SHORTER CONTRIBUTIONS

PATTERNS IN POND ICE

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A curious cell-like partitioning of pond ice excited the interest of the first author during the course of a research project of the United States Navy. Fig. 1 is an aerial view illustrating the partitioning. The same phenomenon has been reported by Brunt (1946), but the authors are not aware of any other published accounts. The purpose of this note is to present observations of the phenomenon and to discuss briefly the underlying mechanism.

On 28 February and 1 March, 1946, these cell-like ice formations were seen on a great many ponds throughout the length of Long Island, New York, and along the coastal regions of the states of Connecticut and Rhode Island. However, some ponds did not exhibit the effect.

The convex appearance of some of the cell-like areas is probably due to a varying intensity of whiteness of the ice. The solar altitude was about 41°, and the azimuth was such as to preclude the possibility that the shadowing effects resulted from actual elevation of the ice.

The dark, elongated areas originating at some of the cell centers are probably open water. They are presumed to be due to wind-wave erosion, which in each case would naturally start in the open water at the cell centers. The long axis of these areas, bearing about 300° true, is probably parallel with the direction of the wind that formed them.

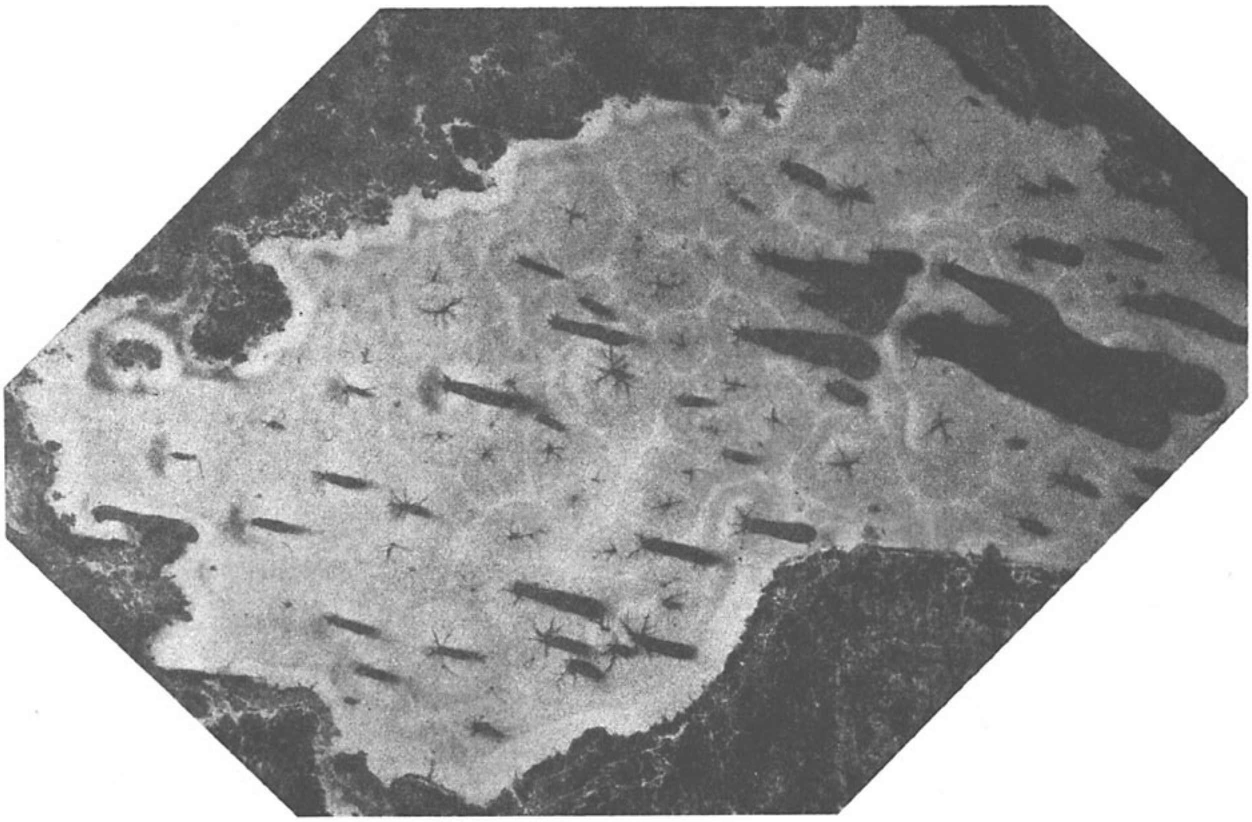

FIG. 1. Vertical photograph of ice-covered Grass Pond on 1 March 1946 from an altitude of 303 meters. The pond is located at lat. 40°53′00″N, long. 72°49′56″W, near River Head, Long Island, New York. North is toward the top of the page. The length of the pond on the east–west axis is 230 meters.

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The pond shown in fig. 1 was subsequently located from the ground on 14 September 1946. Water depth along three lines of soundings was 57 cm (±3 cm). The following additional notes were made at that time:

Inflow or outflow.—There was no readily visible flow of water to or from the pond.

Pond level.—Measurements of the height of clumps of vegetation identified in fig. 1 lead to the conclusion that the surface of the pond was not more than 36 cm higher on 1 March than on 14 September. It is unlikely that the surface was lower, because there was a rapid thawing of the snow cover during several days preceding 1 March.

The patterns that have been described suggest the existence of thermal convective cells under the ice. There is an extensive literature concerning convective cells set up experimentally in various fluids made thermally unstable (Bénard, 1900; Brunt, 1925; Chandra, 1938). These experiments have shown that, in the absence of general lateral flow, polygonal circulation patterns always occurred when sufficient thermal instability was maintained. Theoretical studies of these motions have been made by Rayleigh (1916), Low (1925), and Pellew and Southwell (1940).

There is a striking resemblance between the experimentally produced polygonal convective patterns and the observed ice patterns. Experimental cells (produced by Bénard, 1900, and others) were set in motion by heating the fluids from below. It is suggested that heating at the bottom of the pond shown in fig. 1 caused water motions which etched their pattern in the overlying ice by producing unequal melting.

Heating of lake water under ice has been shown by Fitzgerald (1895) and by Birge, Juday, and March (1927), who explain it as resulting from a flow of earth heat at the bottom and from absorption of solar radiation penetrating the ice cover.

Successive stages in the thermal history of the pond are suggested in fig. 2. The probable condition when the ice formed is assumed to be a uniform temperature of 0C, represented by the left-hand dashed line. In the next stage, warming at the bottom stabilizes the lowest layer until the temperature reaches 4C. Further heating decreases the density, releasing buoyancy forces which cause the bottom water to penetrate the stable layers above. Eventually the temperature of most of the water mass is raised to a point sufficiently above 4C so that mixing at the upper boundary of the isothermal layer produces water denser than that below. This is the condition (represented by the solid line in fig. 2) thought to exist while the differential melting occurs. The mixing region along the boundary between the stable and unstable water layers is thus brought up to a point just below the ice, so that further mixing produces melting by raising the temperature of the water in contact with the ice. Updrafts of unstable warmer water are marked by excessive melting of the ice; open water eventually appears in the centers, radiating lines showing where lateral divergent flow is producing continued melting. Eventually cooled by this process the water sinks, establishing a closed circulation characteristic of convective cells.

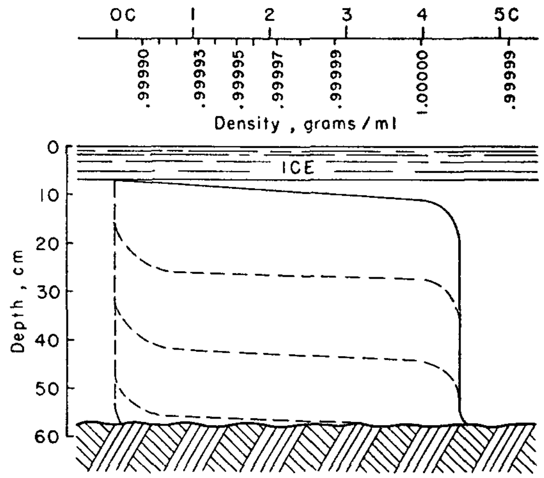

FIG. 2. Suggested vertical distributions of temperature and density.

Bénard (1900) and others have shown that, in experimental convective cells of polygonal form, the cell width is about three times the depth of the fluid layer. The patterns shown in fig. 1 were spaced at distances of ten to thirty times the probable depth of the water. Thus, if these patterns in ice result from convective cells in the underlying water, a different geometrical relationship is indicated.

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