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TECHNICAL NOTE

# SOME RECENT SHORE ICE PILE-UP AND RIDE-UP OBSERVATIONS ALONG THE ALASKA ARCTIC COAST

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and

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SOME RECENT SHORE ICE PILE-UP AND RIDE-UP OBSERVATIONS ALONG THE ALASKA ARCTIC COAST

by

Austin Kovacs and Betty A. Kovacs

## Introduction

Shore ice pile-up and over-ride are frequent events along arctic shorelines. These phenomena are of considerable concern to those planning to locate facilities offshore in the Arctic Ocean. Questions arise as to the frequency anti the severity of these events. A recent survey of shore ice pile-up and ride-up in the winters of 1979-80 and 1980-81 revealed the locations of several major events, both recent and old. This paper discusses several observations and current findings related to these on-land sea ice incursions.

## Observations

In 1980 and 1981 aerial reconnaissance flights were made during May along the Alaska coastline for the purpose of locating significant onshore sea ice pile-up and over-ride events. Some of the more interesting ice ride-up features were first observed in May 1980 on the southeast side of Camden Bay (Fig. 1). Only aerial photos of the features could be obtained at the time (Fig. 2). The features were not recent ice ride-ups but were scars plowed into the tundra by a major onshore ice movement some years before. In May 1981 the distance from the inland boundary of the longest ice scar to the sea was measured and was found to exceed 120 m, a major inland advance.

In August 1981 more detailed observations along this section of the coast were made. These included additional aerial photography, elevation surveys and offshore bathymetric measurements. Two summer aerial views of the tundra scars, shown in winter in Figure 2, are shown in Figure 3. The scars are seen to be surrounded by ice-pushed soil berms. The scars also contain sizable areas of water, suggesting that the scarred terrain is depressed. Another aerial view of the surrounding shore area is given in Figure 4, and a view of the coast about 1 km to the south is shown in Figure 5. These photographs show other ice-push soil berms which we did not observe during the winter due to excessive snow cover. We observed a significant number of additional ice-scarred tundra features along this section of the coast which were not apparent during the winter. These scars suggest that a major onshore ice movement occurred at some time in the past, and that this event left ice scars in the tundra along a large section of the coast. In addition we observed numerous recent ice-push gravel piles which extended up to 20 m inland from the water's edge. These features indicate that onshore ice movement is a frequent event along this coastline.

Panoramic views of the tundra scar shown in Figures 3a and b are shown in Figures 6a and 6b respectively. These views show a beach composed of surprisingly coarse gravel, much driftwood debris, and ice-push tundra berms over 1.5 m high. Most of the driftwood was carried on shore by high water storm events. However, we also found wood deeply embedded in the tundra berms, indicating that it was incorporated into the berm during ice plowing. The back of the berm behind the person in Figure 6b is shown in Figure 7. Note the apparent difference in elevation of the berm from the two sides.

An elevation survey was made along the lines shown in Figures 4a and b. An elevation survey was also made of the undisturbed tundra just north of the berm beyond the B profile line drawn in Figure 3a. The bathymetry off shore was recorded by taking soundings from an inflatable raft (Fig. 8). The survey results are shown in Figure 9. The seabed near the beach is shown to slope at an angle of 8° to 10° to a depth of about 2 m. Beyond this depth, the seabed has a very shallow slope. The steeper slope near shore above the 2-m depth may be controlled in part by ice push, which transfers gravel up onto the beach. The natural or non-ice-scarred tundra surface profile (A) is shown to have an elevation which is more than twice that of the ice-scarred terrain (profile B). It should be noted that profile B does not represent the deeper area of the ice-scarred feature. The deeper area was up to 1/2 m below the pond water level.

Ice plowing clearly resulted in the displacement of surface material. This in turn exposed the underlying material, which allowed solar radiation to thaw the ground ice. Differential subsidence in the scarred area then occurred. A striking feature of the ice-scarred terrain was that all surfaces were covered by vegetation, indicating that these scars must be quite old. The longest ice scar was found to extend 130 m in from the water's edge.

The age of these ice-scarred features is unknown. A July 1950 view of the coastline (Fig. 10) shows that the features existed at this time, and ice ride-up had scarred the tundra along a 2.9-km section of the coast. A 1947 image of "this coastline revealed the same scars. The features are, therefore, over 35 years old. We estimate from the aerial photos that the shoreline is receding at 0.1 to 0.3 m per year. Therefore, since 1947, shoreline retreat has been 3 to 10 m. In short, the ice-push berms we measured were farther from the water in 1947 than they are today.

The pond at arrow A in Figure 10 is in the ice scar shown in Figure 3a. It is interesting that this feature appears on maps, for example the U.S. Department of Commerce, National Oceanic and Atmospheric Administration 1976 map Camden Bay and Approaches no. 16044, as a pond. This may be the only pond ever shown on a map which was formed as a result of an ice ride-up. We have named this feature, Ice Scar Pond in Figure 1.

For this study area our observations indicate that sea ice ride-up to a distance of 20 m from the water is a common event, and that extreme but infrequent ride-up events extend over 100 m inland.

The second site visited was the shoreline near Collinson Pt. (Fig. 1). In May 1980 and 1981 we observed sections of this coast covered with ice ride-up debris. In May 1981 the ice was piled up 4 m high (Fig. 1). In August 1981 we found one area where 510 m of beach was continuously scarred by ice ride-up. These scars extended inland up to 30 m from the water's edge (Fig. 12). Ice-pushed gravel piles up to 1 m high, but typically less than 1/2 m high, were observed (Fig. 13).

Bathymetric and elevation survey measurements made along the line shown in Figure 12 were used to construct the profile shown in Figure 14. Above the 2-m depth the seabed was found to slope at an angle of 11°. From the water's edge to a distance of 10 m inland the beach profile has been modified by storm wave run-up. As a result, the forebeach profile shown in Figure 14 is concave in shape and devoid of all ice-scar relief, as shown in Figure 12.

The findings on this side of Camden Bay, along with those previously reported for the east side of the bay, indicate that for these shores ice pile-up and ride-up is a relatively frequent event that extends inland up to 20 m from the sea.

At the abandoned Bullen Pt. DEW Line station, on the mainland southwest of the Maguire Islands, we inspected a garage which had been damaged by shore ice pile-up. During the 1973-74 winter Walter Audi of Barter Island (pers. comm.) observed ice that had moved inland and piled up to the top of the 4-5 m high garage roof. The ≈ 30-m-thick ice, which moved from the west-northwest, caved in and entered portions of the steel-framed building shown in Figure 15. We found this building to be located 25 m from. the water at an elevation of about 6 m. The interesting' aspect of this event is that it occurred in a relatively sheltered location which is not only inside the barrier islands but also protected in part by the Bullen Pt. spit.

In May 1980 we observed a shore ice pile-up up to 5 m high and 300 m long located some 10 km west of Cape Halkett (Fig. 16). It. extended inland up to 35 m from the base of the 2-m-high bluff onto which the ice had piled. The ice pile-up is shown in Figure 17. In August 1981 we visited this location but found no marks on the tundra to indicate that inland ice movement had occurred. This is not surprising since this section of the coast is known to be retreating at an average rate of 6 to 10 m per year due to thermal and hydraulic erosion of the fine-grained, ice-rich soil composing the bluffs (Fig. 18). Therefore, ice scars on these shoreline bluffs can be expected to be removed by erosion in a few summer seasons.

In May 1981 at Ksook, the site of an abandoned trading post shown in Figure 16, we observed the shore ice pile-ups shown in Figure 19. The higher ice pile-ups extending westward away from the hut in Figure 19 were situated on a low-lying coastline. These ice piles were up to 5 m high and 20 m inland from the sea. The ice pile-ups to the north of the hut were 1 m higher than the ≈ 2-m-high bluff on which the ice came to rest.

Aerial views taken in August 1981 of the ice-pushed tundra relief and coastline are shown in' Figure 20. These views show that the previous winter's shore ice ride-up displaced and scarred a significant area of the shoreline. Ground views of the ice-pushed relief are shown in Figure 21. We found the coastline west of the hut where the ice moved inland to be composed of peat. Large slabs of this material up to 0.25 m thick were found to have been peeled loose and displaced inland by the ice (Fig. 21b).

A profile of one of the representative ice-pushed peat piles is presented in Figure 22. This pile reached an elevation of 2.4 m, or about 1.6 m above the undisturbed terrain. Other ice-push features were either higher or further inland (up to 29 m). The seabed offshore was shallow and composed of stiff peat and silt. The shallow slope of the seabed, 3.8°, is probably the result of the high rate of coastline erosion occurring in this area. Indeed, this coast is retreating faster than any other area on the entire Alaskan Arctic Ocean. Typical annual retreat is 10 to 25 m per year. This shoreline retreat may be illustrated in the 1949 photo shown in Figure 23. The arrows point to six structures. Those north of the dotted line, which represents the approximate shoreline location in 1981, are now gone. The last remaining Ksook structure will be destroyed within two summer open water seasons if annual coastal retreat averages between 10 and 12 m.

On 26 June 1981, at about 10:30 am, sea ice up to 0.5 m thick moved in upon the beach along a broad section of the coast near the Lonely DEW Line station (Fig. 16). Local personnel who observed the event stated that the ice piling lasted less than 10 minutes and reached a height of 4 m (Fig. 24). In August we measured the ice-pushed gravel relief and found that the ice had dozed up beach material consistently for a distance of 30 m from the water's edge along more than 500 m of the shore. The longest inland ice advance as determined by ice scar length was 59 m. No ice remained exposed on the beach in late August. Ice was found, however, under several of the ice-push gravel piles, such as the pile shown in Figure 25.

Along the beach near the Lonely DEW Line station, we discovered several old ice scars which were not detected on previous recon flights (Fig. 26). The distance inland of the ice-push feature furthest from the sea was 85 m. Ground views of the ice-pushed tundra berms (1 and 2) shown in Figure 26 are presented in Figure 27. These berms were impregnated with driftwood, which was incorporated into the soil during ice dozing.

Aerial photos of this coastline taken in 1945 and 1949 before development had occurred shows that these ice-push features were in existence then (the 1949 photo is shown in Figure 28). Our aerial photo assessment of shoreline retreat in the immediate area of the ice scars is 0.4 m per year. Therefore, in 1949 ice-push no. 2 was located around 100 m from the ocean. How far inland the ice-push features were after the ice ride-up event occurred is, of Course, unknown.

Following our observation near Lonely DEW Line station, we stopped at Drew Pt. (Fig. 16) . In April 1981 we had observed extensive sea ice ride-up and ice pile-up at Drew Pt. spit, the latter to 3 m high. In August we measured the furthest inland ice push berm to be 56 m. The spit was found to consist for the most part of peat and fine-grained silt. The ice had pushed this material into piles up to 1.5 m high. Sea ice and driftwood were found incorporated into the debris of the larger piles (Fig. 29). In some locations large slabs of organic material about 0.25 m thick had been displaced (Fig. 30) and stacked layer upon layer (Fig. 31). This area of " the coast is receding at a rate of 6 to 10 m per year. Therefore, summer storms and coastal currents rapidly modify the coastline and in so doing remove ice ride-up scars on the land.

A prime area of interest during this summer field program was Icy Cape and the chain of barrier islands extending to the southwest. On Icy Cape (Fig. 32) we observed in April 1981 a large shore ice pile-up which was . just over 20 m high at its peak (Fig. 33). On June 26 Fred Crory (pers. comm.) visited the site and estimated the ice pile-up to be 17 m high (Fig. 34). We were interested to learn if any of the ice pile was still in" existence in late August. No ice was found (Fig. 35). It was apparent that a significant summer storm had driven seawater over 50 m inland, completely smoothing the silty-gravelly beach. This event also removed any ice scars which might have existed and perhaps the last of the ice pile-up. While a high sea (Fig. 35) would have precluded our obtaining the desired offshore seabed profile, we were also prevented from obtaining a beach profile at this site by a helicopter rotor head malfunction which occurred on landing. This-problem forced our immediate return to Prudhoe Bay.

The mechanical problem also prevented our visiting a site just west of Icy Cape on Solivik Island where in April we observed ice that had piled up on top of a 2-3-in-high bluff. The ice piled along a l-km section of the beach to a distance of 30 m from the sea and to a maximum height of 21.5 m. Some of the ice incorporated into the pile-up was over 1.5 m thick, indicating that the ice piling had occurred in March. From the air the ice formation did not appear at all spectacular (Fig. 36), but from the ice surface it took on a rather impressive appearance (Fig. 37).

Another site of prime interest which we were also unable to visit was 10 km east of Cape Lisburne. " Here the ice had piled along some 3 km of shoreline to a maximum distance of 60 m inland (Fig. 38). The ice blocks in the pile-up were 65-70 cm thick. The highest pile-up was 20 m high. The ice blocks had a relatively steep angle of repose of nearly 40° and extended inland 55 m from the sea (Fig. 39).

Summary and Conclusions

The findings of this brief field program are that ice ride-up can leave scars and soil berms on the arctic coast which remain visible for many decades. Shore ice pile-up and ride-up to 20 m inland from the sea appear to be relatively frequent events.

Old tundra ice scars and ice-pushed soil berms revealed inland ice movements of at least 125 m on the east coast of Camden Bay and 85 m near the Lonely DEW Line station. These features were found to be over 30 years old, as revealed by old aerial photography.

Shore ice pile-ups along the Chukchi Sea 'coast in 1981 were found to be massive, some reaching heights of 20 m and extending continuously along several kilometers of shoreline.

To better understand the potential hazard of shore ice pile-up and ride-up to coastal development, we need to know the frequency, magnitude and inland limits reached by these events. Further reconnaissance flights coupled with on-site observations are vital to achieving this understanding.

Acknowledgment

This study was funded in part by Gulf Canada Resources and by the U.S. Bureau of Land Management through the National Oceanographic and . Atmospheric Administrationts Alaska Outer Continental Shelf Environmental Assessment Program."

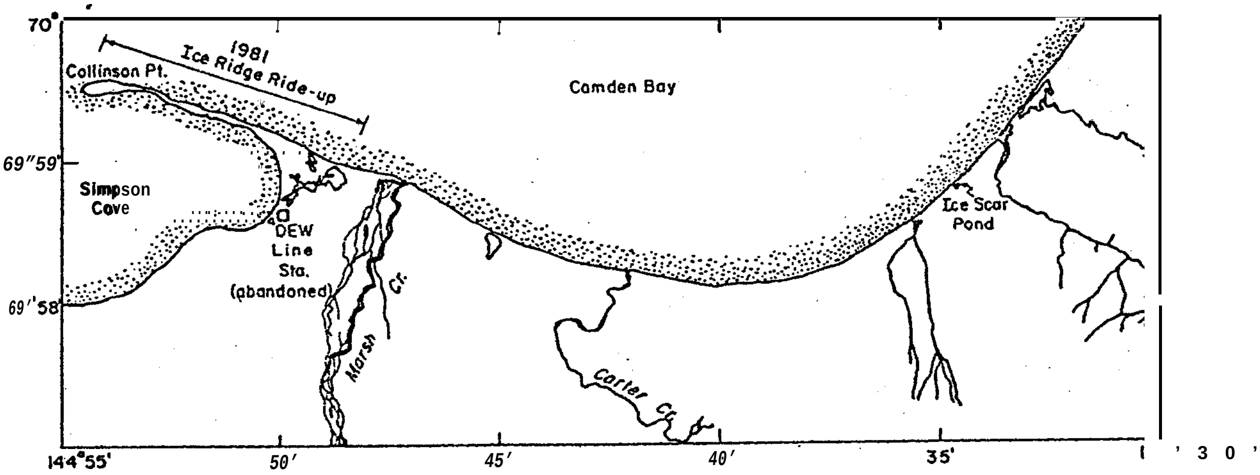
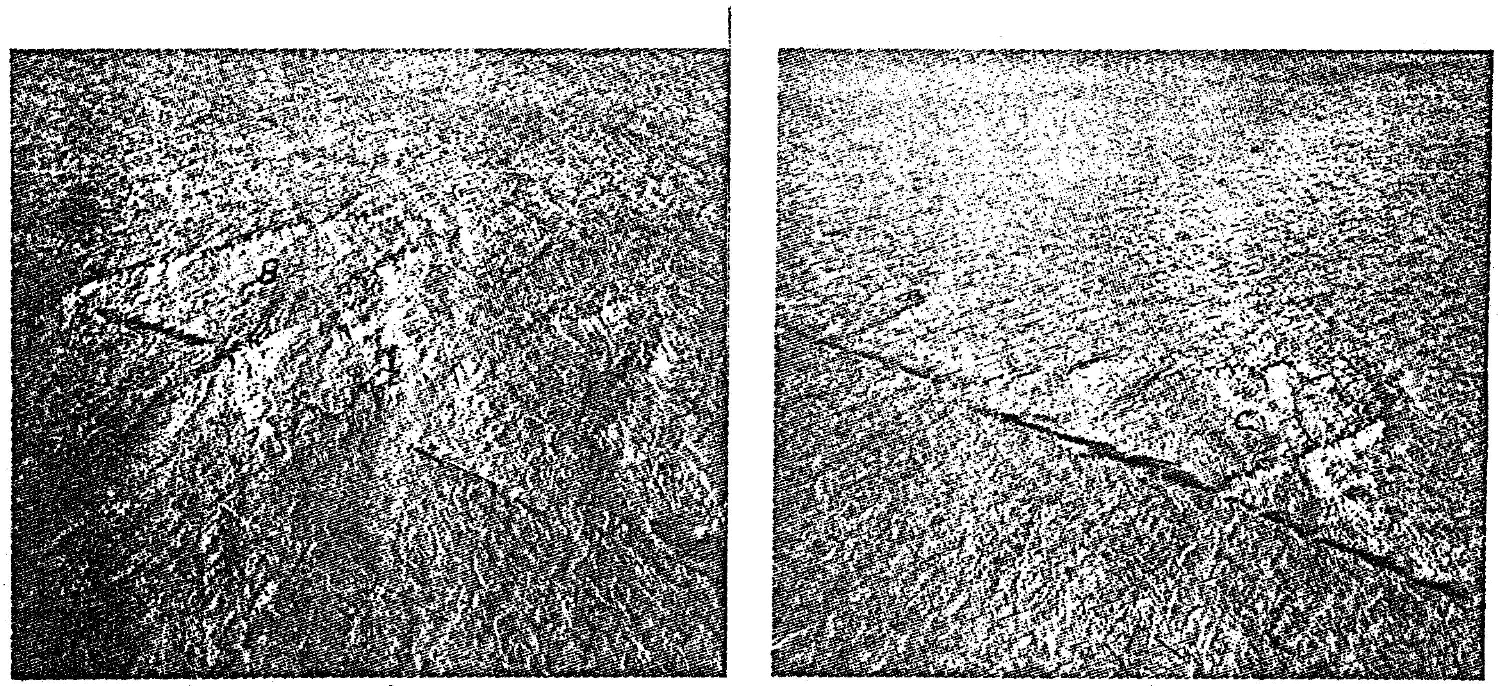
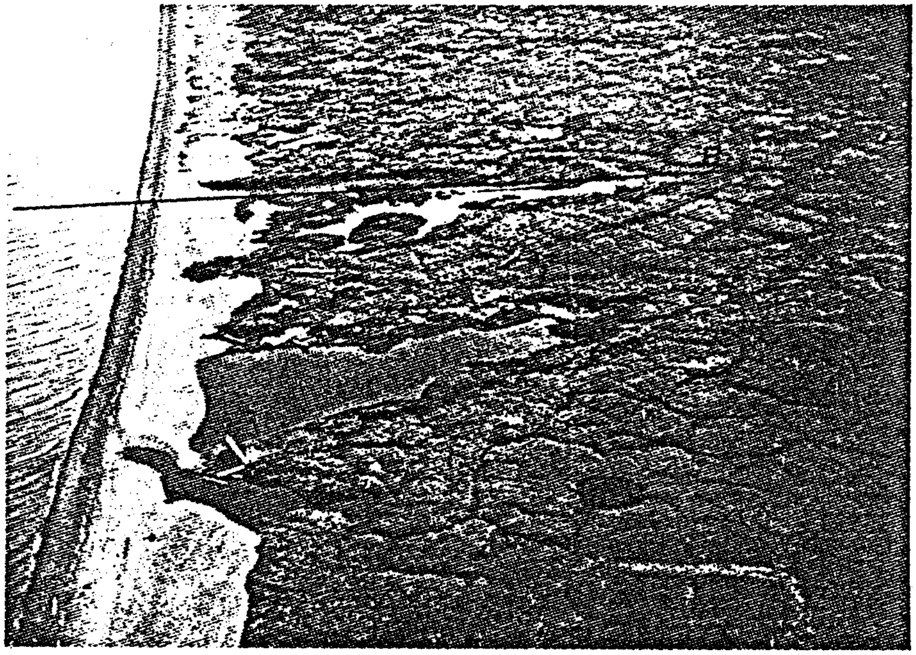



Figure 1. Camden Bay location map.

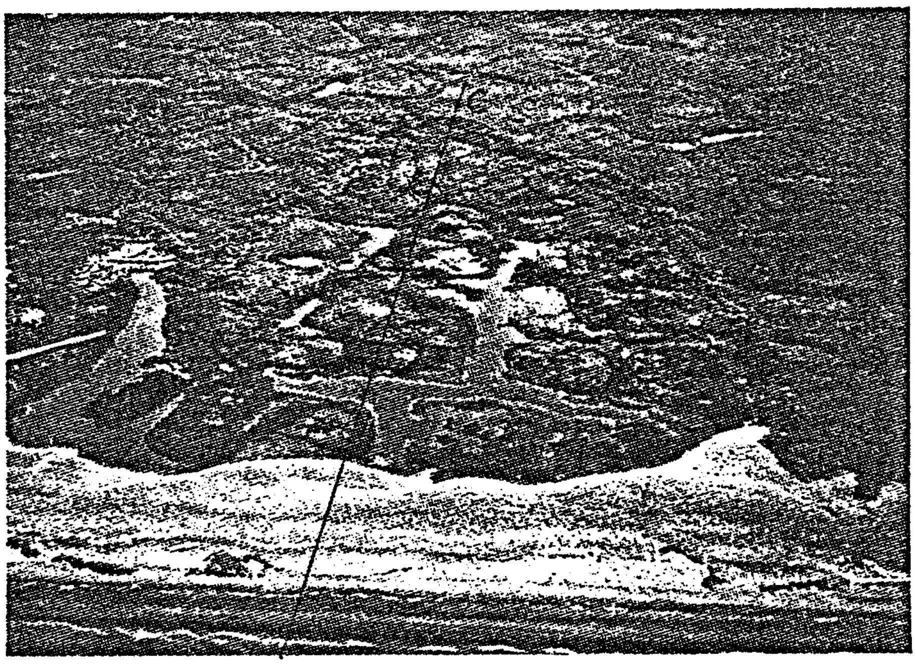


a. b.

Figure 2. Winter view of ice-scarred tundra. Note the lobate outline of the ice-pushed berms, which are similar in outline to thick rafted sea ice.



a.



b.

Figure 3. Summer view of ice-scarred tundra features shown in Figure 2. Lines B and C represent locations of elevation profiles.

Figure 4. Aerial view of" ice-scarred coastal terrain.

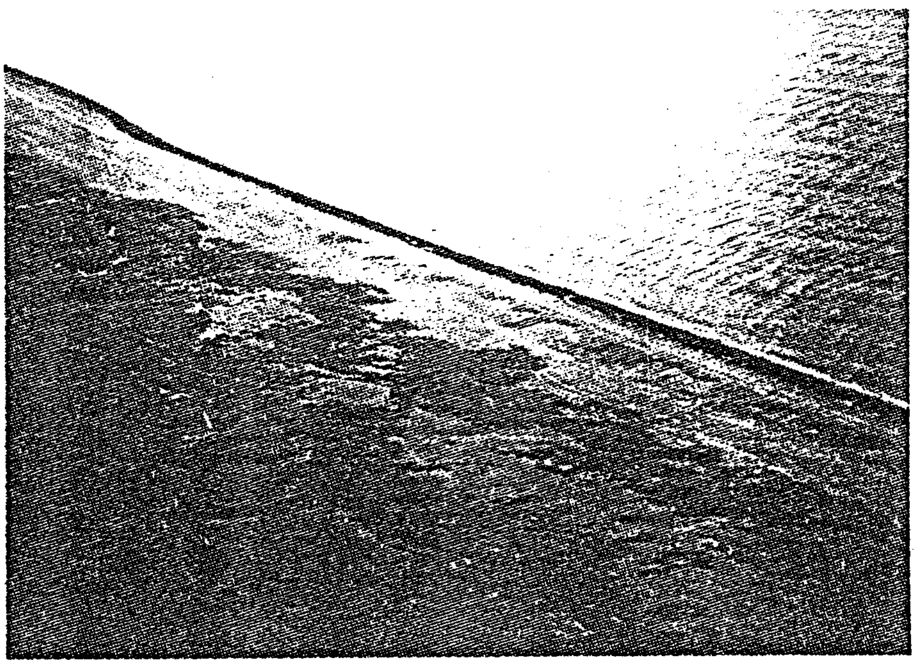
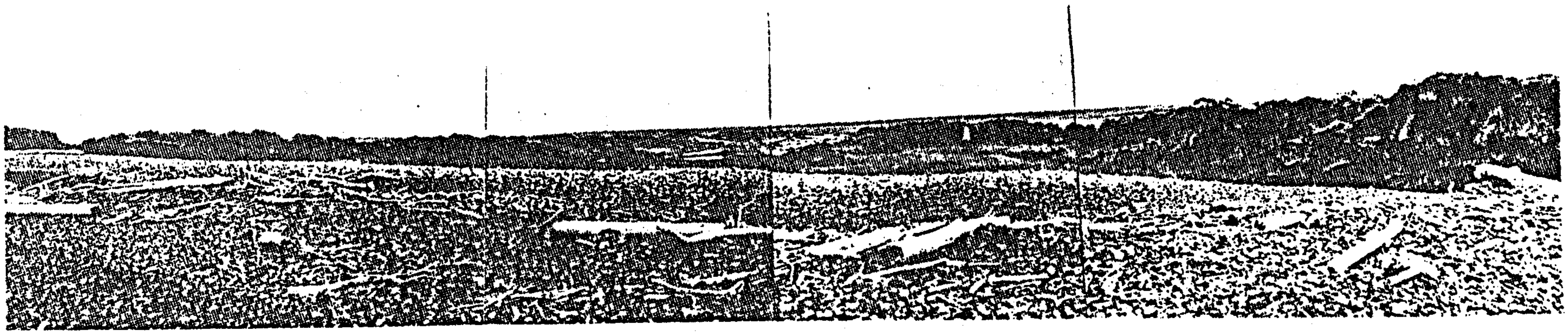
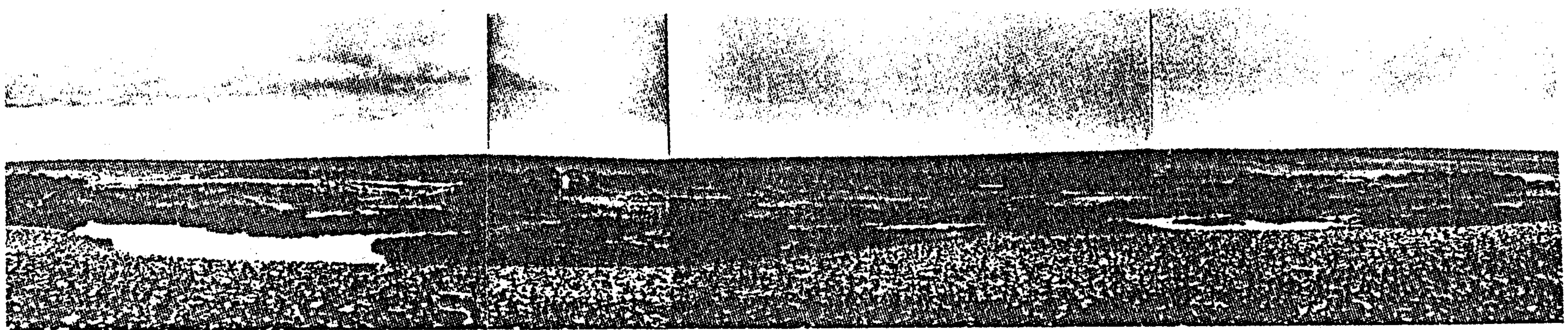


Figure 'S. Ice-pushed tundra berms southwest of those in Figure 4. Note the ice-pushed gravel piles on the beach which were-the result of a previous winter's ice ride-up.



a.



b.

Figure 6. View from the beach of the ice-scarred tundra. Views a and b relate to features overlain by profile lines B and C respectively in Figure 3.

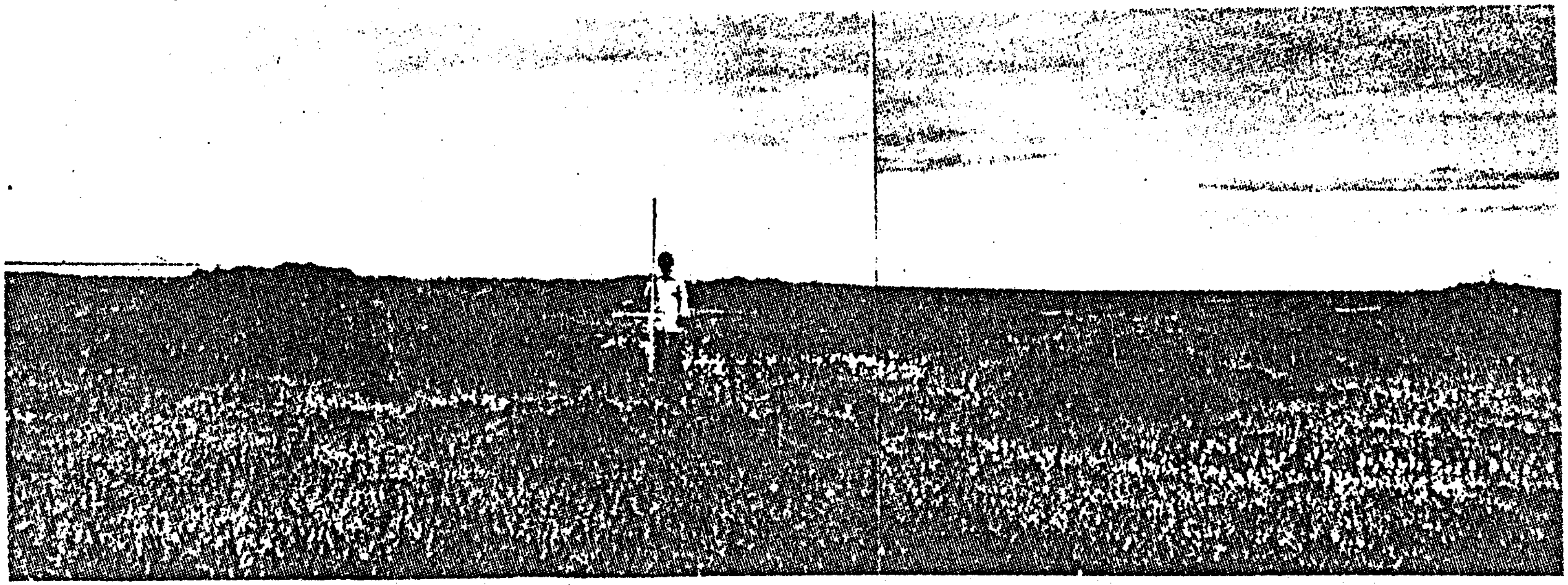


Figure 7. Ice-pushed tundra berm behind person in Figure 6b as seen from **landward side.**

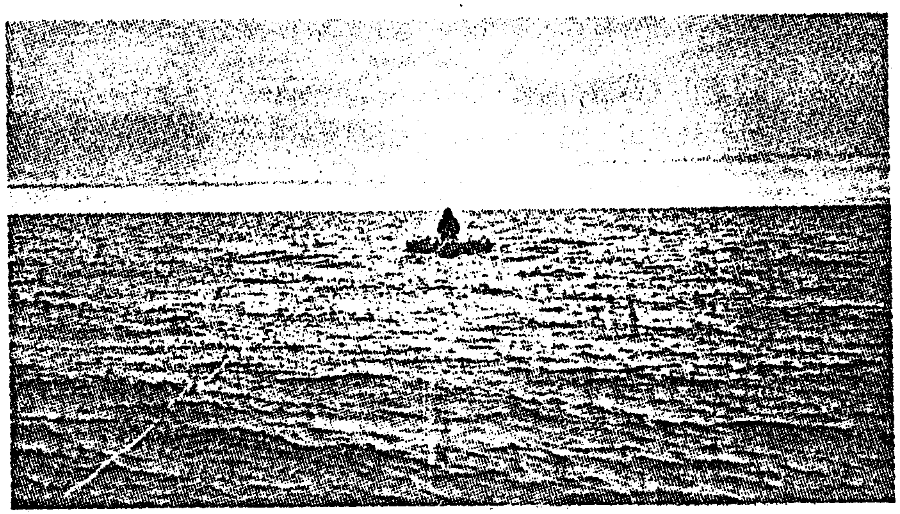


Figure 8. Sounding measurements were made from this raft.

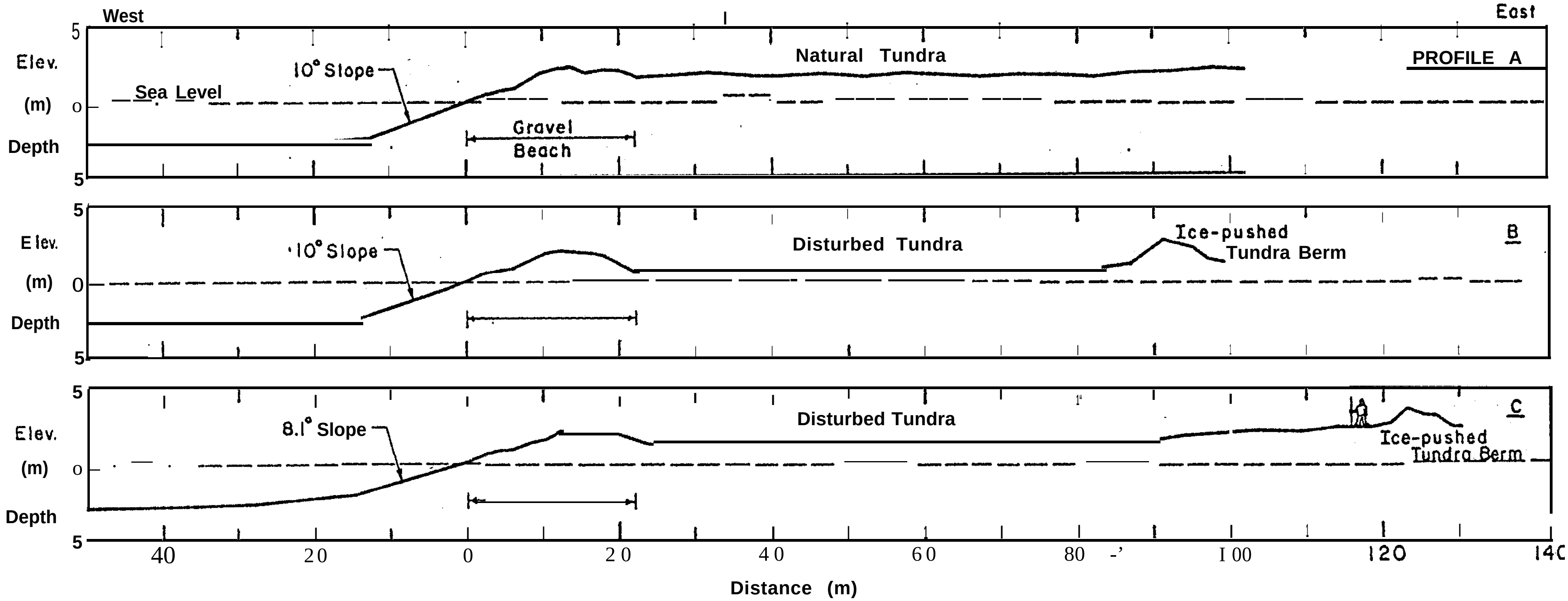



Figure 9. Seabed - beach - tundra profiles.

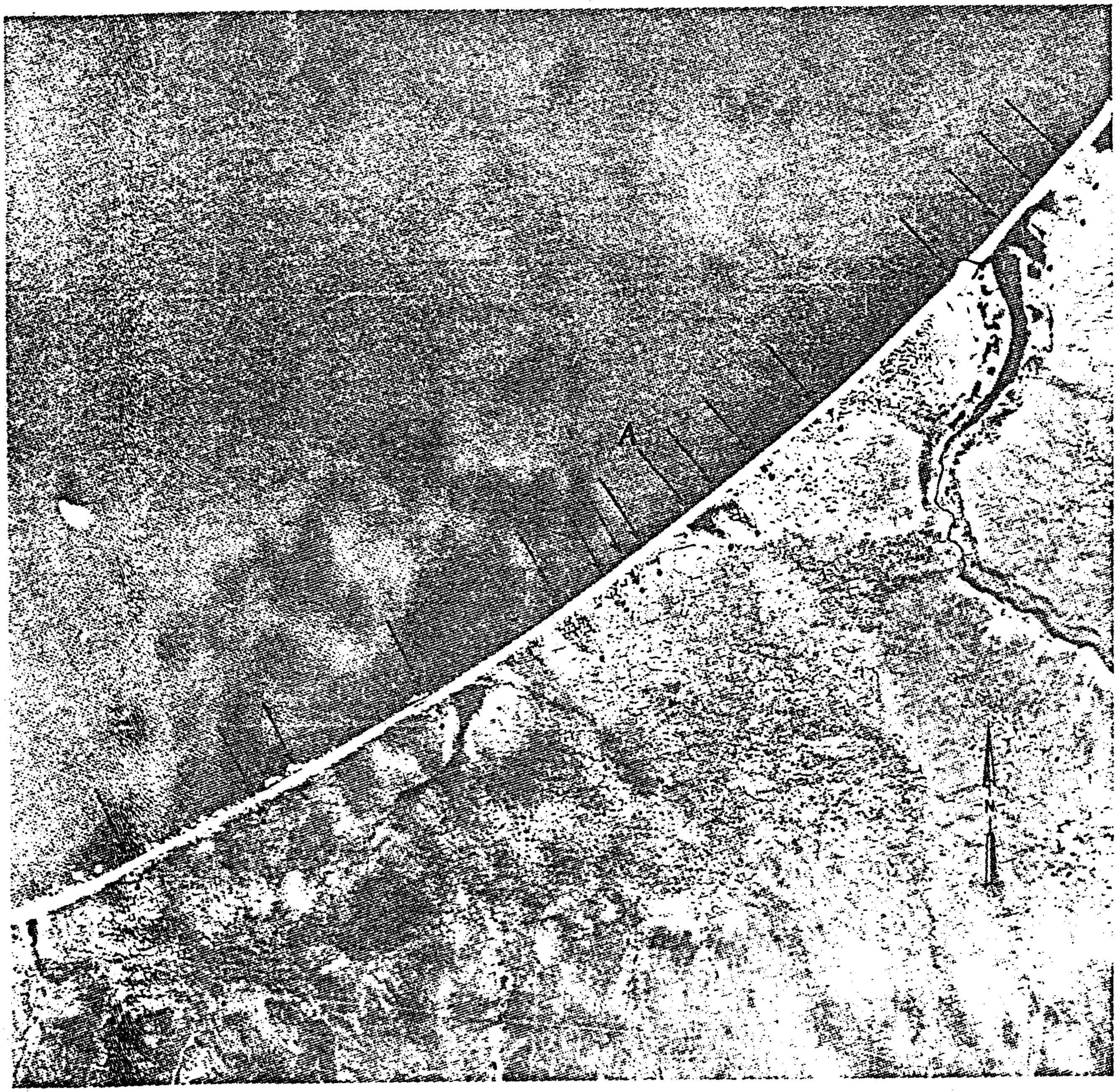



Figure 10. Southeast side of Camden Bay showing ice-scarred tundra coastal features. The arrows point to a number of major ice scars and the dots indicate the ends of the scars. The arrow at the left points to the scarred tundra shown in Figure 5.

Figure 11. Shore ice pile-up near the shore facilities of the abandoned DEW Line station east of Collinson Pt.

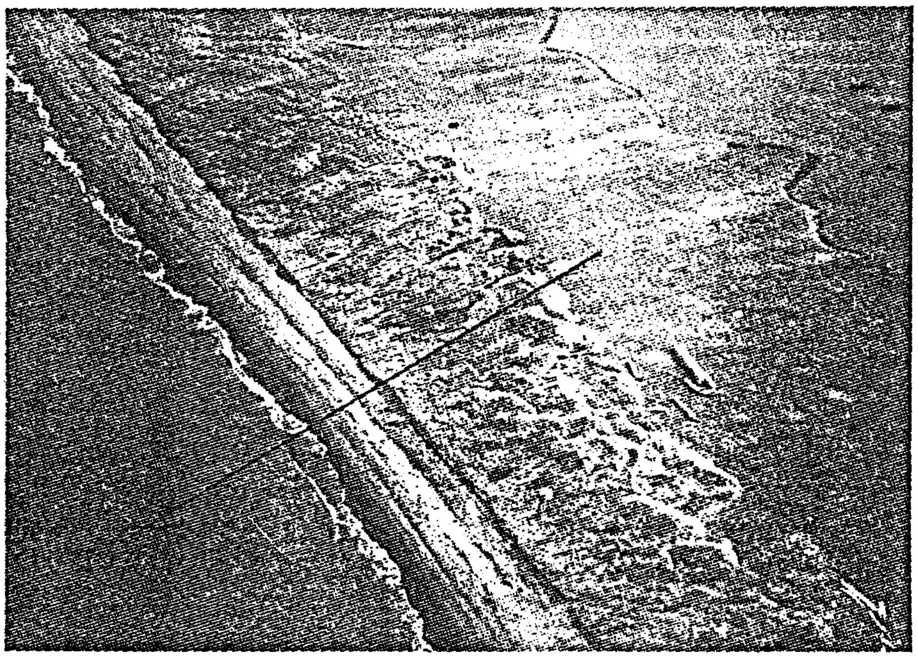


Figure 12. Representative ice ride-up beach morphology along the coastline east of Collinson Pt.

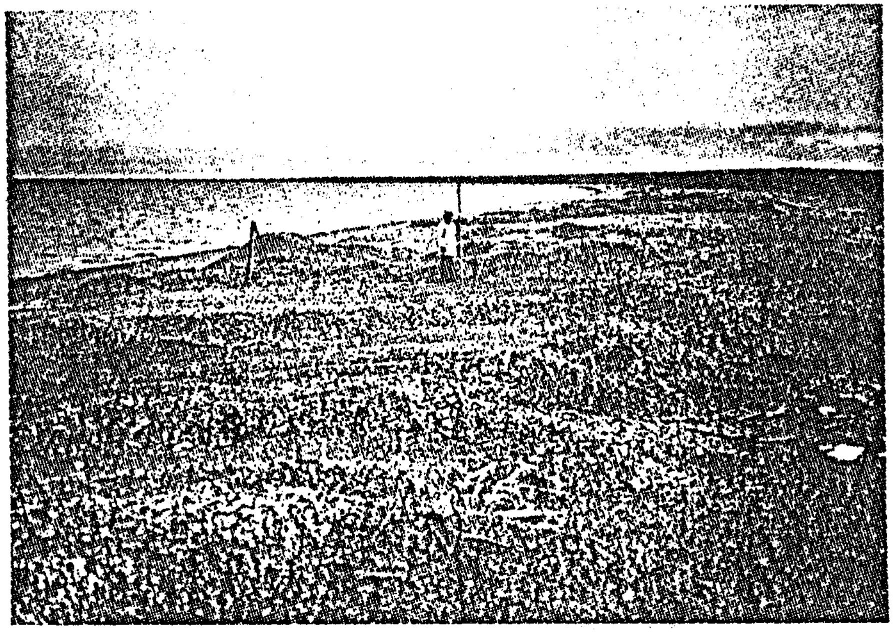


Figure 13. Ice-push beach striations and gravel piles along the shore east of Collinson Pt.

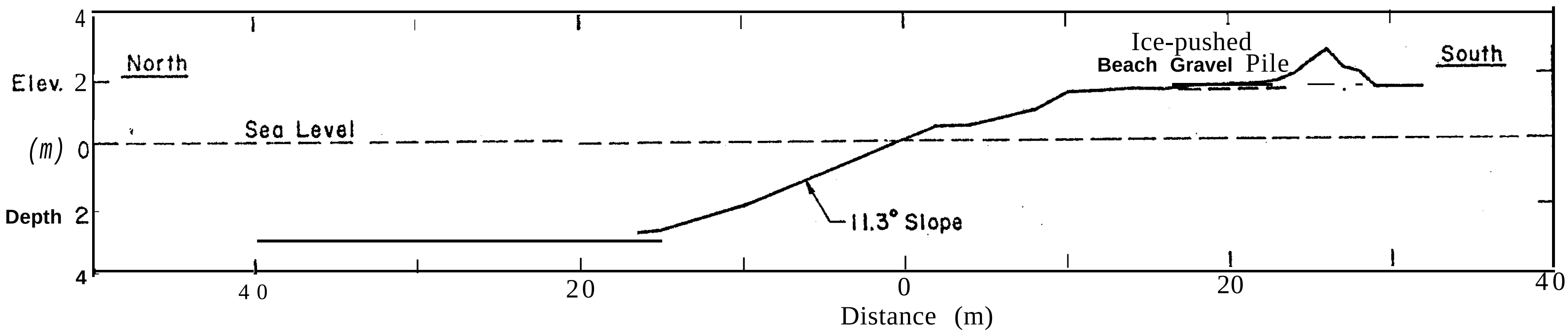
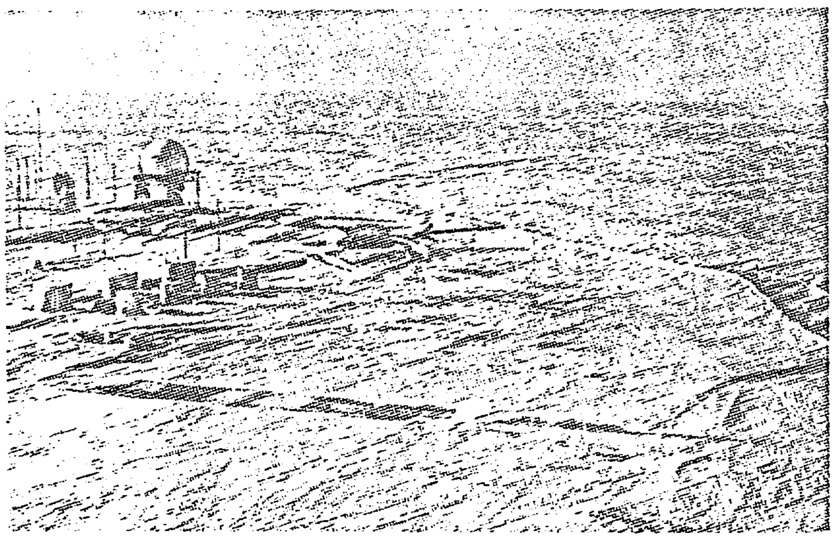
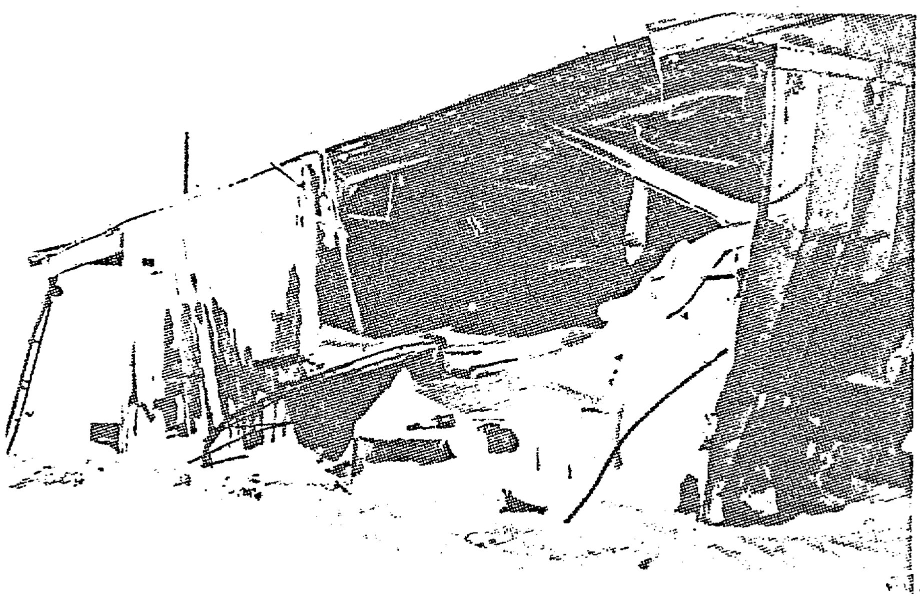



Figure 14. Seabed beach profile along line drawn in Figure 12.



a.



b.

Figure 15. Bullen Pt. DEW Line station. Arrow in photo a points to the garage damaged by ice and also indicates the direction of onshore ice movement and the direction from which the photo in b was taken.

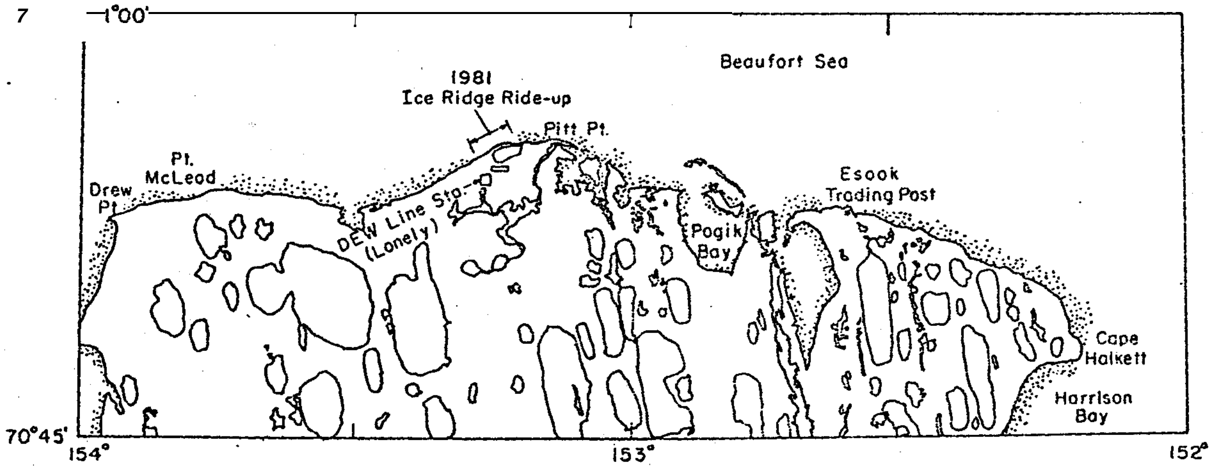



Figure 16. Location map of the Beaufort Sea coast between Cape Halkett and Drew Pt.

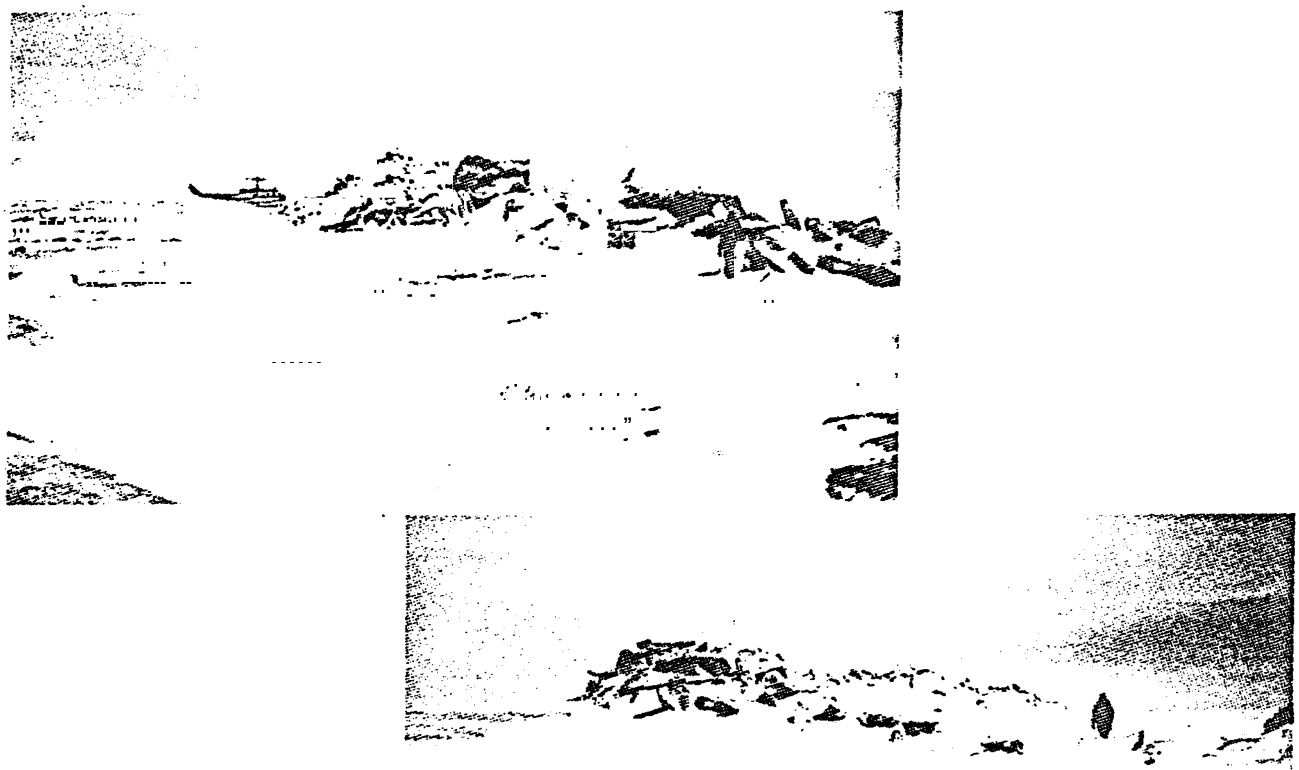


Figure 17. Shore ice pile-up west of Cape Halkett. Note that the ice blocks are exceedingly dirty, indicating that the ice formed in very turbid water.

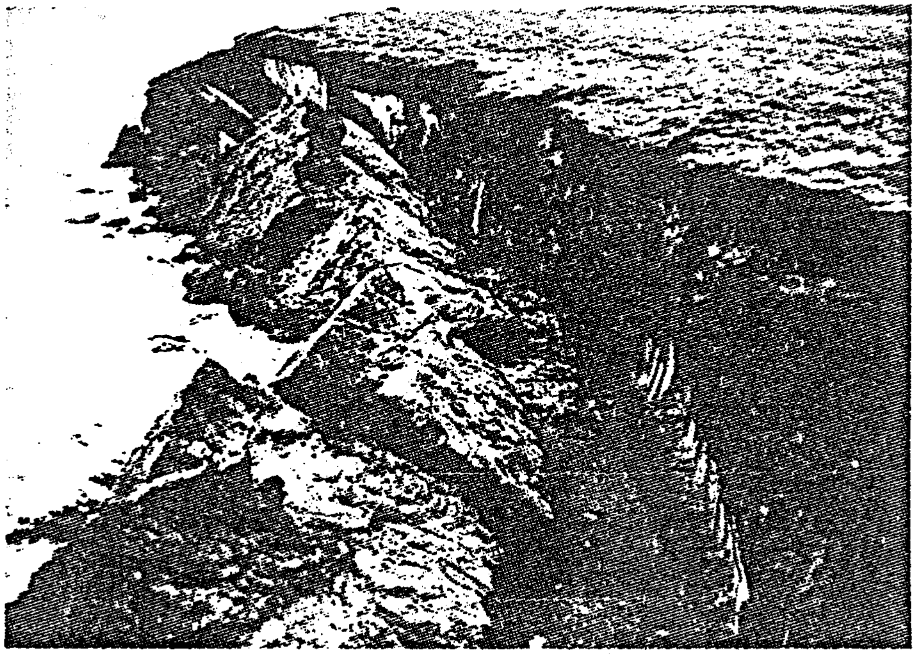


Figure 18. Coastal bluff erosion west of Cape Halkett. The ≈ 2.5-m-thick mat is underlain by massive ice and ice-rich silt easily undercut and eroded by the sea.

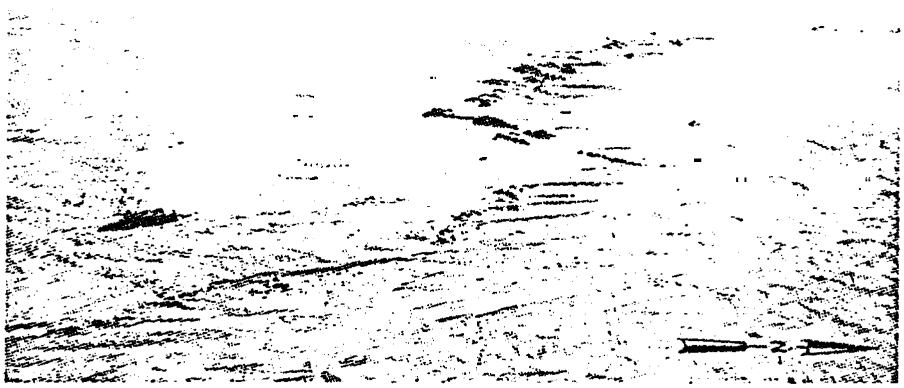
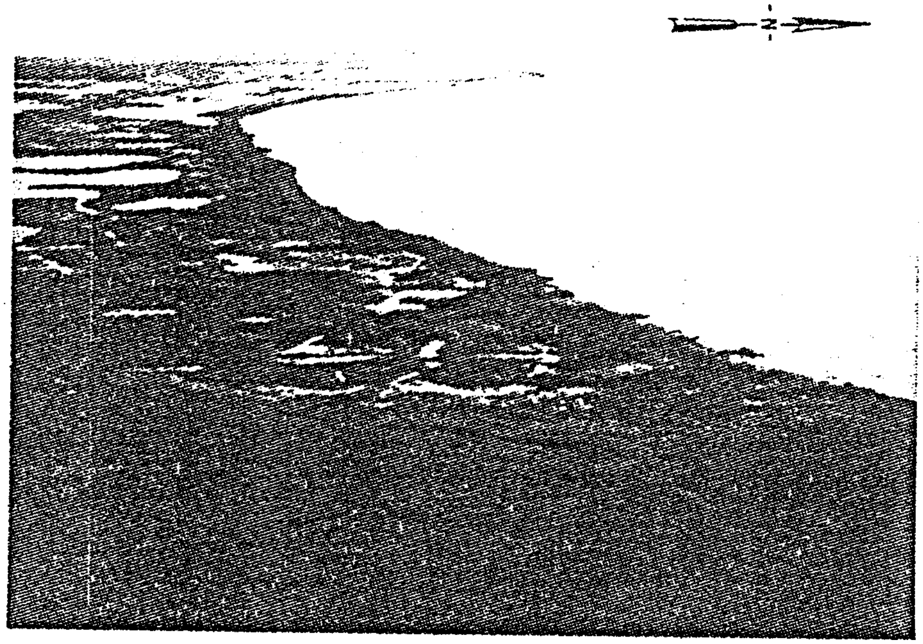
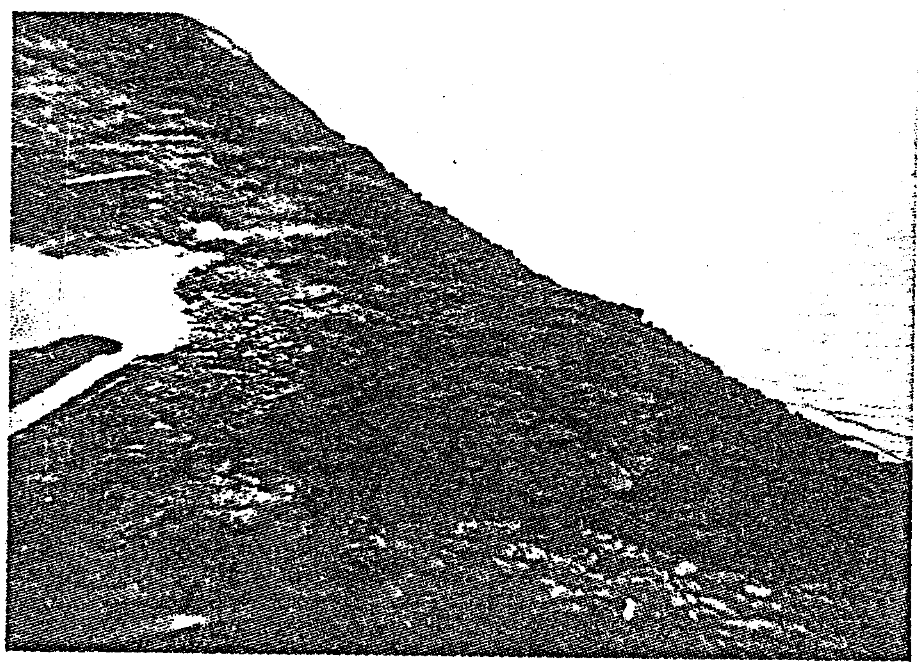


Figure 19. Shore ice pile-up at Ksook.



a.



b.

Figure 20. Aerial view of ice-pushed peat piles near Ksook. Note the general size and stacking configuration of the displaced peat slabs shown in b.

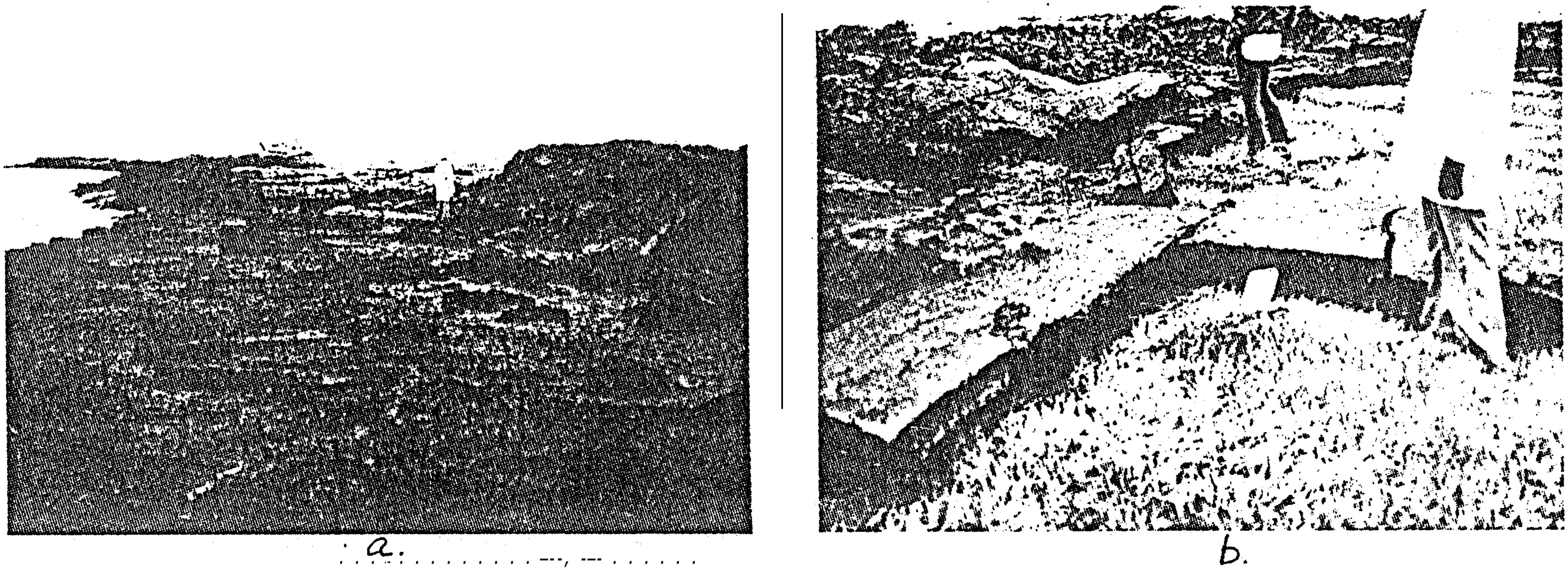


Figure 21. Surface view of Ksook ice-pushed peat piles.

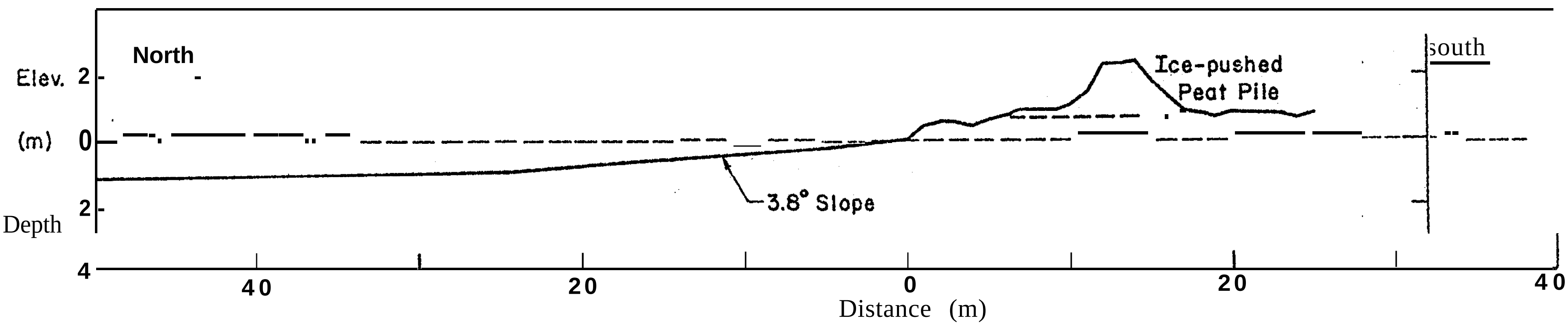



Figure 22. Offshore to onshore profile across one of the ice-pushed peat piles at Ksook.

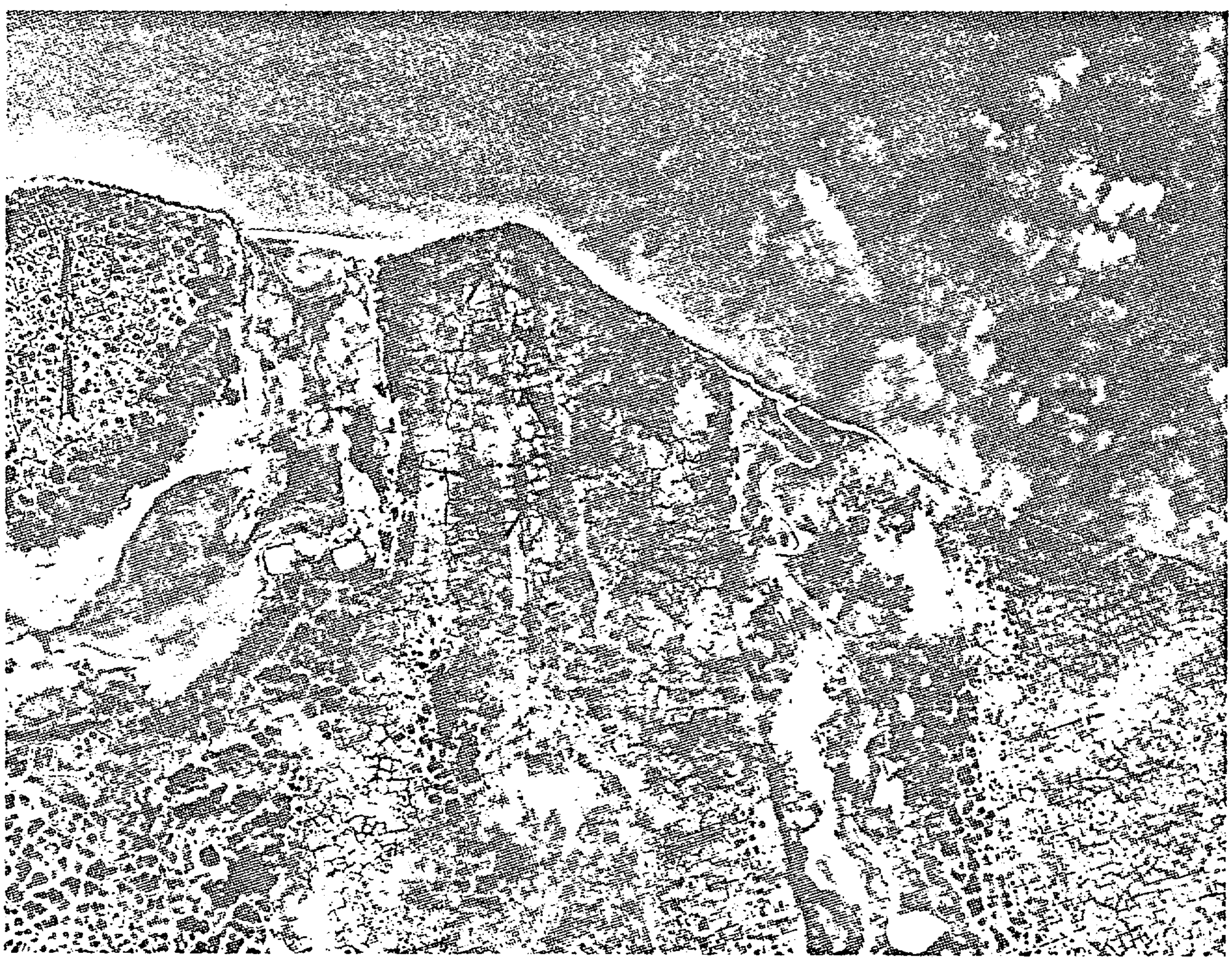
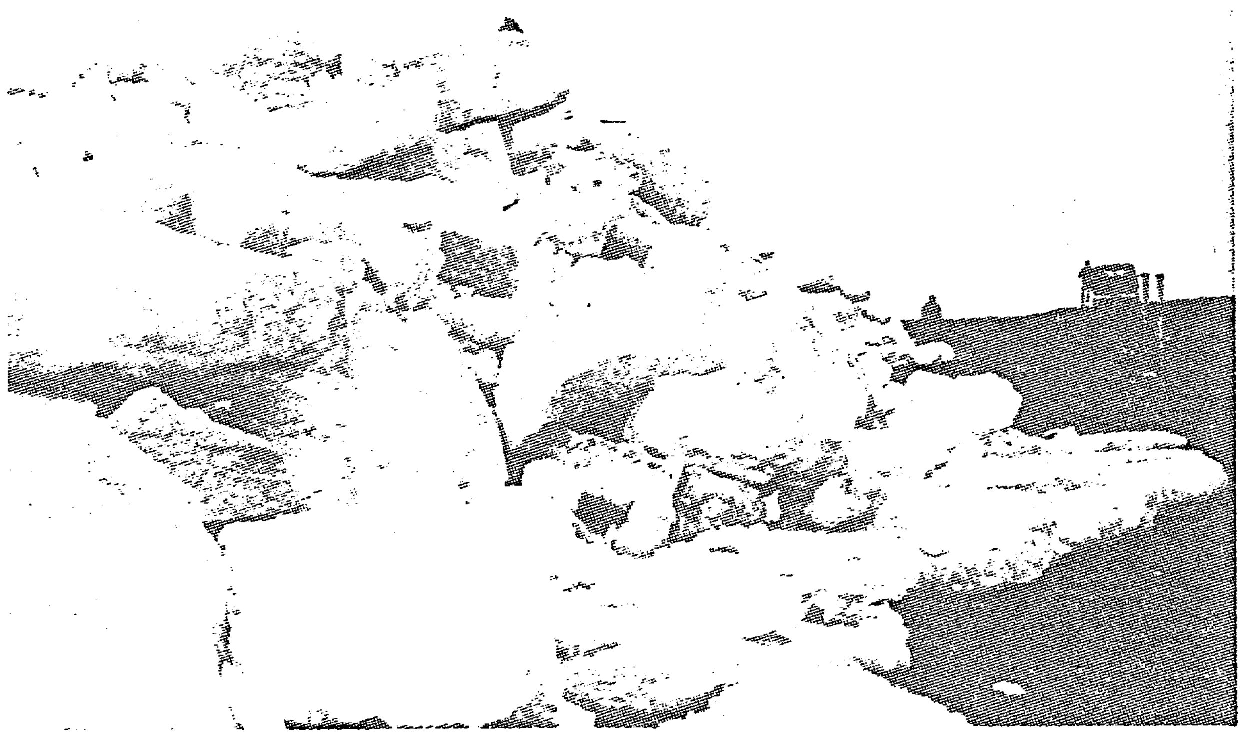


Figure 23. Aerial view of Beaufort Sea coast at Ksook. The lower arrow on the left points to the structure shown in Figure 19.

a.



b.

Figure 24. Ice pile-up on beach near Lonely DEW Line station. Note ice-pushed gravel in a. {Photograph courtesy Fred Crory)

Figure 25. Gravel and pothole beach relief remaining after shore ice pile-up melted away.

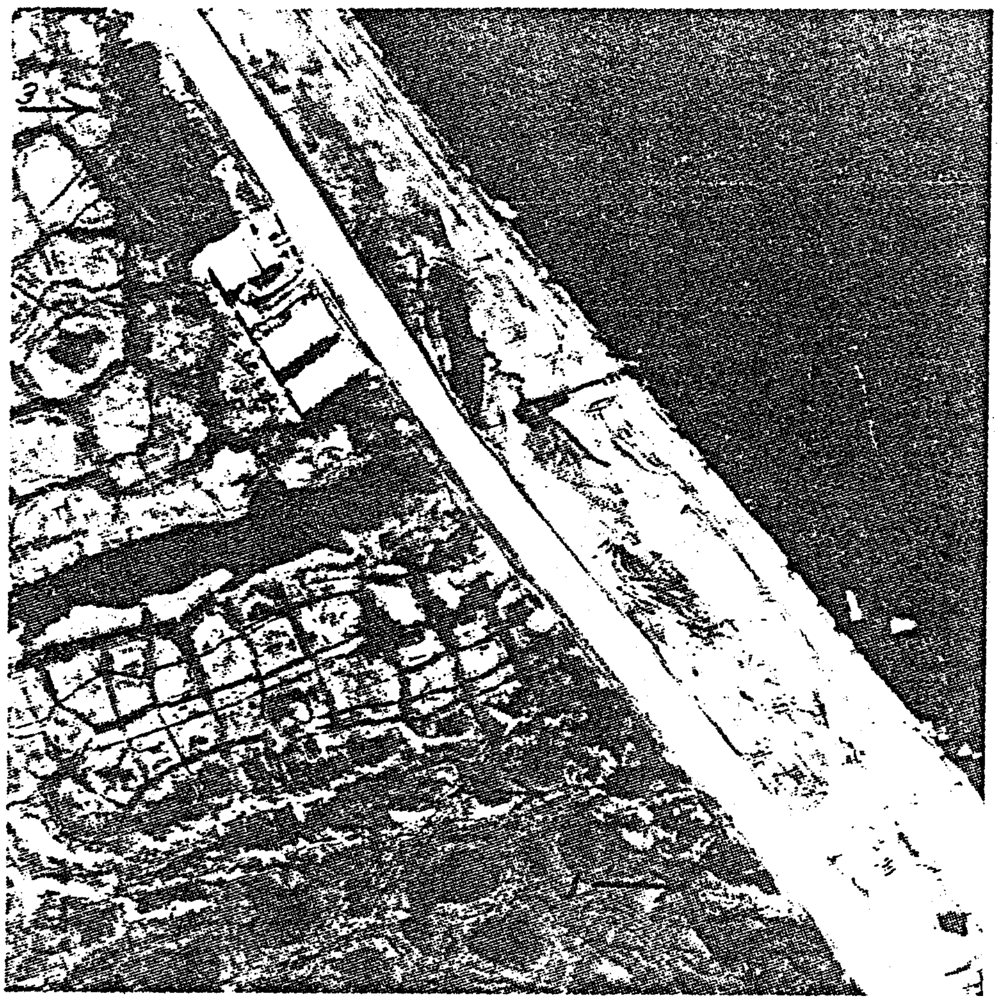
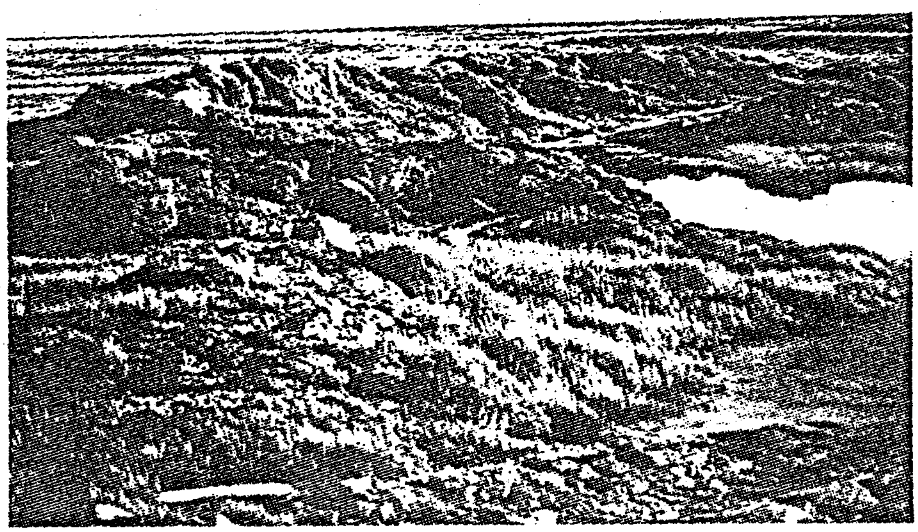



Figure 26. Arrows pointing to old ice-scarred tundra relief near Lonely DEW Line station.

a.



b.

Figure 27. Ice-pushed tundra berms in a and b are features 1 and 2 shown in Figure 25.

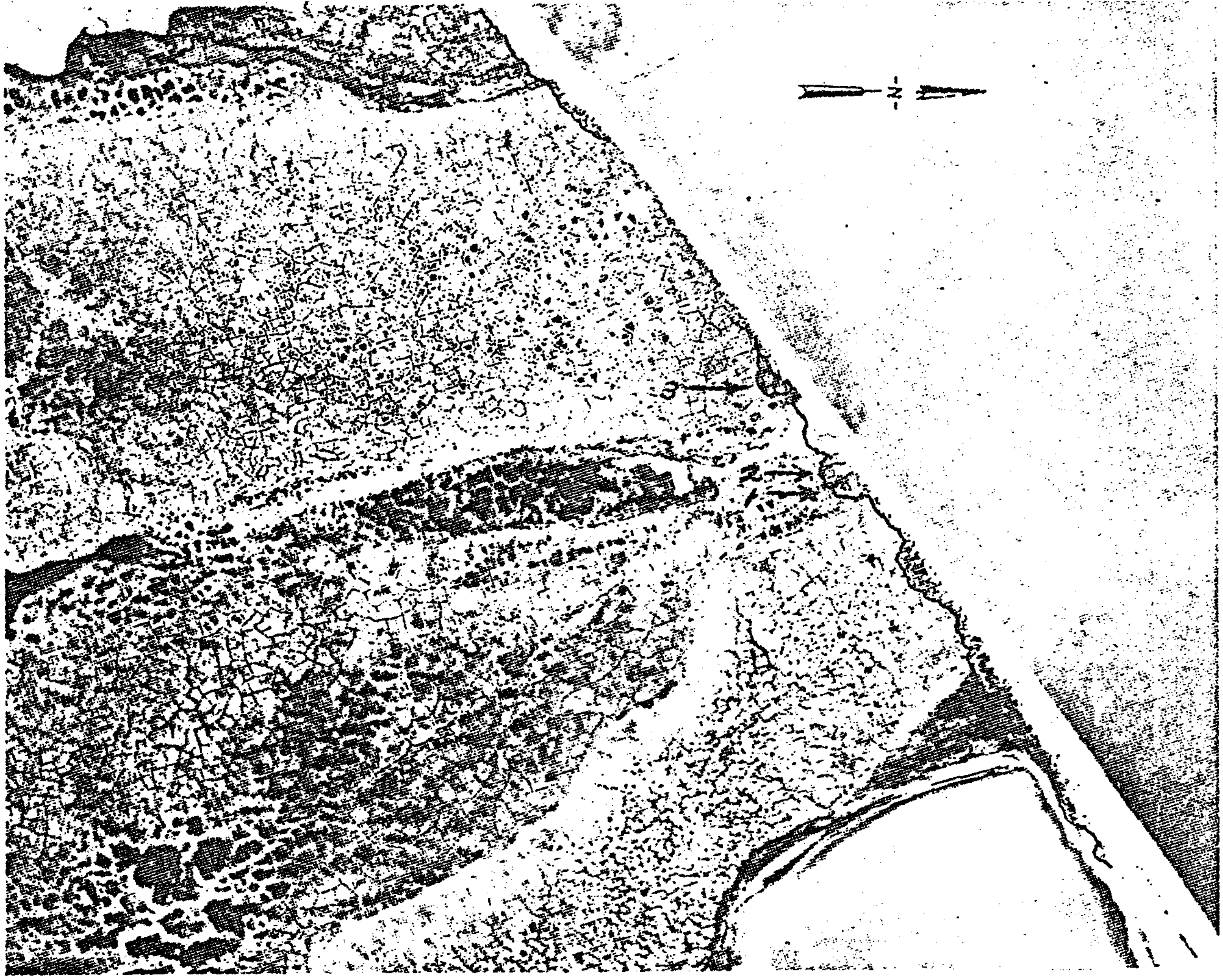



**Figure 28.** Aerial view of tundra ice-push scars 1, 2 and 3 shown in Figure 26 and-other ice-scarred terrain, outlined by black line, not easily detectable today due to shoreline road construction and storm wave modification processes.

**Figure 29.** Ice-pushed silt and peat pile on Drew Pt. spit. White area in front of observer is ice.

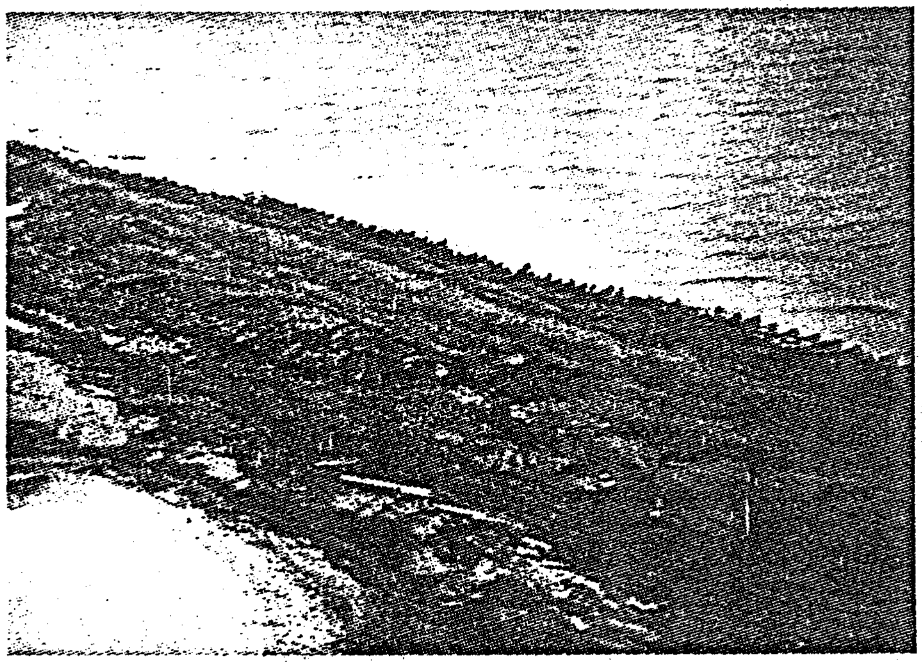


Figure 30. Slabs of peat displaced by ice-push on Drew Pt. spit.

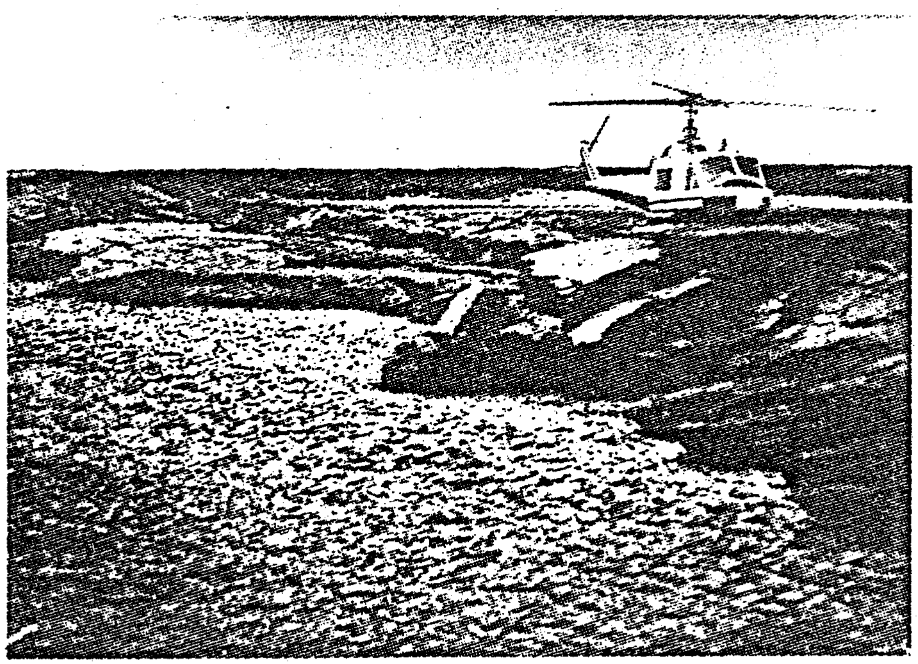


Figure 31. Peat slab piles on Drew Pt. spit.

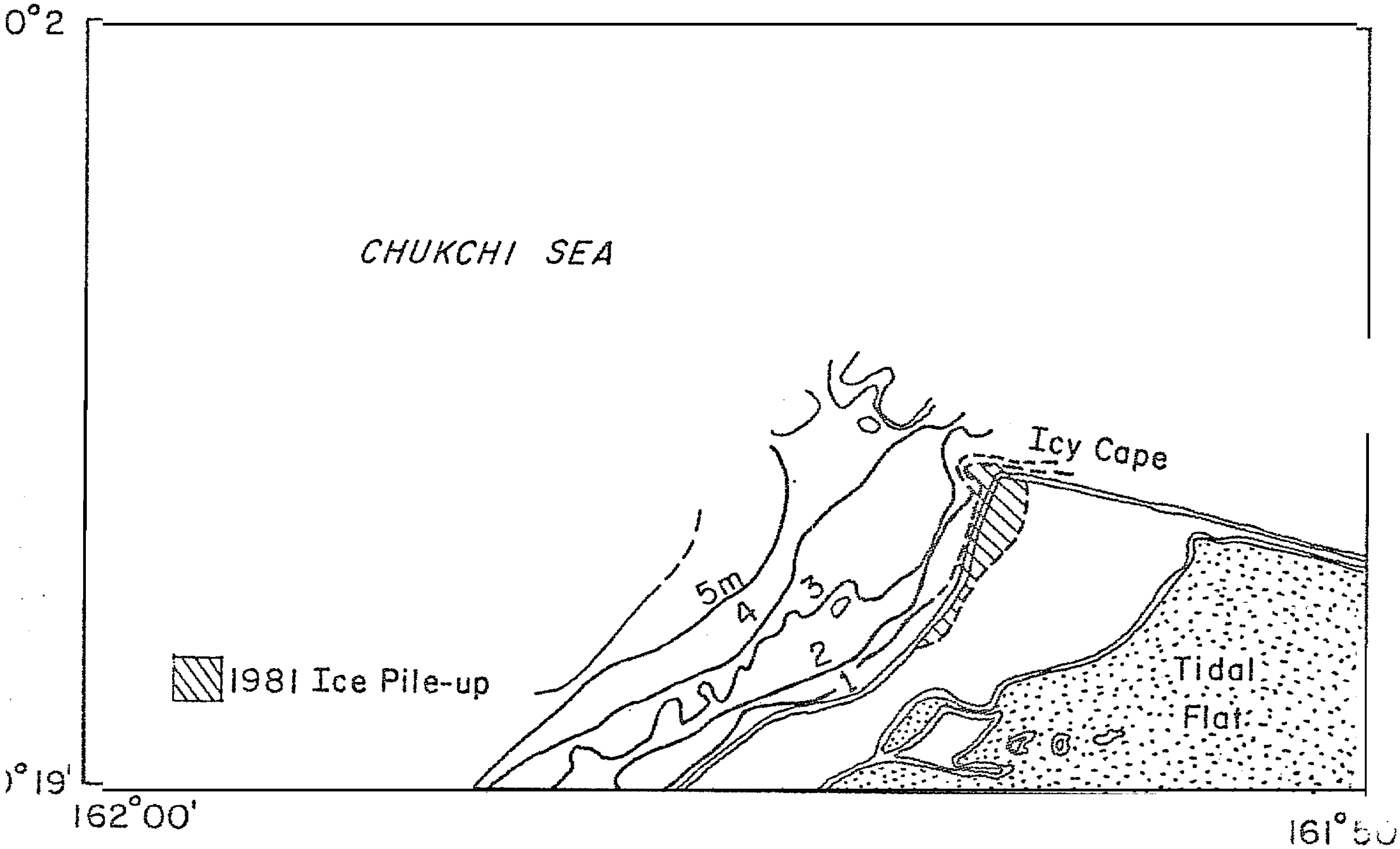



Figure 32. Map of Icy Cape showing the general location of the 1980-81 winter shore ice pile-up. Offshore contours are recent measurements (from J. Hunter, USGS).

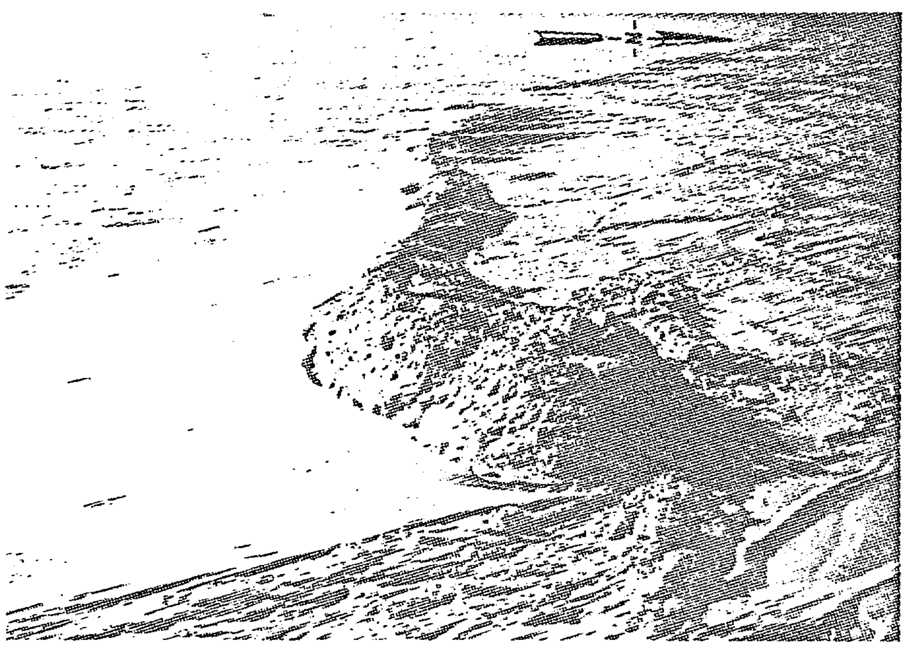
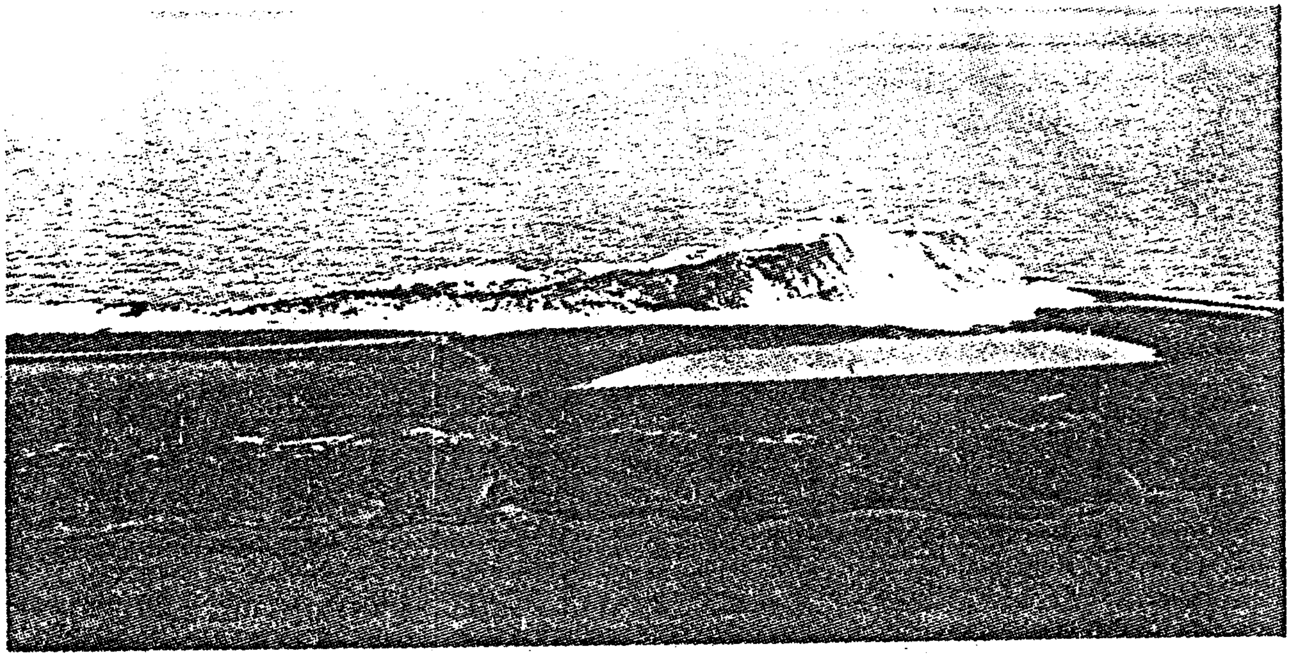
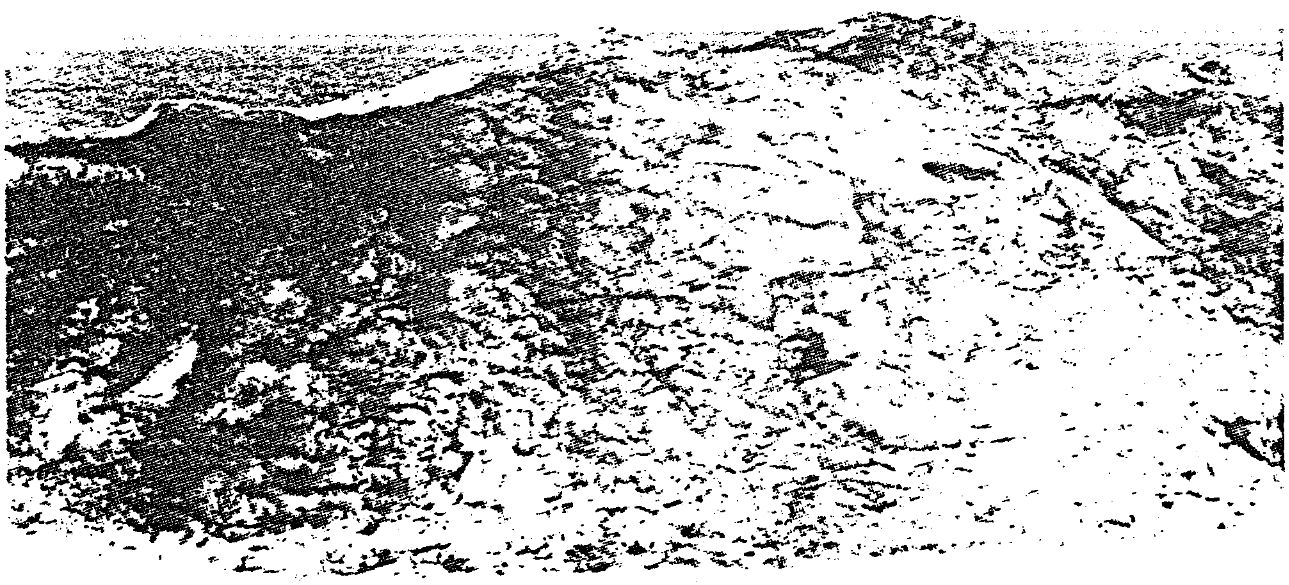


Figure 33. Shore ice pile-up on Icy Cape in April.



a.



b.

Figure 34. Icy Cape shore ice pile-up on 26 June. Note the seabed material which was gouged up by the ice and incorporated into the ice pile. The pile is seen at this time to have very subdued relief, i.e., the angular features of the ice blocks are gone and the interblock voids are filled 'with refrozen meltwater. The pond shown in photo a was fed by melt-water from the ice pile and did net exist when we made our August visit. (photography courtesy Fred Crory)

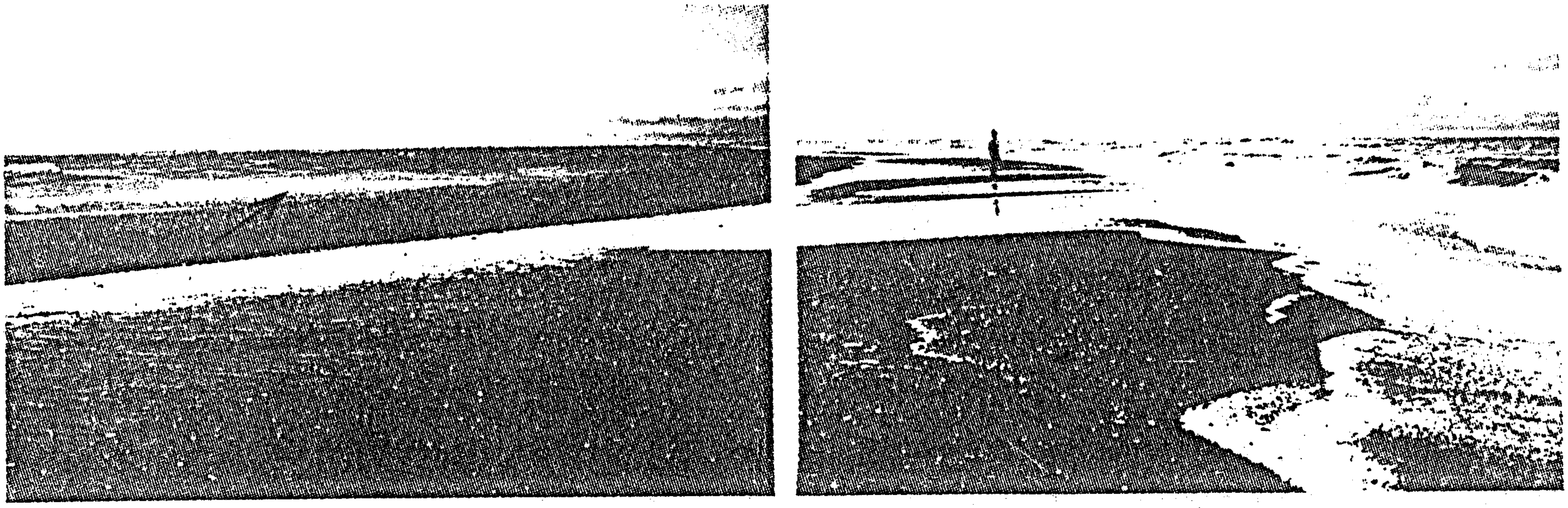


Figure 35. Icy Cape shore ice pile-up site in August. The pond shown in Figure 34a was located in the depressed area indicated by the arrow.

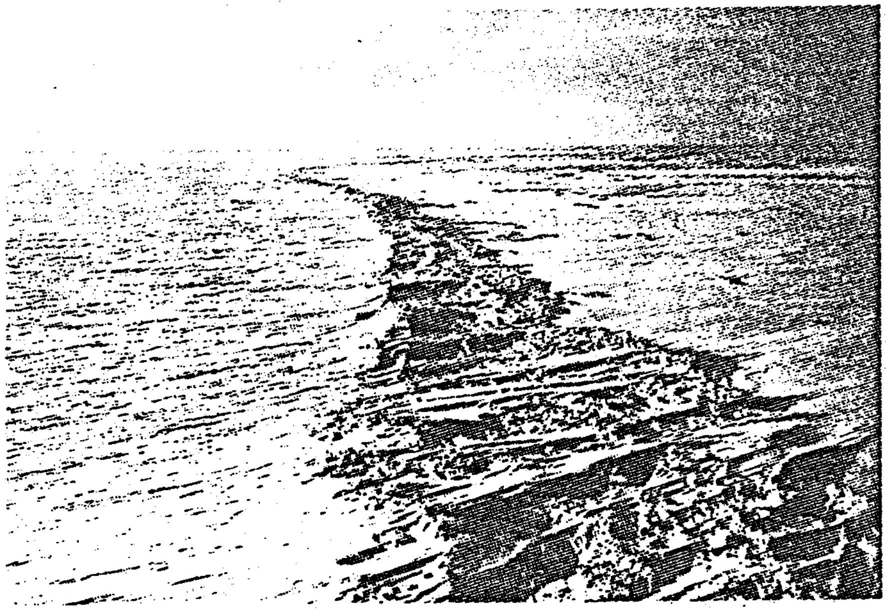


Figure 36. Shore ice pile-up along the coast of Solivik Island. The island is to the left of the ice rubble.

Figure 37. View of shore ice pile-up on Solivik Island taken from the sea ice. After the ridge-building process ended the sea ice moved away from the coast, allowing portions of the pile-up to slump back into the sea. Therefore, some of the pile-ups, such as this one, may have been several meters higher.

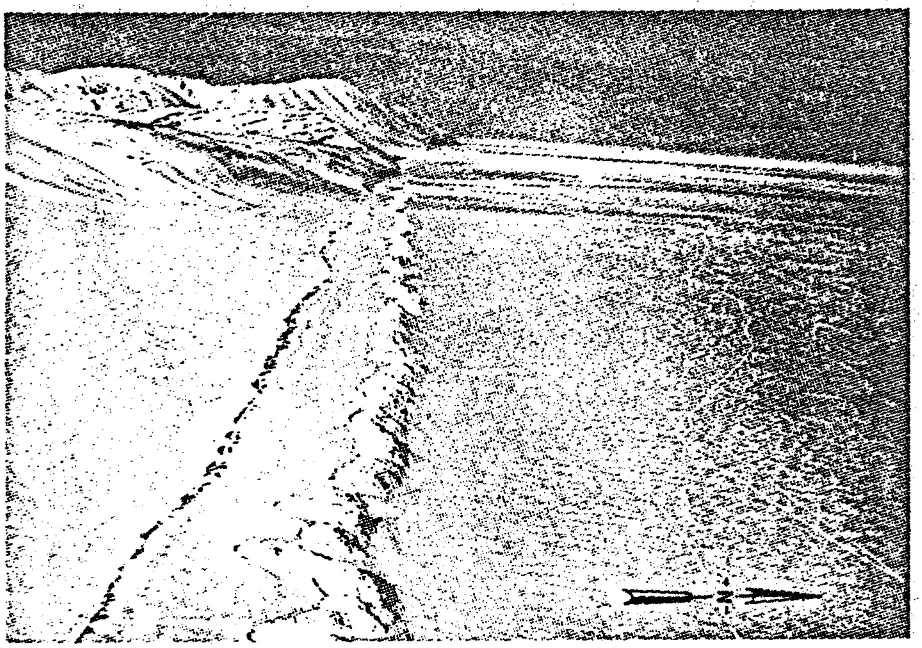


Figure 38. Shore icepile-upalongcoasteast of Cape Lisburne.

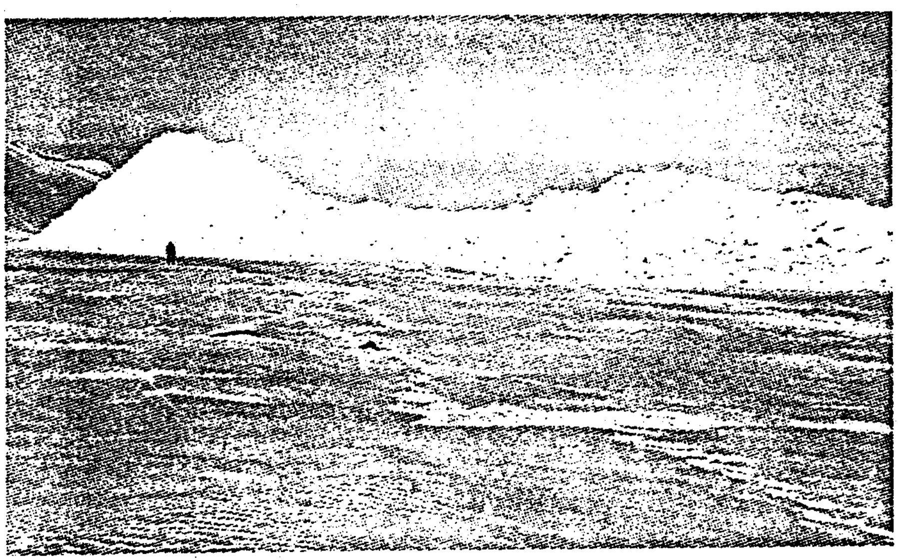


Figure 39. One of the highest" ridges observed in' the shore ice pile-up east of Cape Lisburne.