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EXTENT OF GLACIATION ON THE CONTINENTAL SHELF IN THE BEAUFORT SEA

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ABSTRACT. The continental shelf in the Beaufort and Chukchi Seas is terminated by a shelf-break at a depth of approximately 35 fathoms. This suggests a common origin of the shelf-break in both seas and leads to the conclusion that continental glaciation did not affect the outer shelf in these seas. There is evidence, however, which indicates local glaciation on the inner shelf in the eastern Beaufort Sea.

INTRODUCTION

Scientific expeditions have brought back new soundings from 35,000 square miles of sea floor in the Arctic Ocean and adjacent seas off Alaska and northwest Canada (figs. 1 and 2) in the years between 1950 and 1952 (Carsola, 1953). The shelf-break[1] was crossed in many places between Banks Island and the 165th Meridian West by ships which recorded these soundings continuously on echo-sounding tapes. Figure 3 shows six of these records made as the ship crossed the shelf-break approximately at right angles.

This new information indicates that the shelf throughout the area is less than 40 fathoms deep. Most of it lies near 25 fathoms. The depth of the shelf-break varies between 29 and 40 fathoms, averaging about 35 fathoms. Locally, the shelf is incised by two seavalleys—Barrow Seavalley off Point Barrow and the Mackenzie Seavalley off Mackenzie Bay (fig. 2); another shelf feature, Amundsen Trough, lies under the gulf which separates Banks Island from the mainland (Carsola, 1953). Barrow Seavalley is apparently caused by an oceanic current. Amundsen Trough, U-shaped in transverse cross-section, has a floor averaging about 235 fathoms. Locally it reaches a depth of approximately 300 fathoms. It is thus incised 200 fathoms or more below the surrounding shelf. It is clearly glacial in origin. The Mackenzie Valley (sometimes called the Herschel Island Canyon) is also U-shaped, although not so wide as Amundsen Trough. The floor of this seavalley slopes gently northwestward. At the head it is about 15 fathoms (90 feet) below the surrounding shelf at 25 fathoms, whereas near the edge of the shelf it lies about 200 fathoms (1200 feet) below the surrounding sea floor. It is probably the glaciated, drowned former principal valley of the Mackenzie River.

The nature of the shelf in the Beaufort and Chukchi Seas furnishes some clues to the Pleistocene and post-Pleistocene history of this area, as well as that of the adjacent land areas. It is necessary first, however, to examine some of the more important current theories regarding the origin of the continental shelf and shelf-break.

THEORIES REGARDING THE SHELF AND SHELF-BREAK

Theories regarding the origin of the shelf-break have been discussed in detail by Dietz and Menard (1951) and Shepard (1948). These writers generally agree that the shelf-break was formed at a eustatically lowered

[1] The point on the sea floor where an abrupt increase of slope would be noted by an observer proceeding in the direction of increasing depth from the continental shelf.

Pleistocene sea level, as suggested by most oceanographic and geologic evidence available (Dietz and Menard, p. 2001-2014).

Shepard (1948, p. 157-174) has concluded that shelves are formed by a combination of a variety of processes, including marine clastic sedimentation, current and wave erosion, limestone deposition, glaciation, and deltaic deposition. To these the author adds scour and deposition by sea-ice. While Shepard did not attempt to explain the shelf-break, he inferred that since the shelf has been formed in shallow water and has subsequently been drowned, the shelf-break must have a similar origin. The shelf-break may mark the drowned seaward edge of a limestone platform, the outer edge of a delta, the site of a wave-beveled former chain of islands, or the forward edge of a wave-cut or wave-built platform.

Dietz and Menard propose that the shelf-break was cut by vigorous wave abrasion at a time when the depth at its present site was no more than 27 feet (4½ fathoms). Subsequent post-Pleistocene rise of sea level has placed the shelf-break at its present depth.

Dietz and Menard (1951, p. 2014) give representative depths of the shelf-break: 60 fathoms off the Atlantic coast of North America; 50 to 70 fathoms off the Gulf Coast; 50 fathoms off the Pacific Coast. In general, they state that it is usually found at depths of 45 to 80 fathoms. Shepard (1948, p. 143-145) states that the average depth of the feature here referred to as the shelf-break is 72 fathoms; off glaciated areas in the Arctic and Antactic it is found at an average depth of 112 fathoms. His figures do not include the Beaufort-Chukchi Sea shelf-break at 35 fathoms which may extend as far eastward as Novaya Zemlya off Siberia (fig. 1). Inclusion of the shelf-break over approximately half of the Arctic region would diminish the average somewhat. The same can be said of the average depth of the shelf, quoted as 35 fathoms by Shepard (1948, p. 144). If over half of the Arctic shelf averages 25 fathoms this figure might be diminished a few fathoms.

The location of the shelf-break at similar depths in two adjacent marine areas indicates a similar post-shelf-break history for both areas, regardless of what major process caused it. Here it is assumed with most marine geologists that the shelf-break was formed at a lower stand of sea level than exists at present. This suggests that the Chukchi Sea shelf and the Beaufort Sea shelf must have had a similar history. The shoalness of both the shelf and the shelf-break suggest a history different from that of the glaciated Arctic off northern Europe, Greenland and most of the Canadian Archipelago.

HISTORY OF THE CHUKCHI-BEAUFORT SEA SHELF

The fact that the shelf in the Beaufort and Chukchi Seas is relatively shallow and that it is terminated at a shallow shelf-break eliminates glaciation as a major cause in its formation. The lack of irregularities of glacial origin in shelf topography west of Herschel Island (fig. 2) refutes the possibility that it may have been glaciated during the Pleistocene unless rapid post-Pleistocene sedimentation has masked all traces of glaciation. The presence of at least one and possibly two glacially sculptured troughs in the eastern Beaufort Sea indicates local glaciation in that area, but there is no evidence of any extensive glaciation of the shelf.

This does not mean that the area was not covered by ice during Pleistocene glacial epochs. While adjacent land masses were locked in glacier ice the Beaufort and Chukchi Seas must have been covered all year by sea-ice, even as they are now covered for 8 to 11 months (H. O. 550, 1946). With ice covering the sea, only waves of insignificant size could form in small leads

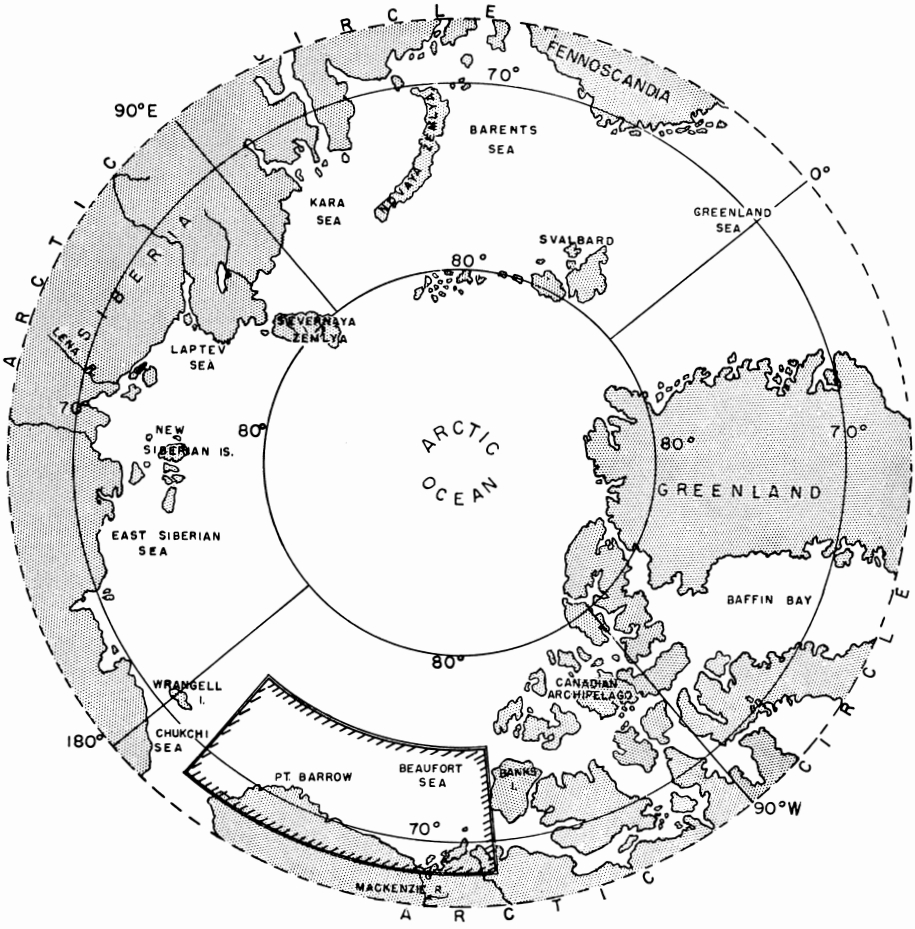

Fig. 1. The Arctic regions showing the location of the area described in this report.

in the ice. Hence, wave action would have been unimportant. Deposition on the floor of such an ice-locked sea would also be insignificant. Ice would have been grounded as during present winters in the area, in depths of 20 fathoms or possibly more (H. O. 77, 1951, p. 30).

Thus, if the shelf-break was formed at shallow depths it must have been formed before the Pleistocene. During Pleistocene interglacial stages it was too deep to permit a shelf-break to be formed, and during glacial stages it was ice-locked and could not have been formed by processes referred to

previously. Grounded ice might be suspected as a cause of a break in slope, but there is no evidence that present ice-grounding forms such a feature, and it is improbable that this process might have formed a Pleistocene shelf-break. The shelf-break, therefore, must have formed before the Pleistocene epoch at a time when the shores of the Arctic Ocean and its adjacent seas were ice-free for most of the year.

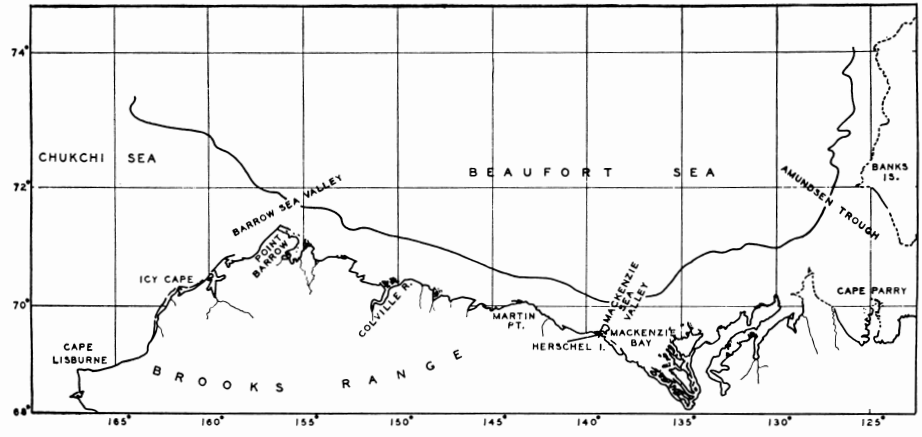

Fig. 2. Approximate position of the shelf-break in the Beaufort and Chukchi Seas.

Evidence concerning glaciation on land areas bordering this region also tends to support a theory of limited glaciation only. According to Flint (1947, pl. 3), Pleistocene continental glaciers during the maximum Wisconsin stage affected only the Brooks Range in northern Alaska. The Arctic plain north of the Brooks Range was affected only by limited glaciation. He shows continental glaciers covering the entire Canadian Archipelago, the eastern Beaufort Sea, and the mainland as far west as Herschel Island.

Jenness (1952), however, has presented physiographic evidence which suggests that continental glaciers did not reach the northern part of Banks Island and probably did not reach the western half of the island (Jenness, 1952, fig. 2). Victoria Island to the east was glaciated, but Prince Patrick and others of the western islands of the Canadian Archipelago escaped extensive glaciation. These islands and the northern part of Banks Island may have been subjected to local glaciation, but they show no evidence of continental glaciation.

There is no evidence to suggest that the mainland bordering the eastern Beaufort Sea was not glaciated by continental glaciers. In this respect the author agrees with Flint. However, there is overwhelming evidence against Pleistocene continental glaciation of the present continental shelf in this area. Amundsen Trough and possibly the Mackenzie Seavalley mark the courses of local glaciers or lobes of the continental glacier which followed old drainage channels onto the Pleistocene plain which is now part of the shelf of the

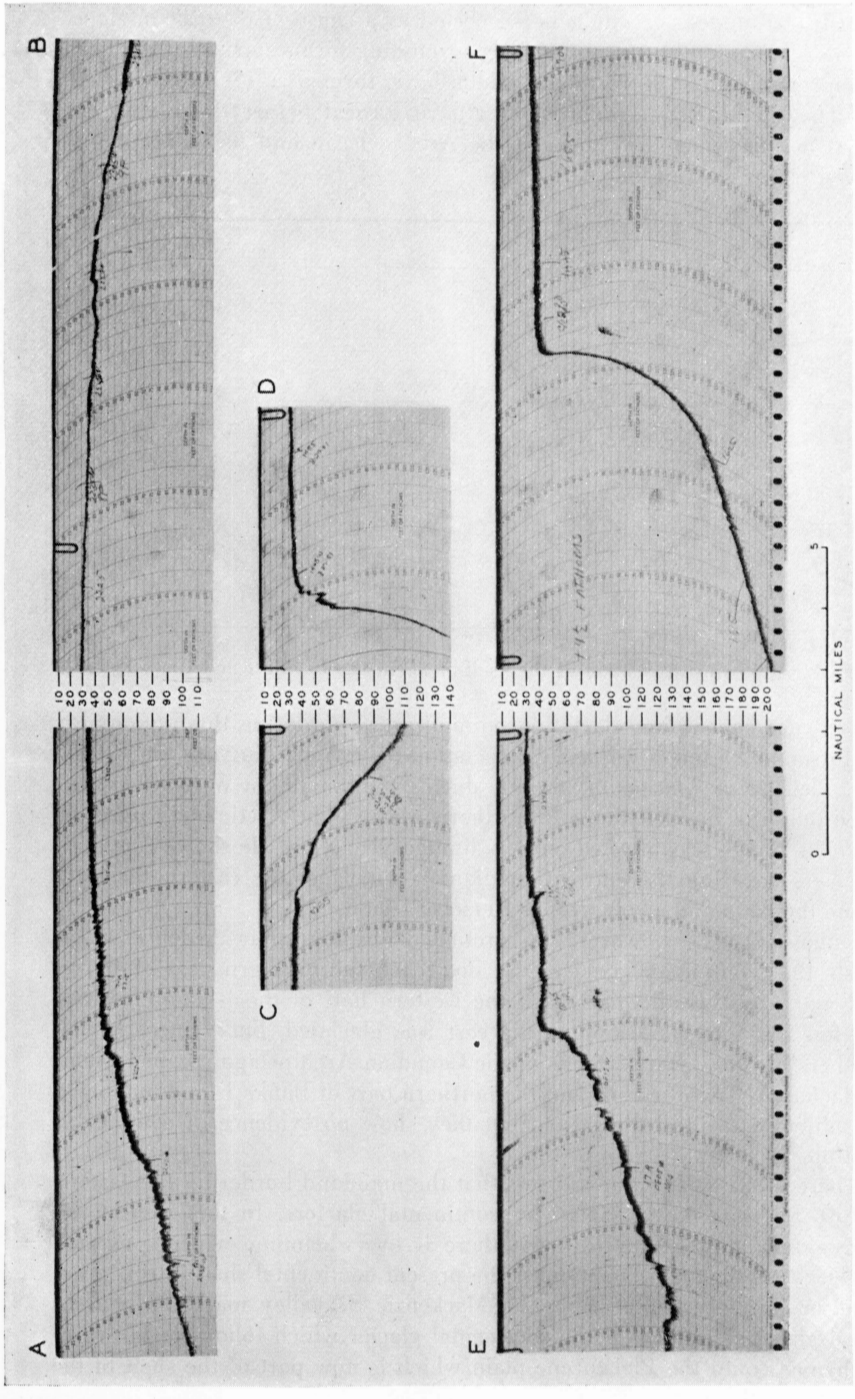

Fig. 3. Details of the outer continental shelf and upper continental slope in the Chukchi Sea (A and B) and the Beaufort Sea (C, D, E and F) showing the shelf-break. Note that correction of 4½ fathoms for the depth of the sound head has been added to depths on the echo-sounding record. All records were made at 10 knots; hence the horizontal distance is 1 nautical mile between each 3 curved lines. Vertical exaggeration is about 253 X horizontal.

eastern Beaufort Sea. But the main body of the ice sheet that covered North America during the Pleistocene lay to the east and south.

In summary, the continental shelf off Alaska and northwestern Canada is terminated by a shelf-break at 35 ± 5 fathoms. It shows the effects of limited glaciation at its eastern end, but this was purely a local effect. The shelf originated before the Pleistocene and has since been altered by several shelf-modifying processes. It is probably a part of the vast unglaciated Arctic continental shelf which is unique in being the shoalest shelf of comparable size in the world.

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