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ABSTRACT

The Canning and Shaviovik River Aufeis Fields were studied on the ground and with aircraft data. Powdered calcium carbonate ($CaCO_3$) patches, a few cm in thickness, were found in discrete locations on both aufeis fields. This is indicative of chemical weathering of limestone bedrock which is known to underlie much of the eastern Arctic Coastal Plain of Alaska. Spring or river water which remains unfrozen throughout much of the winter carries $CaCO_3$ in solution; as the river ice freezes more deeply the $CaCO_3$ in solution is forced upwards through cracks in the river ice. Upon exposure to the cold air $CaCO_3$ is excluded as the water freezes, forming successive layers during aufeis growth. In the melt season $CaCO_3$ slush/powder accumulates in patches on top of the ice as the aufeis melts downward.

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Abundant evidence exists which documents the occurrence of mechanical weathering in the Arctic, but evidence for chemical weathering is much less apparent due to the lack of flowing water during much of the year and to cold temperatures which permit very low rates of degradation of organic matter to produce organic acids. Furthermore most weathering of rock material in cold regions has been thought to occur in the top few centimeters of the surface (Davies, 1969) as a result of freeze/thaw processes.

There is one type of weathering of which little mention has been made in the literature which contradicts some previously held beliefs about chemical weathering in Arctic regions. This is weathering of calcareous rock material by intrapermafrost spring water which remains unfrozen throughout the year. The surface manifestation is in the form of a white calcium carbonate ($CaCO_3$) powder/slush found on river icings or aufeis deposits. Aufeis is a unique type of ice which can form over an existing river ice cover in rivers underlain by impermeable material, in this case, permafrost. River or spring water is forced to the surface as river ice and the active layer coalesce upon freezing in a river bed.

In July, 1978 two melting aufeis fields on the Arctic Coastal Plain of Alaska were studied in the Canning and Shaviovik Rivers. A NASA Convair 990 aircraft was flown over the Arctic Coastal Plain of Alaska on July 12 for the purpose of studying various hydrologic features on the coastal plain using passive and active microwave aircraft and satellite data. Measurements from air photos taken from the Convair 990 revealed that the Shaviovik Aufeis was 1.8 square km in area and the Canning Aufeis was 4.5 square km in area on July 12. On July 15 a field party studied the Shaviovik Aufeis (Figure 1) on the ground. Accumulations of a white powdery material were found on and within the ablating ice (Figure 2). This powder was often found in association with hummocks in the ice, presumably at the point where water under pressure emerges to the surface during aufeis formation. Using x-ray diffraction analysis this material was later determined to be pure calcium carbonate ($CaCO_3$) which was carried upward in solution in spring or river water. $CaCO_3$ and other mineral salts have been noted on other aufeis fields (Williams and Van Everdingen, 1975; Webber and Klein, 1977; C. S. Benson, written comm., 1978).

This $CaCO_3$ material was also found in discrete locations on the Canning Aufeis field. The accumulations of $CaCO_3$ were generally a few cm in thickness and caused irregular ablation of the ice in their vicinity. At least four discrete locations of this material were observed on the Canning Aufeis. This material was also observed in calving ice on the edge of the aufeis field 18 cm below the surface of the ice which was approximately 1 m in thickness.

Limestone bedrock is present in the Canning River area of the coastal plain (Hopkins et al., 1955). Spring and river water, high in CO_2 due to its low temperature, flows through the rocks eroding limestone as it flows; the high CO_2 content in the water facilitates solution of the limestone. $CaCO_3$ in solution then flows to the surface under pressure. Water emanating from a spring freezes rapidly and the $CaCO_3$ and other material in solution is excluded during the freezing process. As the aufeis melts in the summer, this calcium carbonate is released into the river in the meltwater increasing the suspended sediment load in the water. Another mechanism for causing the presence of the $CaCO_3$ precipitate is downward freezing of river ice excluding impurities (of which $CaCO_3$ is one) as it freezes. These impurities become concentrated in the water remaining in the river channel (Benson, written comm., 1978). As this water is forced up under pressure, the water, with calcium carbonate in solution, freezes. If this is the case, then more $CaCO_3$ should occur in the top layers of aufeis because the top layers form last as successive overflows occur. As river ice continues to freeze downward the impurities become more concentrated in the water below.

Calcium carbonate is also significant in oceanography and glaciology. During aufeis melting, the $CaCO_3$ flows to the ocean during the summer providing a non-organic source of $CaCO_3$ to the Arctic Ocean. Dissolved calcium carbonate is of interest in chemical, biological and geochemical oceanography (Chen, 1978). The type of $CaCO_3$ discussed herein is unrelated to decomposition of organic matter which is the usual source of $CaCO_3$ in the oceans. This is another way in which $CaCO_3$ gets into the Arctic Ocean.

Calcium carbonate precipitate has been found beneath temperate glaciers (Hallett, 1976). $CaCO_3$ is dissolved from limestone bedrock in the regelation slip process which is characteristic of the flow of temperate glaciers. Subglacial limestone deposits play a dominant role in modifying the glacial bed and may actually impede basal sliding according to Hallett (1976). This is significant because it shows that glacio-chemical processes are operating at the base of glaciers. Erosion of calcareous rock material under snow drifts has also been studied in Arctic regions (Davies, 1969).

In conclusion it appears that even in the absence of much organic acid available to dissolve limestone in the Arctic, substantial erosion of limestone occurs as in humid regions. Limestone in Arctic and desert regions composes highlands or cliffs whereas in humid regions it forms lowlands because it is easily eroded by rainwater and runoff containing organic acids. Furthermore it appears that weathering of calcareous rock material by chemical processes is occurring at depth and that weathering is not restricted to freeze/thaw processes operating close to the surface.

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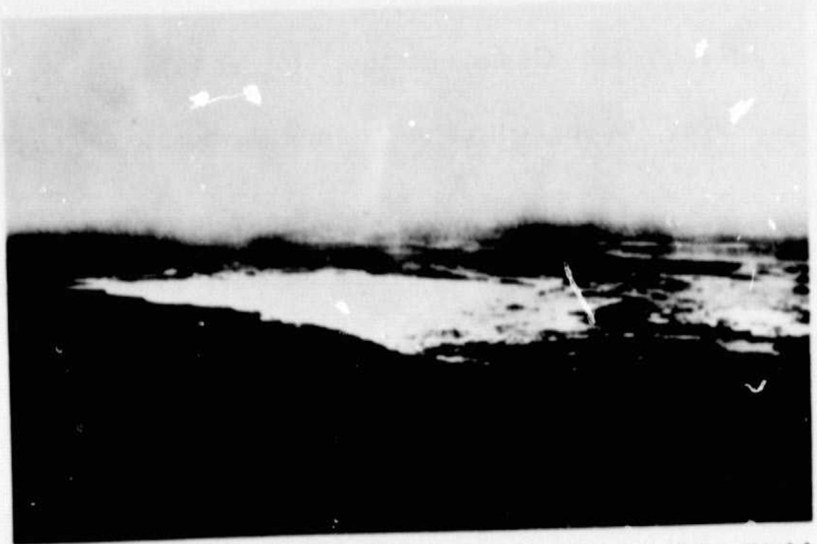

Figure 1. Air Photo of the Shaviovik River Aufeis Field on the Alaskan Arctic Coastal Plain, July 11, 1978.

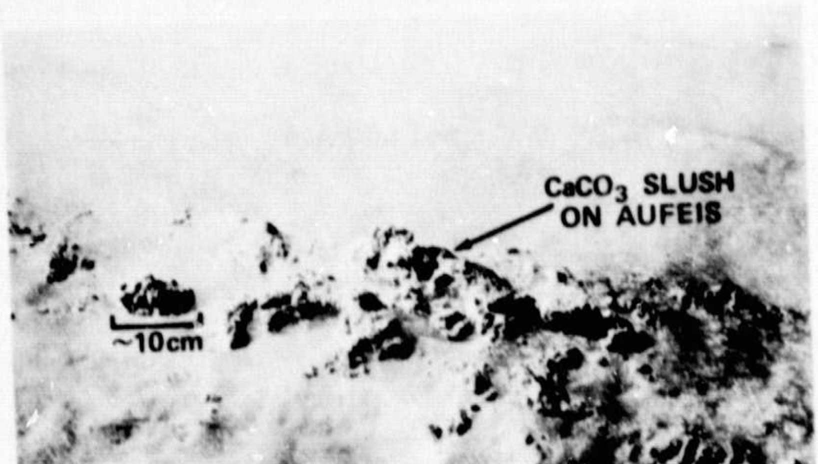

Figure 2. Calcium Carbonate Slush on the Shaviovik River Aufeis Field, July 15, 1978.