A Possible Advanced Hypsithermal Position of the Donjek Glacier

The icefield of the St. Elias Mountains in the southwest Yukon Territory is the source of a number of large valley glaciers. The Donjek Glacier, one of the largest of the valley glaciers on the eastern side of the icefield, flows about 35 miles from the icefield at an altitude of 10,000 feet to the terminus at 3,500 feet in the Donjek River Valley (Fig. 1). The history of the glacier from 1935 to the present is well documented photographically (Walter A. Wood and Austin Post, personal communications). Documentation of the Hypsithermal and Wisconsin history of the glacier is less abundant. Denton and Stuiver[1] produced a detailed study of the glacier terminus area but there are a number of gaps in the Neoglacial and Hypsithermal history. Other studies of relevance to the glacial history of the area are those of Sharp[2], Krinsley[3], Borns and Goldthwait[4], Denton and Stuiver[5], Muller[6], Rampton[7,8], and Bostock[9]. None

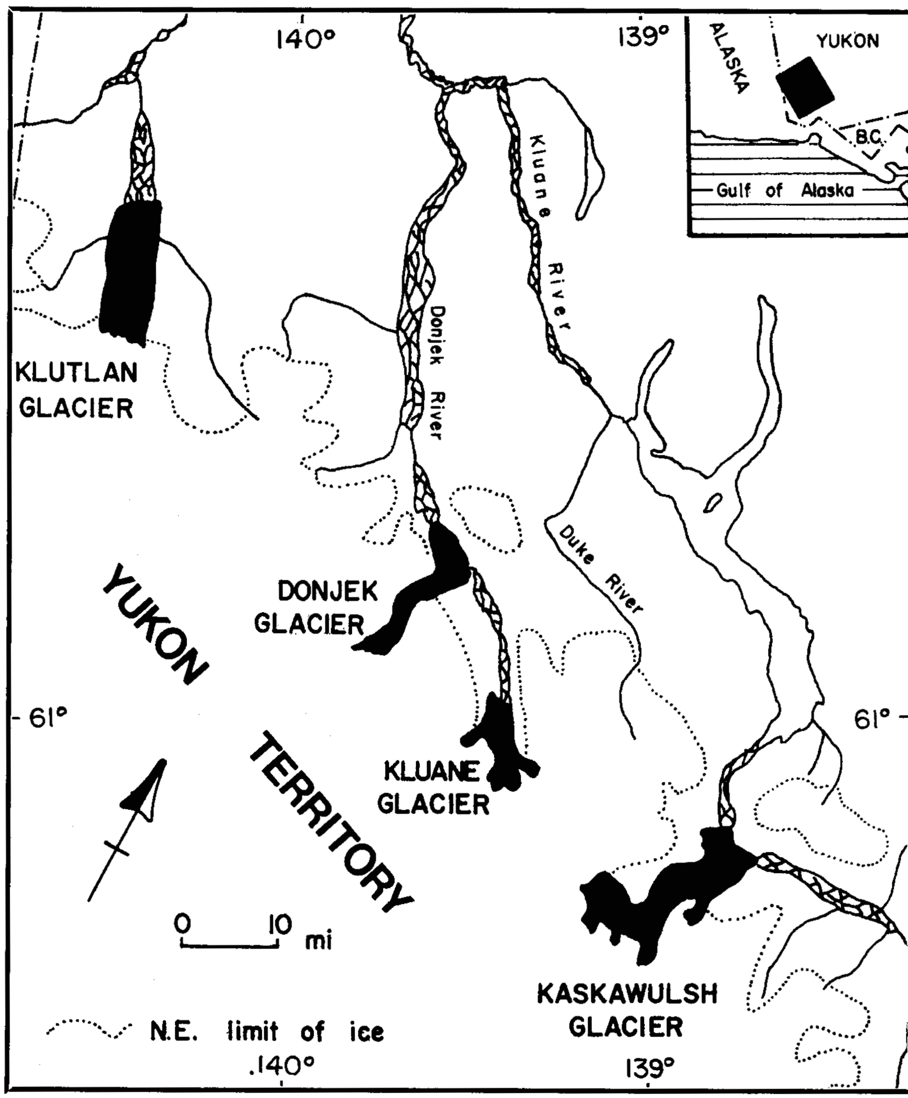

FIG. 1. Location of the study area.

of these studies delimits a Hypsithermal position for the Donjek Glacier terminus. Denton and Stuiver[1] found evidence for the retreat of the Kaskawulsh Glacier during the Hypsithermal Interval to a position 15 miles up valley from the Neoglacial terminus position, but Rampton[7,8] identifies no Hypsithermal terminus position for the Klutlan Glacier (Fig. 1).

During the summer of 1970 the terminus area of the Donjek Glacier and the lower part of the glacier valley were investigated for evidence of its Hypsithermal position. No evidence was found in the valley occupied by the glacier to indicate that it had retreated back into the valley from the Donjek River Valley. The inclusion of 'Slims Soil' (Borns and Goldthwait[4]) in the material of the Neoglacial moraine complex of the glacier indicates that there must have been some retreat up valley of the moraine position before the Neoglacial re-advance.

Down valley from the Neoglacial moraines there is evidence for a relatively recent, probably Hypsithermal, ice marginal position. This evidence is in the form of a lateral moraine, terminal moraine remnants and the distribution and development of the Hypsithermal Slims Soil and volcanic ash. Unfortunately no material was found which could be dated by radiocarbon techniques to verify the age of the features.

The glacial landforms are relatively easily identified when compared with the highly denuded forms which represent the pre-Neoglacial periods found elsewhere in the Donjek Valley. On the edge of the active and fossil areas of the braided river bed there is an area of small water washed mounds (Fig. 2). These forms are fairly linear in their occurrence and are oriented across the valley floor. They rise up to 4 or 5 feet above the highest river terrace level. The surface of these mounds has been well washed by the action of the Donjek River but below the surface washed zone there is a high percentage of matrix material which suggests that the mounds may have been originally composed of till. Forms with very similar characteristics occur between the Neogla-

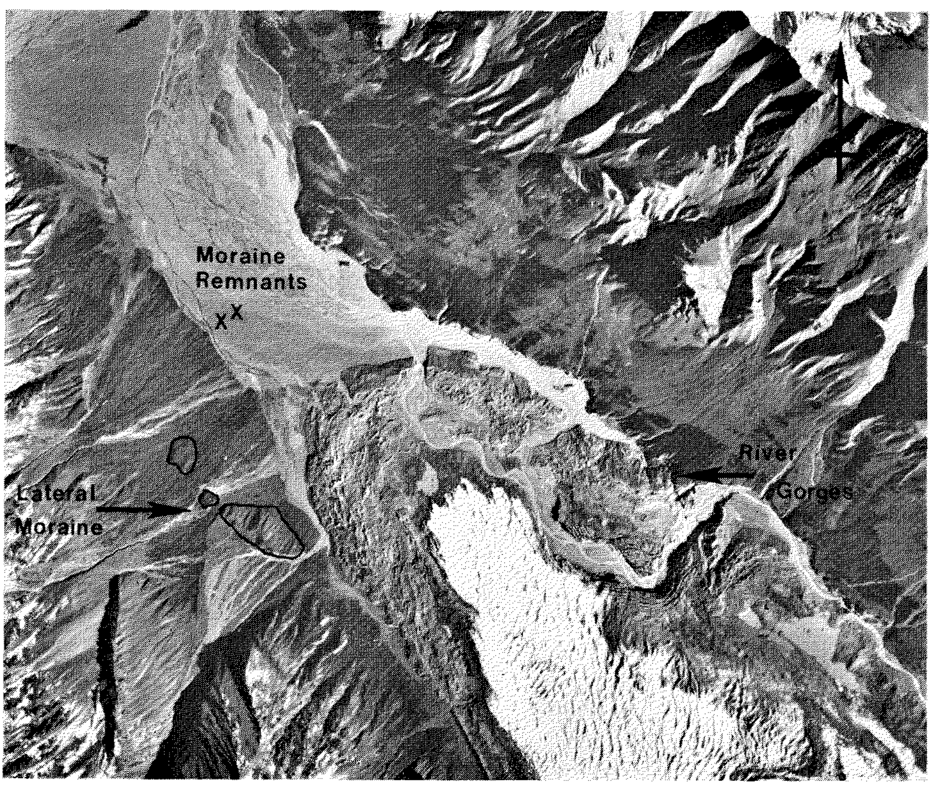

FIG. 2. Down-valley terminus of the Donjek Glacier. (Photo. no. A14960. 11. Courtesy of National Air Photo Library, Surveys and Mapping Branch, Department of the Environment, Ottawa, Canada.)

cial moraines and the glacier terminus where the recent action of meltwater has denuded the small moraines deposited during the last 40 years. The considerably longer period of survival of the mounds outside the Neoglacial position which, from the evidence of the wide extent of the fossil braided river bed, must have survived considerable erosive activity by the river, indicates a form of much greater dimensions than the recent moraines.

The line of orientation of these moraine remnants intersects the southwest valley side at a position which correlates with a line of lateral moraine remnants on that side of the valley (Fig. 2). This lateral moraine rises to a height of 200 feet and is oriented up the valley side from a position close to the Neoglacial moraine. The moraine is dissected by a number of alluvial fans but the remnants indicate that down valley it curves back towards the valley floor and the position of the mounds discussed above. The flow pattern of the Donjek Glacier in its terminus area is directed against the northeast side of the valley and it is difficult to see that an advance to the position discussed above would cause the upslope expansion of the ice indicated by the position of the moraine. In an area where two glaciers are confluent there is a compressional force which can result in local expansion of the combined ice flow. The confluence of the Donjek and Kluane Glaciers at the time of formation of the moraine would account for the upslope orientation of the moraine form. Muller[6] identifies a sub-recent advance of the Kluane Glacier to approximately the position discussed in this paper. Ice marginal features on the northeast side of the valley south of the Donjek Glacier terminus indicate that at this position of the Kluane Glacier the ice would be less than 500 feet thick. Although no datable material was obtained for these forms morphological evidence for other periods of glaciation supports Muller's hypothesis that they are post St. Elias Glacial advance (Kluane Glaciation[1]). The existence of three distinct moraine systems at the terminus of the Kluane Glacier which are apparently of Neoglacial age would support the hypothesis that Muller's Sub-Recent (Neoglacial) position of the Kluane Glacier occurred between the St. Elias Glacial advance and the Sub-Recent stage, that is in the Hypsithermal period.

Although the Hypsithermal Slims Soil, developed on Kluane Loess, occurs both on the proximal and distal sides of the lateral moraine, there is a contrast between the sections. Between the lateral moraine and the Neoglacial moraine the soil sequence is poorly developed, especially when compared with sections in the Slims River Valley[1,4,10]. The existence of volcanic ash of the eastern lobe from the Mount Natazhat source area[11] on both sides of the moraine also indicates formation of the moraine and retreat of the glacier in pre-Neoglacial time but does not help to place the moraine formation at any particular stage of the Hypsithermal. The change in the degree of development of the soil sequence indicates that the period of the Hypsithermal weathering after the retreat of the ice from the moraine was short and suggests that the moraine probably dates from late in the Hypsithermal Interval.

This hypothesis poses two difficult questions. The first is to explain the considerable amount of retreat of the Kluane Glacier from a late Hypsithermal confluence with the Donjek Glacier to its Neoglacial position 15 miles up the Donjek River Valley. This amount of retreat is considerably greater than that indicated for the Donjek Glacier in the same period. Part of the explanation lies in the fact that the Kluane Glacier was relatively thin at the time of its confluence with the Donjek Glacier and a period of negative mass budget in the late Hypsithermal would result in considerably greater retreat. The second question raised is that of the apparent difference between the Donjek Glacier and the Kaskawulsh Glacier during the Hypsithermal[1,5]. Indications that the Kaskawulsh Glacier retreated about 15 miles above its present terminus help to strengthen the hypothesis of the Kluane Glacier retreat but emphasise the lack of evidence for a Donjek Glacier retreat of similar proportions. It is possible that most of the evidence for the Donjek Glacier retreat was destroyed by the Neoglacial advance. As no evidence was found for the extent of the retreat of the Donjek and Kluane Glaciers in the Hypsithermal it is impossible to consider if their amounts of Neoglacial advance correlate with that demonstrated for the Kaskawulsh Glacier.

A rapid retreat of the Kluane Glacier compared with the Donjek Glacier in the late Hypsithermal would help to explain the formation of the Donjek River gorges along the northeast side of the valley adjacent to the Donjek Glacier terminus (Fig. 2). The Donjek River would have been swollen by the considerable volumes of meltwater from the ablating Kluane Glacier and a stable Donjek Glacier position would have restricted this meltwater to the northeast side of the valley. If the Donjek Glacier had retreated into the glacier valley the meltwater from the Kluane Glacier would have taken the easier route across the ablation drift at the confluence of the two valleys. The complexity of the network of river channels indicates a number of periods of formation which may have been due to fluctuations of the Donjek Glacier terminus. Drainage changes have occurred over the last 35 years with periods of surge and ablation of the Donjek Glacier and it is thought that similar late Hypsithermal fluctuations may have been responsible for the formation of the gorges.

It is considered that there is evidence for a stable phase of the Donjek and Kluane Glaciers late in the Hypsithermal period. This position is down valley of the Neoglacial maximum position which contrasts with the documented situation in the Kaskawulsh Valley. Late in the Hypsithermal the glaciers retreated from this stable position, the Kluane Glacier retreating to a Neoglacial position 15 miles up valley and the Donjek Glacier apparently retreating only a short distance before readvancing to its Neoglacial maximum position.

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P. G. Johnson
Department of Geography,
University of Ottawa,
Canada.

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The Simulation of Subsurface Effects on the Diurnal Surface Thermal Regime in Cold Regions

BACKGROUND

Layered substrate materials are common in nature; these include naturally stratified soils, ice and snow. In addition solar radiation penetrates the surface and produces subsurface heating in snow and ice terrain. The stratification problem has been treated by numerous authors as variation of the periodic heat flow problem using surface temperature as the forcing function[1,2]. Maykut and Untersteiner[3] have also treated the problem of radiation penetration in their thermodynamic model of arctic sea ice.

In recent years there has been a considerable interest in the possibility of acquiring surface environmental information using the spatial variance in the phase and amplitude of the diurnal surface thermal regime as an indicator. The most promising data acquisition system for such an undertaking is the thermal mapping of terrain from stiff-winged aircraft at several intervals during the diurnal cycle. This type of information and its analysis have been selected as a priority area for the application of remote sensing technology[4].