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SURFICIAL MATERIALS AND LANDFORMS OF KLUANE NATIONAL PARK, YUKON TERRITORY

V.N. RAMPTON

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SURFICIAL MATERIALS AND LANDFORMS OF KLUANE NATIONAL PARK YUKON TERRITORY

Abstract

Major physiographic elements of Kluane Park are Shakwak Valley along its northeastern edge and the St. Elias Mountains. The latter include the Kluane Ranges, which abut Shakwak Valley, "Bates Ranges", Duke Depression, Donjek Range, and Icefield Ranges, which form their ice-shrouded core.

The region has been subjected to repeated glacial and nonglacial intervals since late Tertiary time. However, most glacial landforms in the main valleys, primarily glacially scoured bedrock and outwash plains, were produced during the Kluane Glaciation between 29 000 and 12 500 years ago and subsequent deglaciation. Most talus fans and aprons and landslides are partly a result of oversteepening of valley walls caused by glacial erosion.

Near the south end of Kluane Lake, the Slims Soil developed during a warm interval between 8700 and 2800 years ago. Climatic deterioration around 2800 years ago marked the beginning of Neoglaciation. Morainic ridges, massive ice-cored moraines, and rock glaciers are the result of glacier advances that occurred around 2800 years ago, between 1250 and 1050 years ago, and during the last 450 years. Repeated advances by Lowell Glacier damned Alsek River and formed large lakes in its drainage basin also during Neoglaciation.

Résumé

Les principaux traits physiographiques du parc Kluane sont: la vallée de Shakwak le long de sa bordure nord-est et le massif St-Élie. Ces derniers comprennent les monts Klouane, qui bordent la vallée de Shakwak, les "chaînons Bates", la dépression Duke, les chaînons Donjek et les chaînons Icefield, qui constituent le noyau central enneigé du massif St-Élie.

Depuis la fin du Tertiaire, cette région a subi plusieurs épisodes glaciaires et interglaciaires. Cependant, dans les principales vallées, la plupart des formes de relief glaciaire (surtout roche de fond râclée par les glaces, et plaines alluviales proglaciaires) se sont constituées pendant la glaciation de Kluane, qui date de 29 000 à 12 500 ans, et la déglaciation ultérieure. La majorité des talus et cônes d'éboulis et des glissements de terrain résultent partiellement de l'affouillement profond des versants de la vallée par l'érosion glaciaire.

Près de l'extrémité sud du lac Kluane, les sols de Slims se sont constitués pendant un intervalle chaud, datant de 8 700 ans à 2 800 ans. Il y a environ 2 800 ans, une détérioration climatique a marqué le début de la période néoglaciaire. Les crêtes morainiques, les moraines massives à noyau de glace et les glaciers rocheux sont les témoins des avancées glaciaires datant de 2 800 ans, de 1 250 à 1 050 ans, et aussi de celles des 450 dernières années. Les multiples avancées du glacier Lowell ont endigué la rivière Alsek et favorisé la formation de vastes lacs dans le bassin hydrographique de celle-ci, pendant cet épisode néoglaciaire.

INTRODUCTION

A helicopter-supported operation was carried out during summer 1974 by the Geological Survey of Canada in order to re-evaluate the geology of the St. Elias Mountains (Campbell and Dodds, 1975). Maps of landforms (Map 14-1979) and surficial materials (Map 13-1979) were produced based on airphoto interpretation and field checking. Well exposed sections showing stratigraphic complexities relevant to the history of the park were studied, and typical Neoglacial (Porter and Denton, 1967) morainal sequences were examined and dated. In addition, the Neoglacial history of Alsek Valley and those tributaries containing Neoglacial lakes was determined. The Quaternary history has been reconstructed from these observations, from the author's familiarity with the area to the north of the park (Rampton, 1970, 1971a, 1971b), and from a review of other relevant studies. The author was assisted in the field by J.J. Dugal, V. Cormier, and W.E. Keenan.

Kluane National Park is located in the southwestern corner of Yukon Territory (Fig. 1); parts of it are within the Dezadeash (115 A), Mount St. Elias (115 B and C(E/2)), and Kluane Lake (115F(E/2) and G) map-areas (National Topographic System maps, 1:250 000 scale). This report is concerned mainly with the northeastern part of the park which is not presently covered by glacier ice.

Previous Investigations

Observations relevant to the Quaternary geology and history of the area included within Kluane National Park have been made by numerous geologists whose main interests were related to bedrock geology (McConnell, 1905; Cairnes, 1915; Sharp, 1943; Bostock, 1952; Kindle, 1953; Wheeler, 1963; Muller, 1967). Only during the last three decades have studies been undertaken that deal solely with the Quaternary geology of the area (Denton and Stuiver, 1967; Rampton, 1971a) or special aspects of it such as Pleistocene glacial limits and flow patterns (Hughes et al., 1969), Neoglaciation (Sharp, 1951; Borns and Goldthwait, 1966; Denton and Stuiver, 1966), postglacial history of Kluane Lake (Bostock, 1969), the distribution and nature of White River ash (Bostock, 1952; Stuiver et al., 1964; Lerbekmo and Campbell, 1969; Hughes et al., 1972), and the formation of geomorphic features such as moraines (Sharp, 1949; Rutter, 1969; Johnson, 1971, 1972) or braided channels and valley trains (Fahnestock, 1969; Williams and Rust, 1969).

Geologic and Physiographic Setting

Pre-Quaternary geology

Kluane National Park is underlain by a eugeosynclinal sequence of rocks, i.e., a great thickness of sediments, predominantly argillaceous but containing abundant volcanic rocks, that have accumulated in a deep-water marine environment. The eugeosynclinal sequence ranges in age from

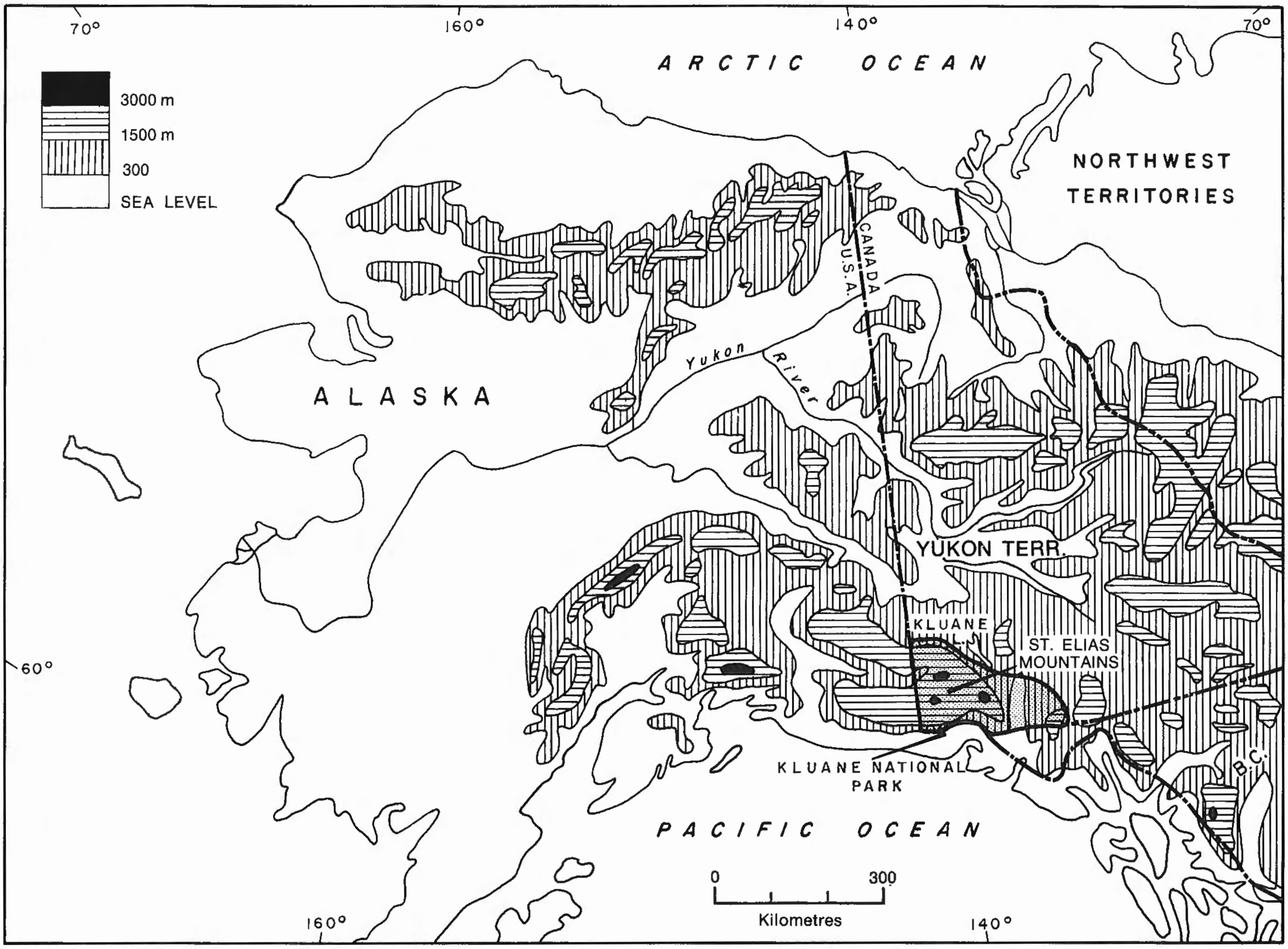


Figure 1. *Index map showing location of Kluane National Park.*

Ordovician to Cretaceous (for more details on geology see Bostock, 1952; Kindle, 1953; Wheeler, 1963; Muller, 1967; Campbell and Dodds, 1975; Eisbacher, 1975; Read and Monger, 1975; Souther and Stanciu, 1975).

The Icefield Ranges consist mainly of carbonates, greywacke, and shale of Devonian to Mississippian age. The eugeosynclinal sequence of the Kluane Ranges and adjacent areas north of Slims River consists primarily of argillite, volcanic, and greenstone rocks of Permo-Triassic age. South of Slims River, the Kluane, "Bates", and Alsek ranges consist of Paleozoic and Mesozoic metavolcanics, carbonates, greywacke, and shale. These eugeosynclinal sequences are intruded by large granitic intrusions of late Paleozoic to Tertiary age and minor pyroxenites and gabbros. Tertiary sediments and thick volcanic rocks commonly overlie the above rocks.

Rocks in Kluane National Park have been highly folded and faulted. Most major faults and folds have a northwest-southeast alignment. Mesozoic and Paleozoic rocks generally shown minor degrees of metamorphism.

Physiography

Most of Kluane National Park lies within the St. Elias Mountains; only the northeastern edge of the park is within Shakwak Valley. In general the physiographic breakdown of the St. Elias Mountains used in this report follows that of Bostock (1948, 1970). Some boundaries, however, have been changed and new units created where it was believed that such changes would reflect more closely the physiography of the area (Fig. 2). The major difference between Bostock's physiographic classification and that used in this report is the extent of the Duke Depression; whereas Bostock shows the Duke Depression extending from the International Boundary through to British Columbia, this report limits it to that area west of Duke River. West of Duke River the depression appears to be a complex of valleys and gently rolling uplands, the latter forming part of an erosion surface (Rampton, 1969); east of Duke River the depression as mapped by Bostock (1948, 1970) includes a complex of mountains, glaciated hills, and valleys. Indeed, between Duke and Kaskawulsh rivers, no major break in the mountains exists to allow a continuity of the Duke Depression. Thus, much of the area east of Alsek River, formerly included within the Duke Depression (Bostock, 1948, 1970), is called "Bates Ranges" in this report (Fig. 2); this name has been used as Bates Lake is central to the terrain included in the unit.

Physiographic elements

A physiographic classification such as that described above shows only broad physiographic units and does not adequately describe the physiographic complexities of an

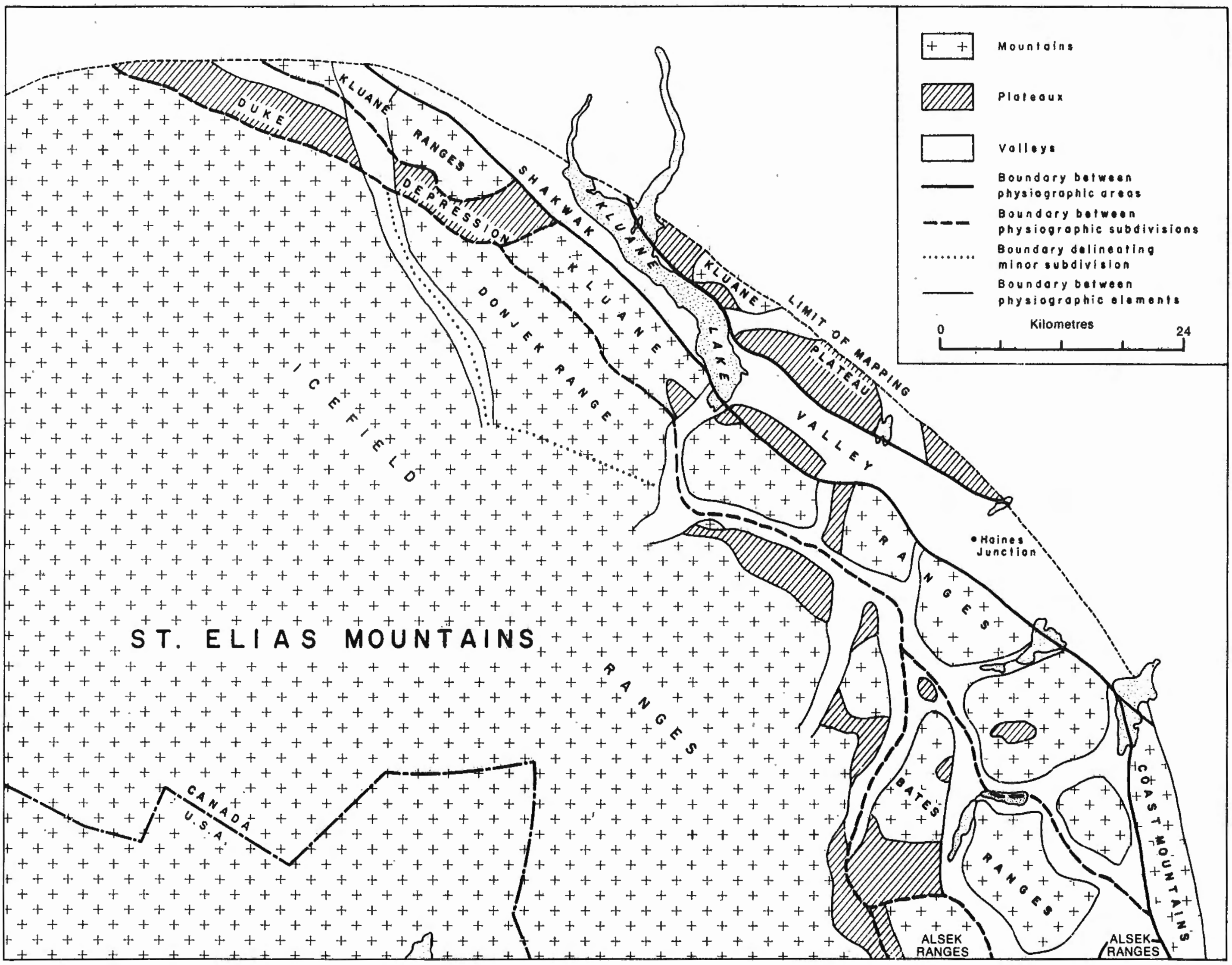


Figure 2. *Physiographic areas, subdivisions, and elements of Kluane National Park.*

area where broad valleys and plateaus occur within major mountain ranges. In a broad classification, major valleys and plateaus may be included within mountain ranges even though the mountains cover only a slightly larger area. Thus to describe the physiography of the park more completely, the basic physiographic elements, namely, mountains, plateaus, and valleys, have been identified separately (Fig. 2).

In this classification, mountains include those parts of the landscape characterized by a series of high summits or ridges standing well above the surrounding countryside and having restricted summit areas. Mountain areas contain valleys, for crests and ridges must be separated by ravines and valleys to restrict their summit areas. Thus all valleys heading within individual mountain ranges have not been identified as valleys in Figure 2, but are included within the mountain unit (Fig. 3).

Plateau has been limited to terrain that is generally flat, gently sloping, or hilly, but which has a relatively smooth surface. Much of the plateau surface is near the summit level; they stand well above valleys, but are below the level of surrounding mountains. Terrain characterized as plateau in Kluane National Park appears to have two separate forms related to origin. First are the rolling surfaces that are likely remnants of old erosion surfaces, e.g., the plateau within the Duke Depression. Second are the gently sloping to hilly surfaces that show signs of intense glacial scour. Due to glacial modification, the preglacial nature of the surfaces is difficult to determine; possibly, they may be modified erosion surfaces, glacially truncated hills, or low mountains. Typical of the second type is a plateau in the southwestern part of the "Bates Ranges" between Bates Lake and Alsek River (Fig. 2).

Areas mapped as valleys include low-lying elongate depressions that do not have their origins within any specific mountain range. In Kluane National Park the axes of some valleys are occupied by major streams (Fig. 4), whereas others have served as the focus of glacier flow.

The above physiographic classification has not been applied to much of the Icefield Ranges as most of the Icefield Ranges are outside the study area. Furthermore, in some areas the continuous ice cover makes it difficult to distinguish plateaus from valleys.

Shakwak Valley

Shakwak Valley is a broad trench-like valley that forms a sharp boundary between Yukon Plateau and the St. Elias Mountains from the International Boundary to Dezadeash

Figure 3. *An example of mountainous terrain in Kluane Ranges. Note the broad U-shaped valley that originates in the mountains. (Photo by William Dekur; GSC 202881-F)*

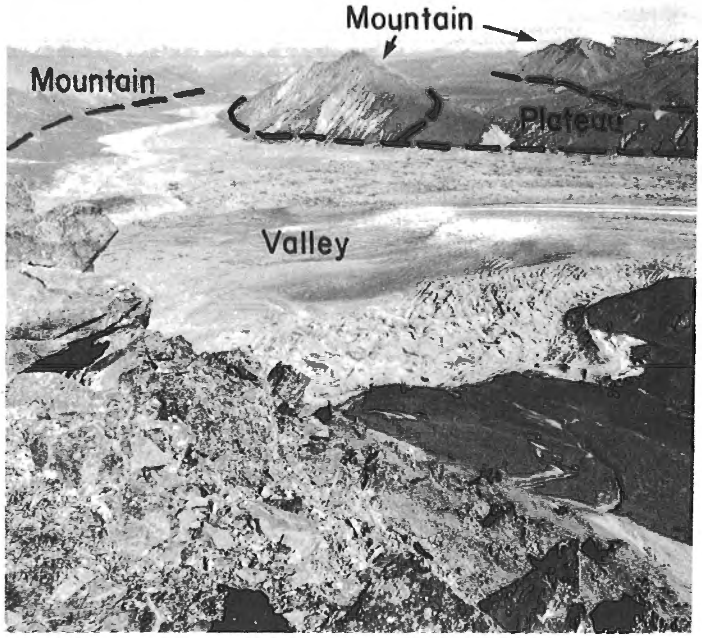


Figure 4. *Physiographic elements near the terminus of Kaskawulsh Glacier. (Photo by William Dekur; GSC 202881-I)*

Lake (Bostock, 1948, 1952). The valley floor is generally 3 to 8 km wide and rises from an elevation of 600 m (2000 ft) at the northern end to about 900 m (3000 ft) near Dezadeash Lake. Major streams cross the valley but do not follow it for any length, e.g., Dezadeash River. A steep escarpment forms the southwestern edge of the valley except where rivers such as the Donjek, Slims, and Dezadeash have formed gaps where they flow out of the St. Elias Mountains (Fig. 5). An escarpment also forms the northeastern edge of the valley, but it is neither as high nor as continuous as the escarpment along the southwestern edge.

St. Elias Mountains

The St. Elias Mountains include the Kluane Ranges, "Bates Ranges", Duke Depression, Donjek Range, Alsek Ranges, and Icefield Ranges.

The Kluane Ranges, which form the northeastern front of the St. Elias Mountains, are divided into distinctive units by cross-cutting valleys. Bostock (1948) had described them as follows:

> "Kluane Ranges show a particular type of ruggedness that contrasts with that of other nearby ranges. Their slopes are steep and uniform, with long, straight talus screes. Their ridges are serrated and narrow, and summits tend to be uniform in elevation. Many are nearly 7,000 feet high, and with one or two exceptions the highest peaks of each range are about 8,000 feet in elevation. Southeast of Duke River, Kluane Ranges contain alpine glaciers, some of which, between Slims River and Kathleen Lakes, are 2 miles long. Most of these ranges consist of two or three ridges parallel with the main front and connected by high saddles. Northwest of Slims River the first range comprises one, broad, rough ridge of summits. Beyond Burwash Creek two distinct ridges become apparent, and beyond Donjek River these are separated by a well-defined valley extending to White River ..."

The individual ridges described above were formed by streams carving valleys within the ranges parallel to structural trends. In some places minor valleys have been cut perpendicular to the physiographic and structural trends of the ranges, e.g., Auriol Range near Haines Junction is crossed by a valley occupied by Beachview and Quill creeks.

Although most of Kluane Ranges are precipitous and rugged as described above by Bostock (Fig. 5), some plateau-like areas are present. Two of the largest are (1) the area at the heads of Dalton and Victoria creeks in the range just north of Mush Lake and (2) the western end of the range east of Jarvis River (Fig. 6). The latter has a gently rolling surface, which has been subjected to glacial scour and subsequently deeply dissected by postglacial stream erosion; the former has both rounded summits and valleys showing evidence of glacial scour with little postglacial dissection.

Duke Depression is a complex of valleys and plateaus (Fig. 7) that separates the Kluane and Icefield ranges in the northwestern part of the park. It has been described by Bostock (1948, p. 97):

> "From Duke River to Donjek River the depression is floored by a gently rolling surface at an elevation of about 4,000 feet, below which the larger streams have cut their valleys. This surface shows particularly well on each side of Duke River where, stretching across to Burwash Creek on the west, a broad gap has been carved through Kluane Ranges. Along this section of the depression, Kluane Ranges rise abruptly on the northeast, and on the southwest the front range of Icefield Ranges... Near Duke River and to the west of the head of Burwash Creek, a higher, more rolling erosion surface shows at about 6,000 feet above sea-level on some partly isolated mountains in the depression and on the flank of Donjek Range. From Donjek River to Klutlan River the depression continues to widen. On its northeast side Kluane Ranges at first continue their steep front and then, near Tepee Lake, their slopes lengthen and farther west resemble the rolling surface of Kluane Plateau as they sweep down into the depression. The central part of the

Figure 5. Southwestern edge of Shakwak Valley along the edge of Kluane Lake. Note the small plateau and the rugged Kluane Ranges. (RCAF airphoto T6-115R; GSC 202974-J)

depression here is a broad, shallow, but relatively steep-walled inner valley in which Tepee Lake lies. To the south a broad, terrace-like area several miles wide and about 4,000 to 5,000 feet high stretches along the front of the mountains, from which spurs extend at right angles down to the terrace."

Badland topography (Fig. 8) also can be seen in the Duke Depression.

The "Bates Ranges", with only one peak above 2000 m (6500 ft), are much more subdued than the Kluane Ranges to the east or the Icefield Ranges to the west. The range southeast of Bates Lake has long continuous ridges and spurs separated by broad U-shaped valleys. Some of these valleys separate the range into small groups of mountains. For example, a broad valley, in part occupied by Onion Lake and Silver Creek, isolates a small group of mountains in the southern end of the range. The range northwest of Bates Lake consists of a group of mountains up to 2020 m (6620 ft) elevation having sharp ridges, long talus slopes, and a rolling plateau with summits to 1520 m (5000 ft).

Alsek Ranges within Kluane National Park are precipitous and have sharp serrated peaks up to 2750 m (9000 ft) elevation and steep valley walls. Valley glaciers are common.

The Icefield Ranges (Fig. 9) have been described by Bostock (1948, p. 98-99) as follows:

> "Icefield Ranges comprise the main body of St. Elias Mountains and embrace all the great peaks except Mount Fairweather. In their general form these ranges themselves resemble a high plateau deeply dissected and surmounted by the great peaks,[1] which appears to be remnants of an older and still higher plateau (Plate I).

Figure 6. *Plateau east of Jarvis River; note the glaciated plateau surface with deep stream dissection. (RCAF airphoto T6-92L)*

Along the northeast side of Icefield Ranges a border area, 15 to 20 miles wide, stands between the Duke Depression and Alsek River Valley on one side and the first line of great peaks on the other. This border area rises abruptly to peaks 8,000 and 9,000 feet high, and in places to others with elevations of more than 10,000 feet. The area is deeply dissected by great valleys such as those of the glaciers tributary to Kaskawulsh River. Southwest of Lowell Glacier the area is mainly one of snow and ice, even those parts bare of snow and ice in summer probably not constituting a third of this part of the border area. Along the border area nothwest from Lowell Glacier, the mountains become increasingly bare of snow in summer, but perennial snow and ice remain on the more level areas at high elevations, in numerous alpine glaciers and icefields, and in the great valley glaciers, Klutlan, Wolf, Donjek, Kluane, Kaskawulsh, and others of lesser size ....

Southwest of this border area looms the main platform of Icefield Ranges, its valleys filled high with snow and ice and its great peaks towering above. The great peaks are the outstanding features of this platform. Chief among them are Mount Logan, 19,850 feet high.... The other great peaks of the platform are Mount St. Elias, 18,008 feet.... In addition, there are many peaks between 12,000 and 14,000 feet high...

These great peaks rise out of the surface of snow and ice that forms the ice-fields between them. North of Mount Logan this surface is between 6,000 and 8,000 feet high, and appears to maintain this elevation along the main divides between the heads of Logan, Hubbard, and the other big glaciers northeast of Mount Logan. From these areas the ice-fields slope outward, gently at first and then more steeply as they separate into defined valley glaciers creeping out of the ranges."

Along the northeastern fringe of the Icefield Ranges some plateau areas are present. The main ones are (1) south of Kaskawulsh River (Fig. 4), (2) between Dusty and Alsek rivers near Marble Creek, and (3) along the west side of Alsek River south of Lowell Glacier. The first plateau area consists mainly of rolling hills with the odd sharp peak projecting above it and a few sharp ravines dissecting it. The second plateau area is really a broad upland forming a pass between Dusty and Alsek valleys; the sharp ravines are present due to stream dissection. The third plateau area resulted from glacial erosion of mountain spurs west of Alsek River; most tributaries to Alsek River crossing this area have cut steep canyons into the plateau.

SURFICIAL MATERIALS

General

Surficial materials have been mapped according to their texture and surface morphology (Map 13-1979). To aid in the actual mapping and airphoto interpretation and possible further extrapolations, however, the deposits have been grouped and labelled according to their genesis. Thus a flat sandy floodplain is symbolized by sF1 (s – sand, F – fluvial, 1 – slope less than 5 degrees). The advantages of labelling materials according to genesis are at least threefold: (1) textural variations within a unit, both laterally and with depth, can be predicted from the given genetic category, e.g. fluvial sediments labelled as sand may contain gravel beds at depth; (2) the genetic category allows for the occurrence of areas of different texture or slope that are too small to map but that are of the same origin, e.g. patches of gravel might be expected in an area mapped as sF1; (3) the basic map unit

Figure 7. Burwash Uplands which form a major part of Duke Depression. (RCAF airphoto T6-155L; GSC 202974-B)

interpretation would remain even though the texture might have been incorrectly assigned, e.g. if, through ground checking, mainly gravel was found in an area labelled fluvial sand (sF), the map unit would remain fluvial but would be considered to be gravel rather than sand.

Genetic groupings used in Kluane National Park are:

1. C – Colluvium: deposits resulting from mass wastage,
2. E – Eolian deposits: windblown materials,
3. F – Fluvial deposits: stream-laid materials,
4. G – Glaciofluvial deposits: fluvial deposits laid down by meltwater,
5. I – Ice: glacier ice,
6. L – Lacustrine deposits: materials deposits in or at the edge of a lake basin,
7. M – Morainal deposits: materials deposited directly from glacier ice with little or no reworking by meltwater,
8. O – Organic deposits: accumulation of dead organic matter,
9. R – Rock: bedrock outcrops,
10. $\frac{v}{R}$ – Veneered bedrock: a mixed veneer of unconsolidated deposits on bedrock.

Colluvial Deposits

All deposits resulting from mass wastage have been mapped as colluvium; included are materials derived from rock falls, landslides, downslope creep, and solifluction. Generally colluvial deposits are poorly sorted diamictons which commonly contain abundant pebble to boulder-sized clasts. Sand, silt, and clay make up the matrix. As the clasts commonly are derived from the disintegration of bedrock, they are angular. Of course, where morainal or glaciofluvial deposits have been deposited on steep slopes and later have been subjected to creep, the colluvium contains semi-angular to round clasts. Lenses and beds of poorly sorted fluvial deposits may occur within the colluvium where small rivulets have eroded and redeposited material.

The texture of landslide deposits largely depends on the manner in which the landslide material disintegrates and the type of motion involved in the landslide. In some cases the landslide debris is mainly rubble (Fig. 10); in others the blocks of bedrock resulting from the landslide are so large that it is difficult to distinguish them from in situ shattered bedrock. Good examples of the latter case are the large bedrock blocks in upper of Halfbreed Creek Valley (Map 13-1979).

Colluvial deposits originating at talus generally consist of angular cobbles or boulders of relatively narrow size range.

Figure 8. *Badland topography developed in Tertiary rocks at Amphitheatre Mountain. (Photo by William Dekur; GSC 202881-D)*

Figure 9. *Typical topography in the Icefield Ranges showing coalescing valley glaciers. (Photo by William Dekur; GSC 202881-M)*

Colluvial deposits range from 30 cm to 20 m thick, but generally they are 1.5 to 5 m thick. Thicker deposits generally are associated with landslide areas and talus fans and aprons.

Most colluvial deposits are well drained because of their relatively coarse texture and the steepness of the slopes that they cover. On gentle slopes, however, colluvial deposits are only moderately drained and therefore are subject to solifluction. Some moderately to gently sloping areas of colluvium show nonsorted polygons, indicating the presence of subsurface ice-wedge networks; the best example of this is an area east of Donjek River in the vicinity of Hoge Creek (Fig. 11).

Areas mapped as colluvial deposits may contain small patches of morainal and fluvial deposits and scattered bedrock outcrops.

Eolian Deposits

Eolian deposits include sand and silt (loess). Eolian sand is generally 0.5 to 6 m thick and well drained. In Donjek Valley where the sand is permanently frozen, however, drainage is impeded. Many areas of eolian sand have not been differentiated on maps because of the small area that they locally cover or because the sand is too thin to identify consistently on aerial photographs.

Loess, common below elevations of 1370 m (4500 ft) throughout the area, ranges from about 30 cm to 1 m thick (Denton and Stuiver, 1967); the thickest deposits of loess occur in Donjek Valley. Loess, in general, impedes drainage, and its presence on flat areas leads to the development of organic mats and permafrost. Loess deposition is continuing today adjacent to active valley trains.

Fluvial Deposits

Fluvial deposits are present beneath floodplains and alluvial fans in most valleys in Kluane National Park. Most fluvial deposits are gravel; a notable exception is the Slims River floodplain, much of which is underlain by sand, silt, and clay (Map 13-1979). Some fluvial deposits, especially those constituting the steeper alluvial fans, are extremely bouldery (Fig. 12). Fluvial deposits generally are from 1.5 to 45 m thick and probably average 5 to 10 m thick.

Most fluvial deposits are well drained, although some flat terraces underlain by permafrost are poorly drained and have peat covers containing significant amounts of ground ice. Terraces and inactive alluvial fans generally have a thin cover of loess, especially in major valleys (Borns and Goldthwait, 1966).

Areas of active fluvial deposition and erosion have been mapped separately because of their instability. Deposits within this unit, however, are texturally similar to inactive fluvial deposits, consisting, in general, of coarse gravel. Permafrost is absent from this unit because of the thermal influence of streams and because of the unvegetated nature of the surface.

Glaciofluvial Deposits

Glaciofluvial deposits occur throughout Kluane National Park; most deposits are gravel, although sand is present locally. In many areas the gravels are bouldery. Glaciofluvial deposits range from 3 to 60 m thick and generally take the form of valley trains, outwash fans, kames, kame terraces, kame-and-kettle complexes, and eskers.

Most glaciofluvial deposits are well drained, but some flat areas where permafrost is present are poorly drained. In such areas, 0.5 to 1.2 m of peat and loess overlies the glaciofluvial deposits; disturbance of the surface of these ice-rich materials will lead to degradation through thermokarst.

Glacier Ice

Glacier ice is common at high elevations throughout Kluane National Park. Thicknesses are variable because of differences in mass balance and the slope of the underlying bedrock. Glacier ice on steep slopes is thinner than that in valleys and on plateaus; glacier ice also is thinner in areas of high ablation. A thickness of 450 m is probably common along large valley and outlet glaciers (cf. Clarke, 1969). Maximum thicknesses of small valley glaciers, however, are probably about 60 to 90 m (cf. Crossley and Clarke, 1972).

Figure 10. *Large boulders in landslide debris along the Alaska Highway near the southern end of Kluane Lake. (GSC 202880-N)*

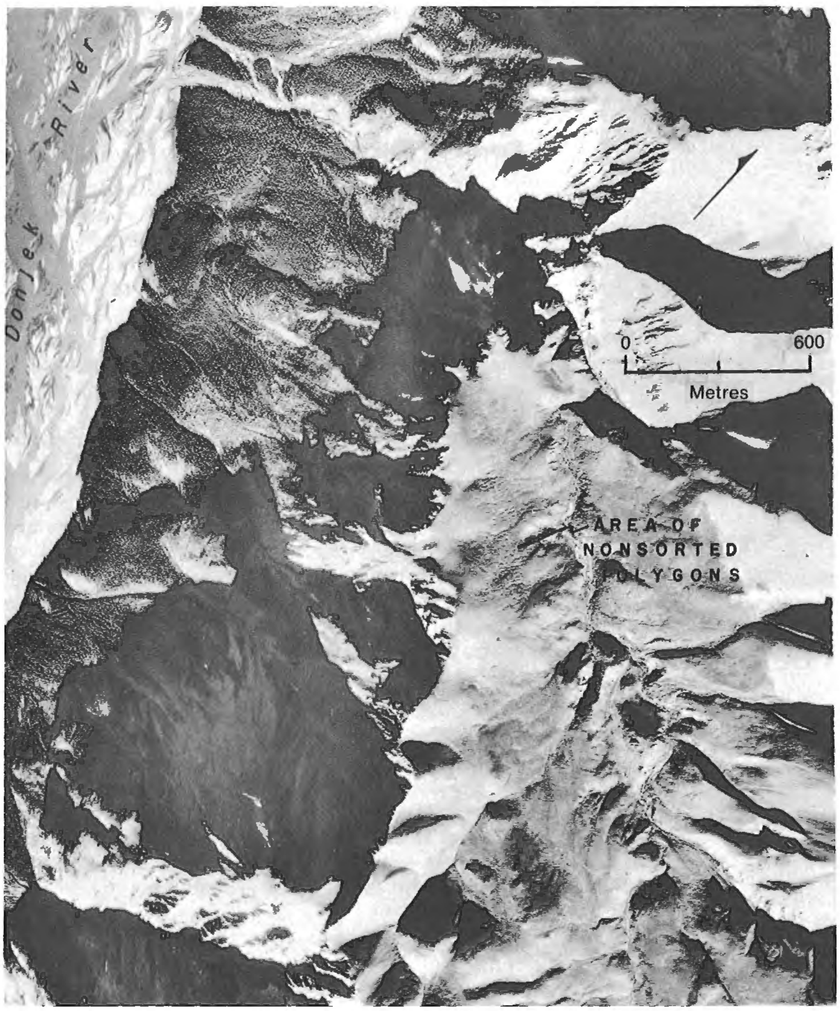


Figure 11. *Area of nonsorted polygons developed in colluvium near Donjek River. (Airphoto A23895-101; GSC 202974-M)*

Lacustrine Deposits

Lacustrine deposits include clayey silt and well sorted gravel and sand. The latter are found in beaches or narrow benches and are generally 1.5 to 5 m thick, whereas the former covers broad flat areas and ranges from 1.5 to 60 m thick. The clayey silt is commonly varved and locally has sand interbeds.

Lacustrine deposits are moderately to poorly drained because of their relatively low topographic position. Where an organic cover has developed on the silt, permafrost and ground ice are generally present at shallow depths. Thaw pits in nearby areas (Day, 1962) and thermokarst depressions in some recently disturbed areas north of Haines Junction attest to the presence of ground ice in these deposits. Lacustrine deposits underlying peat near Alder Creek (Map 13-1979) are frozen at the peat/silt contact.

Small areas of unmapped organic deposits may be present within the map unit.

Morainal Deposits

Morainal deposits in Kluane National Park fall into three categories: (1) sandy lodgment till deposited by larger glaciers in trunk valleys. Lodgment till is generally compact, shows little evidence of sorting, and has a variable stone content. The basal part of most lodgment till is texturally similar to the underlying material, for example, till underlain by stony landslide debris is itself stony; till underlain by lacustrine deposits is rich in silt and clay; (2) stony sandy tills, deposited in some valleys, that appear to be in part stream washed and whose surfaces are covered by a bouldery gravelly lag; (3) bouldery morainal deposits commonly associated with ice-cored moraines and rock glaciers (Fig. 13): Generally the clasts making up bouldery morainal deposits are angular as they have been transported only a short distance downglacier in a supraglacial position. Within many bouldery morainal deposits, especially those deposited by larger glaciers, are areas of till with a matrix of sand, silt, and clay.

The sandy lodgment till found in most large valleys ranges in thickness from 0.5 to 60 m but generally averages 3 to 9 m; stony tills range from 0.5 to 18 m, averaging about 6 m; and bouldery morainal deposits range from 1.5 to 35 m, averaging 3 to 12 m.

Drainage of morainal materials is variable, depending primarily on texture, slope, and the presence or absence of permafrost. Coarse morainal deposits generally are well drained except in depressions where ponds are present. Drainage on flat areas underlain by fine textured morainal materials is moderate, and marshy areas may develop, especially where permafrost is present. Permafrost is sporadic at lower elevations in the eastern part of the area but becomes more common towards Donjek Valley; it is common at high elevations where unsorted polygons and ice wedges occur in morainal deposits. The near-surface, ground ice content of morainal deposits may be locally

Figure 12. *Bouldery gravel on the surface of a small alluvial fan in Duke Valley. (GSC 202880-K)*

Figure 13. *Bouldery morainal deposits. The material has been transported on the surface of a glacier. The large boulders are about 2 m in diameter. (GSC 202880-L)*

high as, for example on the Burwash Uplands. Here subsidence and degradation of the surface has followed disturbance.

Morainal deposits commonly contain small areas of other genetic materials that can be detected only by direct examination of the deposits at ground level. For example, morainal deposits in many valleys and lowlands contain patches of outwash. On the slopes of valleys, small areas of colluvium are common within areas mapped as morainal materials. Morainal deposits in the lowlands commonly have variable thicknesses of loess and peat covering them. Denton and Stuiver (1967) found that loess generally was present below 1370 m elevation in most valleys and that near most major valley trains it ranged from 35 cm to 1 m thick.

Organic Deposits

Two types of organic deposits are present in the area. One is sedge-moss peat, 0.3 to 1.2 m thick, that is poorly drained and contains permafrost at shallow depth. The other is moss peat with wood fragments and layers of wood (Fig. 14). This woody peat is 1.5 to 5 m thick, and, although well drained, is permanently frozen and has a high ice content.

Rock

Rock outcrops are common throughout the park on steep valley walls and cirque headwalls because of the high relief (Fig. 15) and in stream-cut canyons (Fig. 16). Even in areas of little or no relief, bedrock may be exposed because of intense glacial scour. Details of different rock types in areas mapped as rock can be identified by referring to Campbell and Dodds (1975), Kindle (1953), Muller (1967), Read and Monger (1975), and Souther and Stanciu (1975). Included in areas mapped as bedrock are shattered rock and patches of colluvium and till.

Most areas of rock outcrop are well drained and not affected by permafrost. In glaciated valley bottoms where bedrock is common, however, swampy areas and lakes are present.

Veneered Bedrock

Glaciated surfaces in this mountainous terrain commonly are covered by a relatively thin layer of unconsolidated materials which are difficult to map as individual units. These areas are best labelled as a veneer of undifferentiated, unconsolidated materials. Generally the veneer consists of one or a mixture of shattered bedrock, erratics, till, colluvium, outwash, or eolian sand or silt. Isolated bedrock outcrops commonly are present within this unit.

Unconsolidated deposits vary from a negligible thickness to more than 5 m but are generally 0.5 to 1.5 m thick. The deposits are thickest where the veneer consists of till or colluvium, although in places relatively thick patches of outwash and windblown sand are present as, for example, on some of the glaciated rock surfaces in upper Donjek Valley (Map 13-1979).

Veneered bedrock is common on slopes of glaciated valleys and on flat to moderately sloping glaciated surfaces in valleys and on plateaus. Permafrost may be present in this unit on north-facing slopes, and thus the unit may be vulnerable to solifluction. However, as this unit is generally well drained, except for a few marshy depressions in valleys, it is devoid of slumps and periglacial phenomena indicative of materials containing large amounts of ground ice.

LANDFORMS

Landforms have been grouped according to their origin. Thus all landforms related to fluvial activity are grouped together as are all landforms related to mass wastage. This scheme has been extended to map unit notations (Table 1).

Figure 14. *An exposure of woody peat along Donjek River containing two volcanic ash layers (see arrows). Note the decomposed wood within the peat. (Photo by William Dekur; GSC 202881-A)*

Figure 15. *Bedrock exposed on steep valley walls in Icefield Ranges. (Photo by William Dekur; GSC 202881-J)*

For example, all landforms related to fluvial activity are labelled with an "F"; those related to mass wastage are labelled with a "C". Subscripts and additional letters are used to give an exact identification of the landform. For example, Cf indicates a talus fan or apron, CL a landslide or debris flow, Ft a stream terrace (Map 14-1979; Table 1).

The time interval during which the various landforms originated has been identified where possible. The chronologic framework used in this report is given in Figure 17.

Figure 16. *Deeply incised Alsek River exposes bedrock in its canyon walls. (Photo by William Dekur; GSC 202881)*

Landforms Related to Mass Wastage (C)

Talus fans and aprons (Cf)

Accumulations of talus are common below the many glacially oversteepened valley walls, cirque headwalls, and other escarpments (Fig. 18). Many rocks within the area tend to be cliff formers and to break down into large clasts. In valleys occupied by glaciers, much of the talus is removed from the valley walls. Elsewhere talus accumulates as fans and aprons along the valley margins. Some material that is added to the talus fans and aprons may not be from simple rock falls and slides, but from highly fluid debris flows. Also, material may be brought down to and moved across the fans and aprons by fast-flowing ephemeral streams.

Formation of talus fans and aprons probably occurred at a maximum rate during early Postglacial time; in some areas the fans and aprons appear to have stabilized with little recent activity. Many talus fans and aprons, however, are still actively forming, with the fresh accumulations of talus preventing the establishment of vegetation.

Typical talus fans and aprons occur along the northern edge of Kathleen Lakes and on the flanks of Sheep Mountain near southern end of Kluane Lake.

Landslides (CL)

Landslides, which include debris flows, translational and rotational slides, and rock and debris avalanches, are common features throughout Kluane National Park. Landslides are most common in areas of poorly indurated Tertiary sediments and in areas where structurally weak layers of volcanic pyroclastics occur in the Tertiary volcanic sequence. Areas underlain by deformed and faulted Tertiary rocks are very susceptible to landslides.

An example of a complex landslide is that in the first major northern tributary of Bighorn Creek (Map 14-1979; Fig. 19). Large bedrock masses, which show evidence of simple translational or rotational movement, occur at the headwall of the landslide. Downvalley from these coherent masses, the landslide surface is chaotic and blocky, probably

Table 1. Summary of landform descriptions, environmental concerns regarding landforms, and landform ages[1]

Landform	Description	Environmental Concerns	Age
Talus fan or apron (Cf)	Moderately to steeply sloping accumulation of coarse angular bedrock fragments; commonly located below steep cliffs or at the mouths of avalanche chutes; sources are areas of rapidly disintegrating bedrock.	Rock falls and debris flows common on active fans; steep slopes generally unstable to traffic.	Range from late Kluane to Neoglacial; many more still active.
Landslide (CL)	Generally moderately sloping, but with some surface irregularities, accumulation of poorly sorted debris; debris varies from large blocks of bedrock in some slumps to finer material in debris flows; generally landslides have an elongate shape and debris flows have a fan shape; commonly associated with Tertiary rocks.	Landslides generally are recurrent in susceptible areas and may become active if disturbed.	Range from late Kluane to modern.
Colluvium-covered slope (CS)	Gentle to steep slope underlain by unsorted rubble; at the surface are stone stripes, solifluction lobes, and other periglacial features.	Areas of fine textured materials and gentle slopes at high elevations where there is ground ice will be susceptible to high solifluction rates and thermokarst if disturbed.	Generally late Kluane; high slopes may be older.
Sand dunes (Ed)	Elongate parabolic dunes with blowouts. Commonly associated with active braided valley trains; also occur at the top of cliffs containing sandy unconsolidated deposits.	Unstable and subject to blow-outs if disturbed.	Majority are Neoglacial, some are still active.
Alluvial fan (Ff, F_f^A)	Gently sloping accumulation of rounded to subangular alluvium; small-scale surface irregularities due to shallow channels and boulders on surface.	F_f^A subject to shifts in channel and bar positions; Ff occasionally subject to flooding.	F_f^A is modern; Ff varies from early postglacial to Neoglacial.
Floodplain (Fp, F_p^A)	Flat to very gently sloping accumulation of alluvium; minor surface irregularities due to shallow channels on surface.	F_p^A subject to shifts in channel and bar positions; Fp occasionally subject to flooding.	F_p^A is modern; Fp is mainly Neoglacial.
Stream terrace (Ft)	Flat to gently sloping accumulation of alluvium; stream side generally is marked by escarpments; escarpments may be present within the unit.	Relatively stable except where surface is covered by silt or peat containing permafrost and ground ice; disturbance may cause thermokarst and channelling.	High terraces generally early postglacial; low terraces may be as young as Neoglacial.
Kame delta (?) or kame terrace (Gk)	Patches of gravel and sand in the form of deltas and terraces along valley walls; generally flat topped but with steep downslope escarpments.	Steep escarpments may be subject to channelling if disturbed.	Mapped kames are Kluane; small unmapped Neoglacial kames are present.

1 Generally refers to the age of the landform surface.

Table 1. (cont.)

Landform	Description	Environmental Concerns	Age
Outwash plain, fan, and valley train (Gp)	Extensive flat area of gravel and sand well above present stream levels.	Flat areas that are covered by silt or peat may degrade through melting or ground ice if disturbed (probably a serious hazard in Donjek Valley).	Kluane; Neoglacial outwash plains generally have been mapped as Fp, F^A_p, Ft.
Kame-and-kettle complex (Gh)	Irregular mounds and hills of gravel and sand.	Depressions within unit may contains ice-rich fines that will be subject to thermokarst if disturbed.	Kluane
Esker and esker complex (Gr)	Gravel ridges	Steep slopes may be subject to channelling if disturbed.	Kluane
Outwash-covered slope (GS)	Gravel blanket on bedrock-controlled slopes; difficult to ascertain whether gravel is part of a kame system or a collapsed and eroded valley train.	May be subject to channelling on steeper slopes if disturbed.	Kluane
Cirque glacier (Ic)	Glaciers confined to cirques; lower parts generally have gentle to moderate slopes; upper parts may be steep.	Crevasses are a hazard to traffic.	Modern
Mountain ice cap (Im)	Ice caps on higher portions of Icefield Ranges; includes flat ice-covered plateau and valley areas and steep ice-covered mountainous slopes and peaks.	Avalanches, ice and rock falls, and crevasses are hazards to traffic.	Modern
Outlet valley glacier (Io)	Large valley glacier flowing from mountain ice cap.	Crevasses, incised meltwater channels and calving of ice blocks into proglacial lakes are hazards to traffic. Positions of glacier termini unstable.	Modern
Cliff glacier (Is)	Patches of glacier ice confined to cliffs.	Avalanches, ice and rock falls are hazards to traffic.	Modern
Valley Glacier (Iv)	Glacier extending downvalley from its cirques.	Crevasses and incised meltwater channels are hazards to traffic. Positions of glacier termini unstable.	Modern
Lacustrine plain (Lp)	Flat benches in lowlands, generally adjacent to lakes.	Drainage may be imperfect in these areas due to flatness and low topographic position.	Most are late Kluane or early Postglacial; small Neoglacial areas have not been mapped.
Lake beaches (Lb)	Small ridges of sand and gravel generally paralleling present-day shorelines.	Where beaches are clustered in low areas, intervening swales may be swampy.	Late Kluane to early Postglacial.
Drumlinized or fluted moraine (Md)	Elongate hills of drift; in some cases individual drumlins can be identified; in other cases elongate ridges and swales alternate and the terrain may be more appropriately classified as fluted.	Peat may be present in poorly drained swales; disturbance may cause some thermokarst.	Kluane

Table 1. (cont.)

Landform	Description	Environmental Concerns	Age
Ground moraine (Mg)	Area of drift having gentle to moderate slopes, probably controlled by topography of underlying bedrock.	Some flat areas are poorly drained and susceptible to thermokarst.	Kluane
Hummocky moraine (Mh)	Hills and mounds of morainal deposits having moderate slopes.	Many depressions are poorly drained.	Kluane
Rolling moraine (Mm)	Rolling topography with most slopes being gentle to moderate; flat areas common within unit.	Flat areas may be poorly drained, covered by peat, and ice rich; may be susceptible to thermokarst.	Kluane
Morainic plain (Mp)	Area of flat to gentle sloping morainal deposits.	At high elevations may be susceptible to thermokarst.	Kluane
Morainic ridge (Mr)	Ridges of coarse drift, generally paralleling present glacier borders.	Some ridges are ice cored and subject to degradation if ice is exposed.	Neoglacial
Debris-covered glacier (ice-cored moraine) ($\frac{M}{I}$)	Accumulation of coarse drift overlying glacier ice; surface is generally hummocky or ridged with many ice cliffs present within unit.	Younger moraines are hazardous to cross because of melting ice; ice under older moraines makes them vulnerable to thermokarst if surface is disturbed; many unstable slopes.	Neoglacial
Rock glacier (MR)	Coarse bouldery drift; frontal edge generally steep; upper surface flat except for minor ridges.	Ice within rock glaciers may make them thermally susceptible to deep disturbance. Positions of termini unstable.	Neoglacial
Till-covered slope (MS)	Bedrock slopes mantled with till.	Some solifluction may occur.	Kluane
Bog (Ob)	Shallow accumulation of peat having pools of water on the surface.	Poor drainage will affect trafficability; shallow depth of ice-rich, fine grained soils underlying many bogs may lead to thermokarst if bogs are disturbed.	Postglacial to modern
Forested peatland (Ofp)	Thick accumulation of peat draped over an undulating surface of mainly morainic deposits.	Ice-rich peat is subject to thermokarst if disturbed.	Postglacial
Rock cliffs (R)	Steep cliffs commonly having a fine dendritic pattern of avalanche chutes on them.	Rock falls a common hazard.	Erosion leading to cliff development is Pleistocene to modern.
Glacially scoured rock ($\overset{\uparrow}{R}$)	Rounded hills and ridges with depressions and grooves produced by glacier scour; slopes are flat to moderately steep; in some areas a veneer of mixed deposits is present, e.g., shattered rock, patches of drift, and wind-blown silt (loess) and sand.		Rock scoured during Kluane Glaciation.
Glacially scoured valley walls ($R\rightarrow$)	Glacially scoured valley walls, commonly ridged; slopes generally veneered with colluvium and drift.		Rock scoured during Kluane Glaciation.

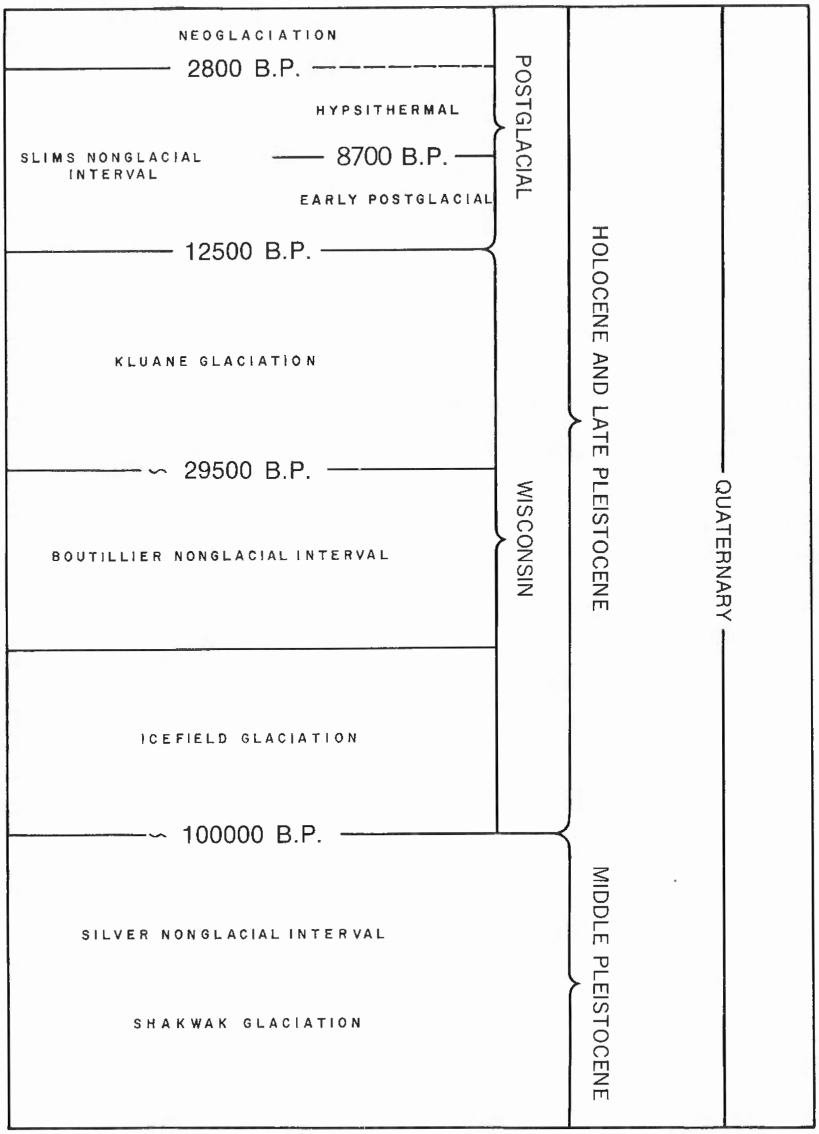


***Figure 17**: Quaternary chronology of glacial and nonglacial events for Kluane National Park. Time intervals follow Denton and Stuiver (1967), Denton and Karlén (1973), Rampton (1971a). For further explanation see section on Quaternary history.*

due to debris avalanching or flowage. Other landslides such as those along Sheep Creek (Fig. 20) appear to be simple slumps with rotational motion occurring along definite planes.

Landslides probably have occurred throughout Quaternary time within the park, as the area has been one of high relief during this time period. Evidence of a Tertiary landslide has been found near Sheep Creek (Eisbacher, 1975) as well as landslide debris of pre-Kluane age in exposures along the west edge of Donjek River. Some landslide debris may have been deposited onto glaciers during the last part of Kluane Glaciation, as the origin of the landslide debris is not obvious from landslide scars and indicates some downvalley movement by glaciers. This is true of a large landslide near the headwaters of Cottonwood Creek north of Alder Creek (Map 14-1979). Post-Kluane landslides can be identified throughout the region. Many landslides at the southern end of Kluane Lake are relatively young; some postdate the White River ash fall of 1220 years ago (Hughes et al., 1979).

Colluvium-covered slopes (CS)

This term has been applied to vegetated and bare slopes underlain by unsorted rubble where creep and solifluction are the main agents of mass wastage. In contrast to talus, where the rock has fallen or rolled some distance, areas of rocky colluvium within this unit are commonly the result of direct rock disintegration and downslope movement by creep.

Some periglacial mass wastage features occur within this unit. Typical are solifluction lobes on the flanks of Observation Mountain and nonsorted polygons on gentle slopes above the eastern side of Donjek Valley (Fig. 11). Nonsorted polygons develop where the downslope movement of the active layer is negligible and patterns resulting from ice-wedge growth are not destroyed.

Most slopes of Kluane National Park owe their configuration to erosion during Kluane Glaciation and to subsequent fluvial erosion and mass wastage. Some exceptions are gentle slopes above levels of the Kluane glaciers; these probably have had a relatively similar configuration since at least mid-Pleistocene time.

Eolian Landforms (E)

Sand dunes (Ed)

Most sand dunes in Kluane National Park are still active as they are associated with modern floodplains, relatively young terraces, or actively eroding escarpments. Most sand dunes along Alsek River and Slims River floodplains and terraces are either parabolic or linear. They are closely associated with local blowouts and instabilities on sandy or gravelly terrain and do not appear to have major net movement in any direction. Clifftop dunes are common on many actively eroding banks (Fig. 21) but generally cover such a small area that they are not mappable.

Loess blanket

A blanket of loess covers much of the area lying at low elevations (Denton and Stuiver, 1966). This blanket has not been mapped as it simply acts as a cover and does little to modify any of the landforms present. Some slopes having no tree cover and a thin cover of loess have a peculiar smoothness to them when viewed from a distance, such as much of the east flank of Sheep Mountain.

The blanket includes loess of both late Kluane/early Postglacial and Neoglacial ages. Both can be seen in many exposures near the south end of Kluane Lake and along Donjek, Slims, and Kaskawulsh valleys (Fig. 22). Near some of the large active valley trains, loess is still being deposited.

Fluvial Landforms (F)

Floodplains (Fp, F_p^A)

Two types of floodplains have been identified. The first is the braided floodplain where the stream covers unvegetated bars in a number of high water stages during the year and on which vegetation is prevented from growing by constant erosion, deposition, and downvalley movement of coarse alluvium (Fig. 23). Relief on the floodplain is due to the presence of channels and bars bounded by scarps from 15 cm to 1.2 m high. Smaller scale features, such as ripple marks, ellipsoidal scours, and silt volcanoes, also are present

Figure 18

Talus aprons at the base of a glacially oversteepened valley wall in Kluane Ranges. (GSC 202880-M)

(Williams and Rust, 1969). Many braided surfaces head at the termini of active glaciers and in a sense are Neoglacial, indeed modern valley trains.

The second type of floodplain is characterized by low terraces that appear to be flooded at frequent intervals, although not necessarily annually; sedimentation on these surfaces occurs mainly through overbank deposition of suspended bedload. Vegetation is present on the surfaces because flooding is relatively infrequent, because there is little or no erosion of the surfaces, and because the rate of deposition of overbank material is slow. Most vegetated floodplains are simply braided channels which have become inactive due to postglacial downcutting by rivers. They do not have as much relief as the active braided floodplains because most channels have been filled by overbank silt and sand. Some channels on low terraces transmit water during flood stages.

Stream terraces (Ft)

Along most streams are terraces which attest to the continued downcutting by streams since Kluane Glaciation. Terraces stand from 1.5 to more than 30 m above present-day stream level. Although some channels can be traced on the terrace surfaces, most are imperceptible because of infilling by silt and peat. Terraces have been forming during post-glacial time.

Of special interest are low terraces along Alsek River, which resulted when Lowell Glacier was breached by water from the impounded lake that is periodically formed in upper Alsek Valley. The terraces show spectacular sedimentary structures (Fig. 24) that formed during drainage of the Neoglacial lakes present in Alsek River basin. Lichen diameters on large boulders downstream from Lowell Glacier indicate that at least two distinct ages of terrace levels are present there. Boulders on the higher terrace, which is between 30 and 45 m above stream level, have **Rhizocarpon geographicum** up to 34 mm diameter; those on the lower terrace, which is between 4.5 and 12 m above stream level, have **Rhizocarpon Geographicum** up to 15 mm diameter. Upstream from Lowell Glacier the two sets of terraces cannot be distinguished easily, although there is a difference in bedforms on surfaces near river level as opposed to those at higher elevation. Wave lengths of fluvial dunes at upper levels (300 to 600 m) are much greater than those at lower levels (30 to 90 m). In some areas the small dune forms are superimposed upon the larger ones. Downstream from Lowell Glacier there is no systematic relationship between dune wave length and terrace level. Normal relief on the terrace surfaces imposed by the dune forms is 0.6 to 3 m, but immediately downstream from Lowell Glacier the dune forms and scour hollows produce a local relief of up to 6 m.

Generally the material making up the terraces along Alsek River is gravelly, but immediately downstream from Lowell Glacier the surface material includes large boulders, 1.5 to 2 m in diameter. These boulders probably were reworked from morainal deposits of Lowell Glacier by the highly competent stream that resulted when the glacier was breached by water from a glacially impounded lake in upper Alsek Valley.

Alluvial fans (Ff, F_f^A)

The high relief of Kluane National Park, emphasized by glacial oversteepening of valley walls, has resulted in the formation of alluvial fans where creeks with rapid rates of descent flow out onto the flatter bottoms of major valleys (Fig. 25). Depending upon the size and slope of the alluvial fan, it may have either a single active channel or a system of distributary channels. The latter is common to large fans with gentle slopes, and the former to small, steep fans. The vegetated surfaces of many alluvial fans generally have some surface irregularities that reflect former braided stream patterns. In many places, however, the channels have been filled with fine grained alluvium or loess.

The surfaces of alluvial fans are early Postglacial to modern. Much of the sediment within the alluvial fans, however, probably was deposited immediately after Kluane Glaciation when small streams in the high valleys were entraining and redepositing drift of the Kluane Glaciation.

Good examples of alluvial fans occur along the edges of Shakwak Valley and most major river valleys. Some of the largest alluvial fans are present along the west side of Donjek River (Map 14-1979).

Glaciofluvial Landforms (G)

Kame deltas and terraces (Gk)

When much of the area was occupied by glacier ice, meltwater flowing across drainage divides and along valley sides deposited sand and gravel in the form of kame deltas

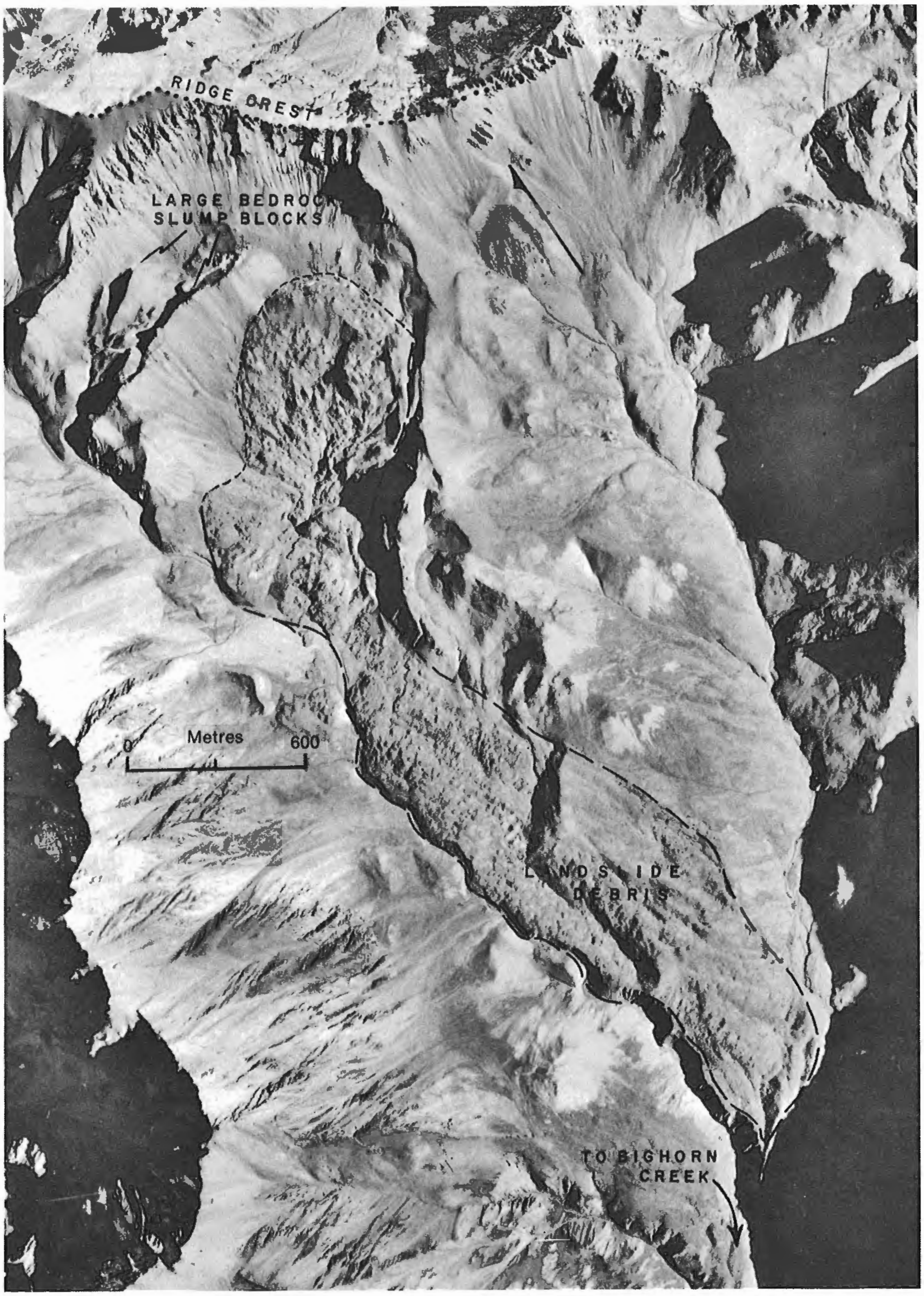


Figure 19. *Landslide on tributary of Bighorn Creek; see text for discussion (Airphoto A23895-117; GSC 202974-H)*

and terraces. The deltas and terraces formed at different levels as the glaciers wasted downward; they were dissected subsequently by glacial meltwater.

The kame deltas and terraces mapped are mainly of late Kluane age, although smaller examples of Neoglacial age are present. Many narrow bodies of outwash that are being deposited along the edges of present-day glaciers may become kame terraces if the glaciers retreat upvalley.

The best examples of kame deltas occur east of Wade Creek where meltwater flowing north away from ice in the upper Burwash Creek valley deposited gravel and sand against ice moving east out of Donjek Valley.

Outwash plains, fans, valley trains, and kame-and-kettle complexes (Gp, Gh)

Outwash plains, valley trains, and kame-and-kettle complexes are common in the park. Indeed, many valley bottoms are filled with outwash because during deglaciation, southward retreating glaciers with large ablation zones provided large volumes of meltwater and deposited large amounts of outwash; typical is Shakwak Valley between Dezadeash Lake and Bear Creek (Map 14-1979). In some cases where stagnant ice still occupied the valleys, the resulting body of outwash has a hummocky form, i.e. a kame-and-kettle complex.

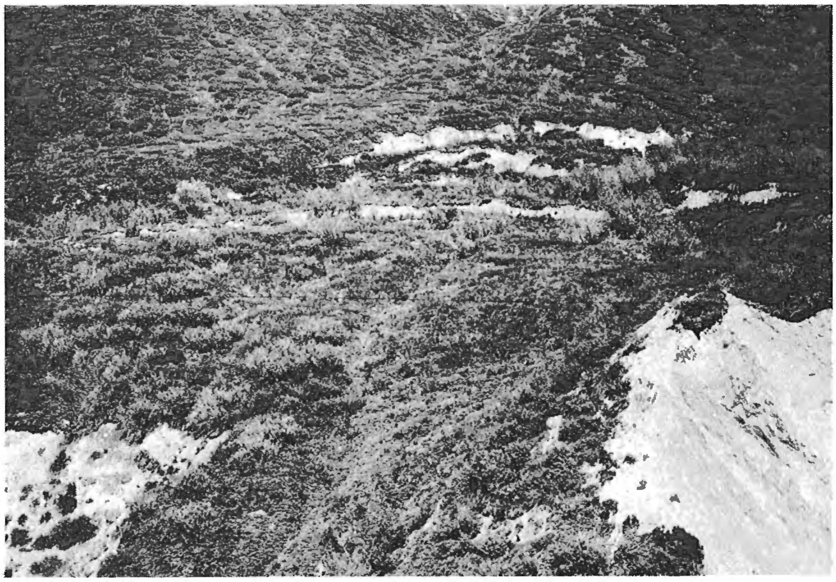


Figure 20

Scarps at the head of a landslide block along Sheep Creek. The scarps are 3 to 6 m high. (GSC 202880-H)

Figure 21

Clifftop sand dunes on unconsolidated materials along upper Donjek River. St. Elias Mountains are in the background. (GSC 202880-F)

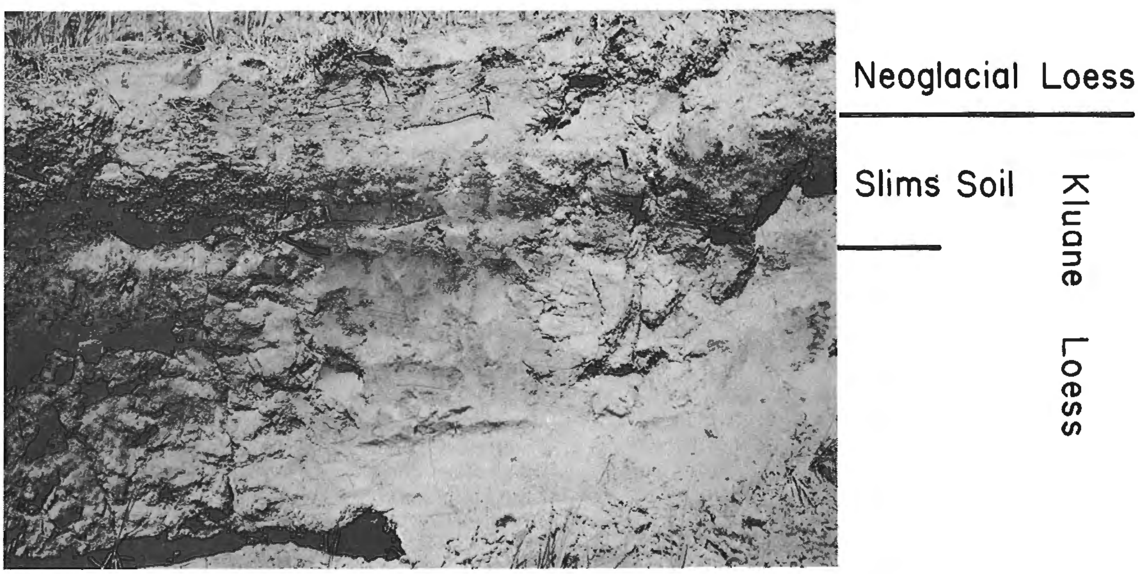


Figure 22. *An exposure of Neoglacial and Kluane loess along Alsek River. A weathered zone is developed in the top part of the Kluane loess. (GSC 202880-G)*

Figure 23. *Donjek River braided valley train, a typical unstable floodplain surface. (Photo by William Dekur; GSC 202881-K)*

Figure 25. *Alluvial fans along the edge of a major valley in the St. Elias Mountains. (Photo by William Dekur; GSC 202881-B)*

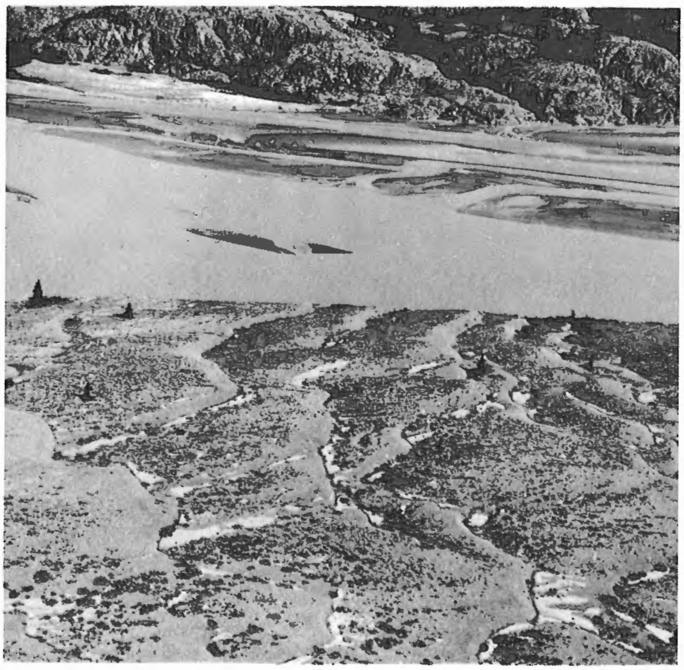


Figure 24. *Dunes on the lowest terrace along Alsek River. (Photo by William Dekur; GSC 202881-L)*

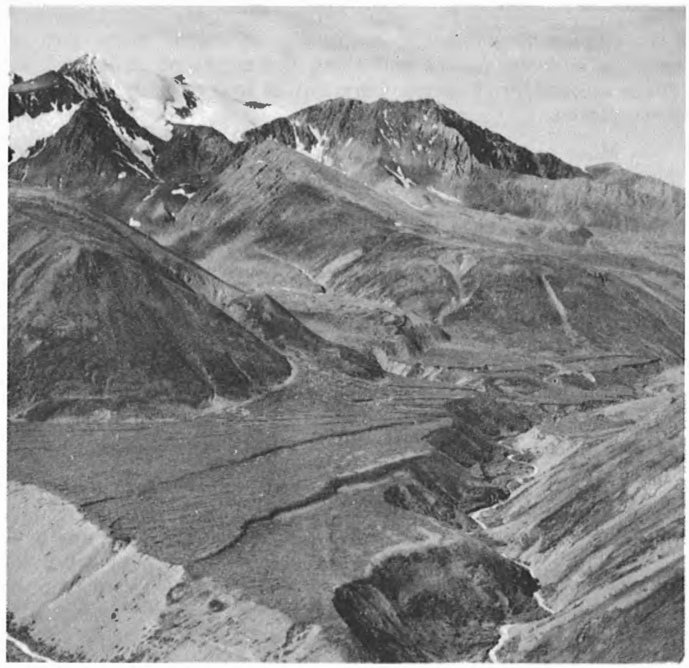


Figure 26. *Valley train formed along Quill Creek when ice occupied Shakwak Valley. (Photo by William Dekur; GSC 202881-H)*

Outwash fills some valleys completely (Fig. 26); in others patches have been deposited only where ice marginal meltwater streams deposited bed load in response to a decrease in the competence. The latter is common at the downstream ends of narrow meltwater channels that cross drainage divides and parallel valley walls.

An example of a late Kluane valley train is at the head of Field Creek where meltwater from glaciers occupying Alsek Valley flowed through the gap at the head of Field Creek (Map 14-1979). The upper part of the valley train is hummocky, indicating that ice occupied the upper reaches of Field Creek during outwash deposition; the lower part is flatter, although it has been dissected by postglacial streams. Other examples are the terrace surfaces along Duke River near the mouth of Granite Creek. Examples of kame-and-kettle complexes are seen at the downstream end of meltwater channels occupied by Alder Creek east of Mush Lake and in the gap between Burwash Creek and Wade Creek. A channelled outwash plain is present at the eastern end of the Burwash Uplands (Map 14-1979).

Most mapped outwash is late Kluane in age. Neoglacial valley trains generally have been mapped as modern floodplains, e.g. the Slims and Kaskawulsh braided floodplains are actually valley trains being formed by meltwater from Kaskawulsh Glacier.

Eskers and esker complexes (Gr)

Eskers form in englacial or subglacial channels through the deposition of sand and gravel by meltwater. Due to shifts in the position of these active channels, a complex of esker ridges may develop. All eskers and esker complexes in the park formed during the late Kluane.

Prominent eskers are present in the area south of Alder Creek; others occur on the Burwash Uplands. Of special interest is the long fragmented, but straight, esker along the southern edge of Shakwak Valley in the vicinity of Donjek River. The meltwater stream that built the esker probably was localized by fractures in the ice which in turn were localized by fault activity (Bostock, 1952).

Outwash-covered slopes (GS)

In some areas, outwash is draped over moderate to steep slopes and is difficult to relate to any original depositional form. Bedrock topography seems to control the surface form of the outwash, thus these areas have been mapped simply as outwash-covered slopes.

Meltwater channels

During deglaciation meltwater channels were cut in bedrock in many passes and along the edges of valley walls. These meltwater channels were cut at lower levels as the ice downwasted.

Most meltwater channels in the park were formed during the Kluane Glaciation, although some of the highest channels may have been cut during earlier glaciations. Meltwater channels near present-day glaciers (for example, Donjek and Kaskawulsh) are of Neoglacial age, and some are still actively forming (Fig. 27).

Examples of meltwater channels of Kluane age are those south of Alder Creek, east of Jarvis River, in the gap between Wade and Burwash Creeks, and along the flanks of Shakwak Valley near Burwash Creek (Map 14-1979).

Glacier Ice (I)

Glaciers are commonly beyond the scope of most reports on surficial materials and landforms. However, as glaciers make up a large part of Kluane National Park and are the origin of most landforms in the park, brief mention will be made of them here. Glaciers in the park include small cirque glaciers, small valley glaciers, and the large mountain ice cap covering the central Icefield Ranges. Outlet valley glaciers lead from the mountain ice cap to peripheral areas. Glacier surfaces are characterized by crevasses, moulins, and medial moraines. The periodically stagnant lower reaches of surging glaciers, of which there are several in the park (cf. Stanley, 1969), have surfaces showing an abundance of thaw features such as moulins, incised meltwater channels, ice bridges, and thaw lakes.

Kaskawulsh, Donjek, Lowell, and Fisher glaciers are all examples of large outlet valley glaciers (Fig. 28). Examples of small valley glaciers and cirque glaciers can be found on the northern flank of Goat Herd Mountain, in the mountains east of Slims River, and in the mountains around Mount Hoge (Map 14-1979).

Lacustrine Landforms (L)

Lacustrine plains and benches, and the beaches and strandlines associated with them, are scattered throughout Kluane National Park. Lacustrine benches, small areas of lacustrine plains, and associated beaches and strandlines, exist in low areas adjacent to Dezadeash Lake, along Kathleen River, and in the vicinity of Haines Junction (Map 14-1979). Beaches and strandlines are common in Alsek and upper Donjek valleys, even though fine grained lacustrine sediments deposited in deeper water generally are absent there.

Most lacustrine features adjacent to Dezadeash Lake, Alder Creek, and Kathleen River are related to glacial Lake Champagne (Kindle, 1953) of late Kluane age. During this period of deglaciation, drainage through the Yukon River system had not become re-established, and drainage to the south through the valleys south and west of Haines Junction, Kathleen Lakes, and Dezadeash Lake was blocked by glacier ice.

Although glacial Lake Champagne also occupied the area around Haines Junction, most lacustrine features there are the result of a Neoglacial lake that occupied the lower reaches of Dusty, Kaskawulsh, Dezadeash valleys, and Alsek valley upstream from Lowell Glacier. Evidence of a lake of late Kluane age in Alsek Valley near Lowell Glacier comes from high beaches at about 730 m (2400 ft) elevation. Because of the discontinuous nature of the strandlines, it is not possible to determine whether this is a late phase of glacial Lake Champagne that was present in Alsek Valley or whether it is a separate lake formed during deglaciation.

Strandlines in upper Donjek Valley were produced at the margin of a Neoglacial lake dammed by Donjek Glacier when it was at its maximum position about 150 years ago (Denton and Stuiver, 1966).

Figure 27. *Meltwater channels cut in bedrock along the eastern edge of Donjek Valley because of drainage diversion by Donjek Glacier which is seen in the background. (Photo by William Dekur; GSC 202881-E)*

Figure 28

Lowell Glacier. Note folded medial and lateral moraines and Neoglacial trimlines on valleysides. (GSC 202880-D)

Figure 29

Wave-cut benches of Neoglacial Lake Alsek along the west side of Dezadeash River. (GSC 202880-E)

Neoglacial Lake Alsek

Beaches, wave-cut benches, and lines of driftwood (Fig. 29), which are present in Alsek, Dusty, Kaskawulsh, and Dezadeash valleys, have been attributed to Neoglacial damming of Alsek Valley by Lowell Glacier (Kindle, 1953). Kindle believed that the strandlines could be separated into two sets of beaches, the higher set having formed about 250 years ago and the lower set about 140 years ago.

Reconnaissance work in Alsek and Dezadeash valleys, however, indicates that the beaches and wave-cut benches probably are related to five distinct lake phases (Fig. 30). Two distinctive strandlines of driftwood are present at about 595 m (1950 ft) and 620 m (2040 ft) in these river valleys. A difference in the diameters of the lichen **Rhizocarpon geographicum** above and below 595 m (1950 ft) at Marble Creek indicates that the two strandlines are of different age. Generally the diameters are less that 17 mm on the lower beaches and are less than 36 mm on the upper beaches; the diameters suggest respective ages of about 125 years and 250 years, if the growth-rate curve for **R. geographicum** determined for an area to the northwest is applicable here (Rampton, 1970). Kindle (1953) also estimated that the lowest strandline was about 125 years old.

Two additional changes in lichen densities occur on the beaches above 620 m (2040 ft) near the bend of Dezadeash River (Fig. 31); one of the beaches is matched by a driftwood strandline at Beachview Creek (Fig. 30). Driftwood from one beach slightly above 630 m (2070 ft) has been radiocarbon dated at 370 ± 60 years (GSC-2100). This date suggests an age for the lower of these two phases of between 320 and 500 years (based on corrections for fluctuations in atmospheric ^{14}C content determined by Stuiver and Suess, 1966).

Lacustrine features of Neoglacial age between 640 and 670 m (2100 and 2200 ft) probably formed around 2800 or 1250 years ago if they are related to the two older lacustrine units identified in the pit between Bear and Pine creeks (Fig. 32). However, no difference in the character of surficial lacustrine features above the 640 m (2100 ft) level could be identified to indicate that these features are of two different ages.

Morainal Landforms (M)

All morainal landforms originate through the deposition of materials by glaciers, either directly at the base of a glacier or from the surface of a glacier as it wastes away, or by ice shove and bulldozing. Morainal landforms commonly contain materials that have been subjected to mass wastage processes such as mudflows on steep glacier surfaces. Also, some washing of morainal materials may occur due to melt-water activity associated with the glaciers.

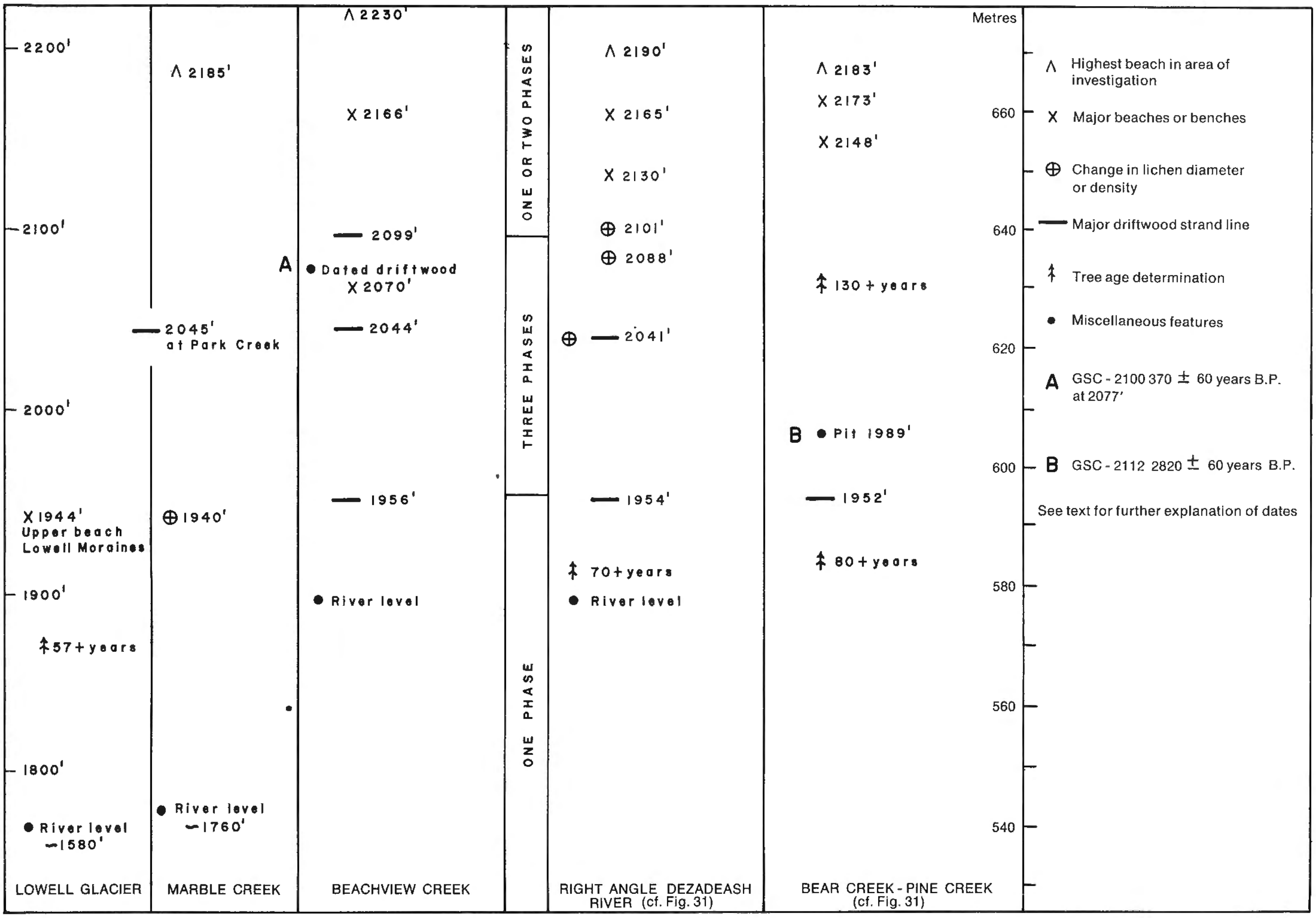


Figure 30. *Elevations of features associated with Neoglacial lakes in Alsek and Dezadeash valleys. Levels were determined by aneroid barometer and are not exact. Note that major beaches do not necessarily belong to separate phases.*

Drumlins and fluted moraine (Md)

Drumlins and fluted moraines form by the deposition and streamlining of till beneath active glaciers. Drumlins generally can be recognized as individual hills whereas fluted moraine consists of a series of long linear depressions and ridges.

Drumlins are present in Donjek Valley below the mouth of Steele Creek (Map 14-1979). Fluted moraine is evident in the Shakwak Valley from Jarvis River north to Donjek River.

Ground moraine and till-covered slopes (Mg, MS)

Ground moraine is used to describe morainal landforms having indistinctive surface expression. Generally the surface form reflects the underlying bedrock morphology. Where the bedrock slopes moderately or steeply the landform is classified as a till-covered slope.

Ground moraine and till-covered slopes commonly have formed by the plastering of till upon a slope beneath an active glacier or by the deposition of ablation till from a melting glacier.

These features are common throughout the area. Most are of late Kluane age, although some till-covered slopes of Neoglacial age are present, for example, at the terminus of Kaskawulsh Glacier (Map 14-1979).

Hummocky and rolling moraine (Mh, Mm)

Hummocky and rolling moraine originates through the wastage of stagnant ice containing much supraglacial and englacial debris. Glaciers flowing through Kluane National Park during the Kluane Glaciation formed many areas of hummocky and rolling moraine north and west of the park (Rampton, 1971a; Denton, 1974). Within the park, however, either glaciers remained active during deglaciation or englacial and supraglacial debris was reworked by meltwater, resulting in a general absence of hummocky and rolling moraine.

Small areas of rolling moraine can be found in Shakwak Valley near Sulphur Lake and on Burwash Uplands near the local limit of glaciation. All areas of hummocky and rolling moraine are of late Kluane age.

Morainic plain (Mp)

Morainic plain describes areas underlain by till that are flat or gently sloping. Morainic plains are formed predominantly through the deposition of lodgment till at the base of a glacier, although some ablation till may be spread evenly over the surface of the lodgment till. All morainic plains mapped are found in Shakwak Valley and on the Burwash Uplands.

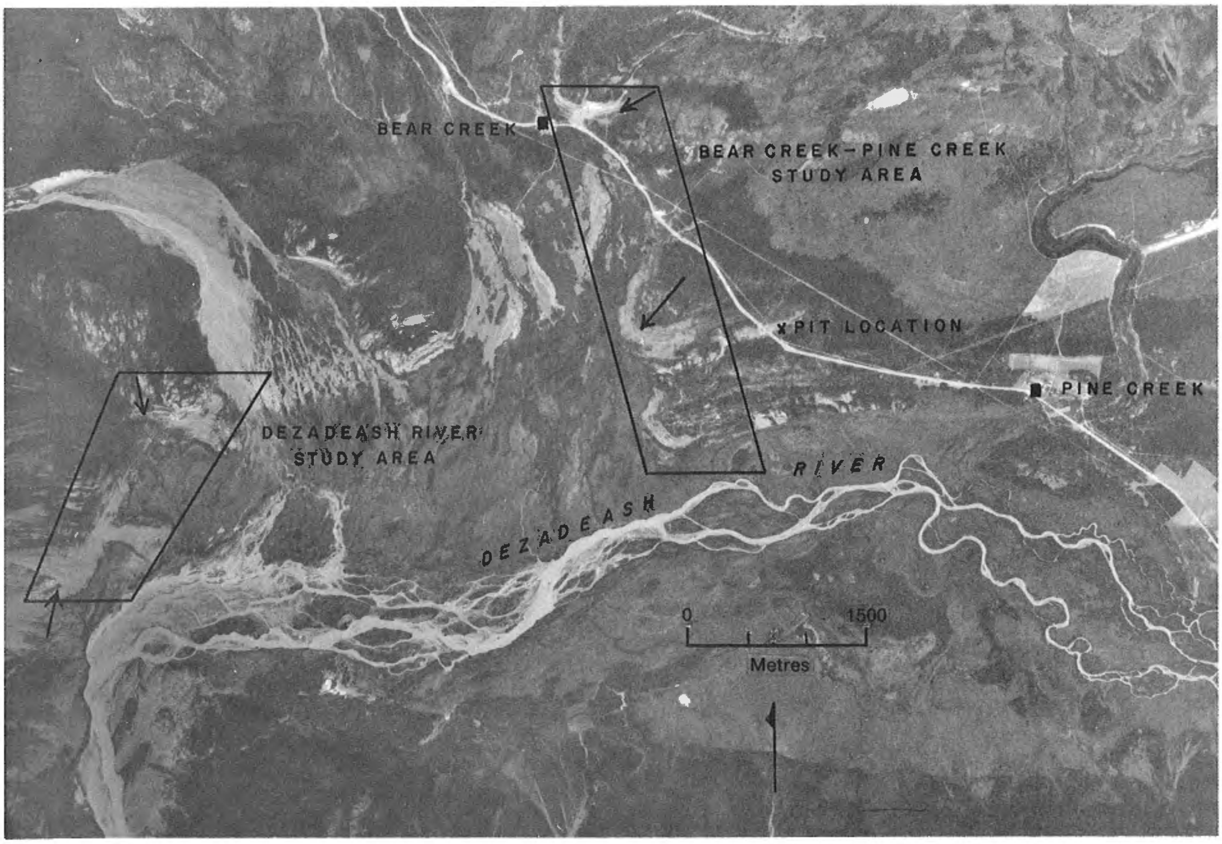


Figure 31. *Dezadeash River and Bear Creek/Pine Creek study areas. Arrows show typical areas of strandlines. (Airphoto A23000-190)*

Morainic ridges (Mr)

Ice push and the sloughing off of supraglacial debris from the edge of a glacier that maintains its terminus at one position over a long period of time are the two most common ways in which morainic ridges form. Most morainic ridges in the park are of Neoglacial age and generally are limited to the terminal zones of modern glaciers, for example, Lowell and Kaskawulsh glaciers.

Erratics

Individual large boulders have been deposited on ridges and mountainsides by valley glaciers (Fig. 33). In some areas, such as in the mountains adjacent to Beachview Creek, granitic boulders derived from the Icefield Ranges indicate the presence of Kluane age glaciers.

Debris-covered glaciers and ice-cored moraines $\frac{M}{I}$

Most large glaciers in the park have ice-cored moraines near their termini that result, in large part, from the downglacier movement of medial and lateral moraines to their termini (Fig. 28). Ice-cored moraines are characterized by chaotic topography, unstable slopes, ice thaw lakes, and ice cliffs, all of which result from varying thicknesses of the material overlying the glacier ice (commonly 0.6 to 3 m), slope aspect, and the activity of meltwater. Glaciofluvial and lacustrine landforms are commonly associated with ice-cored moraines because of the abundance of meltwater streams and ice-thaw lakes.

Neoglacial ice-cored moraines flanking most large glaciers in Kluane National Park exhibit differences in surface maturity and vegetation, which indicate different times of construction. On the basis of lichen diameters **(R. geographicum)** and tree ages, the morainal complex of Lowell Glacier is divisible into five, possibly six, moraines of different ages (Fig. 34). Ice-cored moraines of Kluane Glacier, on the other hand can only be divided into two moraines of different ages on the basis of vegetation cover. Borns and Goldthwait (1966) and Denton and Stuiver (1966) divided the Kaskawulsh Neoglacial moraines into four separate moraines (Fig. 35) by determining the ages of trees on the surfaces. They also divided the Neoglacial moraines of Donjek Glacier into two distinct moraines on the basis of morphology and vegetation. In the southern part of the park a morainal complex at the terminus of an unnamed glacier at the head of Wolverine Creek can be divided into at least four separate moraines on the basis of lichen diameters (Fig. 36).

Ice-cored moraines are also associated with small glaciers in the park. Generally the surfaces of small moraines are not as chaotic as the surfaces of large ones because the supraglacial debris of small glaciers is thick enough to protect against irregular melting. Small glaciers at the head of Duke River and Grizzly Creek have two distinct moraines of different ages. A lichenometric study of ice-cored moraines adjacent to two glaciers in the vicinity of Mount Hoge showed that one glacier has moraines of four distinct ages whereas the other has moraines of only two ages (Fig. 37).

Of course, moraines distinguished by an investigator may be the result of more than one individual glacial advance. Also, the number of moraines of different ages that fringe a glacier is, to a large extent, a function of the size of the moraines formed by early advances. In the case of small glaciers or a glacier such as Donjek Glacier, which carries little supraglacial material, the older moraines were overridden during later advances; whereas the older more massive moraines of Lowell Glacier and the glacier at the head of Wolverine Creek acted as barriers to subsequent advances.

Debris-covered glaciers, which are common in the park in the mountain ranges southwest and south of Haines Junction, consist of glacier ice with a continuous cover of bouldery supraglacial deposits. The ice may be exposed at the head of the glacier or in the walls of thaw lakes (Fig. 38) and furrows.

Moraines formed by one debris-covered glacier near Haines Junction could be divided into a minimum of five separate moraines of different ages based on lichen diameters and tree ages (Fig. 38); moraines of nearby debris-covered glaciers show similar zonations (Fig. 38). Another debris-covered glacier near the head of Grizzly Creek has a large spatulate-shaped moraine (Fig. 39) that can be divided into three zones-an inner zone free of lichens, a zone with **R. geographicum** to 12 mm in diameter, and an outer zone with **R. geographicum** diameters from 30 to 63 mm. The outer zone cannot be subdivided further as there is no systematic increase in diameters across it.

All ice-cored moraines and debris-covered glaciers are of Neoglacial age. Dating of the moraines is based on correlations with dated moraines in Alaska (Denton and Karlén, 1973) and in Yukon Territory northwest of Kluane National Park (Rampton, 1970). These studies suggest that moraines having **R. geographicum** diameters of 55 mm are probably older than 500 years and possibly as old as 1200 years; those having **R. geographicum** diameters of 45 to 48 mm date from 350 to 450 years, possibly earlier; those having diameters of 30 to 37 mm date from 200 to 250 years; those having diameters of 19 to 22 mm date from 120 to 150 years; those having diameters of 6 to 12 mm date from 40 to 70 years; some young moraines have no **Rhizocarpon geographicum** lichens, but shrubs indicate ages of at least 25 years.

Rock glaciers (MR)

Some rock glaciers form at the base of steep slopes and cliffs by the cementing of talus by interstitial ice below the surface. This mass of boulders and fine material moves from its original point of deposition in the form of a rock glacier; the exact mechanism of motion is not clear. In some cases motion may result simply from the flow of ice-cemented rock debris or the downslope heaving of rock fragments by the freezing and melting of interstitial ice. In other cases ice may build up in thick lenses under the rock debris and the entire mass of ice and overlying debris may flow downslope. Some rock glaciers may simply be relict debris-covered glaciers, with the ice at their heads melted away.

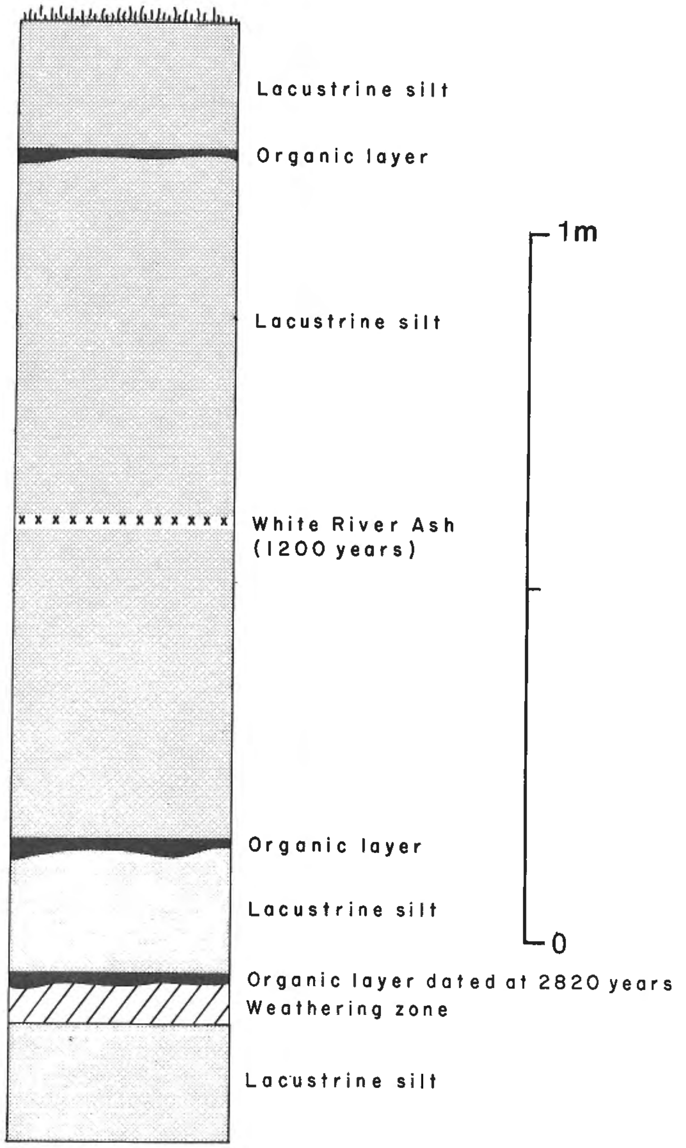


Figure 32. *Stratigraphy in a pit between Bear and Pine creeks. See Figure 31 for location.*

Figure 33

Large erratic boulder on morainic ridge between Alsek and Dusty valleys. (GSC 202880-A)

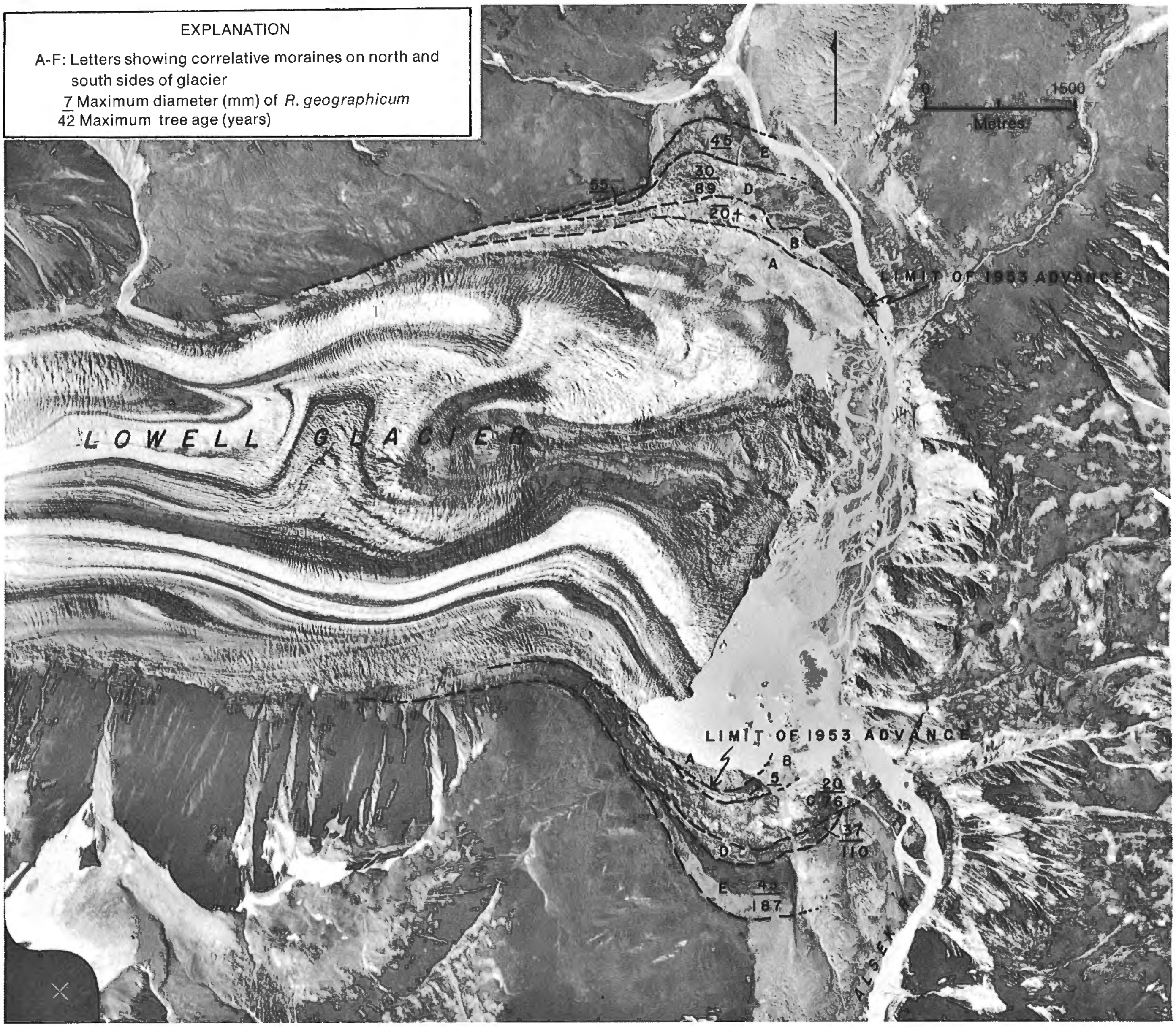


Figure 34. *Ice-cored Neoglacial moraines of Lowell Glacier. The moraines (A-E) have been identified because lichen of similar diameters and trees of similar age cover each moraine. The 1953 advance or Lowell Glacier referred to by Kindle (1953) is identified. (GSC 202974-I)*

Wahrhaftig and Cox (1959) classified rock glaciers according to their shape, namely, lobate, tongue shaped, and spatulate; all are present in Kluane National Park.

Good examples of rock glaciers occur along Slims River, Duke River, and Grizzly Creek valleys, and at the southern end of Kluane Lake (Map 14-1979). A tongue-shaped rock glacier can be seen on the flanks of Sheep Mountain; lobate-shaped rock glaciers are present on the east side of Slims River.

Rock glaciers reconnoitred along Grizzly Creek all have relatively large lichens (Fig. 39). However, even though vegetation and large lichens may be present on the surface of a rock glacier, motion may not have ceased. For example, although the rock glacier flanking Sheep Mountain has trees more than 250 years old growing on it, significant movement can be measured along its axis (Johnson, 1973). Also, a partly vegetated rock glacier is advancing across unvegetated Neoglacial lateral moraines of Kluane Glacier (Fig. 40). Thus, although much of the "rapid motion" of most rock glaciers must have occurred during the early part of the Neoglacial as indicated by the large lichens on their surfaces, some movement has continued to the present.

Organic Landforms (O)

Bogs (Ob)

On many low flat areas in Kluane National Park, organic deposits have accumulated to form marshy, treeless bogs underlain by permafrost. The organic material underlying the bogs probably has been accumulating since early Postglacial time.

Examples of bogs are on the flat areas to the west of Dezadeash Lake and south of Alder Creek (Map 14-1979).

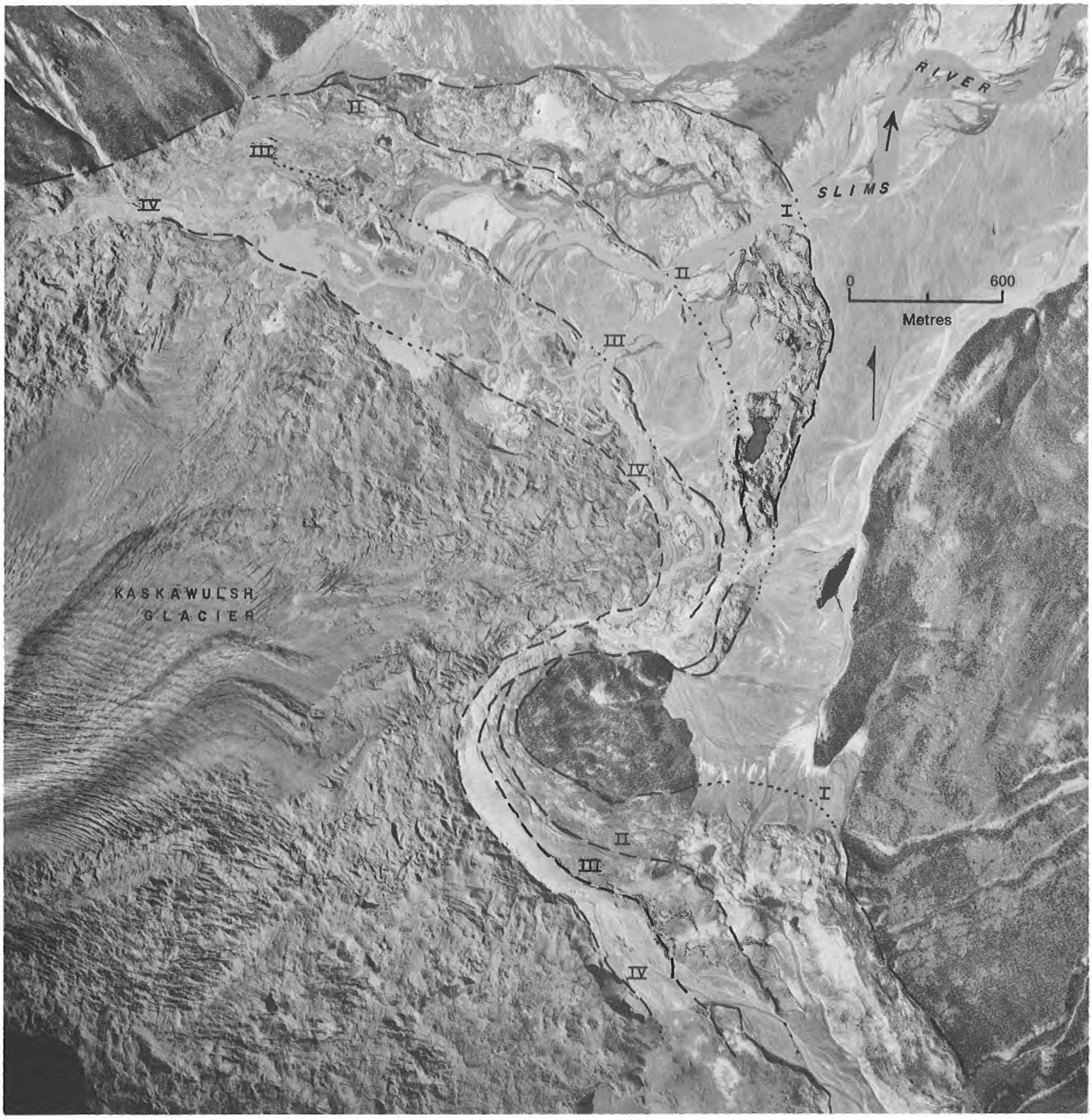


Figure 35. *Ice-cored moraines adjacent to the northern part of the terminus of Kaskawulsh Glacier. Lines I-IV indicate outer limit of advances that produced ice-cored moraines I-IV of Borns and Goldthwait (1966) and Denton and Stuiver (1966). (Airphoto A23894-198)*

Forested peatlands (Ofp)

This term has been applied to a sloping terrain unit underlain by material with a high content of organic matter but which is covered by a mature spruce forest. The surface relief of the forested peatlands appears to reflect the relief of the underlying material.

Forested peatlands probably began to form in early Postglacial time and are still thickening today, in some cases at an average rate of 7.5 cm per 100 years. This growth rate is based on the occurrence of White River ash dated at 1220 years B.P. in peat exposed along Donjek River (Fig. 14).

Good examples of forested peatlands are limited to lower Donjek Valley.

Landforms resulting from glacial Scour (R̂, R⊳)

Many valleys in Kluane National Park are floored by scoured rock. Such valley bottoms commonly have an irregular hummocky morphology resulting from the differential erosion of pockets of relatively incompetent bedrock. Where glaciers flowed parallel to stratigraphic and structural trends, the bedrock is fluted. In many areas the bedrock has no cover of unconsolidated surficial deposits, but in other areas the rock is veneered by glacial material or frost-riven blocks.

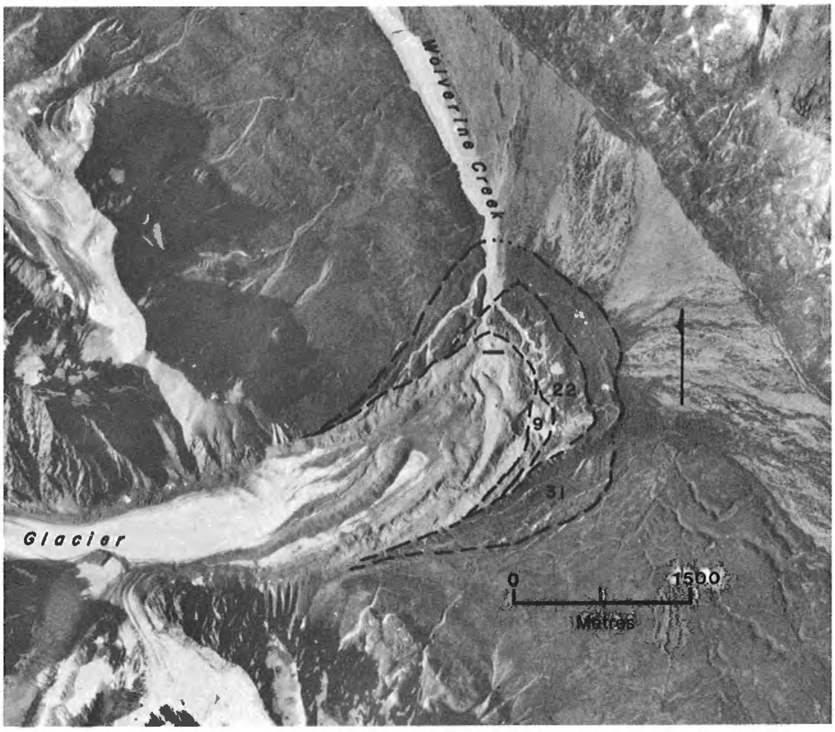


Figure 36

Maximum diameters (mm) of ***Rhizocarpon geographicum*** *on ice-cored moraines of a small unnamed glacier at the head of Wolverine Creek. Areas of similar lichen diameters, vegetation cover, and geomorphic characteristics are separated by broken lines. (Airphoto A23001-218; GSC 202974-L)*

Most of the valleys occupied by Alder Creek, Bates and Mush lakes, and the upland between Alsek River and Field Creek are floored by glacially scoured rock. Other good examples are adjacent to Slims River and Kaskawulsh Glacier and along Alsek valley, especially near Sockeye Lake.

Glacially eroded and smoothed valley walls are also partly a result of glacial scour. Narrow valleys are carved into the classical U-shape. On some valleysides that have been glacially scoured more competent beds commonly stand out as benches or ridges on the valley walls (Fig. 41). Glacially scoured valley walls are common throughout the park.

Most glacially scoured bedrock was formed during Kluane Glaciation.

Rock Cliffs (R)

Bedrock cliffs are a common feature of mountainous terrain resulting from deep stream dissection and over-steepening of slopes by glacial activity. Small valleys trending at right angles to glacially over-deepened trunk valleys generally have steep bedrock walls. Rock cliffs also are present at the head of cirques where glaciers erode bedrock debris from the base of the cliffs, thereby maintaining their steepness (Fig. 15).

Cliffs have existed over long periods of time. Their continued existence, however, requires the removal of weathering products from their bases.

QUATERNARY STRATIGRAPHY AND HISTORY

For the purpose of this paper the Quaternary has been divided into the early and middle Pleistocene, late Pleistocene, and Postglacial (Fig. 17). The early and middle Pleistocene includes all Pleistocene time up to 100 000 years ago, whereas late Pleistocene includes the interval between 100 000 and 12 500 years ago. Late Pleistocene events are believed to correlate with Wisconsin events throughout North America. As deglaciation is though to have been well underway by 12 500 years B.P. (Denton and Stuiver, 1967), this date is used to delineate the beginning of the Postglacial in Kluane National Park.

Early and Middle Pleistocene

Glacial events

Kluane National Park has been subjected to glaciers and glaciation throughout the Quaternary. Indeed, in areas northwest of the park, direct evidence of pre-Quaternary glaciation exists. In Alaska, for example, glacial activity between 10 and 2.7 Ma ago has been documented (Denton and Armstrong, 1969). Within 10 Km north of the park in the St. Clare Creek area, glacial drift, some of which is tilted and faulted (Souther and Stanciu, 1975), is present that appears to have been deposited in valleys unrelated to the modern drainage. This drift may be either Tertiary or early Pleistocene. Although similar evidence has not been found in Kluane National Park, the same events undoubtedly affected the park. The only evidence of definite early or middle Pleistocene glaciation in the park is a till at the east end of Kluane Lake having a weathering zone on its surface that indicates deposition more than 100 000 years ago (Denton and Stuiver, 1967; Fig. 17). The exact age of the till is difficult to determine because it is beyond the range of radiocarbon dating.

Nonglacial events

The weathering zone on the early or middle Pleistocene till at the east end of Kluane Lake was formed during the Silver nonglacial interval (Denton and Stuiver, 1967). This nonglacial interval was probably the last of a number of similar climatic intervals to affect the park area during the early and middle Pleistocene. The characteristics of the weathering zone indicate that the climate was warmer than that at present.

Figure 37. *Ice-cored moraines adjacent to glaciers on the north flank of Mount Hoge. Figures are maximum diameters (mm) of **Rhizocarpon geographicum**. Areas of similar lichen diameters, vegetation cover, and geomorphic characteristics are separated by broken lines. (Airphoto A23895-78; GSC 202974-C)*

Figure 38. Debris-covered glaciers and associated moraines southwest of Haines Junction. Upper figures are maximum **R. geographicum** diameters (mm) and lower ones are maximum tree ages (years) found on moraines. Areas of similar lichen diameters, vegetation cover, and geomorphic characteristics are separated by broken lines. (Airphoto A23893-135; GSC 202974)

Thick Pleistocene sediments are present near the junction of Telluride and Bryson creeks just north of the park boundary (Map 14-1979). Under the interbedded tills and gravels at the top of the sections are thick sequences of gravel and sand with woody and peaty layers that probably were deposited during a nonglacial interval of the early or middle Pleistocene. In one section, part of the sequence of nonglacial sand and gravel contains ice-wedge casts and layers of volcanic ash (Table 2). The ice-wedge casts indicate an interval marked by the presence of permafrost followed by an interval when melting occurred; the presence of volcanic ash indicates sporadic volcanic activity. The complete nonglacial sequence from units 11 to 15, and possibly including units 8 to 10 (Table 2), formed on a floodplain in a high energy environment.

A possible early or middle Pleistocene landslide deposit is located on a small creek tributary to Donjek River above Donjek Glacier. Here, oxidized landslide debris containing peat layers and volcanic ash underlies late Pleistocene till and gravel (Fig. 42). Landslide debris also underlies till along a small creek east of Mount Hoge.

Tectonism

Evidence of late Tertiary or early Pleistocene faulting has been found nearby in Alaska (Denton and Armstrong, 1969), north of the park in the vicinity of St. Clare Creek where glacial drift is tilted and faulted (Souther and Stanciu, 1975), and adjacent to Shakwak Valley north of Donjek River where discontinuities in the elevations of erratics across major valleys have been attributed to faulting (Rampton, 1969). Reconnaissance studies indicate that Pleistocene faulting was more intense in the northern than southeastern part of the park (Campbell and Dodds, 1975; Souther and Stanciu, 1975).

Late Pleistocene (Wisconsin) and Postglacial

General

For the area covered by Kluane National Park, late Pleistocene is defined as the interval between the beginning of the Icefield Glaciation and the end of the Kluane Glaciation, that is, from about 100 000 to 12 500 years ago. (Fig. 17). Although it is not positively known whether the Icefield Glaciation is early Wisconsin or Illinoian in age (Denton, 1974), it is clear that drift deposited during the Icefield Glaciation has not been subjected to the intense weathering that affected drift of the earlier Shakwak Glaciation (Denton and Stuiver, 1967). Few phenomena were examined within Kluane National Park that could be related to the Icefield Glaciation or the Boutillier Nonglacial Interval, which follows it (Fig. 17).

Kluane Glaciation

Most sections of Pleistocene sediments in Kluane National Park consist of interbedded gravel and till. Generally only one till is exposed, and it is presumably of Kluane age.

Many small tributary valleys contain thick glaciofluvial and glaciolacustrine sequences, which were deposited by tributary glaciers that were out-of-phase with those in the main valleys. Examples of such sequences occur on lower Bullion Creek and in the vicinity of the terminus of Lowell Glacier. On lower Bullion Creek, glaciofluvial gravel, glaciolacustrine silt and sand, and landslide debris (Fig. 43) were deposited while the mouth of the creek was blocked by glaciers but before glaciation of Bullion Creek valley itself. Sections in the vicinity of Lowell Glacier indicate that the formation of a glacial lake was followed by two glacial advances and associated glaciofluvial activity (Fig. 44). The two tills may represent phases of Kluane Glaciation or, alternatively, may represent the Kluane and Icefield glaciations. The extent of the glacial lake is unknown; the presence of about 120 m of varved clays is evidence for a long-lived lake, yet these sediments are only present between Fisher and Lowell glaciers and along Clay Creek and the lower part of Bates River. Kindle (1953) called this water body glacial Lake Fisher; however, he interpreted it as having existed following the last glaciation rather than during early parts of the Kluane, or possibly Icefield, glacial intervals as is indicated by the sections near Lowell Glacier.

During Kluane glaciation all major valleys were filled with ice, but most mountains stood above the ice as nunataks; the only notable exceptions were the mountains south of and the lower mountains north of Onion Lake.

Meltwater channels, lateral moraines, and other glacial features indicate that in the southwestern part of the park glacier flow was down Alsek Valley to the north and through the Field Creek/Bates Lake/Mush Lake lowlands and the valley occupied by Kathleen Lakes to the east (Fig. 45). Ice also moved north along valleys occupied by Tatshenshini River, Klukshu River, Fraser Creek, and Wolverine Creek. The glacier surface probably stood above 1800 m in the vicinity of Fisher Glacier, sloped to 1680 m near Dalton Post,

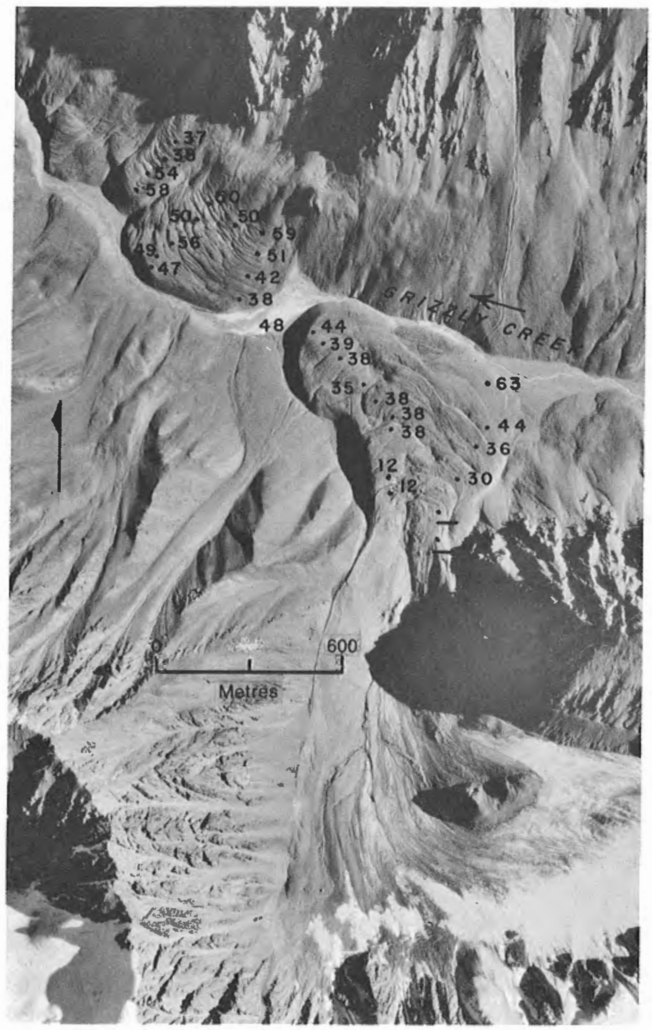


*Figure 39. **R. geographicum** diameters (mm) on a spatulate-shaped ice-cored moraine of a debris-covered glacier (on the right) and on nearby rock glaciers (on the left). (Airphoto A23895-250)*

Figure 40

Partly vegetated rock glacier advancing across lateral moraines of Kluane Glacier. (GSC 202880-J)

Figure 41

Glacially scoured valley wall. Some postglacial gullying has occurred. (GSC 202880)

and to less than 1520 m in the vicinity of Haines Junction; erratics found at higher elevations than these (cf. Kindle, 1953) probably relate to older glaciations.

Glacier flow in the vicinity of the mouths of Jarvis and Dezadeash rivers was complex (Fig. 45). Ice in Dusty Valley flowed east to join ice moving down Alsek Valley and west to join ice moving down Kaskawulsh Valley. The eastern lobe moved north through a gap in the Kluane Ranges occupied by Dezadeash River, whereas the western lobe moved north through the gap in the Kluane Ranges occupied by Jarvis River. In Shakwak Valley Dezadeash River marks the boundary between ice flowing east and ice flowing north and west. Ice moving north and west from the Dezadeash and Jarvis river gaps along Shakwak Valley was joined by glaciers flowing down Slims, Duke, and Donjek valleys. Denton and Stuiver (1967) believed that Kluane ice was at about 1860 m elevation at the southern end of Kluane Lake, and studies by Rampton (1969) indicate that Kluane ice was at about 1520 m near the intersection of Shakwak Valley and Donjek River. Higher erratics found by Wheeler (1963) near the south end of Kluane Lake probably relate to an earlier glaciation.

During the Kluane glaciation local glaciers grew and expanded in the Kluane Ranges, Alsek Ranges, and "Bates Ranges". Commonly these alpine glaciers coalesced with the main valley glaciers. In the mountains in which Duke River and its tributaries head, the growth was enough to produce the major glacier that flowed out of Duke Valley into Shakwak Valley.

Late Kluane and early Postglacial

During deglaciation, meltwater in the main valleys flowed parallel to the general direction of glacier flow outlined above. Some small valleys within the mountain ranges, however, became ice free before the main valleys and were occupied by meltwater streams and lakes. The streams commonly formed valley trains (Fig. 26), kame terraces, and deltas. A good example is the outwash in the valleys of Victoria and Goat creeks (Map 14-1979) deposited by meltwater from glaciers in the Mush Lake/Alder Creek area when ice still occupied the Kathleen Lakes area.

Table 2. Description of stratigraphy in a section on Telluride Creek above the mouth of Bryson Creek

Unit	Thickness (m)	Description (age)
1	2.5	Clifftop dune; sand with peaty layers; some pebbles to 2.5 cm diameter (Postglacial)
2	0.3	Gravel, bouldery (Kluane)
3	7	till, sandy, brown; middle 1 m is very bouldery (Kluane)
4	6	till, sandy, grey (Kluane)
5	3	Gravel, bouldery (Boutillier or Silver?)
6	1.5	Clay, grey, lacustrine (Icefield?)
7	12	Covered; probably till (Icefield?)
8	9	Gravel, crudely stratified; some sandy beds; angular clasts; wood-rich layer near base (middle or early Pleistocene)
9	3	Sand, pebbly, and gravel (middle or early Pleistocene?)
10	8.5	Gravel, bouldery (middle or early Pleistocene?)
11	12	Gravel, pebbly to bouldery; some angular clasts (middle or early Pleistocene)
12	15	Interbedded sand and gravel; beds 0.6 to 1.5 m thick; large-scale crossbeds; discontinuous peaty layers; thin discontinuous bed of volcanic ash 3 m from top (middle or early Pleistocene)
13	2.5	Interbedded sand and gravel; beds 30 to 60 cm thick; thin layers 2.5 to 7.5 cm thick, of flattened organic detritus; ice-wedge casts; volcanic ash in peaty layer (middle or early Pleistocene)
14	2.5	Sand and silt, pebbly; irregular bedding; peaty lenses (middle or early Pleistocene)
15	6	Interbedded silt and gravel; gravel beds about 60 cm thick; silt is organic rich (middle or early Pleistocene)
16	3	Covered
17	12	Covered, but appears to be glaciolacustrine silt (middle or early Pleistocene)
18	20	Covered to creek level

Figure 42. *Peaty layer (shown by arrow) containing volcanic ash in early Pleistocene landslide debris in upper Donjek Valley. (GSC 202880-B)*

An example of meltwater diversion in the northern part of the park can be seen in the passes between Donjek River and Quill Creek where meltwater flowing accross the passes into Quill Creek valley was joined by meltwater flowing west from the headwaters of Burwash and Tatamagouche creeks. At one time this meltwater may have been diverted back to Donjek River via Arch Creek.

Associated with deglaciation and meltwater activity was the deposition of loess. In some areas loess deposition began during the early phase of deglaciation, that is, around 12 500 years ago. Closer to the present-day termini of glaciers, loess deposition may not have begun until about 9800 years ago (Denton and Stuiver, 1967). As glaciers continued to shrink, the amount of loess produced far from the glacier termini in such areas of Kluane Lake, Haines Junction, and Dezadeash Lake diminished although loess was still being produced in large amounts near glacier termini and their active valley trains.

During deglaciation glacial lakes covered parts of the park. Most noteworthy were the western arms of glacial Lake Champagne (Kindle, 1953) which occupied the areas around Haines Junction, along Kathleen River, and in the vicinity of Dezadeash Lake. The areas probably were covered only by the later phase of glacial Lake Champagne as they likely were deglaciated much later than the terrain to the east covered by thicker deposits of glacial Lake Champagne.

Landslide activity during late Kluane and early Postglacial time was probably at a maximum because of the exposure of many glacially oversteepened slopes. For example, north of Alder Creek and at the head of

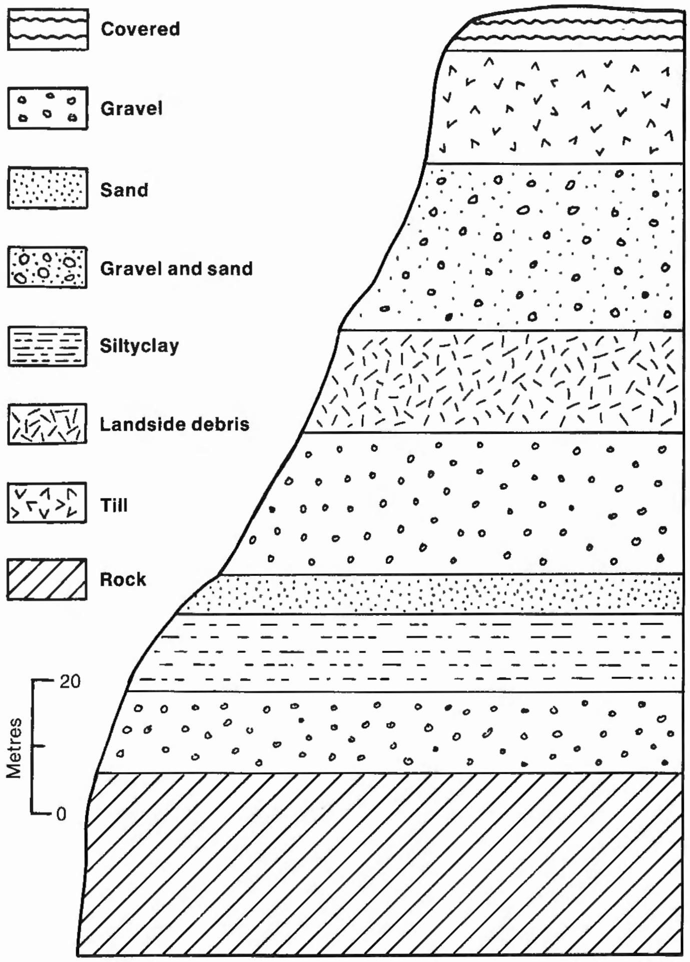


Figure 43. *Stratigraphy along lower Bullion Creek (see Map 14-1979 for location).*

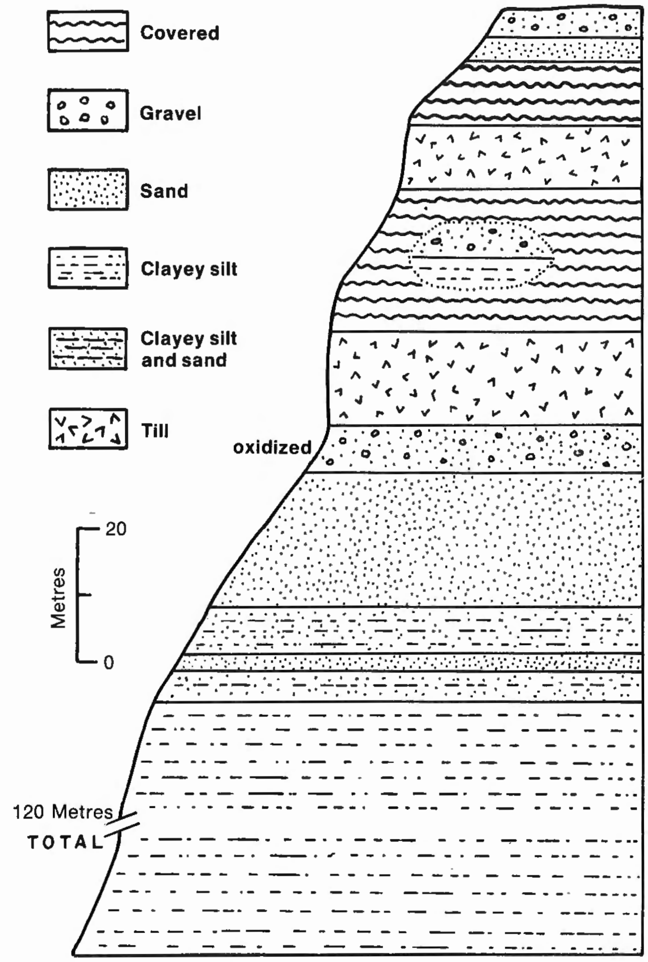


Figure 44. *Stratigraphy along Alsek River opposite Lowell Glacier (see Map 14-1979 for location).*

Cottonwood Creek (Map 14-1979) large landslide deposits having no obvious immediate source are attributed to landslides moving out onto glacier ice during late Kluane time and being moved some distance downvalley without major glacial reworking of the materials. In the gap between Halfbreed Creek and Duke River is a landslide deposit that appears to have been ice pushed (Map 14-1979).

Unrelated to glacial history, but exercising control on the location of some glacial deposits, is fault activity in Shakwak Valley. Bostock (1952) noted a relatively straight line of mounds on the southwest side of Shakwak Valley that parallels the valley for miles. These mounds cross all glacial features but are absent where postglacial fluvial deposition or erosion has occurred. The mounds are composed of glaciofluvial deposits, and it is tentatively concluded that they were deposited by meltwater localized along fractures formed by faulting during the deglaciation phase of the Kluane Glaciation.

Hypsithermal

In Kluane National Park area the Hypsithermal is limited to the interval between 8700 and 2800 years ago, that is, to the later and warmer part of the Slims Nonglacial Interval (Fig. 17). This time interval has been chosen for the Hypsithermal in this area because (1) palynological evidence north of the park suggests that the climate may have become as warm as or warmer than the present around 8700 years ago (Rampton, 1971b) and (2) the climate generally deteriorated and glaciers readvanced to their present positions around 2800 years ago (Denton and Karlén, 1973). Some evidence exists that short warm intervals have occurred since 2800 years ago (Rampton, 1971b; Denton and Karlén, 1973).

During the Hypsithermal glaciers retreated well back from their present positions. Kaskawulsh Glacier is known to have retreated at least 21.9 km above its present terminus (Denton and Stuiver, 1967). This retreat probably allowed Kluane Lake to drain through the Alsek River system to the south until the final readvance of Kaskawulsh Glacier during Neoglaciation (Bostock, 1969).

During the Hypsithermal interval the Slims Soil, an intensely oxidized horizon up to 30 cm developed (Fig. 22) and is present throughout most of the park.

Neoglaciation

Neoglaciation is defined as "the climatic episode characterized by rebirth and/or growth of glaciers following maximum shrinkage during the Hypsithermal interval" or "the period of glacier expansion subsequent to maximum Hypsithermal shrinkage". (Porter and Denton, 1967). The first major regrowth of glaciers in southwestern Yukon Territory began about 2800 years ago (Denton and Karlén, 1973), and this date is considered to be the beginning of Neoglaciation in Kluane National Park.

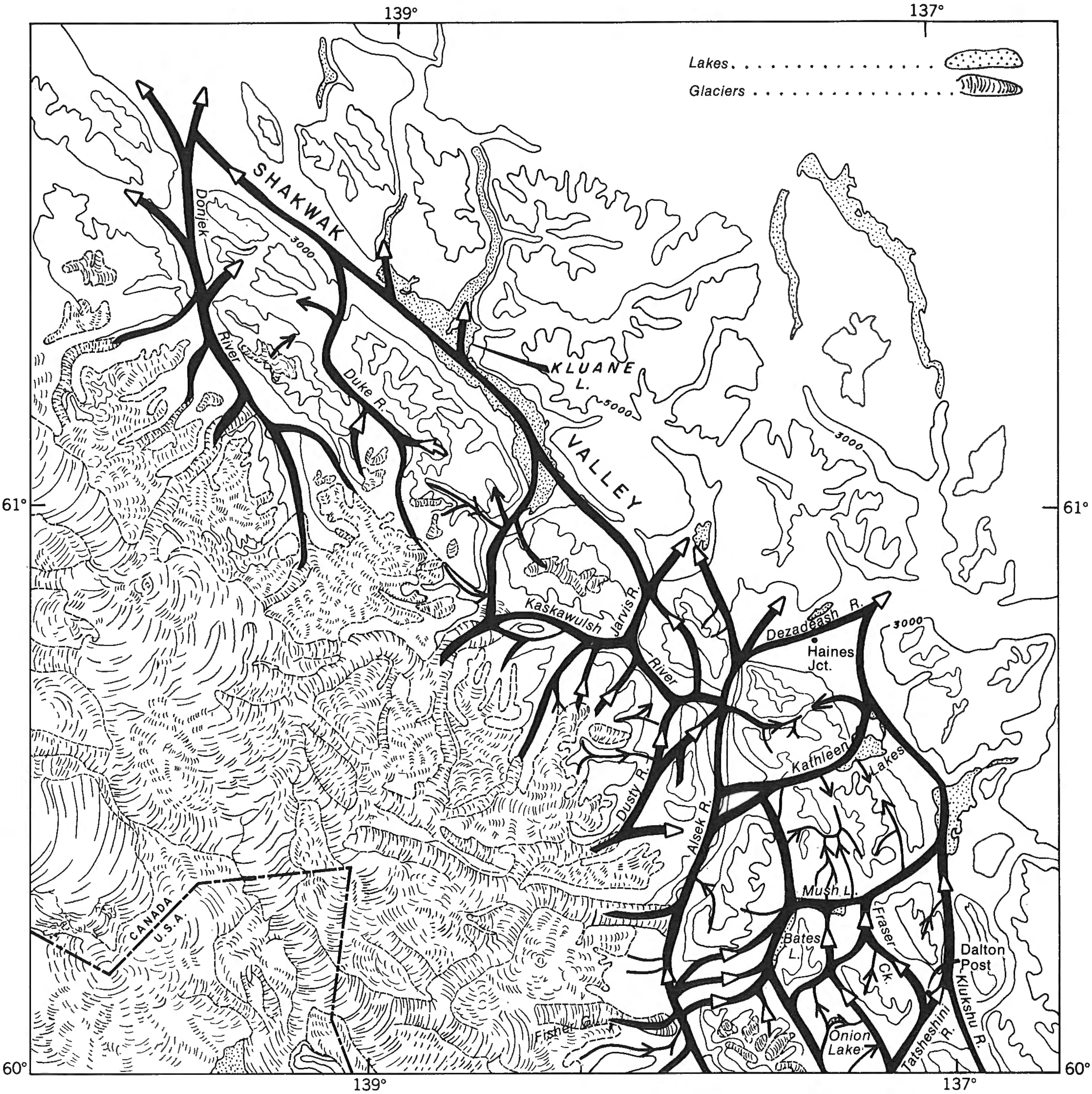


Figure 45. *Glacial flow patterns during Kluane Glaciation.*

Early Neoglacial advances can be documented for Kaskawulsh Glacier where Neoglacial loess deposition began about 2640 years ago (Denton and Stuiver, 1966) and for Lowell Glacier which dammed Alsek River and formed a lake shortly after 2820 years B.P. A second period of glacier expansion occurred between 1250 and 1050 years ago (Denton and Karlén, 1973). Loess deposition along the southeastern shore of Kluane Lake beginning about 1250 years B.P. (Denton and Karlén, 1973) indicates that Kaskawulsh Glacier probably was expanding at this time. Glaciolacustrine silts in the pit near Bear Creek (Fig. 32), which contains the 1220 year old White River Ash (Hughes et al., 1972), indicate that Lowell Glacier had again advanced and dammed Alsek River.

The final period of major Neoglacial activity began about 450 years ago and has continued to the present. Kaskawulsh Glacier was advancing around 500 years ago and reached its Neoglacial maximum between 300 and 420 years B.P. (Denton and Stuiver, 1966). This initial advance probably correlates with the high Neoglacial level of Kluane Lake (Hughes et al., 1972). Donjek Glacier was near its maximum Neoglacial position about 400 years ago (Denton and Stuiver, 1966). Not all glacial advances that occurred during this interval, however, left recognizable moraines. Of the glaciers studied within the park, only the debris-covered glacier near Haines Junction (Fig. 38), Lowell Glacier (Fig. 34), Fisher Glacier (Fig. 46), and a couple of rock

Figure 46. *Fisher Glacier and Neoglacial moraines. Upper figures give maximum* ***R. Geographicum*** *diameters (mm) and lower figures give maximum tree ages (years) found on each morainal belt as identified by similar lichen diameters, vegetation cover, and geomorphic characteristics. (Airphoto A23794-190)*

glaciers on Grizzly Creek (Fig. 39) have moraines that may date from about 450 years B.P. A corrected age of about 450 years B.P. on driftwood from a high beach at Beachview Creek indicates that Lowell Glacier probably dammed Alsek Valley at this time.

Following 450 years B.P. most glaciers synchronously constructed a series of moraines. Generally, moraines can be grouped according to maximum lichen diameters of 30 to 37 mm, 19 to 22 mm, 6 to 12 mm, and 0, which suggest corresponding glacial advances of 200 to 250 years B.P., 120 to 150 years B.P., 40 to 70 years B.P., and 25 years B.P. to the present.

During the Neoglacial two volcanic events occurred in nearby Alaska (Hughes et al., 1972) that spread two major layers of ash over much of the park (Fig. 14). The oldest occurred about 1880 years ago (Denton and Karlén, 1973) and the youngest about 1220 years ago (Hughes et al., 1972).

Today, geologic processes are continuing in equilibrium with a Neoglacial climate. Other than glaciers and the moraine construction associated with them, the most obvious processes operating in the park today are mass wastage phenomena such as landslides and solifluction, loess and eolian sand deposition, beach formation, lacustrine sedimentation, and valley train and floodplain development.

SUMMARY

Kluane National Park is located in the southwest corner of Yukon Territory. The major physiographic elements of the park include Shakwak Valley, a broad trench-like valley that forms the northeastern edge of the Park, and the St. Elias Mountains, which consist of the Kluane Ranges, "Bates Ranges", Alsek Ranges, Duke Depression, Donjek Range, and the Icefield Ranges. The Kluane Ranges, which form the northeastern edge of the St. Elias Mountains, include two to three sharp-crested ridges paralleling Shakwak Valley. Duke Depression is a complex of valleys and plateaus that separates the Kluane and Icefield ranges in the northwestern part of the park. The "Bates Ranges" are a subdued group of mountains in the south. Only a small portion of Alsek Ranges are present in the southern part. The Icefield Ranges, which form the core of the St. Elias Mountains, are shrouded in ice and have numerous peaks and large areas above 3000 m elevation.

Much of the park is a complex of steep slopes and cliffs, which have been modified by mass wastage, stream erosion, and glacial scouring, and which have a veneer of unconsolidated materials. High relief, oversteepened slopes, and moderately competent rock have led to the formation of talus fans and aprons and the occurrence of landslides. Landforms of the major valleys are mainly glacially scoured bedrock and outwash plains produced by late Pleistocene glacial erosion and meltwater activity.

Downvalley from the major valley glaciers, active valley trains with braided channel patterns are present in the valley bottoms. Fringing the glaciers themselves are massive ice-cored moraines. Small valleys in low mountains commonly contain small glaciers with ice-cored moraines or debris-covered glaciers. Rock glaciers also are present at low elevations.

Stratigraphic observations in nearby areas indicate that the Kluane National Park region has been subjected to repeated glaciations from the late Tertiary to the present. Nonglacial intervals during late Pleistocene time are recorded stratigraphically by landslide, floodplain, and Volcanic ash (tephra) deposits, and by periglacial phenomena such as ice-wedge casts.

Most glacial landforms in the park are the result of the Kluane Glaciation, which occurred from approximately 29 000 to 12 500 years ago. During this time most major valleys were filled with ice, and alpine glaciers developed and expanded in the low mountains. In general, the main valley complex of glacier ice east of Dusty River sloped to the north and east, whereas west of Dusty River it sloped north and west. Deglaciation was accompanied by major outwash and loess deposition.

From about 8700 to 2800 years ago, the climate was warmer than that at present. Soil development during this interval produced the reddish browns Slims Soil.

Renewed climatic deterioration marking the beginning of Neoglaciation in Kluane National Park occurred around 2800 years ago. Stratigraphic evidence and lichenometry indicate that marked periods of glacier expansion took place around 2800 years B.P., between 1250 and 1050 years B.P., and during the last 450 years. Synchronous advances of many glaciers appear to have occurred between 200 and 250 years B.P., 120 and 150 years B.P., 40 and 70 years B.P., and from 25 years ago to the present. During Neoglaciation, lakes formed five or six time in Alsek Valley and its tributaries through the damming of Alsek River by Lowell Glaciers. The oldest lake had a maximum surface elevation of about 670 m (2200 ft), whereas the youngest had a surface elevation of about 595 m (1950 ft).

Active geologic processes in the park today are moraine construction, valley train and floodplain development, loess and sand dune formation, and solifluction.

REFERENCES

Borns, H.W. and Goldthwait, R.
1966: Late-Pleistocene fluctuations of Kaskawulsh Glacier, southwestern Yukon Territory, Canada American Journal of Science, v. 264, p. 600-619.

Bostock, H.S.
1948: Physiography of the Canadian Cordillera, with special reference to the area north of the fifty-fifth parallel; Geological Survey of Canada, Memoir 247.

1952: Geology of northwest Shakwak Valley; Geological Survey of Canada, Memoir 267.

1969: Kluane Lake, Yukon Territory, its drainage and allied problems; Geological Survey of Canada, Paper 69-28, 19 p.

1970: Physiographic regions of Canada; Geological Survey of Canada, Map 1254A.

Cairnes, D.D.
1915: Exploration in southwestern Yukon; Geological Survey of Canada, Summary Report 1914, p. 10-33.

Campbell, R.B. and Dodds, C.J.
1975: Operation Saint Elias, Yukon Territory; in Report of Activities, Part A, Geological Survey of Canada, Paper 75-1A, p. 51-53.

Clarke, G.K.C.
1969: Geophysical measurements on the Kaskawulsh and Hubbard Glaciers; in Icefield Ranges Research Project Scientific Results, ed. V.C. Bushnell and R.H. Ragle; v. 1, p. 89-196, American Geographical Society (New York) and Arctic Institute of North America (Montreal).

Crossley, D.J. and Clarke, G.K.C.
1972: Thermal drilling and deep-ice temperatures measurements on the Rusty Glacier; in Icefield Ranges Research Project Scientific Results, ed. V.C. Bushnell and R.H. Ragle; v. 3, p. 103-116, America Geographical Society, (New York) and Arctic Institute of North America (Montreal).

Day, J.H.
1962: Reconnaissance soil survey of the Takhini and Dezadeash Valleys in the Yukon Territory; Canada Department of Agriculture, Research Branch.

Denton, G.H.
1974: Quaternary glaciations of the White River valley, Alaska, with a regional synthesis for the northern St. Elias Mountains, Alaska and Yukon Territory; Geological Society of America Bulletin, v. 85, p. 871-892.

Denton, G.H. and Armstrong, R.L.
1969: Miocene-Pliocene glaciations in southern Alaska; American Journal of Science, v. 267, p. 1121-1142.

Denton, G.H. and Karlén, W.
1973: Holocene climatic variations – their pattern and possible cause; Quaternary Research, v. 3, p. 155-205.

Denton, G.H. and Stuiver, M.
1966: Neoglacial chronology, northeastern St. Elias Mountains, Canada; American Journal of Science, v. 261, p. 577-599.

1967: Late Pleistocene glacial stratigraphy and chronology, northeastern St. Elias Mountains, Yukon Territory, Canada; Geological Society of America Bulletin, v. 78, p. 485-510.

Eisbacher, G.H.
1975: Operation Saint Elias, Yukon Territory: Dezadeash Group and Amphitheatre Formation; in Report of Activities, Part A, Geological Survey of Canada, Paper 75-1A, p. 61-62.

Fahnestock, R.K.
1969: Morphology of the Slims River; in Icefield Ranges Research Project Scientific Results, ed. V.C. Bushnell and R.H. Ragle; v. 1, p. 161-172, American Geographical Society (New York) and Arctic Institute of North America (Montreal).

Hughes, O.L., Campbell, R.B., Muller, J.E., and Wheeler, J.O.
1969: Glacial map of Yukon Territory, south of 65 degrees north latitude; Geological Survey of Canada, Paper 68-34, 9 p.

Hughes, O.L. Rampton, V.N., and Rutter, N.W.
1972: Quaternary geology and geomorpholgy, southern and central Yukon; 24th International Geological Congress (Montreal), Guidebook A11.

Johnson, J.P.
1973: Some problems in the study of rock glaciers, in Research in Polar and Alpine Geomorphology, ed. B.D. Rahey and R.D. Thompson; 3rd Guelph Symposium on Geomorphology, p. 84-94, GeoAbstracts Ltd., England.

Johnson, P.G.
1971: Ice cored moraine formation and degradation, Donjek Glacier, Yukon Territory, Canada; Geografiska Annaler, Series A, v. 53A, p. 198-202.

1972: The morphological effects of surges of the Donjek Glacier, St. Elias Mountains, Yukon Territory, Canada; Journal of Glaciology, v. 11, p. 227-234.

Kindle, E.D.
1953: Dezadeash map-area, Yukon Territory; Geological Survey of Canada, Memoir 268.

Lerbekmo, J.F. and Campbell, J.A.
1969: Distribution, composition, and source of the White River Ash, Yukon Territory; Canadian Journal of Earth Sciences, v. 6, p. 109-116.

McConnell, R.G.
1905: The Kluane mining district; Geological Survey of Canada, Summary Report 1904, p. 1-18.

Muller, J.E.
1967: Kluane Lake map-area, Yukon Territory; Geological Survey of Canada, Memoir 340, 137 p.

Porter, S.C. and Denton, G.H.
1967: Chronology of Neoglaciation in the North American Cordillera; American Journal of Science, v. 265, no. 3, p. 177-210.

Rampton, V.N.
1969: Pleistocene geology of the Sang-Klutlan area, southwestern Yukon Territory, Canada; unpublished Ph.D. dissertation, Minnesota University, Minneapolis.

Rampton, V.N. (cont'd)
1970: Neoglacial fluctuations of the Natazhat and Klutlan Glaciers, Yukon Territory, Canada; Canadian Journal of Earth Sciences, v. 7, p. 1236-1263.

1971a: Late Pleistocene glaciations of the Snag-Klutlan area, Yukon Territory; Arctic; v. 24, p. 277-300.

1971b: Late Quaternary vegetational and climatic history of the Snag-Klutlan area, southwestern Yukon Territory, Canada; Geological Society of America Bulletin, v. 82, p. 959-978.

Read, P.B. and Monger, J.W.H.
1975: Operation Sant Elias, Yukon Territory: The Mush Lake Group and Permo-Triassic rocks in the Kluane Ranges; in Report of Activities, Part A, Geological Survey of Canada, Paper 75-1A, p. 55-59.

Rutter, N.W.
1969: Comparison of moraines formed by surging and normal glaciers: Canadian Journal of Earth Sciences, v. 6, p. 991-999.

Sharp, R.P.
1943: Gology of the Wolf Creek area, St. Elias Range; Geological Society of America Bulletin, v. 54, p. 625-650.

1949: Studies of superglacial debris on valley glaciers; American Journal of Science, v. 247, p. 289-315.

1951: Glacial history of Wolf Creek, St. Elias Range, Canada; Journal of Geology, v. 59, p. 97-117.

Souther, J.G. and Stanciu, G.
1975: Operation Saint Elias, Yukon Territory: Tertiary volcanic rocks; in Report of Activities, Part A, Geological Survey of Canada, Paper 75-1A, p. 63-70.

Stanley, A.D.
1969: Observations of the surge of the Steele Glacier; Canadian Journal of Earth Sciences, v. 6, p. 819-830.

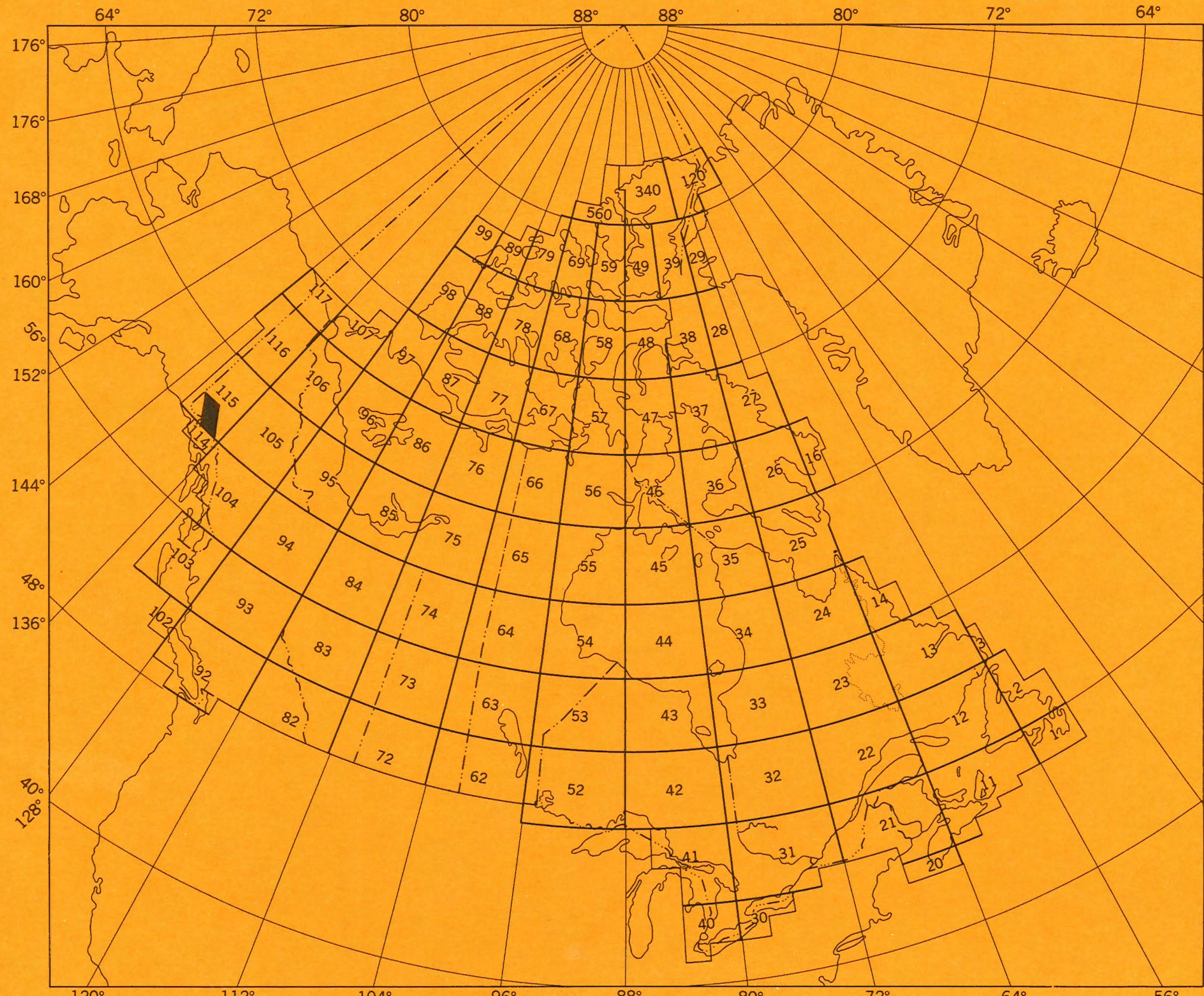
Stuiver, M. and Suess, H.
1966: On the relationship between radiocarbon dates and true sample ages; Radiocarbon, v. 8, p. 534-540.

Stuiver, M., Borns, H.W., Jr., and Denton, G.H.
1964: Age of a widespread layer of volcanic ash in the southwestern Yukon Territory; Arctic, v. 17, p. 259-260.

Wahraftig, C. and Cox, A.
1959: Rock glaciers in the Alaska Range; Geological Society of America Bulletin, v. 70, p. 383-436.

Wheeler, J.O.
1963: Geology, Kaskawulsh, Yukon Territory; Geological Survey of Canada, Map 1134A, Scale 1 in. to 4 miles.

Williams, P.F. and Rust, B.R.
1969: The sedimentology of a braided river; Journal of Sedimentary Petrology, v. 39, p. 649-679.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