UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

MEASUREMENTS OF DEBRIS-LINE ELEVATIONS AND BEACH PROFILES FOLLOWING A MAJOR STORM: NORTHERN BERING SEA COAST OF ALASKA

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INTRODUCTION

During November 1974, a severe storm occurred in the Bering Sea; winds gusted to greater than 100 km/hr and barometric pressure dropped 34 mb (Figure 1). Combined storm surge and wave runup reached as high as 5 m along the northern Bering Sea coast of Alaska. Shortly after the storm, the northern Bering Sea froze. Following breakup in 1975 and during the ice-free season of 1976, we surveyed beach profiles and elevations of debris-lines at stations around the northern Bering Sea coast of Alaska (Figure 2). In this open-file report, these data are used to show the approximate magnitude of combined storm surge and wave runup in the study area.

METHODS

Profiles were measured with level and stadia. Horizontal distances were measured to 1 m using the range-finding stadia-lines of the level and vertical distances were measured to 1 cm. The positions of debris lines, if present, were surveyed in the same manner. Profiles were measured from observed sea level to the landwardmost debris line.

The vertical datum was observed sea level. During our surveys, wave energy was low (less than 30 cm) so sea level could be determined with reasonable accuracy. For most of the study area, tidal range is low and introduces relatively small errors. For example, diurnal range at Nome is 0.48 m and at Port Clarence is 0.43 m. However, at St. Michael, in the southernmost part of our study area, diurnal range is larger, 1.2 m.

DEBRIS-LINE ELEVATIONS

Debris-line elevations provide a combined measure of sea-level rise due to wind setup, inverse barometric effect, wave setup, and wave runup. Wind setup is the rise in nearshore sea level caused by wind-induced shoreward mass transport of water. Shallow bodies of water such as Norton Sound (depth less than 20 m) enhance wind setup. The inverse barometric effect is the change in sea level due to changes in barometric pressure. A 34 mb decrease in barometric pressure, such as occurred during the 1974 storm (Figure 1), would cause about a 0.3 m rise in sea level. Due to the presence of breaking waves, mean sea level is higher in the surf zone than seaward of the surf zone; this increased sea level is called wave setup. Wave height estimates by residents of Nome ranged from 3 m to 5 m. For a 3 m wave with a period of 8 s, the wave setup at the shoreline would be about 0.5 m (U.S. Army, Corps of Engineers, 1975). Runup elevation refers to the elevation reached by the upwash of the wave swash. A debris line would occur somewhat below the elevation of maximum runup.

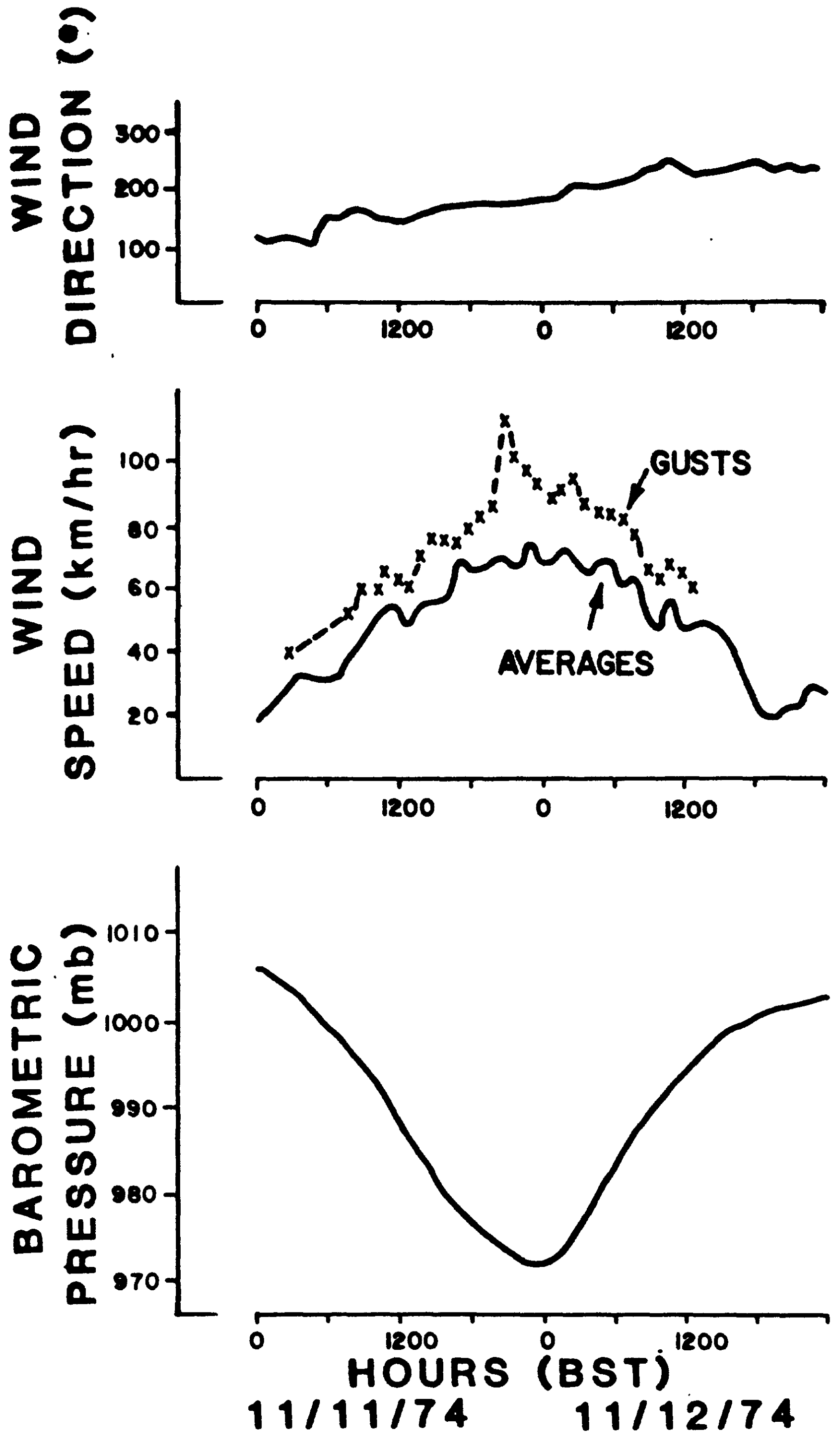

FIGURE 1: Wind direction and speed, and barometric pressure during the 1974 storm. Measurements made at Nome, Alaska airport.

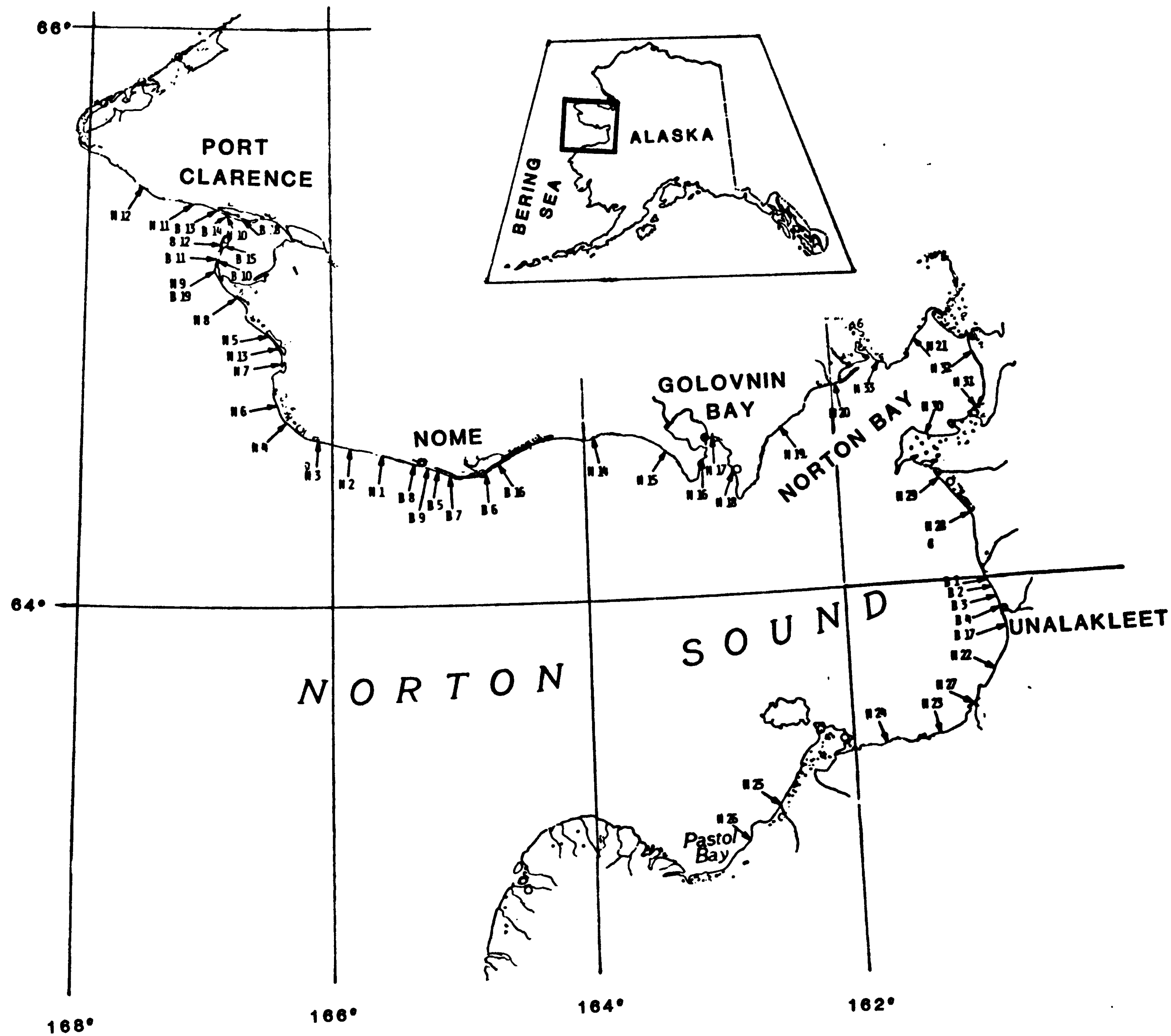

FIGURE 2: Station locations. Some of the stations shown are not relevant to the present discussion.

Storm-surge elevation is generally considered to be the still-water level during a storm. Therefore, storm surge is a function of the first three parameters discussed in the previous paragraph, but not wave runup. Thus, debris-line elevation is a measure of combined storm surge and wave runup.

Debris-line elevation data are given in Table 1. At all but a few stations, only one debris line was observed; evidently, the 1974 storm had incorporated older debris lines and pushed them higher. For the most part, the debris was composed of large logs.

BERM-CREST ELEVATIONS

On sections of coast with relatively low relief landward of the beach, well developed 'storm berms' were observed (Figure 3A and 3B). The storm berms commonly have steeply sloping slipfaces on their landward margins. The slipfaces apparently develop in response to landward transport of sediment into standing water. The slipfaces occur on barrier beaches and beaches that under non-storm conditions do not enclose water. For the latter case, water was transported landward of the berm crest by waves overtopping the crest during storms. Associated with this process is a net landward transport of sediment which migrates the storm berm landward. The coarse size of the beach sediments in the study area (sandy gravels and pebbly sands) contributes to the well developed form of the storm berms.

Generally, where bluffs or cliffs occurred on the landward side of a beach, no berm was present; the foreshore sloped uniformly seaward between the base of the bluff and the shoreline (Figures 4A and 4B). This profile type probably represents storm effects also. During storms severe enough for waves to reach the base of the bluff; the swash reflects from the bluff and prevents the development of a berm.

Where debris lines existed landward of storm berms, debris-line elevations were about the same as berm-crest elevations (Figure 5). This is because berm crests tend to build to an elevation approximately equal to the elevation of wave runup (Bagnold,1940). During a storm, berm crests should build to an elevation that reflects inverse barometric effect, wind setup, wave setup, as well as wave runup. Thus, similar to debris-line elevation, berm-crest elevation can be used as an approximate measure of combined storm-surge and wave runup.

DISCUSSION

In Figure 6, debris-line elevations and berm-crest elevations are plotted versus profile number. The profile numbers are arranged from north to south along the abscissa. All data are tabulated in Table 1 and include distances of coastal inundation for each profile location. The data shown

TABLE 1: Measurements of berm-crest elevations, foreshore slopes and debris line positions along the Northern Bering Sea coast of Alaska.

Profile Number	Location Lat(N)	Long(W)	Berm-Crest Elevation (m)	Foreshore(9) Slope (°)	Debris Line (8) Seaward z(m)	x(m)	Landward z(m)	x(m)
N1	64°31'45"	165°41'0"	- (1)	3.6	-	-	-	-
N2	64°33'0"	165°55'0"	4.5	5.1	4.6	50	-	-
N3	64°34'15"	166°6'30"	3.1	3.4	2.8	43	3.1	52
N4	64°37'15"	166°20'15"	3.2	2.1	3.4	195	3.7	202
N5	64°56'8"	166°31'30"	3.1	4.1	-	-	-	-
N6	64°41'15"	166°26'15"	3.7	4.4	3.1	97	3.3	105
N7	64°50'15"	166°24'0"	3.3	3.4	-	-	-	-
N8	65°3'45"	166°46'0"	3.4	4.3	-	-	-	-
N9	65°9'15"	166°57'0"	3.2	3.7	-	-	-	-
N10	65°20'58"	166°50'0"	3.7	6.0	-	-	-	-
N11	65°29'30"	167°7'30"	-(1)	6.2	3.6(2)	-	-	-
N12	65°26'15"	167°32'15"	-(1)	-	-	-	-	-
N13	64°53'38"	166°26'30"	-(3)	4.3	-	-	-	-
N14	64°34'45"	163°56'30"	3.9(5)	5.4	-	-	-	-
N15	64°31'0"	163°53'0"	4.2	6.7	-	-	-	-
N16	64°28'22"	163°3'30"	3.6	5.0	3.4	58	-	-
N17	64°32'45"	162°57'45"	4.3	6.2	3.4	64	3.9	72
N18	64°25'30"	162°49'15"	6.7	9.3	6.7	41	-	-
N19	64°33'15"	162°27'45"	4.2	4.8	4.0	42	4.1	45
N20	64°41'52"	161°58'30"	2.5	2.5	-	-	-	-
N21	64°50'0"	161°19'0"	2.1	2.7	-	-	-	-
N22	63°40'8"	160°53'30"	3.3	6.7	-	-	-	-
N23	63°28'15"	161°21'0"	-(4)	-	3.8	22	4.3	24
N24	63°27'30"	161°43'15"	-(4)	-	4.0	35	-	-
N25	63°16'15"	162°36'0"	-(6)	-	-	-	-	-
N26	63°9'0"	162°51'0"	-(3)	5.5	-	-	-	-
N27	63°33'45"	161°4'15"	-(4)	-	4.5	40	4.8	47
N28	64°12'45"	160°57'0"	5.0	8.9	4.9	32	4.1	40
N29	64°21'30"	161°12'0"	3.9	4.4	4.5	57	4.9	69
N30	64°30'30"	161°16'15"	-(1)	6.1	-	-	-	-
N31	64°35'30"	160°51'0"	3.5	6.4	-	-	-	-
N32	64°46'0"	160°50'30"	-(7)	-	2.4	-	3.2	-
N33	64°46'15"	161°37'30"	3.5	-	3.1	299	4.1	320

(1) No berm present; foreshore followed by bluff or cliff.
(2) Debris line measured several hundred meters east of N11 where there was no bluff.
(3) Profile did not extend to sea level.
(4) Lava flow coast; no beach present.
(5) Represents elevation of the landward most extent of foreshore; no berm present.
(6) No beach; wet tundra coast.
(7) Measured only the debris line.
(8) Refers to the seaward and shoreward extent of a single debris line. X is distance landward from observed sea level. Z is elevation above observed sea level.
(9) Slope was measured between the landward extent of the foreshore and observed sea level.

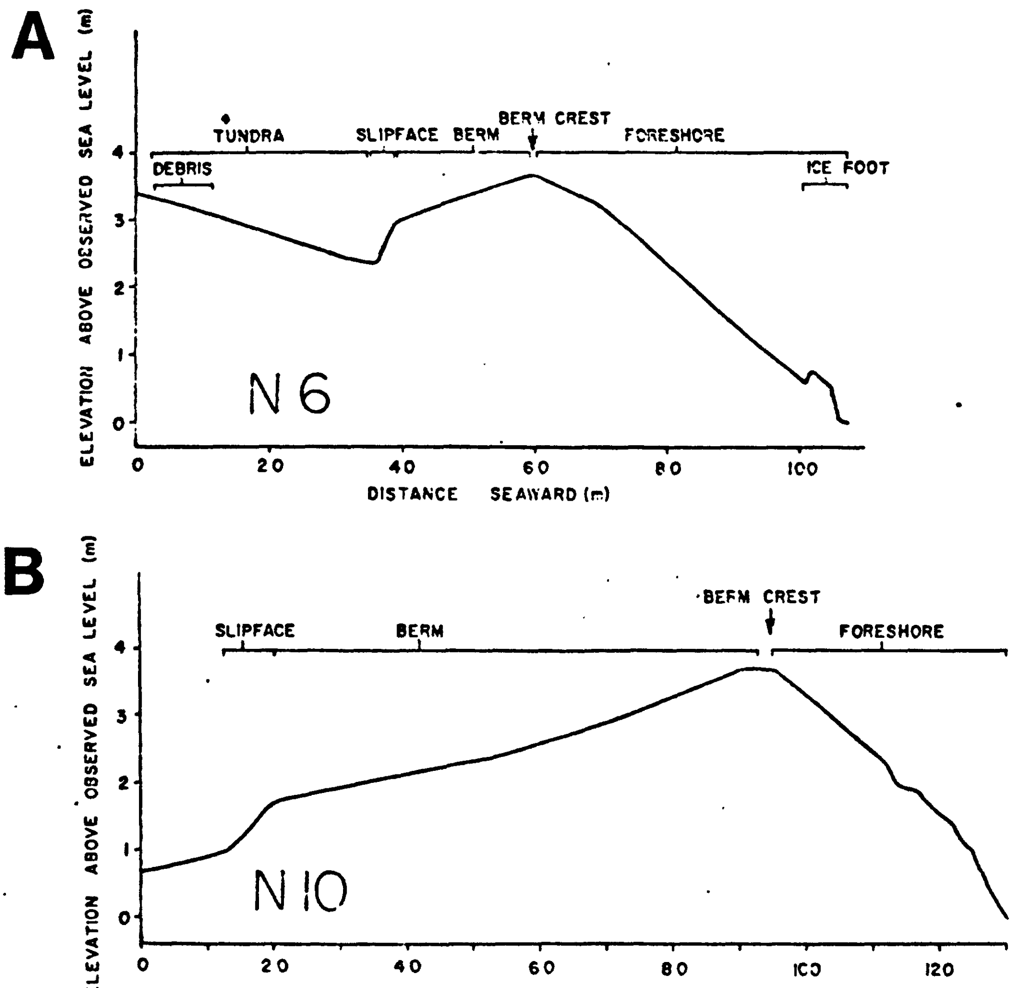

FIGURE 3: Beach profiles from station N6 (a short distance north of Norton Sound) and station N10 (in the vicinity of Port Clarence). Both profiles show well developed storm berms.

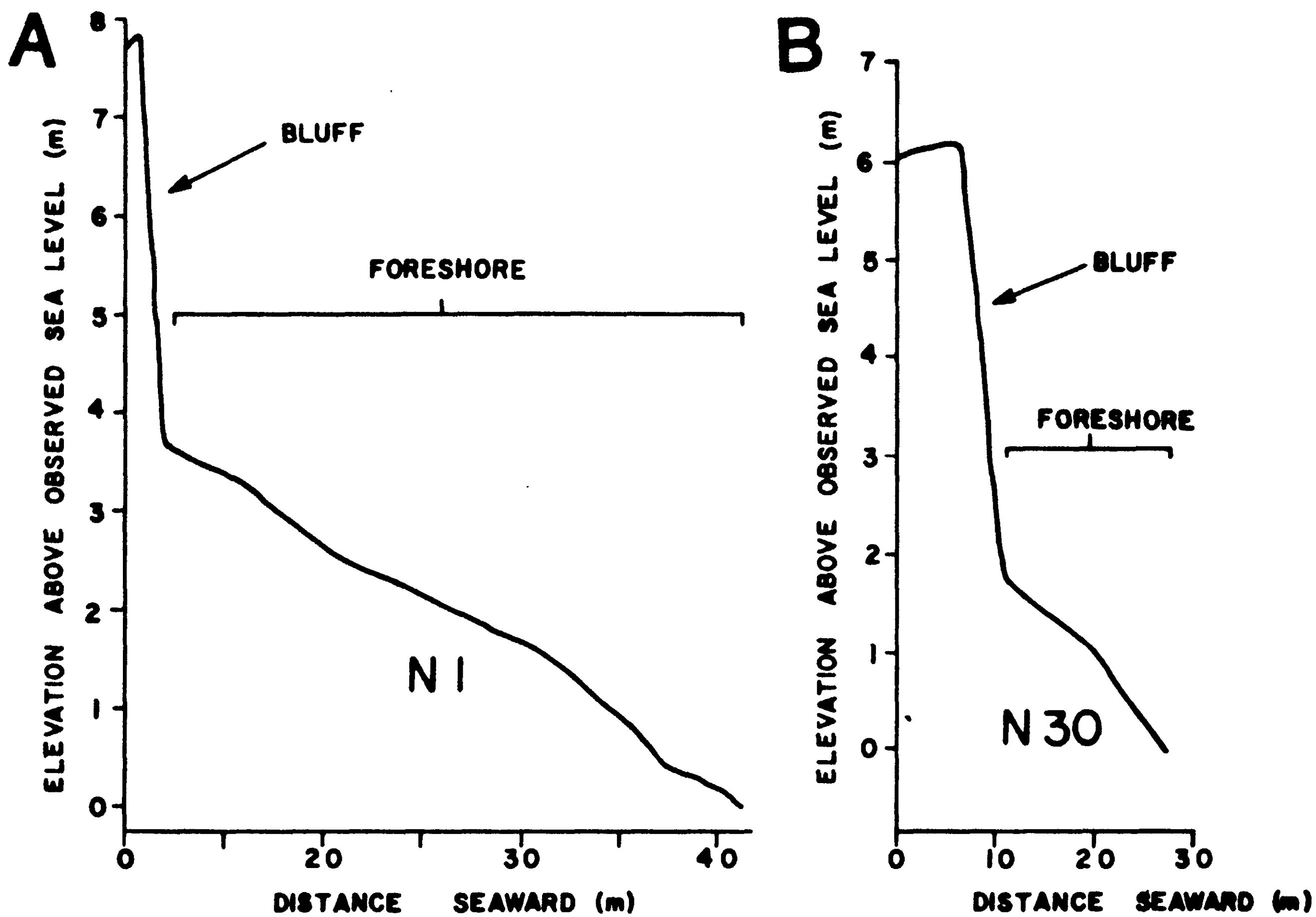

FIGURE 4: Beach profiles from station N1 (west of Nome) and station N30 (in Norton Bay). Due to wave reflection from adjacent bluffs during storms, these profiles do not show well developed storm berms.

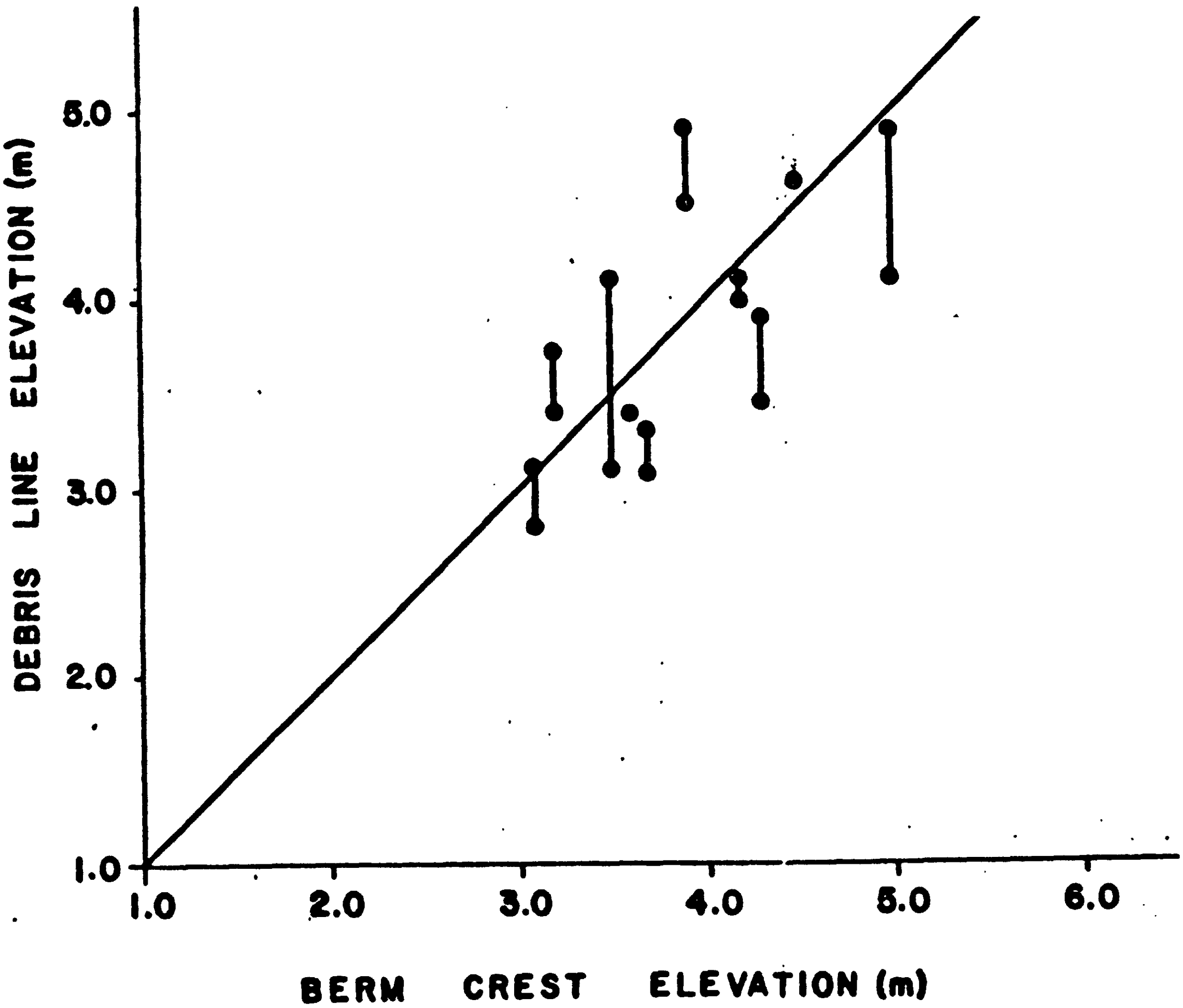

FIGURE 5: Berm-crest elevations plotted against debris-line elevations. Elevations from the seaward extent and landward extent of each debris line are connected by vertical lines. For the data plotted, debris lines occurred well landward of the berm crests. The line of perfect (1 to 1) correlation is drawn on the figure.

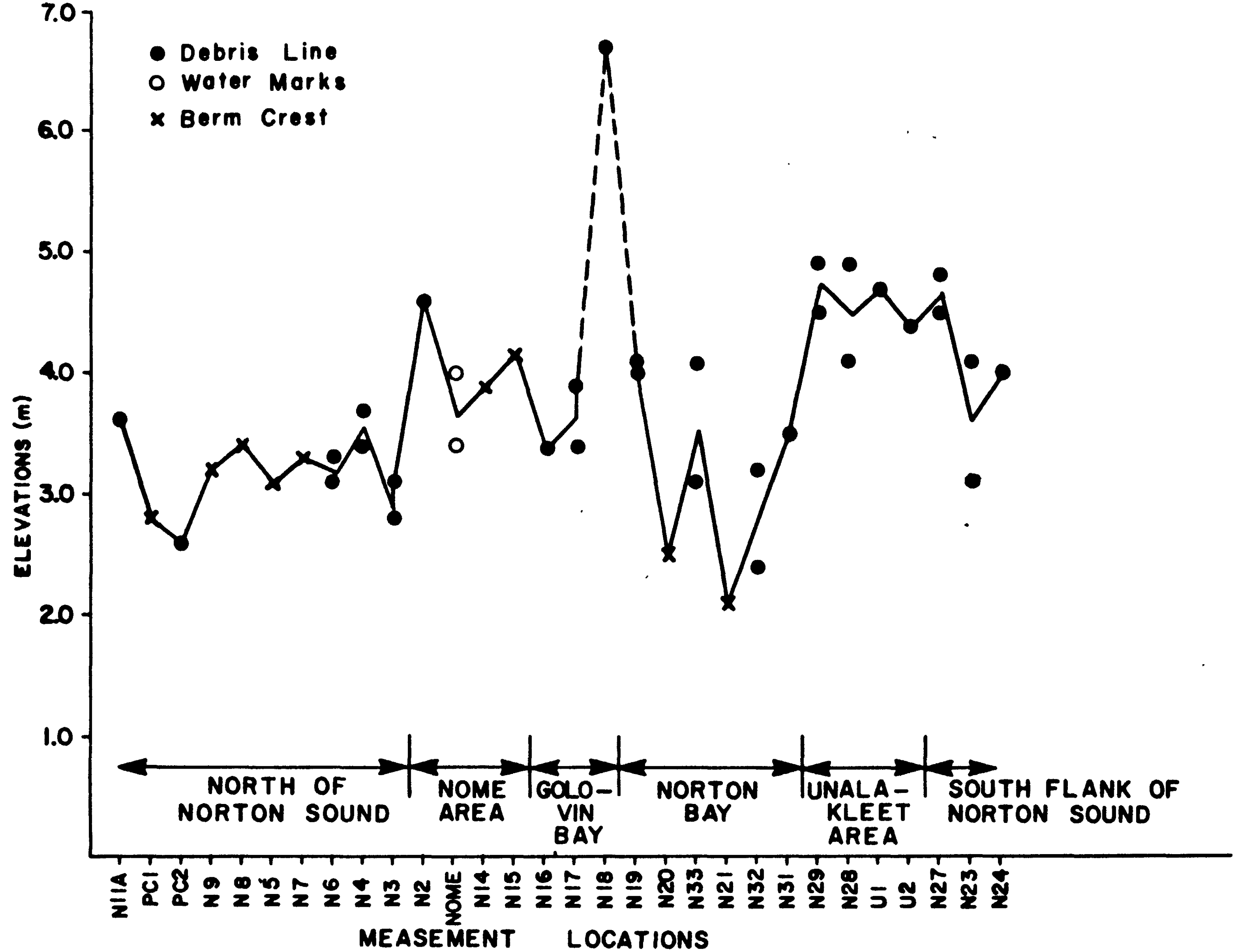

FIGURE 6: Debris-line and berm-crest elevations plotted against station location. The station locations are arranged from north to south along the shoreline of the study area. Also plotted are elevations of still-water marks found in Nome; since these elevations do not include the effects of wave runup they should be somewhat smaller than debris-line elevations.

in Figure 6 do not include debris lines situated on top of bluffs; waves breaking against a bluff can throw debris considerably higher than the storm sea level. For example, at N1, debris on top of a bluff was 7.8 m above observed water level, whereas debris-line elevations in the same general area but not adjacent to a bluff were about 4.0 m. The very high measurement in Golovnin Bay was made on a beach composed entirely of cobbles. Here, the very steep foreshore may have acted as a bluff; the waves breaking against the beach may have thrown debris much higher than the storm surge level.

Also plotted in Figure 6 are elevations of still-water marks found on the interior of buildings in Nome. These measurements do not reflect wave runup and, therefore, should be somewhat less than the elevations of debris lines.

Figure 7 summarizes the data; there appear to be consistent changes in the magnitude of combined storm surge and wave runup around the study area. North of Norton Sound, the elevation was 3.0 to 3.5 m. In the Nome area, on the north side of Norton Sound, the data show an elevation of about 4.0 m. In Norton Bay, elevations ranged between 2.5 and 4.0 m. Highest storm sea level occurred on the east coast of Norton Sound and were about 4.5 to 5.0 m. The elevations appear to decrease on the southern side of Norton Sound.

In essence, combined storm-surge and runup increased into Norton Sound. Due to wave shoaling and refraction, one would expect that wave energy (and therefore wave runup) would, in general, decrease into Norton Sound. Thus, the observed increase of combined storm surge and runup was a result of an increase in storm surge. This is consistent with amplification of storm surge by funneling water into a rectangular embayment.

ACKNOWLEDGEMENTS

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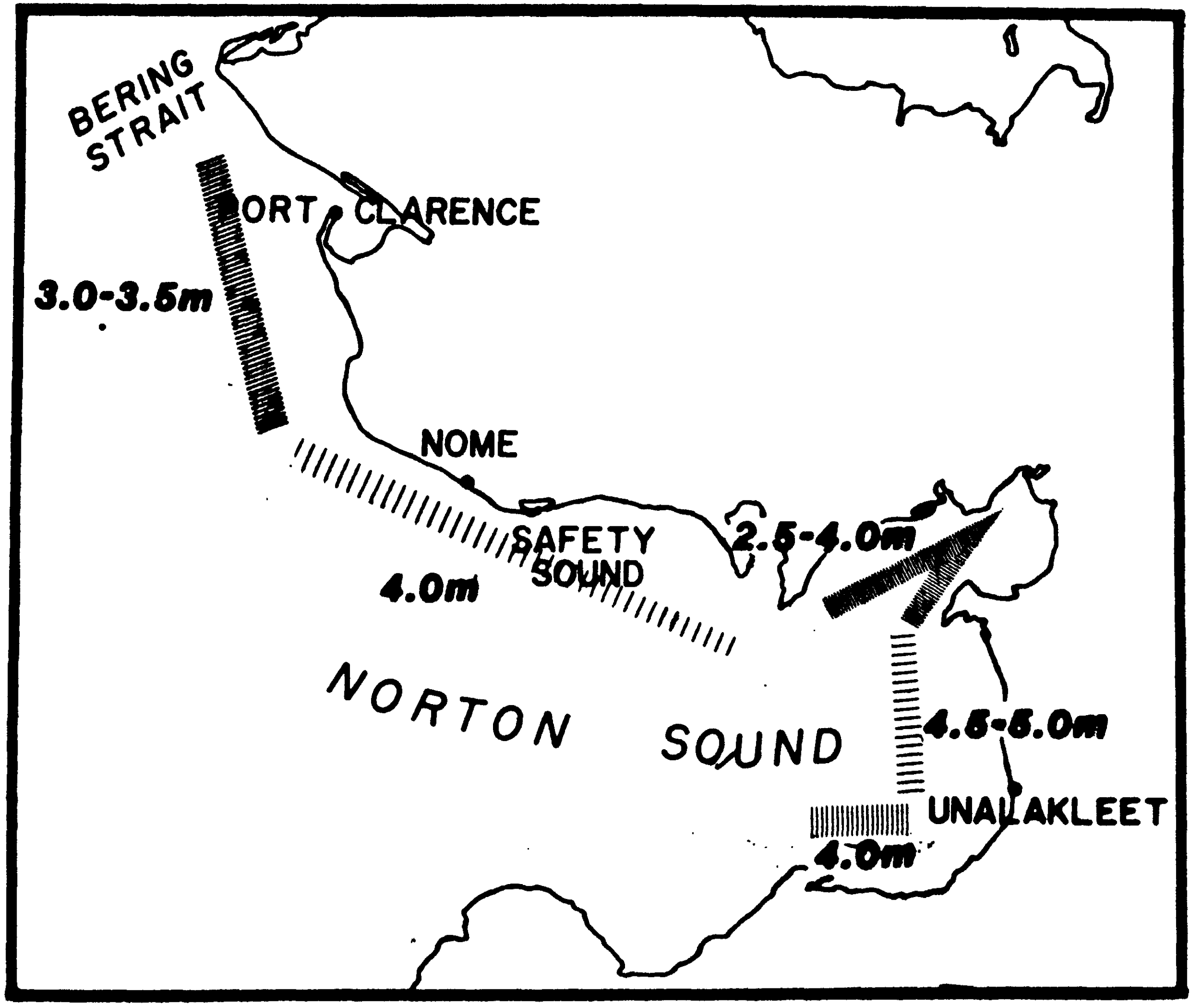

FIGURE 7: Summary of storm surge measurements. Due to the map scale, results from Golovnin Bay are not shown.