UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

ENGINEERING GEOLOGY OF THE SOUTHERN HALF OF THE MT. HAYES A-5 QUADRANGLE, ALASKA

By

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INTRODUCTION

A geological examination of the southern half of the Mt. Hayes A-5 quadrangle was made during July 1954 by a Geological Survey party consisting of Reuben Kachadoorian, Troy L. Péwé, David D. Smith, geologists, and Lloyd Plafker, field assistant (fig. 1). A segment of the proposed Denali Highway crosses over the southern portion of the area examined. The Denali Highway, upon completion, will extend from Paxson, on the Richardson Highway, to McKinley Park Station, in McKinley Park.

The part of the area adjacent to the route of the highway was mapped in detail, and special emphasis was placed upon geological factors that will affect construction of the new highway. This report is a result of the studies along the highway route and describes only those areas that are of immediate importance in planning and construction of the highway.

The Geological Survey has conducted two previous engineering geology investigations of portions of the Denali Highway. Péwé mapped the area east of the Mt. Hayes A-5 quadrangle between the Tangle Lakes and the Richardson Highway during the 1951 and

1952 field seasons. In 1954, Kachadoorian, Hopkins, and Nichols investigated the area west of the Mt. Hayes A-5 quadrangle, between the Susitna and Maclaren Rivers.

Methods of Field Work

Field mapping by the Geological Survey consisted of a series of foot and tractor traverses during which geological information was gathered and plotted on vertical photographs of 1:40,000 scale, and later transferred to a topographic map of 1:40,000 scale. Areas that were not visited on the ground were mapped by photo-interpretation and reconnaissance from a light airplane.

Lithology and permafrost information was obtained by hand- and tractor-dug test pits. Depth to permafrost was established by assuming that 60 to 90 percent of the seasonally frozen ground layer had thawed at the time of the observations.

Acknowledgments

The field work was greatly facilitated by the cooperation of the Alaska Road Commission. Mechanical analyses were prepared by J. R. Watson, Materials Engineer for the Valdez District of the Alaska Road Commission.

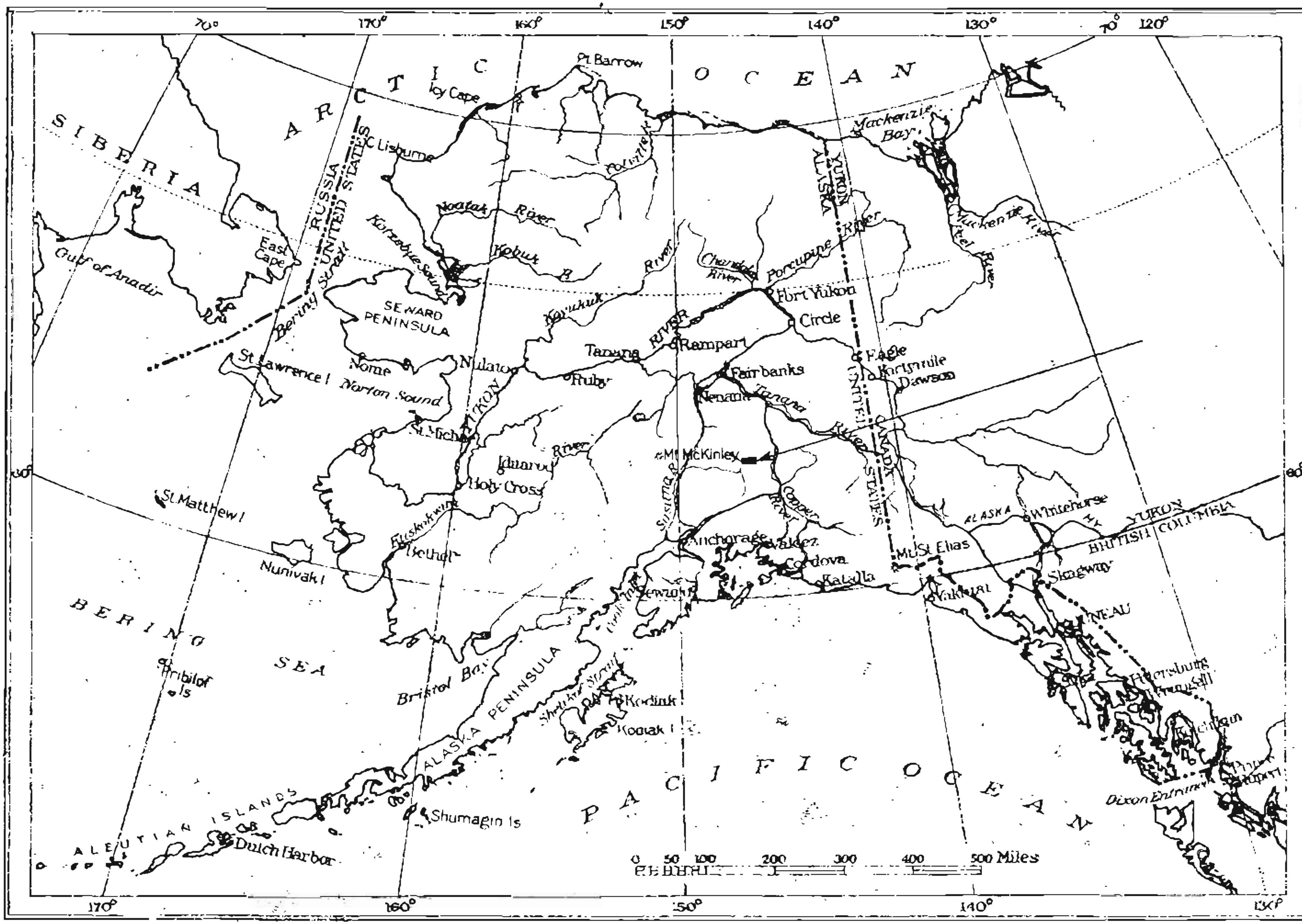

Figure 1. Index map showing location of southern half of Mt. Hayes A-5 quadrangle, Alaska

GEOGRAPHIC SETTING

Topography

The mapped area lies in the southern foothills of the Alaska Range between the Maclaren River and the Tangle Lakes. The area is crossed by two east-west ridges, the Amphitheater Mountains in the north, reaching altitudes of 4,000 to 6,900 feet, and Whistle Ridge near the center of the area, reaching altitudes of 4,000 to 4,800 feet. High Valley, a broad upland surface at an altitude of about 3,700 feet separates the Amphitheater Mountains from Whistle Ridge. High Valley is terminated on the west by a steep slope descending 1,200 feet to the Maclaren River valley and on the east by a gentler but more irregular slope descending 800 feet to the Tangle Lakes. South of Whistle Ridge, the country slopes gently southward to a group of lakes in the Gulkana D-5 quadrangle that drain west into the Maclaren River and east into the Middle Fork of the Gulkana River.

Vegetation

The vegetation in the southern half of the Mt. Hayes A-5 quadrangle consists chiefly of brushland and tundra, but open, park-like stands of black or white spruce surrounded by dwarf birch and willow shrubs are found north of the road in the eastern half of the area and below altitudes of 3,200 feet in the Maclaren River valley. The trees are generally too small for construction purposes.

Brushland vegetation is found chiefly in the southern half of the area between altitudes of 2,900 and 3,500 feet and is interspersed with the spruce at its lower limits. The brushland consists primarily of dwarf birch in well-drained areas and willow shrubs along streams and drainage lines.

Tundra vegetation is found chiefly on surfaces above altitudes of 3,000 feet and below 4,000 to 4,500 feet; it occurs on the higher mountain slopes above the brushland vegetation and in High Valley. The tundra vegetation consists of dwarf birch, several varieties of heaths, many species of herbs, grassy plants, lichens generally growing in a dense mat, and small willows along streams.

GENERAL GEOLOGY

General Features

The general geology of the southern half of the Mt. Hayes A-5 quadrangle is shown on plate 1. Bedrock, exposed chiefly in the Amphitheater Mountains and Whistle Ridge consists predominantly of volcanic rocks of Triassic age, but includes minor quantities of quartz diorite and hornblende diorite intrusives of probable Jurassic age (Moffit, 1912). The lowlands are mantled by unconsolidated Quaternary deposits, chiefly of glacial origin.

Bedrock

Bedrock is exposed in the Amphitheater Mountains, in Whistle Ridge, and in a much smaller area in the extreme eastern part of the area, in the canyon of the creek that drains Landmark Gap Lake (plate 1).

Bedrock in the Amphitheater Mountains consists chiefly of folded, dark, slightly metamorphosed volcanic rocks that originally were diabase and basalt lava flows, locally amygdaloidal, and minor quantities of tuff and argillite. Whistle Ridge consists primarily of light colored metamorphosed diabase and slight amounts of basalt; tuff and argillite were not observed. The diabase and basalt consist of feldspar, epidote, chlorite, augite, and hornblende. This bedrock complex is believed by Moffit (1912) to be of Triassic age.

Intrusive quartz diorite and hornblende diorite of Jurassic (?) age (Moffit, 1912) crops out in the extreme eastern part of the area and ranges from a fresh, light-colored rock to more abundant gray highly weathered rock.

The diabase, basalt and the intrusive diorites can be used for riprap or for crushed road metal. Satisfactory rock for concrete aggregate can be found, but the rocks should be thoroughly prospected and samples carefully analyzed chemically and physically before any site is chosen.

Unconsolidated Sediments

Most of the unconsolidated sediments were deposited by glaciers that several times invaded parts of the area and that at least twice covered all parts of the area below altitudes of 3,800 feet. The ice originated in the high mountains of the Alaska Range and funneled south into the mapped area through the valleys of the Maclaren and Delta Rivers and to a lesser extent through

Landmark and Glacier Gaps. Smaller glaciers originating in the Amphitheater Mountains added significant quantities of ice and debris.

For the purposes of this report the unconsolidated sediments are divided into nonglacial and glacial deposits. The nonglacial deposits include talus, swamp deposits, silty and sandy alluvium, gravelly alluvium, and rubble sheet. The glacial deposits are subdivided into rock glacier, pitted outwash, outwash, end and lateral moraine complex, esker-kame complex, channeled till complex, sandy till, silty till, and till on bedrock. In general, the character of the deposits is not influenced by age; similar deposits of different ages are, therefore, grouped together in this report. The terminology and definitions of most of the individual units are modified from Kachadoorian, Hopkins, and Nichols (1954), which describes the engineering geology of the adjacent area to the west.

Nonglacial Deposits

Talus.--Talus is found along the front of the Amphitheater Mountains and in the steep-walled valleys within the mountains. Talus is not crossed by the route presently planned for the 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 gentler slopes below (plate 1). Angular rocks ranging in diameter from a few inches to 10 feet occur. Some of the deposits reach thicknesses of as much as 50 feet.

Areas of talus are unfavorable for highway construction because of steep surface gradients; stabilized talus deposits commonly are in a state of delicate equilibrium and would develop large-scale slumps and slides if disturbed. Icings can be expected in cuts in talus deposits.

Talus deposits commonly contain abundant coarse material suitable for use as riprap. Talus could be used for fill, but other type deposits of equal quality are generally more accessible in the area.

Swamp.--Large swamps are scattered throughout the area and are especially abundant (1) in the Maclaren River valley, (2) in the area south of Whistle Ridge, and (3) west of the Tangle Lakes, north and south of the highway. The proposed highway alignment crosses a swamp in the Maclaren River valley.

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 much of the surface. Many swamps are flat, but others slope as steeply as 2 or 3 percent. Many swamps bear a chainlike network of broad, low peat ridges enclosing small ponds; the pattern is conspicuous from the air and is useful criterion for the recognition of some swampy areas.

The swamps are underlain by peat, muck, and silt generally more than 5 feet thick; maximum thickness is unknown but it may be as much as 25 feet in many places. Permafrost containing lenses and stringers of clear ice up to 3 feet thick lies below depths of 2 to 3 feet. Clearing or breaking of the turf is followed by collapse and development of thermokarst topography. An example can be seen along the proposed alignment in the Maclaren River valley.

The swamps are extremely unfavorable for highway construction and should be avoided wherever possible. If construction of roads on swamps cannot be avoided, however, the adoption of construction methods which permit leaving the natural vegetation intact and the addition of several feet of coarse, permeable borrow to the surface will be helpful in combating construction and maintenance problems.

Silty and sandy alluvium.--Silty and sandy alluvium underlies the floodplain of the Maclaren River. The fine alluvium of the floodplain underlies nearly flat, marshy surfaces crossed by a few winding sloughs and minor streams. Water table lies at a depth less than 5 feet throughout. The entire surface is subject to occasional flooding. The proposed alignment of the highway will not encounter any silty and sandy alluvium.

Permafrost has not been recognized in the silty and sandy alluvium but may be present locally. The fine alluvium is subject to intense frost-heaving during seasonal freezing and to loss of strength and flowage upon thawing.

Floodplain 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 may be available in the bars of the Maclaren River. Generally, however, silty and sandy alluvium is unfavorable as a source of borrow.

Gravelly alluvium.--Gravelly alluvium, consisting primarily of alluvial fans, occur chiefly in the eastern part of the mapped area. Large deposits of gravelly alluvium are developed along the courses of Rock Creek and the creek draining Landmark Gap Lake. A smaller area of gravelly alluvium exists south of Whistle Ridge. The proposed highway alignment crosses over an extensive area of gravelly alluvium east of the Tangle Lakes.

The fans and floodplains of the gravelly alluvium deposits have relatively little relief and stand only a few feet above the stream channels. The floodplain surfaces are generally dry, but the water table commonly lies less than 5 feet beneath the surface.

Gravelly alluvium consists of interfingering lenses of clean cobble gravel, sandy cobble gravel, and minor quantities of sand and silt. Average grain size decreases with increasing distance from the foothills or from end and lateral moraine complexes, which contribute a new supply of coarse material. The surfaces of the gravelly alluvium deposits commonly are mantled by a few inches of silt.

Rubble sheet.--Rubble sheets, a product of mass wasting, form blankets as much as ten feet thick of coarse detritus on the south slopes of the Amphitheater Mountains and on the north slopes of Whistle Ridge (plate 1). The present highway alignment crosses an extensive area on the north slopes of Whistle Ridge. The rubble consists of angular blocks of basalt and diabase that originated further upslope and moved by strong frost action outward over silty till as far as 3,000 feet. The downslope edges of rubble sheets are generally escarpments 2 to 10 feet high. The surfaces of the sheets generally slope about 10 degrees.

Rubble sheets consist chiefly of angular rocks ranging from 1/2 to 8 inches across, but boulders 3 feet in diameter are common. Fine material is lacking. The rubble is well-drained, but in many test pits water was observed flowing at the base of the sheet along the contact with the underlying silty till.

Permafrost is generally lacking in the rubble sheet. Permafrost, however, does commonly exist in the underlying silty till.

Rubble sheets offer a good source of borrow material for highway construction if the material is crushed. The thicker deposits also offer good road foundations.

Glacial Deposits

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 southern half of the Mt. Hayes A-5 quadrangle. 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 end and lateral moraine complexes, channeled till complexes, sandy till, and silty till.

Glaciofluvial deposits--sand, gravel and cobbles deposited by irregular wash of meltwater or subglacial streams on stagnant ice and beyond the ice terminus--exist in the mapped area as pitted outwash, outwash, and esker-kame complexes.

Rock glacier.--Rock glaciers in the southern half of the Mt. Hayes A-5 quadrangle are of two types: (1) active rock glaciers found in the small valleys of the Amphitheater Mountains, and,

(2) inactive rock glaciers found on the north slope of Whistle Ridge. The proposed highway alignment crosses two inactive rock glaciers on the north slope of Whistle Ridge.

The topography of the inactive rock glaciers are much more subdued than that of the active rock glaciers. Rock glaciers consist primarily of angular blocks and coarse gravel (fig. 2, curve D) imbedded in mud and interstitial ice. They are tongue-shaped or lobate in ground plan and their sides and fronts are generally steep. The sides range from 5 to 100 feet high, and the fronts from 30 to 150 feet high. The surfaces of rock glaciers are generally rough and may contain longitudinal ridges, transverse ridges, mounds, furrows, conical hillocks and depressions, and small ponds.

The material of rock glaciers is derived from the cliffs and cirque-walls at their heads. The surface is composed of angular rocks 6 inches to 5 feet across. At depth, however, they assume the character of till and the angular rock fragments are imbedded in mud or insterstitial ice.

Drainage is generally good in rock glaciers; locally, however, active rock glaciers have poor drainage.

Permafrost is generally lacking in inactive rock glaciers, but generally is at depths of 6 to 10 feet in active rock glaciers.

Inactive rock glaciers offer a good source of borrow material and are considered good as road foundations.

Pitted outwash.--Pitted outwash is confined to an area near the Maclaren Bridge site. The deposit is crossed by the proposed

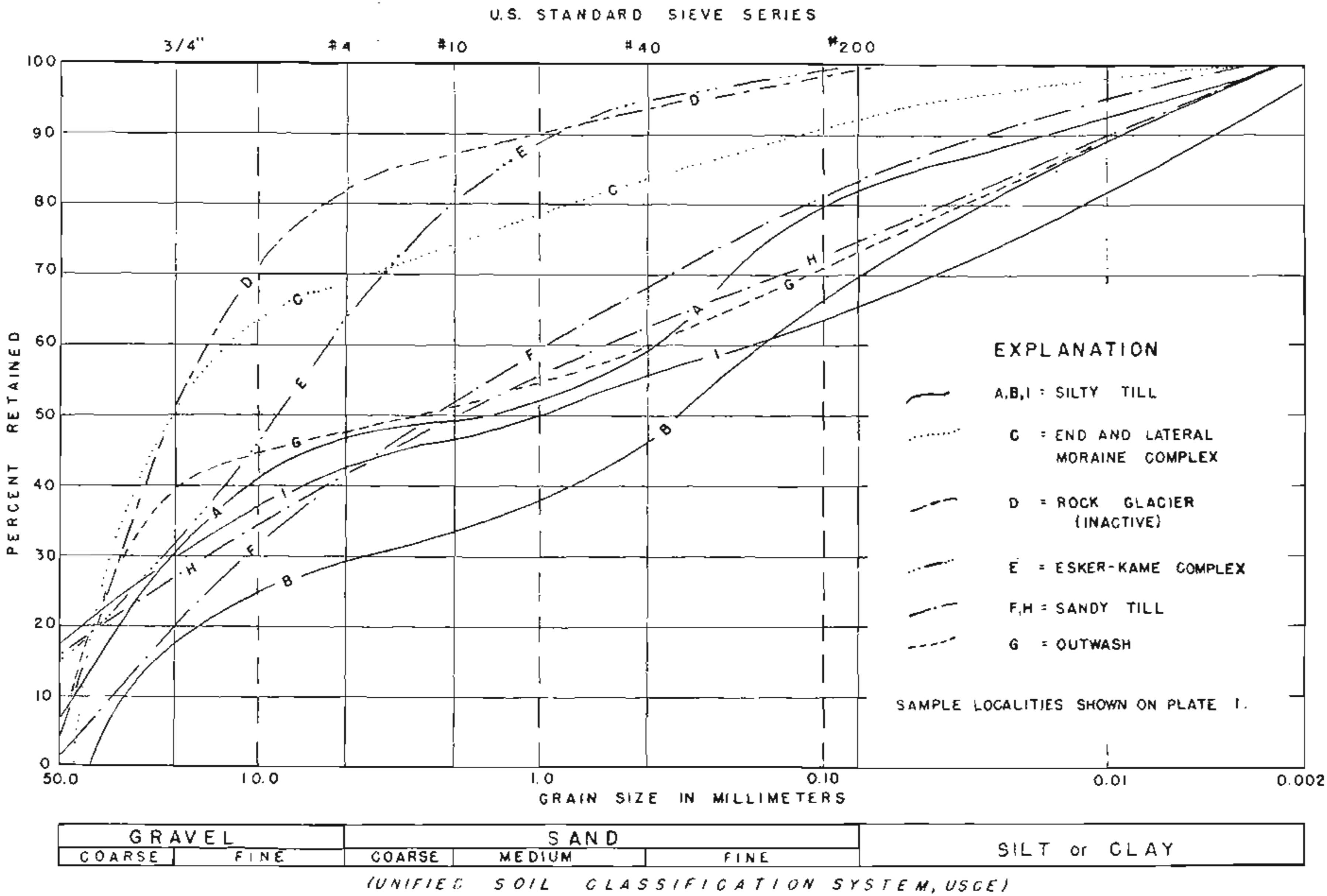

Figure 2: Cumulative size-frequency curves of nine samples of glacial deposits in the the Mt. Hayes A-5 Quadrangle Alaska.

alignment of the highway. The outwash area is flat, plateau-like surface, indented by many sharp-walled, silt-floored kettle holes bounded by sharp escarpments 10 to 100 feet high. Pitted outwash is intermediate in character between unpitted outwash and esker-kame complexes; it consists of sediments deposited in areas formerly underlain by scattered blocks of stagnant ice (figs. 3 and 4).

The pitted outwash plain is generally well-drained, but lakes and swamps are present in the kettle holes.

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

The pitted outwash plain is a favorable site for highway construction. In the least pitted portions, good grades and alignments can be obtained by stripping and side-borrowing; in the more pitted portion, similar grades and alignments can be obtained by balancing cuts and fills. Abundant borrow may be obtained from pitted outwash.

Outwash.--Outwash consists of sediments deposited by meltwater streams. Areas large enough to be mapped separately are found in the eastern part of the area north and south of the highway and in an abandoned glacial meltwater channel west of Asar Lake. The highway alignment crosses a small area of outwash in the eastern part of the area.

The outwash sediments occupy nearly flat surfaces bounded by sharp escarpments cut in till or in esker-kame complexes. The

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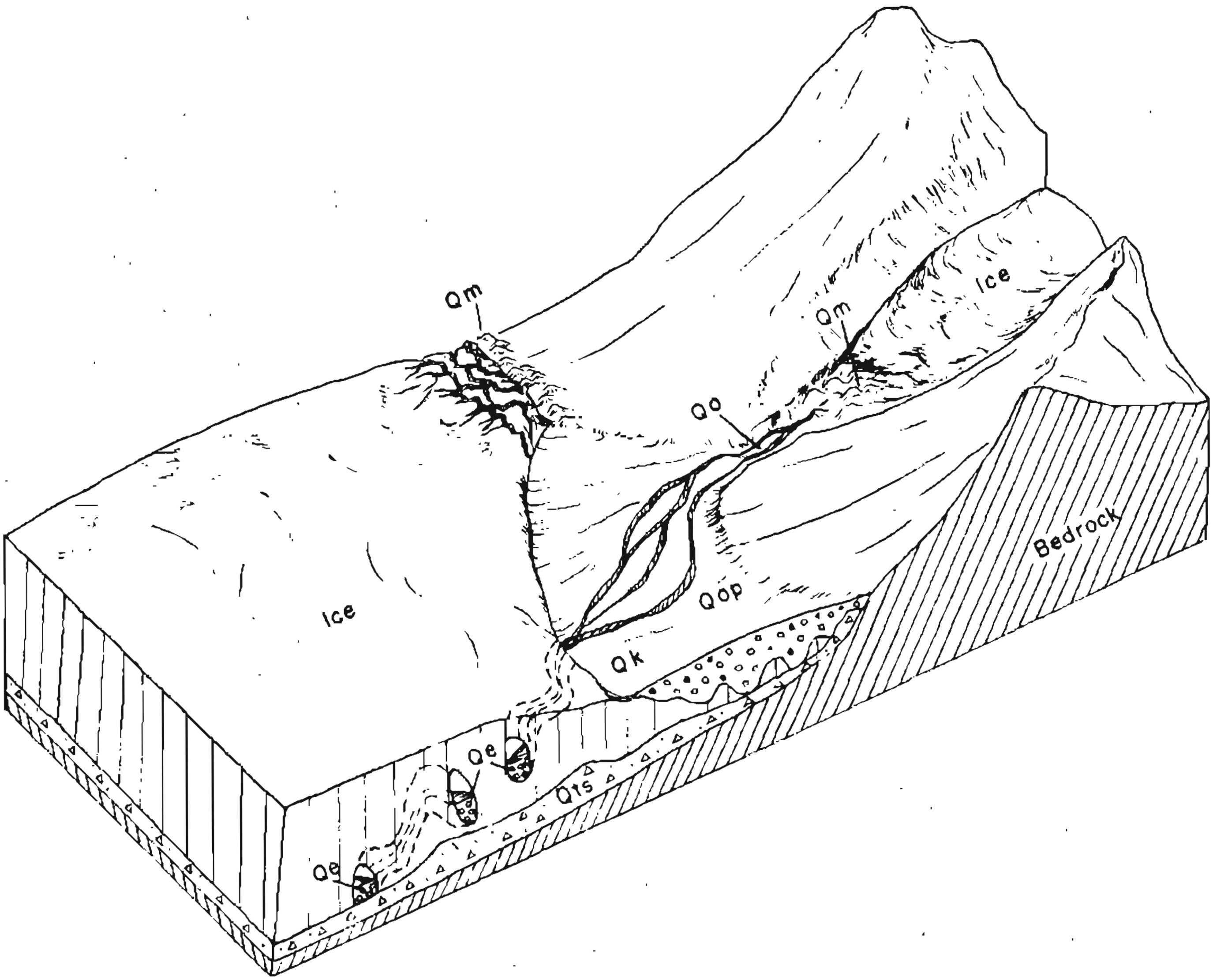

Figure 3 : Block diagram showing origin and interrelationship of end and lateral moraines (Qm); sandy till ground moraine (Qts), outwash (Qo), pitted outwash (Qop), kames (Qk), and eskers (Qe) during glaciation (Kachadoorian, Hopkins and Nichols, 1954)

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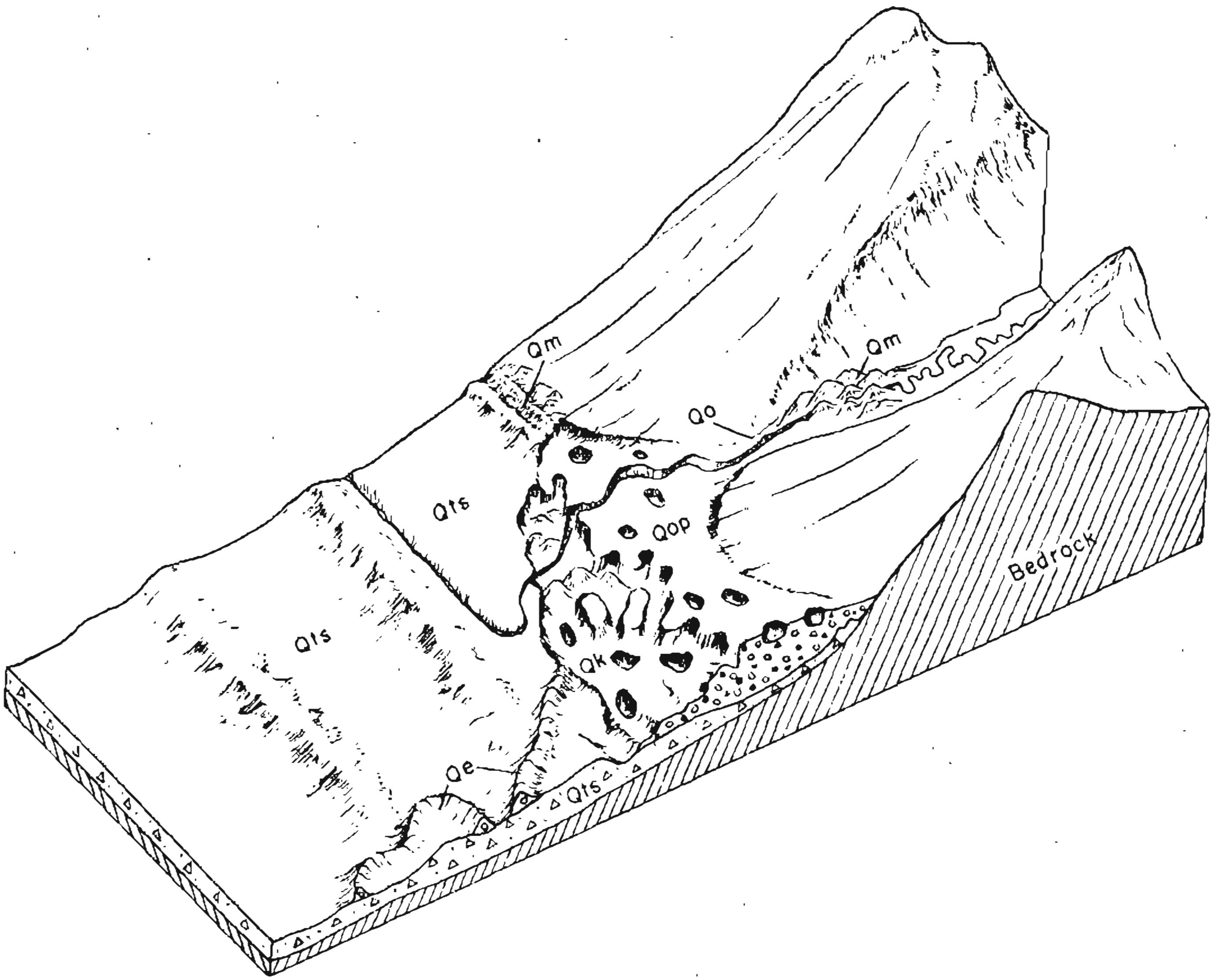

Figure 4: Block diagram showing interrelationships of end and lateral moraines (Qm), sandy till ground moraine (Qts), outwash (Qo), pitted outwash (Qop), kames (Qk), and eskers (Qe) after glaciation (Kachadoorian, Hopkins. and Nichols, 1954)

outwash surfaces have a local relief of 3 to 10 feet consisting of low escarpments, bars, and swales marking the courses of ancient streams.

Drainage conditions vary widely. The outwash is coarse and permeable and thus may have good drainage. However, many of the outwash areas have low gradients and are indented below the surrounding terrain, thereby collecting drainage from large areas.

The outwash gravel is similar to, but slightly coarser than, the modern alluvium in nearby streams. It consists principally of well-rounded cobble gravel in a matrix of sand (fig. 2, curve G). Thicknesses are generally less than 10 feet. In the eastern part of the mapped area the outwash is a thin veneer 1 to 2 feet thick overlying sandy till. Much of the outwash gravel is mantled by 6 inches to 1 foot of wind-blown silt.

Permafrost probably is lacking in the thick well-drained outwash areas. It is present, however, in till immediately below the outwash veneer in the eastern part of the area. The outwash gravel is not frost susceptible, but the underlying sandy till is susceptible to frost action.

Areas of well-drained outwash offer good foundations for highways and will yield small quantities of borrow material.

<u>End and lateral moraine complexes</u>.--Areas of end and lateral moraine complexes are common throughout the southern half of the Mt. Hayes A-5 quadrangle. The highway crosses over extensive areas of end and lateral moraine complexes between the Tangle Lakes and

Whistle Ridge, in High Valley, and from the western edge of High Valley to the floor of the Maclaren River valley.

End and lateral moraine complexes are 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 meltwater 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 meltwater streams. The kettle holes represent the sites of isolated ice blocks that melted away after being buried in gravel.

The moraine complexes are areas of rough topography consisting of ridges 20 to 100 feet high, separated by swales and undrained depressions. Kettle holes, shallow, pan-like depressions, 10 feet deep and 100 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 the lakes and in some kettle holes and swales.

Sandy till is the predominant material composing moraine complexes (fig. 2, curve C), but silty till is found locally. Sandy till or silty till is present everywhere at depth, and it crops out at the surface in the long, smooth ridges that are the dominant element in morainal topography.

Permafrost underlies swales and marshy drainage lines at depths of 1 to 3 feet. Ridges composed of silty till locally contain permafrost at depths of about 5 feet. More commonly, however, permafrost lies below 5 feet.

The moraine complexes are relatively favorable areas for road building. Closed depressions and swampy areas underlain by permafrost are common in the swales between the till ridges, and thus the ridges are generally to be preferred for road foundations. The till is subject to flowage and landslides on slopes steeper than 1:4 and icing may be expected in high side-cuts. Consequently, deep cuts should be avoided whenever possible.

Esker-kame complex.--Esker-kame complexes are most common and best developed in the Tangle Lakes area in the southeastern part of the quadrangle, which the highway alignment crosses, and in the vicinity of Asar Lake in the southern part of the quadrangle. Two small areas of esker-kame complexes exist in Glacier Lake Gap.

Esker-kame complexes consist of material deposited by streams on, in, or beneath glacial ice (fig. 3). Eskers are long, sinuous ridges consisting of beds of former streams that were confined in crevices on the surfaces of glaciers or in tunnels within glaciers; while kames are conical, flat-topped, or irregular hillocks consisting of material deposited in holes and irregularities on the ice surface. Esker-kame complexes commonly grade up- or down-valley into flat-topped, pitted 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 150 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.

Most esker-kame complexes are composed of stratified, subrounded to rounded, sandy gravel (fig. 2, curve E). Pockets of sandy till are common.

The sediments of esker-kame complexes generally are coarse and permeable; consequently the slopes and summits are dry and well-drained. The flat-bottomed depressions are generally dry and well-drained where they are underlain by gravel, but are swampy and may contain lakes where the substratum is till. Locally, however, the depressions are marshy if the water table is within 2 or 3 feet of the surface.

Permafrost probably is not present in the sand and gravel ridges and hillocks of the esker-kame 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 freezing and thawing.

Esker-kame complexes offer the best foundations for highways and sources of borrow in the southern half of the Mt. Hayes A-5 quadrangle.

Channeled till complex.--Areas of channeled till complex occur south of Whistle Ridge. Channeled till complexes consist of discontinuous channels and terraces, mantled by washed sand and gravel superimposed upon slopes and ridges of sandy till and silty till. Most of the channeled till complexes were formed at margins of stagnant glaciers (fig. 5A). Marginal meltwater 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 5 to 35 feet high.

Sand and gravel, ranging in thickness from 6 inches to 6 feet, mantles the terraces and channels. The sand and gravel vary widely in mechanical composition. Lenses of sand, sandy gravel, and clean cobble gravel interfinger with one another. A few large boulders 1 to 4 feet in diameter are nearly always present. Locally the till and gravel is mantled by 2 to 6 inches of wind-blown silt.

Channeled till areas are generally well-drained because of the sharp local relief and the presence of permeable gravel on the flatter surfaces.

Permafrost is present, locally, at depths of 2 feet in gravel or till mantled by silt. Elsewhere, the gravel generally contains no permafrost. Sandy till and silty till in the ridges between channels is locally perennially frozen below depths of 4 to 5 feet. Frozen gravel contains interstitial ice but will not heave upon freezing nor flow upon thawing.

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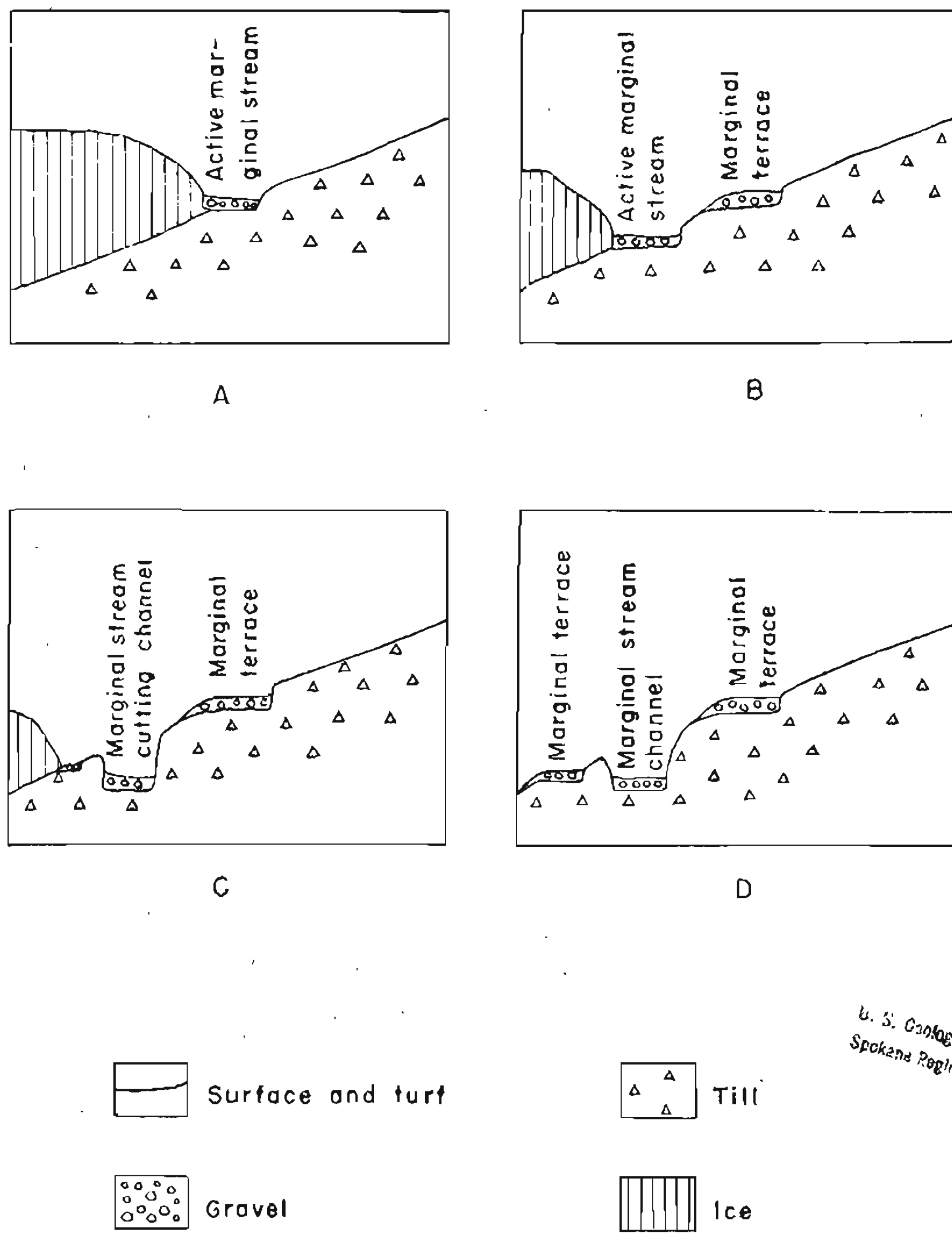

Figure 5: Diagrammatic cross sections showing development of channelized till complex (Kachadoorian, Hopkins and Nichols, 1954)

Channeled till complexes are relatively favorable areas for highway construction. Good grades and alignments can be located on the gravel and channels, but minor construction and maintenance problems probably will be encountered where it is necessary to cross escarpments and ridges in which till crops out at the surface.

Road metal may have to be obtained elsewhere, because the gravel of the channeled till complexes commonly contains considerably more coarse material than is desirable.

Sandy till.--Sandy till is here defined as till containing less than 10 percent silt and 50 to 75 percent sand (fig. 2, curves F and H), and is widely distributed. A large area of sandy till exists in the eastern part of the quadrangle north and south of the proposed highway and a still larger area covers the Maclaren River valley in the western part of the quadrangle between the altitudes of 2,800 and 3,300 feet.

The topography of areas of sandy till consists of long, broad, smooth ridges and swales. Sharp prominences are likely to be eskers or kames, and thus are likely to offer sources of clean gravel and sand. The sandy till represents material dumped along the debris-laden margins of glaciers, and consequently it is generally found in deposits ranging in thickness from 20 to 100 feet.

Sandy till areas are fairly well-drained in spite of generally low slopes and widely spaced drainage lines.

Permafrost is generally lacking in sandy till or lies at depths greater than 5 feet. Locally, however, permafrost is found

2 to 3 feet below the surface. Where the sandy till is overlain by a thin veneer of outwash material, permafrost generally exists at the contact of the two deposits. The sandy till of the Maclaren River valley is less well-drained than the sandy till of the eastern part of the quadrangle and consequently, the permafrost lies at shallower depths.

The silt content in sandy till commonly is sufficient to cause heaving during winter and loss of strength and local flowage during spring thaw wherever it is used for fill material. This is especially true of till within 2 feet of the surface which has been enriched in silt by soil-forming processes and the frost stirring of the loess cover. The siltier phases are subject to slumps and flowage during spring in sides of high cuts and fills.

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

Silty till.--Silty till is here defined as till containing more than 10 percent silt (fig. 2, curves A, B, and I), and is the predominant surface material in High Valley. A smaller area of silty till is present south of Whistle Ridge. Surfaces underlain by silty till generally are smooth and gently undulating. The proposed highway alignment crosses over extensive areas of silty till in High Valley.

Much of the silty till is mantled by wind-blown silt which has been incorporated into the upper few inches of till by frost action; consequently, it is difficult to differentiate between the wind-blown material and silty till within a few inches of the surface. The silt content of silty till ranges from 10 to 36 percent; the maximum silt content of silty till in the Mt. Hayes A-5 quadrangle is much less than in the silty till described by Kachadoorian, Hopkins, and Nichols (1954) in the Susitna-Maclaren area immediately to the west. They report a silt content as high as 90 percent in the Susitna-Maclaren silty till.

Silty till contains a high proportion of fines and therefore is relatively impermeable. Consequently, horizontal and gently sloping surfaces underlain by silty till are poorly drained and are locally marshy.

Silty till is generally perennially frozen at depths of 1 to 3 feet. The frozen till locally contains 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.

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 continue for several years and to total as much as 6 feet. The till will flow during spring in sides of cuts or fills; high artificial or natural cuts are subject to large scale land-sliding on slopes as low as 1:4. Because of the abundance of fines and the low rate of percolation in silty till, this material is subject to rapid gullying.

Permafrost and frost action 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 and the addition of several feet of coarse permeable borrow to the surface will be helpful in combating the problems.

Till on bedrock.--Patches of till form a thin, discontinuous cover on the bedrock slopes north and east of the Tangle Lakes. A smaller area of patchy till on bedrock occurs on the southeastern slopes of Whistle Ridge. The proposed highway alignment does not cross any till on bedrock deposits.

The till is generally less than 3 feet thick and contains a higher proportion of boulders and lower silt content than other types of till in the Mt. Hayes A-5 quadrangle. Quarry sites can be developed in bedrock by stripping the till, but most areas of till on bedrock are remote from the proposed highway alignment.

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