CANADA
DEPARTMENT
OF
MINES AND TECHNICAL SURVEYS

GEOLOGICAL SURVEY OF CANADA

REPORT ON A GEOLOGICAL INVESTIGATION OF THE MAYO RIVER DEVELOPMENT, MAYO, YUKON TERRITORY, for the NORTHWEST TERRITORIES POWER COMMISSION

(REPORT AND MAP)

By

H. S. Bostock and E. B. Owen

OTTAWA
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REPORT ON A GEOLOGICAL INVESTIGATION OF THE MAYO RIVER DEVELOPMENT, MAYO, YUKON TERRITORY.

INTRODUCTION

LOCATION

The Mayo River Development includes a low control dam at the outlet of Mayo Lake and a large dam, with a tunnel and power plant, in the upper part of the canyon of Mayo River 4½ to 5 miles by road north of Mayo Landing.

REASON FOR THE INVESTIGATION

On Wednesday May 16 a meeting was held in the office of Mr. J.M. Wardle, Chairman of the Northwest Territories Power Commission, at which he asked the Director-General of Scientific Services, Department of Mines and Technical Surveys, to have the Geological Survey of Canada investigate and report on the development for which construction had already started. Accordingly the writers were instructed to go to Mayo at the earliest opportunity and to carry out the work, the results of which are described in this report.

During the course of the investigation the problems of construction upon which geology has a bearing were discussed with the staff of the Montreal Engineering Company.

ACKNOWLEDGMENTS

The writers express their appreciation for the co-operation, assistance and hospitality of the Northwest Construction Company and the J.W. Stewart Company in flying them from Vancouver to Mayo and to the officers of the Montreal Engineering Company for their co-operation in all phases of the work.

GENERAL FEATURES OF THE AREA

GENERAL DESCRIPTION

The Mayo River Development lies in the Mayo district, Yukon Territory, and its main works, with which this report deals, are in the Mayo River canyon about 5 miles up the river from its mouth at Stewart River, a main tributary of Yukon River. Mayo River drains an area of about 960 square miles. The precipitation of some 630 square miles of this area flows through Mayo Lake into the river. The lake is forked in plan, the main body, about 2½ miles wide, extending east and west about 19 miles, and an arm, a little more than a mile wide, projecting about 12 miles southeast from near the centre. The lake has an elevation of 2,200 feet, and the confluences of the river with the Stewart about 1,600 feet. Mayo River has a length of about 28 miles, and its fall is about 300 feet in the lowest 10 miles. The water for this drainage area comes largely from creeks heading in mountains and, high plateaus around the lake.

REGIONAL PHYSIOGRAPHY

The Mayo district lies in the Stewart Plateau, the northeast subdivision of the Yukon Plateau physiographic province, and some 50 miles west and southwest of the Selwyn Mountains. The district is characterized by broad, relatively flat-topped ridges with elevations of 3,500 to 4,500 feet, surmounted in places by high isolated summits and separated by a network of broad valleys with steep sides and wide floors, the latter at elevations of 1,600 to 2,400 feet. To the northeast, around the headwaters of the Mayo River, the Gustavus and Ladue Ranges rise above the general levels of the district, with peaks in the former range up to 6,700 feet high. These ranges constitute the beginning of a second "wet belt", similar to that formed by the Selkirk Mountains in southern, British Columbia, and are an important factor in gathering precipitation for the drainage area.

LOCAL PHYSIOGRAPHY

At the Mayo River Canyon, the river is entrenched between 200 and 300 feet deep in drift and bedrock on the west side of its wide valley floor where this valley opens into the still broader valley of Stewart River. The canyon has been cut where a ridge (referred to here as "The Ridge") of drift about 1 mile wide and 2½ miles long extends east to west across the mouth of Mayo River Valley and abuts against the east spur of the hills northwest of Mayo Landing.

'The Ridge' is composed of a great fill of gravel, sands, silt, and till deposited during the melting of the ice at the end of the last Pleistocene glaciation. The top of the ridge has an elevation of about 2,200 feet near the canyon, but rises somewhat eastward. The surface is undulating in its easterly part, but the southwest part is extremely irregular, broken by numerous large and small kettle holes and minor mounds and ridges. Close to the east rim of the canyon these surface irregularities were modified by the work of Mayo River when flowing over 'The Ridge' close to its present course before it developed the present canyon.

'The Ridge' across Mayo River Valley was formed toward the close of Pleistocene time, when great summer floods poured from the masses of ice lying in the valleys and on the mountains to eastward. An important channel for this run-off was located along the north side of Stewart Valley banked between ice in the middle of the valley and the high plateau on the north. From there it continued across the mouth of Mayo River Valley where 'The Ridge' now stands. Here this stream was walled on each side by great bodies of ice, and flowed over many large and small bodies, which it buried in the sediment it carried. Subsequently, the ice melted, leaving the gravel and sand fill along the course of the stream as an elevated ridge with an irregular pitted surface, particularly in its southwest part.

The characteristics of 'The Ridge' show that it is a compound esker and, therefore, largely composed of permeable materials.

With the melting of the Stewart Valley ice, Mayo River began to cut down its course along the west side of its valley where it now occupies the canyon. In doing so, it became superimposed on the lower ends of the spurs of bedrock that formed the lower slopes of the hills northwest of Mayo. Due to this, the main part of the walls of the canyon are composed of bedrock, with till, gravel, sand, and silt forming the upper part.

BEDROCK GEOLOGY

GENERAL FEATURES

The Mayo district lies in a broad area of rocks of the Yukon group, which form the main part of the Yukon Plateau. In the vicinity of the power development, these rocks are altered clastic sedimentary beds now schist and quartzite regarded as almost certainly of Precambrian age. In addition, in the upper end of the Mayo River Canyon several bodies of diorite lie surrounded by the Yukon group.

THE QUARTZITE

The quartzite is micaceous. It is composed of grains of bluish grey, opalescent quartz, white feldspar, and, more rarely, of some carbonate. The grains are commonly squeezed and flattened to elliptical sections with mica wrapped around them. They are up to a $\frac{1}{4}$ inch long in many horizons, and in a few as large as $\frac{1}{2}$ inch long. The interstices around the larger grains are occupied by finer grains of the same materials and by mica, which forms innumerable thin seams, giving the rock, except where it occurs in particularly quartzose beds, many wavy but nearly parallel planes of ready parting and fracture so that even where the outcrops appear solid and massive the rock commonly breaks into slabs only a few inches thick and blocks thicker than 1 foot, can only be obtained at a few horizons. The rock exhibits various shades of light, slate grey when freshly broken, and weathers brown.

For the most part the quartzite occurs as beds a few inches thick interbedded with greater thicknesses of schist, but at some horizons the quartzite is predominant for as much as 20 or 30 feet. The quartzite beds commonly pinch out in a few tens of feet, showing lenticular sections in the outcrops, and may overlap those above or below them.

THE SCHIST

Schist forms the greater part, perhaps 75 per cent or more, of the section of strata found around the development site. The great bulk of this rock consists of quartz-mica schist, but mica schist and some graphitic schist are also present, and all gradations between quartz-mica schist and micaceous quartzite are represented. The schist is best exposed underground, as it forms poor outcrops and is particularly friable. In the tunnel, the schist is dark to light grey and breaks along innumerable wavy, and nearly parallel cleavage planes. Quartzose seams a fraction of an inch thick occur throughout the greater part of the schist, but in some horizons a few tens of feet of mica schist occur without much quartz and, thereby, form softer and less solid strata.

VEINS AND MINERALIZATION

In most outcrops and underground, scattered veins of white quartz up to a few inches thick follow the bedding planes of the schist and quartzite. They commonly occur as a series of lenses connected by thin seams of quartz, and rarely traverse the bedding. Some iron rust is common in them, as a result of the oxidation of iron sulphide.

The cliffs over the intake are traversed by a rusty coloured, rather soft zone in the schist and quartzite, which appears to have been impregnated by solutions yielding silica and iron sulphide. The fresh rock in the zone has a light colour and appears silicified. On exposure to the weather the sulphide has been oxidized, and the rock somewhat softened.

STRUCTURAL FEATURES

Strikes and Dips

The quartzite and schist as a whole strike northeasterly, the direction in the northern parts of the map-area ranging between 10 and 25 degrees east and, in the southern parts, 30 to 55 degrees east. Dips are mainly easterly, and increase southerly from about 20 to 25 degrees in the north to 50 degrees in the south. On the cliffs over the intake and in the upper end of the tunnel, 600 feet or more from the lower entry, the dips flatten. Over the intake the strata show very gentle southward dips in an open and southerly plunging anticline (upward warp).

Joints

Numerous joints traverse the quartzite and quartz mica schist beds. Most of them form two steeply dipping sets, one striking north to about north 15 degrees east and the other 10 to 25 degrees south of east. The cliff over the intake also shows several nearly vertical joints, which, though following approximately the same plane, are offset a few inches to a foot one way or the other every few feet as they pass from one group of beds to another. These joints are important, as they are readily opened by the seasonal freezing of downward seeping surface water. Several in the upper face of the cliffs around the intake are gradually widening. They are a major factor in the cause of large rock falls from the cliffs in the spring.

Minor Faults on the Surface

One or more minor faults show in most of the larger outcrops. Most of these have steep dips and where their displacement is determinable, this is in the order of a few inches. A fraction of an inch of gouge or of vein material is discernible in some of them.

On the cliffs over the intake three distinct minor faults show on the west side, all dipping easterly at 24 to 67 degrees. On one, a normal displacement of the upper side of the fault downward for about 3 feet is apparent. The degree and direction of movement in the others were not determined, as their exposures in the cliffs were not accessible.

Minor Faults Underground

Several minor faults have been intersected by the tunnel. They form three groups, one striking northeasterly, with dips of from 35 to 90 degrees, another nearly parallel with the tunnel, or about north 23 degrees west, and the third striking northeasterly but with dips to the southeast of less than 20 degrees. The displacement on these faults was not determined. They are marked by seams of fine, clay-like micaceous, in some cases graphitic, gouge. Although all the rock in the tunnel is notably damp, only two of the many faults and joint fractures showed visible leakage of a little water. It is apparent that although the faults with flat dips in the tunnel result in over widening and breaking of the back in tunnelling they are all virtually water tight, their gouge generally forming an impermeable seal.

The By-Pass Fault Zone

An important fault zone is exposed on the hill slope at the lower end of the bend where development work is in progress. The By-Pass entry for the tunnel has been driven into this fault zone and pierces the northwest or foot-wall side of the zone approximately 110 feet from the portal. The foot-wall is composed of comparatively undisturbed and solid schist and quartzite. The hanging-wall side to the southeast is not exposed, but outcrops of schist show at about 100 feet from the foot-wall and the zone can be seen to be at least 70 feet wide, so that its true width is between 70 and 100 feet. The foot-wall surface is nearly plane, with very slight, long undulations. It strikes north 15 degrees east and dips southeast at 50 degrees. The drag of the schist against the fault surface indicates a normal downthrow of undetermined magnitude on the hanging-wall or southeast side.

The fault zone is filled with masses of gouge and mica schist. The gouge is mainly blue-grey and is composed of fine mica and graphite in a clay-like plaster condition. The schist is light buff, crumbly, and soft, and occurs in large masses surrounded by gouge. Many faults, most of them probably of small displacement, occur in the gouge and schist inclusions, form a network of smooth, warped, slickensided surfaces. In places in the gouge rounded or lenticular fragments of quartzite and vein quartz are embedded in the gouge.

The whole mass of the fault zone is very soft and unstable. This condition has been evidenced by numerous slips and slides of the hill under which it occurs. When drying, the gouge, and to a less extent the included masses of schist, exhibit cracks, indicating contraction on loss of moisture, and to all appearances these materials swell considerably on absorbing water though no tests have been made. It is thought that the power of this material to swell when exposed to water has been one major factor in the squeezing of the timber sets in the lower part of the By-Pass to which all the water from the tunnel drains. It is evident that this fault zone is most unstable, and that it should be avoided in placing the permanent structures. It has one virtue in the impermeability of its gouge.

DIORITE INTRUSIONS

Several dykes of hornblende-rich diorite outcrop along the Mayo River canyon near the mouth of Canyon Creek. Several of them are scattered at intervals between the mouth of the creek and hub R 35 of the traverse up the canyon. Most of them are small, somewhat schistose and chloritized, and break into fragments a few inches to a foot in size but a larger body on the east bank of the river, 200 to 300 yards above the mouth of Canyon Creek, breaks with a blocky fracture giving a considerable quantity of fragments with dimensions ranging from 1 foot to 3 or 4 feet. This rock is very tough and unusually heavy. It is exposed for 140 feet along the river bank in bluffs up to 30 feet high. The rock along the southwest side of the large body is somewhat schistose and will break into slabs, but on the northeast side the rock is very massive and coarsely jointed, and carries a few small veins of quartz, calcite, and mica. The form of this diorite intrusion is probably that of a somewhat flattened pipe, with a thick, lenticular cross-section, plunging easterly down the dip of the schist.

GEOLOGY OF THE UNCONSOLIDATED DEPOSITS

GENERAL FEATURES

The unconsolidated deposits that overlie the bedrock in the area about the site of the power development consist chiefly of glacial till overlaid by bedded glacial stream deposits ranging from medium-grained sand to coarse gravel. Scattered deposits of fine silt-like loess, ranging in depth from 1 foot to 3 feet overlie the stream deposits in some localities. It is chiefly this material that causes the roads in the vicinity of the camp to be so dusty. A small deposit of peat, overlying coarse gravel, was uncovered in a small valley in bedrock during excavations being conducted in the vicinity of the proposed site of the spillway. Due to the narrowness of the River Canyon and the lack of a floodplain in the vicinity of the site, there are only minor amounts of alluvial material.

GLACIAL TILL

The glacial till is well exposed on the west side of the canyon. There, two layers of till are separated by an irregular rusty zone. The lower glacial till, which directly overlies bedrock, consists chiefly of boulders and rock fragments of schist and quartzite of local origin, showing no bedding or sorting, in a somewhat micaceous, clayey matrix. A relatively small proportion of crystalline boulders is found in this till, and their place of origin is probably some distance beyond the limits of the site.

A considerable amount of the clayey matrix of the till has apparently been derived from the underlying bedrock, and contains quantities of micaceous material, which renders it greasy to the feel and exceedingly slippery when wet. It is thought that the high mica content in the finer parts of the till would decrease the stability of the material and, accordingly, increase the possibility of slides in areas of steep slopes.

The upper till is blue-grey, and contains a large number of black, cherty pebbles. It can be observed overlying the lower till in the walls of the excavation for dam fill on the hill northwest of the river or "of Mayo River" immediately below the proposed location of the axis of the dam. The upper till is separated from the lower by an oxidised zone that possibly represents a brief interglacial period. It appears to be a compact material, with physical characteristics better suited for an earth-fill dam than the lower till.

In most instances the thickness of the till deposits can only be determined accurately by drilling. In the area about the dam site, they appear to vary from nil to 35 feet in thickness. They rarely appear directly on surface, being usually buried beneath the deposits of silt, sand, and gravel.

GRAVEL AND SAND

The bedded deposits of sand and gravel that cover much of the ground surface about the site, and that constitute the most common, unconsolidated deposits in the area, were formed by streams of melt waters flowing from the ice-sheet. The deposits are not well sorted, but are free from organic material and from soft, disintegrated rock, and it is thought that they could supply a good grade of aggregate with proper crushing and screening. The thin layer of calcium carbonate that coats the undersides of a large number of the pebbles and boulders in the gravel is thought to have been deposited there by circulating ground water at some time subsequent to the deposition of the gravel. In most instances the lime appears to be firmly adhered to the boulders, forming a strong film between numerous sand grains and the under sides of the larger pebbles.

PERMEABILITY OF THE GRAVEL AND SAND

The permeability of the sand and gravel deposits is thought to be fairly high. A small body of fresh water, designated as Fivemile Lake, lies about ½ mile east of the camp. The surface elevation of the water in the lake appears to be fairly constant at 1,916.5 feet above sea-level (July 15, 1949). The lake is apparently perched upon some relatively impervious material, such as till, and is draining chiefly through the overlying sands and gravels. It is thought that the surface of the water should indicate the approximate contact of the two materials, in the ridge of fill, which stands immediately north of it. As the area about Fivemile Lake was considered one of the most probable in which leakages around the dam would develop, the presence of a relatively impervious material at an elevation of 1,916.5 feet would lessen the possibility of leakages in this part.

CONCLUSIONS

1. BEARING OF THE BY-PASS FAULT ZONE ON THE TUNNEL

The lower end of the tunnel is located in the wide "By-Pass" fault zone. This zone is composed of soft, plastic material and swells when absorbing moisture. Its characteristics make it quite unsuited for the location of any structure or tunnel, and as in all probability it continues to hundreds of feet in depth, no building requiring a firm foundation should be put in it. Its west boundary is shown on the map.

2. AVOIDANCE OF THE BY-PASS FAULT ZONE

The stability of the bedrock is better to the west of the fault zone along the north side of the river. A point, identified as "A", is shown on the map, west of which the rock is considered to be as stable as can be expected in the area near the lower end of the tunnel.

3. CONSIDERATION OF THE HILL SIDE WEST OF THE TUNNEL

The stability of the overburden on the hillside immediately west of the tunnel portal is poor. This material consists of broken fragments of bedrock intermingled with till, gravel, and silt and the depth to bedrock is generally less than 12 feet. There have been numerous slides and much slumping on this steep slope both of the overburden and frost heaved bedrock for a considerable time past. The slope, however, becomes more stable to westward, and the danger is negligable if the loose material is stripped off west of a point approximately 250 feet west of the portal.

4. IMPORTANCE OF MINOR FAULTS IN THE TUNNEL

Although several faults have been encountered in the tunnel, only those of low-angle dip seriously interfere with tunnel construction. These result in excessive breaking in the back of the tunnel, and where they contain much gouge heavy timbering is necessary.

5. CHANGE OF LINE FOR THE "INTAKE RAISE"

Near the intake, the tunnel as originally laid out with the final intake over the lower one on the tunnel level, would certainly have to contend with excessive breakage due to the weakness of the schist and to inclined joints and faults, some of which show in the face of the cliff above the intake. It is, therefore, most desirable that the raise for the final intake should be driven at a different azimuth to the tunnel so that it will not be directly over it and result in the formation of an undesirable large cavity.

6. LEAKAGE AROUND THE DAMSITE

Though the ridge is a compound esker and composed largely of permeable materials it is not thought that serious leakage will occur through it below the level of the water above the dam.

The bedrock of the spur of the hill to the west, which is cut through by the canyon of Mayo River, outcrops in the high river bank below the camp, and no buried channel through it is apparent from the surface exposures. It may be assumed, therefore, that no serious leakage is to be expected west of the camp. Fivemile Lake lies about $\frac{1}{2}$ mile east of the camp at the south foot of the ridge, and this stretch between the camp and the lake is thought to be the ground where leakage would be most apt to occur. The lake, however, is not far from and perched high above the river. Its level is relatively constant, though no stream flows from it, and not far below that to be attained by the water above the dam. These factors indicate that the ground below the lake level around that area is relatively impervious. However, after the water rises to the level to be maintained by the dam a close watch should be kept along the present river bank below the camp and along the former river course to the south of the camp for the appearance of any new springs.

7. WEAKNESSES DUE TO FROST

Frozen ground was encountered in the bluff, in which the upper end of the tunnel will be located, at a depth of 70 feet from the top of the cliff and 10 feet horizontally in from the original face. It is thought that frost will be encountered in the rocks of the upper part of the tunnel and that weakness will develop in the faults, joints, and cleavage planes as the frost disappears. In this respect, the lower part of the rock face above the intake should be examined with particular care as the water will thaw the rock after the pond above the dam is filled, and this may cause the detachment of rock that would ordinarily be expected to be sufficiently solid.

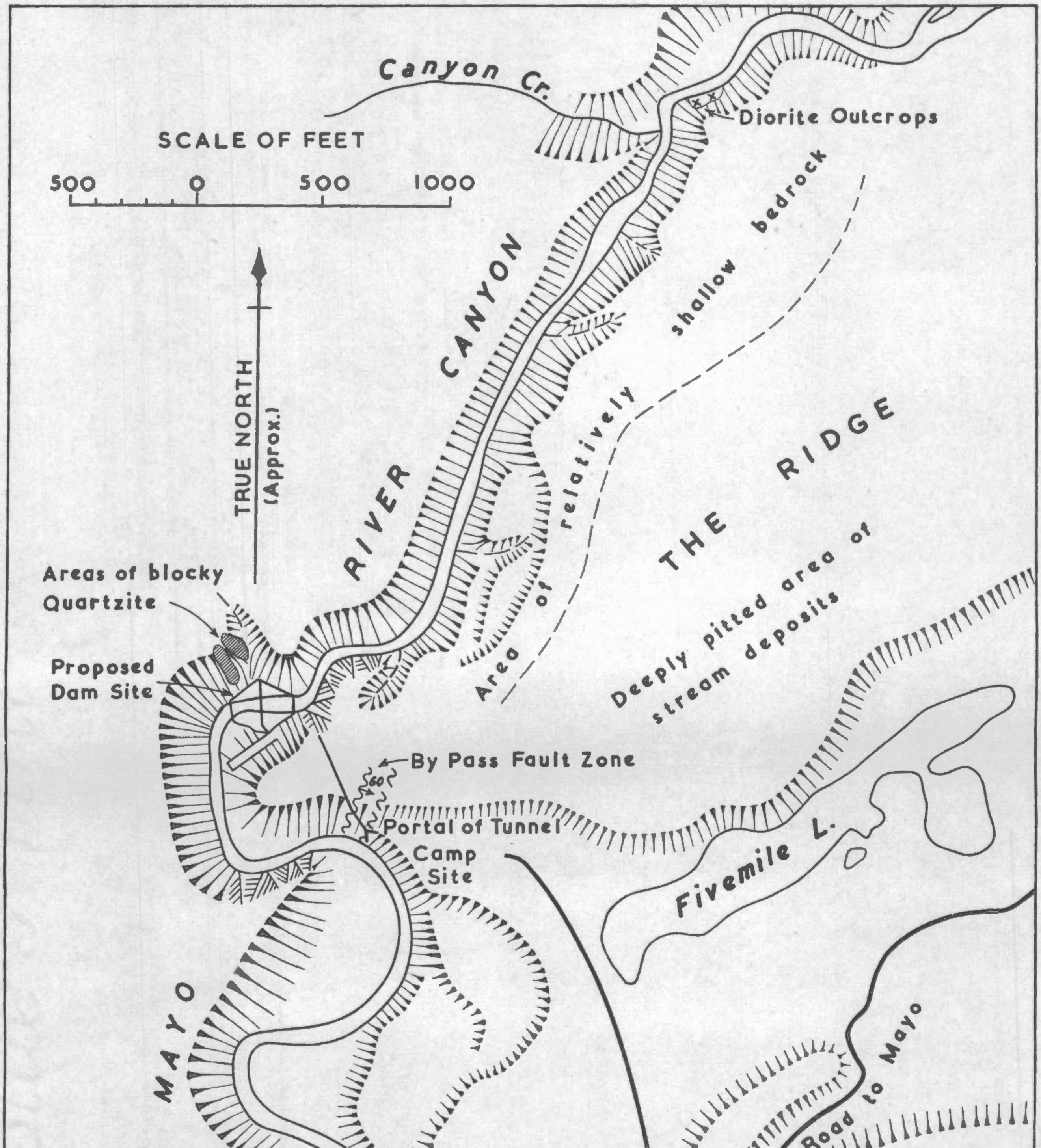
8. DEPTH TO BEDROCK BELOW THE AXIS OF THE PROPOSED DAMSITE

No holes have been drilled along the axis of the dam, and little is known of the history of the erosion of the Mayo River canyon. Judging from similar canyons that have been drilled elsewhere in the Canadian Cordillera, it seems probable that the rock floor of the river bed in the canyon could lie at a much greater depth than the 25 feet at present reported by the Montreal Engineering Company as the depth assumed for their plans.

9. SOURCES OF MASSIVE ROCK

The rock immediately around the development site is largely schist and quartzite, and has a tendency to break into relatively small, flat fragments. West of the proposed damsite and very convenient for the dam, are two small areas underlain by more coarsely broken somewhat blocky quartzite. On the surface, the two areas are approximately 60 by 120 feet and 60 by 100 feet. It is thought that the rock here originated in situ so that after the loose surface material has been scraped away more can be quarried from beneath it. In calculating the volume available to any depth, a figure 50 per cent smaller, i.e., 30 feet for width, should be used. It is thought that there will only be a few feet of loose rock and that perhaps for a depth of 6 feet or more the rock will be sufficiently loosely jointed for a bulldozer to plough it out.

In case this quartzite should be unsuitable in quality or insufficient in quantity the diorite dyke about 300 yards above the mouth of Canyon Creek on the east bank appears to be the best material. This rock is heavier than the quartzite, the specific gravities being about 3 to 2.6. It is exceptionally tough and resistant to erosion and most of the outcrops are coarsely jointed and should break into big blocks. Its superiority over the quartzite may be qualified by the cost of building about a mile of road to it and of quarrying and hauling it. The rock, however, is believed to be an exceptionally good one for the toe of the dam or for other works where large blocks are required to resist erosion.



SKETCH MAP OF THE MAYO RIVER DEVELOPMENT
YUKON TERRITORY