GRANULAR RESOURCE INVENTORY

SOUTHERN MACKENZIE VALLEY

ROOT RIVER, 95 K

GEOLOGICAL SURVEY OF CANADA

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DEPARTMENT OF ENERGY, MINES AND RESOURCES

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SOUTHERN MACKENZIE VALLEY
ROOT RIVER (95K)
1:125,000

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110

Table of Contents

SUMMARY

In the Root River map-area, sources of natural granular material are plentiful and well distributed. Good quality sand and gravel is found primarily in alluvial and glaciofluvial deposits. Morainal, glaciolacustrine, and colluvial deposits also contain some coarse material. Competent, crushable bedrock is exposed throughout the Mackenzie Mountains.

Numerous alluvial plain and terrace deposits are associated with the Root, North Nahanni, and English Chief Rivers and their tributaries. When these deposits have considerable amounts of fine sand and silt, they may contain ground ice and be hard to exploit. Alluvial fan deposits adjacent to bedrock ridges often consist of coarse material which could be utilized for construction purposes when slopes are stable.

Glaciofluvial plain, terrace, hummocky, and ridged deposits are commonly found in major river valleys. These deposits contain sand and gravel and are generally well drained and free of ground ice.

Glaciolacustrine deposits are concentrated near the English Chief River. They are mainly fine sand and silt, but have some buried gravel. The glaciolacustrine silts and sands probably contain significant ground ice in the upper 15 feet or more and as a result they will be difficult to exploit.

Till of morainal deposits is usually fine grained with ridged areas having a higher percentage of gravel-sized material. One small deposit of gravelly till present in the vicinity of Trench Lake.

Colluvial deposits contain both rock fragments and unconsolidated material. These deposits are commonly found adjacent to bedrock ridges and in river valleys. Only deposits with stable slopes could be used for construction materials.

Bedrock that can be crushed to provide granular material includes limestone, dolomite, and sandstone of sixteen geologic formations exposed mostly in the mountainous portion of the Root River map-area.

INTRODUCTION

Granular material for construction purposes can be obtained from unconsolidated deposits or competent bedrock. This report will discuss the distribution and physical characteristics of these sources of granular material and will also present an estimate of the quantity of material available in unconsolidated deposits.

Unconsolidated deposits resulting from various geologic processes, i.e. glacier activity, river deposition, wind action, and mass wasting, are a source of natural granular material of gravel (> 2 mm), sand (1/16-2 mm), silt (1/16-1/256 mm), and clay (< 1/256 mm) sizes.

Good natural granular material for construction uses is generally larger than silt size (1/16 mm)[1]. In the southern Mackenzie Valley good granular material comes primarily from deposits of glaciofluvial and glaciolacustrine origin, and secondarily from morainal, eolian, alluvial, and colluvial deposits.

Bedrock that can be crushed by mechanical means can also supply granular material. Competent bedrock suitable for crushing includes limestone, dolomite, sandstone, and certain igneous and metamorphic rock types. Other less resistant rock types, i.e. shale, can be used for fill material but will not be included here as a bedrock source of granular material. In the southern Mackenzie

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[1] Silt and clay size material < 1/16 mm can be used for fill. This material is unlimited in the unconsolidated deposits of this map-sheet and will not be included in the numerical estimate of the quantity of granular material available.

Valley limestone and dolomite are the best sources of rippable bedrock.

Published and unpublished Geological Survey of Canada maps and reports, personal communication with officers of the Geological Survey, and field investigation have provided the basic data for this report. Supplementary information on distribution, thicknesses, and textures of unconsolidated deposits was obtained from unpublished oil and pipeline company shot hole and drilling records (see sources of information, Appendix A).

A Geological Survey surficial geology map at a scale of 1:125,000 (Rutter, N. W., and Boydell, A. N., in press) provided data on location and areal extent of unconsolidated deposits containing good granular material. This map will be indexed as GSC Open File and when published it may be viewed in the Geological Survey of Canada offices in Ottawa, Calgary and Vancouver. Copies will be obtainable at a nominal cost from Riley's DataShare International, 631 - 8 Avenue South West, Calgary, Alberta.

Quantities of natural granular material in unconsolidated deposits have been computed using data on areal extent and thicknessess obtained from the surficial geology map, drilling results, and field observations. Variables such as ground ice and height of water table were considered when deriving final volumes of material available in each deposit[2]. The tabular summary at the end of this report contains detailed volumetric data.

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[2] The area of each deposit was measured on the surficial geology map with a planimeter. The average thickness of the deposit was multiplied by the area to get the total volume of the deposit. Variables, i.e. water table, type of deposit, were assessed to obtain the final percentage of the total volume that is listed in the table as material available for exploitation.

Information on bedrock that can supply granular material comes mainly from Geological Survey of Canada Paper 61-13. Map 23-1961, which accompanies this paper, has been used as a base for indicating competent bedrock that is available at or near the surface.

GENERAL GEOLOGY AND PHYSIOGRAPHY

The eastern quarter of the Root River map-area falls within the Mackenzie Plain physiographic region. Mackenzie Mountain ranges (Iverson, Whittaker, Manetoe, Delorme, Thundercloud, Painted Mountains) occupy the western three-quarters of the map-sheet (see location map, Figure 1).

Bedrock geology was mapped by the Geological Survey during Operation Mackenzie in 1957 (Douglas and Norris, 1961). A reconnaissance surficial geology investigation was undertaken by B. G. Craig as part of this operation (Douglas and Norris, 1961; Craig, 1965). A detailed surficial geology map based on air photo interpretation and field investigations is being compiled by the Geological Survey in 1972-73 (Rutter, N. W., and Boydell, A. N., in press).

Bedrock formations[3] are basically Mesozoic (Cretaceous shales) and Paleozoic (Ordovician, Silurian and Devonian limestones, dolomites, sandstones, siltstones, and shales).

The shales and siltstones which occur in the Mackenzie Plain region and in lowlands between mountain ranges are poor sources of granular material.

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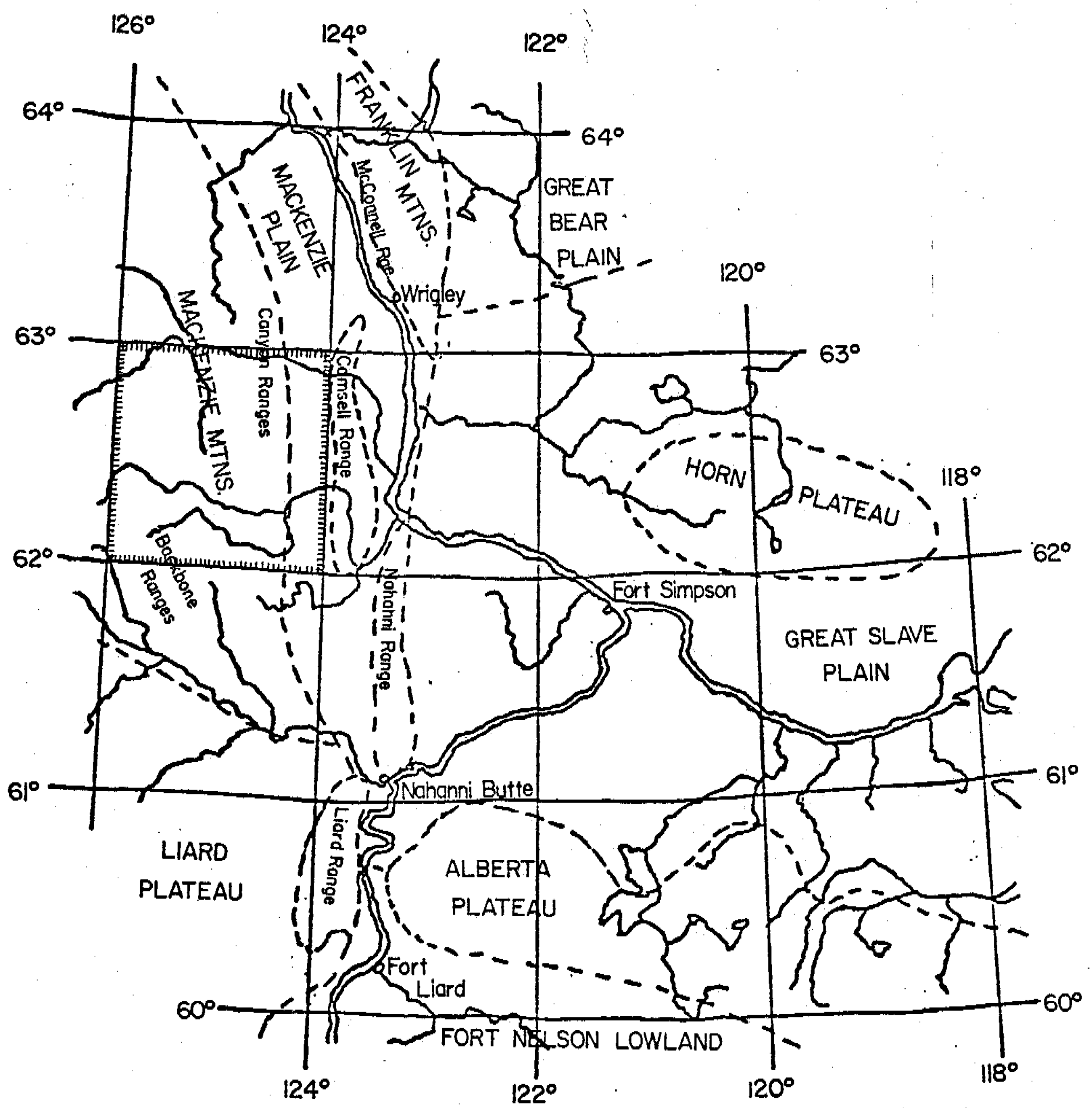
[3] A formation is a bed (of rocks) or assemblage of beds with well-marked upper and lower boundaries that can be traced and mapped orver a considerable tract of country (Holmes, 1965).



PHYSIOGRAPHIC REGIONS — ROOT RIVER, 95K

miles 50 Scale

Figure 1

after Bostock 1969

Competent limestones, dolomites, and sandstones are found at or near the surface in the Mackenzie Mountains.

Morainal deposits mantle the bedrock in lower areas. In addition to the ground moraine cover, glacier activity has produced glaciofluvial plain, terrace, and ridged deposits, and glaciolacustrine plain deposits. Rivers and creeks have reworked unconsolidated material into alluvial plain and terrace deposits and slope wash has created alluvial fans at the base of bedrock ridges. Mass wasting has also produced colluvial deposits of bedrock and unconsolidated material on mountain slopes and in river valleys.

GEOLOGIC DESCRIPTION OF EXPLOITABLE MAP UNITS

Unconsolidated deposits and bedrock that can supply granular material appear on Figures 2 and 3 respectively.

Figure 2 is adapted from a Geological Survey of Canada surfical geology map. Unconsolidated deposits with good natural granular material are labelled with appropriate map-unit name and assigned a pattern designation (see Figure 2, 2b). Pattern designations are based on geologic origin and texture of material in the deposit.

Figure 3 is a Geological Survey of Canada bedrock geology map. Bedrock at or near the surface is indicated by solid lines, heavy dashed lines, or an x. Bedrock formations preceded by an asterisk could be crushed to obtain granular material (see legend, Figure 3).

Unconsolidated Deposits

Glacial Deposits

Glaciofluvial deposits contain high quality granular material of gravel and sand sizes. Glaciolacustrine plain deposits consist of silt and sand with some buried gravel. Morainal deposits are generally made up of fine material, but ridged areas may have some sand and gravel.

Glaciofluvial Deposits
(Gt, Gtx, Gtx/Cx, Gp, $\frac{\text{Gptv}}{\text{R}}$, Gr, Ghr)

Glaciofluvial deposits consist of gravel and sand. In the Root River map-area, they generally occur as plains and terraces adjacent to rivers. Glaciofluvial deposits are indicated by several types of dot and circle patterns on the natural granular materials map (see Figure 2).

The capital G in the unit mapped indicates the glaciofluvial origin of the deposit. The lower case prefix denotes the principal type(s) of material present, e.g. silt (si), sand (s), and gravel and sand (g). It should be noted that if two prefixes are used, the first refers to the most abundant constituent (see legend for surficial geology maps, Figure 2b).

Topographic expression of the unit is indicated by the suffix attached, e.g. ridge (r), plain (p), terrace (t), hummocky (h), veneer (pv). Glaciofluvial units vary from flat and gently sloping (Gp, Gt, $\frac{\text{Gptv}}{\text{R}}$) to hummocky and ridged (Gr, Ghr). Thicknesses of deposits range from 5 to 150 feet. Where no information on thickness was available, an average value of 50 feet was used to estimate volumes of glaciofluvial deposits.

Glaciofluvial deposits are generally well drained and unfrozen. They probably contain from 40 - 70% usable granular material.

Glaciolacustrine Deposits
(Lp, Lpc, Lpe)

Glaciolacustrine plain deposits which are concentrated near English Chief River contain mostly fine sand and silt. Buried deltaic gravel is also present in deposits K-255, K-256, and possibly K-258. On the granular materials map glaciolacustrine deposits have been assigned a striped pattern (see Figure 2).

The capital L in the glaciolacustrine map-unit indicates its origin, and the lower case prefixes and suffixes give textural and morphologic information respectively.

Glaciolacustrine deposits are generally flat or gently sloping (Lp). Irregular topography (Lpc, Lpe) may be caused by erosion. Glacial lake deposits range in thickness from 10 to 450 feet and generally are about 20% usable.

It should be noted that glaciolacustrine deposits are usually fine grained and as a result are poorly drained and frozen. Recovery of material from frozen deposits will be difficult and costly.

Morainal Deposits
(Mp)

Morainal deposits are shown by a capital M with appropriate textural and morphologic modifiers. One deposit with coarse material, K-259, has been assigned a broken line pattern on the natural granular materials map (see Figure 2).

Morainal deposits, probably from 10 to 60 feet thick, cover the bedrock in most lowland areas. These deposits are composed of till which contains a mixture of grain sizes from boulders to clay particles with most particles less than 1/16 mm. When well drained and unfrozen this fine-grained till can be used successfully for fill.

Frozen ground in morainal areas is variable and is controlled largely by topography. Well drained, ridged deposits usually are less likely to be frozen and therefore would be easiest to exploit.

Alluvial Deposits
(Ap, At, Af, Afx, Afe)

Alluvial deposits consist of silt, sand, and gravel-sized material. Only those with sand or gravel have been assigned a cross hatched pattern on the accompanying natural granular materials map (see Figure 2). Alluvial deposits are mapped as A with textural and morphologic modifiers.

Alluvial deposits form plains (Ap) with little relief along present river and stream channels, terraces (At) above present channels, and fans (Af, Afx) at the base of mountain slopes. Alluvial deposits along braided rivers (Root, North Nahanni, and English Chief Rivers) contain significant amounts of coarse material. Sand and gravel alluvial deposits also occur along small rivers and streams and adjacent to bedrock ridges.

Alluvial plain deposits are from 10 to 30 feet thick while terrace deposits range from 30 to 80 feet. Alluvial plain and terrace deposits with considerable fine material usually are frozen.

Alluvial fan deposits formed by slope wash are variable in thicknesses and textures. An average thickness of 25 feet was used in volume estimates.

Colluvial Deposits
(Cx)

These deposits are derived from bedrock or unconsolidated materials and are formed by mass wasting. Material in colluvial deposits range from clay size particles to large rock fragments. Colluvial deposits are common in the mountains and along major river valleys. It should be noted that colluvial deposits with steep, unstable slopes may be potential landslide areas and removal of material from these slopes should be avoided.

Bedrock

Limestone, dolomite, and sandstone of sixteen geologic formations can be used to supply granular material. Outcrop areas of these formations are indicated on Figure 3 with solid lines, heavy dashed lines, or an x. Most of these competent formations outcrop extensively in the Mackenzie Mountains. East of the Mackenzie Mountains incompetent shales, siltstones, and sandstones are covered by thick glacial drift. A few scattered exposures of resistant limestone could provide crushable bedrock in this area.

High Quality Bedrock for Construction Materials

Bedrock formations are described in order of their suitability for construction materials.

The Nahanni Formation, unit 17, is a Middle Devonian limestone that is well exposed throughout the Mackenzie Mountains. It ranges from 600 to 965 feet in thickness at measured sections in the Root River area. Rock of this formation is fairly competent and breaks into blocks with dimensions of three feet square and larger. A few shaly, less competent limestone beds are present at the base of the unit.

The Arnica Formation, unit 11, is a Middle Devonian dolomite that outcrops in all the Mackenzie Mountain ranges. It is a fairly thick unit (2,100 feet on Delorme Range, and 1,700 feet on Iverson Range). The banded appearance of the rocks makes this formation appear thinly bedded but it is generally massive and as a result might be difficult to crush. Brecciated zones at some localities may make ripping easier.

The Sombre Formation, unit 10, is a competent Devonian(?) dolomite. It outcrops in all the ranges, but is particularly widespread in the Sombre Mountains. The dolomite with some limestone beds is thinly and evenly bedded. On the Delorme Range it is 1,600 feet thick.

The Delorme Formation, unit 4, is a Silurian limestone, dolomite, and shale unit. It is exposed throughout the mountains and is 3,250 feet thick in the Delorme Range and 3,800 feet thick in the Whittaker Range. In the Delorme Range the formation is divided into four parts. The basal 500 feet consists of shales, argillaceous limestones, and dolomite. This is overlain by 1,300 feet of resistant, massive dolomite. Silty, fossiliferous dolomite 700 feet thick is above the massive dolomite. The uppermost 750 feet of this section is thinly bedded limestone. Except for the shaly beds, this formation would be a good bedrock source of construction materials.

The Whittaker Formation, unit 3, is an Ordovician or younger sequence of limestones, dolomites, and shales. On Whittaker Range the formation is 4,070 feet thick. In general, throughout most of the Root River area, the formation is divisible into three parts: the lower and middle parts are massive and mainly carbonate; the upper part is recessive and mainly shaly limestone and siltstone. The lower and middle parts would be best to exploit for crushable bedrock.

The Landry Formation, unit 15, is a Middle Devonian thick- to massive-bedded limestone. It is 400 to 500 feet thick on Whittaker Range and 300 feet thick on Delorme Range. The formation is relatively resistant, and forms the peaks and dip slopes of many mountains.

The Sunblood Formation, unit 1, is Ordovician or older and occurs in the axial region of major anticlines. On the Whittaker and Delorme Ranges it is about 1,600 feet thick and contains limestone, shale, dolomite, and calcareous to dolomitic sandstone. All but the incompetent shale members would be usable for construction materials.

Unit 6 is a Devonian formation that consists of two types of dolomite. One of the dolomites is fine grained and darkly laminated and the other is light grey. These dolomites alternate in units 5 to 10 feet thick and give the formation a banded appearance. Both dolomites are competent and would be easy to crush.

Unit 12, the Manetoe Formation, is exposed along the south-eastern slopes of the Iverson Range and in the Sombre Mountains. It is a Middle Devonian dolomite, coarsely crystalline and massive. The Manetoe is very porous to cavernous and vugs are lined with quartz crystals. On the Iverson Range the formation is 500 feet thick.

Unit 2 occurs only in the southwestern Root River map-area. It is a massive- to medium-bedded limestone with dolomite, shale, siltstone, and sandstone interbeds. The shale and siltstone members would be poor sources of granular materials but the rest of the formation would be good.

Unit 20, is an Upper Devonian reef limestone. At most localities the formation is fossiliferous, massive, and poorly bedded. North of Root River the reef limestones are 150 feet thick and grade westward into shales and siltstones of unit 19.

Secondary Bedrock Sources for Construction Materials

Five formations, units 13, 22, 5, 16, and 21, can be used as sources of rippable bedrock. However, the outcrop pattern and rock types involved make them less desirable than the previously mentioned units.

The Middle Devonian Funeral Formation, unit 13, is an argillaceous limestone and shale unit. It is exposed in all the ranges and is 900 feet thick on the Iverson Range and 1,300 feet thick on Whittaker Range. The limestone of the formation produces platy talus when weathered. Where the talus is resistant and large enough, it can be used for granular materials. Shale interbeds are not good bedrock sources for granular materials and are most numerous near the base of the unit. On the Whittaker Range thin beds of chert also occur in the lower part of the formation.

Unit 22 is an Upper Devonian silty, sandy limestone with shale interbeds. It outcrops at several localities along the eastern boundary of the Root River map-area and when exposed it could be used for construction materials.

The Camsell Formation, unit 5, is a limestone and limestone breccia unit. The formation is Ordovician or younger and occurs in most of the mountain ranges where it is approximately 1,500 feet thick. In the northern Root River area, the Camsell Formation is massive bedded as is brecciated on a large scale. Joint faces, pockets and the breccia matrix consist of coarse calcite or limonite and ochre. Breccia fragments are up to 10 feet in diameter and are rounded or subrounded. Salt casts are present on bedding surface.

In the south-central part of the map-area, the formation consists of alternating thick-bedded limestone and shaly recessive limestone. The unbrecciated zones of this formation, e.g. south-central region, would probably be best to exploit for construction materials.

Unit 21 is Upper Devonian in age. It consists of calcareous sandstone 660 feet thick. Mudstone, siltstone, and limestone interbeds are also present. The formation occurs along the eastern boundary of the map-sheet and could be used for granular materials where exposed.

The Headless Formation, unit 16, is Middle Devonian shale and argillaceous limestone unit. It is exposed in most of the mountain ranges and usually contains too many incompetent shale beds to be a good bedrock source of construction materials. However, at localities where shale content is low the formation could be crushed to obtain granular material.

GEOGRAPHIC DISTRIBUTION OF EXPLOITABLE MATERIALS

All natural granular deposits have been assigned an identification number, e.g. K-1, for use in assembling data (Figure 2). Bedrock formations are shown on Figure 3.

Further details on volume estimates of natural granular materials are found in the tabular summary.

Root River and Tributaries

Alluvial plain, terrace, and fan deposits with high quality sand and gravel are found along Root River and its tributaries. These deposits average 30 feet in thickness. At least 20% of their total volumes are probably usable granular material. Finer grained alluvial deposits contain ground ice and will be harder to exploit.

A few glaciofluvial deposits (50 to 150 feet thick) with sand and gravel are also present near Root River and its tributaries, especially between the Iverson and Whittaker Ranges.

North Nahanni River and Tributaries

Alluvial and glaciofluvial deposits border the North Nahanni River and its tributaries. They are similar in terms of textures, thicknesses, and available percentages to deposits along Root River.

English Chief River

English Chief River has alluvial and glaciofluvial deposits like those associated with the Root and North Nahanni Rivers. In addition, glaciolacustrine silts, sands, and gravels are also present.

These sediments were deposited in a local basin. They are 10 feet thick on the western edge and 450 feet thick to the east. Silt and sand are most common with buried gravels representing deltaic deposits.

Mackenzie Mountains

Limestone, dolomite and sandstone which outcrop in the Mackenzie Mountain ranges would supply both colluvium and crushable bedrock for granular materials. Eleven geologic formations are listed as good units to exploit and five are fair (see tabular summary).

Natural granular material in the form of scattered alluvial fan, plain, and terrace deposits are also present at many localities in the Mackenzie Mountains.

TABULAR SUMMARY

	Description & Material	Thickness (ft.)	Area (sq. mi.)	Volumes Total	(Million yd.^{3}) Available
K- 1	Glaciofluvial terrace deposits,	50	0.43	22.61	9.04
K- 3	gravel and sand	50	1.21	63.58	25.43
K- 4		50	0.66	34.68	13.87
K- 9		50	0.16	8.33	3.33
K- 21		50	0.58	30.43	12.17
K- 22		50	0.43	22.61	9.04
K- 23		50	2.57	135.32	54.13
K- 24		50	1.95	102.68	41.07
K- 25		50	0.93	48.96	19.58
K- 26		50	0.89	46.75	18.70
K- 28		50	0.54	28.39	11.36
K- 29		50	0.74	38.93	15.57
K- 30		50	1.63	85.68	34.27
K- 31		50	0.54	28.39	11.36
K- 32		50	1.75	92.14	36.86
K- 33		50	0.74	38.93	15.57
K- 34		50	0.66	34.68	13.87
K- 35		50	0.89	46.75	18.70
K- 36		50	1.09	57.29	22.92
K- 37		50	0.27	14.11	5.64
K- 38		50	0.89	46.75	18.70
K- 43		50	0.89	46.75	18.70
K- 45		50	0.97	51.00	20.40
K- 51		50	0.54	28.39	11.36
K- 52		50	0.62	32.64	13.06
K-187		50	0.23	12.07	4.83
K-188		50	0.19	9.86	3.94
K-257		50	0.12	6.29	2.52

	Description & Material	Thickness (ft.)	Area (sq. mi.)	Volumes Total	(Million yd.^{3}) Available
K-261		50	0.27	14.11	5.64
K-262		50	0.19	9.86	3.94
K- 6	Glaciofluvial terrace complexes; gravel,	50	1.75	92.14	36.86
K- 8	5 - 15% colluvium	50	0.54	28.39	11.36
K- 13	Veneer of gravelly glaciofluvial plain + terrace deposit over bedrock	5	0.89	5.50	2.20
K- 27	Glaciofluvial plain deposits,	50	1.05	55.25	22.10
K- 39	gravel and sand	50	0.70	36.72	14.69
K- 40		50	1.09	57.29	22.92
K- 41		50	0.43	22.61	9.04
K- 42		50	0.47	24.65	9.86
K- 44		50	0.74	38.93	15.57
K- 46		50	2.88	151.64	60.66
K- 47		50	0.54	28.39	11.36
K- 48		50	0.74	38.93	15.57
K- 49		50	0.51	26.69	10.68
K- 50		50	1.01	53.04	21.22
K- 53		50	0.51	26.69	10.68
K- 54		50	0.31	16.32	6.53
K- 55		50	1.67	87.89	35.16
K- 56		50	0.70	36.72	14.69
K- 57		50	1.67	87.89	35.16
K-247		50	0.27	14.11	5.64
K- 5	Glaciofluvial ridged deposits,	50	0.31	18.32	11.42
K- 7	mostly gravel	50	2.18	114.75	80.33
K- 10		50	0.58	30.43	21.30
K- 11		50	0.23	12.07	8.45

	Description & Material	Thickness (ft.)	Area (sq. mi.)	Volumes Total	(Million yd.^{3}) Available
K- 12		50	0.82	43.18	30.23
K- 14		50	0.35	18.36	12.85
K- 15		50	1.36	71.57	50.10
K- 16		50	1.75	92.14	64.50
K- 17		50	0.39	20.40	14.28
K- 18		50	1.40	73.61	51.53
K- 19		50	2.84	149.43	104.60
K- 20		50	1.67	28.39	19.87
K- 2	Glaciofluvial hummocky, ridged deposit; gravel	50	0.89	46.75	32.73
K- 58	Alluvial plain deposits, gravel and sand	30	21.78	674.60	134.92
K- 63		10	1.98	18.39	3.68
K- 69		10	0.43	3.99	0.80
K- 70		10	0.58	5.37	1.07
K- 72		10	2.45	22.74	4.55
K- 84		10	0.74	6.87	1.37
K- 88		10	6.50	60.39	12.08
K- 97		30	5.45	168.88	33.76
K-100		10	0.54	5.01	1.00
K-101		10	8.09	75.15	15.03
K-105		10	0.97	9.00	1.80
K-106		10	0.93	8.64	1.73
K-111		10	1.24	11.52	2.30
K-112		10	3.27	30.36	6.70
K-113		10	6.85	63.63	12.73
K-116		10	3.00	27.87	5.57
K-118		10	0.47	4.35	0.87
K-122		10	1.01	9.36	1.87
K-123		10	0.89	8.25	1.65

	Description & Material	Thickness (ft.)	Area (sq. mi.)	Volumes Total	(Million yd.^{3}) Available
K-124		10	1.28	11.88	2.38
K-125		10	0.54	5.01	1.00
K-126		10	0.54	5.01	1.00
K-130		10	0.51	4.71	0.94
K-133		30	2.33	72.10	14.42
K-134		10	0.31	2.88	0.58
K-136		10	2.06	19.14	3.83
K-142		30	14.12	436.30	87.26
K-148		10	1.21	11.22	2.24
K-159		30	0.27	8.30	1.66
K-165		10	4.51	41.91	8.38
K-170		10	0.31	2.88	0.58
K-172		10	1.83	16.98	3.40
K-174		10	6.38	59.28	11.86
K-176		10	0.62	5.76	1.15
K-181		10	1.36	12.63	2.53
K-185		10	0.89	8.25	1.65
K-186		10	0.08	0.72	0.14
K-189		10	3.81	35.40	7.08
K-190		10	o.86	7.98	1.60
K-193		10	1.87	17.37	3.47
K-198		10	0.27	2.49	0.50
K-199		10	0.78	7.23	1.45
K-200		10	0.97	9.00	1.80
K-201		10	4.47	41.52	8.30
K-203		30	2.92	90.40	18.08
K-208		30	0.89	27.50	5.50
K-209		30	0.62	19.20	3.84
K-210		10	0.12	1.11	0.22
K-211		30	5.68	175.90	35.18
K-212		10	5.72	53.13	10.63

	Description & Material	Thickness (ft.)	Area (sq. mi.)	Volumes Total	(Million $yd.^3$) Available
K-215		10	0.62	5.76	1.54
K-223		10	1.36	12.63	2.53
K-224		10	2.65	24.60	4.92
K-227		10	0.66	6.12	1.22
K-228		30	16.07	497.70	99.54
K-230		10	0.23	2.13	0.43
K-233		10	0.78	7.23	1.45
K-245		30	48.78	1,511.00	302.20
K-246		10	0.39	3.60	0.72
K-216	Alluvial plain deposits, silt	10	0.58	5.37	1.07
K-218		10	0.35	3.24	0.65
K-220		10	0.35	3.24	0.65
K-206	Alluvial plain deposit, silt and gravel	10	0.49	1.47	0.29
K-242	Alluvial plain deposits; gravel and sand,	10	1.05	9.75	1.95
K-248	5 - 15% colluvium	10	2.53	23.51	4.70
K- 59	Alluvial terrace deposits,	40	0.58	23.27	4.65
K- 61	gravel and sand	40	0.54	21.17	4.34
K- 64		40	0.19	7.54	1.51
K- 86		40	0.47	18.85	3.77
K- 92		40	0.39	15.60	3.12
K- 99		40	0.58	23.27	4.65
K-102		40	0.23	9.23	1.85
K-103		40	0.54	21.71	4.34
K-104		40	0.23	9.23	1.85
K-114		40	0.35	14.04	2.81
K-115		40	0.12	4.81	0.96
K-121		40	0.08	3.12	0.62

	Description & Material	Thickness (ft.)	Area (sq. mi.)	Volumes Total	(Million yd.^{3}) Available
K-142a		40	0.07	3.12	0.62
K-155		40	0.39	14.80	3.56
K-162		40	0.16	6.37	1.27
K-163		40	0.12	4.81	0.96
K-202		40	0.97	39.00	7.80
K-204		40	0.12	4.81	0.96
K-231		40	0.70	28.08	5.62
K- 60	Alluvial fan deposits, gravel and sand	25	2.76	68.32	34.16
K- 65		25	0.51	12.56	6.28
K- 71		25	0.35	8.64	4.32
K- 77		25	0.23	5.68	2.84
K- 78		25	0.39	9.60	4.80
K- 79		25	0.27	6.64	3.32
K- 91		25	0.89	22.00	11.00
K- 94		25	0.35	8.64	4.32
K- 95		25	0.08	1.92	0.96
K- 96		25	0.35	8.64	4.32
K-177		25	0.51	12.56	6.28
K-191		25	0.16	3.92	1.96
K-222		25	1.13	28.00	14.00
K-229		25	0.04	0.96	0.48
K-232		25	0.58	14.32	7.16
K-244		25	0.54	13.38	6.69
K- 66	Alluvial fan deposits, colluvium and gravel	25	0.23	5.68	2.84
K- 68		25	0.08	1.92	0.96
K- 73		25	0.47	11.60	5.80
K- 74		25	0.16	3.92	1.96
K- 80		25	0.27	6.64	3.32
K- 81		25	0.23	5.68	2.84

Description & Material	Thickness (ft.)	Area (sq. mi.)	Volumes Total	(Million $yd.^3$) Available
K- 82	25	0.51	12.56	6.28
K- 83	25	1.67	41.36	20.68
K- 85	25	0.19	4.64	2.32
K- 87	25	0.54	13.36	6.68
K- 89	25	0.78	19.28	9.64
K- 90	25	0.19	4.64	2.32
K- 90a	25	0.16	3.92	1.96
K- 93	25	0.51	12.56	6.28
K- 98	25	0.51	12.56	6.28
K-107	25	0.35	8.64	4.32
K-108	25	0.16	3.92	1.96
K-109	25	0.39	10.08	5.04
K-117	25	0.39	10.08	5.04
K-120	25	0.16	3.92	1.96
K-127	25	0.31	7.68	3.84
K-129	25	0.54	13.36	6.68
K-132	25	0.19	4.64	2.32
K-135	25	0.86	21.28	10.64
K-137	25	0.19	4.64	2.32
K-138	25	0.43	10.64	5.32
K-140	25	0.66	16.32	8.16
K-141A	25	0.58	14.32	7.16
K-143	25	2.22	54.96	27.48
K-145	25	0.16	3.92	1.96
K-147	25	0.43	10.64	5.32
K-149	25	0.16	3.92	1.96
K-150	25	1.13	28.00	14.00
K-151	25	0.23	5.68	2.84
K-152	25	0.23	5.68	2.84
K-153	25	0.31	7.68	3.84
K-154	25	1.52	37.60	18.80

Description & Material	Thickness (ft.)	Area (sq. mi.)	Volumes Total	(Million yd.^{3}) Available
K-156	25	2.06	51.04	25.52
K-157	25	0.19	4.64	2.32
K-158	25	0.54	13.36	6.68
K-160	25	0.16	3.92	1.96
K-161	25	0.12	2.97	1.49
K-164	25	0.23	5.68	2.84
K-166	25	0.70	17.28	8.64
K-168	25	0.54	13.36	6.68
K-169	25	0.47	11.60	5.80
K-173	25	0.19	4.64	2.32
K-175	25	0.23	5.68	2.84
K-178	25	0.19	4.64	2.32
K-179	25	0.08	1.92	0.96
K-180	25	0.54	13.36	6.68
K-182	25	0.43	10.64	5.32
K-183	25	0.39	9.60	4.80
K-192	25	0.12	2.97	1.49
K-194	25	0.27	6.64	3.32
K-195	25	0.12	2.97	1.49
K-196	25	0.16	3.92	1.96
K-213	25	0.08	1.92	0.96
K-214	25	0.27	6.64	3.32
K-219	25	0.70	17.28	8.64
K-226	25	0.31	7.68	3.84
K-235	25	0.31	7.68	3.84
K-237	25	0.19	4.70	2.35
K-239	25	0.66	16.35	8.17
K-240	25	0.23	5.69	2.84
K-241	25	0.39	9.66	4.83
K-243	25	0.31	7.68	3.84
K-260	25	0.31	7.68	3.84
K-263	25	0.43	10.64	5.32

	Description & Material	Thickness (ft.)	Area (sq. mi.)	Volumes Total	(Million $yd.^3$) Available
K- 62	Alluvial fan complexes, gravel and some sand	25	0.97	24.00	12.00
K- 75		25	0.51	12.56	6.28
K- 76		25	0.43	10.64	5.32
K-234		25	0.27	6.69	3.34
K-236		25	0.27	6.69	3.34
K-238		25	0.31	7.68	3.84
K- 67	Alluvial fan complexes, colluvium	25	0.70	17.28	8.64
K-110		25	0.51	12.56	6.28
K-119		25	0.35	8.65	4.32
K-128		25	0.58	14.32	7.16
K-131		25	0.78	19.28	9.64
K-139		25	0.82	20.32	10.16
K-141		25	1.17	28.96	14.48
K-217		25	0.47	11.60	5.80
K-221		25	0.62	15.36	7.68
K-225		25	0.16	3.92	1.96
K-249		25	1.56	38.65	19.32
K-144	Alluvial fan deposits, eroded, gravel and colluvium	25	0.82	20.32	10.16
K-146		25	0.27	6.64	3.32
K-184		25	0.47	11.60	5.80
K-197		25	0.08	1.92	0.96
K-167	Alluvial fan complex, eroded; colluvium and gravel	25	0.54	13.36	6.68
K-250	Glaciolacustrine deposits, sand and silt	40	2.84	114.36	22.87
K-252		40	1.21	48.72	9.74
K-253		450	0.93	431.11	86.42
K-254		450	1.09	506.45	101.29

	Description & Material	Thickness (ft.)	Area (sq. mi.)	Volumes (Million yd.^{3}) Total	Available
K-255	Glaciolacustrine plain deposits, eroded;	150	48.59	7,525.61	1,505.12
K-256	sand and silt with buried deltaic gravels	150	9.49	1,469.81	293.96
K-258	Glaciolacustrine plain deposit, channelled; silt, may have some gravel at depth	20	0.58	12.53	2.51
K-259	Morainal plain deposit, gravel	60	0.43	26.63	5.32

Bedrock - limestone of unit 17 (good
dolomite of unit 11 (good)
dolomite of unit 10 (good)
dolomite and limestone of unit 4 (good)
dolomite and limestone of unit 3 (good)
limestone of unit 15 (good)
dolomite and limestone of unit 1 (good)
dolomite of unit 6 (good)
dolomite of unit 12 (good)
dolomite and limestone of unit 2 (good)
limestone of unit 20 (good)
limestone of unit 13 (fair)
limestone and shale of unit 22 (fair)
brecciated limestone of unit 5 (fair)
sandstone and limestone of unit 21 (fair)
limestone and shale of unit 16 (fair to poor)

TOTAL 5,002.74

Total natural granular materials resource estimate: 5,002.74 million cubic yards

Appendix A

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