIONAL GEOLOGY

The Proterozoic rocks lie unconformably on the peneplained Early Precambrian (Archean) surface of the Superior Structural Province. Early Precambrian rocks form several northeast-trending "belts" of metamorphosed and complexly deformed metavolcanic and metasedimentary rocks intruded by felsic, and intermediate to ultramafic intrusive rocks.

The lithostratigraphy of the Proterozoic rocks is shown in Table 1.

APHEBIAN

The Gunflint Formation (Fig. 2) has been studied by Goodwin (1956, 1960) and Moorhouse (1960). The petrology has been studied in detail by Floran and Papike (1975). Detailed descriptions of fossils from the Gunflint Formation are recorded by Barghoorn and Tyler (1965), Barghoorn (1971) and Edhorn (1973). The Rove Formation has been described by Morey (1969) and Geul (1970, 1972). Much of the descriptive detail is taken from these authors.

Gunflint Formation (adapted from Goodwin, 1956)

The Gunflint Formation extends continuously for 110 miles (177 km) from Gunflint Lake east to beyond Thunder Bay, from where it can be traced intermittently to the Slate Islands, (Sage et al 1975), southeast of Schreiber. It averages 400 feet (122 m) in thickness (Goodwin, 1956).

Except for local faulting and brecciation caused by intrusive activity and slumping, the Gunflint Formation is structurally simple and uncomplicated, with an average southeast dip of 5°.

TABLE 1Proterozoic Stratigraphy of Northwestern Ontario

Neohelikian

Osler Group: basalt, minor rhyolite and sedimentary rocks

Intrusive Rocks: gabbro stocks
undersaturated stocks
layered bodies
northeast trending dykes
Logan diabase sills

Paleohelikian

Sibley Group: Kama Hill Formation
Rossport Formation
Pass Lake Formation

Aphebian

Animikie Group:

Rove Formation: shale, greywacke

Gunflint Formation: iron formation (taconite) algal chert,
limestone, tuffaceous shale.

TABLE 2Stratigraphy of the Gunflint Formation

(modified from Goodwin, 1956)

Limestone-dolomite Member

Upper Member

Taconite-chert carbonate submember: taconite (west) facies
chert carbonate (east)
facies

Tuffaceous shale submember

Algal chert submember

Lower Member

Taconite-chert carbonate submember: west taconite facies
chert carbonate facies
east taconite facies

Tuffaceous shale submember

Algal chert submember

Kakabeka Conglomerate Member

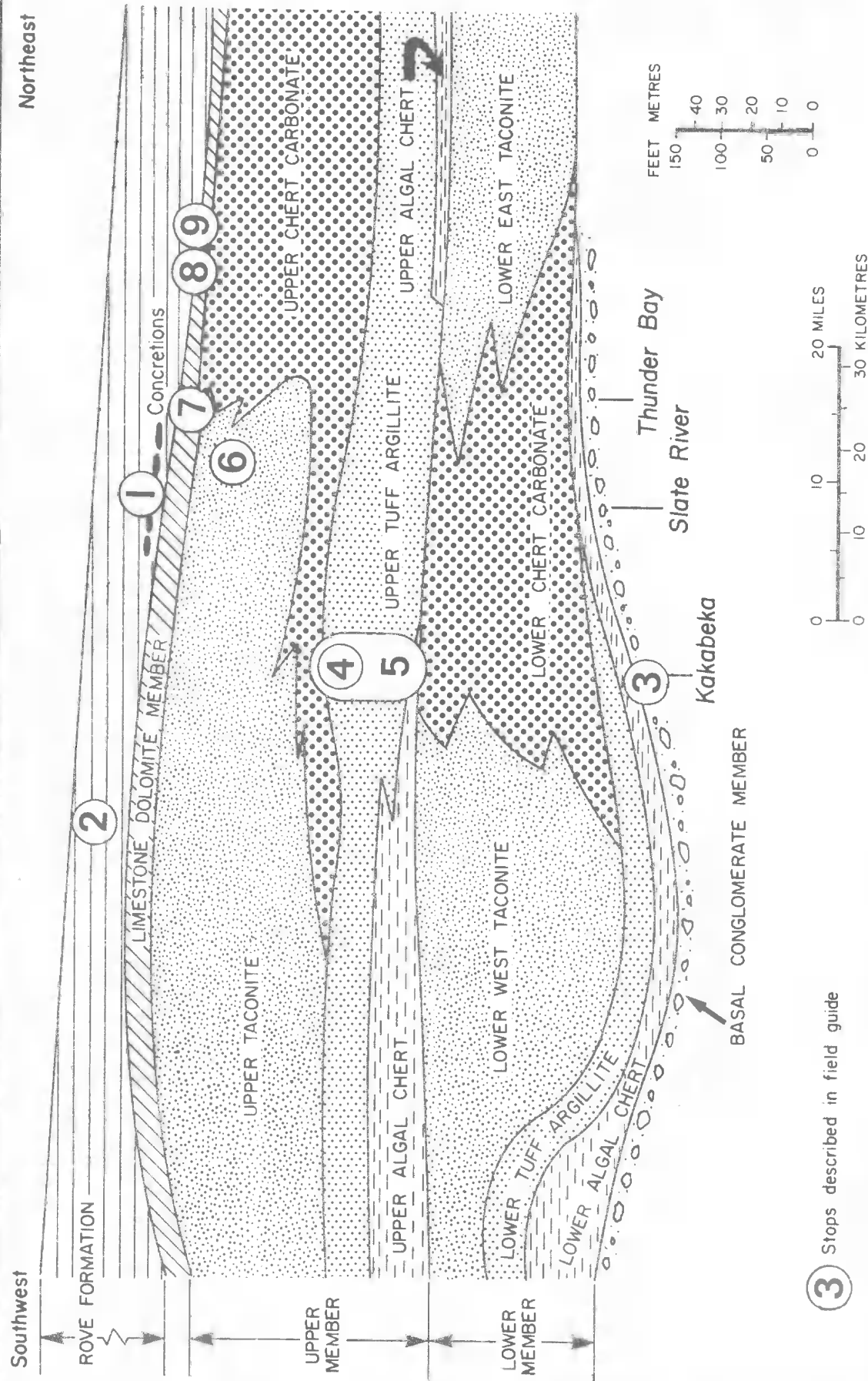


Fig. 1 Longitudinal section of the Gunflint formation. (after Goodwin, 1956). (Rove fm. added by author).

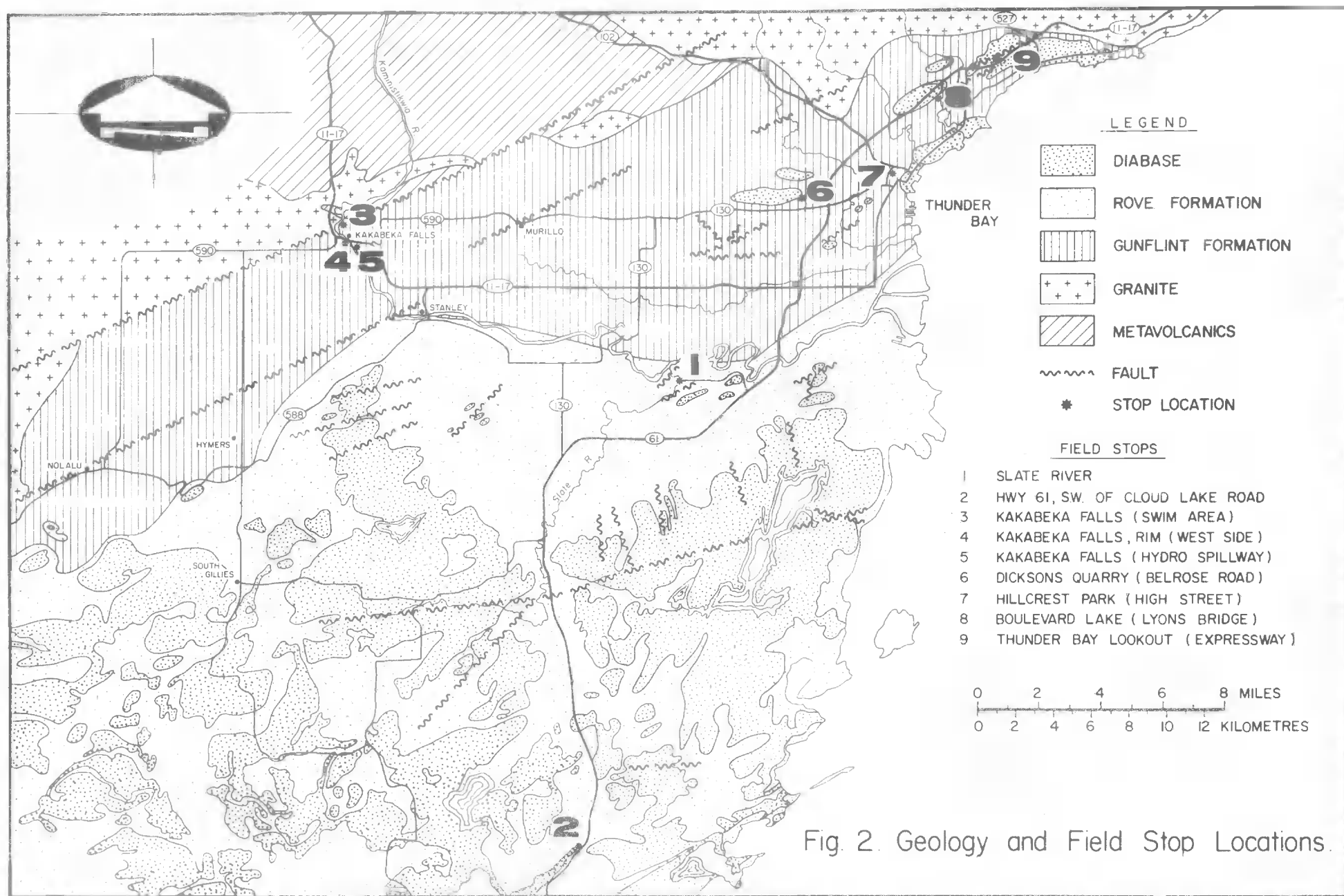


Fig. 2. Geology and Field Stop Locations.

Deposition of the Gunflint Formation was in part cyclical. A basal conglomerate member is overlain by two members each composed of chert, tuffaceous shale, and carbonate-taconite submembers. These members are in turn overlain by a discontinuous limestone member, (Fig. 1 and Table 2). Although no isotopic investigation has satisfactorily established the time of sedimentation, various studies suggest that deposition of Animikie sediments took place 2,000 m.y. B.P. (Floran and Papike, 1975).

Stratigraphic Descriptions

(a) Basal Kakabeka Conglomerate Member

This member ranges to five feet (1.5 m) in thickness and is composed of polymictic conglomerate. Clasts of Archean volcanic rocks, granite and quartz are cemented in a matrix of chlorite and quartz. The unit is highly irregular in thickness but persistent.

(b) Lower Member

The lower algal chert submember (Fig. 1) consists of reef-like mounds of finely banded black, red, and white oolite chert. These mounds are intergrown and cemented in dolomite. This submember forms the western margin of Gunflint outcrop (Fig. 1), but is continuous to just west of Kakabeka Falls. It contains abundant microflora remains (Barghoorn and Tyler, 1965, Barghoorn, 1971, Edhorn, 1973).

The lower tuffaceous shale (lower tuff argillite, Fig. 1) submember ranges to 20 feet (6 m) thick. It overlies the lower algal chert submember in the area west of Kakabeka Falls and is composed of fissile black shale containing much volcanic ash.

The uppermost submember of the lower member is subdivided into three facies (Fig. 1). The lower west taconite facies, which is 150 feet (45 m) thick, extends northeast from Gunflint Lake to Kakabeka Falls and is composed of wavy-banded granular chert, carbonate, and oxides. The lower half contains disseminated greenalite granules in pale grey chert; siderite forms local beds. The upper half contains increasing amounts of hematite and magnetite. This facies grades upward into jaspilitic upper algal chert and grades laterally into the lower banded chert-carbonate facies.

The lower banded chert-carbonate facies extends from Kakabeka Falls to Thunder Bay city, and consists of 4 to 6 inch (10 to 15 cm) siderite beds, with interbedded 2 to 6 inch (5 to 15 cm) grey cherty beds. Carbonaceous material and pyrite are common in shale interbeds. This facies grades into granular taconite towards the northeast.

The lower east granular taconite facies extends from Thunder Bay to Loon Lake. The basal 2 to 6 feet (60 to 180 cm) are formed of interbedded granular chert and ankerite. The upper 10 to 20 feet (3 to 6 m) consist of interbedded red to green mottled chert and dolomitic limestone. This facies grades upwards into the tuffaceous shale (upper tuff argillite, Fig. 1) submember of the upper member.

(c) Upper Member

The upper algal chert submember extends west from Nolalu to Gunflint Lake and consists of basal granular chert overlain by algal chert and, in the Mink Mountain area, amygdular basalt flows. The flows and algal chert are overlain by granular chert and bedded jasper. Jasper beds grade into tuffaceous shale of the overlying submember.

The upper tuffaceous shale (upper tuff argillite) is the only continuous submember in the Gunflint Formation and forms a key stratigraphic marker (Fig. 2). It ranges to 100 feet (30 m) thick and thins laterally in either direction from Kakabeka Falls. It consists of black tuffaceous shale and siltstone with interbedded siderite and pyrite and extensive beds of volcanic ash. The ash contains ellipsoidal, accretionary lapilli and concentric layers of small angular tuff fragments, arranged about a larger central fragment. Similar lapilli have formed due to the accumulation of volcanic dust in water droplets and on water coated shards (Moore and Peck, 1962).

The upper tuffaceous shale submember grades into the upper taconite and chert-carbonate submember. The upper taconite facies extends from Gunflint Lake to Thunder Bay (Fig. 1), and is composed of wavy bands of granular greenalite-bearing chert. The greenalite-bearing granules are round to oval, evenly distributed throughout a layer, and appear to have formed "in situ". The unit exhibits a rusty weathering, contains abundant hematite and magnetite in granules towards the top, and grades laterally (Fig. 1) into the upper banded chert-carbonate facies which extends from west of Thunder Bay to Loon Lake. The latter facies consists of interbedded grey chert and brown carbonate (siderite with lesser dolomite and ankerite). Brecciation and folding, apparently contemporaneous with deposition, are common.

(d) Upper Limestone Member

The upper limestone member marks the top of the Gunflint Formation. Minor chert beds, illite and volcanic shards are present, and tuffaceous shale is most prevalent in the eastern area of Gunflint outcrop.

Stratigraphic Interpretation

Goodwin (1956) concluded that Gunflint deposition occurred in a shallow basin which had limited circulation with an open sea. After initial algal activity in the neritic zone, volcanic activity (tuffaceous shale) was accompanied by sinking of the basin. Silicate-bearing material (taconite) was deposited in the deepest portions while in the neritic, or intertidal zone (between Kakabeka Falls and Thunder Bay) banded chert-carbonate formed. Farther to the northeast, the lower east taconite facies formed in agitated, oxygenated waters. As the basin filled, conditions of algal growth returned, initiating the "Upper Gunflint" cycle.

Volcanic activity, marked by local basalt flows, terminated the upper algal chert deposition and resulted in widespread distribution of pyroclastics of the upper tuffaceous shale. Downwarping resulted in deposition

of granular iron silicate rocks in the deeper, southwest portion of the basin, while on the shallow northeast shore, chert carbonate was deposited. As the basin filled, sporadic but violent volcanic activity was accompanied by the entry of sea water, resulting in formation of the upper limestone.

Goodwin (1956) in drawing an analogy with the Santorin volcano of the Aegean Sea, suggests that volcanism was the chief source of iron and silica. Alternatively, Hough (1958) suggests deposition in a fresh water basin, with material derived through weathering of an adjacent landmass, and deposition controlled by limnic cycles.

Rove Formation

The Rove Formation conformably overlies the Gunflint Formation. In the Thunder Bay and Pigeon River areas, it may attain a thickness of at least 1,250 feet (380 m), and possibly more than 2,000 (610 m), Geul (1970). The formation consists of three lithologic units (Geul, 1970) which are, from base upwards:

- (1) black pyritic shale and argillite (base)
- (2) interbedded argillite and greywacke and shale (transition sequence of Morey, 1969)
- (3) quartzitic greywacke with argillite interbeds (top)

The lower argillite is the dominantly exposed unit in Ontario and commonly enclosed carbonate concretions of varying size and complex in form and texture. The transition sequence consists of thin-bedded greywacke, consisting of grey to pink greywacke and sandstone, is the thickest unit of the Rove Formation and is exposed mostly in north-eastern Minnesota.

The metamorphic age of the Rove Formation is considered to be 1.7 billion years (Peterman, 1966).

Morey (1969) notes that the detrital material comprising the Rove Formation was derived from Archean terrain to the north.

PALEOHELKIAN

The Sibley Group

This section is adapted from Franklin et al (in press).

Introduction:

The distinctive red and white sandstone and dolomite of the Sibley Group were first described by Logan (1863) who considered them as part of his "Upper Copper-Bearing Series". Logan included the Gunflint and Rove Formations, as well as the Sibley rocks, in this "series".

Robert Bell (1872), in completing the first comprehensive description of these rocks, considered them as the Upper Group of the Upper Copper-Bearing Series. He compared the Sibley Group with rocks of Nova Scotia and concluded (p. 321) that "they (Sibley rocks and the overlying Osler volcanic sequence) may now be considered as of Permian and Triassic age". Logan (1872), in strongly reprimanding Bell, outlined evidence for a pre-Silurian age. T. Sterry Hunt (1873) divided Logan's Upper Copper-Bearing Series into Animikie (now the Gunflint and Rove Formations) and Keweenaw Groups, and assigned the Sibley to the latter Group. Wilson (1910, p. 69) indicated that these rocks occupy a "trough-like depression between two areas of Archean rocks" in the western Lake Nipigon area, and tentatively assigned them to the Paleozoic.

The name "Sibley" was first assigned to this group by Tanton (1931). His description of the "Sibley Series" of the Sibley Peninsula is accurate, but unfortunately he did not have an opportunity to map the more northern areas, and thus his stratigraphic analysis is of somewhat limited value.

Although local studies of the Sibley Group rocks were undertaken in subsequent years by Hawley (1929) and Moorhouse (1960) the first comprehensive mapping was completed by Coates (1972) and McIlwaine (1971a, 1971b).

Recent geophysical studies by duBois (1962) and Robertson (1973) have underscored the need for a comprehensive study of the stratigraphy and paleogeography of the unit. Red-bed sequences like the Sibley Group are important environmental indicators and in addition this occurrence may have tectonic implications.

Age:

The age of the Sibley Group is a key question with respect to the position of these rocks within the framework of the Keweenaw tectonic event, and the Helikian polar wandering curve. A rubidium-strontium whole rock isochron was completed in the laboratory of the Geological Survey of Canada. The analytical procedure is outlined by Wanless and Loveridge (1972). The Geological Survey of Canada uses an R_{87} decay constant of $1.47 \times 10^{-11} \text{ yr}^{-1}$, as physically determined and outlined in the aforementioned paper. The widely used $1.39 \times 10^{-11} \text{ yr}^{-1}$, a 'geologically determined' decay constant results in ages approximately 5.75% older.

The age, using the $1.47 \times 10^{-11} \text{ yr}^{-1}$ constant, is $1294 \pm 31 \text{ m.y.}$ Samples were selected from the Kama Hill and Red Rock formation; the areas near diabase sills were avoided as their metamorphic effects are extensive (Robertson, 1973). The Kama Hill section is cut by multiple thin sills; the data for one of the samples probably reflects this metamorphism, and should be discounted.

The Sibley Group is apparently older (by at least 150 m.y.) than the accepted age of the Keweenaw igneous event as typified by the

Duluth complex (1,115 m.y. RbSr, Faure et al 1969) and the Keweenaw extrusive rocks (1,142 m.y. RbSr Faure and Chaudhuri, 1967). However well documented comparable age determinations have not been published on either the Logan sills or the lower Osler group. These latter units are magnetically reversed (duBois, 1962) and are the oldest Keweenaw igneous rocks in this area. K-Ar dates of 1,060 m.y. on Logan sills (Franklin, 1970) probably represent a minimum age due to possible argon leakage. Unpublished RbSr data indicates that the sills may be as old as 1298 ± 33 m.y. (Robertson and Fahrig, 1971), and thus very close in age to the Sibley Group.

The Sibley Group exhibits both normal and reversed magnetic polarity (Robertson 1973); igneous rocks of similar paleomagnetic characteristics have a very similar age to that obtained for the Sibley Group (Peterman et al, 1968, Murthey et al, 1968). Thus the determined RbSr age of the Sibley Group is probably reliable.

Stratigraphy of the Sibley Group

The Proterozoic rocks of the Southern Province of the northern Lake Superior region have been described in a general way by Card et al (1972). Although the Sibley Group has not been heretofore formally subdivided, subdivision into formations is possible. The subdivisions are given in Table and locations of type sections are included in the formation descriptions.

The Pass Lake Formation

The type section for the Pass Lake Formation is exposed along the Canadian National Railway tracks in southern McTavish Twp. (McIlwaine, 1974) near the north shore of Pass Lake where it is 50 m thick; it continues eastward along the tracks for about 3 kms where it is overlain by the Red Rock Formation. Reference sections are located under the type section of the Red Rock Formation at Red Rock cuesta, at Mousseau Mountain north of Nipigon and on Quarry and Channel Islands in Lake Superior near Rossport.

The formation is composed of lensoid basal conglomerate overlain by quartz-rich arenites. It thins rapidly northward; scattered patches are present along the eastern edge of the Sibley basin, but the unit is absent along the western basin margin.

The Pass Lake Formation overlies the Rove Formation in the south and to the north lies unconformably on Archean Rocks. The contact with the Rove is exposed over a distance of about 20 m at Pass Lake; the Rove has been altered for about 50 cm from the contact. This normally black shale has been partially oxidized to a dark reddish brown. Where the Pass Lake Formation lies directly on the Archean there is little or no evidence of a reaction; at the site of the old Enterprise Mine in McTavish Township (McIlwaine 1971b) the sandstone rests directly on quartz monzonite with no apparent affect.

Overlying the basal conglomerate with sharp contact is a succession of arenites which are generally buff to pale pink with a minor number of red interbeds. The arenites are commonly very thickly bedded (greater than 1 m) at the base of the sequence and range to very thinly bedded (1-3 cm) with increasing stratigraphic height. The sharpness of bedding boundaries also increase with stratigraphic height. They are commonly fine-grained (2-3 phi) but are locally very fine-grained (3-4 phi), with generally moderate sorting and locally poorly (especially at Pass Lake) and moderately well sorted (e.g. Mousseau Mountain). There appears to be no systematic variation in grain size or sorting with stratigraphic height.

Thin section examination and modal analyses indicate the rocks range from quartzose arenite to quartz arenite¹ in composition. Detrital grains range from angular to well rounded but are generally subrounded with larger grains tending to be more rounded than finer grains. Quartz grains with undulatory extinction are more abundant than quartz with straight extinction.

Total quartz at Pass Lake appears to be lower in the upper half than the lower half but this is mainly a function of cement content. For the most part there is little or no cement in the lower half and induration is apparently due to compaction.

Feldspar is a minor constituent, especially at Pass Lake. There is a suggestion of a systematic decrease in feldspar with stratigraphic height in the Rossport section.

Chert is present in all areas. Chert content is greater in the top half of the formation than in the bottom half at Pass Lake, other sections exhibit no apparent variation.

Cementing material includes carbonate, mainly at Pass Lake, Red Rock and Rossport, and silica, which is more common at Mousseau Mountain.

The matrix, generally fine mica and clay, forms consistently less than 15%; this is the content generally accepted as the dividing line between arenite and wacke.

The Rossport Formation

The type section of the Rossport Formation, is exposed on the shore of Channel Island, near the village of Rossport. This formation overlies the Pass Lake Formation disconformably through much of the area, and unconformably on Copper Island near Rossport. In the northern area it lies nonconformably on the Archean basement. The Rossport Formation is distinguished by its brick red color, high dolomite content, and concoidal fracture. The formation maintains a relatively constant thickness of about 100m in all measured sections except on the Sibley Peninsula, where it thins to approximately 20m. In the southern area of the basin the formation may be divided into three members (a) lower dolomite, (b) central chert-carbonate (stromatolite to the north) and (c) upper dolomite. In the northern area these members are less clearly distinguishable due to the lack of exposure. Much of the description is thus based on the more southerly sections.

¹The limits used here are based on Pettijohn's (1957) classification but his rock names have been changed.

The lower and upper members exhibit only minor lateral facies changes in the east and west direction, but to the north both members become distinctly more clastic. The central member is lithologically distinct and forms a lateral (east/west) continuous marker bed traceable from Rossport to Sibley Peninsula.

The upper and lower members can be distinguished on the basis of mineralogical composition and bedding development. The lower member has distinct bedding, whereas the upper is more massive. The lower is richer in carbonate and quartz whereas the upper member is clearly richer in clay and feldspar. Dolomite is the dominant carbonate mineral present. No easy distinction between the lower and upper members on the basis of calcite-dolomite ratio may be made, although in general the calcite-dolomite ratio is higher in the upper unit than the lower.

Kama Hill Formation

The type section of the Kama Hill Formation is located along the northern-most powerline, on the west side of Kama Hill, 17 miles (27 km) east of Nipigon. Reference sections are available at Albert Lake, Stewart Lake and Channel Island. The boundary with the underlying Red Rock Formation is placed at the disappearance of carbonate and the change in color. The maximum preserved thickness is 50 m.

The Kama Hill Formation is distinguished by its deep red-purple colour, silt to clay sized particles, thin bedding, moderately well developed fissility, its mineralogy and distinctive structures.

Due to its fine-grained nature, mineralogical analysis is possible only by x-ray diffraction. Two clay minerals, quartz, microcline and minor calcite and hematite constitute the mineralogy.

Colour in outcrop varies from deep red to deep purple and is due to hematite. The amount of hematite varies widely between beds from less than 1% in a few coarse silt beds to over 90% in a few clay rich layers. It normally constitutes approximately 4% of the rock. The coloration is quite homogeneous within individual beds. Conspicuous "bleaching" is present only along a few bedding plane fractures and joint planes. Microscopic variation in coloration intensity is related to grain size, with finer clay rich beds containing more hematite. The lower portion of the formation has up to 10% white spherical "reduction" spots; these are much less common in the upper portion of the unit. Hematite occurs as evenly disseminated very fine grained aggregates. In the coarse silty beds it forms a coating and is interstitial to the clasts.

Bedding is very difficult to distinguish in outcrop but is readily apparent in thin section and cut surfaces. The three types of beds which may be distinguished are:

- (a) regular finely laminated clay rich regular beds.
- (b) irregular partially reworked coarse silty beds.
- (c) stromatolitic beds.

Types (a) and (b) are intermixed but the type (a) beds appear more dominant with stratigraphic height. Bed types (a) and (b) are distinguished by their lack of carbonate. Beds of type (c) are confined to the lower part of the formation.

Sedimentary Structures

Mud cracks are pervasive and a characteristic feature of the Kama Hill Formation regardless of the bed composition (sand, silt, or clay). Linear and polygonal cracks occur on most bed surfaces. Small scale erosional features are common. Disturbed bedding is locally present. Ripple marks are present only in the sand and silt rich beds. These are symmetrical current ripples, with wave lengths of 1.0 to 3.5 cm and amplitudes of 0.5 to 1.5 cm, covered with fine mud; ripple surfaces have small spindle shaped flute casts, superimposed at an oblique angle to the ripple axis. Interference ripples are most common in the more coarse-grained beds on Sibley Peninsula. Rain-print surfaces occur rarely at Kama Hill. Evaporite casts (probably halite) are present, and are particularly evident at Stewart Lake.

Summary of the Depositional History

The Sibley Group was deposited in a elongate, north/south basin which was initially probably deepest in the south. The basin formed relatively rapidly and along its margins fans of locally derived and rapidly deposited conglomerate formed. The initial period of rapid deposition gave way quickly to relatively slow deposition of the arenites of the Pass Lake Formation. The basin transgressed northwards towards the end of the deposition of the Pass Lake Formation and extended far to the north (at least to southwestern Lake Nipigon) during deposition of the lower member of the Red Rock Formation. Moderately rapid regression marked the middle stage of Red Rock deposition, accompanied by increased clastic deposition and stromatolite growth to the north of Nipigon and chert precipitation to the south. Transgression followed as the basin extended northward at least to Armstrong. The basin depth was relatively constant, and it slowly filled with clay-rich dolomites. The transition to the Kama Hill Formation marks a change from predominantly sub-aqueous to predominantly sub-aerial deposition. Deposition of the Kama Hill Formation continued in an extremely consistent very quiet mud flat environment. Primitive life flourished during quiescent periods of deposition of the Kama Hill sediments.

Tectonic Implications

The relation of the Sibley Group in any tectonic reconstruction can only be reviewed in the context of the entire Helikian history of eastern

North America. The dominant tectonic event in the Lake Superior area was the development of the Keweenawan rift zone which forms an inverted U, extending roughly from the northern area of the Michigan basin, around Lake Superior and continuing southwest from Duluth as the mid-continent gravity high. Although no major "opening ocean" event has been firmly documented during the Helikian, Baer (1974) in summarizing papers present at the Grenville symposium (Ottawa, Feb. 1974) indicates that a pre-Grenvillian orogenic event may have initiated with a divergent phase at 1,300 m.y. As part of this rifting, the Keweenawan arm may have developed at this time (Burke and Dewey, 1973). This arm ultimately (at 1,100 m.y.) underwent limited spreading (Burke and Dewey, 1973).

It is probable that igneous activity was initially very limited, but rifting occurred by means of crestral rifts about which developed "rrr" triple junctions. These rifts meet at 120°, and are located at major strike changes of a rift valley (Burke and Dewey, 1973). The major flexure in the Keweenawan rift valley occurs immediately south of Nipigon. Should a triple junction have formed in association with the Keweenawan rifting, the Nipigon area would be the most probable area of development. The 'failed' arm would thus extend north from Nipigon.

The Sibley group occupies a N-S block which is the result of a failed arm developed about the Nipigon crestral rift. Later reactivation of the Keweenawan rift was accompanied by intrusion of the Logan sills into the same failed arm.

Many problems related to the time of development remain unsolved. The Sibley Group is similar in age to the proposed age of initial spreading of the Grenvillian orogen (Baer, 1974). However, little evidence related to time of initial development of the other ultimately actively spreading arms of the Keweenawan rift is available. Minor igneous activity has been recorded at 1400 m.y. (Books 1969). Sibley sedimentation appears to have been controlled by a rapidly developing fault scarp in the southern area, as indicated by a rapid increase in coarse clastic material near the basin margin. Limited exposure of the Sibley Group in the northern area precludes examination of the nature of the basin margins here. The elongate basin shape is suggestive of rift-valley filling, but the possibility remains that the Sibley basin has been preserved in a failed arm, rather than the 'arm' actually controlling sedimentation.

Description of Stops and Road Log for the
Gunflint and Rove Formations

Time and seasonal water level conditions may prevent access to all stops indicated on Figures 1 and 2.

For alternate and additional stops of the Gunflint and Rove Formations, the reader is referred to Franklin and Kustra (1972).

Mileage count begins at the intersection of Highways 11-17 and 61, near the Airline Motor Hotel, Thunder Bay. Proceed south on Highway 61. Figures in brackets record accumulated mileage.

<u>MILES</u>	<u>KM.</u>	
0.0	0.0	Intersection Highways 17-11 and 61. The prominent hill to the southeast is Mount McKay, the most northerly of the "Norwesters" range of hills. Towering over the Kaministikwa River delta, it is 1,581 feet (481 m) above sea level and 978 feet (298 m) above Lake Superior. Mount McKay is a large mesa, made up of shales and greywackes of the Rove Formation overlain by a hard, protective 200 foot (61 m) thick capping of diabase (Pye, 1969, p. 39). The upper half of the mesa is 3,000 feet (914 m) long and has a maximum width of 1,100 feet (336 m). A second sill, about 15 feet (4.6 m) thick is found in the Rove sedimentary rocks and is 474 feet (144.5 m) below the top of the hill. It forms the base of a wide and prominent terrace to which the tourist may drive his automobile for a magnificent view of the City of Thunder Bay (Pye, 1969, p. 39).
5.9	9.5	20th Sideroad; turn right (north).
7.1	11.4	Riverdale Road, turn left (west) and follow to end of road.
8.5	13.7	Parking spot; follow cottage road (J.C. Kirkup); this is private property and permission for access to the Slate River must be obtained from the owner.

STOP 1BASAL CONCRETION-BEARING SHALE OF THE ROVE FORMATION,
SLATE RIVER CANYON (FIG. 1).

The black, graphitic, fissile Rove shale contains an abundance of carbonate concretions. These vary in size from a few inches (cm) to 8 feet (2.4 m) in diameter. Although commonly in the shape of oblate spheroids, they display a complexity in shape and texture. Some show radial septarian cracks on their surfaces.

The concretions form bedded units in the canyon walls. They are in various stages of weathering out of the host shale, some slumping into the river bed and many others lying in the river bed arranged in imbricate fashion. Shale bedding is warped around the top and bottom of the concretions.

Moorhouse (1963) describes these concretions in detail.

Return to Highway 61.

0.0 0.0
(11.1) (17.9)

Intersection of Highway 61 and 20th Sideroad.

Continue south on Highway 61. The range of hills to the south are the Nor'westers.

5.4 8.7
(19.1) (30.7)

Highway 130; continue on Highway 61.

19.4 31.2
(33.1) (53.3)

Entrance to abandoned quarry, west side of Highway 61, approximately 1,600 feet (410 m) beyond Cloud Bay Road.

STOP 2UPPER THICK-BEDDED QUARTZITIC GREYWACKE, ROVE
FORMATION, (FIG. 1).

Quarry operations have exposed thin to thick bedded quartzitic greywacke interbedded with lesser amounts of black fissile argillite. Greywacke displays sole markings and graded bedding.

The quarry walls are bounded by two dikes bifurcating from a single olivine diabase dike of Geul's (1973) Pigeon River intrusions. The west dike is approximately 50 feet (15 m) wide and vertically dipping; the narrower east dike dips steeply southeast, its attitude well exposed at the back of the quarry.

Due to the development of a closely spaced fracture pattern in the Rove Formation, the quarry walls and back may be unstable; extreme caution is advised.

Return to Highway 130.

0.0 0.0
(47.1) (75.8)

Intersection of Highways 130 and 61. Proceed north on Highway 130; continue to end of road.

3.2 5.1
(50.3) (81.0)

Paipoonge Concession 1 Road. Turn left (west). Proceed for 1.8 miles (2.9 km) to unmarked gravel road; turn right (north). Continue for 3.4 miles (5.5 km) to steel bridge over Kaministikwa River. Turn right and proceed over bridge on paved road (Highway 588) for 1.2 miles (1.9 km) to Highway 11-17. Turn left (west) and proceed for approximately 3.5 miles (5.6 km) through village of Kakabeka Falls into Kakabeka Falls Provincial Park. Turn right at the park gatehouse, before crossing the old bridge in the park, and follow road under Highway 17, to its end at the swimming area. Proceed on foot past cabins to the Kaministikwa River shore.

STOP 3

BASAL CONGLOMERATE AND LOWER ALGAL CHERT, GUNFLINT FORMATION, (FIG. 1).

Here, the basal conglomerate and algal chert mounds rest directly on Archean granitic gneiss basement. Basal conglomerate may be seen in place only at very low water. However, large, angular, locally derived blocks of conglomerate are abundant. Note the angularity and polymictic nature of the pebbles. All can be assigned to various Archean rocks to the west and north.

Note also the absence of a paleosol. The Ep-Archean interval, here occupying 800 million years, is represented by little or no "in-situ" weathered basement, suggesting absence of normal weathering conditions, or pre-Gunflint strong fluvial or glacial transport action,

The algal mounds here are similar to those found 1.8 miles (2.9 km) west of Nolalu (Franklin and Kustra, 1972, p. 31). Return to park gate house, turn right and cross the bridge. Proceed to parking area, thence by foot to the rim of the falls.

STOP 4

UPPER TUFFACEOUS SHALE SUBMEMBER (UPPER TUFF ARGILLITE) AND OVERLYING UPPER CHERT CARBONATE, GUNFLINT FORMATION, FIG. 1.

Kakabeka Falls drops 128 feet (39 m) into a gorge formed in fissile, thinly bedded upper tuffaceous shale submember (Goodwin, 1956).

A more resistant massive two-foot bed of thinly banded chert-carbonate caps the escarpment. Note apparent cross lamination in the chert carbonate and the undulating nature of the surface.

The chert carbonate capping is overlain by tuff argillite and a second chert carbonate bed, exposed in a parking lot on the east side of the gorge. A bed of lower chert carbonate occurs at the base of the falls; (Fenwick, personal communication).

Return to Highway 17, turn right and proceed approximately 1/3 mile (0.5 km) Ontario Hydro station access road immediately west of the Kakabeka Falls Motel.

Turn right (south) and proceed to parking lot by the generating station.

Access to STOP 5 is through the generating station to its west side. Permission must be obtained from the station supervisor. The spillway serves as a safety feature to bleed off excess water in the event of generator failure at the power station.

Follow the river bank for approximately 600 feet (183 m) to the "spillway" cut. Beware of Poison Ivy.

STOP 5

UPPER TUFFACEOUS SHALE SUBMEMBER (UPPER TUFF ARGILLITE) GUNFLINT FORMATION (FIG. 1).

The best section of upper tuffaceous shale submember is exposed at this locality. Pyrite-bearing chert, possibly of the upper algal chert submember; occurs at the base of the section. It is overlain by shale containing pyrite nodules and calcareous concretions, interbedded shale and tuff and a cap of thinly bedded upper chert-carbonate.

One of the best exposures of "mud ball tuff" in the shale occurs near the bottom of the section; the tuff is formed of closely packed accretionary lapilli elongated along the bedding. Individual ellipsoids contain small, angular fragments of uniform size, grouped concentrically around a larger shard fragment. The remainder of the material comprising the beds consists of volcanic fragments in a groundmass of green illite.

Higher than background radioactivity (0.004% U_3O_8) has been noted in the tuff argillite by Fenwick (personal communication).

Note downwarping of beds on the west side of the exposure and the fault filled with quartz-carbonate and anthraxolite for which Kwiatkowski (1975) reported a 0.2% nickel content.

Return to Highway 11-17 and proceed east.

0.0 0.0
(64.7) (104.1)

Junction Highway 11-17 and Oliver Road (formerly Highway 590). Proceed on Oliver Road.

9.8 15.8
(74.5) (119.9)

Thunder Bay city limit. Good view of a series of mesa type hills, the Nor'westers, all capped by Logan diabase.

10.9 17.5
(75.6) (121.7)

Junction of Oliver Road with Highway 130; continue east.

16.3 26.2
(81.0) (130.4)

Belrose road. Turn left, proceed 0.5 miles (0.8 km) to quarry on west side of road, (Dickson's Quarry).

STOP 6

UPPER TACONITE SUBMEMBER, GUNFLINT FORMATION, (FIG. 1).

In this quarry wavy-banded, red jaspilitic and darker greenalite-bearing taconite is capped by a Neohelikian (Logan) diabase sill. The taconite contains approximately 50 percent shale, interbedded with 6 to 12 inch (15 to 30 cm) irregular taconite beds that are best exposed at the north end of the outcrop where quarry operations exposed the taconite at a lower stratigraphic level. The diabase sheet displays an irregular, undulating

bottom surface at a slight angular discordance. The upper surface is polygonally jointed and contains occasional patches of a thin veneer of argillite.

Return to Highway 130, turn left (east), and proceed across Highway 11-17 and past Lakehead University to High Street.

19.8 31.9
(83.5) (134.4) Intersection Highway 130 (Oliver Road) and High Street. Turn left at the traffic lights and proceed up High Street.

20.4 32.8
(84.1) (135.4) Entrance to Hillcrest Park.

STOP 7 UPPER LIMESTONE MEMBER, GUNFLINT FORMATION, (FIG. 1).

Hillcrest Park stands about 160 feet (48 m) above the level of Lake Superior and offers a panoramic view of Thunder Bay harbour, the Sleeping Giant, the Welcome Islands, Pie Island and the Nor'westers.

Dolomitic limestone and chert layers are exposed at the base of the flag pole and bell.

Follow stairs to base of hill where fragmental limestone (upper limestone member) is exposed. The rock consists of many angular to rounded chert fragments in a matrix of coarsely crystalline, iron-bearing carbonate, and thin chert interbeds. Volcanic shards and fragments occur in the limestone (Goodwin, 1956).

Proceed north on High Street.

21.9 35.2
(85.6) (137.8) Intersection with Balsam Street. Turn left on Balsam Street.

22.5 36.1
(86.2) (138.7) Huron Street, 300 feet (90 m) south of Highway 17-11. Turn right on Huron Street, then immediate left.

23.9 38.4
(87.6) (141.0) Bridge over Current River, cross bridge, turn right into Boulevard Lake Park and proceed 0.3 miles (0.5 km); park on right side of road. Traverse begins in river bed.

STOP 8UPPER CHERT CARBONATE FACIES, GUNFLINT
FORMATION (FIG. 1)

The upper chert carbonate facies is overlain by the Rove Formation. An upstream traverse encounters ferruginous carbonate, interrupted by thin layers and lenses of granular and algal chert, dark, fissile shale and dolomitic limestone. At the beginning of the traverse, note the rounded chert lenses showing concretionary structures, attributed to action of algae.

Features to observe include stylolite surfaces lined with anthraxolite, pyrite veinlets, imbrication of thin chert layers and the striking weathered appearance of the rock.

Under the bridge, a bed of gray, massive limestone, possibly the Upper Limestone member, contains pancake-like lenses of serpentine material, and is interrupted by a thin band of pyritic and pyrrhotitic chert. Note the hummocky upper surface of the limestone at the shale-limestone interface. The overlying shale is probably Rove Formation.

Several hundred feet north of the bridge, at the lookout, a diabase sheet caps the shale. Heat from the cooling of this sheet metamorphosed the limestone, forming serpentine and pyrrhotite.

East of the bridge, in the picnic area, several well developed river terraces are preserved.

From bridge, proceed east along Arundel Street.

25.3 40.7
(90.0) (144.9)

Intersection, Arundel Street and Hodder Avenue.
Turn left on Hodder Avenue at the Hodder Avenue Hotel.

Highway 17-11. Turn right.

26.9 43.3
(91.6) (147.4)

Scenic lookout. View of Thunder Bay harbour. Park car and walk 500 feet (150 m) east to roadcut on north side of road.

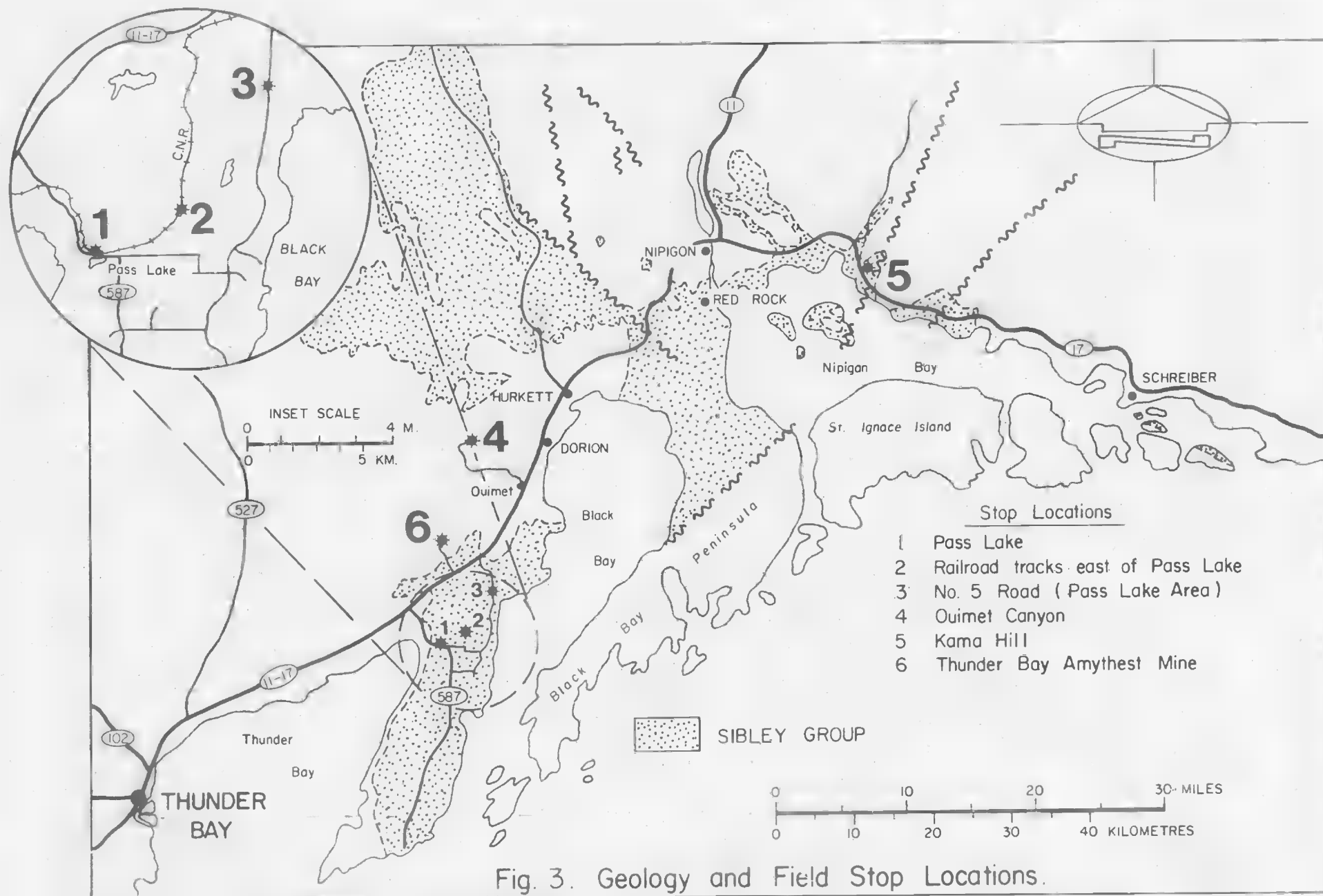
STOP 9

UPPER LIMESTONE MEMBER, GUNFLINT FORMATION,
OVERLAIN BY DIABASE, (FIG. 1).

Sill of Logan diabase overlies argillite and fragmental limestone of the upper limestone member. The contact is gently undulating and visible effects of contact metamorphism are little evident. In this section, however, a microporphyroblastic texture is developed in the argillite. Pyrite is altered to pyrrhotite.

Note the lenticular chert patches within the limestone, some veined with pyrrhotite, exhibiting agate textures.

End of Animikie portion of trip. Additional points of interest concerning a more complete picture of Gunflint Formation stratigraphy are given in Franklin and Kustra (1972).



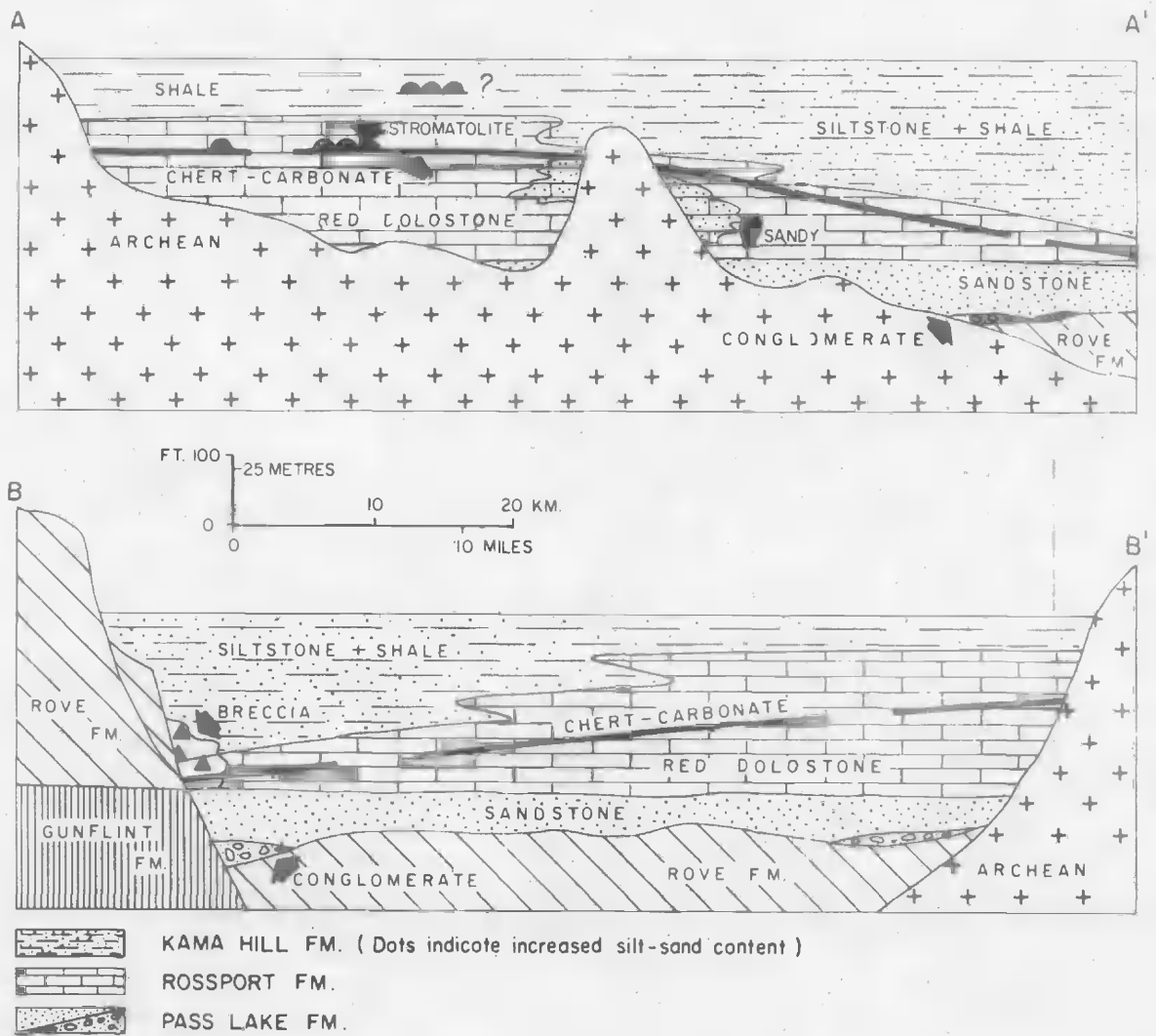
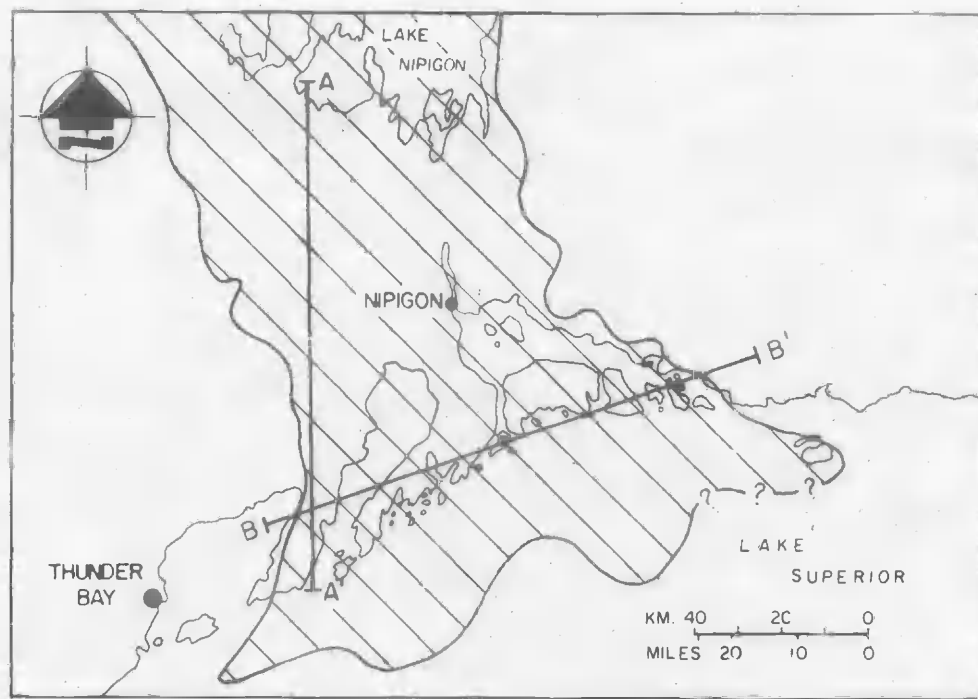


Fig. 4. Longitudinal and Cross-sections of the Sibley Group.

Description of Stops and Roadlog for the
Sibley Group

Mileage count begins at the junction of Highways 11-17 and 61 near the Thunder Bay Airport. Figures in brackets record accumulated mileages.

<u>MILES</u>	<u>KM.</u>	
0.0	0.0	Proceed north along Highway 11-17.
1.9	3.1	Golf Links Road.
2.9	4.7	Oliver Road (Highway 130).
4.9	7.9	John Street.
5.6	9.0	Red River Road (Highway 102).
7.1	11.4	Balsam Street.
9.7	15.6	Hodder Avenue.
10.3	16.6	Scenic Lookout.
12.1	19.5	Spruce River Road (Highway 527 - formerly 800).
21.6	34.8	Lakeshore Drive.
31.2	50.2	Highway 587; turn right and proceed southeast.
35.0	56.3	A large area of outcrop extends along the north side of the C.N.R. railway tracks and Highway 587 where they parallel Pass Lake.

STOP 1

This cliff is the type section for the Pass Lake Formation. Exposure is almost continuous for about 2 miles (3.2 km) along the tracks and gives a stratigraphic thickness of 164 feet (50 metres).

At the western end of this outcrop, a sandstone quarry provides an excellent exposure of Sibley sandstone. In the railway cut at the western edge of the quarry, Rove shale is altered to a reddish colour. This alteration affected the Rove for several feet below its contact with the Sibley Group.

Also present is a thin lens of basal conglomerate.

PLEASE EXERCISE EXTREME CAUTION CLIMBING ON THE DEBRIS.

35.3 56.8

The conglomerate is better exposed behind the railway shed at the east end of Pass Lake.

Clasts in the basal polymictic conglomerate are composed of 93 per cent Gunflint iron formation, 6 per cent quartz and 1 per cent granite. Boulders are of variable size and angularity, and are cemented in a sandy matrix. The contact with overlying sandstone is sharp; only a few pebbles are found in the base of the overlying unit. The sandstone is moderately to poorly indurated, thick bedded at the bottom of the section, and composed of quartz, with minor chert and feldspar, in a calcite matrix.

Continue along Highway 587.

35.7 57.5

Pass Lake East road: turn left and proceed east.

37.6 60.5

No. 4 Road: turn left and proceed north.

37.9 61.0

Y Junction - bear left.

38.6 62.1

Field on left side (west) of road: park here and proceed on foot across field and through bush to CNR tracks - about 1/4 mile (400 metres).

STOP 2

Much of this outcrop is red intraformational breccia of the Rossport Formation. Angular fragments vary from 0.4 in. to 15.7 in. (1 cm up to about 40 cm.) Several clastic dikes are also present.

The lithology is generally a red sandy limestone.

Return to No. 4 Road and continue north.

39.9 64.2 Gravel Pit - for turning vehicle around. Proceed back to Pass Lake East Road.

42.3 68.1 Pass Lake East Road - turn left.

0.0 0.0 Proceed along Pass Lake East Road from Junction with No. 4 Road.

0.8 1.3 Right angle bend to left.
(43.1) (69.4)

1.5 2.4 No. 5 Road - turn left.
(43.8) (70.5)

2.1 3.4 Junction - turn left.
(44.4) (71.5)

4.0 6.4 Area of outcrop.
(46.3) (74.5)

STOP 3

KAMA HILL SANDSTONE

Poorly exposed reddish-brown to reddish-purple sandstone of the Kama Hill Formation. Generally fine- to medium-grained sandstone. Although not evident at this location mudcracks and ripple marks are common in this unit. These occur along the shore of Lake Superior to the east, (see McIlwaine, 1972). The main difference between this sandstone and sandstone of the Rossport Formation is the lack of carbonate in the Kama Hill Formation.

Continue north along No. 5 Road.

9.9 15.9
(52.2) (84.0)

Cross CNR Tracks.

10.3 16.6
(52.6) (84.7)

Highway 11-17 - Turn right.

0.0 0.0
(52.6) (84.7)

Proceed northeast along Highway 11-17.

2.0 3.2
(54.6) (87.9)

Road to Enterprise Mine.

7.8 12.6
(60.4) (97.2)

Road to Ouimet Canyon - Turn left.

8.4 13.5
(61.0) (98.2)

Y Junction - bear left.

9.2 14.8
(61.7) (99.3)

Sharp right turn.

9.7 15.6
(62.3) (100.3)

Sharp left turn.

10.2 16.4
(62.8) (101.1)

Junction - proceed straight.

10.7 17.2
(63.3) (101.9)

Junction - proceed straight.

12.8 20.6
(65.4) (105.3)

Junction - turn right.

13.3 21.4
(65.9) (106.1)

Turn off to Gulch Lake Picnic Grounds - turn left
to Ouimet Canyon.

15.2 24.5
(67.8) (109.1)

Bridge.

15.4 24.8
(68.0) (109.4)

Quimet Canyon.

STOP 4

Ouimet Canyon, a spectacular steep-walled gorge, is located in a thick Keweenawan (Logan) diabase sill. The canyon can be traced for over two miles (3.2 km) and is approximately 600 feet (183 m) wide at its southern end. It has a maximum depth of 400 feet, (122 m).

Although diabase is the most conspicuous rock type, a pink quartz monzonite occurs in the south central portion of the canyon, and a calcareous red mudstone of the Sibley Group has been noted locally at the base of the west wall of the canyon (here bleached grey) and surrounding the southern portion of Gulch Lake.

Mapping along the western rim and wall of the canyon indicates the presence of two major, continuous joint sets and three less-continuous minor sets (Stacey, 1976, p.3). It appears that the canyon is a deep erosional depression, carved out of the diabase along two major joints by the action of glacial ice, running water and freeze-thaw action.

An interesting feature within the canyon is a prominent diabase pinnacle, referred to as the Indian Head, which has been isolated from the west rim by erosion.

The canyon has been declared a Provincial Park under the Quetico Nature Reserves system.

Return to Highway 11-17.

23.8 38.2
(76.4) (123.0)

Highway 11-17 - turn left.

0.0 0.0
(76.4) (123.0)

Proceed northeast along Highway 11-17.

5.6 9.0
(82.0) (132.0)

Bridge over Wolf River.

7.7 12.4
(84.1) (135.3)

Road to Stewart Lake - (see extra stop descriptions at end of Itinerary).

- 20.4 32.8 Highway 627 - proceed straight.
(96.8) (155.8)
- 21.3 34.3 Highway plaque describing Red Rock Cuesta. The
(97.7) (157.2) cuesta features a thick sequence of red sandy
limestone capped by a diabase sill.
- 22.6 36.4 Road cut here shows a diabase sill cutting Archean
(99.0) (159.3) rocks and Sibley Group.
- 25.7 41.4 Road to Mousseau Mountain - (see extra stop
(102.1) (164.0) descriptions at end of Itinerary).
- 28.3 45.5 Junction of Highways 11 and 17 - Proceed straight
(104.7) (168.5) along Highway 17.
- 40.6 65.3 Junction of Domtar Road - (see extra stop
(117.0) (187.3) descriptions at end of Itinerary).
- 41.4 66.5 First Lookout, Kama Hill.
(117.8) (189.6)

STOP 5A

ROSSPORT FORMATION OVERLAIN BY KAMA HILL FORMATION
WITH A CAPPING OF DIABASE.

A broad anticline of sandy red carbonate is exposed in the prominent road cut to the north of this lookout. This represents the lowest member of the Rossport Formation.

Soft-sediment deformation may have produced this structure. Three thin diabase sheets follow bedding planes; the sills pinch out, and locally cut across bedding at a high angle. This homogeneous, calcareous sandy mudstone forms a distinct horizon at the base of the sandy red mudstone unit.

Follow the road (south) to the distinctive red and white interbedded sandy mudstone. Sandstone beds (white) are lenticular in shape, and are interbedded with red, sandy mudstone.

42.1 67.8
(118.5) (190.7)

Second Lookout, Kama Hill.

In the roadcut to the north of the second lookout, the following features may be observed:

- (1) Two thin Keweenawan diabase sills, partially replaced by carbonate, cut across the poorly developed bedding plane at a low angle.
- (2) Finely laminated chert of the chert-stromatolite unit is exposed below the lower sill. Up to six inches (15 cm) of anthraxolite carbonate has accumulated at the base of the chert. An oily smell may be detected when this anthraxolite is freshly broken.
- (3) Limey red mudstone above this unit is marked by many cream-coloured spots, (average diameter 0.5 inch, 13 mm). Similar spots are evident throughout this unit, and commonly have a small amount of graphite or hydrocarbon at the centre. In thin section, the only apparent mineralogical change in the spots is the lack of hematite coating on clay and carbonate grains.
- (4) Irregular, flame-shaped, bleached zones follow structures and bedding plane cleavage in the red limey mudstone. Leaching of hematite and destruction of clay minerals and feldspar has occurred along the fractures.
- (5) Above the road cut and overlying the talus slope, the purple mudstone crops out. It is more highly fissile, and contains approximately 4 per cent hematite, which coats very fine grained corrensite and microcline, and forms blades of specularite in tiny vugs. Bleaching along fractures is common in this rock. Purple mudstone contains abundant syneresis cracks, and to the west, at Stewart Lake, contains thin stromatolite beds.

119.6 192.5

Outcrop on east side of Highway.

STOP 5B

Red Shale of the Kama Hill Formation is exposed here underneath a cap of diabase.

Turning Point - Proceed back towards Thunder Bay.

0.0 0.0
(119.6) (192.5)

Proceed west along Highway 17.

55.2 88.8
(174.8) (281.3)

East Loon Road - turn right (north) and proceed to end of road to Thunder Bay Amethyst Mining Company Limited.

STOP 6

THUNDER BAY AMETHYST MINING COMPANY LIMITED

The Thunder Bay Amethyst Mine is the largest producing amethyst mine in Ontario and is open annually to the public, from May 1st to November 1st. The property has been in production since 1962. The number of rockhounds and tourists visiting the mine site has increased steadily from 900 visitors in 1967 to 24,396 visitors in 1976. There are sufficient reserves to give the mine an expected life of 65 years at current mining rates (R. Hartviksen, Mine Manager, personal communication).

The amethyst deposit is located in an east-west fault zone cutting an intrusive body of massive, medium-grained, red to pink Archean quartz monzonite. Spectacular breccia is noted in the floor of the quarry and in large blocks in the display area exhibiting fragments of unaltered quartz monzonite and highly silicified dolomite of the Sibley Group.

Quarrying, diamond drilling and stripping has delineated the deposit for a length of approximately 1000 feet (305 m) and for a width of over 80 feet (24 m).

Individual amethyst veins vary in width from 1/4 inch (7.6 mm) to 4 feet (1.2 m) and include numerous cavities lined with purple crystals. Well formed crystals (points) line the cavities and vary in size from 1/4 inch (7.6 mm) diameter to large crystals measuring 9 inches (22.9 cm) from tip to root and 6 inches (15.3 cm) in diameter.

Coloration of crystals and the more massive material is dark purple. Variations in intensity of purple colour occur, and locally, colourless and smoky-coloured quartz is found. Crystals are occasionally coated with a reddish brown hematite. The colour of amethyst results from substitution of small quantities of ferric iron for silicon followed by irradiation, (Dennen and Puckett, 1972, p.448).

The deposits of the producing amethyst mines in McTavish Township are found either in fractures that extend below the Sibley-Archean unconformity or at the contact of the Sibley Group with Archean granite.

END OF ITINERARY

For anyone interested in a more complete view of the Sibley Group, the following additional areas may be visited.

1. From Rosspoint, a boat trip to Quarry Channel and Wilson Islands, which lie one to two miles off shore, will allow the visitor to see an almost complete section of Sibley rocks. On Quarry Island, Rove shale is overlain by a thick section of Pass Lake sandstone. Here, crossbeds and ripple marks are abundant.

On Channel Island, the upper part of the sandstone unit, sandy red mudstone units are all exposed. The latter is disconformably overlain by Osler volcanic rocks.

2. The type section of the Kama Hill Formation at the top of Kama Hill. The best access is provided by following the Domtar Logging Road (0.8 mi., 1.3 km west of the first lookout at Kama Hill) for 0.3 mi (0.5 km) to the first powerline. The section is at the top of the hill and is exposed on the powerline.
3. A good section of Pass Lake sandstone is exposed along the road up to Mousseau Mountain. The top of this hill also provides one of the best views of Lake Superior and the surrounding country.

MILES

KM.

0.0	0.0	Leave Highway 11-17 - (see Itinerary for Junction point).
-----	-----	---

- 1.5 2.4 Road junction - turn left.
- 1.9 3.1 Road junction - turn left. Proceed along this road to Mousseau Mountain (see Coates 1972).
4. A further section of Kama Hill Shale may be viewed at Stewart Lake, salt casts may be found here.
5. The stromatolites near Disraeli Lake may be reached by following the Armstrong road north from Hurkett for 21.6 miles, (34.7 km) to the Disraeli Lake road, which connects the Armstrong road with the Spruce River Road (Hwy. 527). Follow the Disraeli Lake road west for 22.2 miles (35.7 km) past Shillabeer and Seagull Creeks to the Disraeli campground road. Proceed for 3/4 of a mile (1.2 km) beyond this, to the first bush road leading north. Follow this road for two miles (3.2 km). Blocks of stromatolite are strewn along side the road for some distance. Stromatolite blocks are common throughout the Disraeli area, and may be found in outcrop and float along most of the bush roads.

ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance of Mr. S. Spivak who compiled and drafted the figures and Mrs. Cathy LeBrun for typing the manuscript. The cover plate was taken by J.F. Scott.

SELECTED BIBLIOGRAPHY OF THE PROTEROZOIC ROCKS OF THE
THUNDER BAY AREA *

- Abelson, P.H. and Hare, P.E. 1968: Recent Amino Acids in the Gunflint Chert; Carnegie Inst. Washington, Yearbook 67, pp. 208-210.
- Alexandrov, Eugene A. 1955: Contribution to Studies of Origin of Precambrian banded Iron Ores; Econ. Geol., Vol. 50, pp. 459-468.
- Alexander, E. Colvin, Jr. 1975: ^{40}Ar - ^{39}Ar Studies of Precambrian Cherts: An unsuccessful attempt to measure the time evolution of the atmospheric $^{40}\text{Ar}/^{36}\text{Ar}$ Ratio; Precambrian Research, Vol. 2, pp. 329-344.
- Annells, R.N. 1973: Proterozoic Flood Basalts of Eastern Lake Superior: The Keweenawan Volcanic Rocks of the Mamainse Point Area, Ontario; Geol. Surv. Canada, Paper 72-10, 51p.
- Annells, R.N. 1974: Keweenawan Volcanic Rocks of Michipicoten Island, Lake Superior, Ontario: An Eruptive Centre of Proterozoic Age; Geol. Surv. Canada, Bull. 218, 141p.
- Baer, A.J. 1974: Grenville Geology and Plate Tectonics; Geoscience Canada, 1, pp. 54-60.
- Bain, George W. 1926: Diffusion in Agate Point Vitrophyres; Amer. Jour. Sci., Vol. 211, pp. 74-88.
- Barghoorn, E.S. 1971: The Oldest Fossils; Sci. Amer., Vol. 224, No. 5, pp. 30-42.
- Barghoorn, Elso S., Schopf, William, J. 1966: Microorganisms Three Billion Years Old from the Precambrian of South Africa; Science, Vol. 152, pp. 758-763.
- Barghoorn, Elso S., Tyler, Stanley, A. 1965: Microorganisms from the Gunflint Chert; Science, Vol. 147, No. 3658, pp. 563-577.
- Barghoorn, Elso S., Tyler, Stanley A. 1965: Microorganisms of Middle Precambrian Age from the Animikie Series, Ontario, Canada; Chap. 3, in Current aspects of exobiology, Calif. Technol. Jet Propulsion Lab., Pasadena, pp. 93-118.
- Bartley, M.W. 1958: The Animikie Sea; a talk given at Institute on Lake Superior Geology, Minneapolis, Univ. Minn. Center Continuation Study, 9p.

* All references are on file with Regional Geologist, Ontario Ministry of Natural Resources, Ontario Government Building, 435 James St. S., Thunder Bay, P7C 5G6.

- Bath, Gordon, D. 1960: Magnetization of Volcanic Rocks in the Lake Superior Geosyncline; U.S. Geol. Surv. Prof. Paper 400-B, pp. B212-B213.
- Battrum, D.D. 1975: Mineralogy and Sedimentation in the Kama Hill Formation of the Sibley Group, Northwestern Ontario; unpubl. B.Sc. Thesis, Lakehead University, Thunder Bay, Ontario, 141 p.
- Bayley, R.W. and James, H.L. 1973: Precambrian Iron-Formations of the United States; Econ. Geol., Vol. 68, No. 7, pp. 934-959.
- Beck, Myrl E., Jr. 1970: Paleomagnetism of Keweenaw Intrusive Rocks, Minnesota; J. Geophys. Res., Vol. 75, No. 26, pp. 4985-4996.
- Bell, R. 1870: On the Geology and Economic Minerals on the North-east Coast of Lake Superior and Adjoining Country from Pigeon River to Black Bay, Black Sturgeon River, Nipigon River and Lake Nipigon; Geol. Surv. Can., Report of Progress 1866-1869, pt. IX.
- Beutner, E.L. 1972: The Iron Formation Syndrome; Econ. Geol., Vol. 67, pp. 254-255.
- Blackadar, R.G. 1956: Differentiation and Assimilation in the Logan Sills, Lake Superior District, Ontario; Amer. Jour. Sci., Vol. 254, pp. 625-645.
- Bonnichsen, Bill, 1969: Metamorphic Pyroxenes and Amphiboles in the Biwabik Iron Formation, Dunka River Area, Minnesota; Mineral. Soc. Amer. Spec. Paper 2, pp. 217-239.
- Bonnichsen, Bill, 1972: The Duluth Complex; Geo. Soc. America, Abstracts with Programs, Vol. 4, No. 7, pp. 453-454.
- Books, Kenneth G. 1968: Magnetization of the Lowermost Keweenaw Lava Flows in the Lake Superior Area; U.S. Geol. Survey Prof. Paper 600-D, pp. D248-D254.
- Books, Kenneth G. 1972: Paleomagnetism of some Lake Superior Keweenaw Rocks; U.S. Geol. Survey Prof. Paper 760, 42 p.
- Books, Kenneth G. and Green, John C. 1972: Further Paleomagnetic Data for Keweenaw Rocks in the Western Lake Superior Area; Geo. Soc. Amer., Abstracts with Programs, Vol. 4, No. 7, p. 454.
- Bowen, N.L. 1926: Concerning "Evidence of Liquid Immiscibility in a Silicate Magma, Agate Point, Ontario", Jour. Geol., Vol. 34, pp. 71-73.
- Broderick, T.M. 1920: Economic Geology and Stratigraphy of the Gunflint Iron District, Minnesota; Econ. Geol., Vol. 15, pp. 422-452.

- Broughton, Paul L. 1975: The Thunder Bay Amethyst Mine; Rock and Gem, July, pp. 58-62.
- Burke, K. and Dewey, J.F. 1973: Plume generated triple junctions: Key indicators in applying plate tectonics to old rocks; Jour. Geol., Vol. 81, pp. 406-433.
- Campling, Neil R. 1973: Some Geological and Environmental Aspects of Remnant Pre-Gunflint and Pre-Sibley Weathered Profiles; unpubl. B.Sc. Thesis, Lakehead University, Thunder Bay, Ontario. 43 p.
- Card, K.D., Church, W.R., Franklin, J.M., Frarey, M.J., Robertson, J.A., West, G.F., and Young, G.M. 1972: The Southern Province; in Variations in Tectonic Styles in Canada, R.A. Price, ed., Geol. Assoc. Canada, Special Paper 11, pp. 336-380.
- Chase, Clement G. and Gilmer, Todd H. 1973: Precambrian Plate Tectonics: The Midcontinent Gravity High; Earth Planet. Sci. Letters, Vol. 21, pp. 70-78.
- Cloud, Preston E. Jr. 1942: Notes on Stromalites; Amer. Jour. Sci., Vol. 240, pp. 363-379.
- Cloud, Preston E. Jr. 1965: Significance of the Gunflint (Precambrian) Microflora; Science, Vol. 148, No. 3666, pp. 27-35.
- Cloud, Preston E. Jr., and Hagen, Hannelore, 1965: Electron Microscopy of the Gunflint Microflora: Preliminary Results; Natl. Acad. Sci. Proc., Vol. 54, No. 1, pp. 1-8.
- Cloud, P.E. Jr., and Semikhatov, M.A. 1969: Proterozoic Stromatolite Zonation; Amer. J. Sci., Vol. 267, pp. 1017-1061.
- Coates, M.E. 1972: Geology of the Black Sturgeon River Area, District of Thunder Bay; Ontario Dept. Mines and Northern Affairs, GR 98, 41 p. Accompanied by Maps 2233, 2234, 2235, 2236, scale 1 inch to 1 mile.
- Cooke, H.C. 1931: Studies of Physiography of the Canadian Shield: III. The pre-Pliocene physiographies, as inferred from the geologic record; Trans. Roy. Soc. Canada, Vol. 25, Sect. 4, pp. 127-180.
- Cornwall, Henry R. 1951: Ilmenite, Magnetite, Hematite and Copper in Lavas of the Keweenaw Series; Econ. Geol., Vol. 46, pp. 51-67.
- Cornwall, Henry R. 1951: Differentiation in Lavas of the Keweenaw Series and the Origin of the Copper Deposits of Michigan; Geol. Soc. Amer. Bull., Vol. 62, pp. 159-202.
- Cornwall, Henry R. 1951: Differentiation in Magmas of the Keweenaw Series; Jour. Geol., Vol. 59, pp. 151-172.

- Courtis, W.M. 1887: The Animikie Rocks and their Vein Phenomena as shown at Duncan Mine, Lake Superior; Amer. Inst. Min. Eng., Transactions, Vol. 15, pp. 671-677.
- Craddock, Campbell, 1972: Structural Evolution of the Keweenaw Province; Geol. Soc. Amer., Abstracts with Programs, Vol. 4, No. 7, pp. 715-716.
- Davies, F. Bryan, and Windley, Brian, F. 1976: Significance of major Proterozoic high grade linear belts in continental evolution; Nature, Vol. 263, pp. 383-385.
- Dennen, William, H. and Puckett, Anita M. 1972: On the Chemistry and colour of Amethyst; Can. Mineralogist, Vol. 11, No. 2, pp. 448-456.
- Dott, R.H. 1972: A Post-Animikean - Pre-Keweenaw Transgressive Sand Blanket over the Lake Superior Region; Geo. Soc. Amer., Abstracts with Programs, Vol. 4, No. 7, pp. 490-491.
- Drever, James I. 1974: Geochemical Model for the Origin of Precambrian Banded Iron Formations; Geol. Soc. Amer. Bull, Vol. 85, pp. 1099-1106.
- Du Bois, P.M. 1959: Correlation of Keweenaw Rocks of Lake Superior District by Palaeomagnetic Methods; Geol. Assoc. Canada, Vol. 11, pp. 115-128.
- Du Bois, P.M. 1962: Palaeomagnetism and Correlation of Keweenaw Rocks; Geol. Surv. Canada, Bull: 71, 75p.
- Edhorn, Anna-Stina, 1973: Further investigations of fossils from the Animikie, Thunder Bay, Ontario; Proc. Geol. Assoc. Canada, Vol. 25, pp. 37-66.
- Ellsworth, H.V. 1934: Nickeliferous and Uraniferous Anthraxolite from Port Arthur, Ontario., Amer. Min., Vol. 19, No. 9, pp. 426-428.
- Fahrig, W.F. and Wanless, R.K. 1963: Age and significance of Diabase Dyke Swarms of the Canadian Shield; Nature, Vol. 200, pp. 934-937.
- Faure, G. and Chaudhuri, S. 1967: The geochronology of the Keweenaw Rocks of Michigan and Origin of the copper deposits. Dept. Geol. Ohio State Univ., Lab. Isotope, Geol. and Geochem. Dept. No. 1.
- Faure, G., Chaudhuri, S., and Fenton, M.D. 1969: Ages of the Duluth Gabbro complex and of the Endion Sill, Duluth, Minnesota; J. Geophys. Res., 74, pp. 720-725.
- Faure, Gunter; Kovach, Jack, 1969: The Age of the Gunflint Iron Formation of the Animikie Series in Ontario, Canada; Bull. Geol. Soc. Amer., Vol. 80, pp. 1725-1736.

- Faure, Gunter; Kovach, Jack, 1969: The Age of the Gunflint Iron Formation of the Animikie Series in Ontario, Canada; Ohio State University, Laboratory for Isotope Geology and Geochemistry, Contribution No. 8, 23p.
- Floran, R.J. and Papike, J.J. 1975: Petrology of the Low-Grade Rocks of the Gunflint Iron Formation, Ontario-Minnesota; Geol. Soc. Amer. Bull., Vol. 86, pp. 1169-1190.
- Franklin, J.M. 1970: Metallogeny of the Proterozoic Rocks of the Thunder Bay District, Ontario; unpubl. Ph.D. Thesis, Western Univ., London, Ontario, 317p.
- Franklin, J.M. and Kustra, C.R. 1970: Proterozoic rocks in the Thunder Bay Area; Institute on Lake Superior Geology, 16th Annual Meeting, Thunder Bay, Guidebook, pp. 48-68.
- Franklin, J.M. and Kustra, C.R. 1972: The Proterozoic Rocks of the Lake Superior Area, Northwestern Ontario; p.20-46 in Guidebook for Field Excursion C34. International Geological Congress, Twenty-fourth Session, Canada 1972, 74 p.
- Franklin, J.M., Poulsen, K.H., and McIlwaine, W.H. 1972: Stratigraphy of the Sibley Group, A Helikian Red Bed Sequence; Geol. Soc. Amer., Abstracts with Programs, Vol. 4, No. 7, p. 509.
- Franklin, James, M. (in press): Interpretation of the Rb/Sr isochrons of metamorphosed and unmetamorphosed Rove shale.
- Franklin, J.M. McIlwaine, W.H., Poulsen, K.H. and Wanless, R.K. (in prep.): Stratigraphy and Sedimentation of the Sibley Group; 37 p.
- Franklin, J.M. and Mitchell, R.H. (in prep.): Lead-Zinc-Barite Veins of the Dorion Area, Thunder Bay District, Ontario; 25 p.
- French, Bevan M. 1973: Mineral Assemblages in Diagenetic and Low Grade Metamorphic Iron-Formation; Econ. Geol. Vol. 68, pp. 1063-1074.
- French, William A. 1976: Silver Mining in the Thunder Bay Region 1845-1891: An Examination of its Economic Viability; Unpubl. B.A. Thesis, Lakehead University, Thunder Bay, 44p.
- Garrels, R.M., Perry, E.A. Jr. and MacKenzie, F.T. 1973: Genesis of Precambrian Iron Formations and the Development of Atmospheric Oxygen; Econ. Geol., Vol. 68, pp. 1173-1179.
- Guel, J.J.C. 1970: Geology of Devon and Pardee Townships and the Stuart Location; Ontario Dept. of Mines and Northern Affairs, GR 87, 52 p. Accompanied by Map 2207, scale 1 inch to 1/2 mile.
- Guel, J.J.C. 1973: Geology of Crooks Township, Jarvis and Prince Locations, and Offshore Islands, District of Thunder Bay; Ontario Div. Mines, GR 102, 46 p. Accompanied by Map 2250, scale 1 inch to 1/2 mile.

- Giguere, J.F. 1975: Geology of St. Ignace Island and Adjacent Islands, District of Thunder Bay; Ontario Div. Mines, GR 118, 35p.
Accompanied by Map 2285, scale 1 inch to 1 mile.
- Gill, J.E. 1926: Gunflint Iron-Bearing Formation; Geol. Surv. Canada, Summ. Rept., 1924, Pt. C, pp. 28c-88c.
- Gill, J.E. 1927: Origin of the Gunflint Iron-Bearing Formation; Econ. Geol., Vol. 22, No. 7, pp. 687-728.
- Gill, J.E. 1957: Summary and Discussions; pp. 183-191 in the Proterozoic in Canada, Roy. Soc. Canada, Spec. Publ. No. 2, 191 p.
- Glaessner, M.F. 1968: Biological events and the Precambrian time scale; Can J. Earth Sci., Vol. 5, No. 3, pp. 585-590.
- Goldich, S.S., 1968: Geochronology in the Lake Superior region; Can. Jour. Earth Sci., Vol. 5, No. 3, pt. 2, pp. 715-724.
- Goldich, S.S., 1973: Ages of Precambrian Banded Iron Formation; Econ. Geol., Vol. 68, pp. 1126-1134.
- Goodwin, A.M. 1956: Facies Relations in the Gunflint Iron Formation; Econ. Geol., Vol. 51, No. 6, pp. 565-595.
- Goodwin, A.M. 1960: Gunflint Iron Formation of the Whitefish Lake Area; Ontario Dept. Mines, Vol. 69, Pt. 7, pp. 41-63.
- Govett, G.J.S., 1966: Origin of Banded Iron Formation; Geol. Soc. Amer. Bull., Vol. 77, pp. 1191-1212.
- Green, John C. 1972: Field Trip Guide Book for Precambrian North Shore Volcanic Group, Northeastern Minnesota; Annual Meeting, Geol. Soc. Amer., Minneapolis, Minnesota, 36 p.
- Gross, G.A. 1961: Metamorphism of Iron Formations and its Bearing on their Benefication; Can. Min. Met. Bull., Vol. 54, pp. 30-37.
- Gross, G.A. 1965: Geology of Iron Deposits in Canada; Vol. 1, General Geology and Evaluation of Iron Deposits; Geol. Surv. Canada, Econ. Geol. Report No. 22, 181 p.
- Gross, G.A. 1972: Primary Features in Cherty Iron Formations; Sediment. Geol., Vol. 7, pp. 241-261.
- Grout, Frank F., Sharp, Robert P., and Schwartz, George M., 1959: The Geology of Cook County, Minnesota; Minn. Geol. Survey, Bull. 39, 163p.
- Gruner, John W. 1922: The Origin of the Sedimentary Iron Formations: The Biwabik Formation of the Mesabi Range; Econ. Geol., Vol. 17, pp. 407-460.

- Halls, H.C. 1966: A Review of the Keweenawan Geology of the Lake Superior Region; in The Earth beneath the continents (edited by J.S. Steinhart and T.H. Smith), Am. Geophys. Union, Monograph 10, pp. 3-27.
- Halls, H.C. 1969: Compressional wave velocities of Keweenawan rock specimens from the Lake Superior region; Can. Jour. Earth Sci., Vol. 6, pp. 555-568.
- Halls, H.C. 1972: Geophysical Studies in Northern Lake Superior; Geo. Soc. Amer., Abstracts with Programs, Vol. 4, No. 7, pp. 525.
- Halls, H.C. 1972: Magnetic Studies in Northern Lake Superior; Can. J. Earth Sci., Vol. 9, No. 11, pp. 1349-1367.
- Halls, H.C. 1974: A Paleomagnetic Reversal in the Osler Volcanic Group, Northern Lake Superior; Can. J. Earth Sci., Vol. 11, No. 9, pp. 1200-1207.
- Halls, H.C. 1975: Shock induced remanent magnetization in late Precambrian rocks from Lake Superior; Nature, Vol. 225, pp. 692-695.
- Halls, H.C., and West, G.F. 1971: A Seismic Refraction Survey in Lake Superior; Can. J. Earth Sci., Vol. 8, No. 6, pp. 610-630.
- Hamblin, William Kenneth, 1961: Palaeographic Evolution of the Lake Superior Region from Late Keweenawan to Late Cambrian Time; Bull. Geol. Soc. Am., Vol. 72, pp. 1-18.
- Hanson, Gilbert N. 1975: $^{40}\text{Ar}/^{39}\text{Ar}$ Spectrum Ages of Logan Intrusions, a Lower Keweenawan Flow, and Mafic Dikes in Northeastern Minnesota-Northwestern Ontario; Can. J. Earth Sci., Vol. 12, pp. 821-835.
- Hanson, G.N., and Malhotra, R. 1971: K-Ar Ages of Mafic Dikes and Evidence for Low-Grade Metamorphism in Northeastern Minnesota; Geol. Soc. Amer. Bull., Vol. 82, pp. 1107-1113.
- Harris, F.R. and Kustra, C.R. 1968: Field Excursion Guide: Gunflint Iron Formation - Sibley Group; Ontario Dept. Mines Geol. Field Trip, Canadian Lakehead Area, 11 p.
- Hawley, J.E. 1929: Lead and zinc Deposits, Dorion and McTavish Townships, Thunder Bay District. Ontario Dept. Mines, Vol. 38, pt. 6, pp. 58-85. Accompanied by Map 38f, scale 1 inch to 1 mile.
- Heslop, John Boyd, 1968: Mineralogy and Textural Relationships of the Mount Mollie Sulphides, Pine Bay Area, Thunder Bay District; Unpubl. B.Sc. Thesis, University of Western Ontario; London, Ontario. 68p.
- Hinze, W.J., Roy, R.F. and Davidson, D.M. 1972: The Origin of Late Precambrian Rifts; Geol. Soc. Amer. Abstracts with Programs, Vol. 4, No. 7, pp. 723.

- Hofmann, H.J. 1969: Stromatolites from the Proterozoic Animikie and Sibley Groups, Ontario; Geol. Surv. Canada, Paper 68-69, 77p.
- Hofmann, H.J. 1969: Attributes of Stromatolites; Geol. Surv. Canada, Paper 69-39, 58p.
- Hofmann, H.J. 1971: Precambrian Fossils, Pseudofossils, and Problematica in Canada; Geol. Surv. Canada, Bull. 189, 146p.
- Holden, Edward F. 1925: The cause of color in smoky quartz and amethyst; The American Mineralogist, Vol. 10, No. 9, pp. 203-252.
- Hotchkiss, W.O. 1923: The Lake Superior Geosyncline; Bull. Geol. Soc. Amer., Vol. 34, pp. 669-678.
- Hough, J.L. 1958: Fresh-water Environment of Deposition of Precambrian Banded Iron Formations; Jour. Sed. Pet., V. 28, No. 4, pp. 414-430.
- Hubbard, T.P. and Ade-Hall, J.M. 1972: Intensity of the Geomagnetic Field during the Extrusion of the Keweenawan Lavas; Geol. Soc. Amer., Abstracts with Program, Vol. 4, No. 7, pp. 546.
- Huber, N.King, 1972: Keweenawan Geology of Isle Royale, Michigan; Geo. Soc. Amer., Abstracts with Program, Vol. 4, No. 7, p. 546.
- Huber, N.K., 1973: The Portage Lake Volcanics (Middle Keweenawan) on Isle Royale, Michigan; Geol. Survey Prof. Paper 754-C, 32p.
- Hunt, T.S. 1873: The Geonostical History of the Metals; Trans. Am. Inst. Min. Eng., 1, pp. 331-345.
- Hurley, P.M., Fairbairn, H.W., Pinson, W.H. Jr., Hower, J. 1962: Unmetamorphosed minerals in the Gunflint Formation used to test the age of the Animikie; Jour. Geology, Vol. 70, No. 4, pp. 489-492.
- Ingall, E.D. 1887: Report on mines and mining on Lake Superior (published 1888); Geol. and Nat. Hist. Survey Canada, Ann. Rept., Vol. 3, pt.H, 124p.
- James, Harold J. 1954: Sedimentary Facies of Iron Formation; Econ. Geol., Vol. 49, No. 3, pp. 235-293.
- Keeler, R.G. 1971: The Petrology of the Moss Lake Noritic Intrusion, District of Thunder Bay, Ontario; unpubl. B.Sc. Thesis, University of Toronto, 53p.
- Klein, Cornelis, Jr. 1973: Changes in Mineral Assemblages with Metamorphism of some Banded Precambrian Iron Formations; Econ. Geol., Vol. 48, pp. 1075-1088.

- Konda, Tadashi, and Green, John C. 1974: Clinopyroxenes from the Keweenaw Lavas of Minnesota; *Am. Mineralogist*, Vol. 59, pp. 1190-1197.
- Kwiatkowski, Dennis 1975: Geology and Geochemistry of the Kakabeka Falls Anthraxolite; unpubl. B.Sc. Thesis, Lakehead University, 103p.
- LaBerge, Gene L. 1964: Development of Magnetite in Iron Formations of the Lake Superior Region; *Econ. Geol.*, Vol. 59, pp. 1313-1342.
- LaBerge, Gene L. 1967: Microfossils and Precambrian Iron Formations; *Geol. Soc. Amer. Bull.*, Vol. 78, pp. 331-342.
- LaBerge, Gene L. 1973: Possible Biological Origin of Precambrian Iron Formations; *Econ. Geol.*, Vol. 68, No. 7, pp. 1098-1109.
- Lepp, Henry and Goldich, Samuel S. 1964: Origin of Precambrian Iron Formations; *Econ. Geol.*, Vol. 59, pp. 1025-1060.
- Logan, Sir. W.E. 1863: The Geology of Canada; *Geol. Surv. Can. Rept. of Progress from Commencement of 1863*.
- Logan, B.W., Rezak, R. and Ginsburg, R.N. 1964: Classification and Environmental Significance of Algal Stromatolites; *J. Geol.*, Vol. 72, No. 1, pp. 68-83.
- Mainwaring, Paul R. 1968: The Sulphide Assemblage of The Great Lakes Nickel Intrusion; unpubl. B.Sc. Thesis, University of Western Ontario, London, Ontario. 63p.
- McCuaig, James Auley, 1950: A Copper-Nickel Occurrence in Pardee Township, Thunder Bay District, Ontario; unpubl. M.Sc. Thesis, McGill University, Montreal, 61p.
- McIlwaine, W.H. 1971a: McTavish Township (West Part of North Half) District of Thunder Bay; Ont. Dept. Mines and Northern Affairs, Prelim. Geol. Ser. Map P.720, scale 1 inch to 1/4 mile.
- McIlwaine, W.H. 1971b. McTavish Township (East Part of North Half) District of Thunder Bay, Ont. Dept. Mines and Northern Affairs, Prelim. Geol. Ser. Map P.721, scale 1 inch to 1/4 mile.
- McIlwaine, W.H. 1975: McTavish Township (South Half) District of Thunder Bay. Ont. Dept. Mines and Northern Affairs, Prelim. Geol. Ser. Map P.990, scale 1 inch to 1/4 mile.
- McIlwaine, W.H. and Wallace, Henry, 1972: Stratigraphy, Petrography, and Chemistry of the Late Precambrian Osler Group, District of Thunder Bay, Ontario; *Geol. Soc. Amer. Abstracts with Programs*, Vol. 4, No. 7, p. 590.
- McIlwaine, W.H. and Wallace, Henry, 1976: Geology of the Black Bay Peninsula Area, District of Thunder Bay; Ontario Div. Mines, GR 133, 54p. Accompanied by Map 2304, scale 1 inch to 1 mile.

- McIlwaine, W.H., Wallace, Henry, Franklin, J.M. and Poulsen, K.H., 1974: Stratigraphy and Tectonic Setting of the Late Precambrian (Helikian) of Northwestern Ontario; Geol. Assoc. Canada Min. Assoc. Canada, Annual Meeting, Program Abstracts pp. 60-61.
- McIlwaine, W.H. and Tihor, L.A. 1975: Dorion-Wolf Lake Area (Western Part)., District of Thunder Bay; Ontario Div. Mines, Prelim. Map 994, Geol. Ser., Scale 1 inch to 1/4 mile or 1:15,840. Geology 1972.
- Moore, J.G. and Peck, D.L. 1962: Accretionary Lapilli in Volcanic Rocks of the Western Continental U.S.; Jour. Geol., V. 10, No. 2, pp. 182-193.
- Moorhouse, W.W. 1957: The Proterozoic of Port Arthur and Lake Nipigon Regions, Ontario; pp. 67-76, in The Proterozoic in Canada, Roy. Soc. Canada, Special Publication No. 2, 191p.
- Moorhouse, W.W. 1960: Gunflint Iron Range in the Vicinity of Port Arthur; Ontario Dept. Mines, Vol. 69, pt. 7, pp. 1-40. Accompanied by 7 maps, Scale 1 inch to 1/2 mile.
- Moorhouse, W.W. 1963: Concretions from the Animikie of the Port Arthur Region, Ontario; Proc. Geol. Assoc. Canada, Vol. 15, pp. 43-59.
- Moorhouse, W.W. and Beales, F.W. 1962: Fossils from the Animikie, Port Arthur, Ontario; Trans. Roy. Soc. Canada, Vol. 56, Series 3, pp. 97-110.
- Morey, G.B. 1967: Stratigraphy and Sedimentology of the Middle Precambrian Rove Formation in Northeastern Minnesota; Jour. Sed. Pet., Vol. 37, No. 4, pp. 1154-1162.
- Morey, G.B. 1969: The Geology of the Middle Precambrian Rove Formation in Northeastern Minnesota; Minnesota Geological Survey Sp-7, Special Publication Series, University of Minnesota, Minneapolis, 62p.
- Morey, G.B. 1972: Gunflint Range; in Sims, P.K., and Morey, G.B., eds., Geology of Minnesota - A Centennial Volume (Schwarcz Vol.), Minnesota Geol. Survey, pp. 218-225.
- Morey, G.B. 1973: Mesabi, Gunflint and Cuyuna Ranges, Minnesota; Unesco 1973, Genesis of Precambrian Iron and Manganese Deposits, Proc. Kiev. Symp., 1970 Earth Sciences, Vol. 9, pp. 193-207.
- Morey, G.B. and Sims, P.K. 1976: Boundary Between Two Precambrian W. Terranes in Minnesota and its Geologic Significance; Geol. Soc. Amer. Bull., Vol. 87, pp. 141-152.
- Mudrey, M.G., Jr. 1976: Late Precambrian Structural Evolution of Pigeon Point, Minnesota and Relations to the Lake Superior Syncline; Can. J. Earth Sci., Vol. 13, pp. 877-888.

- Mudrey, M.G., Jr. and Weiblen, P.W. 1972: Diabase Intrusions of Northeastern Minnesota: Part 1; Geo. Soc. Amer., Abstracts with Programs, Vol. 4, No. 7, pp. 606.
- Murthy, G.S., Fahrig, W.F. and Jones, D.L. 1968: The Paleomagnetism of the Michikamau anorthositic intrusion, Labrador; Can. J. Earth Sci., 5, pp. 1139-1144.
- Palmer, H.C. 1970: Paleomagnetism and Correlation of Some Middle Keweenawan Rocks, Lake Superior; Can. J. Earth Sci., Vol. 7, No. 6, pp. 1410-1436.
- Peterman, Zell E., 1966: Rb-Sr Dating of Middle Precambrian Metasedimentary Rocks of Minnesota; Geol. Soc. Amer. Bull., Vol. 77, pp. 1031-1044.
- Peterman, Z.E., Hedge, C.E. and Braddock, W.A. 1968: Age of Precambrian events in the Northeastern Front Range, Colorado.; J. Geophys., Res., 73, pp. 2277-2296.
- Phinney, Wm. C., 1968: Guide for Field Trip in the Duluth Complex near Ely, Minnesota; Instit. Lake Superior Geology, May 1968, 6p.
- Pye, E.G. 1953: A Petrographic Study of the Textures of Basic and Ultrabasic Igneous Rocks, unpubl. Ph.D. Thesis, University of Toronto, Toronto, Ontario, 93p.
- Pye, E.G. 1964: A Preliminary Study of the Shapes of Plagioclase Feldspars in Some Basic Rocks; Proc. Geol. Assoc. Canada, Vol. 15, Pt. 2, pp. 9-25.
- Pye, E.G. 1968: Geology and Scenery, Rainy Lake and East to Lake Superior; Ontario Dept. Mines, Geol. Guide Book No. 1, 114p.
- Pye, E.G., 1969: Geology and Scenery, North Shore of Lake Superior, Ontario Dept. Mines, Geol. Guide Book No. 2, 144 p. (reprinted 1975).
- Reeve, Edward John, 1969: Petrology and Mineralogy of a Gabbroic Intrusion in Pardee Township Near Port Arthur, Ontario; Unpubl. M.Sc. Thesis, University of Wisconsin, Milwaukee, Wis., 79 p.
- Robertson, W.A. 1973: Pole Positions from the Mamainse Point Lavas and Their Bearing on a Keweenawan Pole Path and Polarity Sequence; Can. J. Earth Sci., Vol. 10, No. 10, pp. 1541-1555.
- Robertson, W.A. 1973: Pole Position From Thermally Cleaned Sibley Group Sediments and its Relevance to Proterozoic Magnetic Stratigraphy; Can. J. Earth Sci., Vol. 10, No. 1, pp. 180-193.
- Robertson, W.A. and Fahrig, W.F., 1971: The Great Logan Paleomagnetic Loop - The Polar Wandering Path from Canadian Shield Rocks During the Neohelikian Era; Can. J. Earth Sci., Vol. 8, pp. 1355-1372.

- Sage, R.P., Treacher, K., Meloche, D., and Bathe, D., 1975: Slate Islands, District of Thunder Bay; Ontario Div. Mines, Prelim. Map P.997, Geol. Ser., Scale 1 inch to 660 feet or 1:7,920. Geology and compilation, 1974.
- Sakamoto, Takao, 1950: The Origin of the Pre-Cambrian Banded Iron Ores; Amer. Jour. Sci., Vol. 248, No. 7, pp. 449-474.
- Schwarcz, G.M. 1942: Concretions of the Thomson Formation, Minnesota; Amer. Jour. Sci., Vol. 240, pp. 491-499.
- Schwarcz, George M., and Sandberg, Adolph E., 1940: Rock Series in Diabase Sills at Duluth, Minnesota; Bull. Geol. Soc. Amer., Vol. 51, pp. 1135 - 1172.
- Silver, L.P. 1906: The Animikie Iron Range; Annual Report, Ontario Bur. Mines., Vol. 15, pt. 1, No. 5, pp. 156-172.
- Silver, Leon T., and Green, John C. 1972: Time Constants for Keweenawan Igneous Activity; Geol. Soc. Amer., Abstracts with Programs, Vol. 4, No. 7, pp. 665-666.
- Simmons, E.C., Lindsley, D.H. and Papike, J.J. 1974: Phase Relations and Crystallization Sequence in a Contact-Metamorphosed Rock from the Gunflint Iron Formation, Minnesota; Jour. Petrology, Vol. 15, pt. 3, pp. 539-565.
- Sims, Paul K. 1976: Early Precambrian Tectonic-Igneous Evolution in the Vermillion District, Northeastern Minnesota; Geol. Soc. Amer. Bull., Vol. 87, pp. 379-389.
- Sims, P.K., 1976: Precambrian Tectonics and Mineral Deposits, Lake Superior Region; Econ. Geol., Vol. 71, No. 6, pp. 1092-1118.
- Smith, W.N., 1905: Loon Lake Iron-Bearing District; Annual Report, Ontario Bur. Mines, Vol. 14, pt. 1, pp. 254-260.
- Smith, T. Jefferson, Steinhart, John S., and Aldrich, L.T. 1966: Lake Superior Crustal Structure; Jour. Geophys. Research, Vol. 71, No. 4, pp. 1142-1172.
- Spall, Henry 1971: Precambrian Apparent Polar Wandering: Evidence from North America; Earth Planet. Sci. Letters, Vol. 10, pp. 273-280.
- Stacey, P.E., 1976: Report to Division of Parks, Ontario Ministry of Natural Resources on the Stability Aspects of the Development of Ouimet Canyon; Golder Associates, Vancouver, B.C., 14p.
- Stacey, Harold R. 1974: Our Beautiful Little Known Gemstones; Can. Geog. J., Vol. 89, No. 6, pp. 4-13.

- Stewart, John H. 1976: Late Precambrian Evolution of North America: Plate Tectonics Implications; *Geology*, Vol. 4, No. 1, pp. 11-15.
- Stockwell, C.H. 1968: Geochronology of Stratified Rocks of the Canadian Shield; *Can. J. Earth Sci.*, Vol. 5, pp. 693-698.
- Sutton, J. and Watson, J.V. 1974: Tectonic Evolution of Continents in Early Proterozoic Times; *Nature*, Vol. 247, Feb. 13, pp. 433-435.
- Symons, D.T.A., 1966: A Paleomagnetic Study of the Gunflint, Mesabi, and Cuyuna Iron Ranges in the Lake Superior Region; *Econ. Geol.* Vol. 61, pp. 1336-1361.
- Tanton, T.L. 1923: Iron Formation at Gravel Lake, Thunder Bay District, Ontario; *Geol. Survey Summary Report.*, Pt. C1, pp. 1-5.
- Tanton, T.L. 1925: Evidence of Liquid Immiscibility in a Silicate Magma, Agate Point, Ontario; *Jour. Geol.*, Vol. 33, pp. 629-641.
- Tanton, T.L. 1927: Stratigraphy of the Northern Subprovince of the Lake Superior Region; *Bull. Geol. Soc. Amer.*, Vol. 38, pp. 731-748.
- Tanton, T.L. 1928: Emulsions of Silicates; *Amer. Jour. Sci.*, Vol. 15, pp. 66-68.
- Tanton, T.L. 1931: Fort William and Port Arthur and Thunder Cap Map Areas: Thunder Bay District, Ontario; *Geol. Surv. Can.*, Mem. 167, 222 p.
- Tanton, T.L. 1935: Copper-Nickel Mineral Occurrences in Pigeon Area, Ontario; *Canada Dept. Mines., Bur. Econ. Geol.*, Paper 35-1, 11p.
- Tanton, T.L. 1948: Radioactive Nodules in Sediments of the Sibley Series, Nipigon, Ontario; *Trans. Roy. Soc. Canada, 3rd Series*, Vol. 42, Section 4, pp. 69-75.
- Tanton, T.L. 1950: The Origin of Iron Range Rocks; *Trans. Roy. Soc. Canada, Vol. 44, Series 3*, pp. 1-19.
- Trendall, A.F., 1968: Three Great Basins of Precambrian Banded Iron Formation Deposition: A Systematic Comparison; *Geol. Soc. Amer. Bull.*, Vol. 79, pp. 1527-1544.
- Tyler, Stanley A., 1949: Development of Lake Superior Soft Iron Ores from Metamorphosed Iron Formation; *Bull. Geol. Soc. Amer.*, Vol. 60, pp. 1101-1124.
- Tyler, Stanley A. and Barghoorn, Elso S., 1954: Occurrence of Structurally Preserved Plants in Pre-Cambrian Rocks of the Canadian Shield; *Science*, Vol. 119, No. 3096, pp. 606-608.
- Tyler, S.A., Mardsen, R.W., Grout, F.F. and Thiel, G.A. 1940: Studies of the Lake Superior Pre-Cambrian by Accessory-Mineral Methods; *Bull. Geol. Soc. Amer.*, Vol. 51, pp. 1429-1538.

- Van Lewen, Melvin C., 1957: The Geology of St. Ignace Island, Ontario and a Correlation of the Keweenawan Series of the Lake Superior Region; unpubl. B.Sc., Mich. College Mining Tech., Michigan, 67 p.
- Van Schmus, W.R. 1976: Early and Middle Proterozoic History of the Great Lakes Area, North America; in A Discussion on Global Tectonics in Proterozoic Times, Roy. Soc. (London) Phil. Trans. A. Vol. 280, pp. 605-628.
- Vos, M.A. 1976: Amethyst Deposits of Ontario; Ontario Div. Mines, Min. Nat. Res., Geol. Guidebook No. 5, 99p.
- Wallace, Henry, 1972: Differentiation Trends in Osler Volcanics, Shesheeb Bay Section; unpubl. M.Sc. Thesis, University of Toronto, Toronto, Ontario, 109p.
- Walter, M.R. 1972: A Hot Spring Analog for the Depositional Environment of Precambrian Iron Formations of the Lake Superior Region; Econ. Geol., Vol. 67, pp. 969-971.
- Weiblen, P.W., Mathez, E.A. and Morey, G.B. 1972: Logan Intrusions; in Geology of Minnesota, A Centennial Volume, P.K. Sims and G.B. Morey (Eds.), Minn. Geol. Surv., pp. 394-406.
- White, Walter S., 1960: The Keweenawan Lavas of Lake Superior, an Example of Flood Basalts; Amer. Jour. Sci., Vol. 258-A, (Bradley Vol.), pp. 367-374.
- White, Walter S., 1966: Geologic Evidence for Crustal Structure in the Western Lake Superior Basin; in The Earth Beneath the Continents (edited by J.S. Steinhardt and T.J. Smith), Amer. Geophys. Union, Geophys. Monograph 10, pp. 28-41.
- White, W.S. 1966: Tectonics of the Keweenawan Basin, Western Lake Superior Region; U.S. Geol. Survey Prof. Paper 524-E, 23p.
- White, W.S. 1972: Keweenawan Flood Basalts and Continental Rifting; Geo. Soc. Amer., Vol. 4, No. 7, pp. 732-734.
- Woolnough, W.G., 1941: Origin of Banded Iron Deposits - A Suggestion; Econ. Geol., Vol. 36, No. 5, pp. 465-489.
- Wynne-Edwards, H.R., 1976: Proterozoic Ensialic Orogenesis: The Millipede Model of Ductile Plate Tectonics; Amer. Jour. Sci., Vol. 276, No. 8, pp. 927-953.