Islands of Grounded Ice

In August 1972, the U.S. Coast Guard icebreaker *Burton Island* confirmed the existence of a large ice formation located at about 160 km northwest of Point Barrow, which had first been observed by 1971 satellite imagery of the U.S. National Ocean and Atmospheric Administration (NOAA-1). Visual observations made from a distance indicated that the relief of the ice formation, which appeared to rise as much as nine metres above the sea, was highly irregular. Although it was at first described as a large hummock field of pressured sea ice, news quickly spread that it was a large piece of tabular shelf ice, i.e., an "ice island."

With the launching into orbit of the Earth Resources Technology Satellite (ERTS-1) in July 1972, there became available for the first time multi-spectral imagery of sufficiently high resolution to allow detailed sea ice studies to be performed. Through the sequential imagery provided by the satellite during its passage over the High Arctic, measurements could be made of the deformation and drift of the ice pack[1,2,3,4], and a continuous observation kept on the formation and break up of fast ice along the Alaska coast[5]. The discovery of the "ice island," together with the availability of satellite imagery, thus provided a unique opportunity to locate and monitor the movement of a specific ice feature for an extended period of time.

In March 1973, the first ERTS-1 images of the area became available. Enlarged portions of those obtained from 8 March through 2 September 1973 are shown in Fig. 1. Two ice formations were observed as shown in the imagery; one was located at 72°N, 162°W and the other at 72°07′N, 162°10′W. The ice formations were observed to increase and decrease in size as the direction and compactness of the moving pack changed, although they did not move west with the drift of the polar pack — a clear indication that the ice formations were grounded.

From recent calculations of ice-keel depth distribution in the Arctic Ocean, it has been shown that several hundred ice keels, each 20 m or more in depth, can be expected to pass a given location during the course of a year[6]. Therefore, the potential frequency of impact of pressure-ridge keels, and the occasion for them to become firmly grounded, can be great in the shoal area of the grounded ice formations. In addition, in recent years several hundred fragments of ice islands have been found both adrift and grounded off the Beaufort Sea coast of Alaska and Canada[7,8]. These fragments typically have keels 15-30 m in depth. While their numbers are few in relation to those of the ridge keels that can be expected to drift over a given location in a year, the grounded ice formations shown in the ERTS-1 imagery may nevertheless consist, in part, of grounded shelf ice.

Whichever situation occurs, the grounded ice acts as a barrier against which the irregular floes of the pack are pushed. Unable to resist the stresses developed, the floes eventually fail. The blocks of sea ice which result are pushed to a considerable height, and the area of the grounded ice gradually becomes enlarged[9]. This fact explains the increase in the ice formation from 8 March to 1 May. For example, the larger sea-ice formation located at 72°N, 162°W increased from 2 km x 5 km on 8 March to 6 km x 20 km on 1 May. The imagery of 5 and 6 June reveals that, under the rarefied conditions of the summer pack, the ice formations decreased in size, presumably as a result of collisions with passing floes and wave action. On 2 September, the larger ice formation had decreased to about 2 km in diameter, while the smaller ice formation could no longer be seen.

In the 1974 ERTS-1 imagery of the area (Fig. 2), the ice formation at 72°N, 162°W was found on 20-21 March to be 6 km x 9 km; by 27 April it had increased to 7 km x 15 km. The smaller ice formation noted in the 1973 imagery at 72°07′N, 162°10′W could not be found in the 1974 imagery.

The bathymetric chart indicates two shoals near the area of the grounded ice formations: at 71°50′N, 161°10′W and at 71°54′N, 161°07′W[10]. The first shoal is 18 m below the ocean surface, the second approximately 22 m. These shoals are approximately 35 km east-southeast of the site of the two grounded ice formations found on the 1973 ERTS-1 imagery, and it may be speculated that the formations were resting upon these shoals. As ERTS-1 imagery can be used to determine the positions of surface features to within 300 m of their true geographic position, the locations of the shoals on the bathymetric chart may not be correct.

This report serves to demonstrate the usefulness of ERTS-1 imagery for the location of islands of grounded ice, and for observing the growth and decay of these features with time. Through the imagery there has also been revealed a possible error on bathymetric charts for the location of two shoals in the southern Chukchi Sea.

Numerous accounts of ice islands and sea ice becoming firmly grounded on the sea floor, some in waters of up to 40 m in depth, have been reported[7,9]. Therefore, the two islands of grounded ice just discussed may be

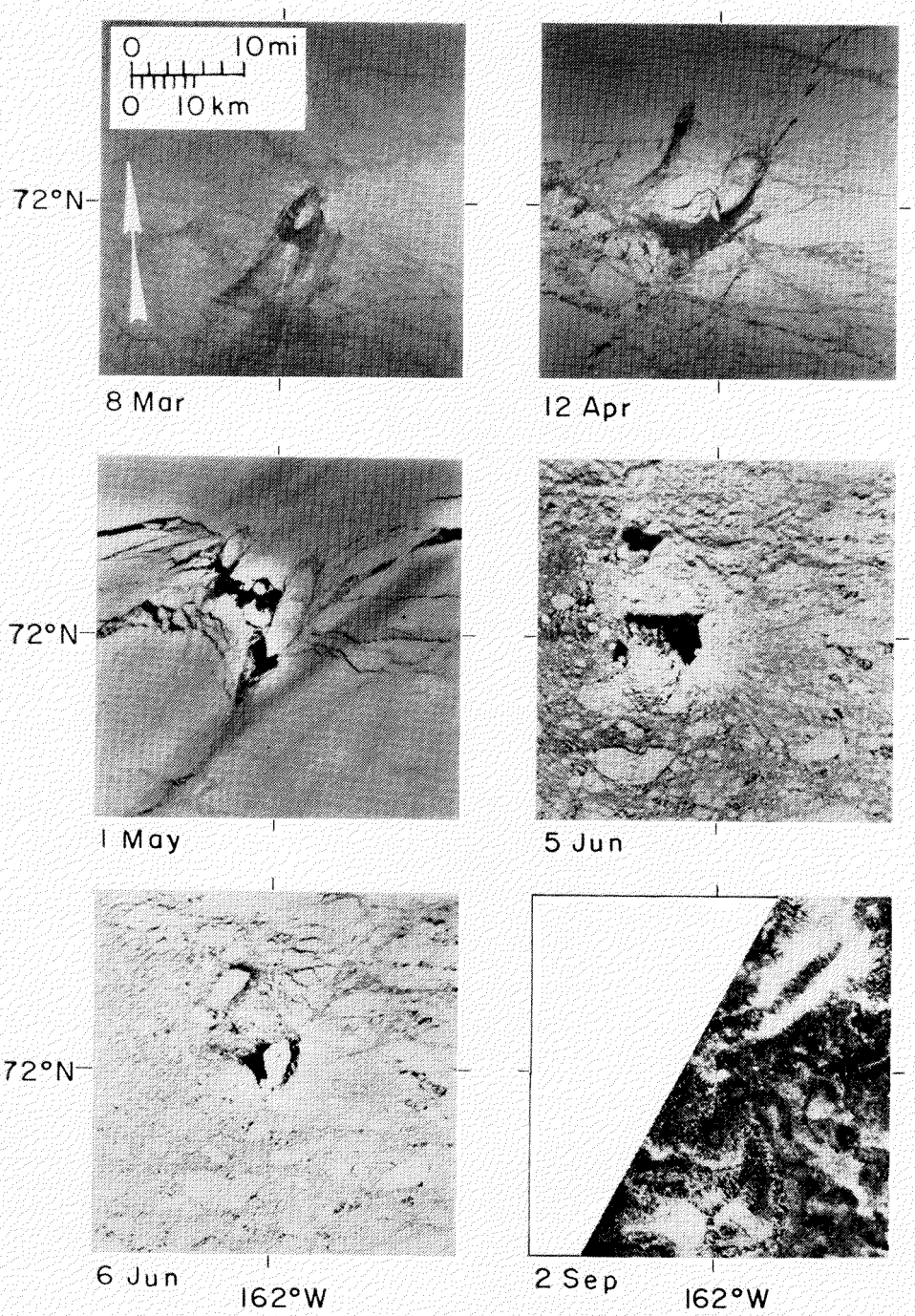

FIG. 1. Sequential ERTS-1 imagery showing islands of grounded ice in 1973.

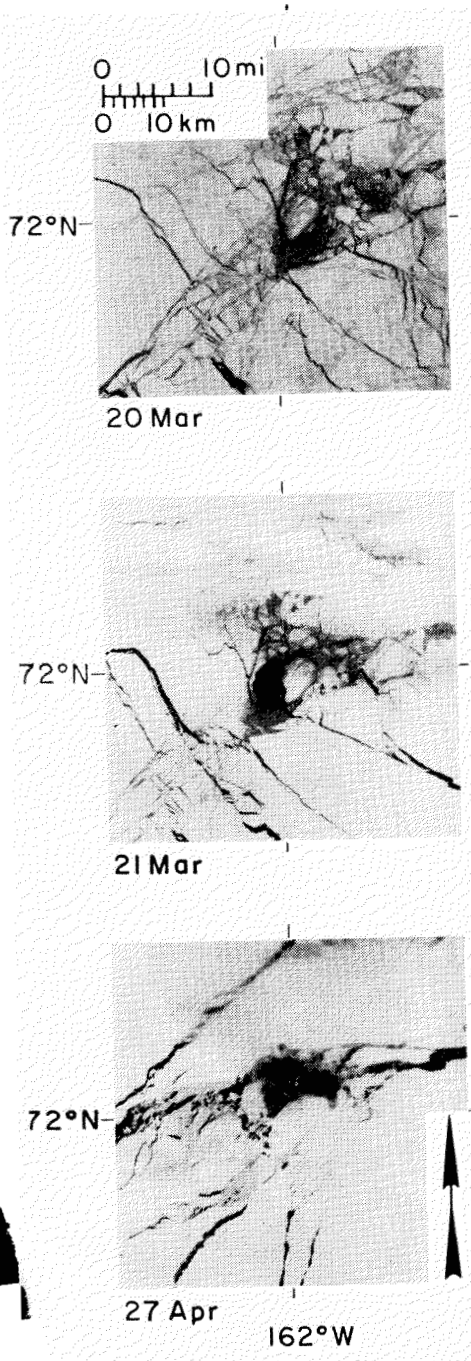

FIG. 2. Sequential ERTS-1 imagery showing island of grounded ice in 1974.

considered unique only because of their location. Similar ice formations occur on Herald Shoal, 70°30'N, 161°30'W, which is only 11 m below the surface of the sea.

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The images shown in Fig. 1 are NASA ERTS nos. 1228-22261, 1263-22203, 1282-22261, 1317-22200, 1318-22255 and 1406-22131, respectively by date. Those shown in Fig. 2 are NASA ERTS nos. 1605-22145, 1606-22203 and 1643-22253, respectively by date.

REFERENCES

[1]Crowder, W. K., McKim, H. L., Ackley, S. F., Hibler, W. D., III and Anderson, D.M. 1973. Mesoscale deformation of sea ice from satellite imagery. *Interdisciplinary Symposium on Advanced Concepts and Techniques in the Study of Snow and Ice Resources, Monterey, California.*

[2]Barnes, J. C., Bowley, C. T. and Smallwood, M. D. 1975. *The Application of ERTS Imagery to Monitoring Arctic Sea Ice: Supplemental Report.* Environmental Research and Technology Inc., ERT Document no. 0408-S.

[3]Hibler, W. D., III, Ackley, S. F., Crowder, W. K., McKim, H. L. and Anderson, D. W. 1974. Analysis of shear zone ice deformation in the Beaufort Sea using satellite imagery: the coast and shelf of the Beaufort Sea. *Proceedings of the Arctic Institute of North America Symposium on Beaufort Sea Coast and Shelf Research.* Arlington, Va.: Arctic Institute of North America.

[4]Shapiro, L. H. and Burns, T. T. 1975. Satellite observations of sea ice movement in the Bering Strait region. In: Bowling, S. and Weller, G. (eds.), *Climate of the Arctic,* College, Alaska: University of Alaska Press.

[5]Stringer, W. J. 1974. Morphology of the Beaufort Sea shorefast ice: the coast and shelf of the Beaufort Sea. *Proceedings of*

the Arctic Institute of North America Symposium on Beaufort Sea Coast and Shelf Research. Arlington, Va.: Arctic Institute of North America.

[6]Weeks, W. F., Kovacs, A. and Hibler, W. D., III. 1971. Pressure ridge characteristics in the arctic coastal environment. *Proceedings of the First International Conference on Port and Ocean Engineering under Arctic Conditions, Vol. I.* Trondheim, Norway: Technical University of Norway.

[7]Kovacs, A. 1972. Ice scoring marks floor of the arctic shelf. *The Oil and Gas Journal*, 70(43): 92, 97, 98, 101, 103.

[8]Kovacs, A. and Mellor, M. 1974. Sea ice morphology and ice as a geologic agent in the southern Beaufort Sea: the coast and shelf of the Beaufort Sea. *Proceedings of the Arctic Institute of North America Symposium on Beaufort Sea Coast and Shelf Research*. Arlington, Va.: Arctic Institute of North America.

[9]Kovacs, A. 1972. On pressured sea ice. *Sea Ice: Proceedings of an International Conference, 1972*. Reykjavik, Iceland: National Research Council.

[10]*U.S. Department of Commerce, Coast and Geodetic Survey*. 1973. Alaska Coast Chart no. 9400.