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POTENTIAL GRANULAR DEPOSITS AND TERRAIN ANALYSIS OF SELECTED AREAS ON THE CAMERON HILLS, NORTHWEST TERRITORIES

J D MOLLARD AND ASSOCIATES LIMITED

CONSULTING CIVIL ENGINEERS AND ENGINEERING GEOLOGISTS

POTENTIAL GRANULAR DEPOSITS AND TERRAIN ANALYSIS OF SELECTED AREAS ON THE CAMERON HILLS, NORTHWEST TERRITORIES

Prepared for:

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POTENTIAL GRANULAR DEPOSITS AND TERRAIN ANALYSIS OF SELECTED AREAS ON THE CAMERON HILLS, NORTHWEST TERRITORIES

1. TERMS OF REFERENCE

Terms of reference as originally set out describe the study-area location, work statement, and deliverables as follows:

1.1 Study Area

The study area is located on the Cameron Hills Upland in the Northwest Territories, north of the NWT/Alberta boundary. The study focuses on three areas (Phase 1a, 1b and 2), which relate to progressive development by the oil and gas industry. These areas are defined by latitude and longitude below:

Area 1 of Phase 1a:

Minimum Latitude	60 degrees 00 minutes North
Maximum Latitude	60 degrees 06 minutes North
Minimum Longitude	117 degrees 25 minutes West
Maximum Longitude	117 degrees 41 minutes West

Area 2 of Phase 1b:

Minimum Latitude	60 degrees 00 minutes North
Maximum Latitude	60 degrees 06 minutes North
Minimum Longitude	117 degrees 11 minutes West on the north boundary
	117 degrees 18 minutes West on the south boundary
Maximum Longitude	117 degrees 25 minutes West

Area 3 of Phase 2:

Minimum Latitude	60 degrees 06 minutes North
Maximum Latitude	60 degrees 14 minutes North
Minimum Longitude	117 degrees 25 minutes West
Maximum Longitude	117 degrees 45 minutes West

1.2 Work Statement

The contractor will undertake the following work to the satisfaction of the Scientific Authority:

1. Obtain and assemble airphotos needed to cover the study area identified by latitude and longitude in item 1.1.
2. Prepare photomosaics of the three study areas.
3. Interpret aerial photographs of the study area to identify potential granular sources and clay deposits.
4. Outline the identified granular material prospects and clay deposits on photomosaics.
5. Provide estimates of potential volumes of the identified granular material prospects.
6. Map drainage patterns in the study area along with a complete interpretation of geographic features (terrain units) in the study area.
7. Prepare a covering report.
8. Deliver one copy of the accompanying mosaics and maps with terrain overlay to the scientific authority, and one additional copy for the technical advisor.

1.3 Deliverables

The contractor will submit the following items to the Scientific Authority:

a) Ten copies of a final report and associated figures, tables and appendices and one report on disk in WordPerfect 5.1 or 5.2, incorporating results of the study required by the above statement of work.

b) The associated materials shall include the following:

   i. photomosaics of the selected study areas
   ii. clay and granular material prospects outlined on photomosaics
   iii. volume estimates of granular material prospects
   iv. a map showing drainage patterns and complete interpretation of geographic features (terrain units) in the study areas
   v. a general statement on glacial history (regional surficial geology) of the study area
   vi. mylar or similar copies of all mosaics and maps produced during the project study

1.4 Additions to the Original Contract

On March 17, 1994, Mr. Stephen Traynor, Geotechnical Scientist, Land Management, Natural Resources and Environment, Indian and Northern Affairs Canada, Ottawa, visited this office and reviewed the study project.

The deliverables were reviewed in light of the complexity and variability of terrain conditions influencing access road and pipeline routes, well site development, and related environmental planning and management of resources.

Based on results of work carried out to March 17, 1994, it was agreed to extend the study area to cover the entire remainder of the Cameron Hills Upland east of longitude 117°45'W. This addition doubled the study area. The additional work was undertaken in large measure because identifiable granular material prospects are virtually non-existent on the upland away from the Cameron River valley in Phase 1a, Phase 1b and Phase 2 areas. Another concern was possible environmental restrictions involving extraction of sand and gravel from the Cameron River valley.

1.5 Study Cost

Original study cost was set at $10,972. Another $4000 was added for a total firm fixed cost of $14,792.

1.6 Completion Date

The study project is to be completed by March 31, 1994.

2. RESOURCE MATERIALS STUDIED

The following materials were obtained and interpreted during study of terrain conditions and potential construction material sources:

- One 1:250,000 NTS mapsheet.
- Four 1:50,000 NTS mapsheets with 10-m contours.
- Two bedrock geology maps of the study area.
- One set of 1:52,400 scale stereoscopic airphotos covering the entire Cameron Hills Upland east of longitude 117°45'W.
- One set of 1:25,000 stereoscopic airphotos covering the three study blocks designated Phase 1a, Phase 1b, and Phase 2.

3. BEDROCK GEOLOGY

Bedrock strata underlying the study area is buried by glacial drift deposits that are extraordinarily thick, ranging up to 305 m (1000 ft) thick in places. The rolling to hummocky surface of the Cameron Hills Upland lies approximately 500 m above the surrounding lowland plain. As a result, deep valleys (such as the lower Cameron River valley) and escarpments are expected to intercept Cretaceous bedrock strata along lower slopes. Bedrock underlying the Cameron Hills is composed of Cretaceous Shaftesbury Formation, which consists of marine shale strata separated by silty and fine sandy intervals, bentonite seams, and layers containing ironstone nodules (Figure 1). The Shaftesbury Formation is notorious for its tendency to develop large landslides along steep valley sides and escarpments (Plate 1).

4. SURFICIAL GEOLOGY

Above buried valleys on the Cameron Hills Upland, the overburden deposits on Shaftesbury shale consist of over 305 m (1000 ft) of mostly clay-rich bouldery till with interbeds of sand and gravel. The dominant surface material is lodgement clay till in smooth ground moraine, meltwater channelled moraine, fluted ground moraine, and hummocky stagnation moraine (Appendix 1, Plate 1 and Figure 2).

In essentially all level and gently sloping areas clayey till is blanketed with 1 to 3 m of organics in frozen peat plateau bogs. On long smooth slopes crossed by closely spaced shallow rills and larger channels, the till surface is often veneered by up to 1 m of organic deposits. And in larger and deeper hollows on the till surface, a thin layer of dominantly organic-rich silty pond and slopewash sediment occurs between surface peaty organics and the underlying hard till. Where this waterlaid sediment is unfrozen it is often soft or loose and weak, possessing a low bearing capacity.

In the far northern and northeastern parts of the Cameron Hills Upland in the Northwest Territories the terrain tends to be more dissected by meltwater channels and small valleys. Tracts of hummocky terrain are much more prevalent in this northern area. As well, more ribbed (string) fens and less peat plateau bogs occur in these northern reaches.

Potential granular deposits away from valley terraces and elevated floodplains along the lower Cameron River valley are virtually non-existent in Phase 1a, 1b and 2 areas. There are many kame-like deposits in the region north and east of Phase 1a, 1b and 2 areas.

Interestingly, there are few localities in Canada where glacial flutings are as strikingly expressed as they are in the Cameron Hills region in the Northwest Territories. There are at least three directions of continental ice flow in the region: two on the Cameron Hills Upland, with ice advance from N80°E and N55°E; and one on the lowland west of Tathlina Lake, with ice advance from the east (<u>Figure 2</u>).

Because the surface of the Cameron Hills Upland is roughly 500 m above the surrounding lowland, the temperature is lower. As a result, permafrost occurs in bogs on virtually all flatland and gentle slopes where the surface drainage is poor or impeded.

5. VEGETATION

Vegetation on the northeastern Cameron Hills was examined on two scales and ages of aerial photographs, and on one false-colour satellite MSS image. Tree cover is influenced by locally colder climate, and by a long history of forest fires. After fire it takes a long time before tall trees become re-established.

Better drained sites on escarpment slopes, the side of the Cameron River valley, margins of larger drainageways, and hill and ridge tops support a mixedwood forest consisting of deciduous (largely aspen) and coniferous (black spruce and white spruce) trees (Figure 3). On old burns and poorly drained mineral soils sites, the vegetation consists of a brushland with commonly occurring areas of treed muskeg (peat plateau bogs). In fact, peat plateau bogs cover nearly all level to gently sloping tracts south of the Cameron River valley. Here the vegetation consists of stunted black spruce, ericaceous shrubs, and a ground cover of Sphagnum moss and lichen. Where peatland is unfrozen in horizontal and ribbed fens, typically the vegetation consists of sedge meadows in hollows and sparse stunted tamarack and black spruce trees on slightly elevated areas (e.g. the strings in ribbed fens).

6. PERMAFROST AND PEATLANDS

Permafrost zones in the study area consist of widespread discontinuous permafrost because of the colder climate on the Cameron Hills Upland than in the surrounding lowland (Figure 4).

Essentially all nearly level areas with poor drainage south of about latitude 60°12'N contain ice-rich permafrost in peat bogs (Figures 5 and 6). These frozen peatlands are characterized by a scatter of small marshy thaw basins that are less than about 130 m across and mostly less than half that diameter -- say, about 65 m. These commonplace peat plateau bogs present a serious problem in road and airstrip construction, pipeline location and construction and weight balancing, and access to well sites because of their high ice content and sensitivity to disturbance.

Many gently sloping, narrow, flat-bottomed small valleys and significantly sloping upland channelways are characterized by ribbed fens where small ponds, called flarks, and wet sedge meadows are permafrost-free. Sporadic permafrost can be expected in strings on ribbed fens. Sedges and shrubs occur on horizontal and sloping fens, which are also expected to be largely permafrost-free.

Disturbance to the living vegetation on peat plateaus initiates thaw of ground ice, resulting in water-filled linear depressions along road ditches and pipelines. Therefore, so far as practical, peat plateaus (PB areas) should be avoided in route and site location. See Appendices 1 and 2 for the terrain legend and evaluation of the terrain units for access routing and gas well siting.

7. DRAINAGE PATTERNS

Drainage lines on the Cameron Hills Upland are shown best on the 1:50,000 NTS mapsheet (Plate 1). Rills and gullies have not been mapped because these fine drainage lines are so numerous they may be confused with the outlines of 19 terrain units, which already form a dense mosaic of lines. Finer and more closely spaced drainage features (shallow rills and somewhat larger drainageways) are included under descriptions of the different terrain units -- such as TR for till surfaces that are intensely rilled, and TC for sloping till surfaces that are cut by small channels that are larger and deeper than rills, which are often only a metre or so deep (Appendix 1).

The 450 to 500 m high escarpment surrounding the Cameron Hills Upland is dissected by large ravines and small valleys. Old landslide scars are common along the top of this escarpment (Plates 1 and 2).

Almost all surface runoff on peat plateaus is shed overland because of the frozen substrate. Minor runoff and snowmelt discharge into small thaw basins that are typically 50 to 70 m across and scattered across peat plateau bogs in a speckled pattern. Thus, drainage patterns may be evaluated from drainage lines appearing on the 1:50,000 NTS maps, with terrain overlay, and from the 1:50,000 photomosaics with terrain overlay, where certain units include a description of the typical drainage pattern (Appendices 1 and 2).

8. POTENTIAL GRANULAR MATERIAL SOURCES

Recognition of potential granular deposits on the Cameron Hills Upland in the Northwest Territories is difficult because prospects are forested where the soil material is unfrozen, and secondly because the diagnostic features on outwash landforms have been modified in appearance by a thick frozen silt and clay overburden. The frozen soil results in little or no infiltration, with the result that long-term runoff erosion rounds angular granular forms and destroys their identifying features in airphotos.

Because of these interpretive problems we purchased 1:52,400 scale airphotos covering a substantially larger area than the area covered by Phases 1a, 1b and 2. As a consequence, the entire area east of longitude 117°45'W was interpreted for potential granular deposits.

Eighty-seven (87) potential granular deposits, including a good many doubtful or questionable prospects, were mapped from 1:52,400 scale airphotos, their airphoto-identifying characteristics better expressed than on the larger scale 1:25,000 airphotos.

Two types of prospective granular deposits were mapped: 1) those prospects inferred to occur beneath densely forested hills, knobs and ridges (mainly kames); and 2) those prospects in forested and non-forested valley outwash terraces and floodplains along the lower Cameron River valley as well as fewer and less promising granular prospects on small locally forested terraces and plains remote from the Cameron River valley (Plates 1 and 2).

Potential sand and gravel deposits occurring on wooded terraces and elevated floodplains in the Cameron River valley west of about longitude 117°35'W offer significantly better chances of finding substantial volumes of developable sand and gravel. If they are developed, it will likely be necessary to leave a suitable width of trees between the present Cameron River bank and an excavated source of sand and gravel in order to meet environmental guidelines. In some cases it may also be necessary or even desirable to remove sand or gravel in the winter when there is a suitable thickness of ice on the Cameron River. Water depth in the river in winter is likely to be low.

I have identified what I think are better-looking granular material prospects and have outlined them on 1:25,000 scale airphotos. Locations of individual airphotos on which granular prospects are outlined are shown on a key map (Figure 7). Individual granular prospects are outlined on six figures (Figures 8 to 13). I have indicated places to check these granular prospects from a helicopter and on the ground, and perhaps from EM 31 seismic survey, before bringing in heavy testing equipment. Shallow hand-dug test pits should be considered before going to the expense of cutting trails and bringing in a drill rig or backhoe equipment.

I have made an estimate of the volume of granular material, in m^3/m of recoverable depth, for prospects shown on Figures 8 to 13. Rough volumes are shown on Table 1. Because hauling sand and gravel might cost 40 cents (and perhaps more) per tonne-kilometre, the closer a suitable developable source is discovered to where the granular material is needed the greater the cost saving. If large quantities of sand and gravel are required, this cost can be a very large sum of money and can justify checking closer prospects that stand little chance of finding an economically developable sand and gravel deposit.

Because of the possibility of environmental restrictions relating to extraction of gravel from deposits in the lower Cameron River valley, and the extreme scarcity of granular prospects in areas designated Phases 1a, 1b and

2, I enlarged the area to the north and northeast, essentially doubling the area examined in search of sand and gravel. Prospects in this northeastern area appear kamelike. They are more doubtful prospects than those listed in Table 1 (Cameron River valley prospects). I show these questionable prospects on Plates 1 and 2, and have numbered them 1 to 32. Roughly estimated quantities of granular material in them appear in Table 2. Chances of finding developable sand or gravel in most of these is considered poor. Therefore, a good deal of field investigation experience and common sense is necessary in assessing the granular material prospects identified from 1:52,400 airphotos and re-examined on 1:25,000 airphotos.

Beyond the confines of the Cameron Hills Upland in the Northwest Territories, sand and gravel outwash deposits are scattered here and there along the Hay River meltwater channel in northwestern Alberta and to the north between latitude 60° and Alexandra Falls.

9. CLAY BORROW PROSPECTS

Nearly all the study area of roughly 500 square miles (1250 km^2) is underlain by clay till and peat over clayey till. A high percentage of this till land surface is wet in summer, covered by a blanket of 1 to 3 m of peat in what are called muskegs by workers in the road and pipeline construction and seismic exploration industries. Accordingly, on the Cameron Hills Upland there are literally hundreds of locations to check for clay borrow. The problem is to find a location where the clay borrow deposit is relatively dry, is not frozen (permafrost), and is not covered by a prohibitive thickness of organic soil (peat).

Clay till borrow prospects can be readily identified by inspecting the 1:50,000 and 1:25,000 terrain-typed photomosaic sheets. The best places to check in the field for dry clay are locations where deciduous trees (lighter-toned trees on airphotos) appear in mixedwood forests, especially on terrain units TC, TF, TH and TV. Thus, better sites for clay borrow are moderately sloping south-facing (sun-facing) slopes and the top of hills and ridges that support aspen and birch trees. South-facing slopes in areas identified as potential granular prospects in terrain units GH and GP that are covered with aspen poplar and that are not granular in composition are also candidates for clay borrow.

Finally, virtually all areas marked DS, especially near the top of the escarpment surrounding the Cameron Hills Upland, are good sources of unfrozen clay borrow. Note that clay till deposits also contain boulders.

If these guides to clay borrow are followed during aerial reconnaissance, there should be little problem discovering suitable clay borrow for access road construction. All areas marked PB, PF, PN and PR should be avoided. Much of unit TR may be too wet to develop clay borrow.

10. USE OF THE TERRAIN UNIT OVERLAY MAPS (APPENDICES 1 AND 2)

Terrain units were more easily and economically identified on 1:52,400 airphotos than on 1:25,000 airphotos. In addition, four times as many stereopairs have to be studied on 1:25,000 airphotos in order to map the same number of outlined terrain units.

Mineral soil terrain on the Cameron Hills consists largely of lodgement and ablation tills in different geologic landforms. These landscapes can be highly variable locally in terms of route access and well site selection, and in road and pipeline design, construction, and maintenance owing to significant variations in topography, surface drainage, vegetation, permafrost, and organic cover (Appendices 1 and 2).

Route and site location engineers should find low relief landforms readily trafficable when the ground is well frozen in winter. Locally, tree clearing may be an environmental constraint.

Lower relief terrain units identified are AA, AC, AF, AP, GP, TR, TS, PB, PF, PN, PR. Terrain units characterized by hills, ridges and steeper slopes include GH, TC, TH, TV, LO, LR and RS. Desirably, terrain units to avoid in summer because of numerous small drainage courses, a high water table, or wetness are AA, AC, AF, AP, TC, TR, PB, PF, PN and PR.

Perhaps the main terrain unit to avoid when constructing and maintaining permanent roads is PB because of ground ice melting and associated ground instability (Figures 5 and 6). Pipelines should be kept to the water-shedding crests of drainage divides wherever it is practical to do so.

Better terrain units to cross with all-weather roads -- assuming suitable nearby borrow exists for raising the gradeline -- are TS, TR, GP and GH and TH where steeper hills and knobby sections can be avoided without significant route alignment and length change.

11. DELIVERABLES

Original and additional deliverables include the following items:

- 1:50,000 NTS map of the Cameron Hills Upland with 10-m contours and drainage; also with a transparent mylar overlay showing terrain units and legend (Plate 1).
- 1:50,000 photomosaic of the Cameron Hills Upland with the terrain units on mylar, including potential granular material and clay (till) deposits thereon (Plate 2).
- Photomosaics of Phase 1a, 1b and 2 areas at scale 1:25,000 with transparent overlay on mylar (Plates 3, 4, and 5).
- Location of granular material prospects on the 1:25,000 and 1:50,000 photomosaics. Potential granular sources having a better chance of discovery of economically developable granular material are shown on individual airphotos at scale 1:25,000 (Figures 7 to 13).
- Granular material prospects with a lesser possibility of discovering granular material are shown on 1:50,000 mosaics (numbered 1 to 32 on Plates 1 and 2).
- Table 1 and 2, giving rough volumes in granular material in outlined prospects.
- A report with accompanying plates, figures, tables and appendices.
- Mylar copies of overlays on photomosaics and maps.

12. CONCLUSIONS AND RECOMMENDATIONS

- Terrain types and distribution on the Cameron Hills Upland in the Northwest Territories are complex. Altogether, 19 significantly different terrain units, often occurring in small areas and distributed in a highly interspersed mosaic pattern, were identified and outlined on 1:52,400 scale airphotos.

- There is much more ice-rich permafrost in peat bogs than anticipated from general knowledge of conditions in the surrounding lowland. Virtually all ice-rich peatlands (PB), regardless of size, have been identified and outlined. Many of these areas are less than one-half square kilometre, yet they are significant in terms of route and wellsite access and road and pipeline location, construction and maintenance.

- There is little or no infiltration into the ground in the permafrost-affected areas. As a result, there is an extraordinarily large number of small drainage channels traversing gently to moderately sloping smooth till landscapes. These drainageways are likely to present a problem in road design and drainage control.

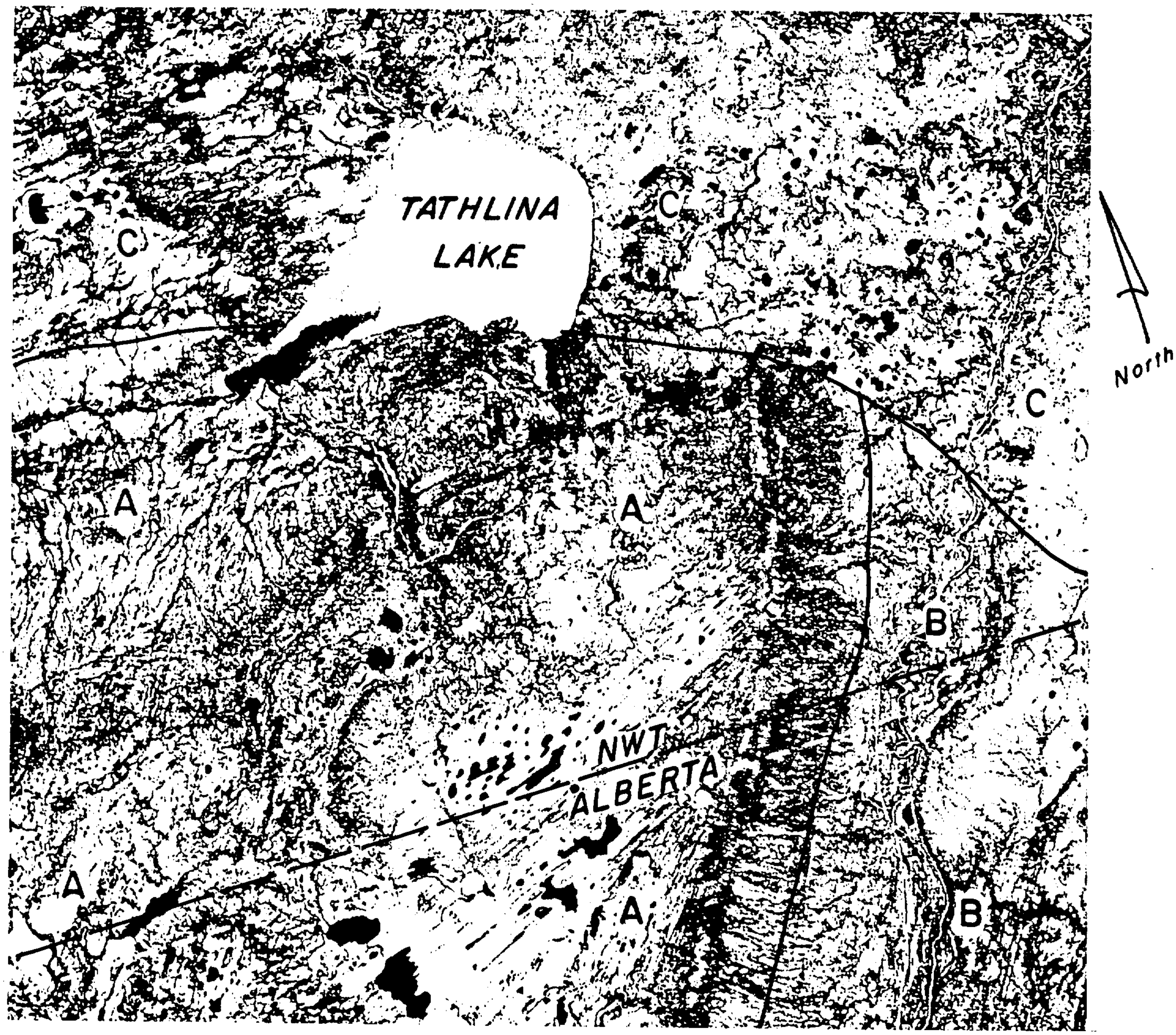
- Promising clay borrow sources occur on hill and ridge tops and south-facing (sunny) slopes covered with deciduous trees. These situations occur in numerous locations on all terrain units except AC, PB, PF, PN and PR.

- In general, granular material prospects are scarce and difficult to identify with confidence on airphotos. There are very few promising-looking granular prospects away from the lower Cameron River valley. I have mapped a total of 87 prospects. I show many doubtful prospects because the discovery of a close deposit can mean major savings in haul cost. Better granular prospects are shown in Figures 8 to 13. In addition, 32 questionable granular prospects are shown on Plates 1 and 2.

- Granular prospects should be investigated by helicopter and ground inspection (and possibly by EM survey or test pitting) before clearing trees and incurring the expense of bringing in a drill rig or backhoe. If field exploration is done in this way, the more economically developable granular prospects should be discovered.

- Many terrain factors and conditions significantly affect the cost of petroleum resource development and environmental planning and management. These factors and constraints are included in descriptions of the 19 terrain units in Appendix 1 and accompanying Appendix 2. Main constraint factors include vegetation (tree clearing and animal habitat), terrain wetness and drainage, surface and near-surface soil material, permafrost depth and ground-ice content, muskegs (peatlands), and macro and micro topography. Detailed terrain typing is required to reasonably assess these factors.

- Because of the terrain complexity and different types of land use and resource development that is likely to occur over time, this report should be read carefully and results digested to make optimum use of the study deliverables.



LEGEND

A Cretaceous Loon River Formation: shale and siltstone, marine

B Cretaceous Shaftesbury Formation: shale, silty, bentonitic, marine

C Devonian Formation: carbonate (limestone) and clastics (shale, siltstone, sandstone)

Drift thickness on the Cameron Hills exceeds 1000 ft (305 m)

REGIONAL BEDROCK GEOLOGY MAP

0 50 km

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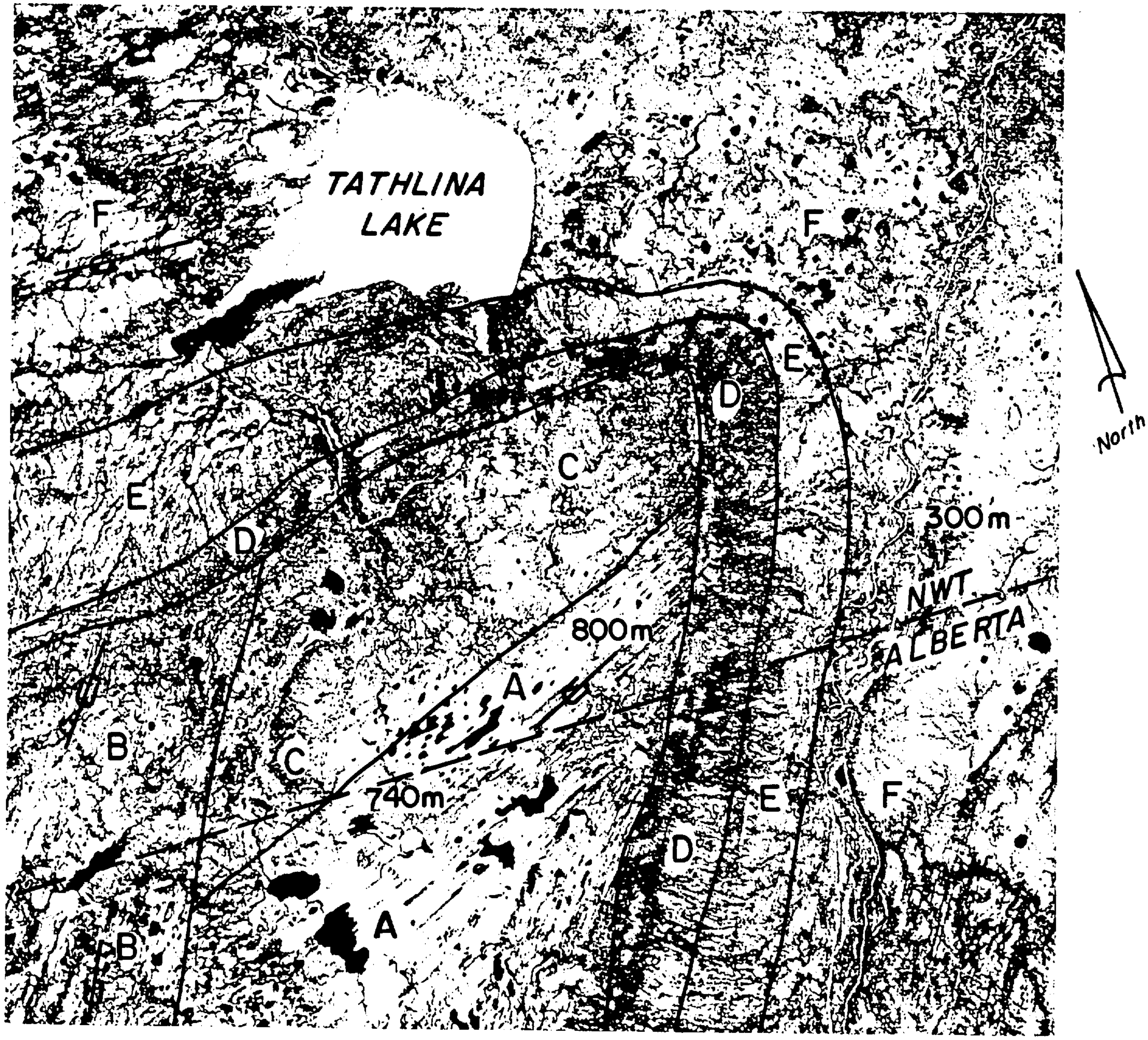
FIGURE 1



LEGEND

A Fluted ground moraine: till, ice advance from N80°E
B Fluted ground moraine: till, ice advance from N55°E
C Hummocky moraine and channelled ground moraine: till
D Escarpment around the Cameron Hills Upland; dissected
E Slopewash alluvium and colluvium, channelled
F Glacial-lake deposits over ground moraine (till)

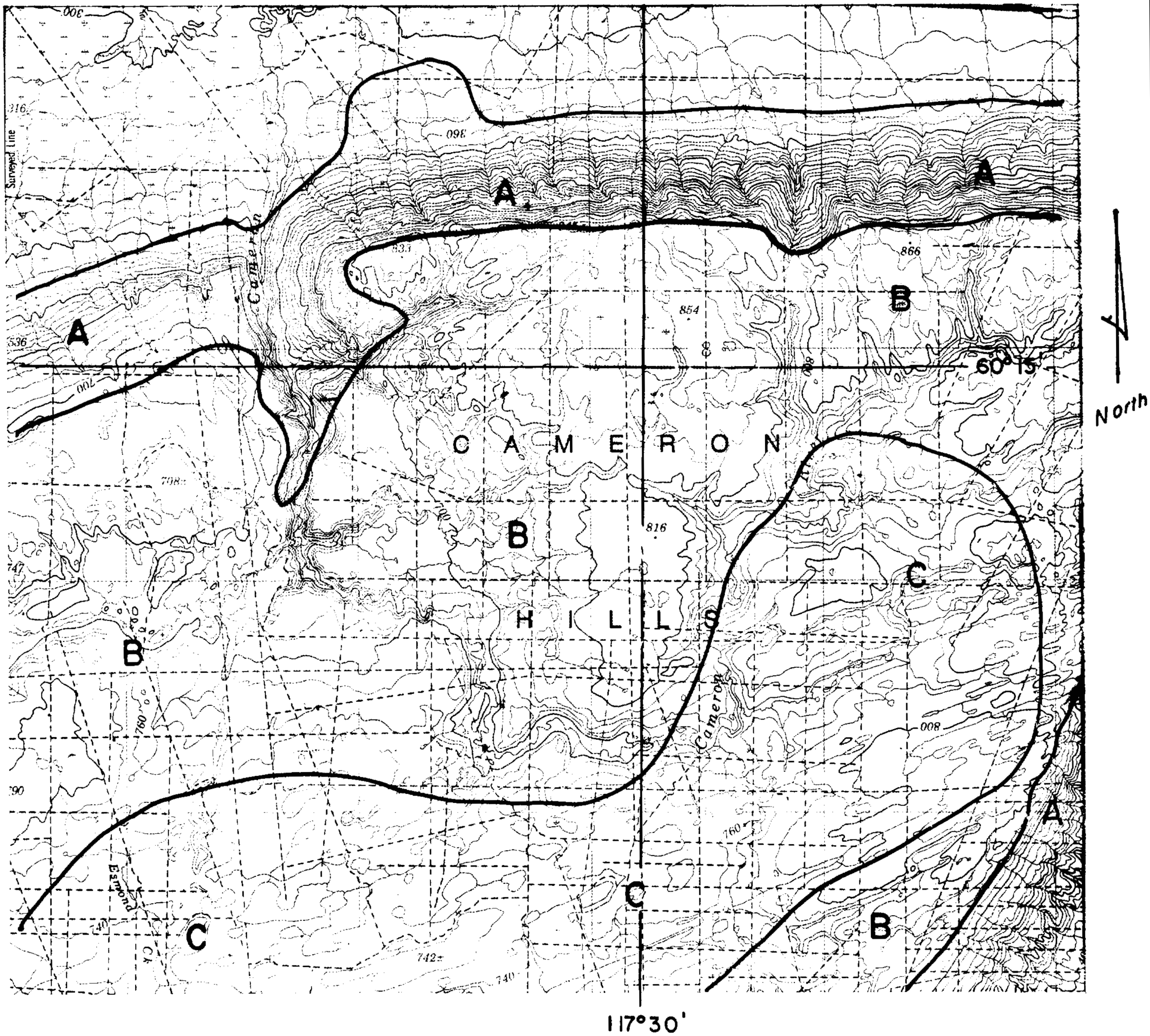
Note: Surficial organic deposits are common on units A to F.

REGIONAL SURFICIAL GEOLOGY MAP

0 50km

J. D. Mollard and Associates Limited

FIGURE 2



LEGEND

A — Productive mixedwood (mixed deciduous and coniferous) forest on steep escarpment and valley slopes

B — Stunted, sparse coniferous woodland; denser and taller tree growth occurs along margins of subparallel drainageways

C — Non-forested brushland and Sphagnum moss/black spruce bogs

REGIONAL VEGETATION MAP

0 5 10 15 20 km

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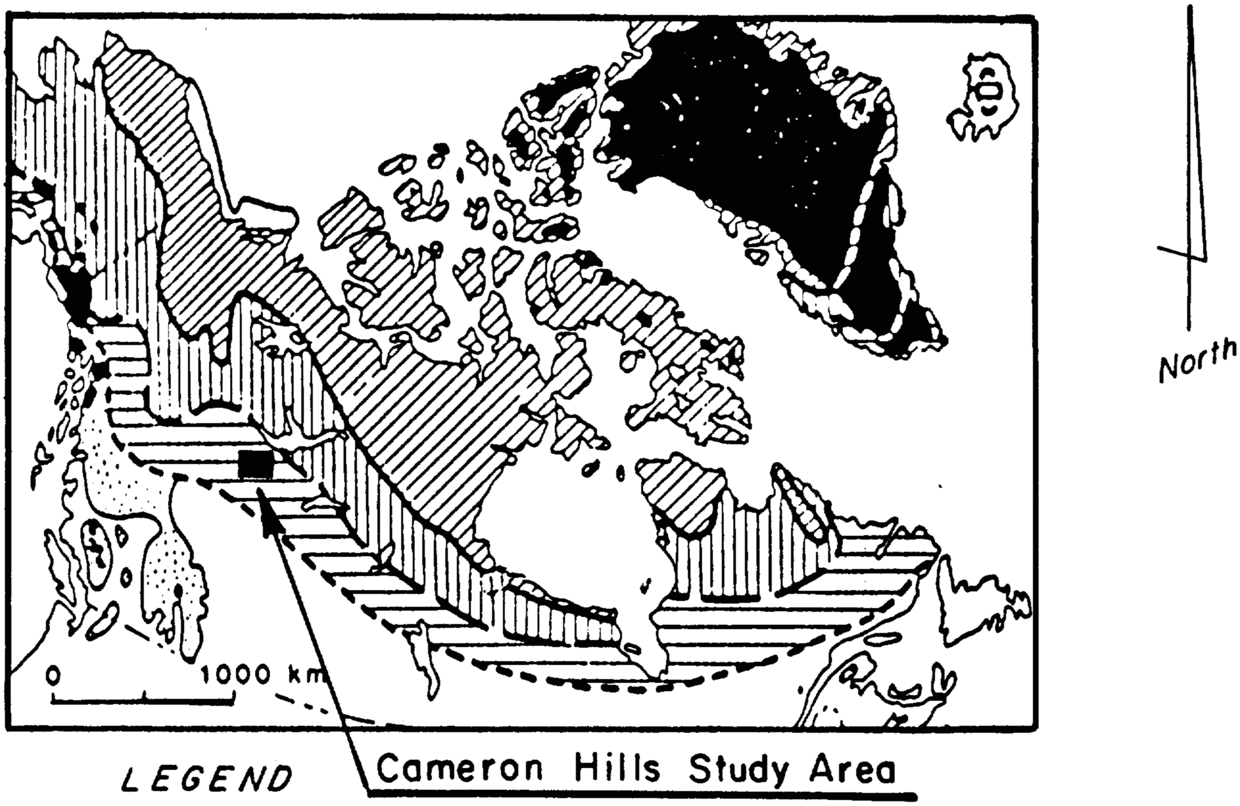
FIGURE 3



LEGEND

- Zone of <u>continuous</u> <u>permafrost</u> (>80% of area underlain by permafrost).
- Zone of <u>discontinuous</u> <u>permafrost</u>: subzone of widespread discontinuous permafrost (30 to 80% of area underlain by permafrost).
- Zone of <u>discontinuous</u> <u>permafrost</u>: subzone of sporadic discontinuous permafrost (<30% of area underlain by permafrost).
- <u>Alpine</u> <u>permafrost</u>.
- Known <u>subsea</u> <u>permafrost</u>.
- Perennial ice caps.

PERMAFROST ZONES OF NORTH AMERICA

0 — 5000 km

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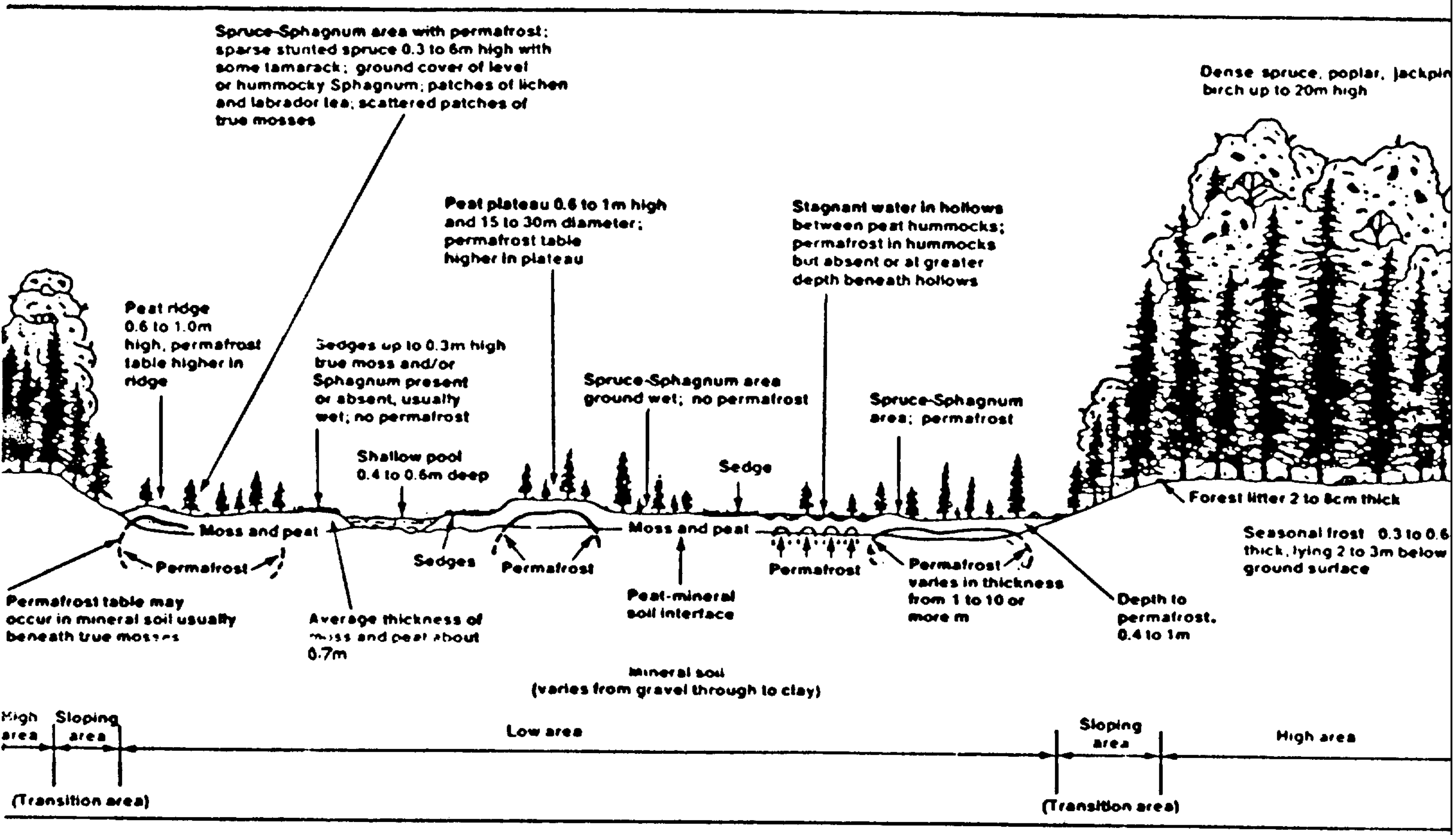
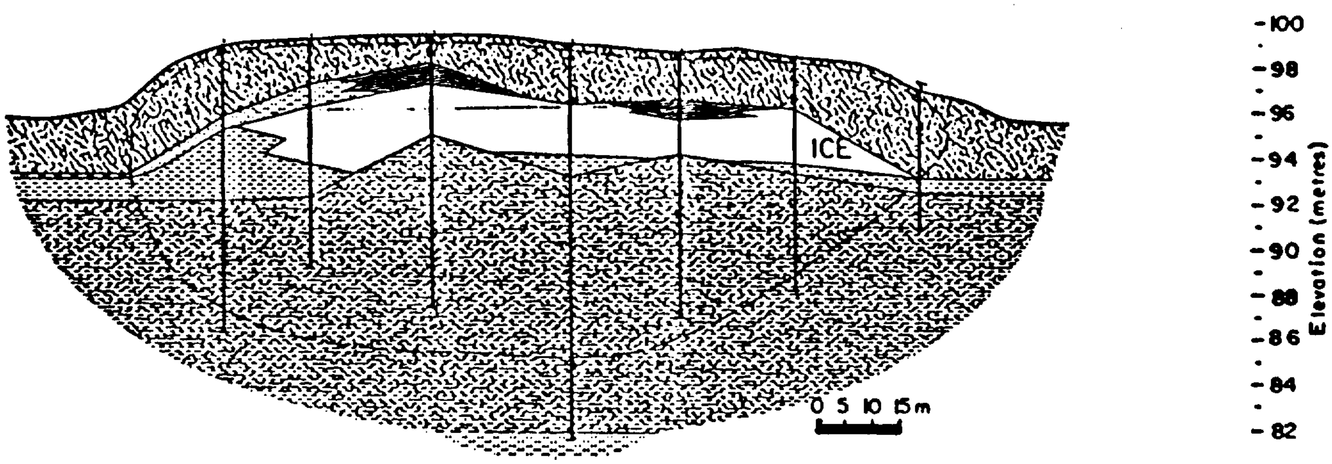
FIGURE 4



TYPICAL PERMAFROST OCCURRENCES IN PEATLAND ALONG SOUTHERN FRINGE OF THE DISCONTINUOUS ZONE (from Mollard and Janes, 1984)



LITHOSTRATIGRAPHIC CROSS SECTION OF PEAT PLATEAU BOG

LEGEND

- ICE +
- PEAT
- SAND
- SILT
- CLAY
- CLAY (TILL)

— — ASSUMED PERMAFROST BOUNDARY

SCHEMATICS OF PERMAFROST SITUATIONS

CAMERON HILLS UPLAND, NWT

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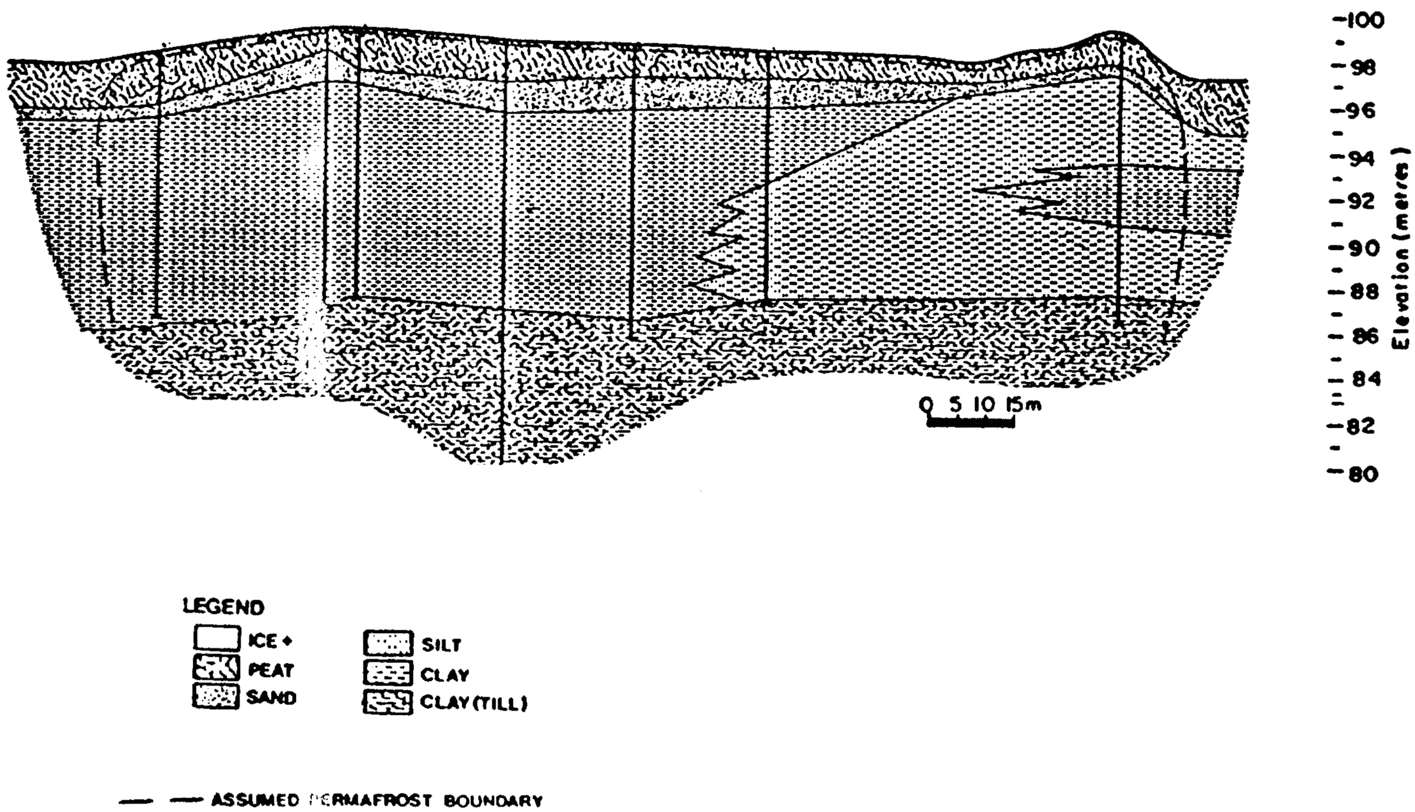
FIGURE 5



LITHOSTRATIGRAPHIC CROSS SECTION OF PEAT PLATEAU BOG

SCHEMATIC OF ICE-RICH PERMAFROST IN ALLUVIAL AND SLOPEWASH SILTY AND CLAYEY SOILS OVER TILL CAMERON HILLS UPLAND, N.W.T.

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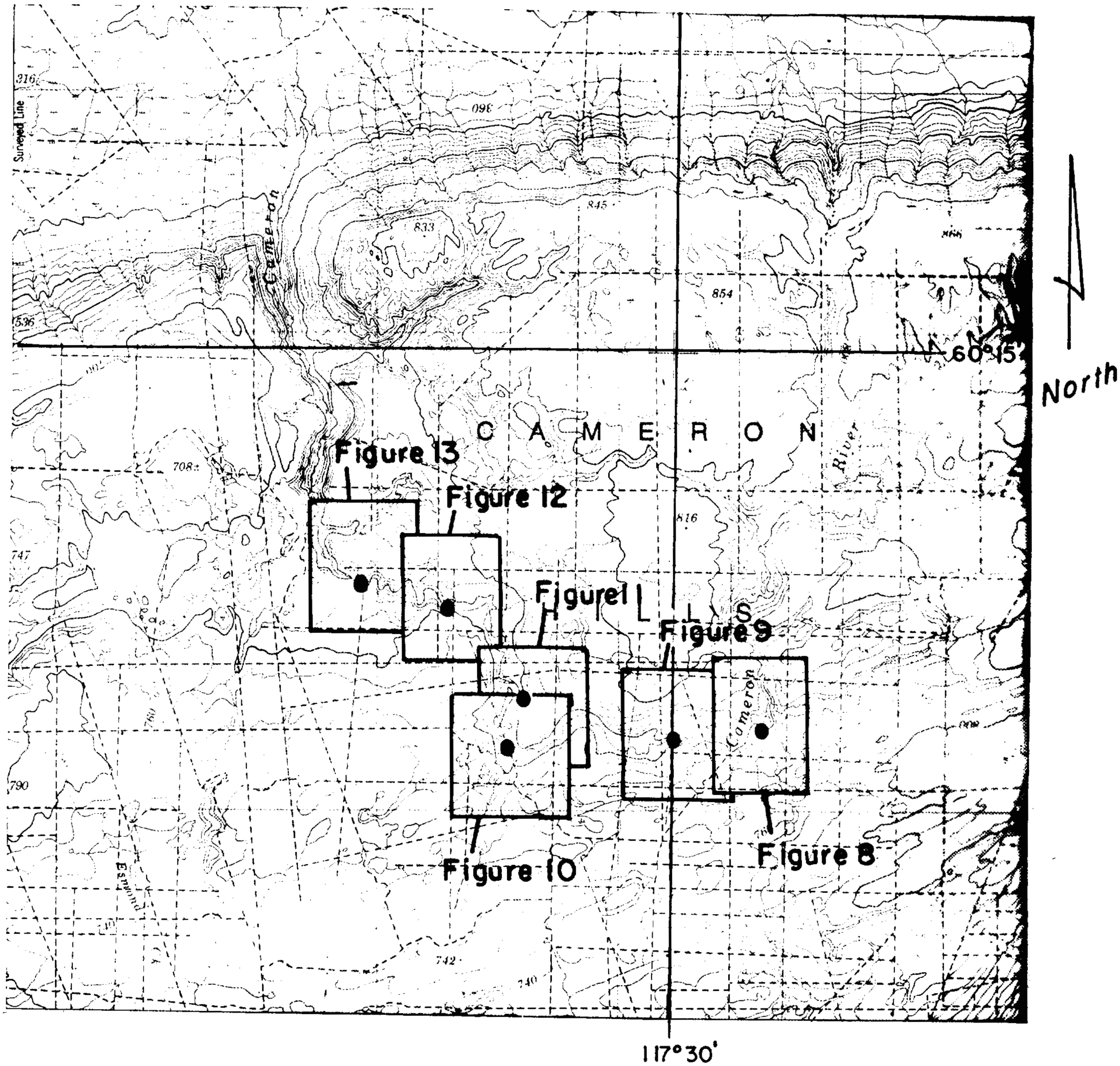
FIGURE 6



KEY MAP SHOWING LOCATION OF FIGURES 8 to 13
SHOWING BETTER GRANULAR MATERIAL PROSPECTS

0 5 10 15 20 km

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FIGURE 7

LEGEND

6 x Granular prospect and number

x Place to check in field (see report)

NTS 85C
GRID REFERENCE MS 7663

GRANULAR MATERIAL PROSPECTS

0 1000 2000m

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FIGURE 8

LEGEND

6 Granular prospect and number

x Place to check in field (see report)

NTS 85C
GRID REFERENCE MS7263

GRANULAR MATERIAL PROSPECTS

0 1000 2000m

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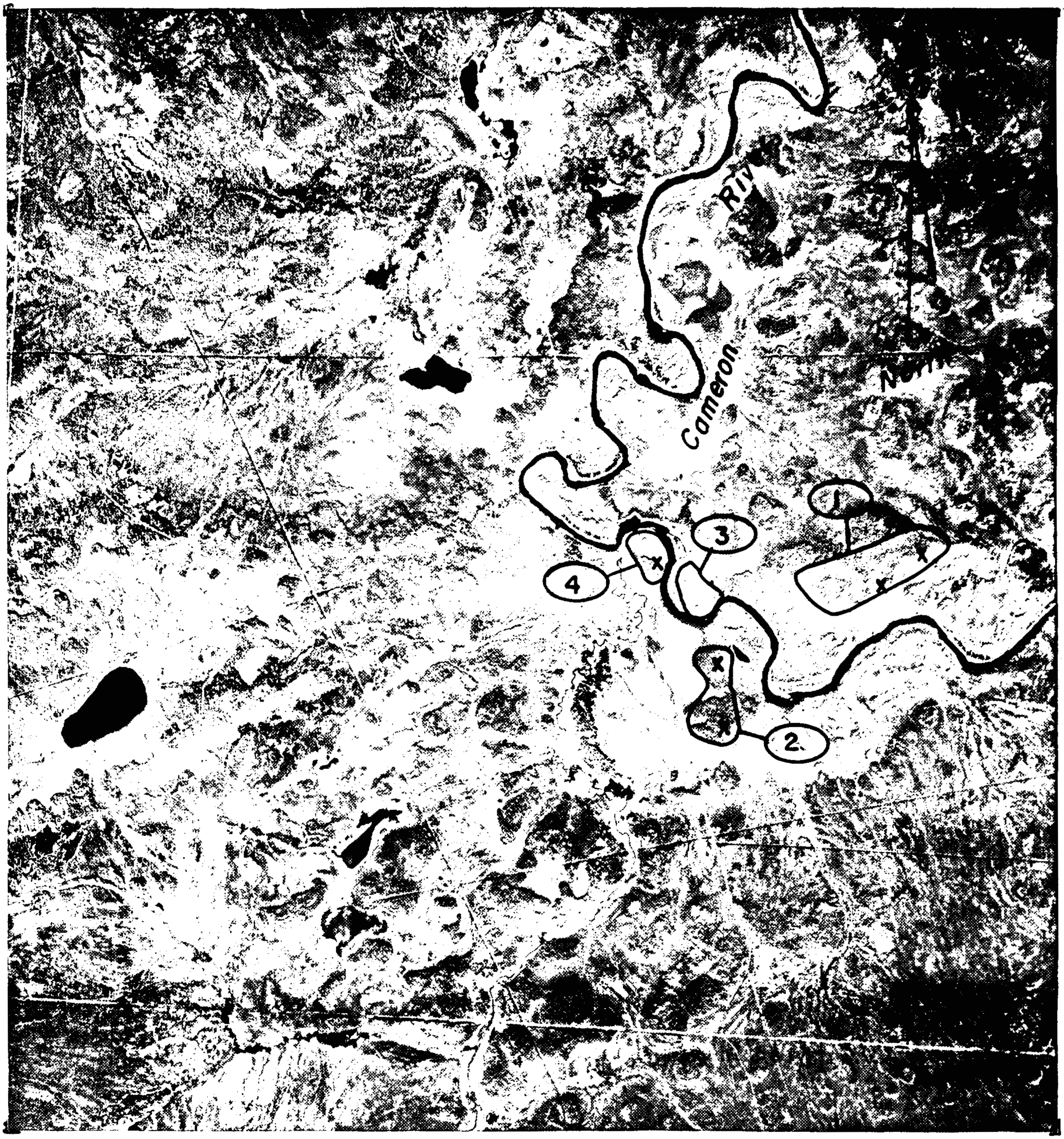
FIGURE 9



LEGEND

6 — x — Granular prospect and number

x Place to check in field (see report)

NTS 85C
GRID REFERENCE MS6563

GRANULAR MATERIAL PROSPECTS

0 1000 2000m

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FIGURE 10

LEGEND

6 — Granular prospect and number

x — Place to check in field (see report)

NTS 85C
GRID REFERENCE MS 6665

GRANULAR MATERIAL PROSPECTS

0 1000 2000m

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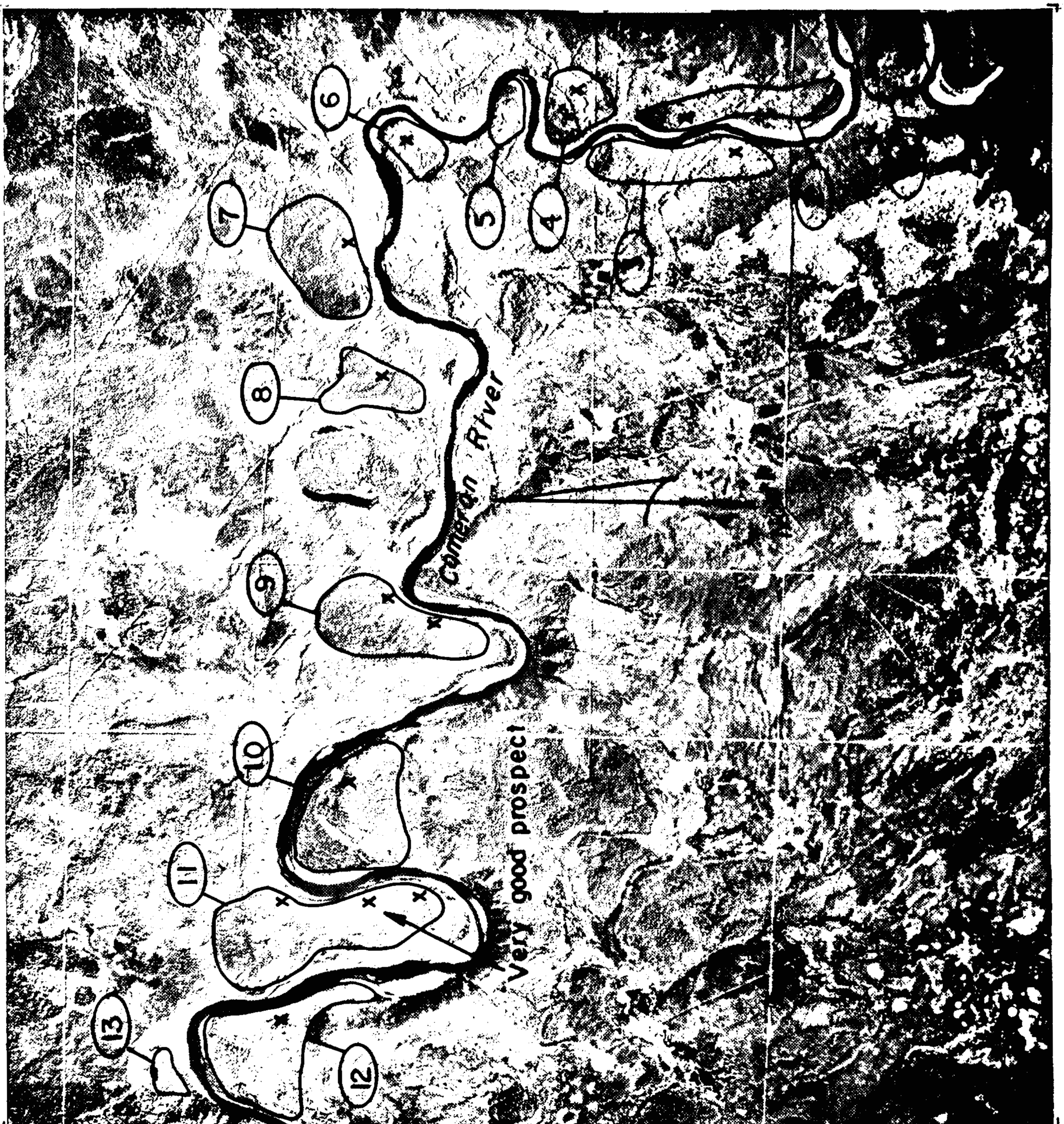
FIGURE 11



LEGEND

(6) Granular prospect and number

x Place to check in field (see report)

NTS 85C
GRID REFERENCE MS 6368

GRANULAR MATERIAL PROSPECTS

0 1000 2000m

J.D. Mollard and Associates Limited

FIGURE 12

LEGEND

Granular prospect and number (6)

x Place to check in field (see report)

NTS 85C
GRID REFERENCE MS5969

GRANULAR MATERIAL PROSPECTS

0 1000 2000m

J.D. Mollard and Associates Limited

FIGURE 13

TABLE 1

ROUGH QUANTITIES OF POTENTIAL GRANULAR MATERIAL IN BETTER-LOOKING PROSPECTS ALONG THE LOWER CAMERON RIVER VALLEY

(See key map for location of figures)

Figure no.	Prospect no.	Rough volume (m^3/m of depth)
9	1	40,000
8	2	160,000
8	3	65,000
8	4	15,000
9	5	110,000
8	6	50,000
9	1	50,000
9	2	80,000
9	3	80,000
9	4	30,000
9	5	130,000
9	6	200,000
9	7	300,000
9	8	110,000
10	1	110,000
10	2	50,000
10	3	15,000
10	4	15,000
11	1	15,000
11	2	80,000
11	3	110,000
11	4	30,000
11	5	15,000
11	6	15,000
11	7	30,000
11	8	15,000
11	9	65,000
11	10	30,000
11	11	30,000
11	12	30,000
11	13	30,000
11	14	150,000

TABLE 1 (continued)

Figure no.	Prospect no.	Rough volume (m^3/m of depth)
12	1	150,000
12	2	100,000
12	3	100,000
12	4	80,000
12	5	30,000
12	6	30,000
12	7	130,000
12	8	65,000
12	9	160,000
12	10	200,000
12	11	80,000
12	12	160,000
12	13	15,000
13	1	160,000
13	2	50,000
13	3	30,000
13	4	50,000
13	5	50,000
13	6	64,000
13	7	15,000
13	8	50,000
13	9	15,000
13	10	80,000

TABLE 2

DOUBTFUL PROSPECTS AWAY FROM THE CAMERON RIVER VALLEY

(VIRTUALLY ALL PROSPECTS ARE LOCATED IN THE ADDITIONAL SEARCH AREA NORTHEAST OF PHASE 1a, 1b, AND 2 AREAS)

Prospect number on mylar overlays (Plates 1 and 2)	Rough volume (m^3/m of depth)
1	150,000
2	200,000
3	70,000
4	200,000
5	150,000
6	150,000
7	70,000
8	70,000
9	70,000
10	70,000
11	70,000
12	70,000
13	70,000
14	35,000
15	35,000
16	70,000
17	70,000
18	200,000
19	35,000
20	35,000
21	100,000
22	70,000
23	70,000
24	70,000
25	200,000
26	200,000
27	150,000
28	35,000
29	70,000
30	70,000
31	70,000
32	35,000

APPENDIX I

TERRAIN LEGEND EXPLANATION
CAMERON HILLS UPLAND, NORTHWEST TERRITORIES

ALLUVIAL LANDFORMS AND DEPOSITS
(Dominantly poorly stratified fine-grained deposits with occasional pockets of clean sand and gravels.)

AA **Alluvial apron.** Dominantly stratified clay, silt, and fine sand. Coarser sand and gravel in channels. Coalesced fans and slopewash deposits. Wet and subject to frequent flooding. Multiple subparallel drainages below valley sides and base of escarpments.

AC **Braided channel.** Sand and gravel with some silt and cobbles on river bars and pointbars. Gravel extraction from the active channel is likely subject to environmental constraints. Mainly Cameron River at low flow stages.

AF **Alluvial fan.** Dominantly silt and sand; minor gravel and clay. Sloping. Wet in summer, with many small channels radiating from its fan apex.

AP **Alluvial floodplain.** Dominantly silt and sand; minor gravel and clay. Thin peat cover. Mostly narrow valley floors with some low terrace remnants. Often wet in summer.

GLACIOFLUVIAL GRANULAR LANDFORM AND DEPOSIT PROSPECTS
(Mostly questioned granular deposits owing to lack of reliable distinguishing features in airphotos.)

GH **Granular material prospects, hills and ridges.** Hills and ridges may occur singly or in clusters. Some contain random pockets of sand or gravel on or within clay till. The possibility of discovering an economically developable granular material source is relatively poor because the kamelike and, occasionally, eskerlike forms are poorly expressed in airphotos. Some knobs and ridges are likely to be composed of till only. Steeper forms are more likely to contain sand or gravel.

GP **Granular material prospects, plains and valley terraces.** The possibility of finding good gravel is poor away from the Cameron River valley because most of the airphoto-identifying features have been greatly modified by the presence of permafrost and its affect on mass-wasting and feature rounding. Apart from forested terraces along the lower Cameron River valley, these granular prospects look to be mantled by a frozen silty overburden.

TILL LANDFORMS AND DEPOSITS
(Till consists of mixed clay, silt, sand and minor gravel, cobbles and boulders. Till is the dominant surface mineral soil deposit in the mapped study area. Till is over covered with less than a metre of organics and slopewash mineral soil.)

TC **Till terrain, channelled.** Channelled and softly rounded slopes underlain by till. Subparallel channels are wider and deeper than rills. Overland surface washes (watertracks) are also common. Moderately sloping.

TF **Till terrain, fluted.** Distinctly fluted till terrain. Closely spaced long, narrow, parallel linear till ridges and intervening wet, long, narrow linear troughs having a variable thickness of organics and ponded sediment over till. The linear ridges tend to be forested and to be steeper on the southeast side.

TH **Till terrain, hummocky.** Treed till knobs that contain randomly distributed pockets, seams, and layers of stratified silt, sand and gravel. Flat to moderately sloping ground between knobs. Tall trees on dry hummocks tend to exaggerate their height in airphotos.

TR **Till terrain, rilled.** Highly rilled and streaked till slope from overland sheetwash and shallow runoff channels. Slopes are smooth owing to solifluction (slow downslope creep of a thin active layer over the permafrost table). Thin peat (less than 0.5 m) over till is expected in many locations. Gentle to moderate smooth slopes.

TS **Till terrain, smooth.** Gentle to moderate smooth till slopes. Relatively few well-defined rills or channels. Smoothly soliflucted surfaces.

TV **Till terrain, valley sides.** Locally channelled and gullied till on steep upper valley slopes. Lower slopes are streaked with slopewash deposits consisting of clay, silt and silty sand.

LANDSLIDE LANDFORMS AND DEPOSITS
(Generally located outside Phase 1a, 1b, and 2 study areas.)

LO **Landslide terrain, old.** Typically occurs along the upper slopes of the Cameron Hills escarpment and the upper sides of larger valleys, such as the lower Cameron River valley. Subparallel slump ridges and intervening elongate depressions. Mostly slumped till on upper slopes and slumped till and Cretaceous clay shale on lower slopes.

LR **Landslide, recently active.** Recent landslide scars composed mostly of slumped till. Failure is inferred to have occurred within the last few decades.

PEATLAND LANDFORM AND DEPOSITS
(PB, the dominant peatland type, occurs extensively on virtually all level and gently sloping terrain.)

PB **Peat plateau, collapse scar bog.** Bogs that are frozen (permafrost) except for small thawed basins. These peat plateau bogs contain scattered small circular collapsed scars, which are permafrost-thawed holes supporting grasslike (sedge meadow) vegetation. Collapse scars show up as white to light gray speckles on airphotos. Gentle slopes to essentially flat. Ground ice occurs in peat that is typically 1 to 3 m thick over till or thin waterlaid organic silt and clay over till. This unit occurs on all poorly drained upland and most poorly drained lowland terrains.

PF **Peatland, nonpatterned linear fens.** Mostly long, narrow channel fens on the floor of small valleys.

PN **Peatland, nonpatterned and undifferentiated.** Mostly fairly extensive nonpatterned peatland (without ribs or small thaw basins). Mostly thinner peat with areas of discontinuous permafrost.

PR **Peatland, ribbed fen.** Patterned ribbed (string) fen, a non-permafrost peatland. Wet hollows and narrow frozen strings (wavy low ridges). Slow groundwater and surface runoff flow, with the water table at or near surface. No permafrost in the wet hollows and ponds and scattered permafrost in the ribs, or strings.

DEEPLY DISSECTED TERRAIN
(Mostly found outside study area.)

DS **Deeply dissected terrain on steep slopes.** Highly dissected escarpment and some upland slopes underlain by thick till, and sparse thin granular layers in the deeper subsurface. Large V-shaped ravines and small V-shaped valleys cross steep escarpment slopes with intervening flat-topped plateaus and steeply sloping sections. Valleys are more U-shaped on dissected upland terrain (vs escarpment).

Drainage classes

PR Wetland having a high water table and seasonally surface and groundwater flow.

TC Channelled surface with channels too numerous to show at map scale of 1:50,000.

TR Rilled surface. Small shallow subparallel drainage channels and watertracks that are too closely spaced and numerous to show at the map scale of 1:50,000.

L Small lake

Defined stream channels in small to large valleys.

Complexly intermingled terrain units

TR+TC; TH+GH; PB+PF; TH+PN, etc.

Assume the first unit covers two-thirds of the total outlined area, and second unit one-third of the area.

TC+DS+NP, etc.

Assume the first unit covers 60%, the second unit 30% and the last unit 10% of the outlined area.

APPENDIX 2

QUALITATIVE EVALUATION OF TERRAIN CONDITIONS INTERPRETED FROM 1:50,000 AIRPHOTOS

Terrain Unit 1	Soil Material 2	Vegetation 3	Topography 4	Drainage 5	Permafrost 6	Relative Summer Trafficability 7	Relative Winter Trafficability 8
AA	Stratified, mainly fine	Mixedwood forest	Gentle slopes	Multiple channels (wetland)	Scattered; minor	Poor	Fair
AC	Stratified, mainly coarse	Exposed sand and gravel	Sand and gravel bars	Stream channel	None	Non-trafficable	Non-trafficable
AF	Stratified, mainly fine	Mixedwood forest	Gentle slopes	Radiating channels	None	Poor	Fair
AP	Stratified, fine and coarse	Mixedwood forest	Gentle slopes	Single channel	Minor; scattered	Poor to fair	Fair to poor
GH	Pockets of granular material	Mixedwood on hummocks and ridges	Mixed knobs and gentle slopes	Minor	None on wooded knobs	Fair to poor	Fair to good
GP	Subsurface layers of granular material	Mixedwood; some minor brushland	Terraces and plains	Minor on terraces	None on wooded terraces; minor on sparse brushland	Fair to good	Fair to good
TC	Mainly clay, boulders (till)	Mostly brushland	Larger channels	Subparallel channels	Scattered	Fair to good	Fair to good
TF	Till on ridges; organics over till in troughs	Mixedwood on ridges only; brushland troughs	Narrow parallel ridges and troughs	Minor; wet troughs	None on ridges, scattered in linear troughs	Depends on route orientation; fair to poor	Depends on route orientation; fair to poor
TH	Mainly clay, boulders; till with pockets of granular material	Mixedwood on hummocks	Knobs and gentle slopes	Minor away from hummocks and ridges (on slopes)	None on wooded knobs; scattered on flats/slopes	Fair	Fair to good
TR	Clay, boulders (till)	Brushland (streaked)	Smooth moderate slopes	Dense rills; subparallel	Scattered	Fair to good	Good
TS	Clay, boulders (till)	Brushland (streaked)	Smooth gentle to moderate slopes	Sheetflow	Scattered	Good	Good
TV	Clay, boulders (till)	Mixedwood	Steep valley walls	Gullies, ravines	Minor to none	Poor	Poor
LO	Mainly slumped till	Mixedwood	Bumpy. Ridges/ hollows on escarpment	Minor	Minor to none	Poor	Poor
LR	Mainly slumped till	Mixedwood (bare areas)	Bumpy. Ridges/ hollows on escarpment	Minor	Minor to none	Poor	Poor
PB	Sphagnum peat	Treed bog; moss/black spruce	Flatland/ gentle slopes	Frozen wetland	Continuous except small thaw basins	Poor	Good
PF	Sedge peat	Mostly sedge meadow	Gentle slopes	Wetland	Rare	Poor	Good
PN	Moss and sedge peat	Mostly sedge meadow	Gentle slopes	Wetland	Rare	Poor	Good
PR	Sedge peat	Mostly sedge meadow	Ponds and strings	Wetland	On ribs only	Poor	Fair
RS	Clay/boulders (till)	Dominantly deciduous forest	Steep slopes; dissected	Ravines and small valleys	Minor to none	Poor	Poor

Notes

1. See descriptive explanation of terrain units in accompanying report.

2. Stratified, mainly fine -- refers to dominantly clay, silt and fine sand with minor clean medium sand to gravel layers and pockets.

   Stratified, mainly coarse -- refers to dominantly stratified sand and gravel with minor cobbles and silt.

   Till -- refers to mixed clay and silt matrix with some sand, gravel, and boulder sizes (often clay and rocks on drillers' logs.) Contains occasional clean sand and gravel pockets or layers. Clayey till may be covered by up to 1 m of organics.

3. Escarpment slopes, south-facing steep valley walls, shores of creeks and rivers and all distinct ridges and knob (hill) tops are covered by mixedwood (deciduous and coniferous) forest. Non-peatland wetlands and sloping till landscapes are mostly nonproductive (stunted, sparse) woodlands and brushland. Peatland vegetation consists of stunted black spruce and Sphagnum moss on PB; pools or sedge meadows with conifers on ridges in PR; sedge flats and stunted conifers on PF and PN.

4. Major upland terrain units TC, TR, TS and gentle slopes in TH and TF units are affected by solifluction and sheetwash and are mostly fairly smooth.

5. Thawed small sedge meadows (whitish speckles in PB) have internal drainage. PR is characterized by overland surface water and groundwater flow. Rills and channels are common in TC and TR; large ravines and valleys are common in TV and DS units.

6. Expect ice-rich (icy) continuous permafrost in PB (except for small circular thaw basins) and scattered permafrost in all other sparsely wooded peatland and TR and TS units. Forested valley sides, escarpments, stream channel shorelines, and ridge and hill tops are expected to have very little if any permafrost.

7 and 8. These assessments must consider local variations in what are necessarily generalized terrain units at the mapped scale of about 1:50,000. Assessments also apply to route and site selection.