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Excursion A11

QUATERNARY GEOLOGY AND GEOMORPHOLOGY, SOUTHERN AND CENTRAL YUKON (NORTHERN CANADA)

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INTRODUCTION

General

Although broad outlines of the Quaternary geology of central and southwestern Yukon are known, detailed mapping and stratigraphic studies have been limited to a few widely scattered localities, of which still fewer are accessible by ground transport. The region, consisting of mountain ranges and mountainous plateaus, and lying within the zone of discontinuous permafrost, exhibits a wide variety of geomorphic features peculiar to alpine and permafrost regions, among which rock glaciers, cryoplanation terraces and pingos are notable. Detailed studies have been made, however, only of rock glaciers of the Kluane Lake area, and of mass-wasting processes and forms in isolated valleys of the Ogilvie Mountains. The excursion therefore emphasizes the glacial succession and broad landscape features, with opportunity for incidental examination of periglacial and permafrost features.

Quaternary successions in the glaciated regions

For convenience of description of the Quaternary geology, central and southwestern Yukon is divisible into four parts: 1) the glaciated Yukon Plateau, lying between the Selwyn Mountains on the northeast, and the Coast Mountains on the southwest (Bostock, 1948, 1970); 2) the northwest flank of the St. Elias Mountains, and the Shakwak Trench adjacent to the northeast; 3) the Ogilvie Mountains; 4) the northwestern Yukon Plateau, unglaciated except for a few centres of minor mountain glaciation.

The glaciated Yukon Plateau is divided by deep, broad, anastomosing, glaciated valleys into mountainous tablelands. The area was invaded repeatedly by northwestward and westward moving ice of the Cordilleran ice sheet. Near the limits of the ice sheet, the tops of many tableland areas stood above the ice sheet, especially during the last and least extensive glaciation.

Bostock (1966) recognized four advances of the Cordilleran ice sheet: Nansen (oldest), Klaza, Reid and McConnell (youngest); few glacial features remain from the Nansen and Klaza advances that can be recognized on airphotos. Much ground study will be required outside the areas mapped by Bostock to define the limits of these advances. Ice-marginal features marking the limits of the Reid advance are moderately well preserved, and those of the McConnell advance very well preserved, permitting airphoto interpretation of their limits across much of central Yukon (Bostock, 1966, Fig. 1; Hughes *et al.*, 1969, Map 6-1968).

The Icefield Ranges of the St. Elias Mountains, the source of Canada's largest existing glaciers, were earlier the source of larger coalescent piedmont glaciers that filled the bordering Shakwak Trench and extended lobes into the mountainous plateau area to the northeast of the trench. In the northwestern part of the Shakwak Trench, Rampton (1969) recognized two drift sheets beyond the limit of Neoglacial advance of the Klutlan Glacier. Moraines that mark the limit of the younger Macauley drift are comparable in degree of preservation to moraines of McConnell age; those of the older more extensive Mirror Creek glaciation are comparable to Reid moraines. Evidence for older, more extensive glaciations comparable to the Klaza and Nansen are lacking. Further south in the Shakwak Trench, around Kluane Lake, landforms associated with Kluane drift (Denton and Stuiver, 1967) are comparable to those of McConnell and Macauley age.

Glaciation was less intensive in the Ogilvie Mountains, where independent glaciers occupied the major valleys. Moraines of the "last" glaciation (Vernon and Hughes, 1966), exemplified by the North Fork Pass moraine (Day 8, Stop 21) are comparable in degree of preservation to McConnell and Macauley moraines, and moraines of an "intermediate" glaciation are in general comparable to those of Reid and Mirror Creek age. Remnants of very subdued moraine, and scattered erratics that lie beyond the limit of "intermediate" glaciation in the Blackstone and other northward-draining valleys, and thick glacial fill in the Tintina Trench southeast of Dawson are the products of one or more still earlier glaciations, possibly correlative with Klaza and/or Nansen glaciations.

Chronology

Stratigraphic data and radiocarbon dates from widely scattered localities can be used to test the broad, geomorphically based correlations outlined above. Radiocarbon dates are in general agreement in fixing retreat following the last glaciation in the respective areas. The oldest dates on top of Macauley and Kluane drifts in Shakwak Trench are 13,600 ± 180 (Rampton, in press) and 12,500 ± 200 (Denton and Stuiver, 1967), respectively. The oldest date on a moraine of the last glaciation in the Ogilvie Mountains is 13,740 ± 190 (GSC-515, Lowdon and Blake, 1968). The oldest date from above McConnell drift is 9,660 ± 150 (GSC-749, Lowdon *et al.*, 1970); older dates can be expected with further sampling. Macauley, Kluane, McConnell and the "last" glaciation of the Ogilvie Mountains are therefore of main Wisconsin age; they are also correlative with Donnelly Glaciation of the Alaska Range (Péwé, *et al.*, 1965) and its Alaskan correlatives.

Only the Silver Creek section near Kluane Lake (Denton and Stuiver, 1967; *see* Day 4, Stop 5) has yielded finite dates from beneath till of the last major advance. There, dates from the Boutillier non-glacial interval range from 37,700 to 30,000 B.P. Organic samples from beneath Macauley drift in the Snag-Klutlan area are all beyond radiocarbon dating range, except for a single sample that may have been contaminated by modern rootlets (Rampton, in press). Two samples from beneath McConnell till near McConnell moraine are likewise beyond dating range. Two explanations of the anomaly are possible: 1) major deglaciation took place in the Snag-Klutlan area and the central Yukon Plateau during the Boutillier non-glacial interval, but evidence is lacking at studied sections by reason of non-deposition, or by reason of erosion during subsequent glaciation; 2) deglaciation was minimal in those areas, so that studied localities remained covered. The latter explanation is preferable in that it is unlikely that all the studied localities (four in the Snag-Klutlan area, one in central Yukon) would exhibit non-depositional and/or erosional gaps. Further, the Kluane Lake area and adjacent source areas for ice in the southern Icefield Ranges could have been more responsive to climatic change than the Snag-Klutlan area or central Yukon Plateau, by reason of closer proximity to the Pacific Ocean. McConnell and Macauley drifts would be, by the latter hypothesis, stratigraphically equivalent to Icefield till, Icefield outwash and Kluane drift of the Silver Creek section.

Wood from volcanic ash near the base of organic silt overlying Reid drift is greater than 42,900 years old (GSC-524, Lowdon and Blake, 1968); three samples from above Mirror Creek drift in the Shakwak Valley are likewise beyond radiocarbon dating range (Rampton, 1969, p. 39). A single bog bottom sample from moraine near Chapman Lake, Ogilvie Mountains, referred to the "intermediate" glaciation, is only 13,870 ± 180 years old (GSC-296, Dyck *et al.*, 1966). Clear-

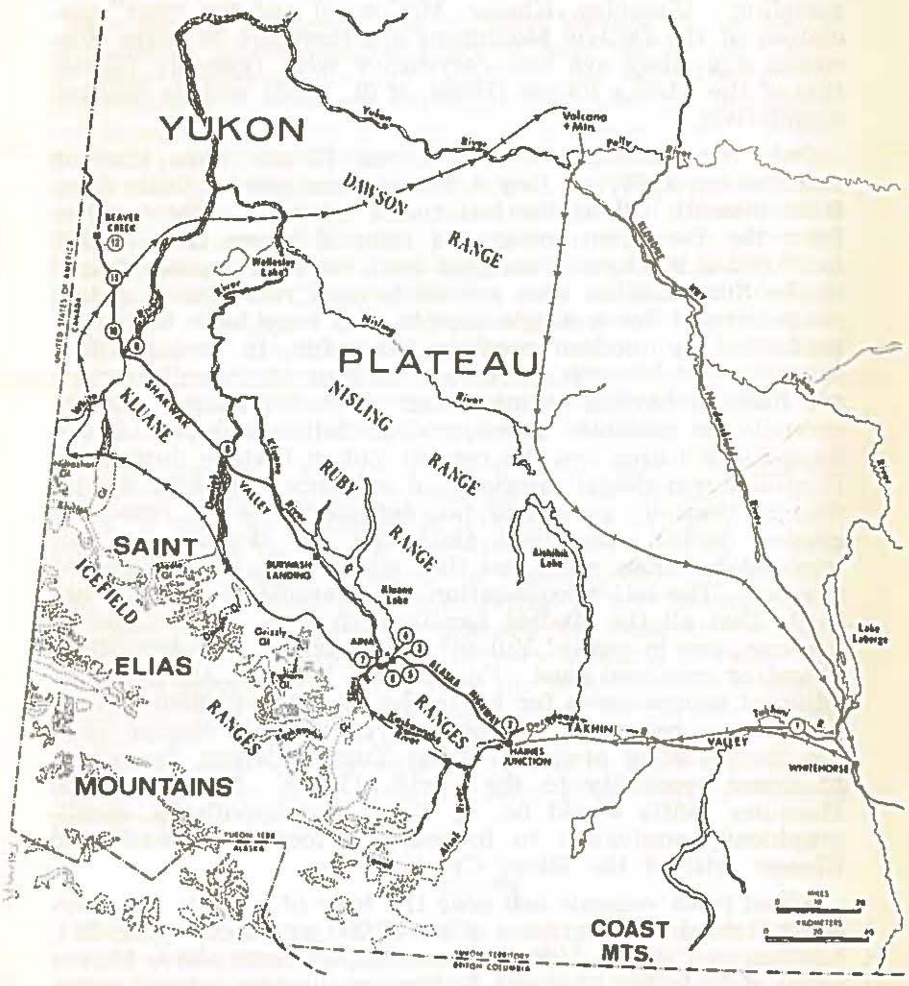


Fig. 1. Index map; reconnaissance flight route, Day 2, and route and stops, Days 3 to 6.

ly, further investigation of the chronologic position of the intermediate glaciation is required, especially in the Blackstone Valley, where Ricker (1968) has shown that two advances are involved. However, we retain here the tentative correlation of the "intermediate" glaciation with Reid and Mirror Creek glaciations. The latter are correlated with Shakwak glaciation of Kluane Lake area, and Delta glaciation and correlatives in Alaska. Whether these advances are of early Wisconsin age, or of Illinoian age, (Péwé *et al.*, 1965, Table 2), is uncertain.

Beyond the immediate areas from which Klaza and Nansen advances were defined (Bostock, 1966) information is too limited for even tentative correlation.

THE FIELD TRIP

Introduction

The field trip consists of a 550 mile (885 km) reconnaissance flight over southern Yukon Territory, and a bus trip of 1,500 miles (2,415 km).

Mileages along the several individually named or numbered highways that will be travelled are marked at irregular intervals by mileposts. Mileages quoted are interpolated from those established mileposts.

Day 2: Reconnaissance Flight, Southern Yukon

Guides: V. Rampton, O. L. Hughes

Upon leaving Whitehorse, the flight will follow along the Takhini Valley, which cuts east-west across the southern part of the Yukon Plateau (Fig. 1). Many typical alpine glacial landforms, e.g. lateral moraines and meltwater channels, kame terraces, and glacial lake beaches, which were formed during the McConnell glaciation and subsequent deglaciation, can be seen along the edges of the Takhini Valley and in its tributary valleys.

At Haines Junction, the flight turns south into the St. Elias Mountains. The Kluane Ranges, which form the northern front of the St. Elias Mountains, contain an abundance of Neoglacial glaciers, debris-covered glaciers, and rock glaciers. Large outlet glaciers occupy the major valleys along the flanks of the Icefield Ranges, which form the core of the St. Elias Mountains and are covered by ice-fields.

The Neoglacial history of most of the large valley glaciers and some of the smaller alpine glaciers has recently been worked out by Denton and Stuiver (1966), Borns and Goldthwait (1966), and Rampton (1970). The earliest recorded Neoglacial advances of the large valley glaciers do not correlate; however this may in part be due to the scantiness of relevant information. Loess stratigraphy indicates that the Kaskawulsh was advancing ca. 2600 B. P. from a retracted hypsithermal position (Denton and Stuiver, 1966; Borns and Goldthwait, 1966): no direct evidence for an early Neoglacial advance by the Donjek Glacier has been found (Denton and Stuiver, 1966): the Klutlan Glacier advanced to near its Neoglacial maximum around 1520 B.P. and constructed a major moraine at its Neoglacial maximum between 850 and 1100 B.P. (Rampton, 1970): the Natazhat Glacier had an early Neoglacial advance ca. 3300 B.P. (Rampton, 1970).

The last 550 years has found most major glaciers near their maximum Neoglacial positions actively constructing moraines. The Kaskawulsh Glacier was approaching its Neoglacial maximum ca. 500 B.P. and reached it between 300 and 420 B.P. (Denton and Stuiver, 1966; Borns and Goldthwait, 1966): the Donjek Glacier was at its Neoglacial maximum between 300 and 420 B.P. (Denton and Stuiver, 1966): the Klutlan Glacier achieved its late Neoglacial maximum between 450 and 300 B.P.: the Natazhat Glacier reached its Neoglacial maximum at 500 B.P. (Rampton, 1970).

Four separate drifts, identified mainly on the basis of their vegetation cover, document the fluctuating retreat of the Kaskawulsh Glacier from its Neoglacial maximum (Denton and Stuiver, 1966; Borns and Goldthwait, 1966). A major break in the geomorphic and vegetation characteristics of the Neoglacial drift surrounding the Donjek Glacier indicate that a major readvance took place during retreat from its Neoglacial maximum. At the Klutlan Glacier, "massive ice-cored moraines extend 11 miles (17.7 km) down valley from the terminus" (Rampton, 1970, p. 1242). Six Neoglacial moraines have been identified on the basis of the geomorphic, limnologic, vegetational, dendrochronologic, and lichenometric characteristics of the moraines (Rampton, 1970). The oldest moraine (Harris Creek) is believed to have been constructed between 850 and 1100 B.P., whereas the younger moraines (Klutlan I-V) are believed to have been constructed between 450 B.P. and the present. The Klutlan Glacier is a surging glacier and immediately up-valley from its Neoglacial morraines, folded medial moraines, which are characteristic of surging glaciers (Meier and Post, 1969), are present. The Neoglacial moraines of the Natazhat Glacier can be separated into at least four distinct parts (Natazhat I-IV) on the basis of relative slope stability, vegetation cover and lichen diameters. Denton (1970, pers. com.) has done more lichen measurements and has concluded that at least one more distinct moraine is present. Today, the Natazhat is stagnant in its lower reaches.

Surging glaciers are common phenomena of the mountains of southern Alaska and southwestern Yukon (Meier and Post, 1969). One of the more famous surging glaciers, which has been studied recently (Stanley, 1969), is the Steele Glacier (Fig. 1). For at least 30 years previous to 1965 the lower part of the Steele Glacier was stagnant and covered by debris: "In detail the topography was highly irregular with short water courses, large closed depressions, and irregular knobs and ridges that were debris covered" (Stanley, 1969, p. 822). Features characteristic of surging glaciers such as medial moraines with distinct loops and irregular bulges were present along the middle part of the glacier. Between the summers of 1965 and 1968 the front of the glacier advanced 15 km; 12 km of this advance occurring during the first year of the surge. The surge resulted in thickening (an average of 100 m) of the lower part of the glacier, and in thinning (50-100 m) of the middle part of the glacier. The dead-ice topography of the lower part of the glacier was replaced by a heavily crevassed surface.

Neoglacial moraines of a normal alpine glacier and a surging glacier in the area have been investigated and compared by Rutter (1969). Stone fabrics in till of the normal (Grizzly) glacier's moraine showed strong preferred orientation and indicated deposition as lodgement till, whereas fabrics in till of the surging (Bighorn) glacier's moraine showed random orientation and indicated deposition as ablation till.

West of the Donjek River, the limits of the Mirror Creek (= Reid Lakes) and Macauley (= McConnell) glaciations can be traced with confidence (Rampton, 1969; in press). "The limit of the Mirror Creek glaciation is defined by large terminal and lateral moraines throughout much of the area north of the Shakwak Valley . . . . In this area erratics have not been found above Mirror Creek terminal moraines, and the upper limits of meltwater channels and Mirror Creek terminal moraines are at corresponding levels where they are closely associated" (Rampton, in press). The limit of the later Macauley glaciation always lies within that of the Mirror Creek at lower elevations. "The limit of the Macauley glaciation throughout much of the area is clearly defined by terminal moraines having a distinctive morphology . . . . Where terminal moraines are absent, meltwater channels and lateral moraines are often present at elevations where the Macauley glacial limit might be expected" (Rampton, in press). The unglaciated Yukon Plateau is characterized by the absence of glacial features, the common presence of tors, and V-shaped valleys.

The route follows northward from Natazhat glacier (Fig. 1), then northeast and east northeast across the north edge of Wellesley Basin and into unglaciated Dawson Range (Hughes et al., 1969, Map 6-1968). The route re-enters glaciated terrain in Yukon River Valley, and continues to Volcano Mountain, where lava flows extend onto a glaciated surface of pre-Reid age. From Volcano Mountain, the route continues southward across the southeast end of Dawson Range, characterized by unglaciated uplands with tors and cryoplanation terraces, and valleys glaciated in pre-Reid time, then along the east side of Aishihik Lake, where the McConnell limit is marked by a prominent moraine system. The remainder of the route to Whitehorse crosses glaciated Yukon Plateau in which features of post-McConnell ice retreat are prominent.

Day 3: Whitehorse to AINA (Arctic Institute of North America) Base

Guide: V. N. Rampton

The route between Whitehorse and Haines Junction for most of its length crosses a thick sequence of late Pleistocene glaciolacustrine deposits that fill the Takhini Valley. Near Whitehorse thin glaciofluvial gravels and sands cap the lacustrine deposits, and where the highway hugs the valley wall bedrock and morainic materials are present at the surface. Of special interest in the central part of the valley are the dunes, shallow thermokarst pits, and alkali flats that overlie the glaciolacustrine deposits (Day, 1962). Lateral moraines and lateral meltwater channels, kame terraces and beaches are common along the valley walls.

Between Haines Junction and Kluane Lake, the road crosses a complex of alluvial-fan gravels and till. West of Haines Junction debris-covered glaciers are present in some small hanging valleys to the south of the highway; in some cases their ice-cores are exposed.

Stop 1: Glacial Lake Champagne deposits; Mile 936.6 (km 1498.6), Alaska Highway

During deglaciation after McConnell glaciation, a large proglacial lake occupied the Takhini Valley and adjacent low-lying areas. Beaches and wave-cut escarpments around Glacial Lake Champagne range between 2,300 feet (700 m) and 2,800 feet (855 m) in elevation (Kindle, 1953). The numerous levels probably reflect gradual down-cutting at the outlet, presumably along the meltwater channel occupied by the present Nordenskiold River, and finally at some point along the Yukon River.

The glaciolacustrine silts and clays in the central parts of the valley are known to be more than 200 feet (60 m) thick (Kindle, 1953; Wheeler, 1961). At this stop, 12 feet (3.7 m) of typical varved silty clay is present: the couplets are generally 4-6 inches (10-15 cm) thick, but range from 2 to 8 inches (5 to 20 cm), the finer part of each couplet generally having a consistent thickness of 1 inch (2.5 cm). The bedding characteristics of the glaciolacustrine deposits at this stop differ considerably from the bedding characteristics of the unit near Whitehorse and towards Haines Junction. In these two areas greater and more variable bed thicknesses, and the presence of crosslaminated sands reflect the closeness of retreating glacier fronts.

Stop 2: Recent Lake Alsek deposits, Mile 1016.5 (km 1626.4), Alaska Highway

During Neoglaciation an advance of the Lowell Glacier dammed the Alsek River, which flows to the Pacific Ocean, and produced a Neoglacial lake. This lake, which extended up the Alsek River with one major arm east along the Takhini Valley, was called Recent Lake Alsek by Kindle (1953). Its numerous beaches are present on many slopes up to a level of 2,240 feet (685 m) above sea level, the present level of the Dezadeash River at Haines Junction being approximately 1,925 feet (585 m). Kindle reported trees up to 165 years old on the upper beaches in 1950. Kindle proposed that the upper beaches were formed during an early stage of Recent Lake Alsek shortly before 1725 and that the lower beaches were formed around 1850. However, his brief observations have not been followed by detailed investigations to allow an exact chronology to be constructed.

Over most of the area covered by Recent Lake Alsek a Brown Wooded soil has been buried by thin silty glaciolacustrine material (Table 1). The Brown Wooded soil is developed on late-McConnell (= Kluane) glaciolacustrine sediments, probably deposited during a late phase of Glacial Lake Champagne. A number of possibilities have to be considered in explaining the slightly coarser and more oxidized unit at the base of the sediments overlying the paleosol, i.e. unit 3 of Table 1: a) the initial sediments deposited by Recent Lake Alsek were coarser than those deposited at a later time; the difference in coloration simply being a function of the grain sizes; b) unit 3 is wind-blown deposit of early Neoglacial age; c) two stages of Recent Lake Alsek occurred; sediments deposited during the first stage were coarser than those deposited during a later stage.

TABLE 1

SOIL PROFILES IN PITS AT STOP 2 (RECENT LAKE ALSEK)

Unit	*Description*	*Thickness* *(inches)*	*(cm)*
1	Black forest duff and decomposed brown peat	0 - 1	0 - 2.5
2	Light greyish brown clayey silt; a few light brown mottles	6 - 8	15 - 20
3	Light brownish grey fine sandy silt	0 - 4	0 - 10
4	Brown silt; a few grey mottles near base; thin peaty layer (0.5 - 1.0 inches) in upper part	0 - 6	0 - 15
5	Silt; mottled light greyish brown and grey; some fine sand; base of unit calcareous	12 - 24	30 - 60
6	Grey clayey silt; varves 3 - 4 inches; very calcareous; base of unit covered (depth to till shallow as indicated by clasts in trench dump).	18+	45+

Stop 3: Slims soil and loess sequence, Mile 1053.1 (km 1685), Alaska Highway

Near the southern end of Kluane Lake, most of the Kluane outwash and till is covered by a loess sequence containing a well developed Brown Forest soil: During the retreatal phase of the Kluane (McConnell) glaciation loess was deposited adjacent active outwash bodies: the loess has been named the Kluane loess by Denton and Stuiver (1966, 1967). Further retreat of the glaciers allowed deactivation of the outwash bodies, cessation of loess deposition, and development of Slims soil on the Kluane loess (Denton and Stuiver, 1966, 1967). Readvance of glaciers along the northern edge of the St. Elias

TABLE 2

LOESS AND SOIL SEQUENCE EAST OF KLUANE LAKE

Stratigraphic Unit as correlated with Denton and Stuiver, (1966, 1967)	*Description*	*Thickness* *(inches)*	*(cm)*
Neoglacial loess	Light greyish brown silt; thin peaty laminae; slightly calcareous	0 - 2	0 - 5
Slims soil (complex)	Brown silt; thin volcanic ash near its top	8	20
Slims soil (complex)	Silt; 2 - 3 inches (5 - 7.5 cm) light brown and reddish brown layers; a few pebbly lenses	8	20
Kluane loess	Light grey silt; very calcareous; burrow casts	12 - 30	30 - 75
Kluane outwash	Gravel; crudely bedded; clasts in upper part have lime coatings on bottom; base of unit covered by slump	24+	60+

Range during Neoglaciation caused reactivation of valley trains and deposition of loess in areas where loess deposition had been interrupted. South of Kluane Lake, loess deposition was governed mainly by the position of the Kaskawulsh Glacier: deposition of Neoglacial loess began around 2600 B.P. near its present terminus, and at some time between the time of the White River ash fall (1320 B.P.; Rampton, this volume) and 870 B.P. near Kluane Lake (Denton and Stuiver, 1966). At Stop 3, root throw and slope processes during the Slims non-glacial interval and early part of Neoglaciation have evidently complicated the loess and soil sequence (Table 2). Oxidized silt and fine gravel were deposited on the *in situ* Slims soil at Stop 3 well beyond the time when Neoglacial loess deposition had begun at the south end of Kluane Lake, as indicated by the presence of White River ash in the oxidized colluvium and soil.

Stop 4: Neoglacial shorelines and history of Kluane Lake, 0.5 mile (0.8 km) north on side road from Mile 1053.9 (km 1687.2), Alaska Highway

Drowned forests and narrow beaches 12 feet (3.7 m) and 43 feet (13 m) above the mean level of present Kluane Lake indicate that major changes in the level of Kluane Lake have occurred in the past. C^{14} dates of 340 ± 130 B.P. (GSC-867) on one of the drowned stumps (Bostock, 1969) and 120 ± 130 B.P. (GSC-1569) on driftwood associated with the highest beach indicate the relative recentness of the fluctuations.

Bostock (1969) believed that Kluane Lake drained as at present via the Kluane River during deglaciation following the Kluane glaciation and perhaps during the early part of the Slims nonglacial interval. However retreat of the Kaskawulsh Glacier during the hypsithermal at least 13.7 miles (22 km) above its present terminus (Denton and Stuiver, 1966) then allowed the Kaskawulsh River, which drains directly to the Pacific Ocean, to capture Kluane Lake and lower it below its present level. Readvance of the Kaskawulsh Glacier to its maximum Neoglacial position at some time between 300 and 420 calendar years B.P. (Denton and Stuiver, 1966; statistical errors of C^{14} dates not considered) then blocked the drainage and the level of Kluane Lake was raised until the old outlet, Kluane River, was reoccupied and down-cutting was initiated. Thus, the high levels of Kluane Lake are representative of a Neoglacial lake.

The age of the rise in lake level and the high beaches are given by C^{14} dates GSC-867 and GSC-1569, and the presence of 250 year old trees below the upper beach (Ragle *et al.*, 1971; N. Potter, Jr., pers. com., 1970). Conversion of the C^{14} dates to calendar years (Table 3) indicates that drowning occurred between 515 and 290 years B.P. and the upper beach was occupied between 320 years B.P. and the present. However the 250 year old trees growing below the upper beach give a minimum age for the beach formation. Therefore the drowning of the forest and formation of the beaches probably coincided with damming of drainage to the Pacific by the Kaskawulsh Glacier.

TABLE 3

C^{14} DATES RELATING TO RECENT FLUCTUATIONS OF KLUANE LAKE

Date No.	*C^{14} Age*	*Possible age range in calendar years B.P. considering statistical errors, corrections for half life, and fluctuations in atmospheric C^{14} content.*
GSC- 867	340 ± 130	290 to 515
GSC-1569	120 ± 130	modern to 320

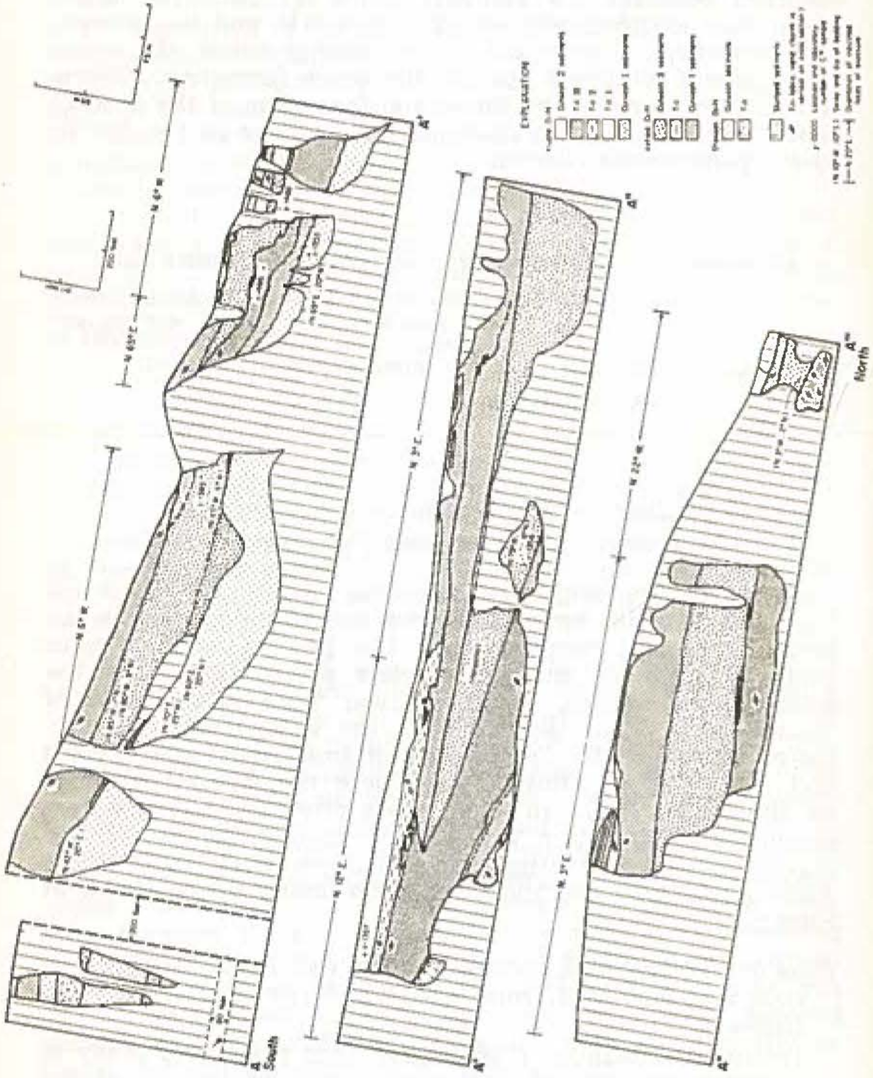
Day 4: AINA to Burwash Landing

Guides: V. N. Rampton, Peter Johnson

The oversteepening of the Slims River and Shakwak River valley walls during glaciation has promoted mass wastage. Landforms resulting from this process, notably, talus cones, debris flows, and rock glaciers, are common along the walls of the valleys, especially near the southern end of Kluane Lake. The deepening of the valleys has also promoted erosion in the headwaters of small tributary streams and deposition of alluvial-fans where the streams debouch on the valley floor: in some cases streams flowing across shoulders in the main valleys have incised themselves and exposed complex stratigraphic sequences along their banks (one of the best and most accessible being Silver Creek at Stop 5).

Stop 5: Silver Creek section, 3 miles (4.8 km) south by side road and foot trail from Mile 1053.9 (km 1687.2), Alaska Highway

Denton and Stuiver (1967) have done a detailed study of the Pleistocene glacial stratigraphy and chronology at the southern end of Kluane Lake. The Late Pleistocene chronology, as follows, has been established on the basis of weather-



ing zones, characteristics of stratigraphic contacts, drift morphology and C^{14} dates (Table 4):

Slims nonglacial interval
Kluane glaciation — end ca. 12,500 - 9,780 B.P.
— start 30,100 B.P.
Boutellier nonglacial interval
Icefield glaciation — end ca. 37,000 B.P.
— start > 49,000 B.P.
Silver nonglacial interval
Shakwak glaciation — > 49,000 B.P.

The stratigraphically lowest till and outwash examined in the area have been attributed to the Shakwak glaciation and is exposed along Silver Creek (Fig. 2). The Shakwak till is oxidized to a minimum depth of 15 feet (4.6 m), and the outwash has an orange colour because of iron oxide coatings on clasts and fine particles of iron oxide in the matrix. These alterations and an erosion surface developed during the Silver nonglacial interval.

"Glacial sediments stratigraphically above Shakwak Drift and below Kluane Drift are . . . termed Icefield Drift" (Denton and Stuiver, 1967, p. 495; Fig. 2). The iron-coated combination of clasts and fine-grained particles of iron oxide in Icefield outwash give the deposit a brown coloration: the upper part of the Icefield Till is locally oxidized a couple of feet (0.6 m) along Silver Creek. The weathering and local dissection of the Icefield Drift occurred during the Boutellier nonglacial interval.

The upper sediments in the Silver Creek sections (Fig. 2) were deposited during the Kluane glaciation. The Kluane Drift consists of three separate till sheets and two outwash bodies (Fig. 2); the units being grouped together because: "(1) a soil and weathering zone separate them from drift sheets, respectively, above and below; (2) the contacts between most of the units are gradational or interfinger; (3) evidence of substantial intervals between the time of deposition of the various units is lacking" (Denton and Stuiver, 1967, p. 498). Kluane loess generally caps the Kluane Drift sequence.

Figure 2. Geologic cross-section, Silver Creek, Y.T., Day 4, Stop 5 (Surficial loess units, volcanic ash and peat not shown; C^{14} dates are given in Table 4; from Denton and Stuiver, 1967 Plate 4).

TABLE 4

C^{14} DATES OBTAINED ON MATERIALS FROM SILVER CREEK SECTION; SEE FIGURE 2 FOR LOCATIONS OF SAMPLES (DESCRIPTIONS AFTER DENTON AND STUIVER, 1967)

Sample No.	*Descriptions*	C^{14} *age years B.P.*
Y-1357	Wood from silt bed in Kluane outwash II. This part of outwash deposited by meltwater from small glaciers in Kluane Ranges	7,340 ± 140
Y-1385	Organic matter, including wood, from silt bed in Icefield outwash II, 4 feet (1.2 m) below its upper surface	30,000 + 600
GSC-769	Same as Y-1385 (Lowdon and Blake, 1970)	29,600 ± 460
Y-1488	Organic matter, including wood, from a silt bed in Icefield outwash II	33,400 ± 800
Y-1356	Organic matter, including wood, from silt bed in Icefield outwash II, 12 feet (3.7 m) above lower surface	$37{,}700 {}^{+1{,}300}_{-1{,}500}$
GSC-734	Same as Y-1356 (Lowdon and Blake, 1970)	>35,000
Y-1486	Sinuous stringers of peat in Icefield till	>49,000
Y-1355	Organic matter, including wood, in silt bed 10 feet (3 m) below upper surface of Shakwak outwash	>46,400

Stop 6: Debris flow and viewpoint, Mile 1057.1 (km 1691.4), Alaska Highway

A small debris flow blocked the Alaska Highway in the summer of 1967 following a period of intense rainfall. The flow originated near the headwall of a small ravine at an elevation of about 5,200 feet (1,585 m). It then proceeded down the ravine and along the creek bed on the alluvial-fan at the mouth of the ravine. Three to five foot (1 m to 1.5 m) levees were built along the edges of the creek and some vegetation was uprooted and moved down the creek. The debris flow finally spread out as a fan at the break in slope near the highway, which here is at an elevation of 2,570 feet (785 m). The flow material is composed mainly of diorite boulders up to 8 feet (2.4 m) in diameter with a sandy silt matrix.

Across the Slims River valley numerous talus cones, debris flows and a rock glacier can be viewed. The debris flows have evidently been occurring periodically since the Kluane glaciation as some of the flows predate the White River ash fall, some postdate the ash fall and predate Neoglacial Lake Kluane and two postdate the Neoglacial lake.

Stop 7: Rock glacier, 1 mile (1.6 km) north by foot trail from Mile 1061 (km 1697.6), Alaska Highway

(Peter Johnson)

The Sheep Mountain rock glacier, R. G. II, is one of four rock glaciers studied in this area (Fig. 3). R. G. II consists principally of unindurated pebble-sized detritus derived from cobbles and small boulders supplied by the talus slope at its head. Fines on the surface include deposits of Slims loess.

In 1966 thirty-five movement markers were established on the surface of R. G. II. Repeated measurements show that those markers, which were originally laid out in straight lines, are assuming an arcuate pattern which is convex downslope. The rate of movement ranges from insignificant on some of the lateral ridges to approximately 35 cm per year along the central axis.

In 1969 a 20.7-metre hole was drilled (Fig. 3). Core was taken continuously, but only about 15 per cent of the core was recovered: ice was not present in the recovered core. The material may be highly porous, as most of the drilling fluid (water) was lost. A two-inch I.D. polyethlene pipe was installed in the hole, so that englacial temperature and deformation could be measured. Below 9 metres the temperature appears to be constant at -0.62°C. Englacial measurement of dip and azimuth in 1971 suggest that no significant change in the orientation of the borehole has occurred yet.

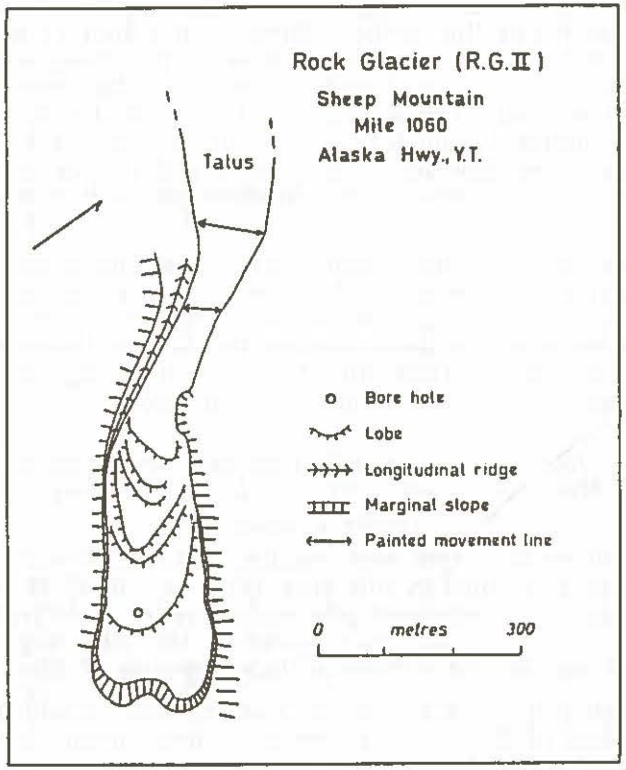


Fig. 3. Sketch map, Sheep Mountain Rock Glacier, Stop 7, Day 4.

Two trenches were dug into sides of lobes, one 2 metres deep, the other 3 metres deep. Permafrost was encountered in the latter but is believed to have been discontinuous. In the copse of trees east of the borehole a pit nearly 2 metres deep passed through a layer of frozen ground which was 20-30 cm thick. Increment borings of the trees indicate ages of at least 250 years.

Day 5: Burwash Landing to Beaver Creek

Guide: V. N. Rampton

During the first part of the day, the route continues along the Shakwak Valley, which is underlain by a complex of Kluane till, often drumlinized, post-Kluane fluvial, alluvial-fan, pond sediments, and sand dunes. The effect of permafrost, namely peat accumulation, drunken forests, and thermokarst lakes become obvious at the northern end of the Shakwak Valley.

Along the southern edge of the Shakwak Valley, Neoglacial debris-covered glaciers and rock glaciers are present in the small tributary hanging valleys. Lateral moraines and meltwater channels, kame terraces, and fluted bedrock can also be seen on the valley wall.

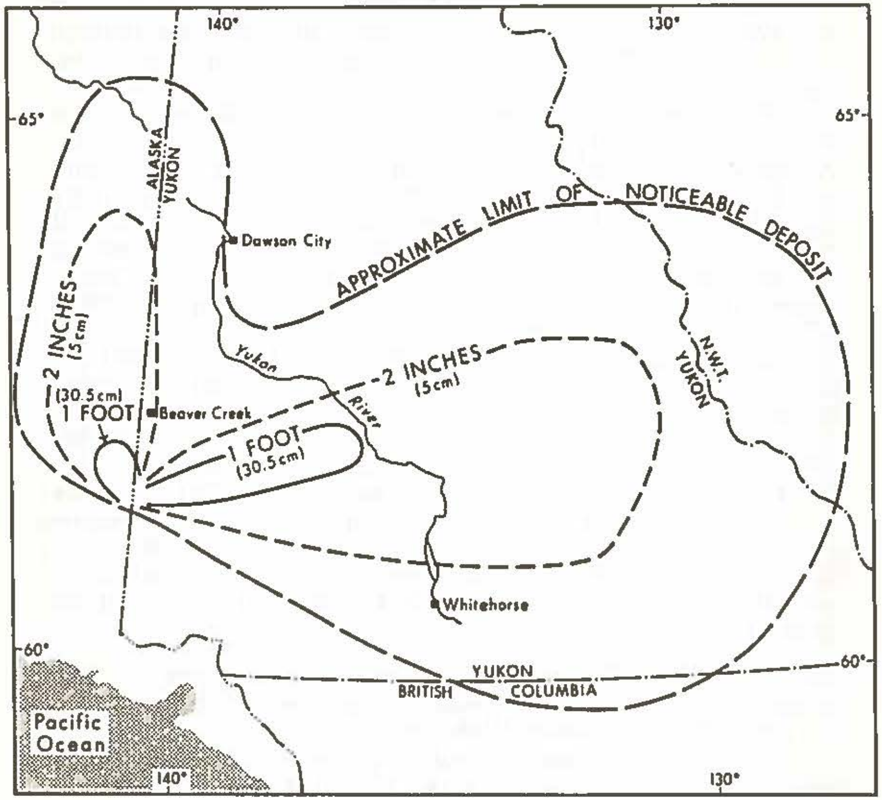


Fig. 4. Isopach map of the White River ashes (Modified from Bostock, 1952; Lerbekmo and Campbell, 1969; Rampton, 1969).

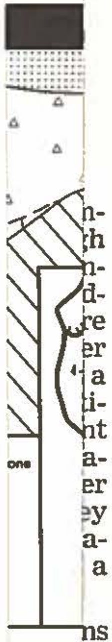
In the area north of White River Bridge, the glaciers fanned out as complex piedmont glaciers during both the Mirror Creek and Macauley glaciations (Rampton, in press). There, the highway crosses mainly outwash of Macauley age, and disintegration moraines of Macauley and Mirror Creek age.

Stop 8: Multiple White River ashes, Mile 1132.8 (km 1812.5), Alaska Highway

A white layer of volcanic ash has been noted by most explorers and geologists throughout southwestern Yukon and eastern Alaska: an isopach map of the ash indicates two distinct fans (Fig. 4). Bostock (1952) considered the distinct fans to be the result of a sudden change in wind direction or of a gradual change in wind direction accompanied by two surges in the volcanic eruption. Although Lerbekmo and Campbell (1969) chemically analyzed numerous samples of the White River ash from both lobes, they did not indicate any obvious differences in the chemistry of the two lobes (the ash was found to be a rhyodacite). However, two layers of near-surface volcanic ash have been found in some exposures near the Alaska/Yukon Boundary south of the Alaska Highway (Moffit and Knopf, 1910, Stitch 1951; Rampton, 1969) and C^{14} dates on the materials associated with the two lobes indicate that each lobe is the result of a separate volcanic explosion. Dates on materials immediately underlying the western lobe [1990 ± 130, GSC-400 (Lowdon and Blake, 1968); 1990 ±80, Y-2303; 1850 ± 80, Y-2304 (Stuiver, 1969); 1750 ± 110, I-175 (Fernald, 1962); 1750 ± 120, GSC-1564 (Table 5)] indicate that it was deposited between 1850 and 1900 years B.P., whereas dates on peat and charcoal underlying the eastern lobe [1240 ± 130, GSC-343; 1200 ±140, GSC-408 (Lowdon and Blake, 1968); 1160 ± 130, GSC-748; 1260 ± 130, GSC-934; 1240 ± 130, GSC-1000 (Rampton, 1969); 1190 ± 130, GSC-956 (Lowdon *et al.*, 1970); and 1280 ± 130, GSC-1568 (Table 5)] indicate that it was deposited ca. 1220 years B.P. C^{14} dates of 1460 ± 70 (Y-1363) and 1390 ± 70 (Y-1364) obtained respectively from peat above and below the ash near the Kaskawulsh Glacier (Stuiver, *et al.*, 1964) seem anomalous.

Stop 9: Macauley and pre-Macauley stratigraphy, White River, 0.5 mile (0.8 km) east on side road from Mile 1171.1 (km 1873.8), Alaska Highway

The complexities and difficulties of interpreting the Quartternary stratigraphy west of the Donjek River are well illustrated in sections downstream from the White River bridge



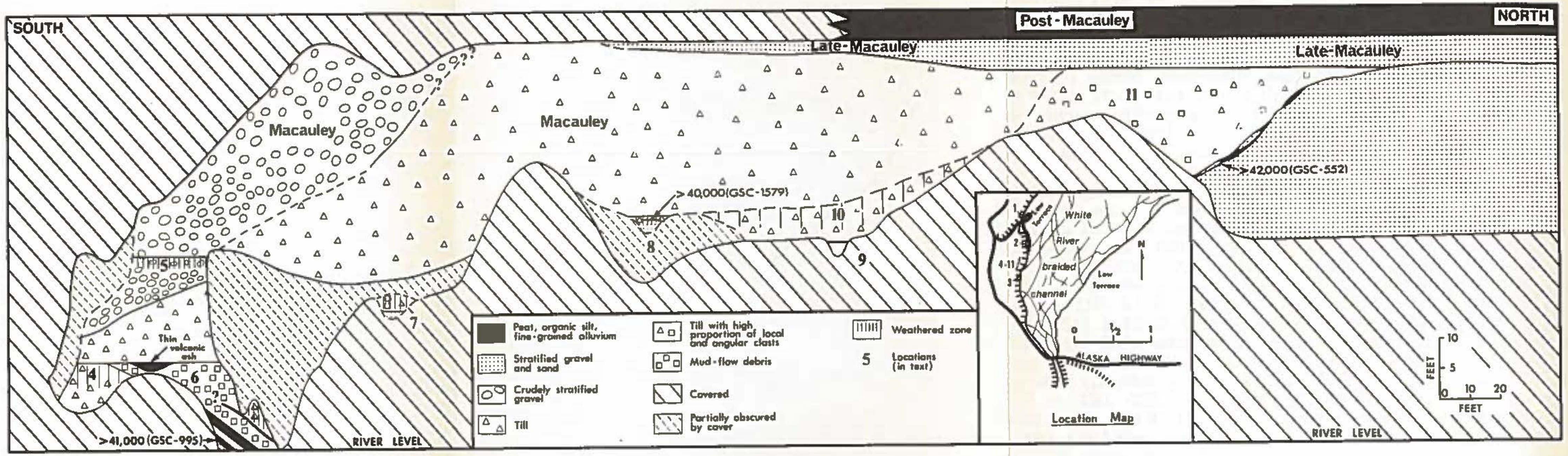
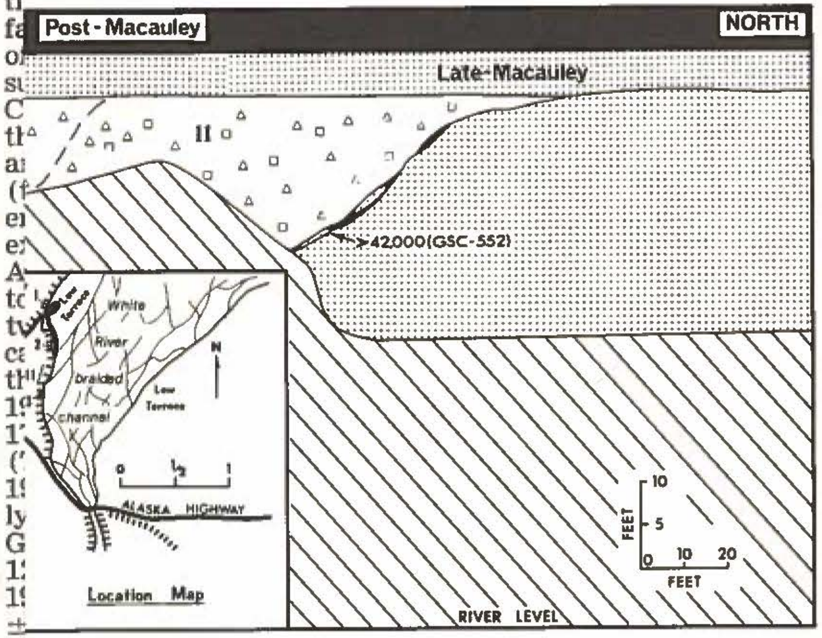


Fig. 5. Geologic cross-section, White River, Y.T., Stop 9, Day 5.



y 5.

Table 5

Stratigraphy exposed in cut at west end of the Donjek River Bridge

Unit	*Description*	*Thickness (inches)*	*(cm)*
1	Covered by slump		
2	White lapilli: contains spruce stumps originating in unit 3: one stump dated at 1280 ± 130 B.P. (GSC-1568)	14	35
3	Light greyish-brown fine sand, silty; peaty layers, woody fragments and small shells	12	30
4	White volcanic ash; some orange mottles	1	2.5
5	Same as 3: organic content decreases with depth; stems 1.5 inch (3.8 cm) diameter, from woody layer at top dated at 1750 ± 130 B.P. (GSC-1564)	30+	75+

(Fig. 5). The discontinuous nature of most exposures hampers correlation of units within hundreds of feet even though unique stratigraphic units and weathering zones can be identified. For example, it is not clear: 1) whether the mudflow debris at location 3 (Table 7) and at location 6 were deposited during the same nonglacial interval; 2) whether the staining at location 5 is a weathering zone developed at a former ground surface or is due to recent groundwater activity; 3) whether the weathering at location 4 is equivalent to that at locations 2 (Table 6) and 10; 4) whether the gravels at locations 7, 8 and 9 are equivalents; and 5) whether the material at location 11 is a special phase of the Macauley till rich in clasts of local origin, a special phase of the weathered till at location 10 rich in clasts of local origin, or a very poorly sorted alluvial-fan deposit.

However, the upper stratigraphic units in most sections can be assigned to a post-Macauley nonglacial interval and to the Macauley glaciation, e.g. 1) the sequence of till, outwash gravel and peat exposed at location 1; 2) the upper till at location 2 (Table 6); and 3) the upper units as labelled on figure 5.

The thick weathering zone on the tills at locations 2 and 10, and the C^{14} dates of >41,000 (GSC-995); >40,000 (GSC-1579) and >42,000 (GSC-552) on materials deposited below the Macauley drift indicate a correlation with Denton and Stuiver's (1967) Silver Weathering Zone and Shakwak Drift

TABLE 6

STRATIGRAPHY AT LOCATION 2 ON FIG. 5

Unit	*Description*	*Thickness*	
		(feet)	*(metres)*
1	Covered by slump; probably organic silt over gravel	15	4.5
2	Till, grey	15	4.5
3	Till, greyish brown (oxidized); some grey mottles	9	2.7
4	Till, grey; upper few feet shows occasional mottles	18	5.5
5	Covered; probably gravel	24	7.3

TABLE 7

STRATIGRAPHY AT LOCATION 3 ON FIG. 5

Unit	*Description*	*Thickness*	
		(feet)	*(cm)*
1	Covered by colluvium composed mainly of grey gravel	4	120
2	Orangish-brown mudflow debris; mainly angular greenstone clasts; spruce logs and layers of peat, occasionally showing slickenslides; one log dated at 48,000 ± 1300 (GSC-732)	15	450
3	Mixed layers of peat, pebbly sand, and till	0 - 0.5	0 - 15
4	Colluvium; composed of bands of oxidized and unoxidized till; occasional layers of local coarse alluvium	1.5 - 3	45 - 90
5	Till, grey; bottom not exposed	0 - 4+	0 - 120
6	Weathered bedrock; bottom not exposed	1+	30+
7	Covered to river level	15	450

rather than their Icefield Drift and Boutellier Weathering Zone. C^{14} dates on materials underlying the Macauley drift in the immediate area and adjacent Alaska (Rampton, 1969, Denton, pers. com.) also suggest that the Boutellier nonglacial interval did not cause extensive deglaciation in the White River area, at least in the period between 30,000 and 40,000 B.P. However if the date of 48,000 ± 130 on a spruce log in the mudflow debris at location 3 (Table 7) is not due to contamination, deglaciation of the area during the early part of the Boutellier nonglacial interval must have occurred. It also raises the possibility that glaciers did not reach this locality during the Icefield glaciation. If spruce was present at this location 48,000 years ago, summer temperatures must have risen to near today's values in the interior Alaska and Yukon during this time interval (considered by most authorities to be an interstadial).

Stop 10: Thermokarst lakes, Mile 1176.3 (km 1882.1), Alaska Highway

Common to areas of fine-grained unconsolidated sediments in permafrost regions are actively expanding thermokarst lakes. These lakes are characterized by shallow depths, and by tilted trees along their edges where banks are undercut by thawing of ice-rich sediments.

Ice lensing is favoured in fine-grained sediments where high pore water pressures and adequate water is available at a slowly advancing frost line (Williams, 1967). The formation of an ice lens will reduce the pore water pressure to a point where ice lens formation is impeded and the frost line will advance through the sediment. Ice lensing can also be impeded by conditions preventing the free flow of water to the frost line. Furthermore, a critical depth exists below which the difference between overburden pressure and pore water pressure is increased to a point where ice lensing is impossible. Thus, the amount of moisture above the saturation point contained in any profile is generally small and thermokarst lakes resulting from the release of this frozen excess moisture are generally shallow.

Stop 11: A. Macauley Moraine, Mile 1189.4 (km 1903), Alaska Highway

Within the limit of the Macauley glaciation, and especially near the limit itself, extensive areas of disintegration moraine are common. These moraines, not only in the very western Yukon, but throughout the interior Yukon, have characteristic morphologies. In the Snag-Klutlan area, quantitative slope investigations of moraines were undertaken because earlier workers (Krinsley, 1965; Müller, 1967) had assigned some moraines within the Macauley glacial limit to widely separated glaciations. The technique used in the field was as follows:

"Grids, each of which involved an area 2,000 feet (610 m) on a side, were laid out on areas typical of the non-oriented hummocky moraine on which each was located. On each grid ten lines were run at 200 foot (61 m) intervals, and

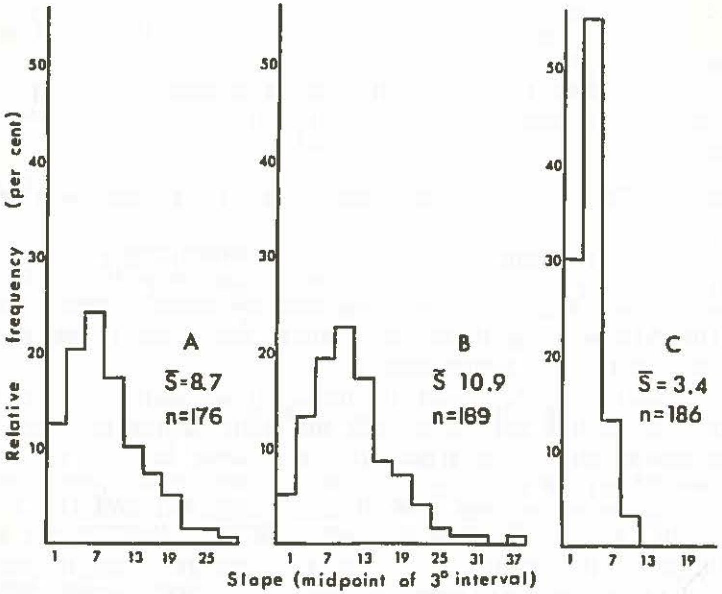


Fig. 6. Histograms of slope measurements on McCauley and Mirror Creek moraines, Stops 11A, 12A, Day 5 (A, B — Macauley moraines; C — Mirror Creek moraine; S mean slope; N — number of measurements).

the steepest slope at 20 points was measured along each line at 100 foot (30.5 m) intervals. All lines were located by pace and compass. Points located in water were considered inaccessible, and no measurements were recorded. The steepest slope at each point was measured by aiming the sights of a Brunton compass at an eye-level mark on a pole positioned 10 feet (3 m) up along the slope" (Rampton, in press). The distribution of slope angles on the area directly north of Stop 11, as measured by the above techniques, are shown in figure 6A and 6B.

Stop 11: B. Ground disturbance and thermokarst

The southwestern Yukon lies in the zone of discontinuous permafrost (Brown, 1967): in this permafrost zone vegetation generally favours the maintenance of permafrost. "It shields the permafrost from the thawing effects of summer air temperatures. This protection is provided mainly by the insulating properties of the widespread moss cover. Removal or even disturbance of this surface cover results in degradation of the underlying permafrost" (Brown, 1967, explanatory notes). This point is well illustrated at Stop 11 where stripping of the vegetative cover during the early history of the Alaska Highway in the mid-40s (aspens and large willows have grown to a moderate height on these areas) has promoted degradation of the upper surface of the active layer. Troughs, up to 3 feet (1 m) deep and 7 feet (2.1 m) across, have resulted where ice wedges, located below the base of the former active layer, have melted.

The ice wedges and the troughs that result after disturbance of the surface can not always be anticipated from simple examination of the undisturbed ground surface. At Stop 11, the ice wedges can not be traced in areas where the ground cover has not been removed.

Stop 12: A. Mirror Creek moraine, Mile 1198.1 (km 1917), Alaska Highway

Mirror Creek hummocky moraines have less relief and gentler slopes than equivalent Macauley moraines (Fig. 6C): the Mirror Creek glaciation is early Wisconsin or Illinoian in age, whereas the Macauley is the equivalent of the "classical" Wisconsin. The Mirror Creek moraines probably had a similar morphology to the younger Macauley disintegration moraines as the spacing and size of the depressions on the Mirror Creek moraines are similar to the spacing and size of the depressions on the younger Macauley disintegration moraines (Rampton, in press). Most of the change has resulted from in-filling of the depressions with silt and peat. "Some of the silt may have been directly blown into the depressions, but much has probably been transported into the depressions from the surrounding slopes by water . . ." (Rampton, in press). For example, "At present in the Snag area, silt (loess) is being removed from some steep slopes and is being redeposited in depressions by water flowing under and over moss covering the slopes" (Rampton, 1971, p. 968).

Stop 12: B. "Antifreeze Pond" pollen diagram

A vegetation and climatic history for the last 31,000 years B.P. has been reconstructed by interpretation of fossil pollen assemblages from "Antifreeze Pond" sediments (Rampton, 1971; Table 8). "Antifreeze Pond" lies just beyond the limit of the Macauley glaciation. The paleovegetation was established by comparing the pollen assemblages from "Anti-

TABLE 8

POLLEN ZONES, CHRONOLOGY, AND INTERPRETED VEGETATION AND JULY TEMPERATURES, OF "ANTIFREEZE POND" DIAGRAM

Pollen Zone	*Interval in C14*	*Zone Characteristics*	*Vegetation*	*Estimated mean July temperature (F), given as most probable and possible range*
6	0 - 5,700	*Picea, Alnus,* and *Betula* dominate: rising *Potamogeton* and *Sphagnum*	Spruce forest	56 (50 - 60)
5	5,700 - 8,700	*Picea* and *Betula* dominate: falling Cyperaceae	Spruce woodland	56 (50 - 60)
4	8,700 - 10,000	*Betula* and Cyperaceae dominate: peaks in *Sphagnum* and *Equisetum* curves	Shrub tundra	47 (45 - 50)
3b	10,000 - 13,500	Cyperaceae and Gramineae dominate: presence of *Potamogeton, Myriophyllum* and *Hippuris*	Sedge-moss tundra	44 (42 - 45)
3a	13,500 - 27,000	Cyperaceae and Gramineae dominate: significant *Betula*	Sedge-moss tundra	43 (40 - 45)
2	27,000 - 31,000	*Betula,* Cyperaceae, and Gramineae dominate	Shrub tundra	47 (45 - 50)
1	possibly pre-31,000	Cyperaceae and Gramineae dominate: significant *Picea,* indeterminable conifer, *Alnus, Artemesia,* Ranunculaceae, and *Sphagnum*	Fell-field or Sedge-moss tundra	40 (? - 45)

freeze Pond" with surface samples from the different vegetation zones of Canada and Alaska. The paleoclimate was then established by determining some of the climatic parameters delimiting the present-day vegetation types. The pollen diagram indicates tundra, cooler temperatures, and probably less precipitation in the surrounding area from 31,000 B.P. to 8,700 B.P. The small depression in snowline relative to the drop in temperatures during the Macauley glacial maximum (Rampton, 1971) supports the hypothesis that Wisconsin time in the interior Yukon and Alaska was not only cold, but also dry in comparison to today (Guthrie, 1968a, 1968b; Matthews, 1968, 1970).

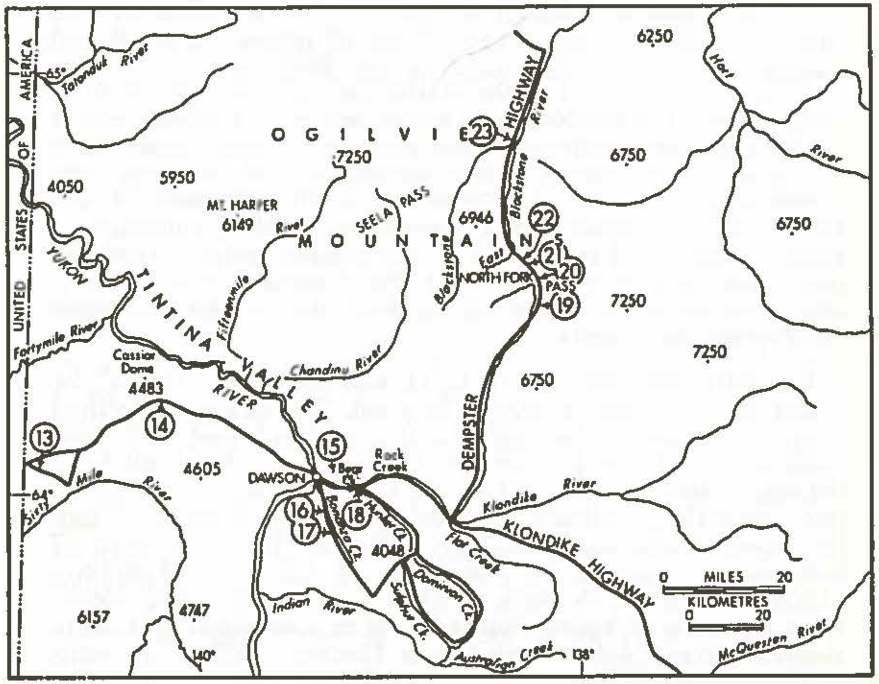


Fig. 7. Index map; route and stops, Days 6, 7, 8.

Day 6: Beaver Creek to Dawson

Guides: Helen Foster, O. L. Hughes

From Beaver Creek the route follows the Alaska Highway northward, crossing the outer limit of glaciation (here the Mirror Creek glaciation), then crossing a low divide into the headwaters of the Tanana River. To Tetlin Junction, the highway follows the northeast margin of the Northway-Tanacross Lowlands (Wahrhaftig, 1965, Plate 1), that separates the extensively glaciated Alaska Range from the unglaciated southeastern part of the Yukon-Tanana Upland. From Tetlin Junction, the route (Taylor Highway) follows ridges and valleys across the rolling dissected Yukon-Tanana Upland [*see* Foster and Keith (1969), for detailed road log], then climbs near the Yukon border to follow a system of connecting high ridges across the deeply dissected Klondike Plateau to Dawson.

Cryoplanation (altiplanation) terraces and tors occur widely in the Klondike Plateau between the Alaskan Border and the Yukon River. The deeply dissected plateau is developed mainly on metamorphic rocks of uncertain age: quartzite and quartz-mica schist of the Nasina series, quartz-muscovite-chlorite schist of the Klondike series, and quartz-biotite gneiss (Pelly gneisses), with extensive areas of andesite basalt and minor shale, sandstone and conglomerate of Tertiary age (Cockfield, W. E., 1921; Green, L. H. and Roddick, J. A., 1962). The cryoplanation terraces are developed mainly on Pelly gneisses and quartzites of the Nasina series. Tors are best developed on quartzites of the Nasina series, but examples occur on all main rock types within the plateau except the Tertiary sediments.

In California Creek (116 C/1) and Sixtymile (116 C/2) map-areas, crossed by Sixtymile road, 55 terraces identified from airphotos lie between 3,200 and 4,711 feet (975 and 1,435 m the highest elevation in the map areas) with 47 between 3,600 and 4,600 feet (1,097 and 1,402 m). Sixty-two similarly identified tors and clusters and rows of tors lie between 2,800 and 4,200 feet (853 and 1,280 m), with 57 between 3,000 and 4,100 feet (914 and 1,250 m). Rampton (1969) has noted similarly that tors range to lower elevations than the cryoplanation terraces in southwestern Yukon. Residual pyramidal hills or *tumps* (Demec, 1969, p. 7) commonly surmount summit flats, the uppermost terraces of terrace series. Although a few of the tors lie on summit flats, most occur on rounded ridges or hills, or on moderate slopes, with no immediate association with typical cryoplanation terraces.

Cryoplanation terraces have been observed throughout the unglaciated part of the Yukon Plateau, in those parts of the Ogilvie Mountains too low to have supported cirque glaciers (i.e. below about 5,000 feet, 1,525 m) and in the Richardson Mountains which supported only minor cirque glaciers. They have not been identified anywhere within former limits of the Laurentide ice-sheet, or the Cordilleran ice-sheet, or mountains that were sculpted by cirque glaciers, although nivation niches or hollows are common in such areas. Development of the terraces is judged to have been essentially preglacial, terraces within the glacial limit having been destroyed or modified so as not to be readily recognized. Tors are found throughout the unglaciated area, but also on glaciated surfaces of probable Reid age in the vicinity of Aishihik Lake, and of pre-Reid age in the Ogilvie Mountains. A possibility exists that the basic form of such tors is preglacial, the tors surviving glaciation as *roches moutonnées,* with subsequent modification to present form. No decisive evidence for the age of the initial form has yet been determined.

Cryoplanation terraces of Yukon collectively exhibit all of the major and minor features described by Demek (1969) for European, Asian, and other North American examples. They are judged, following Demek, to be the product of parallel retreat of scarps in a periglacial environment. Some tors doubtless are the final stage in the reduction of *tumps* that in themselves are remnants of once larger masses that have been removed by cryoplanation. However, the common occurrence of tors without immediate association with cryoplanation terraces, the occurrence in the western Klondike Plateau of tors at a mean elevation some 500 feet (150 m) lower than that for the terraces, and their occurrence in glaciated areas where recognizable terraces are lacking, suggest a different origin for many of the tors. A possible process is that of downwasting by solifluction, rather than scarp retreat. Tors would be left where the rock was more resistant to weathering for one or more reasons. Some rows of tors on sloping ridges appear to be interrupted outcrop of resistant quartzite. Individual tors may be rock masses in which jointing is more widely spaced than in surrounding rock, or rock which is locally more resistant by reason of secondary alteration, for example silicification.

Stop 13: Cryoplanation terraces, Mile 66.7 (km 106.7), Sixtymile Road

From Mile 66.7 (km 106.7), Sixtymile Road (1 mile, 1.6 km east of Little Gold Creek Customs house), the route follows a mining road 0.6 miles (1 km) southward, across a broad cryoplanation terrace, then diagonally down a scarp face to the stop on the next lower terrace. A still lower terrace lies to the south below another scarp, and a series of terraces is visible on a hill to the south.

No detailed studies have been made of these or other cryoplanation terraces in the Yukon; the following comments are necessarily brief and incomplete.

The three terraces are separated by stabilized frost-riven scarps (Demek, 1969, p. 7), mostly covered by rock detritus but with outcrops of grey quartzite that dip gently to the northeast. Surfaces of the two lower terraces are almost completely vegetated with sedge and low shrubs; the uppermost surface is sparsely vegetated and covered with stone polygons. Rock detritus of the polygons is lichen-covered, indicating long-term stability. Small lichen-free patches at the outer edge of the uppermost terraces suggest minor soil movement . Otherwise the terraces and scarps are essentially inactive, fossil forms.

From Stop 13, the route is retraced to Sixtymile Road, then continues eastward to Dawson.

Stop 14: Tor, Mile 35.7 (km 57.1), Sixtymile Road

On the north side of the road is a typical castellate tor, developed on quartzite of the Nasina series that dips gently southward. The sides of the individual towers of the tor are clearly controlled by joint sets in the quartzite.

From Stop 14, the route continues east along Sixtymile Road, with a brief picture stop at Mile 5.2 (km 8.3), overlooking the Yukon River.

Day 7: Geomorphology and auriferous deposits of the Klondike District

Guides: O. L. Hughes, V. Rampton

The geology and geomorphology of the Klondike gold fields were studied in detail by R. G. McConnell (1900, 1905, 1907), when thousands of shafts, adits and open cuts were available for inspection; his reports were drawn on freely for the following discussion, with citation of specific references only.

The Yukon River and such principal tributaries as the Sixtymile, Indian, Klondike and Fortymile Rivers, and gold bearing tributaries of the Klondike River such as Bonanza and Hunker Creeks, flow in rather narrow inner valleys that are incised into much broader high level valleys. The high level valleys are themselves deeply eroded into the Klondike Plateau.

Prior to the cutting of the inner valleys, there was marked aggradation of alluvial gravel along the Yukon River, the gravel attaining a thickness in excess of 350 feet (107 m) in the vicinity of Dawson. Remnants of the high level valley floor and the surface of the overlying alluvium are traceable along the Yukon River from above the mouth of the Stewart River to the Alaska border, and up major tributaries and subtributaries almost to their headwaters, where the terraces merge with the gradients of the modern streams.

Lack of good exposures of the contact of the alluvial fill on the bedrock terrace, and partial removal by erosion of the alluvial fill preclude precise reconstruction of the terrace. Approximate levels of the Yukon River, the bedrock terrace and the original alluvial surface above the Yukon River at selected points are as follows: near the mouth of the Stewart River, 1,170, 1,275 and 1,300 feet (357, 388, and 396 m); near the mouth of the Sixtymile River 1,120, 1,350 and 1,590 feet (341, 411 and 485 m); at the mouth of the Indian River, 1,090, 1,295 and 1,645 feet (332, 395, and 501 m); at Dawson 1,050, 1,325 and 1,725 feet (305, 373 and 525 m); near the site of Fort Reliance, 6.5 miles (10.5 kilometres) below Dawson, 1,035, 1,520 and 1,775 feet (315, 365 and 541 m), at the mouth of the Fortymile River, 955, 1,325 and 1,780 feet (301, 403 and 543 m). Below the Fortymile River, the bedrock terrace and the top of the alluvial fill are too poorly defined to permit determination of levels, but both surfaces appear to decrease in elevation.

Terrace gravels of the Sixtymile and Fortymile Rivers are derived mainly from resistant rocks (quartz, quartzite) of their respective drainages. Terrace gravels of the Indian River are similar, but with an admixture of foreign chert that entered the drainage via a tributary from the southeast. The tributary formed a glacial spillway when a tongue of the Cordilleran ice-sheet extended down the Stewart River in an early (pre-Reid) glaciation.

Gravel of high terraces along Bonanza and Hunker Creeks is distinctive in consisting mainly of white quartz and very pale, leached quartz-muscovite-chlorite schist, giving rise to the name "White Channel gravels" for these deposits. The upper 25 to 50 feet (7.6 to 15.2 m) of these deposits is commonly yellowish to reddish. Typically the White Channel gravels are overlain by 5 to 15 feet (1.5 to 4.6 m) of gravel which shows marked increase in schist and quartzite at the expense of quartz.

Dominion and Sulphur Creeks, south-flowing headwaters of the Indian River differ markedly from north-flowing Bonanza and Hunker Creeks in lacking entirely high-level terraces, although Dominion Creek especially has low terraces along its upper reaches. The lower reaches of these creeks contain thick quartzose gravels of White Channel type, overlain by stream gravel of quartzite schist and quartz similar to that found in the beds and low terraces of all streams in the area.

Between Dawson and Rock Creek, the high bedrock terrace is well developed on the south side of the Klondike River on rocks of the Nasina and Klondike series. Above Rock Creek, the river flows in the Tintina Trench, underlain by weak sandstone, conglomerate and shale of Late Cretaceous and/or Tertiary age; possibly because of weakness of the rocks, there is no recognizable bedrock terrace above Rock Creek. The upper surface of the alluvial fill (Klondike gravels; McConnell, 1905), is traceable along the south side of the river to Flat Creek, where it merges with a broad undulating surface that extends southeast along the Tintina Trench almost to the Stewart River. The surface is underlain by a fill of gravel, silt, and intercalated till in excess of 600 feet (180 m) thick (Flat Creek beds; McConnell, 1905, p. 24B).

At the mouth of Bonanza Creek, the modern stream channel is displaced downstream of the high-level channel. In abandoned hydraulic workings ("Jackson cut") the bedrock terrace, at 1,400 feet (427 m), is overlain by 130 feet (40 m) of White Channel gravel, with 185 feet (56.4 m) of Klondike gravels overlying, as measured to the upland surface at 1,715 feet (520 m) elevation behind the cut. The Klondike gravels thin abruptly up Bonanza Creek and are not exposed on Cripple Hill, 1.2 miles (1.9 kilometres) south of Jackson cut. At Trail Hill, between Jackson cut and Cripple Hill, White Channel and Klondike gravels are interbedded, suggesting that deposition of the upper part of White Channel gravels in Bonanza Creek was contemporaneous with deposition of Klondike gravels in the Klondike Valley.

McConnell (1907, p. 6) invoked an episode of depression followed by one of uplift to explain the terrace systems. An alternate explanation offered here involves uplift and drainage changes related to glaciation, as follows:

1. Broad upwarp along a west-southwest trending axis that crossed the Yukon River between the Fortymile River and the Alaska border.
2. Aggradation of the Yukon River in response to reduction of its gradient.
3. Aggradation of major tributaries such as the Sixtymile, Indian and Fortymile Rivers, in response to rise of their local base levels as the Yukon River aggraded. At this stage, the Klondike drainage probably included only Hunker Creek and tributaries below Hunker, with the greatest part of the drainage, that from the Ogilvie Mountains, flowing southeast in the Tintina Trench to the Stewart River. North flowing creeks such as Hunker and Bonanza would be affected both by reduction of their gradients and rise in local base level. South flowing creeks such as Dominion and Sulphur would be increased in gradient, initiating minor downcutting in their headwaters and formation of low bedrock terraces. Because the Indian River to which they are tributary was aggrading, the lower reaches of these creeks also aggraded.
4. Near the end of the aggradation cycle, cooling initiated the first glaciation (pre-Reid) of the Ogilvie Mountains and of the central and southern Yukon Plateau. Mountain glaciers from the North Klondike, South Klondike and lesser valleys formed a coalescent piedmont glacier in the Tintina Trench, diverting the main Klondike drainage to its present course, and depositing much if not all of the Flat Creek beds and Klondike gravels. Beyond the piedmont glaciers in the creeks of the Klondike district, the climatic change was reflected by a change of composition in gravel being deposited in the high level streams. Gravel rich in residual quartz, and with bedrock clasts completely leached, judged to be the product of weathering in a climate warmer than at present (McConnell, 1905, p. 33B), gave way to gravel containing abundant unleached bedrock clasts, judged to be the product of weathering in a periglacial environment. Thus, although McConnell considered the White Channel gravels to be at least as old as Pliocene (1905, p. 33B), the uppermost part is here considered to be earliest Pleistocene.
5. Following the glacial episode described above, but preceding the Reid glaciation, the Yukon River was cut down almost to its present grade, with downcutting extending almost to the headwaters of the Sixtymile and

Fortymile Rivers; the Klondike River was entrenched through the thick fill of Klondike gravels into subjacent bedrock, and into thick glacial fill of the Tintina Trench. The Indian River in its lower part is incised to the present Yukon grade, but downcutting has not yet extended to Sulphur and Dominion Creeks, hence high level terraces are lacking on these streams.

Stop 15: Midnight Dome viewpoint, 4.7 miles (7.6 km) by side road from Dawson

The view from this point displays most of the geomorphic features of the Klondike district. Features of special interest include:

— the general aspect of the Klondike Plateau, with deeply entrenched streams and intervening ridges radiating from "domes" that surmount the plateau level.

— the high terrace extending downstream along the Yukon River.

— the upper limit of alluvial fill on the high terrace, exposed in a cut along the recently relocated Sixtymile Road across the Yukon River.

— the upper surface of alluvial fill, and a broad, sloping intermediate terrace up the Yukon River.

— the bedrock terrace (Lousetown Bench) and the upper surface of alluvial fill to the south across the Klondike River.

— the bedrock terrace, White Channel gravels and Klondike gravels in Jackson cut, and the massive fan of tailings derived from the cut.

— the bedrock terraces (forming the floors of abandoned hydraulic workings) and overlying White Channel gravels, extending up Bonanza Creek.

— the highly irregular pattern of dredge tailings in the Klondike Valley, governed in part at least by sporadic distribution of permafrost on the flood plain.

Above the alluvial fill level (on which Dawson cemetery is situated), the road to Midnight Dome is constructed on deeply weathered bedrock. The active layer on this south-facing slope is deep and well-drained. Vegetation consists of immature white spruce, aspen poplar, white birch, with open patches of grasses and juniper.

From Stop 15, the route is retraced to Dawson, thence to Mile 111 (km 177.6), Klondike Highway, thence along the Bonanza Creek Road to Grand Forks at the confluence of Bonanza and Eldorado Creeks. The road is constructed on ridged dredge tailings, and fans of tailings from bench workings. More recent bulldozer workings are visible at several points.

Stop 16: Yukon Consolidated Gold Corporation Dredge No. 4

This dredge, electrically powered, with 16 cu. ft. (0.44 m^3) buckets, and the largest to operate in the Klondike District, was last operated in 1959.

From Stop 16, the route continues to Grand Forks, where a few cabins remain from a settlement of about 4,000 population, then returns to Stop 17.

Stop 17: Discovery Claim Monument, Bonanza Creek

From Stop 17, the route up Bonanza Creek is retraced to the Klondike Highway, thence east to Mile 106.1 (km 169.8), thence by side road to Bear Creek, the abandoned headquarters of Yukon Consolidated Gold Corporation. Here a span across the former course of the Klondike River carries the last remaining segment of the Klondike siphon. The siphon was part of a system of ditches, flumes and inverted siphons that carried water from the Little Twelvemile River in the Ogilvie Mountains to hydraulic workings on benches along Bonanza Creek.

From Bear Creek, the route continues east to Stop 18.

Stop 18: Open-system pingo 1.8 miles (2.9 km) by side road from Mile 106.1 (km 169.8), Klondike Highway

The pingo, one of some 461 such pingos identified in central Yukon (Hughes, 1969) is situated at the transition between the steep south side of the Klondike Valley and the alluvial valley floor. It consists of a crater enclosed on the north side (downhill) by a high, rather steep-sided rim, and on the south by the valley wall. The rim is breached where it abuts against the valley wall on the east side. A pond occupies the crater, its level controlled by seepage issuing as a spring downslope from the breach. Although the pingo is decadent, slumping and cracking on the inner slope of the rim indicates continuing subsidence, presumably due to melting of pingo ice.

Detailed observations of the hydrologic regimen of the pingo were initiated in 1968 by A. Lissey, Inland Waters Branch, Department of Energy, Mines and Resources, as part of a broader study of hydrology of permafrost areas. The study has been suspended indefinitely without conclusive results.

Vegetation on the north-facing slope above the pingo consists of immature black spruce and white birch, willow and dwarf birch, with a floor cover of lichens, feather mosses and sphagnum. The vegetation, growing on an active layer 6 to 10 inches (15 to 25 cm) thick, contrasts markedly with that on the south-facing slopes of Midnight Dome.

From Stop 18, the route is retraced to Dawson.

Day 8: Mountain glaciation, Ogilvie Mountains

Guides: O. L. Hughes, V. Rampton

Glacial deposits and landforms of the North Klondike, East Blackstone and upper Blackstone Valley record at least three major glacial advances (Vernon and Hughes, 1966). The advances, "last", "intermediate" and "old" have been correlated with McConnell, Reid and pre-Reid glaciations, respectively, of the Yukon plateau (Hughes, *et al.*, 1969). Ricker (1968) in detailed mapping of the North Klondike and East Blackstone Valleys, inferred two separate advances from moraines in the vicinity of Chapman Lake that had been classified by Vernon and Hughes (1966) as of "intermediate" age or uncorrelated. Ricker was unable to find a comparable two-fold sequence in the lower North Klondike Valley, nor were firm criteria available to determine whether the two advances represented two distinct glacial events, or two phases of a single event. Faced with several alternatives, Ricker (1968) preferred tentatively to correlate the oldest ("Taiga Valley") of the two moraine systems with Reid glaciation, regarding the younger ("Chapman Lake") as the product of a readvance following the Reid maximum.

Minimum dates for retreat following the "last" glaciation (bog bottom samples from within or up-valley from terminal moraines) range up to 13,740 years (GSC-515, GSC VII), but the oldest date from moraine assigned an intermediate age ("Chapman Lake" of Ricker) is only 13,870 ± 180 B.P. (GSC-296, Dyck and Fyles, 1964) as compared with >42,900 (GSC-524, Lowdon and Blake, 1968) for wood in volcanic ash above Reid drift. Therefore, correlation of "intermediate" glaciation in the Ogilvie Mountains with Reid advance of the Cordilleran ice-sheet remains tentative.

From Dawson the route follows the Klondike Highway along the flood plain and low terraces of the Klondike River to Mile 88.2 (km 141.1), then follows the Dempster Highway north into the Ogilvie Mountains. From the north side of the Klondike River, the highway ascends a gently sloping outwash fan to a terminal zone marking the limit of "intermediate" age glaciation in the North Klondike Valley (Vernon and Hughes, 1966; Map 1170A). The terminal deposits are inset below the high level surface of the Tintina Valley, hence the glaciation clearly post-dates the early piedmont glaciation(s) and the succeeding erosional cycle. The upper limit of the intermediate glaciation is visible on the east side of the valley from Mile 11 (km 17.6).

Stop 19: Stabilized rock glacier, Mile 42.1 (km 67.4), Dempster Highway

In contrast to currently active rock glaciers in cirques of the Ogilvie Mountains, St. Elias Mountains and elsewhere in Yukon, this example appears to be completely stabilized, as indicated by lichen growth on blocks of Keno Hill quartzite, of which the rock glacier is composed. The terminus of the rock glacier is compound, consisting of an older outer zone immediately adjacent to the highway that is separated by a transverse depression from a younger inner zone. Transverse ridges, lacking in the outer zone, are well-preserved on the inner zone, suggesting that the latter zone is distinctly younger than the former.

Stop 20: Late Wisconsin terminal moraine, North Klondike Valley, Mile 46.6 (km 74.7), Dempster Highway

The stop overlooks the "big bend" of the North Klondike Valley, with a view upstream to the Tombstone Range. Irregular hummocky moraine on the valley floor, and a series of meltwater channels cut in bedrock on the north side of the bend mark the limit of the last (late Wisconsin = McConnell) major glaciation in the valley.

Tombstone Mountain, developed on syenite of the Tombstone intrusions (Tempelman-Kluit, 1970) is visible near the pass between the North Klondike and Tombstone Valleys.

From Stop 20, the route climbs to the summit of the North Fork Pass and the headwaters of the East Blackstone River.

Stop 21: North Fork Pass moraine, Mile 51.2 (km 81.9), Dempster Highway

The stop is on the southern loop of a hammer-head shaped moraine system built by a late Wisconsin glacier with its source at the head of the East Blackstone River (Vernon and Hughes, 1966, Map 1170A). The sharply ridged and hummocky topography, with numerous closed depressions, is typical of late Wisconsin moraines of the area.

Stop 22: Palsa, Mile 53.1 (km 85), Dempster Highway

Palsa are common on valley floors within the alpine tundra zone of the Ogilvie Mountains, occurring in shallow depressions where peat is developed over silt. They range in form from circular or elliptical domes 5 to 12 feet (1.5 to 3.7 m) high and 20 to 50 feet (6.1 to 15.2 m) in diameter, to low platforms of irregular outline up to 100 feet (30 m) or more in diameter.

The palsa of this locality are low platforms about 3 feet (1 m) high, of irregular outline, and are remains of formerly larger palsa. In several (as of September, 1971) remarkably clean ice about 3 feet (1 m) thick, overlain by a mat of sedge peat 12 to 18 inches (30 to 45 cm) thick, is exposed in vertical, mostly southfacing faces. The vertical faces are determined by marked "candling" of the ice, apparently parallel to axes of the ice crystals. Decay of the palsa proceeds by backward melting of the ice face, the peat mat becoming draped down over the ice face. Periodically the mat shears at the upper edge of the ice, re-exposing the face, and leaving strips of the mat essentially undisturbed on the lowered surface.

Two characteristics of these palsa appear to be common to all palsa of the region: the relief of the palsa is fully accounted for by the thickness of ground ice beneath them, and the ground ice is the result of ice segregation by migration of pure water added from below to a freezing plane (Mackay, 1971, p. 410). Development of segregated ice requires that the freezing plane be underlain by permeable saturated sediments. This requirement explains the typical occurrence of palsa in bogs occupying former ponds, beneath which sediments are typically thawed, at least to considerable depth.

From Stop 22, the route continues along the Dempster Highway to Blackstone Crossing, passing across the northern loop of North Fork moraine at Mile 56 (km 89.6). Beginning about Mile 62 (km 99), and continuing for about 6 miles (9.7 km), moraines of "intermediate" age are visible to the east. Trenches resulting from melting of ice wedges can be seen at several points immediately adjacent to the highway.

Stop 23: Hummocky disintegration moraine, closed system pingo, Mile 72.6 (km 116.2), Blackstone Crossing, Dempster Highway

The stop is in an area of hummocky moraine with numerous lakes and ponds, with a view of the flood plain of the Blackstone River. A closed system pingo is visible on the flood plain in the distance.

The moraine is composed mainly of bouldery till with predominantly silt sand matrix, but includes areas of hummocky gravel (Ricker, 1968, Quaternary geologic map). The topography, though markedly subdued compared with the south lobe of North Fork Pass moraine, is not markedly different from the north lobe of the same system (Ricker, 1968, p. 142). Clearly differences in physiographic and topographic setting, in the mode of deposition of the glacial sediments, and in the character of the sediments themselves, seriously limit direct geomorphic comparison as a tool in correlating moraines of this region.

From Stop 23 the route continues along the Dempster Highway to Mile 82 (km 131.2), from which tors are visible on a limestone ridge to the west. The entire ridge has been glaciated, as evidenced by erratics of quartzite and syenite, but the tors lie above the limit of "intermediate" glaciation.

From Mile 82 (km 131.2) the route is retraced to Dawson.

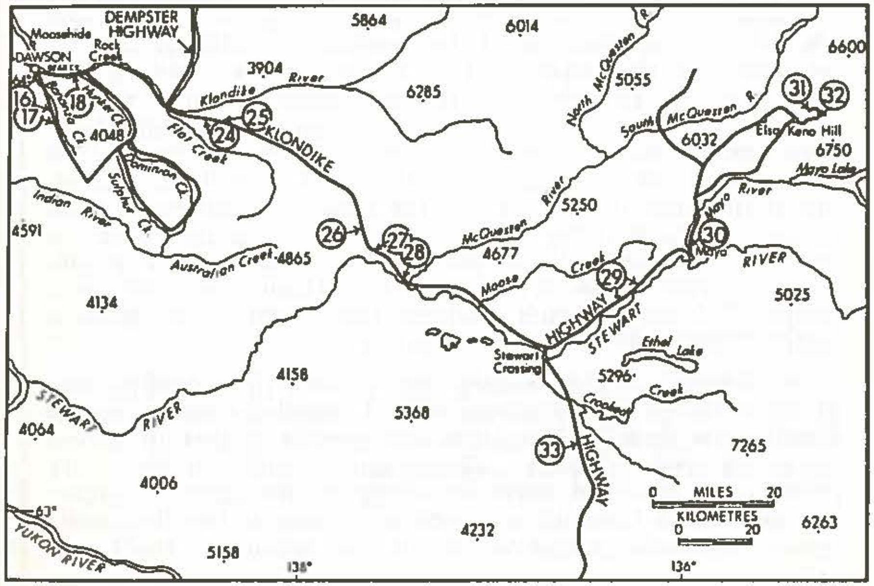


Fig. 8. Index map; route and stops, Days 9, 10.

Day 9: Pre-Reid drift (Flat Creek beds) of the Tintina Trench; Reid and McConnell drift of the Stewart River Valley; Soil development on drift of pre-Reid to McConnell age

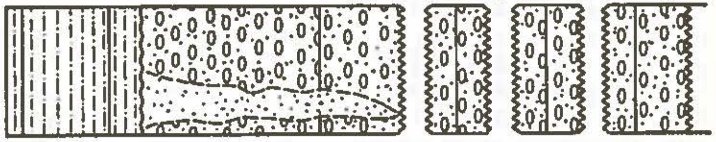
Guides: N. W. Rutter, O. L. Hughes, A. E. Foscolos

INTRODUCTION

During days 9 and 11 we will inspect soils that have developed in pre-Reid, Reid and McConnell surfaces. The contrast in weathering observed below loess and windblown sand in these three surfaces has long been recognized by workers in the area. It was suspected therefore that a study of these zones might aid in elucidating the Quaternary history of the area. The objectives of the present study were to classify the soils, to record differences in soil formation in different varieties of parent material, to determine age relationships between deposits through soil development and to aid in determining paleoclimates. Six sites were selected in well drained areas: two on pre-Reid outwash, one each on Reid and McConnell till and outwash. In all cases loess or eolian sand overlie the older deposits.

Six top soils developed in the loess or eolian sand and six paleosols formed in the outwash or till have been tentatively classified. Classification of the paleosols is difficult for two reasons: 1) the upper part of the solum has been eroded away prior to deposition of the windblown material and 2) some of the products of weathering from the top soils have been translocated to the lower parts of the paleosols thus altering the pre-existing morphology and chemistry. In addition the classification of the top soils is hampered by the initial C horizon being altered to a Bm during movement of weathering products to the paleosols. For example it is difficult to verify if the pre-existing C horizon was a Ck or a simple C horizon which changes the classification from a Eutric Brunisol to a Sombric Brunisol.

In addition to determining the genesis and classification of the soils through analyses of soil samples conclusions regarding the time of deposition and genesis of certain parent materials were possible. Preliminary results indicate 1) paleosols of pre-Reid outwash belong to the Luvisolic order; 2) paleosols of Reid till and outwash belong to the Brunisolic order (paleosols of McConnell till also belong to the Brunisolic order, but are more weakly developed; 3) all of the top



HORIZON		DEPTH IN CM.	COLOR	pH in H_2O	% ORGANIC MATTER		TEXTURE ≤ 2 mm		
							% SAND	% SILT	% CLAY
H		2.5- 0	10YR 3/2 vy dk greyish brown	5.4					
Ah		0 - 13.5	10YR 6/6 brownish yellow	4.9	.7	Silty loam	26.35	57.46	16.19
Bm		13.5- 18.5	10YR 5/4 yellowish brown	5.0	.5	Silty loam	17.00	61.59	21.41
II Bf		18.5- 46	7.5YR 4/5 brown	4.9	.3	Sandy clayey loam	51.15	17.19	31.66
II Bm_1		46 -117	10YR 4/5 dk yellowish brown	5.2	.3	Sandy clayey loam	69.91	5.52	24.57
II Bm_2		117 -190	10YR 3/4 dk yellowish brown	6.1	.3	Sandy loam	78.38	5.42	16.20
II BC		190 -255	10YR 4/4 dk yellowish brown	6.1	.3	Loamy sand	88.50	2.50	9.00
II C		258+	2.5Y 4/4 olive brown	6.6	.3	Sand	93.89	2.01	4.10

Fig. 9. Soil profile in pre-Reid drift, Stop 24, Day 9.

soils belong to the Brunisolic order; and have comparable degree of development.

The following conclusions can be drawn from the soil classification above, together with field evidence relating to sand wedges: 1) the similarity of the soil types indicate no major climatic change since the formation of the pre-Reid surface. However, greater soil moisture efficiency was required for development of the Luvisols; 2) sand wedges in the Reid and pre-Reid surfaces were probably developed at the same time, most likely during McConnell glaciation; 3) a period of non-deposition between deposition of McConnell drift and the overlying loess is indicated by sand wedges, sparsely distributed ventifacts and separate soil development in both the drift and overlying windblown material.

From Dawson the route follows the Klondike Highway southeastward (Fig. 8) along the flood plain and low terraces of the Klondike River to Mile 82.5 (km 132). At Mile 82.5 the route leaves the present highway and follows an abandoned section, climbing steeply to the glacial fill surface of the Tintina Trench.

Stop 24: Soil development on pre-Reid drift, Mile 79.2 (km 126.7) Klondike Highway (abandoned section) (Elevation ± 2,300 feet, 701 m)

At this point, indeed throughout the Tintina Trench from here to the Stewart River, the surface deposit is gravel of pre-Reid age with a thin cover of McConnell loess. One-half mile (0.8 km) to the north where the Klondike River is incised some 700 feet (213 m) into thick drift fill, intermittent exposures along an abandoned road indicate that the lowermost 300 feet (90 m) of sediments consist of stratified glaciolacustrine clay, silt, and sand. Slumped gravel masks the upper 400 feet (120 m), possibly concealing additional thickness of glaciolacustrine sediments or possibly till as at Mile 77.4 (km 123.8) (see further).

At this stop we will examine soils developed in the oldest glacial landscape in the area. The site is located in well drained terrain with little post-depositional modification. The pre-Reid outwash consists of moderately to poorly sorted and bedded gravel and sand. The gravel contains pebble-sized material with frost shattering common in the upper part, but decreasing with depth. Sand wedges have developed, less weathered than the enclosing material, and form with the outwash an erosional surface at the contact with overlying loess. Deflation played a part in forming the erosional surface as evidenced by ventifacts. Pebbles in the loess indicate post-depositional modification.

A soil at least 240 cm thick has developed in the outwash (Fig. 9). The paleosol is identified as a Luvisol but cannot be classified further until mineral stability analyses are made. The top soil is classified as an Orthic Sombric Brunisol having a profile thickness of 21 cm.

The sequence of Quaternary events is:

1) Deposition of the pre-Reid outwash
2) Development of the Luvisol under conditions of greater moisture efficiency than today.
3) Formation of sand wedges under cold-dry periglacial conditions.
4) Deflation and ventifact formation.
5) Loess accumulation during McConnell glaciation.
6) Development of the Orthic Sombric Brunisol.

From Stop 24, the route continues southeast, rejoining the present highway at Mile 77.4 (km 123.8). There, about 100 feet (30 m) of drift, mainly gravel but including two horizons of gravel-rich till, is exposed in a recent borrow pit. No detailed study has been made of the exposure; cursory examination revealed no weathering zones or nonglacial deposits indicative of interglacial or interstadial intervals.

Stop 25: Viewpoint, Mile 75.1 (km 120.2), Klondike Highway

The stop provides a view north across the Klondike Valley (here entrenched over 600 feet, 180 m into glacial fill) to the Ogilvie Mountains beyond. The North Klondike River Valley to the northwest, and O'Brien Creek and the Klondike River Valley to the northeast, are assumed to have been the main sources of piedmont glaciers that deposited the thick drift fill of this part of the Tintina Trench, during one or more pre-Reid glaciations.

From Stop 25, the route continues southeast over the rolling and broadly dissected glacial fill of the Tintina Trench.

Stop 26: Soil development on pre-Reid drift, Mile 41.6 (km 66.6), Klondike Highway (Elevation + 1,800 feet, 549 m)

Here, as at Stop 24, the surface deposit is gravel of pre-Reid age. Near Belleview Point, 3 miles (4.8 km) to the east, grey till overlies reddish-brown gravel. Bostock (1966, p. 9) considered the till to be of Klaza age. Belleview Point has an elevation of about 1,900 feet (579 m), compared with

1,800 feet (549 m) at the present locality, which should therefore be within the limits of the glaciation that deposited the till at Belleview Pont. The surface deposits here should then be of Klaza age, younger than those at Stop 25, which Bostock considered to be of Nansen age. Soil development here is not significantly different to that at Stop 24, but this does not necessarily negate Bostock's interpretation.

The only major differences in parent material are a thicker loess deposit, the presence of a thin sand layer associated with the sand wedges and a more complex sand wedge network. The paleosol is over 83 cm thick and is classified as a Luvisol, the same as the last stop but considerably thinner (Fig. 10). The top soil is a Degraded Eutric Brunisol with a profile over 42 cm thick.

The sequence of Quaternary events is:

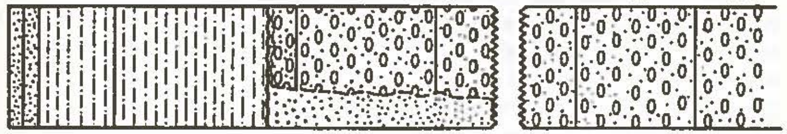
1) Deposition of pre-Reid outwash
2) Development of the Luvisol under conditions of greater moisture efficiency than today.
3) Formation of sand wedges under cold-dry periglacial conditions
4) Deflation and ventifact formation
5) Loess accumulation sometime after McConnell glaciation
6) Development of the Degraded Eutric Brunisol.

From Stop 26 the route continues along the Klondike Highway, descending into the Stewart River Valley, which here lies in the Tintina Trench.

Stop 27: Soil development on an outwash terrace of Reid age, Mile 36.8 (km 58.9), Klondike Highway (Elevation 1,500 feet, 457 m)

The locality is approximately at the limit of Reid glaciation in the Stewart River Valley (Bostock, 1966, Fig. 1; Hughes *et al.*, 1969, Map 6-1968), but evidence of the exact limit is buried beneath glacial outwash gravel of Reid age. The stop is on a terrace below the highest levels of Reid outwash, but is judged to have been formed shortly after the Reid maximum. Loess that mantles the terrace surface is judged on the basis of soil profiles to be of McConnell age (see below).

The parent material is not unlike that of the older surfaces. The outwash consists mostly of poorly and moderately sorted and bedded gravel with pebble-sized material commonly frost shattered. Sand wedges are present and are less weathered



HORIZON	DEPTH IN CM.	COLOR	pH in H_2O	% ORGANIC MATTER		TEXTURE < 2 mm % SAND	% SILT	% CLAY
F-H Aeh	2.5- 0 0 - 2.5	10YR 2/1 black 10YR 3/2 vy dk greyish brown	6.1 4.8	8.6	Sandy loam	53.00	30.00	17.00
Bmh	24 - 15	10YR 5/3 brown	5.4	3.4	Loam	40.06	41.82	18.12
Bm	15 - 40	10YR 6/3 pale brown	6.0	1.0	Silty loam	24.31	54.99	20.70
II	40 - 45	10YR 5/3 brown	6.4	.5	Loamy sand	84.19	10.17	5.64
III Bf_1	45 - 68	10YR 5/6 yellowish brown	6.4	.3	Sandy loam	76.27	11.35	12.
III Bf_2	68 -103	7.5YR 6/6 dk yellowish brown	6.7	.3	Loamy sand	83.33	5.15	11.52
III BC	103 -123	10YR 5/6 yellowish brown	6.6	.3	Loamy sand	85.27	8.32	6.41
III C	123+	10YR 5/6 yellowish brown	6.7	.2	Sand	90.42	5.28	4.30

Fig. 10. Soil profile in pre-Reid drift, Stop 26, Day 9.

than the enclosing gravel. The outwash and wedges have been eroded by deflation with ventifacts present near the contact with the overlying windblown deposits. The upper part of the wind blown material is loess grading downward into sandier material that in part may have been deposited by surface creep and saltation.

The paleosol is classified as an Orthic Eutric Brunisol (Fig. 11), and is at least 63 cm thick, thinner and not as well developed as the older paleosols. The top soil is over 32 cm thick and classified as an Orthic Dystric Brunisol, different only from the paleosol by its lower pH and thinner horizons. This of course suggests that the climate was not much different during the formation of each soil. Horizon thicknesses in the paleosol indicate a greater age of development.

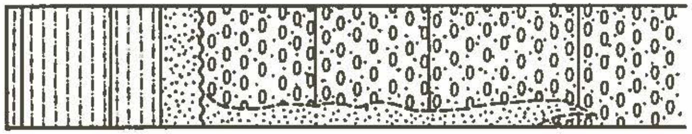
The sequence of Quaternary events is:

1) Deposition of the Reid outwash
2) Development of the Orthic Eutric Brunisol
3) Formation of sand wedges under cold-dry periglacial conditions
4) Deflation and ventifact formation
5) Deposition of loess and windblown sand
6) Development of the Orthic Dystric Brunisol.

From Stop 27, the route continues along the Klondike Highway, crossing the McQuesten River onto a broad outwash gravel surface of McConnell age, the youngest glacial surface. The outwash surface can be traced intermittently from McConnell moraine fifty miles upstream (Stop 29) to a point 25 miles downstream, where the outwash surface merges with the floodplain of the Stewart River.

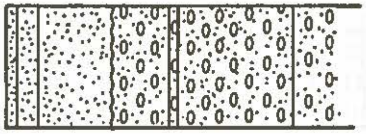
Stop 28: Soil development on a McConnell outwash surface, 0.5 mile (0.8 km) northwest on a side road from Mile 36.8 (km 58.9), Klondike Highway (Elevation 1,500 feet, 457 m)

The site about 25 feet (8 m) above the level of the Stewart River is well drained with little post-depositional modification. The parent material consists of sandy gravel, mostly of pebble-sized material, some frost shattered, moderately to poorly sorted and bedded, overlain by windblown material. There is an erosional surface between the two deposits but not to the extent and duration as on the older surfaces. Ventifacts have not been observed in the immediate area, but are sparsely distributed elsewhere on McConnell outwash surfaces.



HORIZON	DEPTH IN CM.	COLOR	pH in H_2O	% ORGANIC MATTER		TEXTURE < 2 mm % SAND	% SILT	% CLAY
E-H	2.5- 0	10YR 2/2 vy dk brown	6.3					
Bf	0 -14.5	5YR 5/4 reddish brown	5.9	1.7	Silty loam	27.86	52.41	19.73
Bm1	14.5-22.5	10YR 4/4 dk yellowish brown	6.0	1.0	Loam	38.24	46.38	15.38
Bm2	22.5-30	2.5 YR 4/4 light olive brown	6.4	.5	Sandy loam	76.69	15.31	8.0
II Bm_1	30 -49	10YR 5/4 yellowish brown	6.4	.7	Sandy loam	69.13	16.37	14.50
II Bm_2	49 -63	10YR 5/4 yellowish brown	6.4	.5	Sandy loam	78.50	10.75	10.75
II BC	63 -93	2.5Y 5/4 light olive brown	6.9	.2	Sand	81.70	10.14	8.16
II Ck	93+	2.5Y 5/4 light olive brown	7.1	.2	Sand	96.79	1.02	2.19

Fig. 11. Soil profile in Reid outwash gravel, Stop 27, Day 9.



HORIZON	DEPTH IN CM.	COLOR	pH in H_2O	% ORGANIC MATTER		TEXTURE ≤ 2 mm % SAND	% SILT	% CLAY
F-H	2- 0	10YR 3/3 dk brown	5.5					
Ah	0- 3.5	10YR 5/4 yellowish brown	5.0	6.4	Sandy loam	58.51	31.93	9.56
Bm	35-12.5	10YR 5/4 yellowish brown	4.9	2.2	Sand	63.08	26.56	10.36
II Bm	125-21	10YR 5/4 yellowish brown	5.4	.9	Sand	90.86	3.87	5.27
II C_1	21-23	10YR 4/2 dk greyish brown	6.4	.7	Sand	95.86	1.44	2.70
II C_2	23-42	10YR 4/2 dk greyish brown	6.2	.5	Sand	97.88	.35	1.77
III C?	42+	10YR 4/2 dk greyish brown	6.2	.5	Sand	95.04	1.61	3.35

Fig. 12. Soil profile in McConnell outwash gravel, Stop 28, Day 9.

The Paleosol and top soil are identified as Orthic Dystric Brunisols with the lower profile 8.5 cm thick and the upper 14.5 cm (Fig. 12). The differences in the soils are slight indicating about the same conditions of formation.

The sequence of Quaternary events is:

1) Deposition of the McConnell outwash
2) Development of an Orthic Dystric Brunisol
3) Deposition of the windblown material
4) Development of an Orthic Dystric Brunisol.

From Stop 28, the route follows the Klondike Highway to Stewart Crossing, then Highway 2 to Mayo.

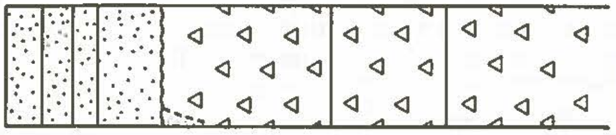
Stop 29: McConnell moraine, Mile 232.1 (km 371.4), Highway 2 (Elevation 1,800 feet, 610 m)

The McConnell moraine was first recognized as a significant glacial limit in the Stewart River Valley by R. G. McConnell (1903), and was named after him by Bostock. The moraine marks the limit of McConnell advance in the Stewart River Valley; the informal terms *McConnell glacial limit* and *McConnell advance* are applied to correlative phenomena (Bostock, 1966, p. 1). A lateral moraine on the northwest side of the Stewart River Valley is traceable continuously into the McConnell moraine, which forms a U-shaped loop that crosses the valley and turns upstream to join a lateral moraine on the southeast side. A gap in the moraine one mile (1.6 km) wide at mid-valley is occupied by the Stewart River and bordering outwash terraces and floodplain. The moraine consists of a belt ¼ to ½ mile (0.4 to 0.8 km) wide, with relief to 100 feet (30 m) or greater. At the stop, the moraine is almost submerged beneath outwash gravel and an alluvial fan-apron that lies against the valley side.

Till of McConnell age is exposed intermittently along the Stewart River to an exposure ¾ mile (1.2 km) southeast of Stop 29, just within the moraine loop.

In a borrow pit at the stop, till is overlain by eolian silt and sand. The till is extremely stony and sandy; frost shattering is considerably less apparent than in older deposits; ventifacts are lacking but a few poorly developed sand wedges have been observed. The overlying windblown material is sandier than that overlying outwash at Stop 28, probably as a result of proximity to source.

The paleosol is at least 47 cm thick and is identified as an Orthic Eutric Brunisol or perhaps a Degraded Eutric Brunisol



HORIZON	DEPTH IN CM.	COLOR	pH in H_2O	% ORGANIC MATTER	TEXTURE ≤ 2 mm			
						% SAND	% SILT	% CLAY
F-H	6- 0	10YR 3/2 vy dk greyish brown	6.4					
Ah	0- 5	10YR 5/2 greyish brown	6.0	2.9	Sandy loam	72.97	17.59	9.44
Bm_1	5- 9	10YR 5/3 brown	5.6	1.7	Loamy sand	80.37	11.29	8.34
Bm_2	9-20	10YR 5/4 yellowish brown	5.6	.5	Sand	88.36	6.01	5.63
II Bm_1	20-45	10YR 6/4 light yellowish brown	4.9	1.0	Sandy loam	67.20	22.87	9.93
II Bm_2	45-67	10YR 5/2 greyish brown	5.4	.7	Sandy loam	64.00	23.69	12.31
II C	67+	10YR 5/2 greyish brown	6.4	.3	Sandy loam	74.79	17.95	7.23

Fig. 13. Soil profile in McConnell till, Stop 29, Day 9.

because of the low pH of the Bm_1 horizon whereas the top soil is an Orthic Sombric Brunisol with a profile thickness of 26 cm (Fig. 13).

The sequence of Quaternary events is:

1) Deposition of McConnell till
2) Development of the Orthic Eutric Brunisol
3) Formation of sand wedges under cold-dry periglacial conditions
4) Deposition of the windblown material
5) Development of the Orthic Sombric Brunisol.

Day 10: McConnell glaciation in the Mayo-Keno Hill area

Guide: O. L. Hughes

The Mayo-Keno Hill area lies at the western limit of the McConnell advance of the Cordilleran ice-sheet. Ice movement in the area was strongly controlled by local relief of 2,500 to 4,500 feet (750 to 1,350 m). The ice margin was divided into several sublobes, and ice surrounded high mountainous plateau elements (Hughes *et al.*, 1969, Map 6-1968). The valleys of the Stewart, Mayo and South McQuesten rivers are flooded by thick deposits of glacial, glaciolacustrine and glaciofluvial sediments of McConnell age.

Stop 30: McConnell glacial limits and outwash, Mile 247.2 (km 395.5), Highway 2

The stop is on a promontory on a retreatal McConnell outwash terrace immediately west of Mayo airport. The McConnell limit is discernible on valley slopes to the northeast and south. The outwash surface continues to the west across the Mayo River. Outwash gravel is exposed in a pit below the promontory.

From Stop 30 the route follows Highway 2 to the settlement of Keno Hill then 7.0 miles (11.3 km) along a mining road to the abandoned Shamrock property on the upland surface of Keno Hill, from which there is a short walk across a cryoplanation terrace to Stop 31, a promontory overlooking the South McQuesten River.

Stop 31: Upland surface, Keno Hill, and glacial features of the South McQuesten Valley

The upland surface at the west end of Keno Hill has four steps, probably cryoplanation terraces, with one below and two above the surface crossed enroute to the stop. Well-developed stone-polygons cover the cryoplanation surfaces. Except for a few showing slight activity, the polygons are stabilized and the terraces are fossil forms.

From the promontory, limits of McConnell glaciation are discernible across the Keno-Ladue Valley to the north and the South McQuesten Valley to the northwest. A complex of moraine ridges and pitted outwash on the floor of the South McQuesten Valley probably marks a still-stand of the ice front subsequent to retreat from the McConnell maximum. Terraced outwash extends for many miles down the South McQuesten Valley.

From Stop 31, the route is retraced 2.7 miles (4.3 km) to Stop 32.

Stop 32: Moraine of local valley glacier, Lightning Creek

Mount Hindle, elevation 6,750 feet (2,060 m) supported several small glaciers during McConnell glaciation, none of which joined with the Cordilleran ice-sheet. The terminal moraine of one such glacier is visible in Lightning Creek from the stopping point.

From Stop 32, the route is retraced to the United Keno Hill Mines, Elsa, where R. E. Van Tassell, Exploration Manager, U.K.H.M., will describe techniques of mineral exploration in areas of drift cover. The route is then retraced to Mayo.

Day 11: Reid and McConnell age deposits of the Cordilleran ice-sheet, Mayo to Whitehorse

Guides: O. L. Hughes, N. W. Rutter

From Mayo, the route (Fig. 14) follows Highway 2 southwest, recrossing the McConnell moraine and continuing to Stewart Crossing. From there the route, following the Klondike Highway southward, lies mostly on drift of Reid age to Minto. South of Minto the route lies on McConnell outwash for about 18 miles (29 km), then crosses the McConnell limit, south of which the route lies entirely on drift of McConnell age.

Stop 33: Soil development on ablation moraine of Reid age, Mile 195.6 (km 313), Klondike Highway (Elevation 2,500 feet, 762 m)

We now will examine soils that have developed in Reid age till and overlying loess. The terrain is little disturbed

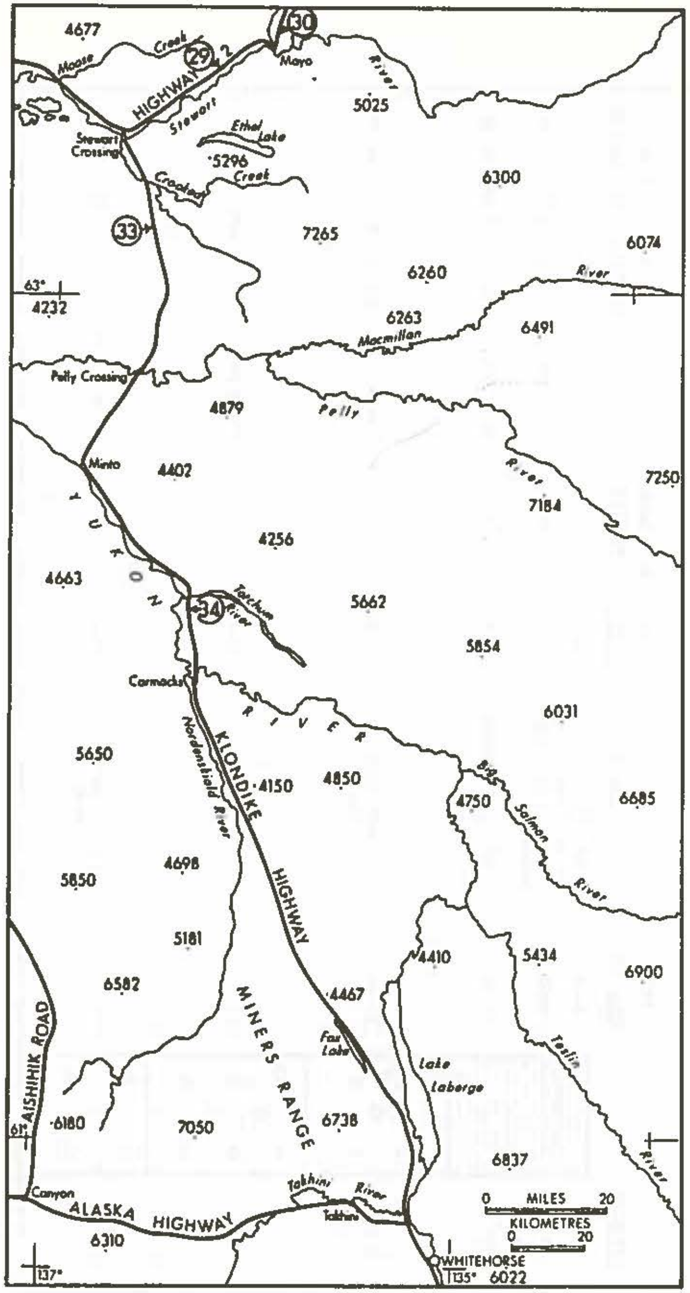
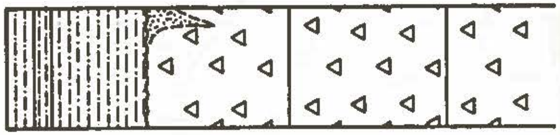


Fig. 14. Index map; route and stops, Day 11.



HORIZON	DEPTH IN CM.	COLOR	pH in H_2O	% ORGANIC MATTER		TEXTURE ≤ 2 mm		
						% SAND	% SILT	% CLAY
F-H	5- 0	10YR 3/2 vy dk greyish brown	4.8					
Ah	0-25	10YR 5/4 yellowish brown	4.5	3.4	Silty loam	18.82	64.79	16.39
Bm	25-17	10YR 5/4 yellowish brown	5.0	1.0	Silty loam	18.86	59.55	21.59
II Bm	17-40	2.5Y 5/4 light olive brown	5.1	.3	Loam	49.64	34.91	15.45
II BC	40-66	2.5Y 5/4 light olive brown	5.3	.3	Sandy loam	71.01	19.88	9.11
II C	66+	2.5Y 5/4 light olive brown	6.3	.3	Loamy sand	84.72	8.97	6.31

Fig. 15. Soil profile on Reid ablation moraine, Stop 33, Day 11.

and well drained. The lower unit consists of washed till that is highly stony and sandy. It could be argued that the unit is a poorly sorted outwash. Sand wedges and frost shattering of pebbles decreasing with depth, are common. An erosional surface caused by deflation separates the till and loess with ventifacts found near the interface. The loess contains scattered pebbles indicating some post-depositional modification.

The paleosol and top soil (Fig. 15) are classified as Orthic Sombric Brunisols. The profile thickness of the paleosol is at least 49 cm whereas that of the top soil is only 22 cm. Once again the climate during the formation of both soils was similar, the only difference is in a greater degree of development.

The sequence of Quaternary events is:

1) Deposition of Reid till
2) Development of an Orthic Sombric Brunisol
3) Formation of sand wedges under cold-dry periglacial climate
4) Deflation and ventifact formation
5) Deposition of loess
6) Development of an Orthic Sombric Brunisol.

Stop 34: Scenic stop, Five Finger Rapid, Yukon River, Mile 116 (km 185.6), Klondike Highway

Here the post-glacial channel of the Yukon River is incised into conglomerate and sandstone of the Laberge Group. Four rock islets divide the river into 5 channels or fingers. A buried preglacial or interglacial channel may lie to the west.

Stop 34: B. Five Finger Rapid Section, Mile 115.4 (km 184.6), Klondike Highway (Elevation 2,100 feet, 640 m)

The Five Finger Rapid section exposes McConnell glacial drift with overlying loess and White River ash. The deposits and the soil profile developed in them (Table 9, 10) are typical for this part of the Yukon River Valley.

From Stop 34 to Whitehorse, the route lies entirely within the limit of McConnell glaciation, although higher parts of the Miner Range west of Fox Lake stood above the McConnell ice-sheet. Glacial features, which include extensive outwash trains, pitted and terraced glaciofluvial deposits, hummocky moraine and meltwater channels, exhibit the characteristic freshness of McConnell age deposits.

TABLE 9

GEOLOGIC SECTION, FIVE FINGERS RAPID

Description	*Thickness*
Artificially emplaced material	30 cm
White River volcanic ash	5 - 15 cm
Loess, clay 12%, silt 55%, sand 33%; <1% carbonate	18 cm
McConnell till (ablation) 15% - 20% stones (> 2 mm), mode 1 to 4 cm, metamorphics (mostly quartzite), volcanics, coarse basic and acidic igneous carbonates, siltstones, grits, sandstones and conglomerates (in soil zone intense weathering); angular to well rounded, mostly subangular to subrounded; striations; matrix 58% sand, 27% silt, 15% clay; carbonate content 0 - 4% depending on soil influence	74 cm
McConnell till (basal) as above; 10 - 20% stones (> 2 mm); dense; matrix 59% sand, 25% silt, 16% clay; 4% carbonate	97 cm
Outwash gravels 90% sandy gravels; flat lying; mostly coarse, mode 5 to 10 cm; poorly bedded; moderately to poorly sorted; subangular to well rounded; 10% sand; well sorted medium to coarse grained lenses	>1.8 m

The soil profile is classified in the Brunisol Order. Labratory analyses are necessary for further subdivision. The profile consists of:

TABLE 10

SOIL PROFILE, FIVE FINGERS RAPID SECTION

Description	*Thickness*
A horizon eroded	
Bm$_1$ (loess) 7.5YR 5/4 brown	5 cm - 10 cm
Bm$_2$ (loess, buff) 10YR 5/4 yellowish brown	15 cm
Bm$_3$ (till) 10 YR 5/6 yellowish brown	31 cm
Cca (till)	20 cm - 25 cm

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