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UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

A PRELIMINARY REPORT OF GEOLOGIC FACTORS AFFECTING HIGHWAY CONSTRUCTION IN THE AREA BETWEEN THE SUSITNA AND MACLAREN RIVERS, ALASKA

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This report is preliminary and has not been edited or reviewed for conformity with U. S. Geological Survey standards and nomenclature.

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CONTENTS

ILLUSTRATIONS

TABLES

A PRELIMINARY REPORT OF GEOLOGIC FACTORS AFFECTING HIGHWAY CONSTRUCTION IN THE AREA BETWEEN THE SUSITNA AND MACLAREN RIVERS, ALASKA

Reuben Kachadoorian, D. M. Hopkins, D. R. Nichols

INTRODUCTION

Preliminary surveys for a highway route between the Maclaren and Susitna Rivers (fig. 1) were made during the summer of 1953, by an Alaska Road Commission location party headed by Joseph Bell, Jr. The proposed highway is to be a part of a road extending from Paxson, on the Richardson Highway, to Cantwell, on the Alaska Railroad. Construction of the road from Paxson to the Maclaren River and construction of other segments from Cantwell to the Susitna River was nearly completed during 1953.

A geological examination of parts of Healy A-1, Healy A-2, and Mt. Hayes A-6 quadrangles was made during the summer of 1953 by a Geological Survey party consisting of D. M. Hopkins, Reuben Kachadoorian, and D. R. Nichols, geologists, and Lloyd Plafker, field assistant. The part of the area lying along the route of the proposed road and along a possible access road to Denali was mapped in detail, and special emphasis was placed upon geologic factors that will affect construction of the new highway. This report, prepared at the request of the Alaska Road Commission, is a result of the studies along the proposed highway routes, and describes only those areas that are of immediate importance in planning the highway.

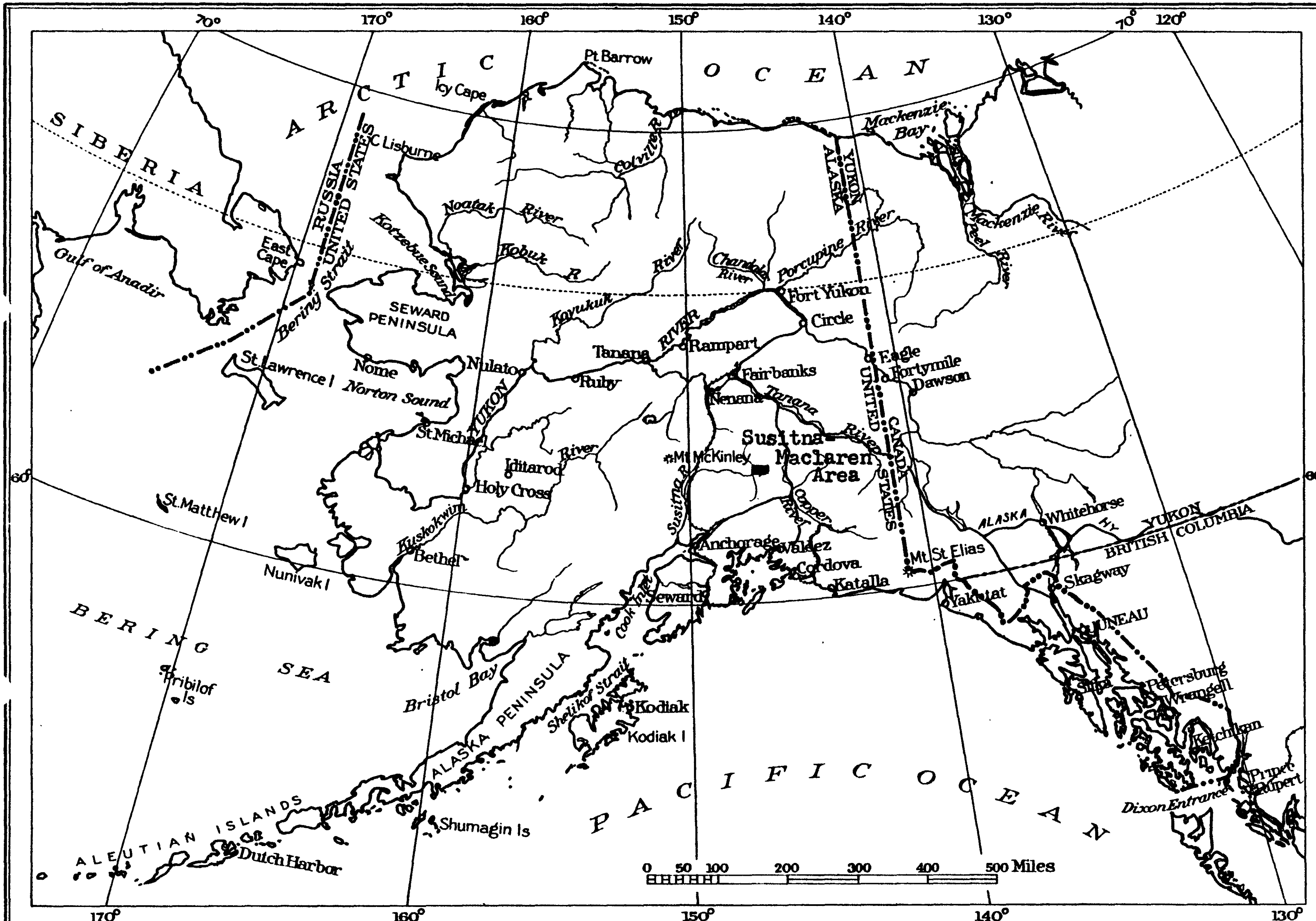

Figure 1. Index map showing location of Susitna-Maclaren area, Alaska

Method of Field Work

Field mapping by the Geological Survey consisted of a series of foot traverses during which geologic information was gathered and plotted on air photographs of various scales, and transferred later to a topographic map of 1:40,000 scale. Areas that were not visited on the ground were mapped by photo-interpretation and reconnaissance examination from a light airplane. The accuracy of the geologic map depends largely upon the density of the foot traverses and therefore, a discussion of their distribution is pertinent.

Lowland areas within a mile of the proposed highway route between the Susitna River and Corkscrew Creek were mapped in detail. In this area tractor-dug test pits spaced at 500 feet intervals along the road alignment provided data on depth of permafrost, lithology and the soil profile. In areas of low relief and dense vegetation cover, the test pits provided the best means of obtaining subsurface information and critera was established to extend lithologic units into adjacent areas.

Mapping in the area between the bridge site on the Susitna River and Denali, and between Corkscrew Creek and Little Clearwater Creek is of intermediate accuracy. Traverses in these areas are somewhat farther apart than in the area between the Susitna River and Corkscrew Creek. Test pits had to be dug by hand and were more widely spaced.

The area between Little Clearwater Creek and the Maclaren River was mapped chiefly by photo-interpretation. Time permitted only sketchy ground coverage of this area. Some places, including "Crazy Notch" through which the highway will pass 3 miles west of the Maclaren River, were not examined on the ground.

The names Clearwater Mountains, Swampbuggy Lake, Hatchet Lake, Nowater Creek, Raft Creek, Alpine Creek, Corset Creek, Corkscrew Creek, Osa Creek, "Crazy Notch", have no formal standing at the present but have been submitted for approval to the Board of Geographic Names, Department of the Interior. All other names used in this report already have received the approval of the Board of Geographic Names or have appeared on the published 1:250,000 maps of this area.

Acknowledgements

The field work and logistic support was greatly facilitated by the cooperation of the Alaska Road Commission employees. Of particular value was the cooperation of Joseph Bell, Jr., chief of the location party, and Peter Bagoy, foreman at Cantwell.

Don Sheldon of Talkeetna Air Service extended many services beyond the requirements of his flying contract with the Alaska Road Commission.

The results of mechanical analyses in this report are based on tests being made in the laboratories of the Twelfth Naval District at San Bruno, California. These results have been submitted informally to the Geological Survey pending completion of the tests.

GEOGRAPHIC SETTING

Topography

The southern part of the Susitna-Maclaren area, the area through which the highway route passes between the Susitna and Maclaren Rivers, lies in the northwestern corner of the Copper River lowland physiographic province. The area consists of an undulating lowland dominated by long, sweeping slopes extending south from the Clearwater Mountains of the Alaska Range. A range of low bedrock hills extends west from the junction of Corset Creek and the Susitna River. A lower, till-covered ridge extends south from the junction of West Fork and the Maclaren Rivers, separating the valley of the Maclaren River from the drainage basin of Clearwater Creek.

The northern part of the mapped area north of the main highway route and east of the proposed spur-road to Denali, lie in the Clearwater Mountains of the Alaska Range. These mountains gradually rise westward from subdued, widely spaced bedrock hills near the junction of West Fork and Maclaren Rivers, to a higher range of rugged mountain ridges near the mouths of Windy and Valdez Creeks. The Clearwater Mountains are abruptly terminated in the west by the broad flat-bottomed upper valley of the Susitna River, through which the spur-road to Denali would pass.

Vegetation

Vegetation in the Susitna-Maclaren area consists of three principal types: spruce forest, brushland, and tundra. Large spruce is abundant only below altitudes of 2,500 to 3,000 feet, but small spruce is scattered through much of the brushland which is found chiefly at altitudes of 2,500 to 3,500 feet. Tundra is confined largely to surfaces above 3,000 to 3,500 feet in altitude.

Most of the spruce forest consists of open, park-like stands of black or white spruce surrounded by dwarf birch and willow shrubs. The trees generally are too small for use in the construction of buildings but may be used as corduroy. Open spruce forest is found along the route of the proposed highway between Lake and Nowater Creeks and locally between Alpine and Corset Creeks.

Dense stands of tall spruce and cottonwood grow on the lower parts of alluvial fans and on the flood plains of large streams. Timber for structures and corduroy can be obtained from dense spruce stands along the highway alignment at Nowater, Raft, and Alpine Creeks.

Brushland vegetation is found interspersed with the spruce near timberline and at higher altitudes. The brushland is covered by dense thickets of dwarf birch and willow and is difficult to traverse on foot, though the brush offers no obstacle to tracked vehicles.

Both of the proposed alignments from Corset Creek to the Maclaren River lie almost entirely in brushland, and much of the route from Nowater Creek to Corset Creek and the proposed spur road to Denali, also lie in brushland.

Tundra is found chiefly on the higher mountain slopes above the brushland vegetation, but it also is found locally at lower altitudes near the Susitna River bridge site and in mountain valleys. The tundra vegetation consists of dwarfed woody plants including birch, willow, blueberry, and several heaths, and many species of herbs, grassy plants, and lichens generally growing in a dense mat. Taller representatives of many of the species that comprise the tundra are also found in the brushland vegetation. Tundra is found from the Susitna bridge site to a point about one mile to the east, and in isolated patches along the higher part of the road alignment between Nowater and Alpine Creeks.

Alder thickets are present locally on steep bedrock slopes ranging in altitude from 2,500 to 4,000 feet and along minor drainage lines that cross the highway alignment between Nowater and Alpine Creeks.

I. GENERAL GEOLOGY

General Features

The general geology of the area along the projected highway in the Susitna-Maclaren area is shown in figure 2. Bedrock, confined chiefly to the foothills north of the highway route, consists predominantly of volcanic rocks of Triassic age, but includes minor quantities of limestone, argillite, and quartzite. Tertiary coal, shale, and sandstone are exposed along Coal Creek, a small stream draining into Clearwater Creek 9 miles north of the proposed highway route. The lowland through which the highway passes is mantled by thick deposits of unconsolidated materials, chiefly of glacial origin. Bedrock in the Susitna-Maclaren area has been described by Moffit (1912) and Ross (1933). The unconsolidated materials have not been described in detail except in the vicinity of Denali, where placer gravels are of economic importance (Moffit, 1912; Ross, 1933; Tuck, 1938).

Bedrock

Bedrock will be encountered along the highway alignment only at the crossing of Windy Creek on the spur road to Denali. However, bedrock is exposed throughout the mountain front north of the highway between Lake and Corkscrew Creeks, in several low hills between Clearwater Creek and the Maclaren River, and in the mountain front east of the Denali spur road.

The bedrock consists chiefly of folded and slightly metamorphosed volcanic rocks which originally were basalt and andesite lava flows, ash, conglomerate, and breccia. Locally, the volcanic rocks are cut by tabular and irregular masses of coarse-grained diorite. The volcanic rocks are folded and fractured and their compositions have been changed slightly. This alteration was brought about mostly by heated waters and weathering processes. The rocks consist of feldspar. quartz, epidote, chlorite, augite and hornblende. In most places where they were examined the volcanic rocks contain sparely dessiminated small grains of iron sulphide. Rock colors generally are greenish-gray, but red and dark blue-gray rocks are common.

The volcanic rocks are thick-bedded, but are cut by fairly close spaced fractures. Weathering along these fractures yields angular boulders 0.5 to 3.0 feet across.

The volcanic rocks can be used for riprap or for sources of crushed rock road-metal. Satisfactory rock for concrete aggregate can be found locally but commonly the sulphide content renders the volcanic rocks unsuitable. Sulphide-free rocks are most common west of Nowater Creek. The rocks should be thoroughly prospected and samples carefully analyzed chemically and physically before any site is chosen as a source of concrete aggregate.

Volcanic rocks between Raft and Corset Creeks are more highly metamorphosed than volcanic rocks elsewhere in the area, and locally have been altered to chlorite schist. Throughout this highly metamorphosed zone, the rocks contain abundant micaceous and sulphide minerals. They weather to relatively small, platy fragments which are further weakened by the decomposition of the sulphides. Volcanic rocks between Raft and Corset Creeks are thus generally unsatisfactory for use in concrete aggregate. They will tend to crush and disintegrate under traffic, yielding a high proportion of fines and thus will offer less satisfactory material for road subgrades or surface than rocks found farther west.

Argillite predominates in the Clearwater Mountains between Windy and Valdez Creeks. Thin argillite and slate beds are interlayered with the volcanic rocks in other areas, especially in the mountains between Raft and Corkscrew Creeks. The argillite and slate generally are dark blue-gray to black in color. They consist of quartz, sericite, chlorite, biotite, and dark coloring matter which probably is carbonaceous (Ross, 1933, p. 436). Commonly the slate and argillite are impregnated with sulphides. The rocks are thoroughly fractured and weather rapidly into platy fragments 1 to 2 inches across. Their bearing strength is low and therefore slate and argillite are generally unsatisfactory for subgrade or surface material. The platy shape of the fragments and the presence of micaceous minerals and sulphides make the argillite and slate poor materials for concrete aggregate.

Chert, interbedded with volcanics and argillite, is common in the area between Raft and Corkscrew Creeks. The chert generally is in beds 5 to 20 feet thick, ranges in color from white to bright red-brown and green, and consists mostly of microscopic grains of quartz. The chert is closely fractured and breaks into angular fragments less than 2 inches across. The chert probably would be an excellent source of crushed rock, but it is relatively scarce and inaccessible from the road alignment.

Limestone is rare in the parts of the Susitna-Maclaren area adjacent to the proposed highway. Where present, it consists of thin beds, generally less than 5 feet thick, interbedded with the volcanic rocks and sediments. The limestone is white to light-gray and coarsely crystalline. It breaks along bedding planes and fractures into blocks a few inches to a foot across. Many of the limestone lenses are impregnated with sulphides. The limestone beds are too thin and too inaccessible to be of use as a construction material for the projected highway.

Unconsolidated Sediments

Most of the unconsolidated deposits of the Susitna-Maclaren area were deposited by glaciers which several times have invaded the lowland and which at least twice have covered all parts of the area that lie below altitudes of 4,000 feet. The ice originated chiefly in the high mountains of the Alaska Range and funneled into the lowland area through the valleys of the Susitna and Maclaren Rivers. Glaciers originating in smaller valleys in the Clearwater Mountains have contributed significant quantities of ice to the lowland glaciers, and thus significant quantities of debris to the deposits that mantle the lowlands.

For the purposes of this report the glacial deposits are subdivided into silty till, sandy till, rubble till, channel till complexes, end and lateral moraine complexes, kame-esker complexes, outwash gravel, pitted outwash, and channeled outwash. In general, the character of the deposits crossed by the road are not influenced by their relative age, and consequently, similar deposits of different age are grouped together for the purposes of this report.

A somewhat different terminology was used by the authors in preparing the Materials Log Book for the Alaska Road Commission during the 1953 field season. The names used there were strictly field terms and reflected incomplete knowledge of the range of variation of materials to be found in the Susitna-Maclaren area. Further field mapping and the results of mechanical analyses have caused the authors to revise their interpretations slightly.

Most of the material logged as silty till in the Materials Log Book is classified here as sandy till. Material now classified as silty till was originally logged as sandy silt.

Non-glacial unconsolidated sediments occupy only a small part of the Susitna-Maclaren area, but they are locally important in planning the new highway. The non-glacial deposits include gravelly alluvium of minor streams, silty and sandy alluvium of the Susitna and Maclaren Rivers, swamp deposits, and talus which mantles the lower slopes of steep bedrock hills.

Glacial Deposits

Till.--Till--unsorted glacial debris plastered at the base of moving ice or dumped without reworking by meltwater at the point where the ice finally melts--covers much of the Susitna-Denali area. Commonly the till is interspersed with deposits of sand and gravel at the surface and cannot be mapped separately; thus, till is a prominent constituent of the channeled-till complexes and the end and lateral moraine complexes. In many areas, however, till predominates at the surface and can be mapped separately.

The till is subdivided according to its texture into silty till, containing more than 10% silt and generally less than 20% pebbles, cobbles, and boulders; sandy till, containing less than 10% silt and less than 50% pebbles, cobbles, and boulders; and rubble till, containing little or no silt and more than 50% pebbles, cobbles, and boulders.

The texture of the till varies with its proximity to the rock cliffs from which most of it was derived. Thus, till in the central part of the Susitna and Maclaren valleys and in the Clearwater basin is generally silty, while till at the base of Clearwater Mountains, north of the proposed road between Lake and Corset Creeks generally is sandy. Rubble till is mostly confined to mountain valleys in the foothills, but locally, tongues of rubble till extend into the lowland in the area crossed by the road.

Silty till--Silty till is the predominant surface material below an altitude of 2,900 feet in the lowland area between Corset and Clearwater Creeks. The ridge, followed by the 1953 "L" line from the Susitna bridge site to Station 64 + 50, consists of a smaller area of silty till.

Surfaces underlain by silty till generally are smooth and gently undulating. Because of the high proportion of fines, the till is impermeable; consequently, horizontal and gently sloping surfaces underlain by silty till are poorly drained and marshy.

Undoubtedly much of the silty till has been mantled by wind-blown silt. However, the incorporation of this silt into the underlying silty till by frost action makes it difficult to differentiate between the wind-blown silt and silty till.

Silty till is defined here as till containing more than 10% silt. In most places, the silty till contains 25 to 50% silt (Curve F, fig.3); in the ridge followed by the "L" line east of the Susitna bridge site, silt locally comprises as much as 90% of the till. Angular or poorly rounded rocks of all sizes are dispersed through the silty till, but comprise only a small proportion of the whole deposit--generally less than 20%. About half of the rock fragments consist of granite, gneiss, schist, and argillite; the rest are volcanics. Many of the granite, schist, and argillite pebbles are deeply weathered and can be cut with a knife.

Silty till generally is blanketed with peat 0.5 to 1.5 feet thick. Much thicker layers of peat are common along marshy drainage lines and in the flat lowlands south of the projected alignment between Corset and Alpine Creeks.

The silty till between Corset and Clearwater Creeks forms a relatively thin blanket, 10 to 20 feet thick, underlain by bedded sand and gravel. Silty till in the area near the Susitna Bridge site, on the other hand, probably is at least 50 feet thick.

The silty till generally is perennially frozen at depths of 1.5 to 3.0 feet. The frozen till contains much ice in the form of lenses and veinlets; sufficient ice is present to exceed the liquid limit of the till upon thawing. Consequently, the till is extremely susceptible to frost-heaving during winter and during early spring the newly thawed, oversaturated till has little strength and flows readily. Thermokarst topography--small lakes, depressions, and steep-walled, flat-bottomed, swampy gullies resulting from collapse following the thawing of ice-rich permafrost--is common locally in areas underlain by silty till. Most silty till areas also contain polygonal and stripped vegetation patterns which result from intense frost heaving. Slopes greater than 10% commonly bear solifluction lobes which are formed by flowage of saturated till under a vegetation cover during the spring thaw. All of these features are present in the area of silty till near the Susitna bridge site.

Silty till is unsuitable for most construction purposes because of its frost susceptibility and high proportion of fines. Stripping of vegetation from surfaces underlain by silty till will be followed by thawing of permafrost and subsidence which is likely to last several years and total as much as 3 to 4 feet. Its use in subgrades or road surfaces will result in intense deformation of the surface due to heaving each winter. The till will flow during spring in sides of cuts or fills; high artificial or natural cuts are subject to large-scale landsliding on slopes as low as 1:4. Because of the abundance of fines and the low rate of infiltration in silty till, this material is subject to rapid gullying.

Permafrost, frost action, and poor drainage combine to give many construction and maintenance problems in silty till. Thus, it is desirable that large areas of this material be avoided. However, if construction of roads on silty till cannot be avoided, the adoption of construction methods which permit leaving the natural vegetation intact will be helpful. Placement of a corduroy of spruce trees on the undisturbed surface, followed by several feet of well graded gravel will minimize problems of frost action and contamination of the base course by the underlying silt.

Ditches may be constructed to insure better drainage. Narrow and deep ditches will increase the depth of seasonal thawing and are likely to become loci of rapid thawing and collapse or of rapid gullying. Wide and shallow ditches will have less tendency to increase the seasonal thaw; thereby minimizing problems related to the construction and maintenance of the ditches.

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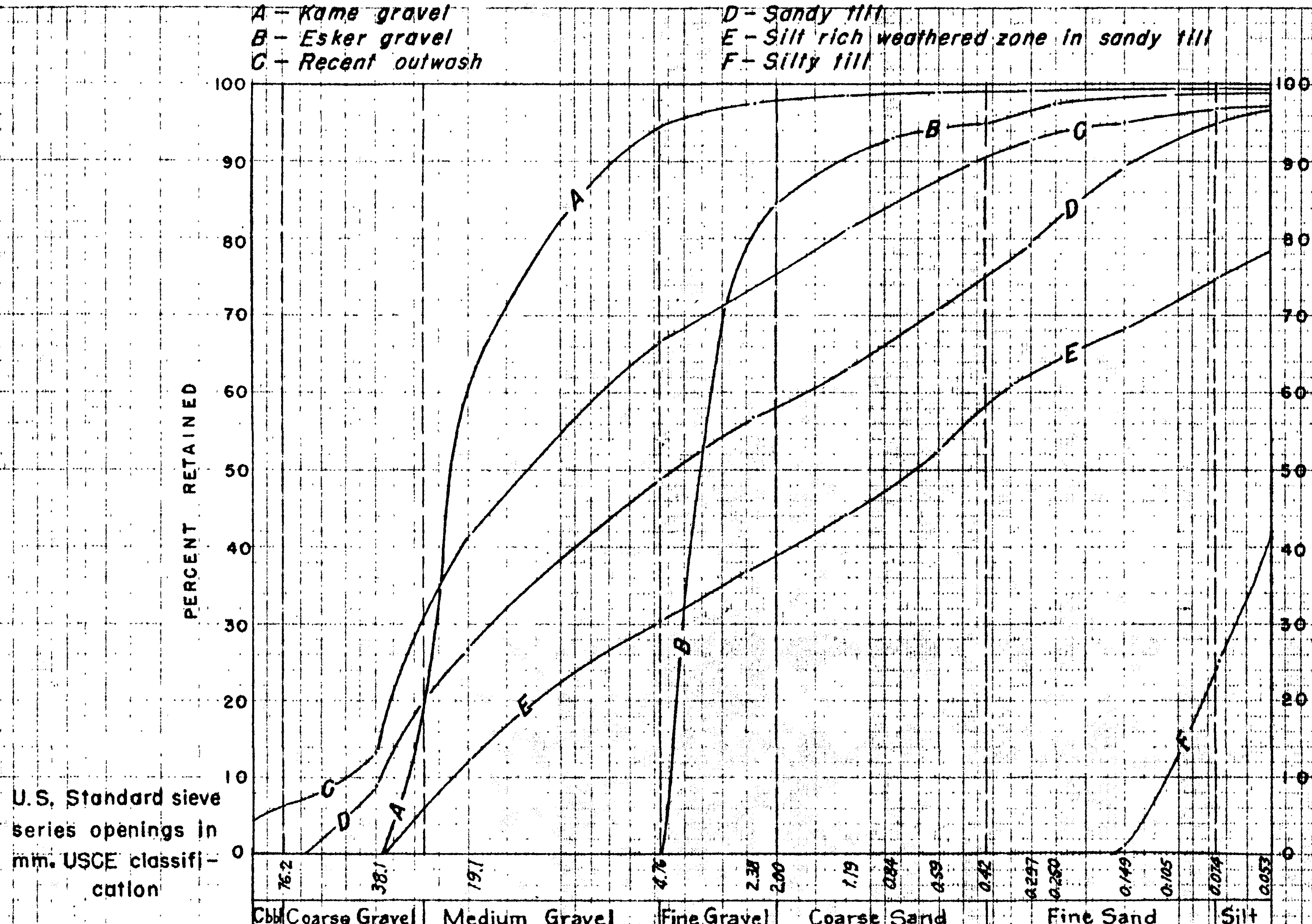

Figure 3: Cumulative curves showing mechanical compositions of glacial deposits in the Susitna-Maclaren area, Alaska.

Sandy till.--Sandy till is widely distributed along the base of Clearwater Mountains from Lake Creek to Corset Creek and from Windy Creek to Valdez Creek. Much of the Clearwater Creek basin and the Maclaren River valley consists of sandy till at the surface.

Sandy till is here defined as till containing 50 to 70% sand and less than 10% silt. The sandy till generally contains a higher percentage of rocks than silty till; pebbles, cobbles, and boulders commonly comprise about 30% of the till, and locally they make up as much as 50% of the total volume (Curve D, fig. 3). Volcanic rocks comprise 60 to 80% of the pebbles and larger fragments in the till. Slate, argillite, granite, and schist make up most of the remaining rock fragments. Many of the argillite, granite, and schist fragments are deeply weathered.

The topography of areas of sandy till consists of long, broad, smooth ridges and swales. Sharp prominences are likely to be sand dunes, eskers, or kames, and thus are likely to offer sources of clean gravel and sand. Sandy till is considerably more permeable than silty till, and consequently sandy till areas generally are fairly well drained in spite of generally low slopes and widely spaced drainage lines.

Most areas of sandy till are mantled by 2 to 12 inches of wind-blown silt. Frost action and infiltration of rain and snow melt-water have carried some of the silt downward into the till, so that the upper 1.5 feet of till may contain as much as 25% silt (Compare curves D and E, fig. 3). This upper silt-rich zone can be recognized by its toughness and by the presence of platy horizontal parting which is lacking in the more friable sandy till below.

Swales and drainage lines crossing areas of sandy till are blanketed by 0.5 to 2.0 feet of moss peat and several feet of sandy silt or coarse boulders whose interstices are filled with sandy silt (Fig. 4).

The sandy till represents material dumped along the debris-loaded margins of glaciers, and consequently it is generally found in thicker accumulations than is silty till. In most areas the sandy till ranges in thickness from 20 to 100 feet.

The silty sediments overlying sandy till in swales and drainage lines are perennially frozen at depths of 1.5 to 2.0 feet. Elsewhere permafrost lies below depths of 4 feet or more; commonly permafrost is lacking.

Seasonal frost thaws rapidly in most areas of sandy till. In mid-July, 1953, seasonal frost had receded to depths of 3 to 5 feet.

The ice content of frozen sandy till varies widely. Till having an estimated silt content of less than 3% generally is "dry frozen"--ice does not completely fill the pores, and the till does not flow upon thawing. Till having an estimated silt content of 3 to 10%, however, contains sufficient clear ice to cause it to flow like stiff concrete upon thawing. The silty sediments overlying the till in swales commonly contain much more than 10% clear ice and flow like heavy lubricating oil upon thawing.

Sandy till is far from an ideal construction material, and it presents some problems for highway building. The turf and thin mantle of silt at the surface should be stripped before the subgrade

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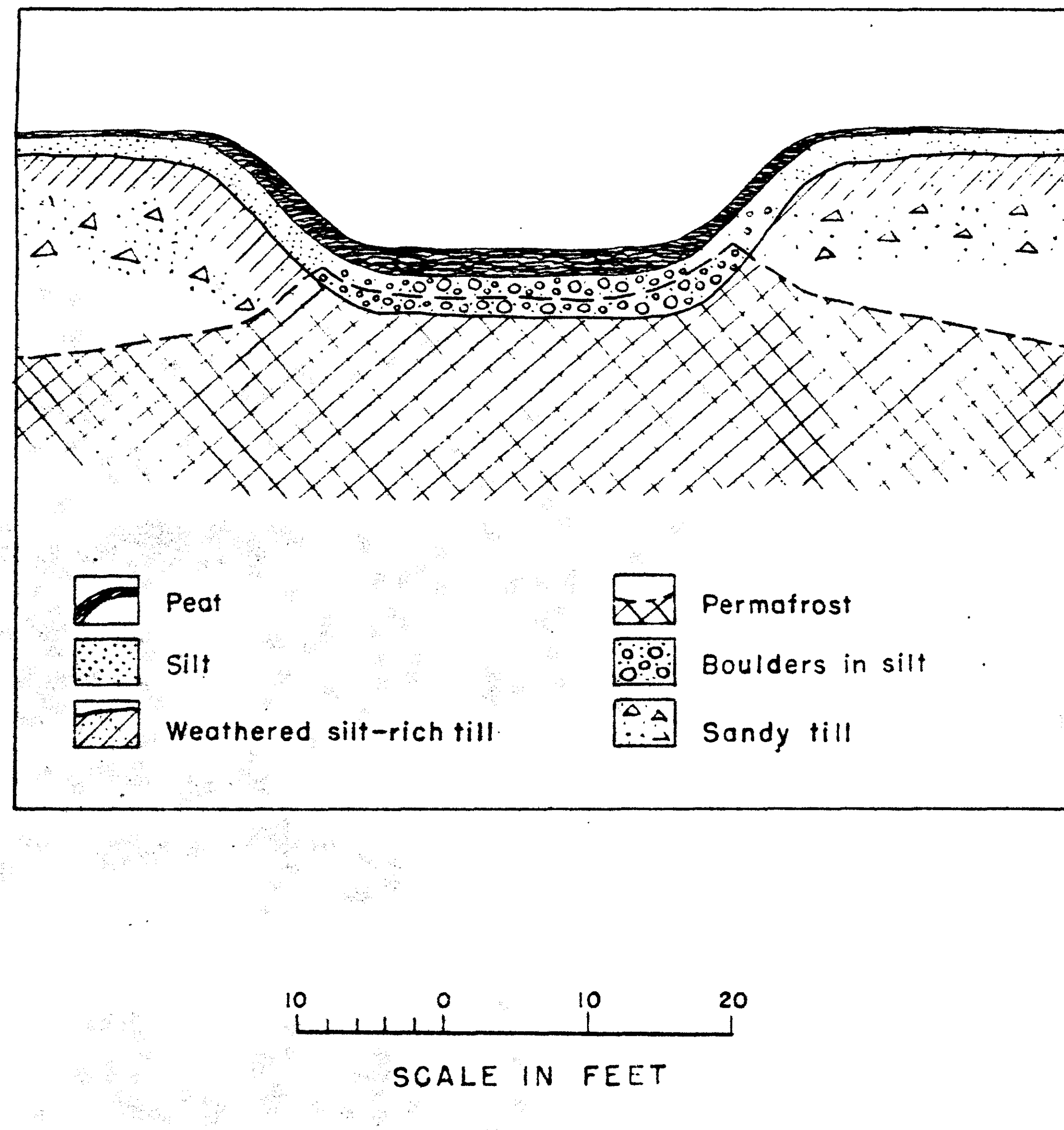

Figure 4: Diagrammatic cross section showing distribution of permafrost and sediments in swales on sandy till

is placed. Thicker peat, silt, and silt-filled rubble in swales and drainage lines should be excavated until sandy till is reached. Little or no subsidence due to thawing of permafrost will result from stripping of vegetation and silt.

Although sandy till is less frost-susceptible than silty till, the silt content commonly is sufficient to cause severe heaving during winter and loss of strength and local flowage during spring thaw, wherever it is used for fill. This is especially true of till within 2 feet of the surface which has been enriched in silt by soil-forming processes. Consequently, subgrades constructed by usual side-borrow methods will consist almost entirely of the upper, silt-rich till, while the more desireable, underlying sandy till will be left in the excavations. Better material can be obtained in selected borrow pits from which the upper, silt-rich zone has been stripped away. Wherever cleaner gravel can be obtained economically from nearby alluvial fans, kames, eskers, and outwash deposits, it should be used in subgrades in preference to sandy till.

The siltier phases of the sandy till are subject to slumps and flowage during spring in sides of high cuts and fills. They cuts probably could be stabilized with plantings of stout willow, alder, poplar, or cottonwood cuttings.

Although it is used in many low-standard roads in Alaska, sandy till is an undesireable surface material. Because of the high silt content and the abundance of cobbles and boulders, road surfaces of sandy till are muddy in spring and rough in summer.

Rubble till.--[illegible] till derived from a steep mountain valley extends northward across the 1953 "L" line between Stations 1[illegible]+00 and 1[illegible]+00. Rubble till is rare elsewhere in the lowlands but is the predominant glacial deposit in valleys in the Clearwater Mountains.

Rubble till areas are characterized by extremely rough topography composed of small, steep hillocks and ridges 5 to 50 feet high separated by swales and closed depressions. The rubble till is highly permeable, and thus these surfaces are well-drained.

Rubble till consists chiefly of talus-like debris containing 3[illegible] to [illegible]0% angular pebbles, cobbles, and boulders in a matrix of sand and silt. Locally, the till consists of open-work rubble. Blocks 1 to 5 feet in diameter are abundant. Rubble till consists almost exclusively of materials derived from nearby bedrock. The rubble till crossed by the "L" line consists entirely of volcanic rocks derived from the mountain valley to the north. Deeply weathered fragments are rare.

The rubble till crossed by the "L" line ranges in thickness from 5 to 30 feet. However, accumulations as thick as 100 feet are common in the mountain valleys.

No permafrost has been observed in rubble till at the altitudes of the 1953 "L" and "P" lines, but it may be present locally at depths greater than 5 feet. Because of the low silt content and abundance of coarse rubble, the rubble till is less subject to frost-heaving and flowage during the spring thawing season than is the sandy till;

however, some heaving and flowage can be expected in local pockets of siltier material.

Rubble till at altitudes higher than 3,500 feet commonly is perennially frozen and contain much ice which is at least partially derived from snow originally buried beneath talus avalanches. Some of the rubble till deposits at these altitudes move several feet per year in a glacier-like motion. Subsidence, flowage, and severe heaving would be expected in rubble till at these altitudes.

Construction problems in rubble till below altitudes of 3,500 feet arise chiefly from its coarse texture and rough surface topography. The abundant coarse, angular rubble is difficult to handle with bulldozers and carry-alls, and blasting of the larger rocks will be required. Though the topography is rough, the total relief is low, and cuts and fills can be balanced easily to give good grades and alignment. No subsidence due to thawing of permafrost is to be expected.

The rubble till is suitable for local use in fills, but requires crushing before it can be used for highway surfaces. The abundant large, angular rocks render untreated rubble till unsatisfactory for highway surfaces.

Channeled-till complexes.--Channeled-till complexes are extensive in the western part of the Susitna-Maclaren area. The 1953 "P" line crosses areas of channeled-till between Corset and Corkscrew Creeks.

A channeled-till complex consists of discontinuous channels and terraces, mantled by washed sand and gravel superimposed upon

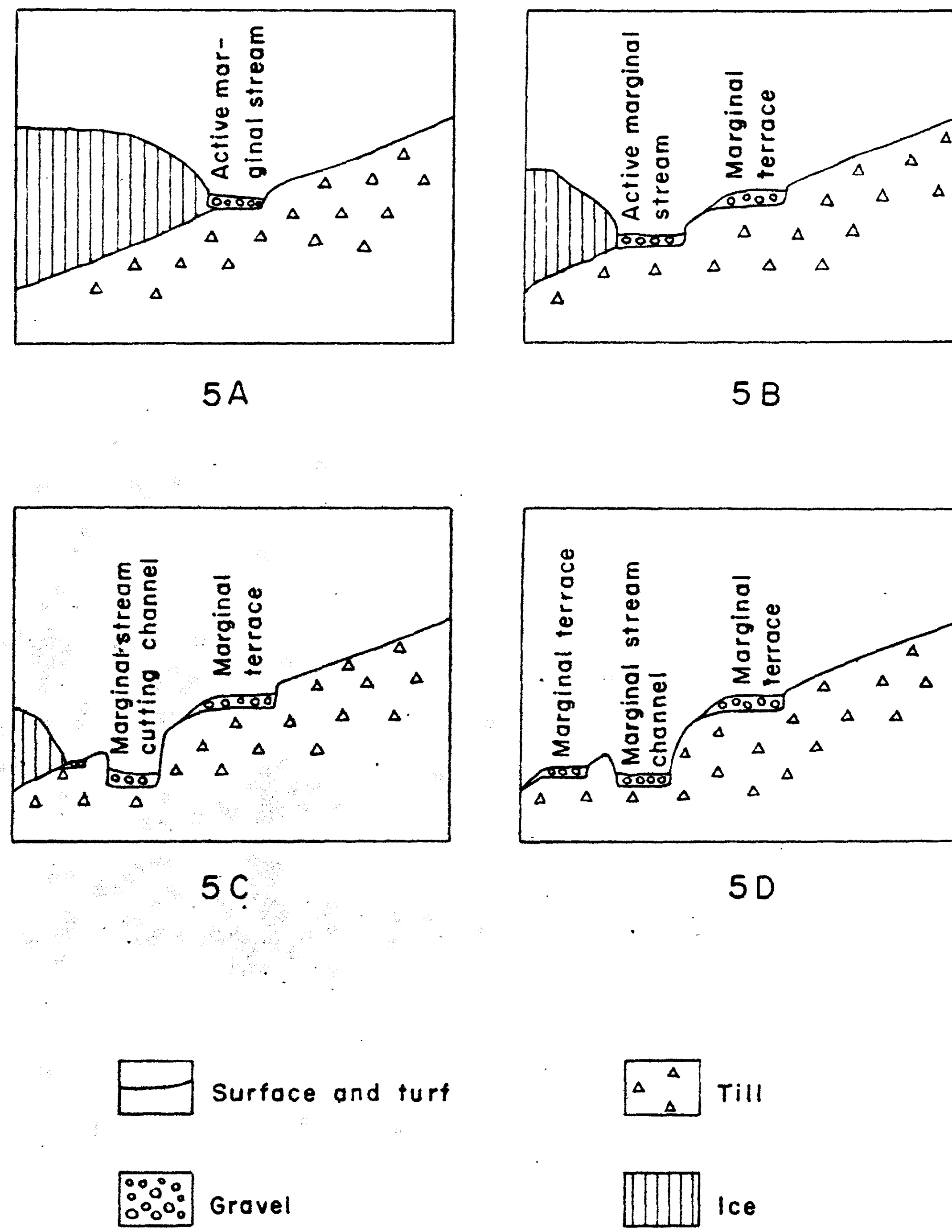

Figure 5: Diagrammatic cross sections showing development of channelized till complex

slopes and ridges of sandy till (fig. 5). Most of the channeled-till complexes were formed at the margins of stagnant glaciers. Marginal melt-water streams flowed in valleys, one wall of which was ice and the other till (fig. 5a), and gravel was deposited on the resulting terraces. In some areas the melt-water streams flowed for short distances entirely in till, cutting discontinuous channels (fig. 5c).

Most areas of channeled-till have a regional slope of 5 to 20 percent extending at right angles or obliquely to the channels and terraces. The channels and terraces thus are separated from one another by ridges or escarpments 10 to 50 feet high. Individual channels and terraces 50 to 200 feet wide and reach lengths of as much as half a mile. A few shallow lakes and undrained depressions 100 to 500 feet wide are present at the inner edges of some terraces and in some channels.

Because of the sharp local relief and the presence of permeable gravel on the flatter surfaces, channeled-till areas are generally well drained. Even the lakes are ephemeral, being drained through their floors when the water table is lowered during periods of dry weather. Large swamps are rare, but small swampy areas are present locally.

Sand and gravel, ranging in thickness from 0.5 to 6.0 feet, mantles the terraces and channels. The sand and gravel vary widely in mechanical composition, both vertically and horizontally. Lenses of sand, sandy pebble gravel, and clean pebble-cobble gravel interfinger with one another. A few large boulders 1 to 4 feet in diameter are nearly always present, and locally they are so abundant that the material is difficult to excavate. Estimated mechanical compositions of pit-run material from several channel or terrace deposits are given in Table 1. Column A represents a typical deposit; column B represents one of the coarsest; and column C one of the finest-grained deposits encountered.

Sand and gravel within 2 feet of the surface commonly is impregnated with iron oxide. Locally the stratified sediments are firmly cemented.

Both till and gravel are mantled in most places by silt ranging from 0.1 to 1.0 feet in thickness. Frost action and infiltration of surface water have carried silt downward into the underlying material. Clean gravel thus is commonly overlain by 0.5 to 1.5 feet of rocks in a matrix of silt, and till commonly has an upper silt-rich zone 0.5 to 1.0 feet thick.

Small lake beds and lake basins generally contain several feet of fine, clayey silt.

Permafrost locally is present at depths of 2.0 feet where the gravel is mantled by silt 1.5 to 2.0 feet thick. Elsewhere, the gravel generally contains no permafrost. Sandy till in the ridges between channels is locally perennially frozen below depths of 4.0 to 5.0 feet. Frozen gravel contains insufficient ice to fill the pore spaces, and it thus will not heave upon freezing nor flow upon thawing. Frozen till, however, locally contains sufficient ice to cause it to flow like stiff concrete upon thawing.

Areas of channeled-till complexes offer some problems in highway construction. The till of the ridges commonly contains sufficient silt to make it susceptible to frost-heaving and flowage. Side cuts in till capped by gravel are likely to become sites of winter icings.

The gravels of the channels afford good foundations and convenient sources of borrow. However, many of the channels probably are flooded for short periods during the spring snow-melt and during occasional periods of intense or long-continued rain in late summer. Icings may develop during winter in some channels. The deeper channels probably are sites of heavy snow accumulations that may persist into late spring.

Despite these problems, the terraces and channels probably afford better sites for construction than the adjoining till ridges. Subgrades can be constructed by stripping and discarding the turf and silt cover and then borrowing the underlying gravel mantle. Large roadside ditches and lengthy outfall ditches extending well downslope from the road alignment are desirable to assure good drainage during all seasons.

Subgrades along portions of the alignment that cross escarpments and ridges can be constructed of gravel from the terraces or channels. The local till is much less desirable for fill or road surfaces because it is frost-susceptible. High side cuts will be necessary in segments of the alignment that cross the till ridges, and these will be subject to flowage and slumping unless they can be cut to a slope of 1:4 or less, and stabilized with vegetation.

The gravel of the channeled-till complexes commonly contains considerably more coarse material than is desirable in surface materials for highways.

End and lateral moraine complexes.--Areas of end and lateral moraine complexes are common throughout the Susitna-Maclaren area. The 1953 "P" line follows a moraine complex throughout most of the segment between Nowater and Corset Creeks, and the "A" line continues along a morainal complex most of the way from Corset Creek to Clearwater Creek. The proposed "P" line will follow another morainal complex for about a mile east of the crossing of Little Clearwater Creek.

The moraine complexes are areas of rough topography consisting of ridges 20 to 100 feet high, separated by swales and undrained depressions. The moraine complex near Hatchet Lake has even higher relief; it stands as much as 500 feet above lowlands to the east and west, and the local relief generally exceeds 100 feet. Kettle holes ranging from shallow, pan-like depressions 10 feet deep and 100 feet wide to steep-walled pits 100 feet deep and 100 to 1,000 feet across are common. Lakes are common in the kettle holes and in depressions dammed by till ridges.

Drainage is generally good, but small swampy areas are found at the margins of lakes and in some kettle holes and swales.

End and lateral moraine complexes were formed at the sides and fronts of glaciers. The larger ridges represent material plowed up during periods when the glaciers were expanding and material dumped without much reworking by melt-water during periods when the glaciers were receding. Smaller sand and gravel hillocks consist of material washed into tunnels along the margins of the ice and onto the surface of the ice by melt-water streams. The kettle holes represent the sites of isolated ice blocks which melted away after being buried in gravel by these streams.

Sandy till is the predominant material composing moraine complexes. It is present everywhere at depth, and it crops out at the surface in the long, smooth ridges which are the dominant element in the morainal topography.

Stratified sand and gravel are found in eskers, kames, and outwash channels and terraces. The stratified deposits range in thickness from 3 or 4 feet on terraces and in channels to 10 or 20 feet in kames and eskers. Locally, gravelly sand, as much as 100 feet thick, is found in areas where large tributary streams dumped sand and gravel on melting ice.

The stratified deposits show a greater range of gradation than do sand and gravel deposits of channeled-till areas. They generally contain a considerably higher proportion of sand; sand-free gravel layers are rare. Large, angular boulders generally are present, especially in the upper few feet of eskers and kames. Table 2 gives the estimated mechanical compositions of pit-run material in several sand and gravel deposits in morainal complexes. Column A is typical; column B represents an extremely coarse deposit, and column C an exceptionally fine-grained deposit.

Swales and kettle holes in moraine complexes generally contain peat 0.5 to 1.0 feet thick underlain by silt or rocky silt 1.0 to 3.0 feet thick. Moraine complexes along the sides of valleys are crossed by drainage lines along which narrow alluvial fans of poorly rounded pebble-cobble-boulder gravel cover the glacial sediments.

Permafrost underlies swales and marshy drainage lines at depths of 1.5 to 2.5 feet. Sandy till in the ridges locally contains permafrost at depths of about 5 feet. More commonly, permafrost lies below the depths reached by test pits excavated during the road survey and may be entirely lacking. Gravel and sand in eskers and kames

TABLE 1

Estimated mechanical composition of pit-run material from sand and gravel deposits in channeled till areas (in percent)

	A.	B.	C.
Silt (under .0029 in.)	0	0	0
Sand (.0029 to .079 in.)	40	35	60
Fine Gravel (.079 to 3 in.)	45	40	30
Coarse gravel (larger than 3 in.)	15	25	10
	100	100	100

TABLE 2

Estimated mechanical composition of pit-run material from sand and gravel deposits in end and lateral moraine complexes (in percent)

	A.	B.	C.
Silt (under .0029 in.)	0	0	1
Sand (.0029 to .079 in.)	50	30	73
Fine Gravel (.079 to 3 in.)	40	25	25
Coarse gravel (larger than 3 in.)	10	45	1
	100	100	100

Estimates of the percent of each component are based upon visual examination and simple field tests.

generally is free of permafrost.

The sandy till of the moraine complexes is as frost-susceptible as sandy till in other areas. The fine sand of some eskers and kames may be subject to mild frost heaving, but most of the stratified deposits are not frost-susceptible.

The moraine complexes are relatively favorable areas for road building. Where considerations of grades and alignments permit, roads should be located on eskers and kames. Where eskers and kames are not abundant, the ridges offer the most satisfactory foundations. Closed depressions and swampy areas underlain by permafrost are common in the swales between till ridges, and thus the ridges are generally ~~to~~ be preferred for road foundations. Washed sand and gravel can be obtained for fills in any required amount from kame and esker deposits scattered throughout most moraine complexes. Maintenance problems will be reduced and a better road will result if these materials can be used in subgrades instead of sandy till. The till is subject to flowage and landslides on slopes steeper than 1:4. Icings must be expected in high side cuts in till ridges along the proposed highway alignment between Nowater and Corset Creeks. Consequently, high cuts should be avoided whenever possible.

Kame-esker complexes.--Kame-esker complexes are most common and best developed in the part of the Susitna-Maclaren area east of Corkscrew Creek, but smaller areas of kames and eskers also are present in the western part. Of particular importance in planning the Susitna-Maclaren highway are areas of kames and eskers about 3,000 feet southeast of the Susitna bridge site; along the lower course of Windy Creek; at the west end of the foothills, 1,000 feet northeast of Station 110 + 00 on the 1953 "L" line; approximately a third of a mile northeast of Swampbuggy Lake; parallel to and north of the "A" line of Osa Creek; and from "Crazy Notch" to the Maclaren River bridge site.

Esker-kame complexes consist of material deposited by streams on, in, or beneath glacial ice (fig. 5). Eskers are long, sinuous ridges consisting of beds of former streams that were confined in crevices on the surfaces of glaciers or tunnels within glaciers, while kames are conical, flat-topped, or irregular hillocks consisting of materials deposited in holes and irregularities on the ice surface. Esker-kame complexes commonly grade up-or down-valley into flat-topped, pitted outwash plains consisting of material dumped into an area where isolated ice blocks were melting away, but no continuous ice mass existed.

Esker-kame complexes thus consist of areas of low but rugged and intricate relief. Inverted V-shaped, steep-sided ridges and conical or irregular hillocks are intermingled or are separated by flat-bottomed depressions. Relief ranges from 5 to 100 feet. Individual eskers have more or less even summits interrupted locally by gaps and saddles; summits of adjoining, parallel eskers, however, may differ in altitude by as much as 50 feet.

The sediments of kame-esker complexes generally are coarse-grained and permeable; consequently the slopes and summits are always dry and well-drained. The flat-bottomed depressions also are dry and well-drained where they are underlain by gravel, but are swampy and may even contain lakes where the substratum is till.

Most kame-esker complexes are composed of stratified, subrounded to rounded, sandy gravel (fig. 3, curves A and B). Pit run compositions are similar to the gravels listed in Table 2. Pockets of sandy till are common within the eskers, and locally the eskers are mantled with 1 to 5 feet of silt-free sandy till. Large, angular boulders are common, especially in the upper few feet.

The kame-esker complex at the west end of the Clearwater Mountains, 1,000 feet northeast of Station 110+00, grades from pebble-cobble gravel at the base of the mountains to uniform, medium sand at the west edge of the deposit. The kame-esker complex at the mouth of Windy Creek probably shows a similar gradation from coarse gravel in the east at the mouth of Windy valley to sand in the west near the Susitna River. All test pits in the kame-esker complex 3,000 feet southeast of the Susitna bridge site exposed well-sorted medium and coarse sand containing few or no pebbles.

The depressions between kames and eskers commonly are areas that were occupied by ice blocks and which are now floored by sandy till.

Permafrost probably is not present in the sand and gravel ridges and hillocks of the kame-esker complexes, but some of the depressions may be underlain by permafrost at depths of only a few feet. The sand and gravel are not subject to heaving, subsidence or flowage during cycles of freezing and thawing.

Kame-esker complexes offer the best foundations for highways to be found in the Susitna-Maclaren area. In many areas, eskers trend in the general direction of the proposed highway; wherever this is true, serious consideration should be given to locating the road on them. Despite their rugged relief, the material is easily handled with heavy equipment. In most cases, cuts and fills can be balanced to give good grades and alignments.

The kame-esker complexes also offer the most widely distributed sources of good borrow. Because they stand above the general level of surrounding terrain, pits can be developed with a minimum of drainage and frost problems.

Outwash gravel.--Outwash gravel consists of sediments deposited by melt-water streams. Areas of outwash gravel large enough to map separately are found in terraces along Clearwater Creek, Little Clearwater Creek, and Osa Creek, and in abandoned glacial melt-water channels in many other places. The proposed highway crosses a narrow band of outwash at Lake Creek and larger outwash areas near the crossing of Clearwater Creek and to the east and west of "Crazy Notch".

The outwash sediments occupy nearly flat surfaces bounded by sharp escarpments cut in till or kame-esker complexes. The outwash surfaces have a local relief of 3 to 20 feet consisting of low escarpments, bars, and swales marking the courses of ancient stream channels.

Drainage conditions vary widely. The outwash is coarse and permeable and thus has good subsurface drainage. However, many of the outwash areas have low gradients and are indented below the surrounding terrain, collecting drainage from large areas. Outwash terraces along Clearwater Creek at and below the junction with Little Clearwater Creek are exceptionally dry and well drained. Steeply sloping outwash channels, such as those east and west of "Crazy Notch" also are well drained. Flatter outwash areas are likely to be wet in spring and late summer, and some of them are the sites of large, permanent swamps.

The outwash deposits are similar to but slightly coarser than the modern alluvium in nearby streams. They consist principally of well-rounded pebble-cobble gravel with a matrix of sand. Curve C, fig. 3 is typical. Thicknesses are generally less than 10 feet; however, the extensive outwash terraces east of the junction of Clearwater and Little Clearwater Creeks probably are underlain by about 20 feet of gravel. Most outwash deposits are mantled by 0.5 to 1.0 feet of sandy silt. Outwash deposits at Lake Creek are mantled by 2 feet of peat.

Permafrost probably is lacking in the well-drained outwash areas. It is present, however, below depths of 3 to 5 feet in swampy areas bearing a mantle of peat or silt. The gravel is not frost-susceptible, but the peat or silt mantle, where present, is subject to heaving during freezing and flowage during thawing.

Areas of well-drained outwash offer good foundations for highways. Grading problems are at a minimum. Subgrades can be built by stripping the surface turf and sandy silt, followed by side-borrowing.

Outwash terraces at the junction of Clearwater and Little Clearwater Creeks offer good sources of borrow for highway subgrades or surfaces. Ground-water table lies near the surface of outwash deposits in other areas, limiting the possible depths of borrow pits to less than 5 feet in most places.

Pitted outwash.--Pitted outwash is mostly confined to the eastern half of the Susitna-Maclaren area east of Corkscrew Creek. The only large areas of pitted outwash crossed by the proposed highway alignment lie on each side of the Maclaren River near the bridge site.

Pitted outwash is intermediate in character between unpitted outwash and kame-esker complexes. The outwash consists of sediments deposited in areas underlain by scattered blocks of stagnant glacier ice (figs. 6 and 7). The outwash areas are flat, plateau-like surfaces indented by many sharp-walled kettle holes; generally they are bounded by sharp escarpments 10 to 100 feet high. Pitted outwash plains are generally well drained, but lakes and swamps may be present in the kettle holes.

Pitted outwash plains are underlain by sandy pebble-gravel in most places. Pitted outwash deposits along the lower course of Raft Creek, 2 miles south of the highway alignment, and near the Maclaren River 1 mile south of the bridge site are composed predominantly of sand. Kettle holes are floored with silt several feet thick.

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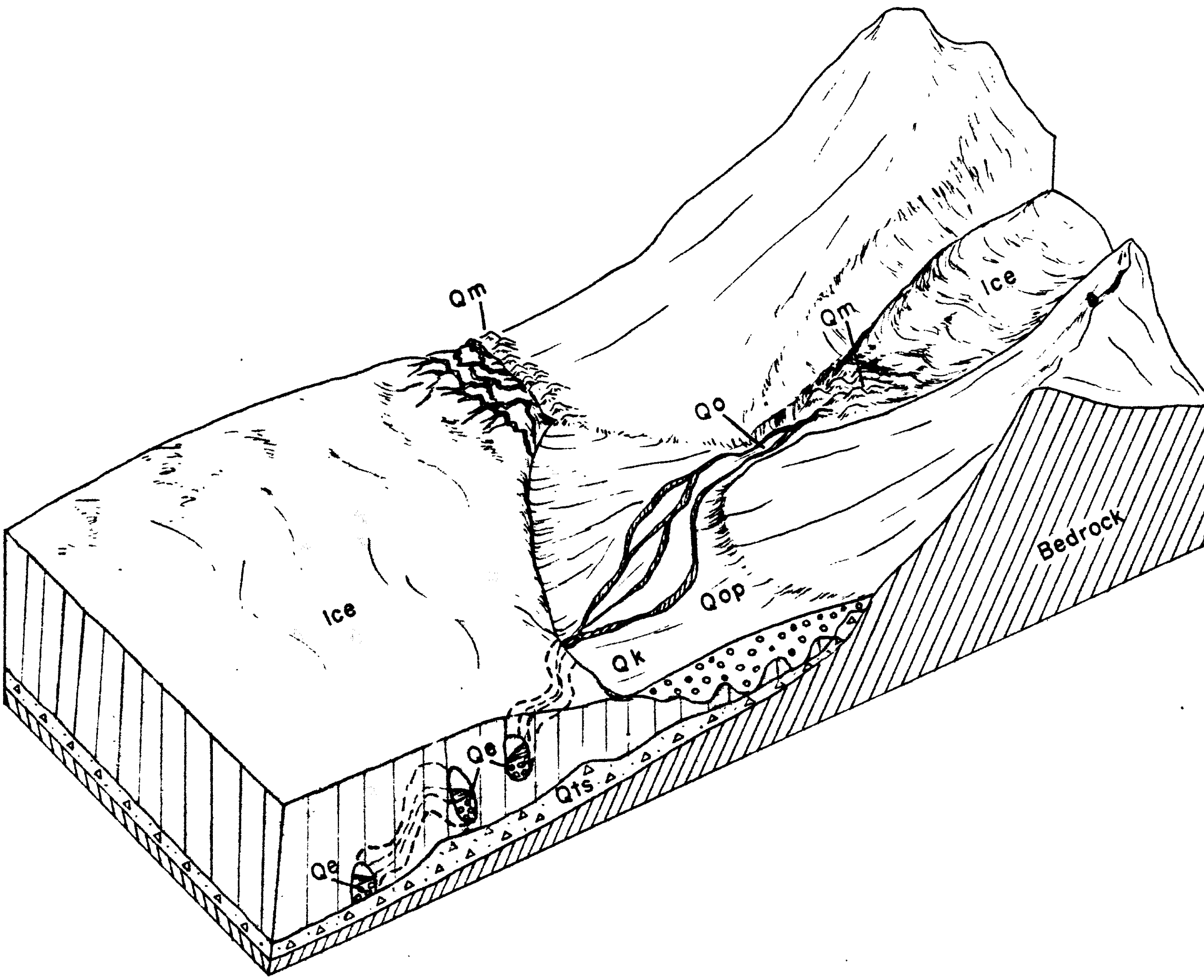

Figure 6: Block diagram showing origin and interrelationship of end and lateral moraines (Qm); sandy till ground moraine (Qts), outwash (Qo), pitted outwash (Qop), kames (Qk), and eskers (Qe) during glaciation in the Susitna-Maclaren area.

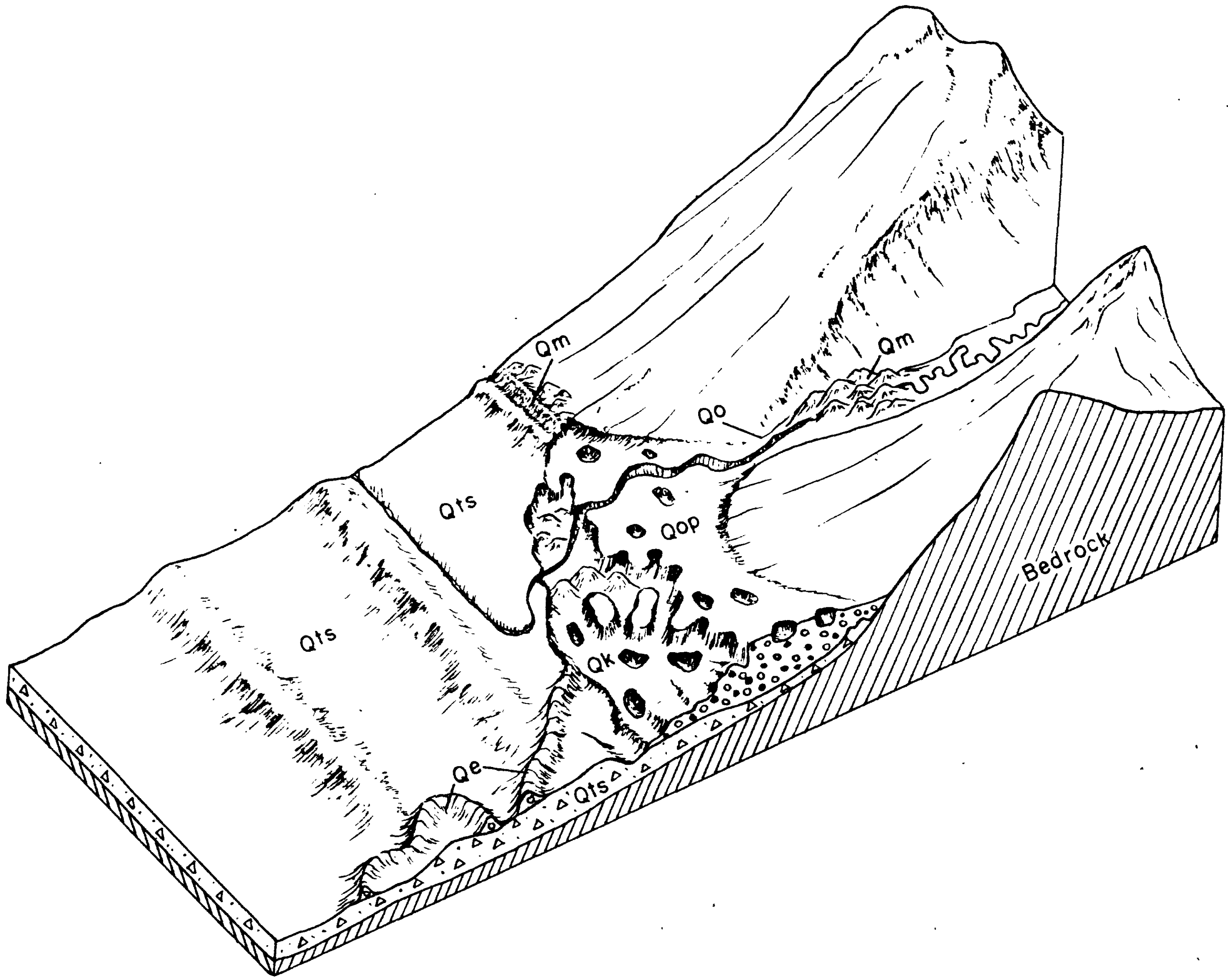

Figure 7: Block diagram showing interrelationships of end and lateral moraines (Qm), sandy till ground moraine (Qts), outwash (Qo), pitted outwash (Qop), kames (Qk), and eskers (Qe) after glaciation in the Susitna - Maclaren area.

Permafrost is probably lacking beneath the upland surfaces of most pitted outwash plains, but swampy kettle holes are likely to be underlain by permafrost at depths of 3 to 5 feet.

Pitted outwash plains are generally favorable sites for highway construction. In the least pitted portions, good grades and alignments can be obtained by stripping and side-borrowing; in the more pitted portions, similar grades and alignments can be obtained by balancing cuts and fills.

More than a million yards of gravel can be obtained in the pitted outwash plain east of the Maclaren River bridge site. Many of the other pitted outwash plains contain as much as several hundred thousand yards each. Because the pitted outwash plains stand above the surrounding terrain, the gravel can be quarried with a minimum of drainage problems.

Channeled outwash.--Channeled outwash is confined to low-lying areas between Clearwater Creek and the Susitna bridge site, half a mile to one mile south of the proposed highway alignment.

The channeled outwash represents fine alluvial material deposited on a flood plain by the Susitna River when glaciers were more extensive than at present. When the glaciers retreated, the melt-water streams became incised to form a network of broad channels separated by low, flat-topped or rolling hills. Later, the topography was modified further by frost action and the activities of beavers.

The channeled outwash thus consists of flat-bottomed valleys, 100 to 1,000 feet wide, twining among hills and knolls which stand 5 to 50 feet higher. The valleys are marshy and lake-dotted.

Streams connecting the lake are narrow, deep and sluggish.

Most of the hills and knolls are underlain by fine, silty sand. A few are underlain by silty till. Wind blown silt, 1 or 2 feet thick, and moss peat, 0.5 to 2.0 feet thick, mantles the surface. Peat and muck (silt rich in shreds of organic matter), 3 to 15 feet thick covers the floors of the valleys in most places.

Permafrost is present below depths of 2 or 3 feet throughout the hills and knolls but may be lacking in the valleys. The soils of both hills and valleys are highly frost-susceptible. Vegetation stripes and polygons and tilted trees testify to intense and widespread frost-heaving. Many of the lakes, swamps, and beaver meadows are being enlarged by thawing and collapse of the steep banks at their margins.

Areas of channeled outwash are as unfavorable as silty till for highway construction because of the poor drainage and the high frost-susceptibility of the peaty and silty soils. Extensive marshes, shallow permafrost, and highly frost-susceptible soils combine to create construction and maintenance problems. No sources of suitable borrow for subgrade or highway surfaces exist in the channeled areas. If a part of the channeled outwash complex should have to be crossed, the measures recommended for construction in areas of silty till should be considered.

Non-glacial Deposits

Gravel alluvium.--Gravel alluvium underlies channels and flood plains of all of the tributaries of the Susitna and Maclaren Rivers. In addition, large alluvial fans of gravel are developed along the courses of Nowater, Raft, Alpine, and Corset Creeks where they emerge from the foothills. The "P" and "A" lines cross the alluvial fans of Nowater and Corset Creeks and narrower strips of alluvium along several other creeks.

The fans and flood plains have relatively little surface relief and stand only a few feet higher than the stream channels. Trenches a few feet deep crossing the fans and flood plains represent abandoned channels and channels that are now occupied only during floods. The flood plain surfaces generally are dry, but water table lies less than 5 feet beneath the surface. The upstream parts of the fans are well-drained and water table generally lies 10 to 15 feet below stream grade. Further downslope, water table is near the surface; the lower ends of the fans are ringed by springs marking the points where ground water emerges.

The alluvial gravel consists of interfingering lenses of clean pebble-cobble gravel, sandy pebble-cobble gravel, and minor sand and silt. Average grain size decreases with increasing distance from the foothills or from end and lateral moraine complexes. The surfaces of the alluvial gravel deposits commonly are mantled by a few inches of silt.

The alluvial gravel areas offer good foundations for highways. Subgrades can be constructed by side-borrowing methods. Flood plain areas are subject to occasional floods and thus should be crossed on fills several feet high. Occasional radical channel changes during or following floods must be anticipated on alluvial fans and wide flood plains. The lower ends of alluvial fans are likely to be poorly drained, but drainage can be improved with adequate ditches.

Alluvial gravel areas are among the best sources of borrow and subgrades and surfacing material in the Susitna-Maclaren area. Because of the rapid size gradation from coarse gravel at the heads of fans to fine gravel at the toes, gravel of any desired average size can be obtained by selecting the proper position of the fan. Gravel size varies less regularly on flood plains. Borrow pits will be limited to depths of less than 5 feet by high ground-water table on flood plains and on the lower ends of alluvial fans. Deeper pits can be excavated on the upper ends of alluvial fans.

Silty and sandy alluvium.--Silty and sandy alluvium underlies the flood plains of the Maclaren and Susitna Rivers. Bars and channels of the Susitna River also are underlain by sandy silt alluvium.

The flood plains underlain by this fine alluvium are nearly flat, marshy surfaces crossed by a few winding sloughs and minor streams. Lakes, beaver meadows, and natural swamps are abundant. Water table lies less than 5 feet beneath the surface throughout. The entire surface is subject to occasional flooding.

The flood plain of the Susitna River is underlain by silt and sand extending to unknown depths. The surface is mantled by peat ranging in thickness from 0.5 to 10 feet. Thin peat beds also are interbedded with the sand and silt.

The flood plain of the Maclaren River is underlain by interlayered sandy silt and thin peat beds having a total thickness of

1 to 10 feet and averaging about 5 feet. The sandy silt is underlain by sandy gravel extending to unknown depths.

Permafrost has not been recognized in the sandy and silty alluvium of the flood plains, but it may be present locally. The silt and sand are subject to intense frost-heaving during seasonal freezing and to loss of strength and flowage upon thawing. Because permafrost is not present, no subsidence would be expected to result from stripping of the surface vegetation.

Flood plain areas underlain by silty and sandy alluvium are unfavorable for highway construction because they are composed of highly frost-susceptible materials and are subject to seasonal flooding. Gravel suitable for highway subgrades is available at the surface in the bars of the Maclaren River. It may also be available locally at depths greater than 5 feet beneath the flood plain. Similar gravel is more easily obtained, however, from eskers, kames, and pitted outwash deposits near the Maclaren River bridge crossing.

Swamp deposits.--A few large swamps are scattered throughout the Susitna-Maclaren area. Swamps are especially abundant in the flat flood plain of Clearwater Creek, 4 miles above the junction with Little Clearwater Creek, in the valley of Osa Creek, and along the unnamed creek that drains north to the West Fork of the Maclaren River from a point near the head of Osa Creek.

Several minor swampy areas, too small to be shown on figure 2, may be crossed by the proposed highway alignment. A larger swamp lies across the projected alignment one mile east of the Maclaren River. The alternate, northern route that has been considered for the segment of the highway between Corset Creek and "Crazy Notch" would cross a swamp 2 miles west of "Crazy Notch". Large swamps between Windy Creek and Valdez Creek are a major factor in the selection of a route for the Denali spur road.

The swamps consist of large areas of impeded drainage in which the soils are saturated throughout the year. Standing water a few inches deep covers most of the surface. Many swamps are flat, but others have slopes as steep as 2 or 3%. Many swamps bear a chain-like network of broad, low peat ridges enclosing small ponds; the pattern is conspicuous from the air and is a useful criterion for the recognition of some swampy areas.

The vegetation on the swamps generally consists of a dense growth of grassy plants. Swamps behind beaver dams generally are covered with willows 3 feet high.

Swamps in the Susitna-Maclaren area are underlain by peat, muck, and silt generally more than 5 feet thick. The maximum thickness reached by the swamp deposits is unknown but it may be as much as 20 feet in many places. Permafrost containing clear ice lenses and stringers lies below depths of 2 to 3 feet. Clearing or breaking of the turf is followed by collapse and development of thermokarst lakes. Thermokarst lakes have been formed in the tote road near the point where the projected alignment crosses the swamp one mile east of the Maclaren River.

The swamps of the Susitna-Maclaren area are extremely unfavorable for highway construction. A few swampy areas can be drained, if necessary, and beaver meadows can be partially drained by removal of the beaver dams.

Where construction across swamps is unavoidable, subgrades should be placed with a minimum of disturbance to the natural vegetation. Well-graded gravel should be laid on the natural surface--or preferably on a dense corduroy previously placed on the natural surface. If the vegetation is stripped, permafrost will thaw and subsidence will follow. The highway grade may not become stabilized for many years. Ditches also are likely to become sites of thawing and collapse which ultimately may undermine the highway grade. Consequently, no ditching should be done unless the swamp can be completely drained.

Talus.--Talus deposits are found along the front of the foothills and in steep-walled valleys within the foothills. No talus deposits are crossed by the route presently planned for the Susitna-Denali highway.

The talus consists of loose rock pried from bedrock cliffs by frost action and other weathering processes, and deposited in aprons and cones on the gentler slopes below. Angular rocks ranging from a few inches to 10 feet or more in diameter occur. However, the talus commonly consists of unsorted rock debris similar to rubble till. Some of the talus deposits reach thicknesses of as much as 100 feet. They are relatively unfavorable areas for highway construction because of their steep surface gradients. Many of the talus deposits are the sites of active rock slides. Other stabilized talus deposits may be in a state of delicate equilibrium and would develop large-scale slumps and slides if disturbed. Icings can be expected in side-hill cuts in talus deposits.

Talus deposits commonly contain abundant coarse material suitable for use as riprap. Talus could be used for fill in constructing subgrades, but kame-esker, outwash, or alluvial gravels generally are more accessible.

II. ENGINEERING GEOLOGY ALONG THE ROUTES LOCATED IN 1953

Introduction

Part I described the general characteristics of the bedrock and unconsolidated deposits in the Susitna-Maclaren area. The following part treats in detail the geological conditions along the actual routes located or considered during 1953 as well as along the proposed Denali spur road. For this purpose, the routes are divided into segments, each crossing terrain having approximately the same general characteristics. Descriptions of these terrain units are held to a minimum in order to avoid repetition of information given in Part I.

Part III discusses the problems relating to bridge construction at the proposed river-crossing sites.

Locations are given by approximate distance in miles from the nearest prominent topographic feature crossed by the route. Because of inaccuracies in the 1:40,000 base map and because of the authors' uncertainty as to the precise location of the road in several areas, some of the distances given here may not coincide with the distances measured by the Alaska Road Commission party in 1953.

Engineering Geology

"L", "P", and "A" Lines

1. Susitna bridge site to Mile 1.3 (Station 16 + 80 to 64 + 50)

The "L" line follows an east-west ridge consisting of silty till (Qtf) for 1.3 miles east of the Susitna River crossing. The till is exceptionally fine-grained; gravel sized particles make up less than 1% of the total volume. The till is perennially frozen at depths of 1.5 to 3.0 feet, and the frozen material contains clear ice lenses or stringers 1 to 2 inches thick. Larger masses of clear ice up to 8 inches thick and 18 inches wide underlie polygonal surface ridges of peat throughout the area between Station 33 + 80 and 64 + 50. The low permeability of the silty till and the presence of frozen material at shallow depths impedes subsurface drainage and results in poor surface drainage everywhere in the silty till area except on the steepest slopes.

The surface vegetation was stripped from areas adjoining the "L" line early in June, 1953. When the authors visited the bridge site a month later, the minor relief of the peat polygons had been reversed by the thawing of ice masses beneath the peat ridges. The polygons then consisted of shallow trenches underlain by peat, surrounding mounds of plastic silt. Differential subsidence of 0.3 to 0.7 feet had taken place, though the ground had thawed to depths of only 2 to 3 feet.

Severe construction and maintenance problems are to be expected along the part of the "L" line that crosses silty till. The till in the stripped area will probably continue to subside for several years as a result of the melting of ice lenses in deeper layers of frozen ground. The total subsidence may amount to as much as 3 or 5 feet. The possibility that deep gullies or thaw lakes ("thermokarst lakes") may develop along ditches and undermine the road bed poses additional problems. If silty till is used to construct the subgrade, severe frost-heaving in winter and soil flowage in spring must be anticipated.

Stabilization of the road foundation in the stripped area will require the removal of 30 inches or more of silty till and back-filled with well-graded gravel. Though these measures will reduce the effects of frost-heaving, subsidence, and flowage of the till beneath the fill material, moisture still is likely to collect under the road bed and cause severe annual frost-heaving.

Stabilization problems would be reduced but not eliminated if the line were relocated parallel to the present "L" line about 100 feet to the south, in the area that has not been stripped. The base course could be placed upon a corduroy. Subsidence due to thawing of permafrost would be reduced, but probably not completely eliminated.

Plenty of borrow for construction across the silty till area can be obtained from a kame-esker complex (Qk) located 1/4 mile northeast of Station 110 + 00 (fig. 2). This deposit grades from clean sand containing few pebbles at its outer, western edge to cobble gravel containing little sand at its inner edge at the base of the Clearwater Mountains. Clean sand containing little gravel also is available in the kame-esker complex 1/4 mile south of the "L" line between Stations 16 + 00 and 64 + 50.

An alternate route about 1/2 mile south of the present "L" line offers considerably more favorable foundation conditions than the present route between Stations 16 + 80 and 64 + 50 (fig. 8). The alternate route would extend across a relatively coarse phase of the silty till for about 1/2 mile from the bridge site and then would enter an area about 1/4 mile wide of eskers and kames composed mostly of sand. Farther east the alternate route crosses a narrow, marshy swale along Lake Creek and then extends across sandy till (Qts) to rejoin the "L" line at Station 130 + 00. The kame-esker complex has a local relief of about 40 feet so that cut and fill becomes a major factor in the economics of the alternate route. However, the absence of permafrost and drainage problems in this relatively porous sand would ease construction and maintenance problems significantly.

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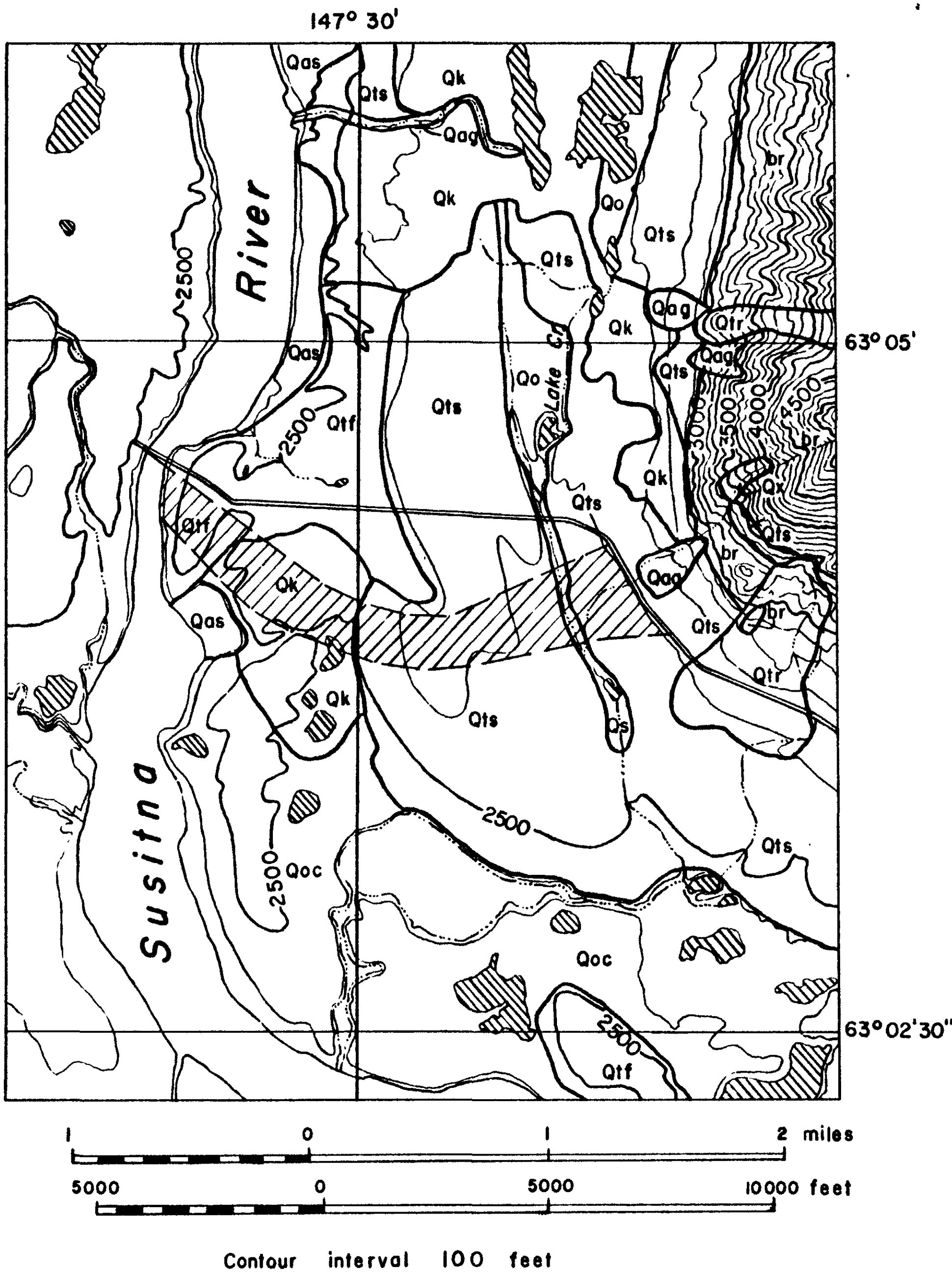

EXPLANATION

Areas of favorable geologic conditions

Qx Talus

Qag Gravel alluvium

Qo Outwash gravel

Qk Kame-esker complex

Qtr Rubble till

Qts Sandy till

br Bedrock

Areas of unfavorable geologic conditions

Qs Swamp deposits

Qas Silty and sandy alluvium

Qoc Channelled outwash

Qtf Silty till

Lake

"L" line

Zone in which geologic factors are more favorable than "L" line

Figure 8: Possible alternate road locations near Susitna bridge site.

2. <u>1 mile west of Lake Creek to 0.9 miles east of Lake Creek (Station 64 + 50 to 155 + 00)</u>. This portion of the highway route around the southwest base of the Clearwater Mountains rest upon a nearly level surface crossed by shallow, poorly drained swales at Stations 99 + 00 and 100 + 00. The area is underlain by sandy till (Qts) containing a relatively high silt content in its upper 1.0 to 1.5 feet and mantled by a surface layer of pure silt a few inches thick (fig. 4 and pg. 17, Pt. I). Drainage is good except in the swales.

Permafrost is generally lacking but seasonal frost persists at depths of 2 to 4 feet throughout most of the summer in a few areas where the silt or turf mantle is exceptionally thick. Permafrost containing clear ice underlies the swales at depths of 1.5 to 3.0 feet.

Fill can be obtained in most places by stripping and discarding the turf, silt and upper layer of silt-rich till and side borrowing the underlying sandy till. Cleaner, less frost-susceptible fill can be obtained from the kame-esker complex 1/4 mile northeast of Station 110 + 00.

Construction and maintenance problems are likely to be encountered in the fine-grained, highly frost-susceptible sediments in the swales. These problems will be minimized if the fine-grained sediments are excavated and the base course placed directly on the underlying sandy till.

The eastern half of the suggested alternate route from the Susitna bridge site to Station 130 + 00 extends across sandy till which is similar in all respects to that described here.

3. <u>0.9 miles to 1.5 miles east of Lake Creek (Station 155 + 00 to 180 + 00).</u> Rubble till (Qtr) pushed out of a small valley in the Clearwater Mountains during a comparatively recent glacial advance, constitutes the road foundation along this segment. The irregular surface is composed of angular volcanic rocks in a matrix of silty sand. The percentage of rocks ranges from 20 to 90% and average 60%.

The rubble till is relatively permeable, and drainage is excellent. No evidence of permafrost was noted and the material is relatively non-frost-susceptible. Borrow material is readily available in the immediate vicinity.

4. <u>1.5 miles east of Lake Creek to 0.5 miles west of Nowater Creek (Station 180 + 00 to 300 + 00).</u> The terrain and sediments of this unit is similar to unit 2 above. The western portion of the route rests on an east-west ridge while the eastern portion crosses a gentle south-facing slope. The surface is underlain by sandy till capped by silt rich till and a few inches of pure silt. Drainage is generally good.

Seasonal frost was encountered immediately beneath the vegetation cover during July, 1953 in test pits from Station 270 + 00 to 295 + 00. No frozen ground was encountered elsewhere in this part of the line.

The principle drainage line crossed by this segment of the route is the outlet of Swampbuggy Lake between Stations 225 + 00 and 225 + 80. During the drier part of the summer this swale has no surface flow, but a considerable underflow discharges through a layer of clean gravel about a foot thick which underlies 1.5 to 2.5 feet of peat and silt. A culvert probably will be required at this point to ensure that this underflow is not blocked by fill during construction of the highway.

Material for base course can be obtained throughout this segment of the road by stripping and discarding surface silt and the upper silt-rich till and then side-borrowing the underlying sandy till. Less frost-susceptible gravel is available in the alluvial fan of Nowater Creek between Stations 295 + 00 and 329 + 00.

5. <u>0.5 mile west of Nowater Creek to 0.3 mile east of Nowater Creek (Station 295 + 00 to 329 + 00)</u>. This segment of the "L" line crosses the alluvial fan (Qag) of Nowater Creek. The fan is composed of sandy pebble-cobble gravel containing lenses of sand and silt. It is free of permafrost and is composed of non-frost-susceptible materials.

The present channel of Nowater Creek crosses the "L" line near the axis of the fan and is incised only 2 to 3 feet below the general surface. During most of the summer the entire discharge of Nowater Creek seeps into the gravel about one-fourth mile upstream from the "L" line. However, the channel carries considerable discharge at the crossing during spring thaw and heavy summer rains.

Many abandoned drainage channels similar to the present channel of Nowater Creek cross the fan approximately at right angles to the "L" line. Spruce, willow, and alder trees several decades old grow in the abandoned channels, indicating that the channels have not recently served to carry much of the discharge of Nowater Creek, However, some of these channels may occasionally be occupied during short periods of high water in spring or late summer. Nowater Creek may also jump its course into an entirely new channel during some future period of high runoff. To prevent such a channel change, deepening or widening of the present channel or the construction of levees along the banks upstream from the road may be found advisable.

One of the important geological processes on alluvial fans is sedimentation, that is, aggradation of the stream beds in the magnitude of 5 to 10 feet within a few years. Thus, the depth of possible aggradation should be considered in determining the height of the bridge above the stream bed.

Fill material, generally sandy gravel, can be obtained at the surface in any required amount throughout the Nowater Creek fan.

6. <u>0.3 mile east of Nowater Creek to 0.1 mile west of Raft Creek (Station 329 + 00 to 482 + 00)</u>. The "L" line passes along an end and lateral moraine complex (Qm), locally crossing esker and kame ridges, on the south flank of the Clearwater Mountains between Nowater and Raft Creeks. The topography is generally irregular, characterized by short, east-west ridges and benches and south-draining swales and small alluvial fans.

The morainal deposits are composed chiefly of sandy till with local concentrations of washed sand and gravel. The sandy till is capped by silt and silty till about 1.5 feet thick except on the steep slopes and sharp-crested knobs. The "L" line takes advantage of a few eskers in the area by following them for short distances. As described elsewhere, the eskers are composed of stratified sand and gravel, commonly having a thin till cover. The most notable swales occur at Stations 348 + 00, 356 + 65 to 359 + 33, 369 + 00 to 371 + 00, 395 + 00, 399 + 00, and 406 + 00. Many other small swales also cross the "L" line. The swales are of two general types: swamp and alluvial. The swamp swales are very gently sloping and have very poor drainage. They are characterized by

1 to 3 feet of peat underlain by silt, muck, and sand. These fine-grained deposits commonly enclose abundant rocks up to boulder size.

The alluvial swales represent small alluvial fans on which the gradient has become so gentle that silt or organic matter is the material now being deposited. Fans of both types generally are underlain by permafrost at shallow depths, and their materials are highly frost-susceptible. Whenever possible, the organic mat and silt should be removed to the underlying till and the swale then backfilled with coarse, non-frost-susceptible material.

Side cuts in the till of the morainal complex are likely to be subject to slumping and soil flowage. Icings are likely to develop where swales are crossed or where gravelly layers in the till are intersected in side cuts. Maintenance problems thus will be considerably reduced if side cuts are held to a minimum.

Moderately frost-susceptible fill can be obtained by side-borrowing the sandy till along the "L" line. Eskers and kames occur in many places a short distance south of the "L" line; these offer good sources of non-frost-susceptible borrow.

7. <u>0.1 mile west to 0.1 mile east of Raft Creek (Station 482 + 00 to 492 + 00)</u>. "The "L" line crosses the head of the Raft Creek alluvial fan, which is here incised about 50 feet below the morainal complexes on each side. The creek is incised 2 to 3 feet below a flood plain several feet wide. The rest of the alluvial fan crossed by the "L" line consists of low terraces 5 to 10 feet above stream grade. The fan is composed chiefly of cobble-boulder gravel along the "L" line. Finer gravel is available in any desired quantity in the lower part of the

Raft Creek alluvial fan, one-fourth to one-half mile downstream from the crossing.

8. <u>0.1 mile east of Raft Creek to 0.1 mile west of Corset Creek (Station 492 + 00 to 660 + 00).</u> The "L" and "P" lines cross an end and lateral moraine complex, an extension of similar deposits west of Raft Creek.

However, differences are encountered from Alpine Creek to a point about 1.2 miles to the east. The line crosses an area of exceptionally boulder-rich till between Stations 547 + 60 (Alpine Creek) and 602 + 00. Rocks as large as 10 feet across are exposed at the surface. Some excavations in this area probably will require blasting. Slightly farther east, between Stations 610 + 00 and 645 + 10, the "P" line crosses an area in which the till of the morainal complex is mantled by 2 to 5 feet of stratified sand and gravel. The base course in this area can be constructed of non-frost-susceptible material by stripping the turf and surface silt and then selectively side-borrowing the gravel and sand.

Elsewhere, construction problems are generally similar to those in the morainal complex between Nowater and Raft Creeks (unit 6).

9. <u>0.1 mile west of Corset Creek to 0.1 mile east of Corset Creek (Stations 660 + 00 to 666 + 00).</u> This segment of the "P" line crosses the head of the Corset Creek alluvial fan. The material, topography, and construction problems are similar to those at the head of the Raft Creek fan (unit 7).

10. <u>0.1 mile east of Corset Creek to Corkscrew Creek.</u> The "P" line crosses channeled till (Qc) from Corset Creek to Corkscrew Creek. The general characteristics of channeled till are described on pages 22 to

25, Pt. I.

The Geological Survey's materials survey was discontinued approximately one-fourth mile west of Corkscrew Creek, so that the precise station locations of materials boundaries crossing the "P" line cannot be given from this point eastward.

The eastern part of the route between Corset Creek and Corkscrew Creek, between stations 666 + 00 and 696 + 00, crosses a series of benches and shallow terraces (Qc) on which the till bears a gravel mantle generally less than 6.0 feet thick. Most of this part of the route could be constructed by selectively side-borrowing the local gravel.

West of Station 696 + 00 the "P" line crosses a series of ridges of sandy till separated by wide, gravel-filled channels (Qc). The sandy till in the ridges has a relatively high silt content and is highly frost-susceptible. The channels, however, contain abundant non-frost-susceptible gravel covered by a mantle of peat and silt 1 to 3 feet thick. The gravel in the channel offers good foundations and a convenient source of borrow. The possibility that many channels may become flooded during the spring snow-melt or during heavy summer rains should be borne in mind when designing ditches for parts of the line which cross the channels. The till of the ridges is likely to flow on exposed slopes as low as 1:4. Consequently, side cuts in the ridges are likely to offer troublesome stabilization problems.

11. <u>"P" line between Corkscrew and Little Clearwater Creeks</u>. Time did not permit detailed materials studies along the "P" line east of Corkscrew Creek. The part of the route east of Corkscrew Creek, therefore, is discussed only briefly and in little detail. The geologic factors

affecting construction in each unit already have been discussed in as much detail as possible in Part I.

From Corkscrew Creek to a point 0.3 mile east, the "P" line crosses a southeasterly zone of eskers. The esker ridges are transverse to the road alignment, necessitating considerable grading, but since the materials are permeable sand and gravel, no serious construction problems are anticipated. Permafrost is absent, and seasonal frost should present no problems in maintenance.

The "P" line from 0.3 mile to 1.1 miles east of Corkscrew Creek crosses a series of braided outwash channels cut in sandy till (Qo and Qts). About one-third of this segment crosses outwash gravel mantled by a thin layer of silt in the channels. The rest of the line lies on hills of sandy till.

The channels probably are wet after heavy rains and in late spring, but the porous gravel underlying the thin silt mantle soon drains away any standing water. During wet seasons, however, the water table probably is close to the surface. Borrow can be obtained in any required quantity in the kame-esker complex to the east and in the outwash swale south of the "P" line.

Another kame-esker complex is crossed by the "P" line from 1.1 miles east of Corkscrew Creek to 1.1 miles west of Clearwater Creek. Aside from considerable grading, no construction or maintenance problems are anticipated.

Most of the "P" line between 0.8 mile west of Clearwater Creek and 0.3 mile east of the Clearwater Creek crossing extends across sandy till. The east approach to the Clearwater Creek bridge site extends across a series of terraces underlain by outwash gravel (Qo).

From 0.3 mile to 0.6 mile east of Clearwater Creek, the "P" line crosses gravel outwash of unknown thickness, capping sandy till. The outwash should offer an excellent foundation material; the writers do not have sufficient information to estimate the quantity of borrow that would be available, however. Ground water emerges as seeps at several points along the slope between Clearwater and Little Clearwater Creeks. This slope is a particularly favorable locality for icings to occur.

From 0.6 mile to 1.2 miles east of Clearwater Creek, the "P" line crosses an end and lateral moraine complex. The surface topography is irregular, and many parts are poorly drained. The outwash deposit to the west and a kame-esker complex immediately south provide good sources of borrow.

From 1.2 miles to 3.3 miles east of Clearwater Creek, the "P" line crosses a channeled till slope similar in most respects to unit 10. Many of the channels, however, contain water throughout most of the summer.

From 1.6 miles west to 0.4 mile west of Little Clearwater Creek, the "P" line is drawn such on figure 2 that it passes over an end and lateral moraine complex similar to Unit 8 described above. As stated earlier the authors do not know the precise location of the "P" line which may be located along an abandoned outwash channel (Qo) immediately south of the end and lateral moraine complex. The bottom of the channel is floored with peat and silt, probably several feet thick, underlain by a few feet of outwash gravel. The channel is swampy and probably carries considerable drainage during the snow-melt and during periods of heavy rain. Large ditches will be required to prevent flooding of the roadbed and to prevent icings. Cuts in the channel walls are likely to expose sandy till which will be subject to flowage and slumping during spring thaw.

Whether the "P" line passes over the end and lateral moraine complex or over the channel of the channel outwash complex, the "P" line will cross over pitted outwash (Qop) from 0.4 miles west of Little Clearwater Creek to the creek. This segment of the line will be characterized by good grades, good drainage and ample supply of borrow which can be obtained from the immediate vicinity.

Gravel alluvium (Qag) is traversed for 0.4 mile across the valley of Little Clearwater Creek. Most of the line crosses terraces 5 to 10 feet above stream grade. The lower parts of these terraces may be subject to occasional flooding.

Cobble gravel can be obtained in any required quantity from the valley of Little Clearwater Creek, for use in subgrades in nearby parts of the road.

12. <u>"P" line and alternate "P" line between Clearwater Creek and Crazy Notch</u>. The geologic map (fig. 2) of most parts of the area traversed by the "P" line and alternate "P" line between Little Clearwater Creek and Crazy Notch is based upon photo interpretation. The general characteristics and the anticipated construction problems anticipated in the various units traversed already have been described in as much detail as possible in Part I.

13. <u>"A" line from 0.1 mile east of Raft Creek to 0.4 mile east of Alpine Creek.</u> The "A" line departs from the "P" line near the Raft Creek bridge site. Kame-esker deposits underlie this first segment of the road,

offering favorable foundation conditions and abundant sources of borrow. The "A" line crosses the head of Alpine Creek alluvial fan one mile east of Raft Creek. At the bridge site, the fan is composed of cobble gravel. Large boulders, such as those exposed at the "P" line bridge site, are lacking.

14. "A" line from 0.4 to 1.7 mile east of Alpine Creek. This segment of the "A" line crosses an end and lateral moraine complex. The line rests upon generally south-sloping terrain, occasionally crossing a kame or esker. Most of the foundation material, however, is sandy till which is silt-rich in its upper 1 or 2 feet. Drainage is better, permafrost is rarer, and thicker silt accumulations in swales less common than in adjoining parts of the "P" line.

15. "A" line from 1.7 miles east of Alpine Creek to 0.6 mile east of Corset Creek. This segment crosses the alluvial fan of Corset Creek. The line is underlain by sandy gravel alluvium 5 to 10 feet thick underlain in turn by sandy till. The sandy gravel alluvium is considerably thicker and more extensive south of the road, where any desired quantity of non-frost-susceptible borrow can be obtained.

16. "A" line from 0.6 to 2.8 miles east of Corset Creek. The "A" line in this section crosses an end and lateral moraine complex, an extension of the one described in unit 14 west of Corset Creek. Much of this section is underlain by pebble-cobble gravel 3 to 6 feet thick, which is underlain in turn by sandy till. Sandy till extends to the surface locally. Numerous small eskers and kames are crossed, and others are present within a few hundred yards of the line.

17. <u>"A" line from 2.8 miles east of Corset Creek to Corkscrew Creek.</u> The "A" line here crosses the same channeled till complex that underlies the "P" line in unit 10. Relief is not so great, however, nor are the channels so continuous and broad.

The channels and terraces on which the line rests are generally parallel to the alignment. However, a few channels must be crossed. Drainage is generally good, but some poorly drained swales and channels are encountered. A particularly swampy channel is crossed immediately west of Corkscrew Creek. Here, the line could be placed on small east-trending eskers that continue with few breaks to the creek.

The till of the channeled till complex is generally less silty and therefore less frost-susceptible along the "A" line then along the "P" line. Small quantities of non-frost-susceptible fill can be obtained in small eskers a few hundred feet north of the road, one mile west of Corkscrew Creek and in the flood plain and terraces of Corkscrew Creek. Larger quantities are available in an outwash plain that extends north from the road at the west wall of the valley of Corkscrew Creek.

18. <u>"A" line from Corkscrew Creek to 0.8 mile west of Clearwater Creek.</u> After crossing Corkscrew Creek, the "A" line extends for 3.1 miles across a broad morainal ridge (Qm). Minor ridges and swales on the ridge trend parallel to the trend of the ridge itself. The ridge is composed chiefly of coarse sandy till which appears slightly washed in its upper few feet. A few swales and undrained depressions probably contain silt several feet thick. A small esker crosses the "A" line 1 1/2 miles east of Corset Creek.

Permafrost was not encountered in the few test pits excavated on the ridge. Permafrost probably is present locally at depths of 3 to 4 feet but probably will not present problems in maintenance or construction.

19. <u>"A" line from 0.8 to 0.4 mile west of Clearwater Creek.</u> The "A" line rests upon a till (Qtf) surface about 50 feet lower than the morainal ridge to the west. Sandy till predominates but silty till is present locally. Large cobbles and boulders are strewn about the surface. To minimize the effects of frost action in the silty till it may be advisable to bring this segment of the line to grade by placing non-frost-susceptible fill directly upon the vegetation and exposed rocks. An ample supply of gravel can be obtained in nearby terraces along Clearwater Creek.

20. <u>"A" line from 0.4 mile west to 0.5 mile east of Clearwater Creek.</u> The "A" line on both sides of Clearwater Creek crosses gravel outwash terraces (Qo). The terrace surfaces are level, well-drained, free of permafrost, and composed of non-frost-susceptible sandy gravel. Large quantities of borrow can be obtained from the terraces along the "A" line.

21. <u>"A" line from 0.5 to 1.0 mile east of Clearwater Creek.</u> The "A" line here crosses a kame-esker complex composed of non-frost-susceptible gravel. Permafrost either is lacking or at such depths as not to affect road construction and maintenance.

22. <u>"A" line from 1.0 to 1.7 miles east of Clearwater Creek.</u> This segment of the "A" line crosses an end and lateral moraine complex forming a bluff at the north side of the valley of Osa Creek. The morainal complex here is believed to be composed chiefly of sandy till which may be silt-rich in the upper 1 to 2 feet. Permafrost probably is lacking

within 100 feet of the edge of the bluff but may be present farther north.

23. <u>"A" line from 1.7 to 2.0 miles east of Clearwater Creek</u>. Sandy till underlies this area. The surface drainage is poorer and the silt content of the surface till probably is higher than in unit 21. A line of springs and seepages extends parallel to the contour, 10 to 15 feet below the top of the bluff and along the walls of gullies crossed by the "A" line. Walls of cuts intersecting this spring line will be subject to slumping and will be sites of large icings during winter.

24. <u>"A" line from 2.0 to 2.7 miles east of Clearwater Creek</u>. Pitted outwash (Qop) forms the surface material. The surface is well-drained, devoid of permafrost, and is generally favorable for road foundations. The outwash probably is less than 10 feet thick; small quantities of borrow for use in other areas can be obtained here.

25. <u>"A" line from 2.7 to 3.8 miles east of Clearwater Creek</u>. The "A" line here crosses the flood plain (Qs) of Osa Creek for 1.1 miles, according to the sketch of the alignment transmitted to the writers by Mr. Joseph Bell, Jr. Beaver dams further downstream have partly flooded the area and it was covered with 1 or 2 feet of standing water when visited by the writers. The flood plain is composed of sandy gravel, probably mantled by 1 to 3 feet of silt and peat. Good foundations can be obtained by stripping and discarding the peat and silt mantle. Coarse, non-frost-susceptible gravel for back-fill can be obtained from the Osa Creek esker or from the pitted outwash of unit 23.

The standing water can be drained by destroying the several beaver dams that block Osa Creek within a mile downstream from the "A" line. Osa Creek, however, is an ideal beaver stream and supports a large beaver population which probably cannot be permanently eliminated. Beaver dams that are destroyed probably will be rebuilt within a year. After initially draining the area, it may prove more economical to construct a high fill which will stand above the level of future beaver ponds than to build a low fill and periodically dynamite the beaver dams.

Consideration also may be given to the value of the beaver population as a focal point of tourist interest along the proposed road.

26. <u>"A" line from 3.8 miles east of Clearwater Creek to 5.5 miles west of the Maclaren River</u>. The "A" line here follows a long, narrow, slightly sinuous gravel esker ridge (Qk). The esker offers excellent road foundations and offers a source of large quantities of borrow for use in nearby areas.

27. <u>"A" line from 5.5 to 4.2 miles west of the Maclaren River</u>. This part of the "A" line crosses a channeled till complex for 1.3 miles. The area was not visited on the ground. Study of air photos and comparison with known areas suggests that the till of this area has a relatively low silt content, that it will afford relatively good foundations, and that the line can be brought to grade by side-borrowing local material. If the till should prove unsatisfactory, any required amount of gravel can be obtained from the Osa Creek esker (unit 25) or from the esker followed by the "P" line immediately east of the point where it joins the "A" line.

28. <u>"A" line from 4.2 to 3.0 miles west of the Maclaren River</u>. The proposed "P" line joins the "A" line near the west edge of this unit (washed till). The line then trends directly east for one mile through Crazy Notch, a steep-walled dry canyon incised 300 feet into a till-capped

ridge. The notch was cut at a time when glaciers occupied the lowlands. Meltwater from a glacier which occupied the drainage basin of the West Fork River drained east into the Maclaren Glacier.

The writers were unable to visit Crazy Notch; however, Mr. Joseph Bell, Jr. has furnished the following information: "The floor of the notch contains till material that has been slightly washed, reducing the fines in varying degrees in different locations. There are alluvial fans... which are nothing more than washed till. At the summit of the notch there is a depression filled with silt..."

Study of air photos suggests that a layer of gravel 5 to 10 feet thick may underlie the washed till and silt reported by Mr. Bell in the floor of the notch. The writers had expected that bedrock would be found in the walls of the notch, but Mr. Bell's observations indicate that bedrock either is not present or is buried under a thick mantle of till and alluvial fan deposits.

Cuts in the steep walls of Crazy Notch are likely to be unstable and subject to slumping and mudflows. Troublesome icings also are likely to develop if the natural walls are disturbed.

29. <u>"A" line from 3.0 miles west of the Maclaren River to the Maclaren River</u>. The last 3 miles of the line cross a kame-esker complex (Qk) for 0.8 mile, a channeled till complex (Qc) for 1.4 miles, and finally another kame-esker complex for 0.8 mile. The area crossed by this part of the line was not visited on the ground. Study of air photos suggests that gravel is available in eskers, kames, and outwash deposits throughout this segment of the line and that foundation conditions are generally good.

Comparison of the "P" and "A" lines. Planning and designing of the new highway may be facilitated by a comparison of geologic conditions along the "P" and the "A" lines. West of Clearwater Creek the two lines are close to one another and pass over materials that differ only slightly from one line to the other. East of Clearwater Creek the two lines are widely separated and pass over radically different materials.

Only minor differences exist between the geologic conditions along the two routes between Raft Creek and Clearwater Creek but these minor differences favor the "A" line. A slightly larger proportion of the "A" line rests on sandy or gravelly soils. Kames, eskers, and alluvial fans which offer sources of large quantities of borrow are generally nearer the "A" line. Gentler slopes prevail along the "A" line so that few side cuts will be required. Side cuts in sandy till are likely to offer stabilization problems, and may become sites of icings; consequently a reduction in the number required is desirable where other considerations are not overruling. The proportion of frost-susceptible to non-frost-susceptible soils does not differ significantly from one route to the other between Raft and Clearwater Creek; however, the "A" line is generally closer to eskers, kames, and alluvial fans offering sources of large quantities of borrow.

Between Clearwater Creek and Crazy Notch the "A" line passes through an area in which the geologic conditions are very much more favorable than in the area along the "P" line. Only a small part of the "A" line rests on till, whereas most of the "P" line is on till or on end and lateral moraine complexes. Again, few side-cuts are required along the "A" line. Numerous side-cuts probably would be required along the "P" line, especially in the portion of the route between Clearwater and Little Clearwater Creeks. Large sources of non-frost-susceptible borrow are available to most parts of the "A" line in the gravel terraces near Clearwater Creek and in the Osa Creek esker. Similar deposits are scarce and widely separated along the "P" line.

III. BRIDGE SITES

Susitna River

The Susitna River is crossed by the "L" line approximately 7.6 miles south of Denali at a point where the river is confined between high banks of till. Both approaches are nearly level.

Silty till is exposed at the top of the bluff on the east side of the river. The depth to which the till extends is unknown, but it probably extends at least to river level. A test pit dug by the Alaska Road Commission in spring, 1953 at the base of the slope on the east bank exposed only sand forming a slope-wash mantle over the slope.

The silty till contains permafrost at a depth of 5 feet. The thickness of the permafrost is unknown but may be 100 feet or more.

The bluffs lining the west side of the river were not visited by the writers. A test hole drilled by the Alaska Road Commission in early winter, 1953, at a point a few feet above the river on the west bank passed through 10 feet of muck and then 24 feet of silty till. The material was perennially frozen throughout.

Several shallow drill holes in the river bed exposed 20 to 40 feet of unfrozen stratified sand and gravel.

Silty till is likely to prove an unstable material in which to place the foundations of a large.bridge, especially if the till is frozen when construction begins. Excavations in the till will be difficult to drain, and the till probably will thaw and lose strength as the excavation progresses. For these reasons it appears that the character of the materials in which the foundations are to be placed will affect the design of the bridge and estimates of construction costs. More information concerning the character of the substratum at each bridge abutment is urgently needed. One or more drill holes at each abutment, extending at least 50 feet is recommended.

Flood plain icings probably accumulates each winter to a thickness of 5 to 10 feet in the river bed at the bridge site. However, icings probably will not affect the design of the bridge unless a pier is to be placed in the river beds.

Borrow and concrete aggregate for the Susitna bridge can be obtained from the kame-esker complex 2,000 feet northeast of Station 110 + 00. Physical and chemical analyses of this material are suggested previous to its use.

Clearwater Creek

The "A" line crosses Clearwater Creek a few hundred feet downstream from the confluence with Little Clearwater Creek. Both approaches cross series of low gravel terraces.

Gravel is exposed at the surface on both sides of the river. The gravel is at least 10 feet thick and probably much thicker. It is possible, however, that the gravel is underlain by stratified silt at a depth of 10 or 15 feet. Test holes at the site of each pier may be desirable in order to explore this possibility. Permafrost is lacking in the river gravel.

Clearwater Creek probably is free of flood plain icings at the bridge site, however, destructive river icings do occur 1 mile upstream.

All required borrow can be obtained from gravel terraces east of the bridge site. Tests should be conducted to determine the chemical and physical characteristics of the gravel before it is used for concrete aggregate.

Maclaren River

The Maclaren River is to be crossed at a point where the river is confined by eskers and kames that stand 10 to 50 feet above river level. Both approaches extend across esker-kame complexes underlain by gravel and sandy gravel. The gravel is free of permafrost.

The thickness of the gravel is at least equal to the height of the river banks. It may be underlain at about the level of the river bed by stratified silt. If the presence of silt at this depth will affect the design of the bridge, test holes should be drilled at the site of each pier.

The Maclaren River probably is free of icings at the bridge site.

Concrete aggregate and borrow can be obtained in any required quantity from the esker-kame complex on either side of the river. The material should be tested for its chemical and physical properties before use in concrete.

IV. POSSIBLE ROUTE FROM THE SUSITNA BRIDGE SITE TO DENALI

Introduction

Future economic conditions may permit a rejuvenation of placer mining at Denali. In that event, there would undoubtedly be a demand for a road connection with the Denali Highway, 7 1/2 miles to the south. Such a road would permit cheaper transportation of equipment and supplies into Denali than is now possible and would provide a rapid means of communication for mining personnel.

In anticipation of the possible demand for a spur road to Denali, several foot traverses were made in the area through which the road would be located. In all, about 5.5 miles of the possible route was examined on the ground. This route is herein designated as the "D" line and not shown on geologic map (fig. 2).

"D" Line to Windy Creek

Only 3 geologic units within the area bounded by the "D" line, the Clearwater Mountains, Windy Creek, and the Susitna River are unsuitable for road construction. They are the silty till (Qtf), described in Part II, unit 1, the alluvial silts and sands (Qas) of the Susitna River flood plain, and the outwash swales occupied by Lake Creek and smaller drainages.

The sandy till, across which the present "L" line is laid for 0.6 miles west of Lake Creek, is the most suitable road foundation and subgrade material for the first 1 1/4 miles of the "D" line. The terrain is a north-south ridge with gently east and west sloping flanks. Drainage is fair with only a few, easily by-passed undrained depressions.

Base course could be obtained by side-borrowing the sandy till or by obtaining fill from readily accessible kame-esker deposits to the north.

At the northern limit of the sandy till, kame-esker deposits extending all the way to Windy Creek are encountered. A long, sinuous esker may be picked up and followed almost to the creek. If the locating engineer should prefer not to follow the crooked and sometimes irregular topography of an individual esker however, he can still utilize the discontinuous kame-esker deposits that extend in a belt one-half to one mile wide all the way to the edge of the Windy Creek canyon.

Drainage is excellent, permafrost is lacking to depths of 3 feet or more, and borrow is plentiful and of good quality.

Windy Creek Crossing

At least two good crossing sites are available. The first involves crossing the canyon on a high bridge or fill, while the second involves a descent to the flood plain of Windy Creek and a short span crossing the creek itself.

If the road is built to high grade and alignment standards, a crossing employing a span across the entire canyon of Windy Creek probably will be preferred. Such a crossing can be effected between 1.0 and 1.4 miles east of the mouth of the creek. In this area the upland surfaces forming the north and south canyon rims are only 300 feet apart. Most of the crossing is above terrace and flood plain deposits upon which a high fill could be constructed, if desired. The stream itself is about 15 feet wide but a much longer bridge span presumably would be required.

Windy Creek can also be crossed by a road descending into the canyon at a point about 1.8 miles above the mouth. Here the high canyon walls swing away from both sides of the creek and consist of a series of terraces cut into the upland surface. The road could approach the stream from the south in a wide curve constructed across the terraces. The north approach would side-hill down the bluff from the upland surface; a sharp curve at the north edge of the bridge probably would be required.

Windy Creek to Valdez Creek

From Windy Creek to a point one mile north the only feasible route passes west of the large swamp (Qs) at the base of an alluvial fan (Qag), crossing an area of sandy till (Qts) locally interrupted by kame-esker deposits (Qk).

Starting one mile north of Windy Creek, two alternate routes may be considered. A route following the 2600 foot contour appears most desirable. This line would follow the break between the gentle upland slope that extends west from the Clearwater Mountains and the steeper slope that descends to the Susitna River flood plain. The route lies entirely on sandy till underlain by coarse outwash gravel. At many places the top of the gravel is within a few feet of the surface. A test pit 8 feet deep revealed no permafrost. Drainage is fair to good. Run-off is channelized into streams that have incised themselves into the bluff.

It would be possible but less desirable to place the route along the base of the Clearwater Mountains at the east edge of the gentle upland slope. The route would cross the heavily forested, convex surface of a series of alluvial fans and a series of talus slopes extending beyond the bedrock slopes of the mountains. Large quantities of coarse rubble would be encountered. Drainage is generally good, but icings and seeps can be expected in the many side cuts that would be required.

The upland area between these two alternate routes appear to be least suitable for construction. The surface consists of the lower parts of alluvial fans and swampy areas. It consists of silty alluvium underlain by sandy till. The silt and organic material at the surface in the swamps is highly frost-susceptible. Permafrost probably is present at depths of a few feet in many places. The natural drainage is dispersed at the base of the fans into innumerable anastomosing and occasionally flooded channels, locally resulting in swamp and bog conditions. The swamps may be partially drained by construction of drainage ditches and artificial levees.

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