Iceberg Plough Marks in the Vicinity of the Norwegian Trough

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Side-scan sonar pictures (sonographs) obtained from the southern Norwegian shelf and the Norwegian Trough show the presence of large furrows which are attributed to the action of icebergs ploughing into the sediment as they touch bottom. These iceberg plough marks are similar to others recently described from the continental margin west of the British Isles. Plough marks are best developed on the north side of the Trough. Parallelism of plough marks is observed on the sides and low rises on the floor of the Trough not covered by mud.

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Marks made on the sea floor by the grounding of drifting ice have been observed in the Canadian Arctic (Pelletier & Shearer 1972) and on the continental shelf and upper slope west of the British Isles from Porcupine Bank to The Faeroes (Belderson, Kenyon & Wilson 1973). Off Canada the feature is still being formed while in the latter areas it is a relict form of Pleistocene age. The method of observation has been side-scan sonar, which produces an acoustic picture (sonograph) of the sea floor analogous to an oblique aerial view. The sonographs show a distinctive, often random, criss-cross pattern of large furrows averaging about 20 m in width, 2 m in depth, and up to at least several km in length, with maximum dimensions considerably greater than these values. The furrows are ploughed into sea floors ranging in composition from mud to boulders with various admixtures of sand. Sometimes they can be seen to be flanked by raised rims due to the shoving aside of sediment by the advancing iceberg. The present paper is concerned with a search for this feature in the Norwegian Trough that was made during a cruise by R.R.S. *Discovery* to the North Sea in 1972, using side-scan sonar, and gives an account of their form and location.

Iceberg plough mark occurrences

Fig. 1 shows the tracks along which side-scan sonar records were obtained, and the occurrences of iceberg plough marks along these tracks. The best exposures of the feature (for example Figs. 2 and 3) are found on the shelf and slope on the Norwegian side of the Trough, except where there is continuous rock outcrop or a cover of recent mud, as was found along the lines off south-eastern Norway and towards Sweden. Fig. 4 gives an example of partial to complete burial of marks by younger sediment in certain of

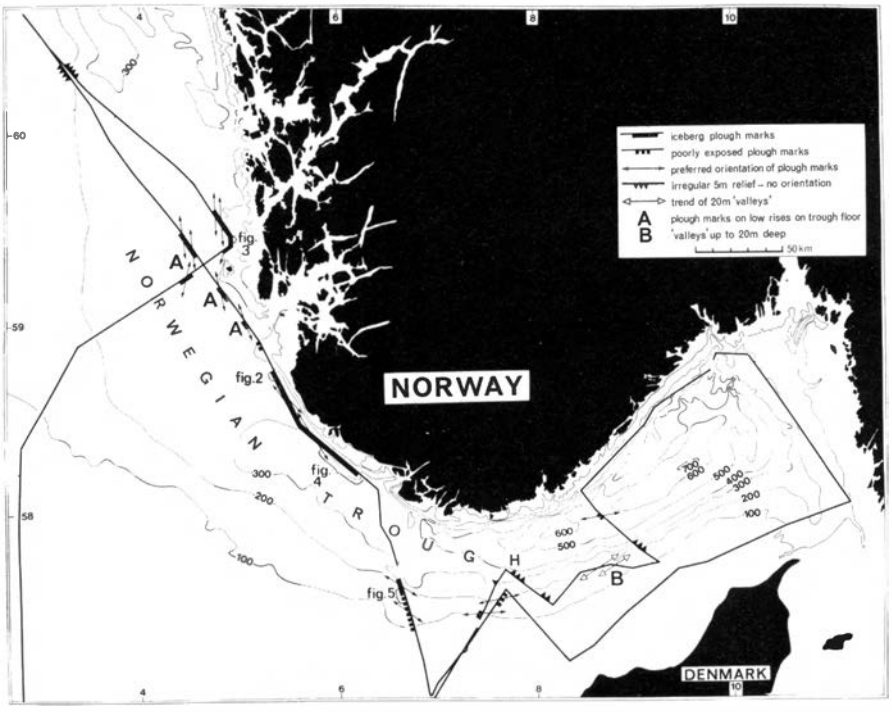

Fig. 1. Tracks along which side-scan sonar was used from R.R.S. *Discovery* during 1972. Occurrences of iceberg plough marks are shown, and where these have a preferred orientation the trend is indicated. Patches of irregular relief up to 5 m high which may be remnants of plough marks are shown, although there is no clear supporting evidence of this interpretation from side-scan sonar. 'A' indicates patches of plough marks that are located on low rises above the deep floor. 'B' indicates an area of deeper valleys running parallel to the slope. Locations of Figs. 2–5 are shown. Bathymetry is in metres, after O. Holtedahl (1940).

the hollows, together with patches of rock outcrop devoid of plough marks in the shallower areas.

On the southern and western side of the Trough the marks are less well exposed or are absent. This may be partially due to the reworking of the floor by currents but is probably mainly the result of recent burial. Areas of irregular relief of up to 5 m high (see Fig. 1) may represent remnants of plough marks, but the sonographs show no obvious trends to the features. The nearest good examples of the criss-cross pattern on this side of the Trough are found north-east of the Shetland Islands at 0°40′E, 61°30′N. The lower depth limit of their occurrence on both sides of the Trough coincides with the boundary of an acoustically transparent mud layer seen on echograms to be about 10 m or more thick. Thus, it is likely that the plough marks also exist beneath the floor of the Trough but have been largely blanketed from view by the mud layer. For instance, at the localities marked 'A' on Fig. 1 there are slight rises in the floor not covered by young mud, where plough marks are observed. Towards the eastern end, at the upper

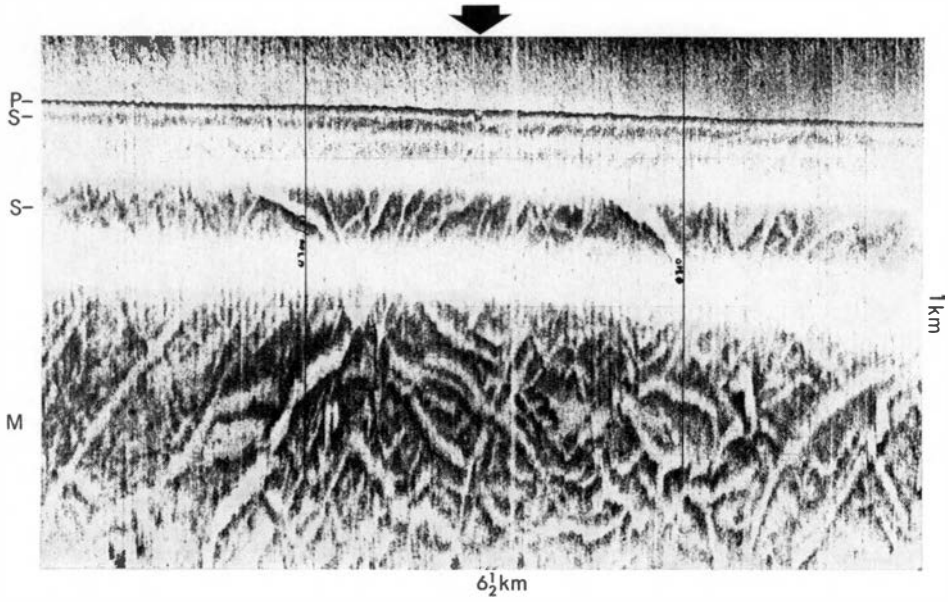

Fig. 2. Sonograph showing numerous iceberg plough marks with a random criss-cross pattern of superimposition. Lightest tones correspond to the furrow floors, about 2–3 m deep, but which may be partly infilled by younger sediments. Darkest tones represent the rims, often slightly raised to either side of the furrows. Water depth is about 200 m. Location is given in Fig. 1. In this and subsequent figures the broad arrow gives direction of 'view' from the ship, P is the profile of the sea floor directly beneath the ship, S represents side-lobes in the beam pattern and M the main beam. Width exaggeration due to differing length and width scales should be allowed for when viewing the sonographs.

part of the southern slope of the Trough (marked 'B' on Fig. 1), there is a series of larger 'valleys' up to 20 metres deep which trend parallel to the slope. These might possibly be remnants of much larger plough marks, although their exceptional size makes this seem unlikely. Incisions in the sea floor profile up to 20 m deep were also noted by O. Holtedahl (1963) from this area.

In general size and appearance the marks resemble those already described from north and west of the British Isles. The irregular criss-cross pattern is a distinctive feature. There are however localities (see Figs. 1 and 5) where the marks have a much more linear aspect and run parallel or sub-parallel to each other. The trend of these is usually along the axis of the Trough.

Discussion

The presence of iceberg plough marks off Norway was to be expected, following their discovery north and west of the British Isles. They should be found abundantly in those other parts of the Norwegian slope and shelf

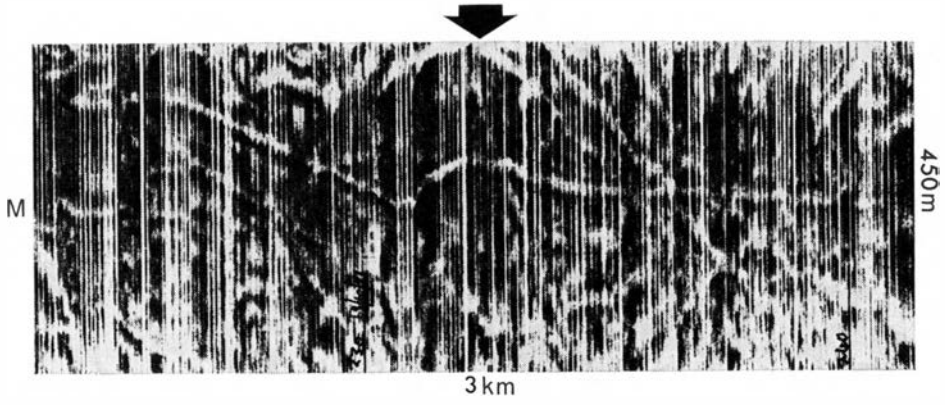

Fig. 3. Sonograph showing a conspicuous iceberg plough mark almost 3 km long with a pronounced kink indicating a change in course of the iceberg. The series of straight white lines across the record are the result of 'quenching' produced by the pitching of the ship in heavy seas. Water depth is about 160 m. Location is given in Fig. 1.

not discussed in the present paper which are shallower than about 500 m wherever conditions allowed their formation and subsequent survival. The sites of origin of the icebergs may have been local or distant. The Oslo-Skagerrak area may have been an important source, as shown by H. Holtedahl (1955), who found material originating from there in glacial deposits off western Norway. If plough marks are found on or buried beneath the deep floors of closed basins such as fjords, or the eastern, deepest part of the Norwegian Trough, then a local derivation for the bergs is indicated.

The poorly preserved nature or absence of the marks on the slope and shelf edge to the south and west of the Trough is probably due to a more rapid rate of post-Glacial deposition than that found on the Norwegian side, although it is possible that the marks were never as abundant on this side. In this connection it is interesting to note that no evidence of plough marks has yet been obtained south from here over the broad expanse of the North Sea shelf, although side-scan coverage there is so far limited.

In those places where the alignment is sub-parallel, the plough marks usually trend along the contours of the sides of the Trough. A possible explanation of this is simply the constraining influence of sloping ground upon the icebergs, since, at any given draught, they could only plough along-slope. Upslope drift would bring them to a halt, and downslope drift would free them from the floor altogether. However, the occurrence of parallel-trending marks on slight topographic highs on the floor of the Trough suggests another possible explanation. At a time of lower sea level (say -100 to -150 m) tidal currents might be expected to have flowed up and down the then confined waters of this long and narrow embayment, assuming there was a stage at which it was not choked by the continental glaciation, and the relative isostatic and eustatic levels allowed this to happen. Such longitudinally directed palaeo-currents could not have been

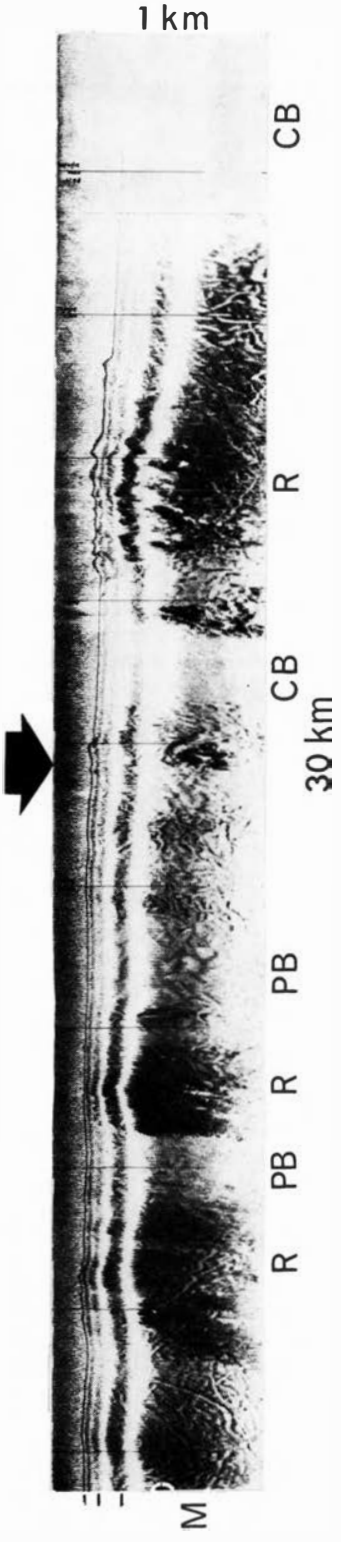

Fig. 4. Sonograph showing plough marks on irregular topography with some rock outcrops (R, darkest tone) and partial (PB) to complete burial (CB, lightest tone) by younger sediments. Water depth is from about 160–320 m. Location is given in Fig. 1.

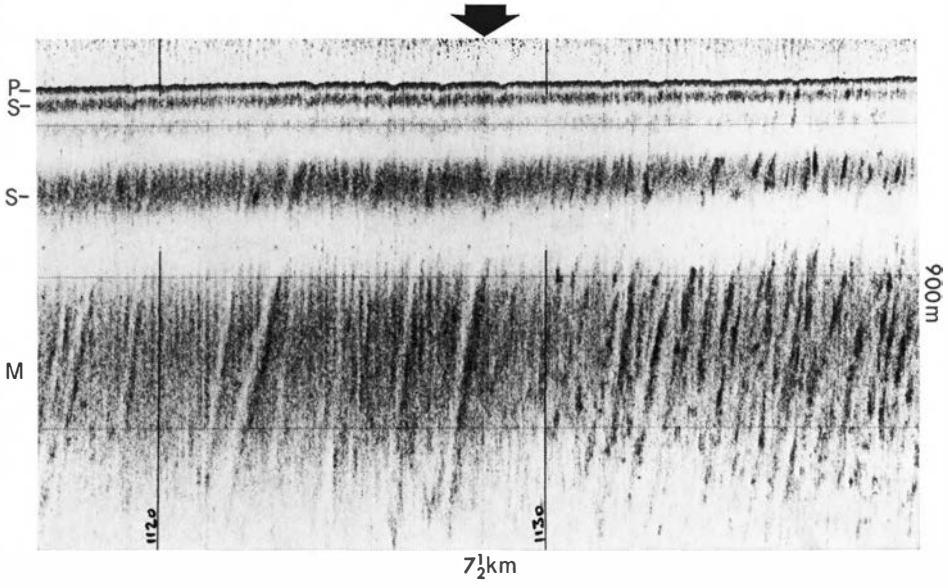

Fig. 5. Sonograph showing marked tendency to parallelism of plough marks along the slope of the Norwegian Trough. Note relief of up to 5 m along profile P. Towards the right hand side of the figure (upslope) the marks are more numerous but not so well preserved. Water depth is from about 160–180 m. Location is given in Fig. 1.

particularly strong otherwise the marks would soon have been obliterated by bed movement of sediments.

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REFERENCES

Belderson, R. H., Kenyon, N. H. & Wilson, J. B. 1973: Iceberg plough marks in the North East Atlantic. *Palaeogeogr., Palaeoclimatol., Palaeoecol. 13,* 215–224.

Holtedahl, H. 1955: On the Norwegian Continental terrace, primarily outside Möre-Romsdal: its geomorphology and sediments. *Univ. Bergen Årb. 14,* 1–209.

Holtedahl, O. 1940: The submarine relief off the Norwegian Coast. With bathymetrical maps in seven sheets of the Norwegian coastal waters and adjoining seas. *Norske Vidensk.-Akad. i Oslo, Spec. Publ.* 43 pp. Oslo.

Holtedahl, O. 1963: Echo-soundings in the Skagerrak. *Norges geol. undersøkelse 223,* 139–160.

Pelletier, B. R. & Shearer, J. M. 1972: Sea bottom scouring in the Beaufort Sea of the Arctic Ocean. *Section 8, 24th Int. Geol. Congress, Montreal,* 251–261.