Short Papers and Notes

ICING MOUND ON SADLEROCHIT RIVER, ALASKA*

Icing mounds — small to large domes, mounds, and ridges resulting from an upward arching of soil and ice associated with fields of aufeis — have been described in detail for Siberia[1]. Icing mounds have also been mentioned briefly in connection with aufeis fields in Alaska by Leffingwell (ref. 2, p. 158) and Taber (ref. 3, p. 1528; ref. 4, p. 249), but there is little descriptive literature on this phenomenon in the North American Arctic. One such icing mound was examined briefly by the author on June 25, 1959 during the course of a trip down the Sadlerochit River in northeastern Alaska (Fig. 1).

Sadlerochit has emerged from the mountains, has a relatively low gradient and flows in a broad, braided bed characterized by many anastomosing shallow channels separated by bare, gravelly and bouldery bars (Fig. 2). As is characteristic of all rivers of the Arctic Slope, the change from a single deep channel to a braided pattern of many shallow channels allows the formation of an aufeis field every year near the mountain front. During the fall the shallow channels freeze early and the obstruction of the resulting ice causes the river to overflow its bars; this overflow then freezes and by repeated freezing, overflow and freezing successive layers of ice are built up to form an aufeis field. Another factor contributing

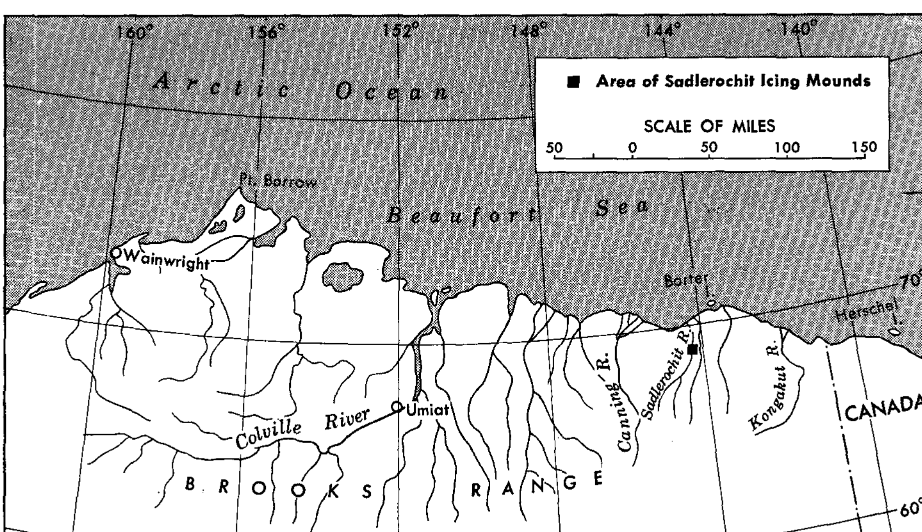

Fig. 1. Location map, Arctic Slope, Alaska.

The Sadlerochit River rises in the Franklin Mountains of the eastern Brooks Range and flows northward in a relatively broad, shallow valley through foothills and coastal plain to the Arctic Ocean. At approximately 69°50'N. the

to the formation of large aufeis fields is a source of water that persists for some time after freezing begins. Because a major tributary of the river has its source in large, deep lakes (Lake Peters and Schrader Lake) and other tributaries may be spring fed, the Sadlerochit River continues to flow long after freezing begins each fall.

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In late June 1959 patches of ice as much as 8 feet thick and low ice-shoved ridges remained from the extensive aufeis field that had filled the active bed of the river during the preceding winter. A channel-scarred low terrace that lies several feet above the river bars consists of gravelly and bouldery alluvium with a veneer of organic silt and fine sand. The flood-plain alluvium is covered by water during normal high-water stages and by aufeis in the winter; the low terrace is rarely flooded and is generally free of aufeis. The wide gravelly high terrace that flanks the low terrace on the west has to the south a separate aufeis field built by a spring-fed tributary, which parallels the Sadlerochit River. This high terrace stands about 15 feet above the river level. The Sadlerochit valley is bordered on the east by a 30-foot escarpment marking the edge of a high bouldery terrace, which is probably formed of glacial

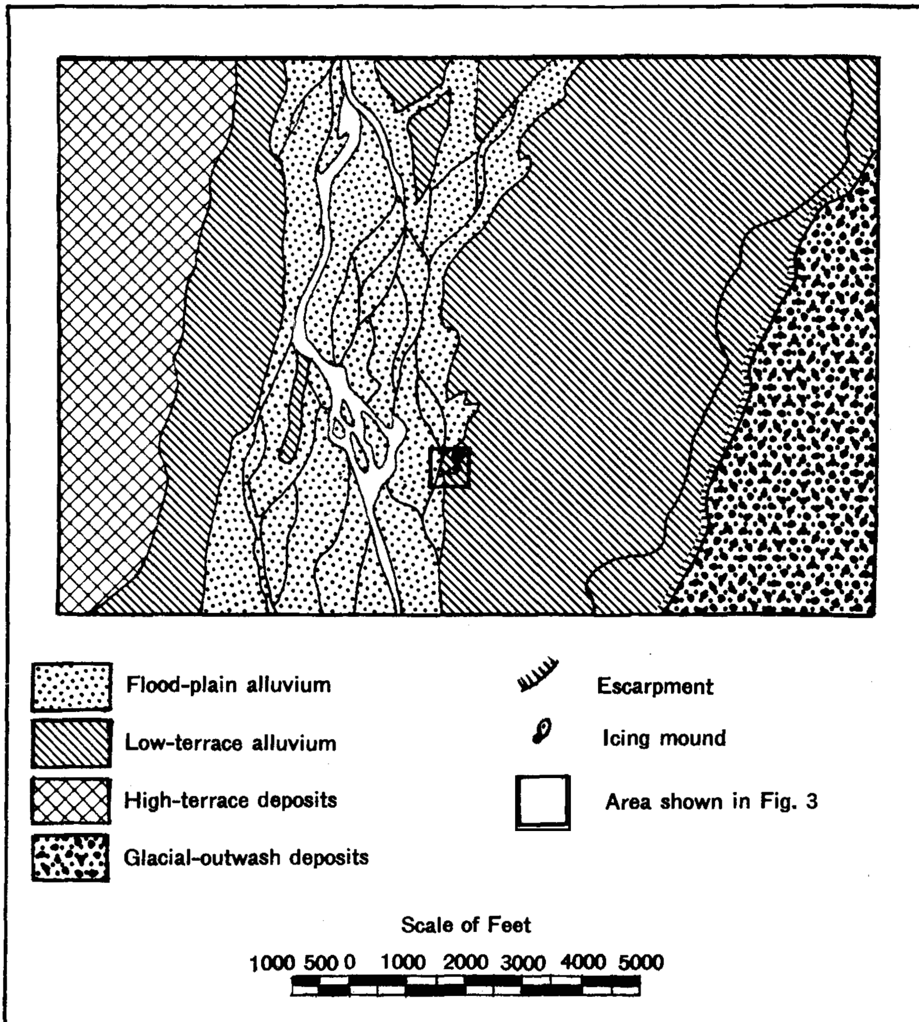

Fig. 2. Surficial geology of Sadlerochit River valley in vicinity of icing mound.

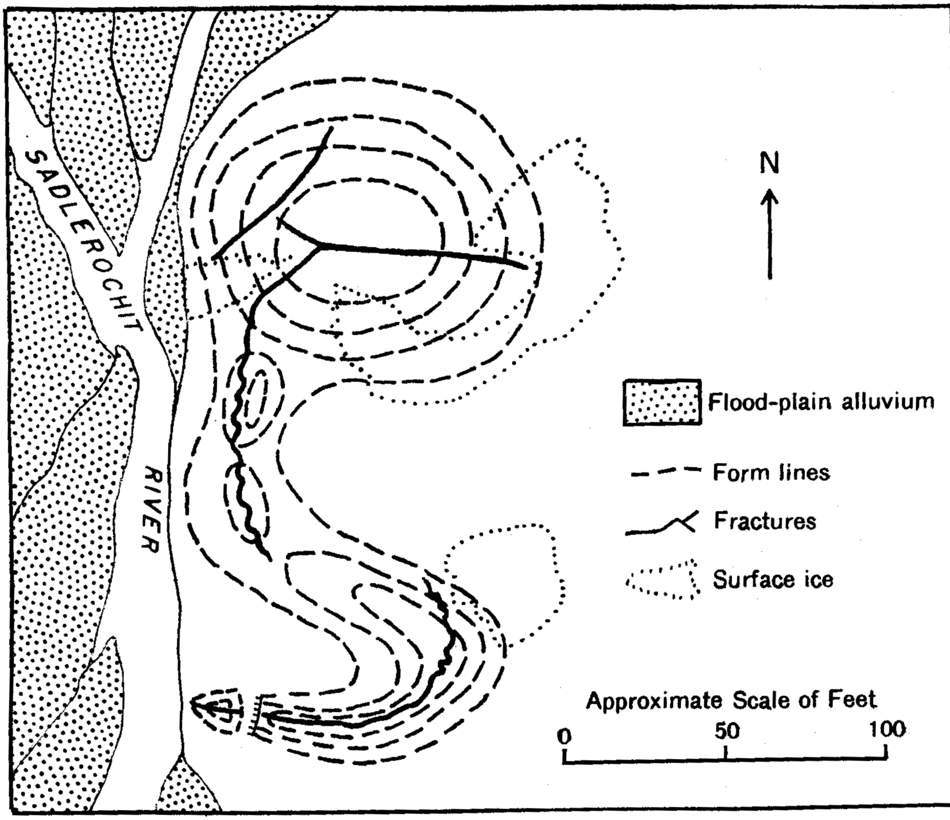

Fig. 3. Field sketch of icing mound.

outwash deposits. The entire area is well within the zone of continuous permafrost; depth of seasonal thaw ranges from about 18 to 24 inches near the coast to about 3 feet in the foothills.

The icing mound occurred at the inner edge of the low terrace adjacent to the aufeis field along the east side of the river (Fig. 3). It consisted of a sinuous ridge about 250 feet long, which terminated in a low dome about 20 feet high at the north end and in a lower pointed "tail" at the south end (Fig. 4). A part of the "tail", which was immediately adjacent to a then active river channel, had collapsed and revealed an underlying layer of ice. The ridge was broken by several shallow cracks along the crest; elsewhere the slopes were smooth. The vegetation on the mound as well as on the flood plain was predominantly cottongrass. The flanks of the mound were in places still covered with patches of surface ice.

The exposed ground ice was generally a very clear, white, sharply folded tabular mass approximately 4 feet thick (Fig. 5). It appeared to be of uniform thickness although there may have been a slight thickening near the apex of the fold. The ice was characterized by a well-developed vertical columnar structure, which was accentuated by melting. The ice was overlain by 2 feet of dark-grey, highly organic silt and fine sand. The contact between the ice and silt was minutely irregular; the bottom surface of the ice was generally smooth. The exposed face of the ice was mostly clean and there had been no appreciable slumping of the silt. At this date the ground was still frozen about 6 inches below the surface. Underneath the ice was a flat-floored vaulted cavity

10 to 12 feet high; the floor of the cavity was covered by a shallow pool below which there appeared to be silt and gravel. The pool was being fed by seepage from the river as well as by melting of the ice. The apparent freshness of the mound and cracks, and the fact that last season's (1958) cottongrass was normal to the surface of the mound rather than vertical seemed to indicate that the feature was formed during the preceding fall or winter. Several other low mounds, seen only at a distance, occurred in the vicinity of the aufeis field and were assumed to be similar to the one examined.

The occurrence of pingos and other ice mounds has long been noted in arctic Alaska and their localization in areas of relatively deep thaw, such as recently drained lake basins and deltas, is well established. The mechanics of the formation of such mounds, however, have been subject to divers views. Leffingwell (ref. 2, pp. 150-5) and later writers have ascribed the growth of ice mounds in northern Alaska to hydrostatic pressure operating at frost dams; Porsild (ref. 5, p. 55) in reviewing similar mounds suggested that the formation of many pingos is caused by expansion during freezing of localized ground water below drained lake beds; Sharp (ref. 6, p. 421) believed that the formation of some small Alaskan ice mounds was due to the growth of ground ice fed by seepage in the active zone; Sumgin (quoted in ref. 1, pp. 111-5) attributed the heaving of icing mounds both to forces produced by the growth of ground ice and to hydrostatic pressures; Taber (ref. 3, p. 1528) held that most ice-mound uplift was caused by the force of crystallization in ground-ice

Fig. 4. View south, showing sinuous form of icing mound. Brooks Range in background.

Origin

The uplift of the icing mound is considered to be related to the formation of ground ice. That the ground ice represents buried lake or river ice is discounted because (1) the minutely irregular upper surface of the ice indicated a growing upward of ice crystals into the overlying silt and (2) the banding that is such a prominent feature of aufeis was lacking in this ground ice.

layers. More recently, Müller (ref. 7, pp. 56-70, 97-101) distinguished two major mechanisms that produce pingos: one involving primarily hydrostatic pressure in an open system, as in East Greenland pingos; and a second involving crystallization pressures accompanying an advance of permafrost into intra-permafrost ground water in a closed system below lake beds, as in the Mackenzie Delta. Although Müller restricts the term "pingo" to mounds that are caused by forces operating within permafrost in contrast to icing mounds that are formed entirely within the active zone, similar forces are probably involved in both. The author believes that the Sadlerochit icing mound showed evidence that uplift involved both cryostatic pressures accompanying growth of a ground-ice lens and later hydrostatic pressures accompanying a restriction of ground-water flow.

During icing of the Sadlerochit River in the preceding fall, overflow from the river seeped through permeable alluvial gravel of a meander channel buried by silt. This seepage provided an abundant local source of water for the growth of ground ice. As freezing in the active zone proceeded downward ground ice grew in the organic silt. That the ground ice was localized was indicated by the absence of any depression around the uplifted area and by a general lack of thermokarst features and patterned ground in the low terrace. Localization may have been caused by several factors: greater permeability of the gravel in buried meander channels may have allowed a flow of ground water sufficient to keep the channel unfrozen longer than the surrounding area; furthermore, the merging of the frozen active zone and permafrost may have occured sooner in the area adjacent to the mound because of a difference in degree of heat conductivity between these areas. Growth of the ground ice continued as long as water was available or until the water-bearing gravels were completely frozen.

Fig. 5. Folded ground-ice lens revealed by collapse of part of icing mound. Fracture at apex is being enlarged by melting.

Growth of the ground ice proceeded by continuous growth of ice crystals fed by water from below. That the growth of the ice was not by the formation of successive ice layers or wedges was shown by the lack of banding in the ice. During the initial stage, forces accompanying the formation of ice —

either the force of crystallization or the force of expansion — caused doming of the ice lens and overlying silt. Yielding was upward because of the direction of crystal growth (ref. 3, p. 1528) or because expansion forces were confined by adjacent frozen ground (Sumgin, ref. 1, pp. 111-5) and in part perhaps by aufeis. At a later stage accumulated lateral as well as vertical stresses formed by the growth of ice from below rather than from above may have reached a point where the final uplift of the mound and concurrent cracking along the apex occurred explosively. The fact that the exposed ice layer appears to be sharply bent rather than gently domed suggests that uplift was violent. Such violent explosive heaving of ice mounds in other parts of the Arctic have been noted by Chekotillo (ref. 1, p. 123), Taber (ref. 4, p. 249), and others.

In the final uplift of the mound hydrostatic pressure may also have played a part as suggested by Taber (ref. 4, p. 249) and Sumgin (ref. 1, pp. 11-5). The formation of aufeis in the river bed below the site of the mound may have formed an ice dam, which restricted and eventually stopped the flow of water through the meander channel. Any water that may have continued to flow into the cavity may have been trapped between the ground-ice lens and the permafrost and the resulting pressure helped to raise the mound and cause fracturing of the ice and frozen silt. Some of the ice around the periphery of the northern part of the mound may be the remnants of icing formed from outflow from the fractures.

The Sadlerochit icing mound is probably ephemeral; when seen, part of the mound had already collapsed and the ice lens was melting slowly. Furthermore, a slight rise in river level would allow water to flow through the cavity and hasten collapse of the mound. Aerial photographs taken 9 years before show the suggestion of a mound in this location, however; thus the old meander channel may be a site of recurring ground-ice formation. Because of wide-spread general similarity of hydrologic and geologic conditions in the valleys of most major rivers, icing mounds may be expected to occur frequently in association with aufeis fields on the Arctic Slope of Alaska.

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[1]Chekotillo, A. M. 1940. Naledi y borba s nimi (Icings and countermeasures). Dor. Izdat. NKVD, SSSR, Moscow. 133 pp. (Detailed abstract translated in Part II, Investigations of airfield drainage, arctic and subarctic regions, prep. by St. Anthony Falls Hydraulic Lab., Univ. of Minnesota for Office of the Chief of Engineers, U.S. Army. 1950, pp. 99-148).

[2]Leffingwell, E. de K. 1919. The Canning River region, northern Alaska. U.S. Geol. Surv. Prof. Paper 109, 251 pp.

[3]Taber, S. 1943. Perennially frozen ground in Alaska; its origin and history. Bull. Geol. Soc. Am. 54:1433-548.

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[5]Porsild, A. E. 1938. Earth mounds in unglaciated arctic northwestern America. Geog. Rev. 28:46-58.

[6]Sharp, R. P. 1942. Ground-ice mounds in tundra. Geog. Rev. 32:417-23.

[7]Müller, F. 1959. Beobachtungen über Pingos: Detailuntersuchungen in Ostgrönland und in der kanadischen Arktis. Medd. om Grønl. 153, 3, 127 pp. In German with English summary.

Correction. In redrafting the map on page 67 of No. 1, Vol. 15, three errors were introduced, which should be corrected as follows: for "Kong Oscar Fjord" read "Kong Oscars Fjord"; the altitude of Scheeles Bjerg should read 1180 m., not 1280 m.; the 1200-metre contour line surrounding the peak should be deleted. In the table on page 68 the following asterisks should be replaced by question marks: under Y 596, after "deltaic"; under Y 606, after "*Mya arenaria* L."; under Y 704, after "frost-worked".