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V.G. Milne, Director
Ontario Geological Survey



FOREWORD

The Hydrocarbon Energy Resources Program (HERP) of the Ministry of Natural Resources consists of four main components. Inventories and assessments of the peat, lignite, and oil shale resources of the Province are the responsibility of the Ontario Geological Survey. Evaluation of conventional oil and gas resources are being conducted by the Petroleum Resources Section in Southwestern Region.

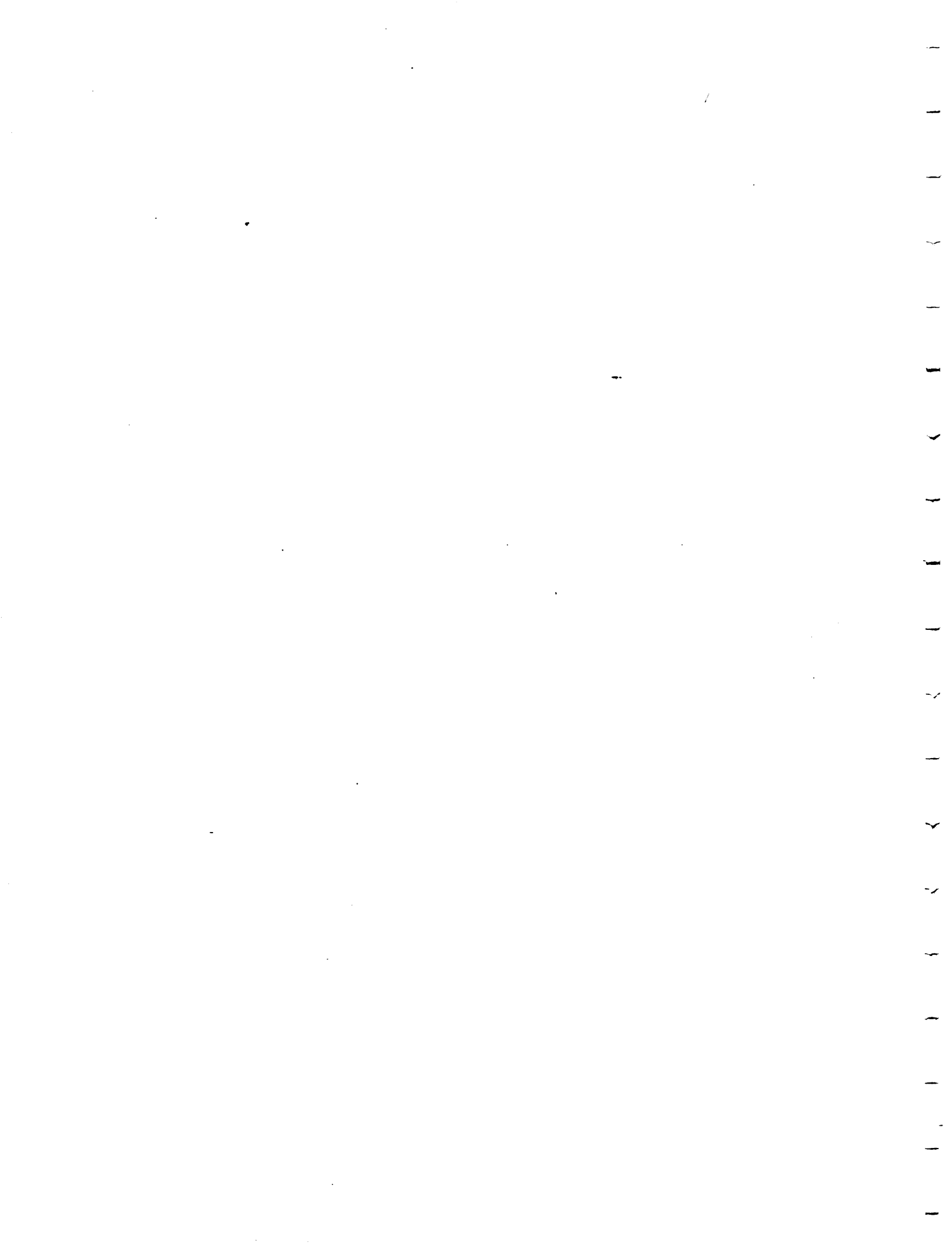
The Moose River Basin in the James Bay Lowland contains peat, lignite, and potential oil shale deposits. The Paleozoic strata of the basin are also a potential source of conventional oil and gas. Thus, a significant proportion of the activities of HERP has been concentrated in this region. This report provides the results and recommendations emanating from the drilling of a deep borehole in the basin at Schlievert Lake. The borehole was intended to provide new data on the hydrocarbon resources of the region and to help establish a better stratigraphic framework of the Paleozoic, Mesozoic and Quaternary deposits for subsequent resource evaluations.

V.G. Milne, Director
Ontario Geological Survey



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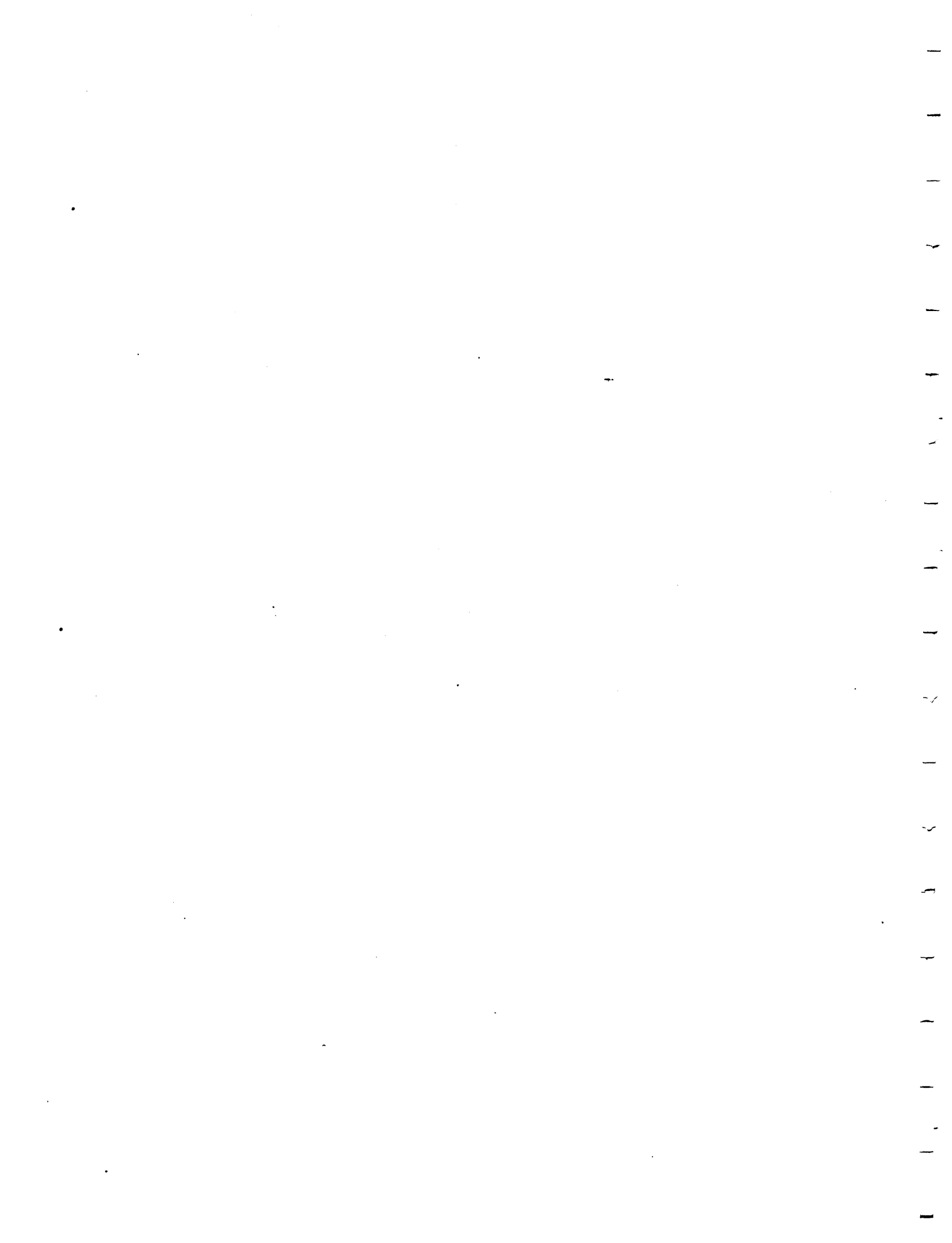


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THE SCHLIEVERT LAKE BOREHOLE (O.G.S. 83-8D):
REPORT ON DRILLING OPERATIONS AND PRELIMINARY
GEOLOGICAL FINDINGS

By

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1. INTRODUCTION

In September of 1983, the Ontario Geological Survey (OGS) engaged Longyear Canada Ltd. to drill a deep borehole near the Schlievert Lakes, in the Moose River Basin area of northern Ontario. This borehole was drilled as part of the Hydrocarbon Energy Resources Program of the Ministry of Natural Resources and was funded by the Ontario Ministry of Treasury and Economics under the Board of Industrial Leadership and Development (BILD). The entire Phanerozoic section was to be cored, thereby permitting an improved assessment of the lignite, oil shale and conventional oil and gas resources of the region.

This report is divided into five sections. The first section is an introduction and includes these general remarks, a review of the geology of the Moose River Basin, and a statement of the aims of the Schlievert Lake borehole project. The second part is an operations report on the drilling of the borehole, and includes some recommendations concerning drilling techniques suitable for the area. The third section presents the results of observations performed on both the core taken from the hole (geological logging, palynology) and tests on the hole itself (geophysical logging). The final two sections are a discussion of the relevance of the results presented to the interpretation of the regional geology and mineral resources of the area.

Geology of the Moose River Basin

Because of the virtually complete coverage of the area of the Moose River Basin by swamp and muskeg the Phanerozoic geology of the basin is poorly known. Early work (e.g. Bell 1877; Williams 1920) was concentrated on the relatively scarce riverside outcrops. However, subsequent drilling activities such as the sinking of the Onakawana "A", Jaab Lake and Campbell Lake holes (Dyer 1931, 1932; Ontario Department of Mines, 1949, 1950), provided evidence which, together with comprehensive outcrop studies, allowed the construction of more precise regional stratigraphic sections and geological maps (Sanford and Norris, 1975). Figure 1 shows a generalized map of the geology of the Moose River Basin and a stratigraphic cross section according to these authors.

Paleozoic Stratigraphy

The oldest Paleozoic strata found in the Moose River Basin are of Ordovician age and consist of shallow marine or supratidal carbonates referred to the Red Head Rapids Formation and Churchill River Group. Their presence in the subsurface throughout the Moose River Basin is only inferred (see Sanford and Norris 1975, Figure 22). Similarly, two Middle Silurian units present on the north side of the Moose

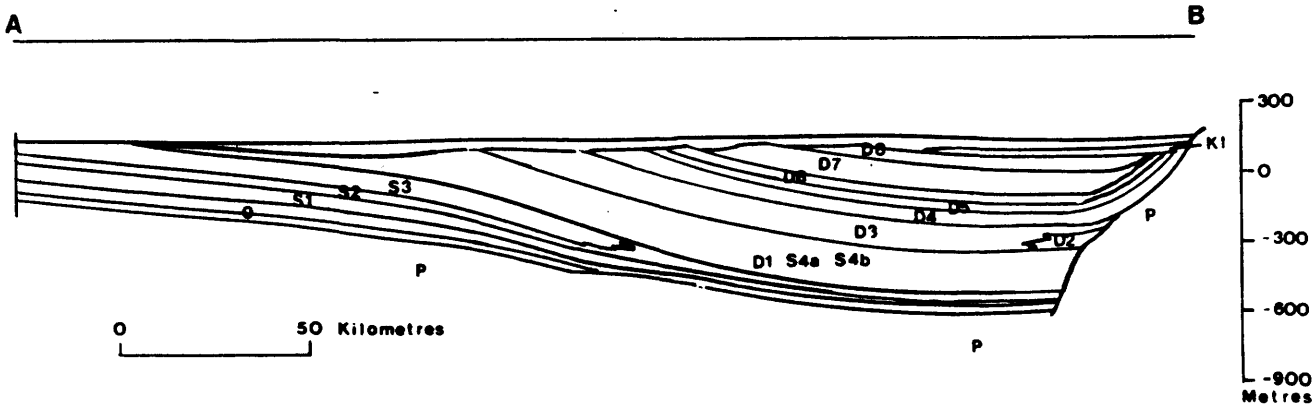
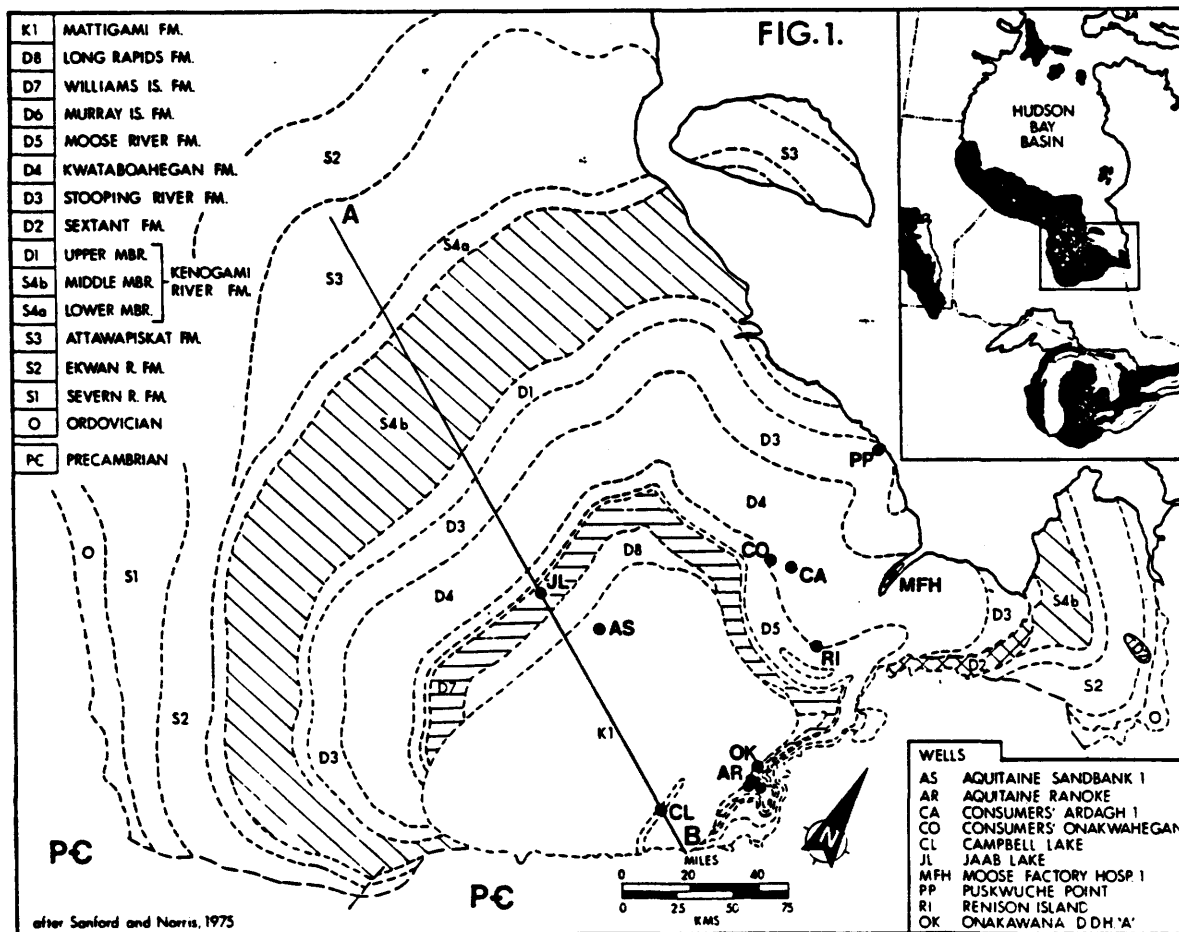


FIGURE 1. Generalised Geology Map of the Moose River Basin and Stratigraphic Cross Section

River Basin (Severn River and Attawapiskat Formations) are not known in the subsurface of the basin. These and the Ekwan River Formation (interpreted as being present in the O.D.M. Jaab Lake well) are equivalent in age (Niagaran) and overall environment of deposition (basin margin reef complex and related carbonates) to the Dyer Bay to Amabel Formations sequence of the northern Michigan Basin (Sanford and Norris 1973).

The only strata of Silurian age definitely widespread in the Moose River Basin are those of the lower part (lower member and lower part of the middle member) of the Kenogami River Formation. Redbeds characteristic of the middle member of this formation outcrop on the southern edge of the basin. The entire formation was intersected in the Jaab Lake borehole. The lower member consists of subtidal and supratidal carbonates.

Devonian strata make up most of the Paleozoic stratigraphic sequence of the Moose River Basin. In upward sequence, they are divided into the Kenogami River (upper member), Sextant, Stopping River, Kwataboahegan, Moose River, Murray Island, Williams Island and Long Rapids Formations (see Figure 3, from Sanford and Norris 1973). All but the Sextant and Long Rapids Formations are marine carbonate units, with significant evaporites in the Moose River Formation and shale in the Williams Island Formation. Stoakes (1975) interpreted the carbonate sequence as the product of a transgressing epeiric sea. Solution of

evaporites in the Moose River Formation and the open texture of the Kwataboahagan Formation provide enhanced porosity and therefore hydrocarbon reservoir potential. The Sextant Formation is a mainly terrigenous unit ascribed by Stoakes (1975) to reworking of coastal sediments during the initial stages of the transgression. However, Sanford and Norris (1975) refer to it as a continental facies.

Overlying the predominantly carbonate sequence of the Lower and Middle Devonian lies the Upper Devonian Long Rapids Formation. This unit is the lithostratigraphic and biostratigraphic representative in the Moose River Basin of the widespread black shale facies known as the Kettle Point Formation (southern Ontario), Antrim Shale (Michigan), Ohio Shale (Allegheny Trough), New Albany Shale (Illinois) and Chattanooga Shale (Tennessee). Preliminary determination of its total organic carbon content by OGS indicate that it has good potential as an oil shale, and it is presently under study as such.

The occurrence of diamonds in glacial drift along the Abitibi River is reported by Satterly (1971). The potential for discovery of diamond-bearing kimberlite pipes is considered significant; Selco Exploration Company Limited, in an extensive drilling program in the Moose River Basin, have encountered many examples of kimberlitic breccias (Exploration Report Files, Geoscience Data Centre, Ontario Geological Survey).

Mesozoic Stratigraphy

Unconsolidated Mesozoic sediments occur in the southeastern part of the Moose River Basin. Interest in these units has been sporadic over the century since Bell (1877) reported lignite along the Missinaibi River. Two periods of drilling activity by the Ontario Department of Mines (1926-1933) and by the Ontario Geological Survey from 1975 to the present time have provided the basis for subdividing the Mesozoic strata (Verma 1982; Telford 1982). Two lithostratigraphic units can be identified. The Middle Jurassic Mistuskwia Beds are restricted to the central part of the Mesozoic basin, and have only been observed in drill samples. They consist of varicoloured calcareous clays with thin white calcareous quartz sands. Overlying the Mistuskwia Beds disconformably, the Mattagami Formation (Lower Cretaceous) is the Mesozoic unit of economic interest. It consists of a highly variable sequence of varicoloured clays, quartz sand and detrital and in situ lignite. Try et al. (1984) consider these sediments to represent the product of a large northwesterly flowing anastomosing river system, the location of lignite deposits being controlled in part by the location of bedrock highs. However, using more recently available data Telford and Russell (1984) show that the assumptions of Devonian bedrock topography used by Try et al. may be in error.

Quaternary Stratigraphy

The Quaternary geology of the entire Hudson Bay-James Bay area is poorly known. Skinner (1973) provides an account of the Quaternary stratigraphy of the Moose River Basin, but many of his inferences are tentative. He reports the existence of three tills in the Moose River Basin which underlie interglacial sediments. These tills, which Skinner believed recorded oscillations of a retreating ice margin, were deposited by an ice advance from the northeast. The tills are separated by intertill glaciolacustrine sediments displaying south facing paleocurrents indicating blockage of the natural drainage to the north.

Overlying this till sequence in the Moose River Basin is a series of deposits termed the Missinaibi Formation. The Missinaibi Formation is an interglacial sequence of probable Sangamonian age of marine, fluvial and organic sediments. The organic rich component of the Missinaibi - the Forest Peat member - has been confused with the lignite of the Lower Cretaceous Mattagami Formation in the past. Overlying the Missinaibi Formation are, in ascending order, the Adam and Kipling Tills. The exact age of these tills is in doubt, the nonglacial unit separating the two tills being either Late or Middle Wisconsinan. Succeeding the deposition of the Wisconsinan tills, a period of lacustrine, then marine sedimentation ensued. Isostatic uplift slowly brought the Moose River Basin above sea level, halting

sedimentation in the area about 6000 years ago. Since then extensive peat bogs and spruce forests have developed.

Aims of Schlievert Lake Borehole

The Moose River Basin area has potential for resource development in the industrial mineral and energy sectors. In the former sector, the Cretaceous silica sands and kaolinitic clays have been the subject of considerable interest (Vos 1982). However, an improved assessment of the energy resource of the area was the overall aim of the Schlievert Lake borehole project. According to Try et al. (1984), the area around the Schlievert Lakes should be a promising area for development of lignite seams in the Cretaceous deposits. Mapping by the Geological Survey of Canada (Sanford and Norris 1975) shows the presence of the Long Rapids Formation in the subsurface of the area. Organic carbon contents determined by OGS and the yield of oil of 3.6 gallons/ton reported by Martison (1953) make this unit a potential oil shale. Sanford and Norris (1973) cite the possibility of oil and gas accumulations in zones of porosity formed by dissolution of evaporites in the Devonian carbonate units. By coring the entire Phanerozoic section (Quaternary to top of Precambrian), at Schlievert Lake, the aim was to provide a base of high quality, easily accessible data with which a more reliable evaluation of the hydrocarbon energy resources of the Moose River Basin can be

made. In addition, data concerning the nature of the crystalline rocks underlying the sedimentary pile would add to knowledge of the Precambrian geology of the province.

2. TECHNICAL OPERATIONS

Account of Drilling Operations

In the fall of 1983, the Ontario Geological Survey contracted with Longyear Canada Inc. of North Bay to drill the Schlievert Lake borehole.

The drilling contractors provided equipment to complete a diamond drill hole to 750 metres. The drill used was a diesel powered, 110 horsepower, GMC Longyear '44', equipped with slow beveled gears. It had a feed stroke of 40 inches and a 12 metre drill tower. A Twin 435 water pump with 265 litre/minute capacity was also used. Various weight muds were mixed to control caving and slumping of unconsolidated sediments while drilling. Drilling was done on a 24-hour basis. The accessibility to the drill from the camp permitted 24-hour surveillance of the operation by the foreman and the OGS representative.

Continuous coring of the Pleistocene, Cretaceous and Paleozoic sediments was desired. The unconsolidated nature of the post-Paleozoic sediments necessitated triple tube coring (a thin walled split tube inside the core barrel), to obtain the best recovery. This method was successful using

PQ, HQ and NQ core diameters through tills, clays, shales, mudstones and highly fractured and/or porous limestones.

Table 1 lists core diameters and depth intervals with percentage core recovery. Split spoon sampling was attempted in unconsolidated sand zones associated with poor core recovery.

TABLE 1. CORING DATA SUMMARY

Core Size		Cored Interval		Total Core Recovery	Percentage Core Recovery
Type	Diameter	From	To		
PQ	8.49 cm (3.345 in)	11.95 m (39.2 ft)	103.6 m (340.0 ft)	91.68 m (300.8 ft)	79% or 92% *
HQ	6.35 cm (2.500 in)	103.6 m (340 ft)	351.4 m (1153 ft)	247.8 m (813 ft)	96.4% or 98% **
NQ	4.76 cm (1.874 in)	351.4 m (1153 ft)	624.5 m (2049 ft)	273.1 m (896 ft)	100%

* Applicable figure if the sand section between 68.0 m - 103.6 m (233 ft - 340 ft) from which no core was recovered is excluded.

** Applicable figure if the sand section between 103.6 m - 122.9 m (340 ft - 400.3 ft) from which no core was recovered is excluded.

Table 2 and Figure 2 provide a sequential description of intended and actual drilling procedures. They are summarized below. The upper 15 metres of sediments in the Moose River Basin are often unconsolidated and too loose to be cored easily and were, consequently, cased off. The two initial casing sizes used were SW (168.2 mm) and PW (139.7 mm) set at 8.8 metres and 12.8 metres respectively. PO coring of the Pleistocene clay-sand-pebble tills commenced at 12.8 metres and continued through to 103.5 metres. Unconsolidated sands prevented further PO advancement.

Reduction from PO to HO diameter rods was necessary to continue drilling because the Pleistocene sands, to 123 metres depth, were impeding drilling progress. After these sands were cased off, drilling through the surficial deposits resumed and proceeded to 185 metres. After geophysical logging, extreme difficulty in casing off the surficial deposits was encountered; eventually surface casing was cemented in at 167.5 metres. HO core was obtained to a depth of 351.4 metres.

Shearing of the HO rods at the level of the Devonian mudstones and shales required reduction to NO to allow further coring. HO rods were then used as NW casing. NO coring continued from 351.4 metres to the final depth of 624.5 metres. Table 3 is a summary of the drilling hours. After final geophysical logging, five cement plugs were placed in the hole, and the HO rods (NW casing) and part of the HW casing retrieved.

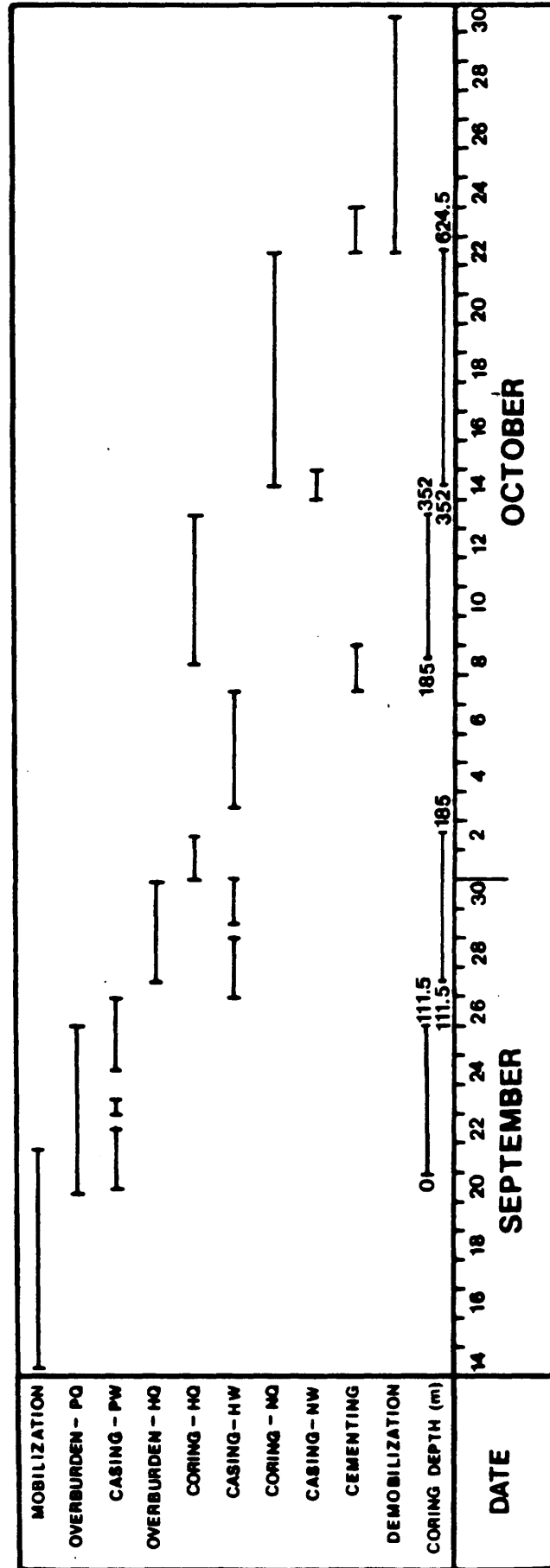


FIGURE 2. Schlievert Lake Borehole Daily Analysis

TABLE 2. PROPOSED AND ACTUAL DRILLING PROGRAMME

<u>Proposed</u>	<u>Actual</u>
1. Run collar of SW casing 6 metres into surficial deposits.	1. Ran SW casing to 8.8 metres.
2. Commence coring. Should no core be recovered, a split spoon sample would be taken. Continue PQ coring until necessary to reduce to HQ.	2. PQ coring continued to 103.5 metres but was terminated due to poor recovery in an unconsolidated sand sequence. Split spoon samples taken yielded poor results, consequently a 55 metre sand section is unrepresented. Reduction to HQ coring was necessary due to the following problems associated with the sand layers: <ul style="list-style-type: none">i) Sand would follow the core tube up the rods when pulling, necessitating flushing the rods of sand before the drilling could recommence.ii) sanding in (the packing in of sand around the core tube preventing its removal) required all the rods to be pulled out of the hole.iii) Slumping and caving of the sand during drilling necessitated higher torque to be applied to advance the drill. Casing off the sands alleviated this problem.iv) PW casing shoes wore out before they could advance the casing significant distances through sand or became stuck.
3. Drill 15 metres of PQ or HQ into bedrock, insert plastic pipe through the PQ or HQ, pull the drill rods and log the hole.	3. HQ drilling continued through the unconsolidated sediments into a Devonian mudstone/shale sequence 185 metres below the surface. The plastic pipe was inserted, the casing pulled and the hole logged.

4. Pull the plastic pipe, ream hole using a 5 7/8" tricone and run casing 15 metres into bedrock. Cement casing, install B.O.P. and flare lines.

5. Drill HQ recovering HQ triple tube core to the Sextant Formation (approximately 340 metres). Pull the rods, log the hole, reduce to NQ and case off all lost circulation and cave areas with the HQ rods as NW casing.

6. Continue drilling hole in NQ to completion, 50 metres into Precambrian.

4. The plastic pipe was pulled out upon completion of the logging. The hole was reamed with a 3 7/8" tricone ledge-finder ahead of the HW casing to 170 metres below surface. However, the casing shoe was worn by this depth and pinched over the tricone bit. The ledge finder would therefore not release and all the HW casing had to be pulled. The HW casing was reamed with a casing shoe to a depth of 100 metres where it became stuck in sand. HQ rods, equipped with a tricone, were used inside the HW casing to clear the sand; however, the tricone became stuck on the casing shoe. A jarring hammer was used to free the tricone and both the HQ rods and HW casing were pulled out. In a final attempt, the HW casing was reamed with a casing shoe to 167.5 metres below surface and cemented. The B.O.P. and flare lines were installed.

The HQ coring continued through several zones of lost circulation associated with the Moose River and Kwataboahegan Formations. The HQ rods sheared at approximately 200 metres depth while drilling in the Stooping River Formation 351.4 metres below the surface. A washout had developed in the mudstones and shales of the Williams Island Formation, below the HW casing shoe. The 152 metres of HQ rods down the hole were retrieved using fishing techniques. The hole was logged and a string of HQ rods used as NW casing for the NO coring. The HQ (NW) casing isolated the washout area and several zones of lost circulation.

The NQ coring commenced at 351.4 metres. NO rods sheared off inside the NW casing at a point approximately 200 metres below the surface. The NW casing had bowed in the washout zone and had to be straightened prior to drilling. The bow was straightened by the drill lifting the casing and welding it to the B.O.P. The NO coring continued into Precambrian

rock. At 624 metres the NQ rods sheared in the washout zone once more. The broken rods were replaced and the hole advanced 0.5 metres before shearing again. A decision was taken to terminate the borehole at this point, 36 metres into Precambrian.

7. Pull NQ rods and log hole.

7. The NQ rods were pulled and the hole was logged.

8. Cement the hole as per the Petroleum Resources Regulations.

8. A plugging program was provided by Petroleum Resources (London) as follows:

Plug 1: 550 metres below surface, 6 sacks of cement to 1 barrel of water.

Plug 2: 488 metres below surface, 6 sacks of cement to 1 barrel of water.

Plug 3: 355 metres below surface, 10 sacks of cement to 2 barrels of water.

Plug 4: 198 metres below surface, 10 sacks of cement to 2 barrels of water.

Plug 5: the surface plug consisted of 17 sacks of cement pumped down the hole.

The HQ rods were pulled as the cementing program proceeded. Four attempts at retrieving the HW casing by cutting were made. All were unsuccessful and only 18 metres (11%) of the HW casing was recovered.

9. Either cap surface casing or cut off below the ground level.

9. The casing was cut below ground level.

Table 3: Summary of Drilling Hours

	PO	HO	NO	TOTAL ³
Coring Hours	122	293	323	738
Casing Hours ¹	83	336	11	407
Caving Hours ²	30	173	5	208

Based on a 2-man drill crew

¹Included time required to drive and remove metal casing

²Included time required to redrill zones already drilled.

³The extreme difficulty in placing casing in the surficial deposits is reflected by the fact that only 55% of rig time was spent coring; the other 45% was spent in attempting to run casing or clearing caved zones.

Difficulties and Recommendations

Three major difficulties were encountered during the drilling of the Schlievert Lake borehole:

- a) extreme difficulty in casing the surficial deposits where thick sands were present;
- b) washouts in the soft mudstones of the Williams Island Formation;
- c) lost circulation zones in the Moose River and Kwataboahegan Formations.

Of these, (a) and (c) were anticipated from drilling projects either carried out by OGS or reported to the Petroleum Resources Section, M.N.R., London. Problem (b) was compounded by the effects of problem (c).

With regards to problem (a), experience at the Schlievert Lake borehole shows that when an extremely thick sequence of sands is encountered in boreholes of this type, the hole should be cased off permanently as soon as possible after penetration. The extreme problems in running the surface casing to bedrock were caused by having the 35 metre section of Pleistocene sand uncased and disturbed by various types of casing and rods for over a week. It is to the drillers credit that the overburden was ever cased off in the hole; the drill foreman, with over 20 years experience,

said it was the worst overburden problem he had ever encountered. With the problems encountered in mind, the priority for a certain borehole should be set, then the techniques and equipment selected which are suited for that purpose. Again with perfect hindsight, the best way (more efficient and, probably, cheaper) to have accomplished the aims of the Schlievert Lake borehole was to have used a coring/reverse circulation rig (e.g. the Acker or Longyear 38) for the overburden, then drill a completely new hole with a large tricone to permit casing the surficial deposits prior to coring the bedrock.

Problems (b) and (c) can be discussed together. Although circulation was never fully obtained throughout drilling of the bedrock, at no time did the lack of circulation cause excessive problems such as burning in or clogging of the bit. Inevitably, large volumes of mud were consumed because new mixes of mud were being prepared constantly. However, the more serious problem exacerbated by the lack of circulation was the washouts in the Williams Island Formation mudstones. As no mud circulated past these soft units, the vibration of the drill rods against them was damped. The mudstones therefore eroded away leaving washouts of up to at least 25 cm (10") diameter. Future drilling projects should plan to case off the Williams Island Formation as soon as possible, to prevent development of these washouts which cause rod breakage when drilling at

greater depths. The problems of lost circulation, although severe in the Moose River and Kwataboahegan Formations, seemed to persist to the bottom of the hole. These two named formations should be cased off, but good drilling techniques are still required for successful completion.

In conclusion, the following sequence of drilling is recommended for future projects of this type.

1. Simultaneously, drill (i) or a cored/reverse circulation NO hole with Longyear 38/ Acker type drill and (ii) a 6 3/4" tricone hole to bedrock, with a Longyear 44 type drill.
2. Geophysically log and plug the small borehole. Demobilize small drill rig.
3. Run PW casing to bedrock in the deep hole; seat with casing shoe.
4. Core to 15 m (50') into bedrock in PO size; if still in Williams Island Formation, core to base of it.
5. Cement HW casing in hole; install R.O.P., flarelines.
6. Core HO diameter to base of Kwataboahegan Formation.
7. Set NW casing with a shoe at that depth.
8. Complete hole in NO diameter.

Helicopter Support

The location of the Schlievert Lake borehole required a helicopter supported drill program. Ranger Helicopters Ltd. of Sault Ste. Marie provided a Bell 204 and a Bell 206 Jet Ranger for the duration of the project. The 204 was to be used primarily during mobilization and demobilization and the 206 for drill site servicing and interim trips to Kapuskasing. The detail of the use of the helicopters is shown in Figure 3. The separate categories are explained below.

Mobilization and Demobilization. The mobilization relied chiefly on the 204 for transporting the camp and drill from the staging area to the site. The preformed loads were constructed to weigh approximately 3,500 lbs., the maximum lifting capability of the 204, thereby eliminating 1/2 load trips. The round trip flying time was approximately 1.5 hours during slinging operations. The 206 was useful during the demobilization when smaller loads (up to 1000 lbs.) were possible.

Interim Drilling Supplies. Drill servicing consisted of flying fuel, casing, mud and other supplies to the drill when required. Between the dates September 29 and October 3rd a large amount of 204 time was used. The loads carried by the 204 consisted of 3 loads of replacement fuel

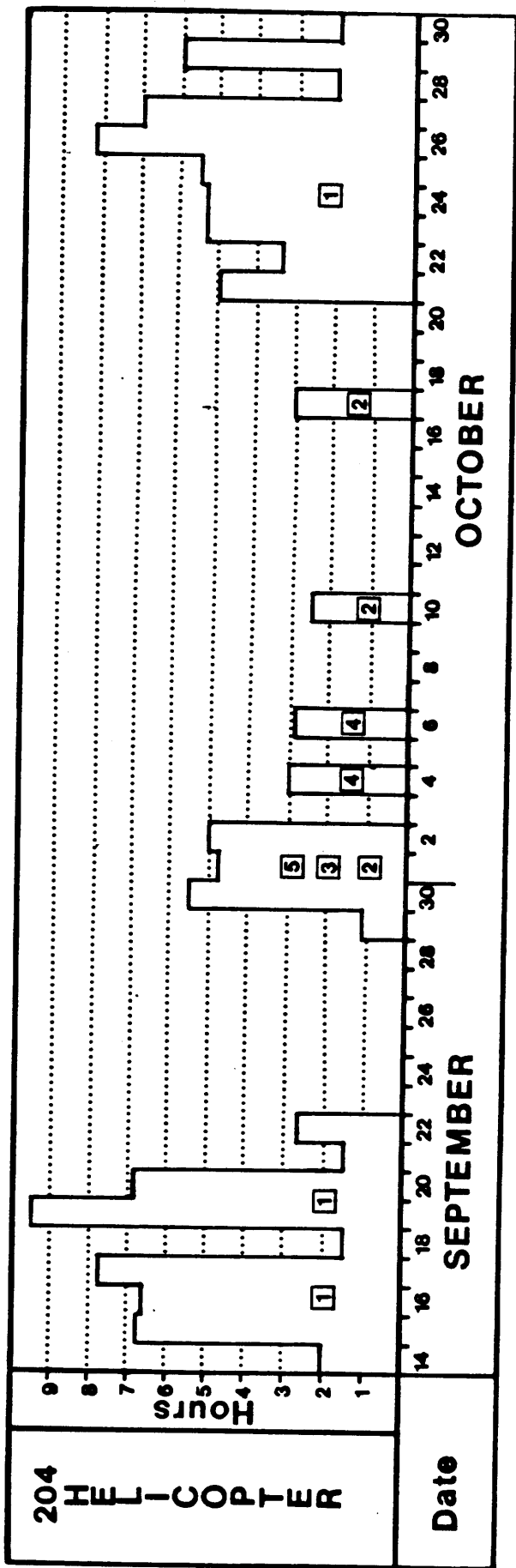
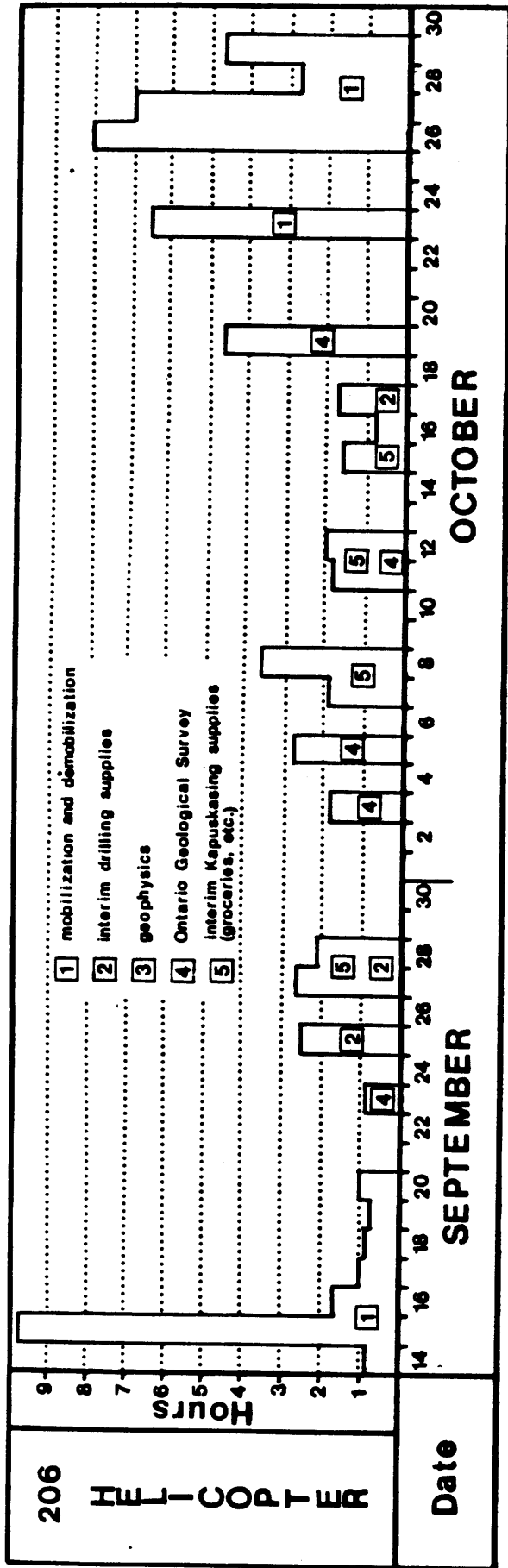


FIGURE 3. Helicopter Support Daily Analysis

(propane, stove oil and diesel), 3 loads of mud (overburden drilling had depleted on-site supplies), and 4 loads of HW casing (used for casing of the overburden). The flights on October 10 and October 17 were used for fuel, mud and casing during the NO coring.

Geophysics. BPB Instruments, of Calgary, performed the down hole geophysics. The equipment was housed in a box 8' x 4' x 4' and was mobilized from the BPB pick-up truck at the staging area. The box did not sling well (i.e. twisting, swaying), due to its rectangular shape combined with a 60 km/hour head wind. These factors explain the 1.1 hours required to sling the box one way to the drill site. During the return flight, the box was flown with a spruce tree attached to the roof. The altered aerodynamics caused by the tree made the box take a straighter flight path.

Ontario Geological Survey. The helicopters were available for use by the OGS personnel on site. Several Moose River Basin outcrops were visited during 5 days in October (3rd-6th, 19th) which accounted for approximately 15 hours of helicopter time. The helicopter was also used for transportation to the phone in Smoky Falls where direct communication to OGS, Toronto could be made. Two flights to Kapuskasing were also made to meet OGS staff at the airport when it was deemed necessary.

Interim Kapuskasing Supplies. A grocery flight to Kapuskasing was made on a weekly basis. Drilling supplies awaiting pick-up from the transport or bus lines would also be incorporated into this flight. However, many non-grocery flights were also made. The lost circulation zones caused unexpected depletion of the mud supply and it was necessary to have it delivered as soon as possible or the drill crew would be put on stand by. Two emergency health-related trips were also made to Kapuskasing.

3. GEOLOGY OF SCHLIEVERT LAKE BOREHOLE

Borehole Logs

The various sections of the core were logged by the following OGS personnel.

Depth Range (metres)	Person
12.0-122.0	C.L. Baker
122.0-154.0	P.G. Telford
154.0-588.2	D.J. Russell
588.2-624.5	J.W. Sanderson

Preliminary on-site logging of the core retrieved from the upper part of the borehole revealed a very thick unconsolidated section, which was initially regarded as a Quaternary section of tills and glaciofluvial sands overlying a Cretaceous section of clays and quartz sands. Subsequent analysis of pollen from the lower section revealed no flora other than Quaternary or Recent forms. This section is therefore included in the Quaternary section.

Figure 4 illustrates the generalised stratigraphy of the Schlievert Lake borehole.

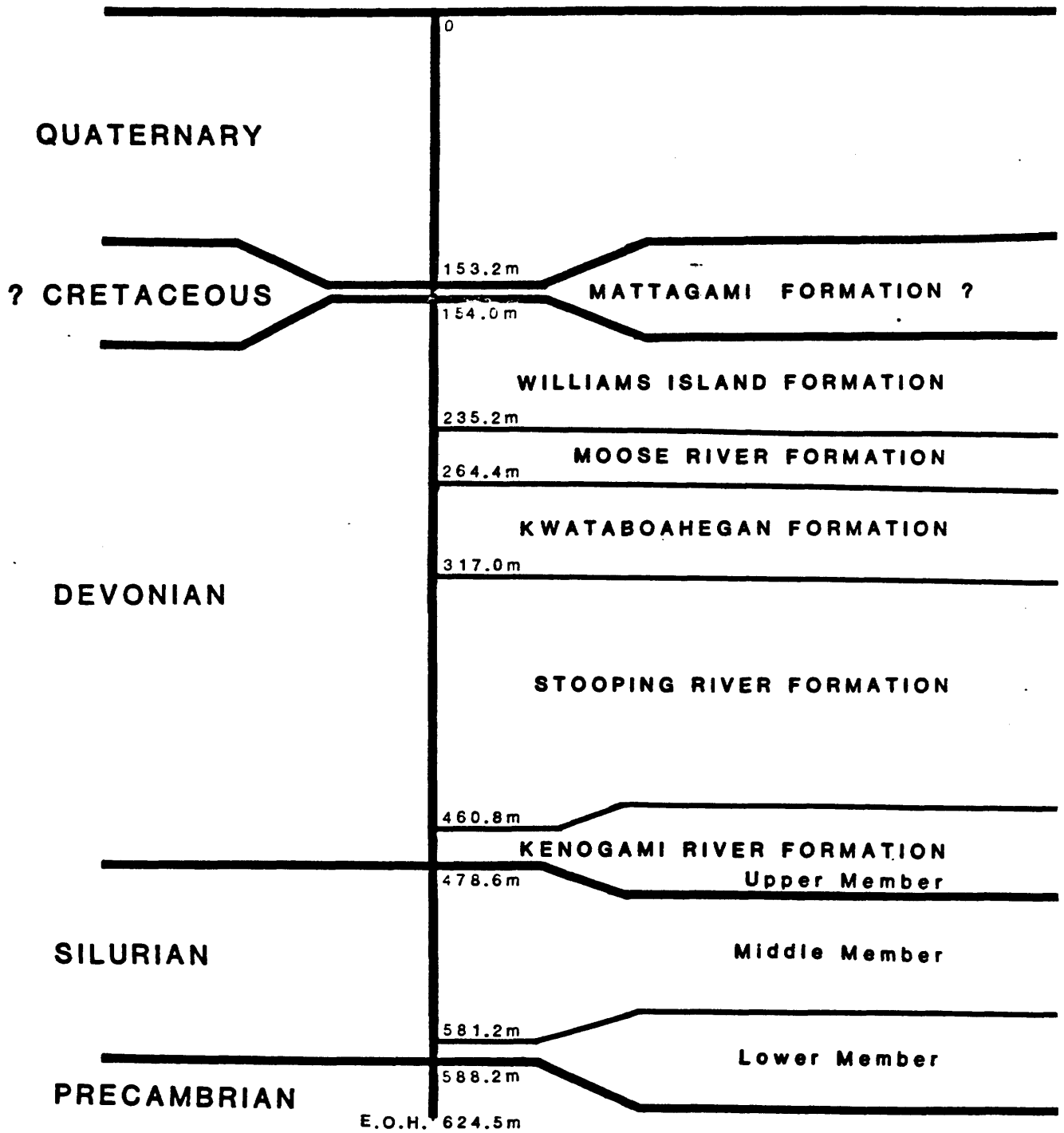


FIGURE 4. Generalised Stratigraphy of the Schlievert Lake Borehole.

The complete borehole core log is given in Appendix A. Where recovery was poor (e.g. in the Quaternary section), inferences concerning gross lithology and location of lithological contacts were taken from geophysical logs, as noted in Appendix A.

Geophysical Logs

Geophysical logging was carried out by B.P.B. Instruments Ltd. of Calgary. Table 5 shows the sections logged using different logging tools.

Depth range (metres)	Logging Tools used	Casing
0-182	CCS	Plastic to 182 m
0-184	Neutron	Plastic to 184 m
0-344	CCS	Steel to 167.8 m
48-344	Neutron	Steel to 167.8 m
167-342	Focussed electric	Steel to 167.8 m
280-618	CCS	Steel to 352 m
280-620	Neutron	Steel to 352 m
330-590	Focussed electric	Steel to 352 m

Table 4. Sections of Schlievert Lake Hole logged with various tools, casing types. CCS tool is a combined gamma ray, linear gamma-gamma density, caliper tool. The neutron tool also carried a gamma ray tool.

The logs produced by the various tools are enclosed in the back pocket of this report. The unconsolidated sections are shown at a vertical scale of 1:100, the bedrock at 1:200. A problem in using a slim-line focussed electric tool to determine formation resistivity is encountered when the resistivity of the borehole is much less than that of the formation. In this case, a "spikey" response is seen in the focussed electric log, and results of this log are not reliable. However, these logs are included for completeness sake.

Palynolgy

Nine samples (as indicated in the borehole log, Appendix A) of generally argillaceous units from the section initially regarded as Cretaceous Mattagami Formation were taken for palynological analysis by G. Norris and P. Zippi of the Department of Geology, University of Toronto. They report that the section from 127.0 m to 150.6 m contains only Quaternary-age pollen such as Pinus, Picea and Betula, with no Cretaceous forms. The samples from 152.7 m and 156.7 m were virtually barren, with only some poorly preserved bisaccate pollen of unknown affinities.

4. DISCUSSION OF RESULTS

Quaternary Strata (CLB)

No core was recovered from the upper 12.0 m of the Schlievert Lake hole so that surface casing could be set. Bluff sections in the area of the drill hole indicate that a thin veneer of organic material lies directly on till. It is presumed, but not certain, that this till is the same unit encountered below 12 m.

The till recovered between 12 m and 54.7 m is remarkably uniform in appearance, composition and physical characteristics. This silt till is dense, brown-grey and contains between 5 and 10 percent clasts. The clasts are usually striated and range from angular to subangular in shape. Pebble counts are dominated by Paleozoic carbonates (60%-80%) while Precambrian crystalline rocks account for an average of 10% of the clasts. Black greywacke and/or arkose comprise the majority of the remaining clasts (10%-30%). The greywacke/arkose clasts are considered to be Proterozoic in age and may have been derived from either the Sutton Ridge on the western side of James Bay or the Circum-Ungava Geosyncline on the eastern side of Hudson Bay.

The till appears massive and structureless with the exception of the glaciolacustrine bands detailed in the drill log (Appendix A). The glaciolacustrine zones, occurring at 15.8-17.4 m and 30.8-32.2 m, appear to have

been deposited in an ice proximal environment. This is indicated by the texture of the material, the abundance of grit size clasts deposited as dropstones and, in the case of the lower zone, the interbedding with flow till bands. Contacts of the till and clayey bands are both sharp and gradational.

The organic rich silt and sand below the till (54.7-66.1 m) is tentatively correlated with the Missinaibi Formation. The texture and composition of the material indicate deposition in a shallow water environment. The underlying thick sequence of stratified sands and gravels, into which the upper material grades, is of fluvial origin. Very poor recovery from 76.8 m to 122.0 m precludes a detailed discussion of these sediments, however, they are presumed to be interglacial sediments of Sangamonian age.

The series of interbedded clay and gravelly units occurring from 122.0 m to 153.2 m was field logged as Cretaceous based on its appearance. Palynological examination, however, determined the strata to be Quaternary in age. The exact age and correlation of these beds is somewhat perplexing. The material bears little resemblance to the Missinaibi Formation at other locations. It is possible that this lower organic bearing zone predates the Sangamon and represents an older interglacial. The character of the sediments below 122.0 m indicates deposition in a shallow water-subaerial environment. Detailed palynological work and clay mineralogy may provide

additional information to aid in determining the age and climatic conditions during deposition.

Absence of Mesozoic Strata (PGT & DJR)

That virtually no Jurassic or Cretaceous strata occur in the Schlievert Lake borehole was revealed only by palynological analysis of the lower 32 m of unconsolidated sediments. Although containing some lithologies which were not typical of the Mistuskwia Beds or the Mattagami Formation, the gross lithology of alternating clays and silica-rich sand and gravel appeared to fit the overall definition of the Mattagami Formation. The negative impact on the lignite resource potential of the restricted area around Schlievert Lake is obvious. However, perhaps a more significant impact of this finding is to throw into question at least some of the results of previous drilling, especially if interpretations of unconsolidated sediment stratigraphy were dependent on samples provided by reverse circulation drilling methods. Without palynological control, it may be that these Quaternary-age deposits would be regarded as Cretaceous when seen in a disturbed state. However, given the core available from the Schlievert Lake borehole, it should now be possible to review previous drillhole data to confirm or refute the presence of Cretaceous strata.

Comparison of the gamma-ray and neutron-neutron logs from the relevant section of the Schlievert Lake borehole with those from a deep clayey sequence of definite Cretaceous age (borehole O.G.S. 83-05, Watts, Griffis and McQuat, 1984a) reveals no clear difference in geophysical log response. However, the use of geophysical logs should not be discounted as a means of distinguishing between these units, since coarse-grained parts of the Cretaceous sequence in OGS 83-05 were not logged. A more detailed study may reveal geophysical criteria of use in this problem. However, detailed lithological logging and palynological analysis is the only method of distinguishing Cretaceous from Quaternary sediments at present. As stated above, the strata originally considered as Cretaceous are of problematic age. Clearly, the establishment of a better basis of knowledge of the Pre-Wisconsinan Quaternary history of the Moose River Basin is critical in both the resolution of particular problems such as the logging of individual boreholes and in the construction of regional syntheses such as Cretaceous isopach maps.

Paleozoic Strata (DJR & PGT)

Each Paleozoic formation will be reviewed, in downward order, comparing the lithology, contacts and thickness of the unit in the Schlievert Lake borehole to that reported by Sanford and Norris (1973, 1975) and Sanford et al. (1968) for the Moose River Basin.

Long Rapids Formation (Upper Devonian). Although the Long Rapids Formation is shown as underlying the area around the Schlievert Lake borehole site by Sanford and Norris (1975), it was not intersected in this borehole. This observation, allied with drilling data obtained during the winter of 1984 (Watts, Griffis and McOuat, 1984b), has indicated a much more restricted subcrop area for this potential oil shale unit than was originally thought (Telford and Russell, 1984). Based on the thickness of the Williams Island Formation found at Schlievert Lake, and the lithology of the topmost bedrock units, the bedrock surface may be very close to the contact between the Long Rapids and the Williams Island formations, with the relatively easily eroded shale of the Long Rapids Formation having been removed.

Williams Island Formation (Middle and Upper Devonian). The Williams Island Formation, as defined by Sanford and Norris (1975, p.63) "includes all the limestone and shale between the Murray Island Formation below and dark shale of the Long Rapids Formation above ... and may be subdivided into a lower shale and an upper carbonate member". These authors speculate that the lower contact is disconformable, and characterise the upper contact as sharp. Thicknesses reported by Sanford and Norris (1973, 1975) range, for upper and lower members, from 33.2 m to 44.8 m and 36.6 m to 46.9 m respectively.

The upper carbonate member of the formation is 28.5 m thick in the Schlievert Lake borehole, the lower shaly member being 48.2 m thick. Thus, relatively little of the upper member is apparently missing. The lithology of this member is somewhat shaly, but is easily recognizable as of Williams Island Formation. The regolith developed on the formation and the underlying ten metres has the appearance of a weathering profile developed by solution of carbonate rocks, i.e. karstic weathering. The brecciation of the topmost limestone, with an intact zone beneath, suggests that some sinkhole-type features may exist in the area. If the borehole was actually situated in an old sinkhole developed in pre-Sangamonian time, this may explain the presence of thick Missinaibi Formation sediments at this site.

The lower member and the lower part of the upper member are affected by brecciation, the intensity of which increases downwards. This is interpreted as being caused by removal of evaporites from lower formations. This disturbance is best shown in interbedded limestone/shale units, but is reflected in the massive mudstones by the slickensided shears at 45° to the core axis. Little can be said regarding the contacts of the Williams Island Formation since the top contact is missing and the lower contact is disturbed.

Murray Island Formation (Middle Devonian). Sanford et al. (1968) defined this unit as a relatively thin sequence of fossiliferous limestones between the Moose River and Williams Island Formations. In boreholes close to the Schlievert Lakes, it is generally a tan and buff calcarenite. Upper and lower contacts are reported as disconformable, with the formation thicknesses varying from 6.1 m to 19.8 m. Because of brecciation, identification of the very thin (100 mm) zone at the base of the Williams Island Formation as Murray Island cannot be made with confidence. However, the presence of the distinctive fossiliferous lithology implies its widespread initial deposition but subsequent removal by differential erosion.

Moose River Formation (Middle Devonian). Sanford and Norris (1975) use Moose River Formation in the Hudson Bay area to refer to the gypsum and associated brecciated carbonate rocks overlying the Kwataboahegan Formation. In the southern part of the Moose River Basin, the gypsum has been removed widely by dissolution. Thicknesses vary widely because of this effect, from 28.6 m to 88.7 m. The contact with the overlying Murray Island Formation is reported as sharp and undulating; that with the Kwataboahegan is transitional.

The Schlievert Lake borehole is sited in an area of relatively thin, evaporite-poor Moose River Formation. The thickness, 29.2 m, is only slightly greater than the minimum previously recorded. Inevitably, the formation is heavily brecciated, but moldic and vuggy porosity also lead to a highly porous and permeable texture. No gypsum was found in the Moose River Formation at this location, finely crystalline to sublithographic limestone being the dominant lithology. The top contact is disturbed due to brecciation; the lower contact is sharp, but no evidence for an erosional break exists.

The enhanced porosity and permeability of this unit makes it an ideal reservoir for hydrocarbons. No oil or gas has been reported from this formation in the past, presumably due to lack of a suitable source-rock in the Paleozoic sequence of the area.

Kwataboahegan Formation (Middle Devonian). The Kwataboahegan Formation is an extremely fossiliferous bituminous calcarenite (Sanford et al., 1968), generally interpreted as reefal or biohermal deposits (e.g. Stoakes 1975). Presumably as a result of this type of deposition its thickness varies considerably, with a maximum of 76.5 m. The upper contact is reported as being transitional, the lower sharp and disconformable but with little time break between the two units.

At Schlievert Lake, the lithology is very similar to that exposed at the type section on the Abitibi River and the thickness is well within the range for the formation. As mentioned above, the top contact is sharp but conformable; the lower contact is gradational and arbitrary.

Stooping River Formation (Lower Devonian). - Sanford and Norris (1975) characterise the Stooping River Formation as a sequence of generally nodular or thin-bedded, cherty carbonates with some very fossiliferous beds. The upper contact is discussed above; the lower contact is extremely variable, ranging from unconformably overlying Precambrian, Ordovician or Devonian strata to a transitional contact with either the same Devonian strata or those of the Sextant Formation. Thickness is again extremely variable, being typically less than 50 m, but extending to 143 m at Jaab Lake.

The range of lithologies intersected in the top 133 m of the strata referred to the Stooping River Formation at Schlievert Lake (cherty limestone and limestone) conform well with the rock types given by Sanford and Norris (1975). Chert is an important component of the upper 112 m. Included in the Stooping River Formation because of the predominance of carbonate material is a somewhat terrigenous unit, about 11 m thick, at the base of the formation. These

beds show evidence of turbidity current-type deposition (e.g. graded bedding) and are probably the far offshore facies of the continental or near-shore clastics of the Sextant Formation. The evidence of the Schlievert Lake borehole substantiates the statement of Sanford and Norris (1975, p.35) that the Sextant Formation beds "are overlain gradationally and merge northwards into carbonate beds of the Stooping River Formation". As such it is difficult to envisage the Sextant Formation as being continental in origin over most of the area. The base of the terrigenous unit (and therefore the base of the Stooping River Formation) is marked only by the absence of siliceous clastic material, and is therefore conformable, but quite sharp. The thickness of the whole unit (143.8 m) at Schlievert lake exceeds the previous maximum for the unit at Jaab Lake; the terrigenous unit was not present at that location. The area extending from Schlievert Lake to Jaab Lake probably constituted the basin centre during mid-Early Devonian time.

Kenogami River Formation (Lower Devonian and Upper Silurian). This unit has been subdivided into three members, with conformable contacts between them, as follows (Sanford et al. 1968):

<u>Member</u>	<u>Gross Lithology</u>	<u>Thickness</u>
Upper	brown, tan dolostone, dolostone breccia	11-33 m
Middle	red and green gypsiferous mud- stone; dolostone	145-168 m
Lower	brown dolostone with some gypsum	23-53 m

Sanford and Norris (1973) imply (their Figure 11) continuous sedimentation in the Moose River Basin from the underlying reefal, Middle Silurian carbonates of the Attawapiskat Formation. McGregor et al. (1970) showed, using palynomorphs, that the lower and most of the middle members of the Kenogami River Formation were of Silurian age.

Both upper and middle members of the Kenogami River Formation are well developed in the Schlievert Lake borehole. The upper member, 17.8 m thick, exhibits some evidence of brecciation in its upper part although the intense fracturing of the topmost section is more likely a later effect since no infilling or healing of fractures has occurred. The variety of lithologies and form of gypsum in the middle member (102.6 m thick) leads to a terrestrial interpretation for the environment of deposition of this unit. However, contacts between it and the overlying and underlying members appear conformable.

The lower member of the Kenogami River Formation is very thin (6.4 m) and almost entirely dolomitic. The lower

half of the member is slightly silty and shaly, grading down into the regolith of weathered Precambrian rock.

The distinctive nature of the middle member of the Kenogami River Formation and the small thickness of the underlying sediments leads to an unequivocal conclusion that the Attawapiskat, Ekwan and Severn River Formations (Silurian) and all the Ordovician units shown by Sanford and Norris (1973) as present in the Moose River Basin are absent in the Schlievert Lake borehole. It now seems that, unless the Schlievert Lakes area was an anomalously uplifted area throughout Ordovician and Early Silurian times, the southern half of the Moose River Basin is an entirely post-Late Silurian feature.

Precambrian Rocks. Below a thin silty dolomitic regolith, the Schlievert Lake borehole penetrated 36.3 m of fairly uniform gneissose granite. The gneissosity was inclined at about 30° to the core axis, with some coarser grained cross-cutting veinlets also occurring.

5. SUMMARY OF GEOLOGICAL FINDINGS IN SCHLIEVERT LAKE
BOREHOLE

The following preliminary conclusions may be drawn following logging and some analysis of core from the Schlievert Lake borehole.

1. Wisconsinan age sediments are represented by a thick till unit. The till is interbedded with thin glaciolacustrine layers indicating: 1) an oscillating ice front during deglaciation; and 2) the presence of an ice-marginal lake during retreat of the ice.
2. A thick sequence of pre-Wisconsinan, post Cretaceous clays and sands was identified. The upper portion, and perhaps the entire sequence, may represent the Sangamon-age, interglacial sediments of the Missinaibi Formation.
3. The only possible Mesozoic strata intersected in the borehole are the varicoloured clays overlying the Paleozoic regolith, which are tentatively assigned to the Cretaceous Mattagami Formation.
4. The Long Rapids Formation (black shale) has a much more restricted distribution in the Moose River Basin than previously thought.
5. A period of subaerial weathering following erosion of the Long Rapids Formation has caused karstic weathering of limestone of the upper member of the Williams Island Formation. This type of weathering

may be significant in the development of hydroelectric generating schemes in the area.

6. Complete removal of gypsum and/or other evaporite minerals from the Moose River Formation has caused intense brecciation in overlying units up to the middle of the Williams Island Formation. Cessation of upward migration of this collapse brecciation may have been caused by lateral flow of the plastic clays of the Williams Island Formation (lower member).

Alternatively, evaporite dissolution may have been restricted to periods prior to that when the upper parts of the formation were being deposited.

7. Because of the brecciation referred to above, reliable identification of the Murray Island Formation is difficult and characterisation of the type of contacts it has with overlying and underlying units is impossible.

8. The Sextant Formation, as usually defined, is absent from the Schlievert Lake borehole. However, the lower part of the Stopping River Formation contains terrigenous clastics in a dolomitic matrix, presumably equivalent to those of the Sextant Formation to the south.

9. Pre-Late Silurian sediments are absent at Schlievert Lake, implying a significant restriction of the Moose River Basin in Ordovician to Middle Silurian time.

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APPENDIX A

Lithological Log of the Schlievert Lake Borehole

LITHOLOGICAL LOG

O.G.S. 83-8d

Latitude: 50°33'17"

Longitude: 82°58'20"

Elevation: 178m a.s.l.+1.5m F.B.

0- 12.0 m No Recovery

Quaternary

- 12.0- 15.8 m SILT TILL; moderately gritty, poorly sorted, massive, dense; grey, calcareous; 5% grits and pebbles, of these 60% are Paleozoic.
- 15.8- 17.4 m LACUSTRINE CLAYEY SILT; slightly gritty, highly contorted bedding; appears to grade into overlying till.
- 17.4- 30.8 m SILT TILL; moderately to very gritty, poorly sorted, dense, massive; consistent brown-grey colour, calcareous. 5-10% clast content (grit and pebbles), angular to subangular, majority striated. Pebbles 75% Paleozoic carbonates, 15% Precambrian crystalline rocks, 10% arkose, greywackes. Boulders of bioclastic limestone (22m), mafic intrusive (23.5 m), quartzite (24.4 m). Till is remarkably uniform, but there is a slight increase in clast content with depth.
- 30.8- 32.2 m INTERBEDDED LACUSTRINE CLAY AND (FLOW?) TILL; clay has highly contorted silty laminae; frequent grits, no pebbles; occurs in bands 10 cm to 20 cm thick. Till bands are 5 cm to 10 cm thick; matrix is silt rich, poorly sorted; till is gritty, with scattered sub-angular to angular pebbles.
- 32.2- 33.7 m SILT TILL; as described above, 17.4 m - 30.8 m.
- 33.7- 33.8 m LACUSTRINE "BALL"; uneven, near vertical contact between gritty silty clay with silt till; bedding in lacustrine sediments is highly contorted.

- 33.8- 54.7 m SILT TILL; massive, dense, highly calcareous, with occasional blebs of red shale. Clasts (grits and pebbles) 5-10%, are angular to subrounded; scattered cobbles and boulders, most clasts striated. Proportion of carbonate clasts varies from 80% to 60%; black arkose/greywacke clasts from 10% to 35%; granitic clasts from 5% to 15%. Pebbles break cleanly away from matrix.
Till is very uniform; only exception is a 10 mm thick clay band at 40.8 m.
- 54.7- 66.1 m INTERBEDDED SAND AND ORGANIC (?) CLAYEY SILT TO SILTY CLAY; Sandy layers (65%) coarsen from silty very fine to fine sand downwards to a silty fine to medium sand at the base of the sequence; occasional grits throughout, sand is very calcareous. Silty and clayey layers (35%) vary from 1 mm to 40 mm thick, black to grey black, faintly laminated, moderately calcareous. Gives off a weak H₂S odour when cut. No clasts.
- 66.1- 76.8 m SAND; fine to medium grained, very uniform, grey to brown grey, horizontal stratification. Sand grains are angular to subangular predominantly quartz or carbonate (strong reaction to HCl); well sorted, no grits or pebbles.
- 76.8- 93.0 m SAND; less than 1% recovery; material appears to coarsen with depth; scattered gravel layers.
- 93.0- 96.9 m SAND; coarse to very coarse grained; poor recovery (about 30%), disturbed core. Sand is highly calcareous, angular to subangular, moderately to well sorted. Numerous grits present; scattered near base of unit.
- 96.9- 98.5 m SAND; medium to coarse grained; sand grains are angular to subangular, predominantly quartz and carbonate; moderately well sorted, no grits or pebbles.

- 98.5-100.0 m NO RECOVERY; geophysical logs indicate sandy lithology.
- 100.0-101.2 m SAND; coarse to very coarse grained, as in 93.0 m to 96.9 m limited recovery.
- 101.2-106.7 m NO RECOVERY; geophysical logs indicate sandy lithology.
- 106.7-112.8 m SAND; less than 2% recovery; gritty, coarse to very coarse grained sand, scarce small pebbles. Sand is clean, well sorted, grains are angular; pebbles are subrounded.
- 112.8-118.9 m SAND AND GRAVEL; less than 2% recovery; sand is poorly sorted medium to very coarse grained, subangular. Grits are subrounded to rounded. Clasts range from pebbles to cobbles, possibly boulders. Ratio of Paleozoic to Precambrian clasts is 2:1.
- 118.9-122.0 m NO RECOVERY; geophysical logs indicate sandy lithology.
- 122.0-140.4 m CLAY; predominantly green, varying from dark greenish grey to light grey green in centre of unit to greenish brown at base. Minor silty and sand grains and Precambrian grits and pebbles throughout, non-calcareous. Massive, unlaminated; some small scale slicken-sided fractures and scarce large fractures. Coarse quartz sand grains at 139.0 m; minor plant remains (rootlets) and sand grains at 140.2 m. Palynological Samples (Norris and Zippi):-
127.1 - 128.3 m
130.1 - 130.4 m
133.0 - 133.2 m
136.6 - 136.9 m
- 140.4-141.8 m CLAY; laminated light and dark greenish brown, laminae 2 mm thick. Upper 0.5 m of unit contains rip-up clasts of clay laminae. Minor silt, but no quartz sand grains. Palynological Samples (Norris and Zippi):
140.2 m
141.7 m

- 141.8-144.6 m SAND AND GRAVEL; highly variable, extremely poorly sorted unit.
- 144.6-149.4 m CLAY; dark greenish grey, becoming brownish at base; minor silt and pebbles. Massive, unlaminated, but with minor small scale fractures with some slickensided surfaces.
Palynological Sample (Norris and Zippi):
147.2 - 147.4 m
- 149.4-153.2 m SAND AND GRAVEL; very coarse grained sand and gravelly sand, poorly sorted, with minor silt and fine sand; abundant clasts up to boulder size. Sand is mainly quartz, with minor mafics; subrounded to rounded, with fewer frosted grains than above.
Palynological Sample (Norris and Zippi):
152.7 m

Pebbles are Paleozoic and Precambrian; larger clasts are Paleozoic, including claystone clasts and a 25 cm boulder of limestone at 151.5 m.

CRETACEOUS (?) MATTAGAMI FORMATION

- 153.2-154.0 m CLAY; varicoloured red, reddish brown, tan, green blue grey, weakly calcareous. Mottled texture in places, appears brecciated, with red and brown fragments in grey-green or blue grey matrix.

DEVONIAN
WILLIAMS ISLAND FORMATION

- 154.-159.7 m REGOLITH; weathered limestone, very fine grained with some colour laminations of light and dark grey; heavily brecciated with rubbly, clayey zones; top and bottom contacts indistinct, gradational.
Palynological Sample (Norris and Zippi):
156.7 m

- 159.7-170.2 m LIMESTONE; fine grained, sucrosic, generally light grey with some tan, brown grey laminations; very disturbed, with rubbly zones probably of karst-type weathering origin.

- 170.2-173.2 m DOLOMITIC LIMESTONE; as above (159.7-170.2 m), but slightly dolomitic and undisturbed. Some signs of leaching (vugs) are present, but no brecciation.
- 173.2-182.5 m INTERBEDDED SHALY LIMESTONE AND LIMESTONE; limestone is a calcisiltite, light grey, unfossiliferous; interbedded with dark very fine argillaceous limestone, with a few bituminous laminae. Brecciation is common, but is more intense at the base of the unit. Unit becomes more shaly towards base.
- 182.5-219.3 m MUDSTONE; grey, dark grey, slightly silty, calcareous and non-calcareous, non-fissile. High moisture content, causing plastic consistency. High angle shears (approx. 45° to core axis) occur throughout.
- 219.3-223.0 m INTERBEDDED LIMESTONE AND MUDSTONE (BRECCIATED); limestone is light grey, fine grained, with some quartz sand grains and a few vugs. Mudstone is grey to dark grey, plastic, non-calcareous, non-fissile.
- 223.0-230.7 m MUDSTONE; dark grey, non-calcareous, non-fissile, plastic, very homogeneous. Shears at 45° to core axis throughout. Base clear, but disturbed due to brecciation; marked by incoming dolostone.
- 230.7-235.2 m BRECCIATED LIMESTONE AND MUDSTONE; probably originally interbedded dolostone and mudstone; dolostone is calcareous in places, light grey to tan, very fine to medium grained with some calcisiltite layers and scattered recrystallization. Mudstone is grey, calcareous. Unit is heavily brecciated. A thin (100 mm) zone at base of the unit may represent an erosional remnant of the Murray Island Formation.

MOOSE RIVER FORMATION

- 235.2-241.2 m BRECCIATED LIMESTONE; slightly calcareous in parts, fine to medium grained; grey, buff in colour; unit is

characterised by very high porosity formed by vugs and brecciation caused by dissolution of (?) anhydrite.

- 241.2-247.4 m BRECCIATED LIMESTONE AND MUDSTONE; similar to 230.7-235.2 m (above), but with significantly higher mudstone content.
- 247.4-258.4 m BRECCIATED LIMESTONE; top part is light-grey to white, very finely crystalline to sublithographic, with some fine grains and quartz sand grains; non-porous, but disturbed laminae; grades down into heavily leached, rubbly zone of the same lithology and with many vugs; grain size is slightly coarser at base.
- 258.4-264.4 m DOLOMITIC LIMESTONE; tan, light grey becoming browner at base, very finely crystalline; texture ranges from nodular to bioturbated (toward the base) and faint colour laminations. Base is sharp, but conformable.

KWATABOAHEGAN FORMATION

- 264.4-317.0 m No systematic subdivision of the formation seems apparent; two basic lithologies alternate in units 3-4 metres thick.
- (a) Characteristic lithology of the formation is a highly fossiliferous limestone. The matrix is typically light grey and tan, medium crystalline, but most of the rock is made up of stromatoporoids, corals (halysitids, favositids) and crinoid fragments. Where stromatoporoids dominate, texture is coarsely laminar, often in association with bituminous, slightly shaly stringers.
- (b) The secondary lithology is a more massive, less clearly laminar, blue-grey, very finely to finely crystalline dolostone and calcareous dolostone; some recrystallization gives medium calcite crystals. Some very faint colour laminations (bluish-brownish grey) are present. Stromatoporoids are

absent; main fauna is brachiopods. Lithology is vuggy in places, formed by solution of fossils (i.e. moldic porosity). Some sandy sections. Base of formation is fairly sharp, conformable; marked by incoming nodular cherty horizons.

STOOPING RIVER FORMATION

- 317.0-429.6 m CHERTY LIMESTONE; fairly consistent unit, minor variation in colour, grain size. Generally finely to very finely crystalline, becomes sublithographic at base of unit. Buff, brownish grey and grey in colour, becomes darker grey at base, with some fine colour laminations in these darker lithologies. Base is sharp, apparently disconformable, marked by loss of nodular chert. Scattered large corals in upper part of unit, some bioclastic debris at 357.0 m. Chert is both chalky, white and harder, blue; nodules typically 50-80 mm diameter.
- 429.6-444.5 m LIMESTONE; light-grey grading down into darker and colour laminated grey; fine calcarenite at top becoming finely to very finely crystalline at base - both these changes reflect greater dolomite content at base. Some isolated chalky chert, usually as layers about 25 mm thick.
- 444.5-449.9 m DOLOSTONE; very light grey to white, very finely crystalline to sublithographic. Some faint colour laminations, but unit characterised by intense fracturing, with pyrite mineralization along some fractures. Gradational base, marked by incoming darker grey colour laminations, coincident with loss of fracturing.
- 449.9-460.8 m DOLOSTONE AND SANDY DOLOSTONE; also silty dolostone and thin sandstones. Dolostone is generally light grey or white, very fine grained to sublithographic, with scattered floating well rounded quartz sand grains. This lithology with siltstone laminae dominates at top of unit; middle is

sequence of disturbed (soft sediment deformation?) laminae of dolostone and silty dolostone; base of unit is series of fining upward sandstone alternating with dolostone. Sandstone is quartzose, medium to coarse, poorly sorted, dark grey with quartz pebbles (subangular to rounded) and dolostone intraclasts, with a clayey matrix. Base marked by lack of terrigenous component; sharp, but apparently conformable.

KENOGAMI RIVER FORMATION

Upper Member

- 460.8-469.7 m DOLOSTONE; faintly colour laminated (dark/light grey), very fine to sublithographic, with pinpoint porosity. Intensely fractured in upper part. Base gradational.
- 469.7-474.9 m DOLOSTONE; as above (460-8-469.7 m), but porosity is absent, and laminae often contorted (soft sediment deformation?).
- 474.9-478.6 m DOLOSTONE; interbedded light grey very fine to sublithographic dolostone (as above) with very finely crystalline grey and dark grey dolostone. Light grey beds have very small laths of anhydrite. Base conformable, but sharp.

SILURIAN

Middle Member

- 478.6-581.2 m RED AND GREEN MUDSTONE. Red silty non-calcareous mudstone with interbeds and laminations of green dolomitic mudstone and dolostone; gypsum mineralization as joint coatings and beds; and sandstone beds. Soft sediment deformation/brecciation at 488.3 m, 557.5 m, 531.9m. Honeycomb dolostone from 495.6 m to 498.0 m. Gypsum-poor, green mudstone dominates from 522.1 m to 552.2 m. Laminated green/red mudstone from 563.1 m to 565.7 m. Sandstone bands at around 561.4 m. Gypsum occurs as layers of satin spar below 566.0 m. Base is conformable, grades over 0.3 m, with loss of red colour.

Lower Member

581.2-587.6 m DOLOSTONE; grey, fine-medium crystalline, with a few floating quartz grains. Below 584.0 m, dolostone is silty, shaly with a few thin shale partings.

587.6-588.2 m REGOLITH; pebbles and boulders of granitic rock with dolomitic sandy, silty, shaly partings, joint coatings.

PRECAMBRIAN

588.2-624.5 m GNEISSOSE GRANITE; 30% quartz, 50% feldspar (mainly potassium feldspar), 20% mafics (amphibole, mica); gneissosity at about 30° to core axis; some cross-cutting pegmatites. Unit is generally very consistent.

624.5 m END OF HOLE.