placed the andesite-diabase sill in limestone of the Lisburne Group 1.5 km to the southwest (fig. 11, loc. 4) (Keller and others, 1961).

The other known occurrence of upper Paleozoic volcanogenic rocks in this region is marked by several outcrops in an area approximately 14 km south of Anaktuvuk Pass on the headwaters of the John River (fig. 11, loc. 5). The volcanogenic rocks are tightly folded and faulted along with the enclosing shale and limestone. The exposed sequence is probably not more than 30 m thick, ranges from tuff to pebble and boulder conglomerate, and locally includes tuffaceous limestone. Although no flow rock was found in place, several pieces of vesicular, highly chloritized basaltic(?) andesite were seen in the scree. The tuffs are massive to schistose, and most of the original minerals are thoroughly chloritized and altered to clay so that only rare relict fragmentary plagioclase and clinopyroxene are preserved. On the basis of available evidence, the volcanic rocks were originally andesite to basaltic andesite. Although lithologically similar to the volcanogenic sequences previously described, the sequence at Anaktuvuk Pass is older. It occurs in the Lower Mississippian Kayak Shale, encloses small boudins of fossiliferous Lower Mississippian limestone, and locally contains blastoids in calcareous tuff. The occurrence of the productids *Orbinaria* and *Pustula* together with other macrofossils strongly indicates an Early Mississippian, probably late Kinderhookian, age.

Thus it is now known that volcanogenic rocks of Early Mississippian, Late Mississippian, and Late Permian age are present in central and eastern Brooks Range.

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Late Cenozoic glaciations and erosion intervals, north-central Brooks Range

By Thomas D. Hamilton

Drift sheets and erosion surfaces in the Anaktuvuk River region document four successive drift complexes of late Tertiary and Pleistocene glaciation that followed and were separated by long-lasting intervals of widespread river planation (table 1). The oldest surface, 135–165 m above modern flood plains, truncates bedrock and bears a gravel cap as thick as 10 m. Although large erratic boulders are absent, abundant large cobbles and very small boulders indicate high transport energy and are similar in shape and composition to stones in Pleistocene outwash derived from the Brooks Range.

The oldest drift and landforms possibly created by glacial abrasion occur near Gunsight Mountain in areas clearly beyond the limits of the Anaktuvuk River Glaciation mapped by Detterman, Bickel, and Gryc (1963). These deposits, here informally termed Gunsight Mountain drift, may represent either one or several individual glaciations. Erratic boulders of probably correlative age are scattered across erosion surfaces 75–100 m high south and southwest of Gunsight Mountain. Exposures typically exhibit truncated bedrock capped with alluvium that contains residual erratics and is overlain in turn by loess. Distribution of the Gunsight Mountain drift and of the erosion surfaces that formed before and after glaciation reflect drainage patterns appreciably different from those of the present. Chandler River flowed northeast as a tributary to the Anaktuvuk River at that time, and Nanushuk River flowed northeast as a tributary to the Itkillik.

The symmetrical placement of drift of the Anaktuvuk River Glaciation within modern river valleys indicates that major drainage patterns had evolved to essentially their present configuration by the time of this glacial advance. Along Anaktuvuk valley, Anaktuvuk River drift has been eroded to a width of 5.5 km by streams flowing at a level about 60 m above the modern flood plain. Comparable erosion surfaces, 45–65 m above modern stream levels, dissect Anaktuvuk River drift in valleys farther to the east and west.

Drift of the Sagavanirktok River Glaciation lies nested within Anaktuvuk River moraines. It

TABLE 1.—*Late Cenozoic glacial succession, Anaktuvuk River region*

	Porter (1964)	This paper
Neoglaciation	Fan Mountain Glaciation	Fan Mountain Glaciation
	Alapah Mountain Glaciation	------------
Itkillik Glaciation	Anivik Lake Stade	------------
	----------------	Late Itkillik readvance
	Antler Valley Stade	Itkillik II
	Anayaknaurak Stade	------------
	Banded Mountain Stade	Itkillik I
	------------------	Early Itkillik(?)

extends to within 35–45 m of modern floodplain levels in Anaktuvuk valley, where it appears to form two distinct sheets that subsequently have been eroded to widths of about 4.5 and 3.0 km. As at its type locality along the Sagavanirktok River, 100 km east of Anaktuvuk valley (Hamilton, 1978), the Sagavanirktok River drift forms two surfaces that contrast in postglacial modification and possibly were separated by an interglacial rather than interstadial interval. In smaller valleys farther to the west and east, Sagavanirktok River drift appears to form only a single body and is associated with outwash trains that stand 20–25 m above modern stream levels.

Deposits of the Itkillik Glaciation, of late Quaternary age, occupy modern valley floors and are less modified than Sagavanirktok River drift. Itkillik drift sheets are divisible into two principal subunits, Itkillik I and Itkillik II, throughout the central Brooks Range (Hamilton and Porter, 1975). Itkillik I end moraines are relatively subdued in appearance and are dissected by axial streams, which commonly have cut about 15 m into underlying bedrock. The moraines almost entirely overlapped a somewhat older drift of presumed early Itkillik age that still was ice cored at the time of the Itkillik I glacial advance. The less extensive Itkillik II moraines are morphologically fresh and appear to be still ice cored in parts of the Anaktuvuk and Nigu valleys and near Natvakruak Lake. This advance was followed by a readvance into lake deposits that formed behind Itkillik II moraines, and then by a long interval of ice downwastage and stagnation within major valleys of the Brooks Range.

Detailed studies of type localities within the Anaktuvuk valley indicate that substantial revisions are necessary in the late Quaternary glacial sequence developed by Detterman, Bowsher, and Dutro (1958) and later modified by Porter (1964). The Itkillik Glaciation appears to consist of three or four separate advances, only two of which coincide with Itkillik events defined by Porter (tables 1, 2). Porter's Anayaknaurak Stade is deleted because the type locality for its drift exhibits diamicton of probable colluvial rather than glacial origin. This deposit formed along an eroding cut bank that intersected till of Itkillik I age and caused it to flow downslope under gravity. Type deposits for Porter's Anivik Lake Stade are now considered to be part of an extensive complex of subglacial meltwater deposits that formed during widespread stagnation and downwasting of late Itkillik ice. They do not represent a distinct glacial readvance. Moraines that comprise the deposits at the type locality of the Alapah Mountain Glaciation of Detterman and his coworkers are impressive lateral moraines of late Itkillik age that terminate at the former interface between stagnating glacier ice in the upper Anaktuvuk Valley and still-active tributary ice streams originating in high-altitude cirques near the Continental Divide.

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Record of a prehistoric storm surge in the Wainwright Inlet-Kuk River area

By D. M. Hopkins, R. W. Hartz, and S. W. Robinson

Storm surges along the Beaufort and northern Chukchi Sea coasts have occasionally reached heights of 3 m above mean sea level during the present century (Aagard, 1978; Reimnitz and Maurer, 1978). The frequency of these events is not yet known, nor has there been evidence that

TABLE 2.—*Late Quaternary glacial succession, Anaktuvuk valley*

Age	Glaciation	
Holocene	Fan Mountain Glaciation	
Late Pleistocene	Late Itkillik Itkillik II Itkillik I Early Itkillik(?)	Itkillik Glaciation
35-45 m surface		
Middle Pleistocene	Sagavanirktok River II Sagavanirktok River I	Sagavanirktok River Glaciation
45-65 m surface		
Early Pleistocene	Anaktuvuk River Glaciation	
75-100 m surface		
Late Tertiary(?)	Gunsight Mountain drift	
135-165 m surface		