SEA ICE THRUST STRUCTURES

By W. F. Weeks* and D. L. Anderson
(Geophysics Research Directorate, Air Force Cambridge Research Center, Bedford, Massachusetts)

Abstract. Unusual thrust structures in thin sea ice sheets were observed in Labrador and Greenland. These structures are the result of thin ice sheets being forced into each other by a combination of wind and waves. When thicker pack ice is subjected to these same forces pressure ridges result.

Zusammenfassung. In Labrador und Grönland wurden ungewöhnliche Überschiebungsformen in dünnen Meereisdecken beobachtet. Diese Formen werden dadurch hervorgerufen, dass durch die vereinten Kräfte von Wind und Wellen dünne Eisschichten ineinander geschoben werden. Wenn dickeres Packeis denselben Kräften unterworfen wird, so werden Druckrücken erzeugt.

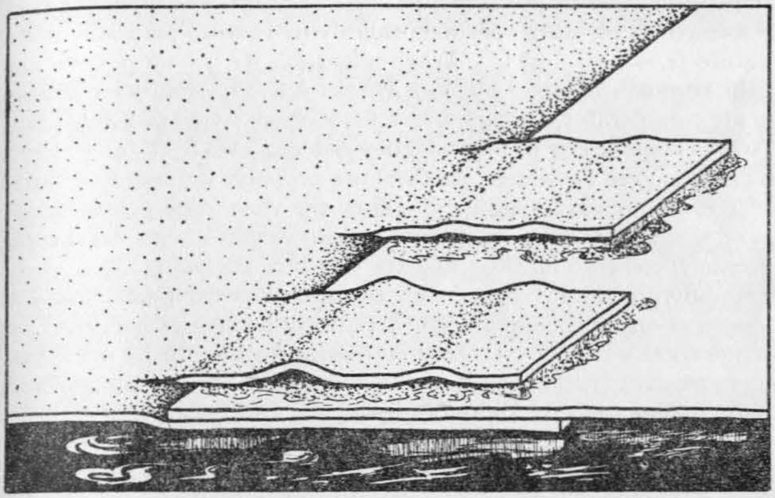

Fig. 4. Sketch showing the general spatial relationship of thrust sheets

During recent field studies in the Arctic, some interesting ice structures were noted. These structures are similar to geologic overthrusts and are the result of the interaction of thin sheets of sea ice. The structures consist of a series of parallel, rectilinear overthrusts alternating with similarly shaped underthrusts. The general surface outlines of these features can be seen in Figs. 1, 2 and 3 (p. 175). Fig. 4 (above) is a diagrammatic sketch showing the complete spatial relations of the structures.

These thrust structures were commonly seen in open leads at the edge of the fast ice at Hopedale, Labrador and during the initial freezing of Wolstenholme Fjord, Greenland. Notes on similar structures were made by Oliver [1] during flights over the Beaufort Sea in March and April of 1951. Oliver estimated that one might see from one to twenty of these thrust patterns in ten miles of flying.

The patterns observed by the present authors all had certain similar features.

(1) They occur in areas of extremely thin sheet ice (2 to 6 cm.).

(2) There does not appear to be any correlation between the sea ice thickness and the width or length of the thrust structure. The dimensions of the features vary from 0·1 by 1·0 m. to 40 to 100 m. Oliver reports seeing structures from the air up to approximately 600 m. in length.

(3) The regularity of the structures is extremely striking. The corner angles involved usually are 90 degrees although angles as low as 70 degrees were occasionally observed. Many of the thrusts appear to have been laid out by a draftsman.

* Present address: Department of Geology, Washington University, St. Louis 5, Missouri, U.S.A.

(4) The maximum dimension of the thrust sheet is usually perpendicular to the initial ice edge.

(5) The maximum dimension of the thrust sheet appears to be parallel to the wind at the time of formation.

(6) The overthrust sheet is separated from the underlying sheet by a thin film of brine.

All the thrusts observed were formed during the dark hours and offshore, too far to permit detailed observations until the ice had become thick enough to walk on. Rough measurements were then taken including drilling through the ice to verify the underthrusts. Therefore it was only possible to observe the effects of the thrusting and to speculate on its formation. Our explanation is as follows:

A thin homogeneous sheet of sea ice is split by a combination of wind, tide and waves. This split is often very ragged. The offshore segment or segments are carried away from the shore fast ice. Then a change in the wind or tide direction starts the offshore ice moving back toward the fast ice. Newly formed sea ice has a very high salinity (*c.* 15 to 20 per mille) and a very high average temperature (*c.* -2 to -4° C.). When afloat this ice is dark in color and extremely flexible, hence the common name of black or rubber ice. This thin ice transmits water waves although they are considerably damped. The ice is so weak, even in samples up to 5 cm. in thickness, that it will collapse under its own weight when removed from the water.

The foremost portions of the ragged advancing ice sheet are probably deposited on top of the shore fast sheet by the crest of an advancing wave. When the wave crest passes on, the deposited sheet collapses, and since it is too thin to support its own weight it tears, leaving the irregular portion lapping onto the sheet and dropping the rest into the water. Part of the collapsed portion then slides under the fast ice sheet during the next wave trough. This process continues with the adjoining portions of the advancing sheet being thrust under or over the fast ice, depending on whether there is a wave crest or trough present when the ice edges join. Once this initial over-under structure is established, continued wind and wave action push the offshore sheet further and further onto the shore fast ice.

It is especially interesting to note the large distances (100 m.) that a horizontal force can be transmitted through a relatively thin and weak substance. Since these large thrusts form even during relatively calm periods (wind velocity < 15 knots), it can be concluded that the frictional forces between the ice sheets are quite small. The lubricating film of liquid that separates the sliding ice sheets is composed of interstitial brine from the uppermost ice sheet. This brine starts to drain gradually as soon as the ice is removed from the sea water and supplies a continuous source of lubricating fluid. If this film were composed of normal sea water (salinity *c.* 32 per mille), it would freeze quickly to the upper surface of the lower ice sheet and would tend to increase instead of decrease friction. The brine on the other hand has a high salinity and freezes at a very low temperature.

Open folds are commonly found in the longer overthrusts. The axes of these folds are always perpendicular to the length of the thrust sheet showing that the component of movement is parallel to the length of the thrust sheets.

Sea ice changes from a weak flexible to a strong brittle material during the first few days of its growth due to rapid decreases in salt content and temperature. Therefore it is doubtful if thrust structures of the type described in this paper can ever form in ice that is more than approximately 12 cm. thick. This thicker ice would respond to stresses by forming the irregular pressure ridges that are so commonly observed in pack ice. In pack ice the thrust features would occur only in the thin ice of newly formed leads in response to compressive forces exerted by the motion of the thick, older ice floes.

MS. received 2 May 1956

REFERENCE

1. Oliver, J. E. "Notes on some peculiar pressure ridges in Arctic ice." Personal communication (1957).

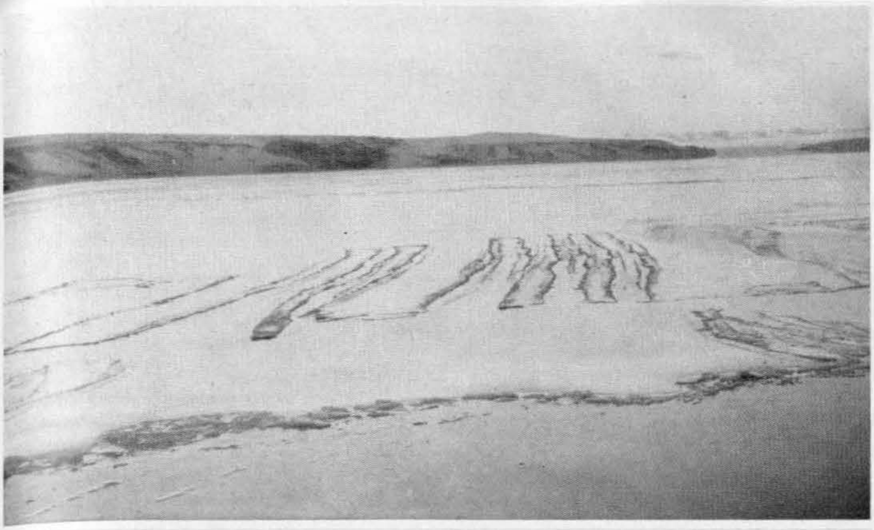

Fig. 1. View along the long axes of the overthrusts. Thrusting is toward the reader. Structures are approximately 6 m. long and upwards of 1 m. wide and show considerable linearity

Fig. 2. Many thrusts lying side by side. The ice was approximately 3 cm. thick when thrusting occurred. Note fold in the foreground

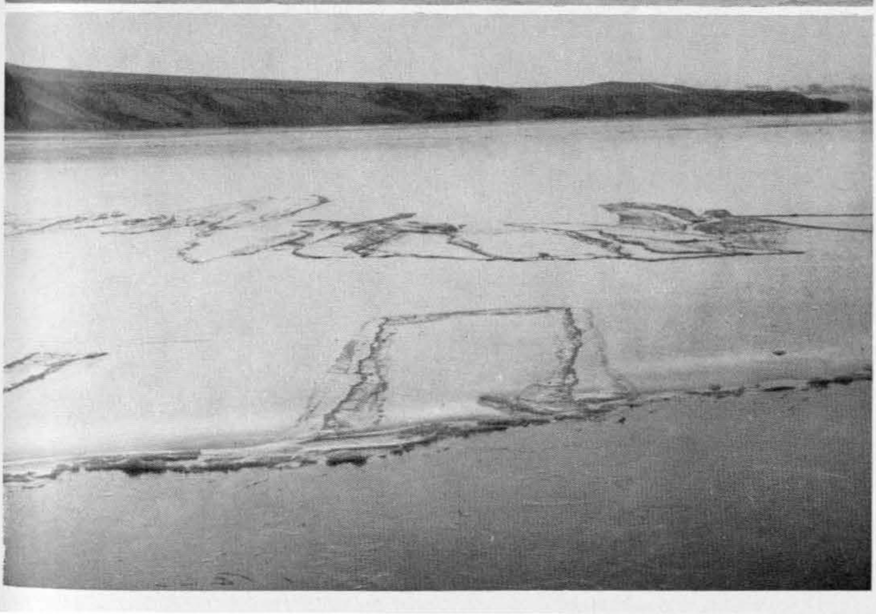

Fig. 3. Two parallel rows of overthrusts. Note that the ice is thin enough to transmit water waves