ARCTIC
VOL. 31, NO. 4 (DEC. 1978), P. 428-433.

Coastal Erosion Rates along the Chukchi Sea Coast near Barrow, Alaska

JOHN R. HARPER[1]

ABSTRACT. Coastal cliff retreat along the Chukchi Sea coast from Barrow to Peard Bay is determined by comparison of 1949 and 1976 vertical arial photographs. Results indicate that the cliffed coast line had a mean long-term retreat rate of 0.31 m/yr. This retreat is considerably lower than that reported for the Beaufort Sea coast and suggests that offshore permafrost along the Chukchi Sea coast may be relatively scarce. Cliff retreat is lowest near Barrow, about 0.06 m/yr, and increases to the south. Migratory offshore bars, beach-borrow activity, and variations in annual wave energy levels due to storms cause temporal variation in the coastal erosion rates.

INTRODUCTION

The long-term erosion rates along the Chukchi coast from Barrow to Peard Bay were determined as part of a larger study on the physical processes affecting tundra cliff stability along arctic coastlines (Harper, 1978). Estimates of shoreline retreat on this coast are of interest because of: 1) their variance with other coastal retreat rates in the Barrow area (Lewellen, 1970, 1977); 2) their importance in sediment budget calculations; and 3) their relationship to the potential occurrence of offshore permafrost along the Chukchi Sea coast.

The 75-km coastline from Barrow to Peard Bay (Fig. 1) is backed by nearly continuous cliffs. Maximum cliff heights exceed 18 m and are generally greater than 10 m (Harper, 1978). Cliff sediments are comprised of the Gubik Formation, mainly unconsolidated clays, silts, and sands (Black, 1964) and Cretaceous clays which crop out at the cliff base along much of the coast (Hopkins, personal communication). Although most of the sediments are unconsolidated, bonding by frozen interstitial pore water cements the sediments into a rock-like material. The presence of pack ice limits the open water season, usually to less than 3 months, and wave heights seldom exceed 1 m (Hartwell, 1972).

Previous investigations of coastal erosion in the Barrow region have been carried out by MacCarthy (1953), Lewellen (1970, 1972, 1977), Hume (1965), Hume and Schalk (1967), and Hume *et al.* (1972). These studies have shown that cliff retreat rates in Elson Lagoon, east of Barrow, are high, generally exceeding 1 m/yr (MacCarthy, 1953; Lewellen, 1970, 1972), and occasionally exceeding 10 m/yr (Lewellen, 1970, 1977). However, on the Chukchi Sea coast southwest of Barrow there has been less consistency in reported erosion rates. MacCarthy (1953) reports retreat rates which range from 0 to 1 m/yr for the coastal cliffs. Hume *et al.* (1972) discuss changes to the cliffs southwest of

[1]Coastal Studies Institute, Louisiana State University, Baton Rouge, Louisiana 70803, U.S.A. (Author's present address: Pacific Geoscience Centre, Institute of Ocean Sciences, Sidney, British Columbia V8L 4B2)

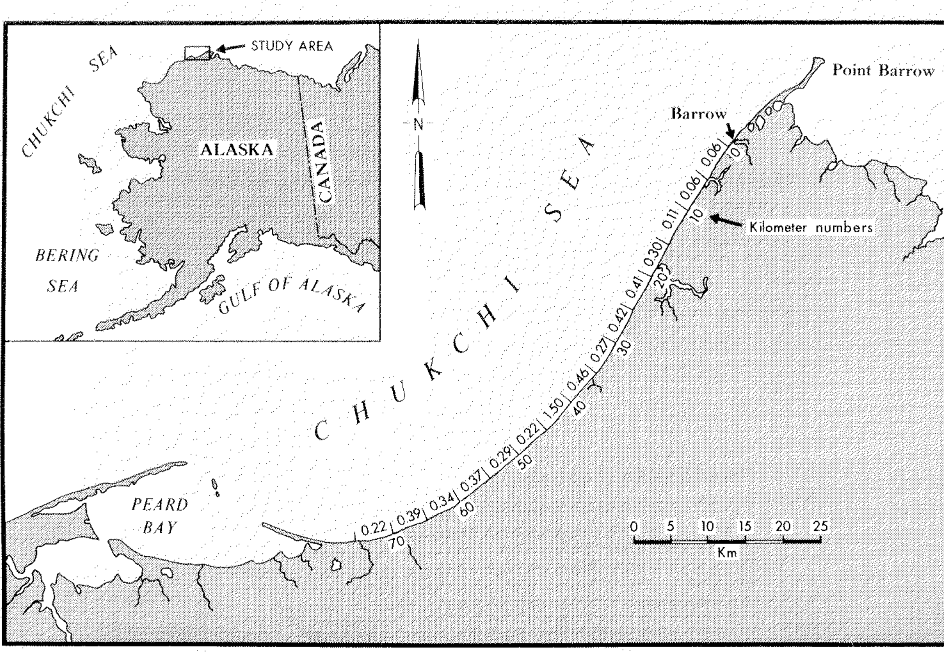

FIG. 1. Location map of study area showing 5-km shoreline segments between Barrow and Peard Bay. Averaged erosion rates for each 5-km segment are listed in metres per year.

Barrow over a 21-year period (1948 to 1969) and indicate that cliff erosion rates range from 0.3 m/yr to 3.0 m/yr with long-term retreat of over 2 m/yr. They suggest that the temporal variations in erosion rates are related to the passage of intense storms and that spatial variation is related to the presence of offshore bars and borrow pits.

METHODOLOGY

Retreat was estimated by comparing 1948/1949 vertical aerial photos (mean scale 1:19,665) to 1976 vertical aerial photos (mean scale 1:8,108). A common point on the respective photos was identified, usually a distinctive polygon intersection pattern, and the distances to: 1) the cliff edge; 2) the cliff base; and 3) the water line were noted. At some stations, only one or two of these distances could be measured owing to the presence of snow cover or to the indistinctness of the cliff edge.

The distances were measured with a magnifying scale readable to 0.1 mm. In order to determine the precision of the measurements, sampling error (error resulting from uncertainty in the measurement technique) was estimated in a separate analysis. At ten stations along the coast, retreat (at the cliff base) was estimated five times, and a statistical analysis of this data provided an estimate of variance between stations (i.e., experimental error) and that within stations (i.e., sampling error) (Steel and Torrie, 1960, p. 119).

Sampling error accounted for less than 1% of the sample variance and was neglected in further calculations.

Other possible errors include shrinkage of prints, lens distortions, atmospheric refraction distortions, and photograph tilt. The first three of these were assumed minor. Tilt errors were minimized by determining the relative scales of each set of compared photos and by measuring short distances.

RESULTS

The results (Table 1) indicate that this section of the Chukchi Sea coast is erosional, retreating at an average rate of 0.31 m/yr (±0.06 m/yr, 95% confidence interval). This mean was computed by averaging: 1) retreat rates computed for the cliff base; and 2) retreat rates for the cliff top stations where no cliff base rates were available (Table 1). The cliff base is probably the more reliable feature of cliff morphology as the cliff top is often indistinct owing to the sawtoothed form, and the water line position is subject to large temporal variations and thus is a poor estimator of retreat.

Retreat rates are further compartmentalized into 5-km shoreline averages (Table 2). These means were computed by averaging retreat rates of all stations occurring within the 5-km segment (Fig. 1).

DISCUSSION OF RESULTS

The coastal cliff retreat rates listed in Table 1 are surprisingly low compared to reported erosion rates for the Beaufort Sea coast (Lewellen, 1970, 1977). The retreat rate along the Chukchi Sea coast of 0.31 m/yr is nearly an order to magnitude less than the 2.7 m/yr average for the Beaufort Sea coast, computed from Lewellen's (1977) data (mean of 105 observations from Point Barrow to Demarcation Point). Possible explanations for this difference include: 1) cliff sediments on the Chukchi coast are generally coarser and less easily removed by suspension; 2) ice contents of the Chukchi Sea cliffs are lower, resulting in less susceptibility to thermal erosion; 3) the lower Beaufort

TABLE 1. Coastal cliff retreat: Chukchi coast

	Mean	Standard Deviation	95% Confidence Interval	Number of Observations
Cliff top	-0.37	0.32	0.06	96
Cliff base	-0.26	0.31	0.08	56
Water line	-0.41	0.28	0.06	75
Grand mean	-0.31	0.31	0.06	101

NOTE: Measurements are in m/yr.

TABLE 2. Averaged cliff retreat (m/yr) over 5-km segments, south of Barrow

5-km* Segment	Mean	Standard Deviation	Number of Observations
0-5	0.06	0.12	4
5-10	0.06	0.13	3
10-15	0.11	0.37	5
15-20	0.30	0.32	6
20-25	0.41	0.29	8
25-30	0.42	0.28	7
30-35	0.27	0.29	8
35-40	0.46	0.53	5
40-45	1.50	—	1
45-50	0.22	—	1
50-55	0.29	0.29	14
55-60	0.37	0.31	5
60-65	0.34	0.30	11
65-70	0.39	0.32	7
70-75	0.22	0.16	16

*See Figure 1 for location.

Sea coast cliffs release much less sediment than Chukchi Sea cliffs for a given amount of erosion; and 4) topography may be important in controlling the distribution of mass-wasting processes, which in turn controls erosion rates (Harper, in preparation). One probable consequence of the low erosion rates is that offshore permafrost may be much less extensive than that found in Beaufort Sea areas.

Some spatial variation exists in the erosion rates (Table 2). The measurements indicate that the coastline for 15 km south of Barrow is nearly stable, with retreat rates farther to the south fairly constant at 0.3 to 0.4 m/yr. The maximum retreat rate measured was 1.5 m/yr (this is also the only observation made between kilometres 40 and 45, Table 2). In terms of longshore power gradients (May and Tanner, 1973), decreasing erosion rates to the north should be expected from waves predominantly out of the southwest.

There is a discrepancy between the long-term bluff retreat rates reported by Hume *et al.* (1972, Table 1) and those of Table 2 for the Barrow area. As previously mentioned, these authors noted a range in cliff retreat rates from 0.3 to 3.0 m/yr with a 21-yr mean of 2.2 m/yr. Their study apparently fell in an area of highly localized erosion that is atypical of the coast as a whole. The effect of beach borrow and the presence of offshore bars is mentioned by the authors as a possible source of this variation. In the present study only those observations made south of Barrow Village were used, thus minimizing the possible influence of beach borrow pits.

The influence of offshore bars in controlling erosion rates is uncertain. Short (1975) notes that along this coast offshore bars frequently attach to the shoreline at an acute angle and that beaches associated with these attachment points are significantly wider than surrounding beaches. In theory, these wider beaches afford greater protection from wave attack, and one would expect cliff erosion rates at these points to be lower, However, 34 observations made at nine bar attachment points give a mean retreat rate of 0.30 m/yr, almost exactly equal to the mean retreat rate for the entire coast. If the bars and attachment points are migratory, as suggested by Short (1975), their long-term stabilizing effects may be greatly reduced at any one site. In at least one area (kilometres 65 to 70) bar migration (approximately 500 m to the south from 1949 to 1976) did occur and affected cliff form. In 1949 cliffs backing the former attachment point were deeply dissected by runoff concentrated in ice wedges, producing a characteristic sawtoothed form. Runoff fans at the slope base coalesced into an indistinct baseline. Subsequent migration of the bar resulted in a compound cliff profile being formed (evident on 1976 photos) and a retreat rate of approximately 0.5 m/yr. Slightly to the southwest, in the overlap area where the beach remained wide, dissection of ice-wedge polygons continued and slope gradients became low enough to allow revegetation. The retreat rate here averages 0.05 m/yr. If a longer photograph interval had been available, mean retreat rates might have averaged out the temporal and spatial fluctuations due to bar migration.

An additional feature of cliff form supports the observation of Hume *et al.* (1972) that temporal variation of erosion is related to the frequency of storm occurrence. A highly significant difference ($P < 0.01$) exists between 1949 and 1976 slope widths (based on a paired t-test). The mean slope width in 1949 was 15 m but in 1976 it had increased to 18 m. This difference suggests that the years immediately prior to 1949 were relatively high in wave energy and consequently slope widths were relatively narrow. The years immediately prior to 1976 were relatively quiescent and surface wash processes contributed to increasing slope widths.

In summary, several observations may be made about coastal cliff retreat along the Chukchi Sea coast between Barrow and Peard Bay. These are:

1) The mean cliff retreat rate, 0.31 m/yr (±0.06 m/yr, 95% confidence interval), is relatively low compared to Beaufort Sea coastal retreat rates; 2) This low retreat rate suggests that offshore permafrost will be relatively scarce off the Chukchi Sea coast; 3) Retreat rates in the first 15 km southwest of Barrow, of less than 0.15 m/yr, are the lowest along the coast whereas along the next 60 km of coast, retreat rates are fairly uniform, ranging between 0.20 and 0.5 m/yr; 4) The influence of offshore bars on retreat rates is less than expected, possibly because of the migratory nature of bar attachment points; and 5) Temporal variations in erosion rates may result from variations in annual wave energy levels associated with storms, migratory bar-attachment points, and localized beach borrow activity.

ACKNOWLEDGEMENTS

This research was performed under a contract between the Geography Programs, Office of Naval Research, Arlington, Virginia 22217, and Coastal Studies Institute, Louisiana State University, and was supported by the Arctic Program, Office of Naval Research.

REFERENCES

BLACK, R. F. 1964. Gubik Formation of Quaternary age in Northern Alaska. United States Geological Survey Report 302-C: 59-91.

HARPER, J. R. 1978. Physical processes affecting the stability of a tundra cliff coast, Peard Bay, Alaska. Ph.D. dissertation, Louisiana State University, Baton Rouge.

———, In preparation. Topographic control of mass-wasting processes on coastal cliffs, Alaskan Arctic Coastal Plain.

HARTWELL, A. D. 1972. Coastal conditions of arctic Northern Alaska. In (P. V. Sellmann, K. L. Carey, Charles Keeler, and A. D. Hartwell, eds.) Coastal and Terrain Conditions on the Arctic Alaskan Coastal Plain, pp. 32-72. Cold Regions Research and Engineering Laboratory Special Report 165, Hanover, New Hampshire.

HUME, J. D 1965. Shoreline changes near Barrow, Alaska, caused by the storm of October 3, 1963. (Unpublished manuscript), AINA Project, Office of Naval Research 343, final report, 63 pp.

HUME J.D. and SCHALK, M. 1967. Shoreline processes near Barrow, Alaska: a comparison of the normal and the catastrophic. Arctic, 20(2):86-103.

HUME, J. D., SCHALK, M., and HUME, P. W. 1972. Short-term climate changes and coastal erosion, Barrow, Alaska. Arctic, 25(4):272-278.

LEWELLEN, R. 1970. Permafrost erosion along the Beaufort Sea coast. (Published by the author, Arctic Research, Box 1068, Littleton, Colorado 80161, 15 pp.

———, 1972. Studies on the fluvial environment, Arctic Coastal Plain province, northern Alaska. Volumes I and II (Published by the author, P.O. Box 1068, Littleton, Colorado), 281 pp.

———, 1977. A study of Beaufort Sea coastal erosion, northern Alaska. Environmental Assessment of the Alaskan Continental Shelf, Annual Reports of Principal Investigators, Vol. XV (Transport). National Oceanic and Atmospheric Administration, pp. 491-527.

MacCARTHY, G. R. 1953. Recent changes in the shoreline near Point Barrow, Alaska. Arctic, 6(1):44-51.

MAY, J. P. and TANNER, W. F. 1973. The littoral power gradient and shoreline changes. In (D. R. Coates, ed.) Coastal Geomorphology, State University of New York Press, Binghampton, New York, pp. 43-60.

SHORT, A. D. 1975. Offshore bars along the Alaskan Arctic coast. Journal of Geology, 83:209-221.

STEEL, R. G. D., and TORRIE, J. H. 1960. Principle and procedures of statistics. New York: McGraw-Hill, 481 pp.