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GLACIAL CHRONOLOGY OF ULLSFJORD, NORTHERN NORWAY

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Abstract.—Quaternary features of Ullsfjord record Late Glacial fluctuations of the Fennoscandian ice sheet and of local alpine glaciers. The earliest known advance left erratics and subdued moraines near the coast. The subsequent Breidvika advance formed lateral moraines which continue into the sea as sharp submarine end moraines. Shortly thereafter the Skardmunken advance also resulted in moraines with both terrestrial and marine facies. Radiocarbon dates of marine shells place the Skardmunken maximum between 11,500 and 10,390 years B.P. (late Allerød and Younger Dryas time). A nearly continuous beach level, probably the "main beach level" of northern Norway, is cut in bedrock and unconsolidated materials from the outer coast to the top of the deltaic sediments of the Skardmunken moraine. Shortly after the Skardmunken advance, the Stordal advance left small moraines and deltas at a level slightly below the projection of the "main beach level." Lastly, cirque glaciers deposited steep unweathered moraines in historic time.

Ullsfjord is a deep, narrow trough with a total length of 50 kilometers, a maximum width of 5 kilometers, and a maximum relief of nearly 1,700 meters. In places the sides are so steep that no surficial deposits remain. The fiord was eroded along the contact between gabbroic rocks that make up the high, spectacular Lyngen Alps, and schistose rocks that form the slightly lower alpine peaks to the west. Scores of mountain glaciers originated in these mountains during the Pleistocene, and many cirques are still filled with ice. Narrow structural valleys connect Ullsfjord with fiords to the east, west, and south. These troughs were access routes for outlet glaciers of the Fennoscandian ice sheet that invaded the fiord in Pleistocene time. The bottom of the fiord is very irregular, as a result of bedrock relief and glacial deposition. Depths range from about 11 meters over submarine moraines, to 268 meters in the outer fiord.

Although Ullsfjord lies well above the Arctic Circle, its climate is humid temperate, very similar to that of southern Alaska (Haurwitz and Austin, 1944). The nearest weather station, at Tromsø, 25 kilometers to the west, has a mean annual temperature of 2.3°C and a mean annual precipitation of 940 mm (Hansen, 1960, p. 46-47).

The glacial record in Ullsfjord is typical of northern Norway. Our studies show that the glacial sequence consists of (1) an unnamed early glaciation, (2) the Breidvika advance, (3) the Skardmunken advance, (4) the Stordal advance, and (5) a Recent advance (see accompanying table and fig. 154.1). One important basis for this chronology is the prominent elevated shoreline (informally referred to here as the "main beach level") that was formed at the time of the

Glacial chronology of Ullsfjord

Glaciation	Age	Correlation	Basis for correlation
Recent	18th Century.	"Little Ice Age."	Near or in contact with existing glaciers.
Stordal	Slightly younger than Skardmunken.	Possibly Preboreal.	Moraines are behind and (or) at lower levels than Skardmunken ice margins.
Skardmunken	11,500-10,390 years.	Equivalent to Tromsø-Lyngen advance of northern Norway.	Radiocarbon dates are approximately the same as the Tromsø-Lyngen moraines. Moraines graded to "main beach level."
Breidvika	Slightly older than Skardmunken.	Possibly equivalent to Skarpmes advance of northern Norway.	Moraine position is a short distance beyond Skardmunken moraines. Moraines truncated by "main beach level."
Early	Somewhat older than Breidvika.	Possibly equivalent to one or more older advances in southern Norway.	Drift occurs seaward of Breidvika moraines.



FIGURE 154.1.—Glacial and marine deposits near Ullsfjord, northern Norway. A-A', line of profile shown in figure 154.2, large dots in Ullsfjord are projections of points on the shores where the "main beach level" was measured.

EXPLANATION

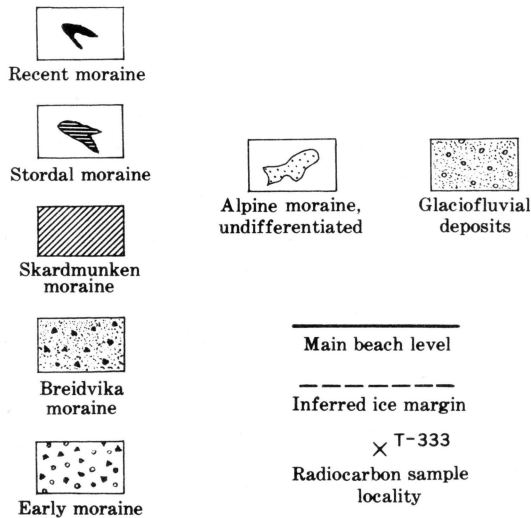


FIGURE 154.1.—Continued

Skardmunken glaciation, between 11,500 and 10,390 years B.P., according to radiocarbon dates. Some moraines in the mountains are not clearly related to datable features and are designated only as alpine moraines, undifferentiated.

SHORELINES

Elevated, tilted Pleistocene shorelines in northern Norway were first recognized by Bravais in 1838 (Marthinussen, 1960, p. 416) in Altafjord, about 100 kilometers east of Ullsfjord. Their discovery created a basis for the theory of isostatic recovery of glaciated terrain. These shorelines were formed at times when sea level was nearly constant, which in late Pleistocene time probably corresponded to intervals when the sea and the land were rising at the same rate.

The most distinct shoreline in Ullsfjord is informally named the "main beach level." It is nearly continuous from the outer fiord, where it is about 35 meters above sea level, to a few kilometers south of Skardmunken, where it is about 70 meters above sea level. The "main beach level" is cut in bedrock, older moraines, marine till, and gravel deposits. It is about the same age as the Skardmunken moraine, for (1) it is graded to the top of that moraine at about the level that separates the terrestrial and marine portions; (2) it is graded to extensive Skardmunken outwash deposits west of Breidvika; and (3) it does not extend far beyond the Skardmunken moraine, indicating that ice of this advance filled the inner fiord while the shoreline was being cut.

Shorelines related to other glaciations are limited in extent, and are marked primarily by deltas. Sea level was probably changing too rapidly during these in-

tervals to create a persistent shoreline. A distinct lower shoreline formed after the "main beach level," but it apparently is not related to a glacial advance and merely represents a second period of sea-level stability.

GLACIATION

Early glaciation

The oldest recorded glaciation left scattered erratics, patches of till, a few indistinct moraines, and drainage channels in the northern part of the fiord district. The most distinct feature is a broad moraine that dams Trollvann in the northwestern part of the mapped area. The ice sheet that deposited this drift probably extended north of the present shoreline and covered the continental shelf. The age of this glaciation is not known, but the drift occupies a position analogous to that of the Lista substage, of Oldest Dryas age (more than 13,000 years old), or the Spangereid substage (dated about 13,000 years B.P.) (Andersen, report in preparation).

Breidvika glaciation

The oldest glaciation in Ullsfjord which left large well-preserved moraines is here named informally the Breidvika advance, for the cove on the west side of the fiord. The largest Fennoscandian outlet glacier moved northward and terminated in the sea just south of Breidvika, leaving a prominent lateral moraine on the east side of the fiord and a small segment on the steeper west side. Profiles of the lateral moraine on the east side of the fiord (fig. 154.2) show that the ice sloped steeply toward its terminus in the fiord.

Echo soundings show a very sharp double ridge (fig. 154.2) on the fiord bottom with a relief of approximately 38 meters. A western arm of this glacier pushed westward out of the fiord, turned north, entered a parallel valley, and deposited a prominent terrestrial end moraine.

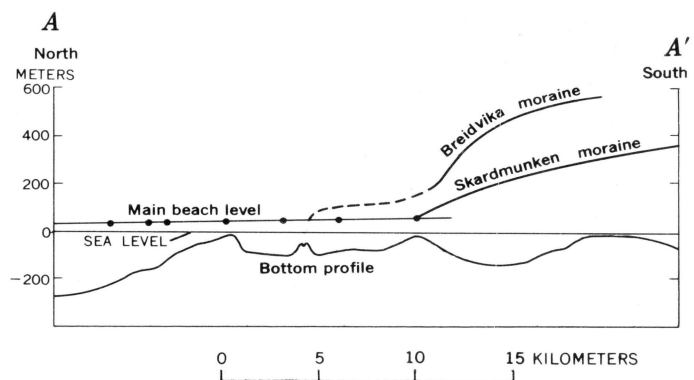


FIGURE 154.2.—Profiles of prominent moraines, shorelines, and submarine ridges in the main part of Ullsfjord. Large dots are projections of points on the shores where the "main beach level" was measured. Location of profile shown in figure 154.1.

A second large glacier moved westward from Lyngenfjord (east of the mapped area) and the Lyngen Alps down the east arm of the fiord, leaving a smaller pair of lateral ridges and a submarine ridge with a maximum relief of approximately 45 meters (fig. 154.1). The echo profile of this ridge shows many smaller ridges on the east (upglacier) side, but not a sharp reverse slope in that direction.

The age of the Breidvika glaciation is not known. Its moraines appear to be only a little older than the succeeding (Skardmunken) glaciation, and related shorelines are only 2 to 4 meters above the "main beach level," which is roughly the same age as the Skardmunken glaciation. Also, the Breidvika moraines occupy positions analogous to the Skarpnes moraine near Tromsø to the west, which is regarded to be somewhat older than Younger Dryas (Andersen, report in preparation), that is, the age of the Skardmunken glaciation.

Skardmunken glaciation

The best preserved moraine in Ullsfjord is here named informally for the settlement on the terminal section. This part of the moraine was deposited in the sea and consists of stratified drift displaying foreset bedding which was smoothly planed by subsequent wave action. The submarine part is a smooth ridge crossing the fiord; it is being reworked by strong tidal currents.

The terminal section merges with a large terrestrial lateral moraine on the east side of the fiord. This lateral moraine, which in places branches into several ridges, extends southward for a distance of about 9 kilometers. The glacier that formed this moraine also pushed into the valley joining the fiord on the west. However, ice of this glaciation did not leave a clear record in the east arm of the fiord. A terrestrial moraine of this glaciation was also deposited in the broad trough west of Breidvika by ice which moved from adjoining Balsfjord. Glaciofluvial deposits spread down the valley from this moraine and merged with the "main beach level" along the shores of Ullsfjord.

A minimum and probably close radiocarbon date of 10,390 years B.P. (T-333, Trondheim Radiological Dating Laboratory, 1962) for the Skardmunken moraine was obtained from mollusk shells (*Macoma calcarea*(?), *Saxicava arctica*(?), and *Mya truncata*(?)). The shells were collected from varved north-dipping sandy marine clay on the proximal side of the end moraine, lying about 30 to 40 meters above sea level and overlying coarse stratified south-dipping drift. The date probably corresponds to the beginning of the retreat of the Skardmunken glacier.

Shells of *Portlandia arctica* and *Macoma calcarea* (T-110) collected near the top of pebbly glaciomarine clay beds which underlie outwash of Skardmunken age in the valley west of Breidvika (fig. 154.1) were dated at $11,500 \pm 400$ years B.P. The lithology and date of the shell-bearing material suggest it was deposited in a glacial environment immediately before the maximum of the Skardmunken advance.

Marine till on the east side of Ullsfjord opposite Breidvika, although not demonstrably related to the Skardmunken moraine, is somewhat younger than the glaciomarine clay west of Breidvika. Shells in the former (*Saxicava arctica*, *Macoma calcarea*, and *Mya truncata*, T-332) have a radiocarbon date of $11,090 \pm 190$ years B.P. On the basis of the first two dates, the Skardmunken advance occurred between about 11,500 and 10,390 years B.P., or at approximately the same time as the Tromsø-Lyngen maximum in adjoining fiords (Andersen, report in preparation). These dates span late Allerød and Younger Dryas time in southern Scandinavia (Flint, 1957, p. 397).

Stordal glaciation

Distinct end moraines occur behind Skardmunken moraines in several valleys, in some places in groups of two or more; none are associated with present glaciers. These minor readvances are here named informally for Stordal, a tributary valley on the west side of the inner fiord. Here is a small but distinct end moraine, at an elevation of about 70 meters, well below the projected level of the Skardmunken glacier and at about the same level as the oldest elevated shoreline in the inner part of the fiord. Similar moraines occur behind terrace-dated Skardmunken moraines in the northeastern corner of the mapped area. The outwash delta from the type Stordal moraine, graded to the oldest elevated marine terrace in the inner part of the fiord, is only about 5 meters below the "main beach level." Thus this advance occurred shortly after the Skardmunken glaciation and is possibly Pre-Boreal in age.

Recent glaciation

Nearly all the existing glaciers are fronted by small, steep, bouldery, unweathered moraines. These are similar to modern moraines found in most alpine environments throughout the Northern Hemisphere. Although it is generally held that Recent moraines are not necessarily of precisely the same age, those in northern Scandinavia probably formed in the 18th century, as suggested by historical records in Norway (Liestøl, 1960, p. 487).

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