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ACCRETION AND EROSION OF A LAKE ONTARIO BEACH, SELKIRK SHORES, NEW YORK

Barry P. Cohn
Department of Geology, Syracuse University, Syracuse, New York

Abstract. Changes in partial beach morphology were studied from October 1971 to October 1972 for a two-kilometer stretch of Lake Ontario shoreline near Pulaski, New York. Estimates of net sand transport were calculated from weekly beach profiles measured from the base of the dune into water depths of 1.25 m. Profile changes were examined in terms of wind conditions and fluctuations in lake level.

Loss of sediment occurred during spring and summer months when high lake levels coincident with winds from the northwest induced strong wave attack on the upper beach. Lowered water levels and offshore winds during the late summer and early fall initiated deposition upon the beachface and in the extreme nearshore zone. Accretion was not sufficient to compensate for spring and summer losses. As a consequence, the shoreline retreated 4.5 m during this twelve-month period. The observed erosion entailed the removal of 8.4×10^3 m^3 of sand (somewhat more than 10^5 tons). Sixty-five percent of this loss occurred from the subaerial portion of the beach, the remainder having been removed from the extreme nearshore zone. (Key words: Beach morphology; net sand transport; erosion; accretion; Lake Ontario).

INTRODUCTION

The shoreline along the eastern end of Lake Ontario in the vicinity of the Salmon River Estuary is undergoing extensive erosion at the present time. Estimates of net sand transport were made for a two-kilometer length of coastline at Selkirk Shores during the period from October 1971 to October 1972. The estimates were calculated from beach traverses repeatedly surveyed at intervals of about one week. Changes in partial beach profiles were examined in terms of wind conditions and fluctuations in lake level. The interaction among these variables appears sufficient to explain the severe erosion observed during the course of the study.

GEOLOGIC FRAMEWORK

The eastern shoreline of Lake Ontario trends approximately normal to the strike of local Ordovician shales and sandstones, but these bedrock units appear to exercise little or no influence upon the orientation of the present shoreline (Sutton et al. 1970).

The fine-grained sand beaches at Selkirk Shores are located approximately six kilometers west of Pulaski, New York (Pulaski 7.5-minute topographic quadrangle) (Fig. 1). The study area is characterized by narrow barrier beaches backed by stabilized dune complexes and by marshes and by fresh-water estuaries.

The southern and eastern shorelines of Lake Ontario are being progressively flooded by the waters of the lake. This transgression can be attributed to the continued post-Pleistocene upwarp of the outlet of the lake. The St. Lawrence River is rising relative to the southern end of the Ontario basin at a rate of approximately 30 cm per hundred years (Clark and Personage 1970). This differential upwarp is raising the water level at Oswego, New York by approximately 15 cm per century. Geological evidence for this transgression includes: 1.) deposits of marsh material underlying the beach, 2.) drowned river mouths and 3.) the contrast between narrow beaches (20 m) and overfit

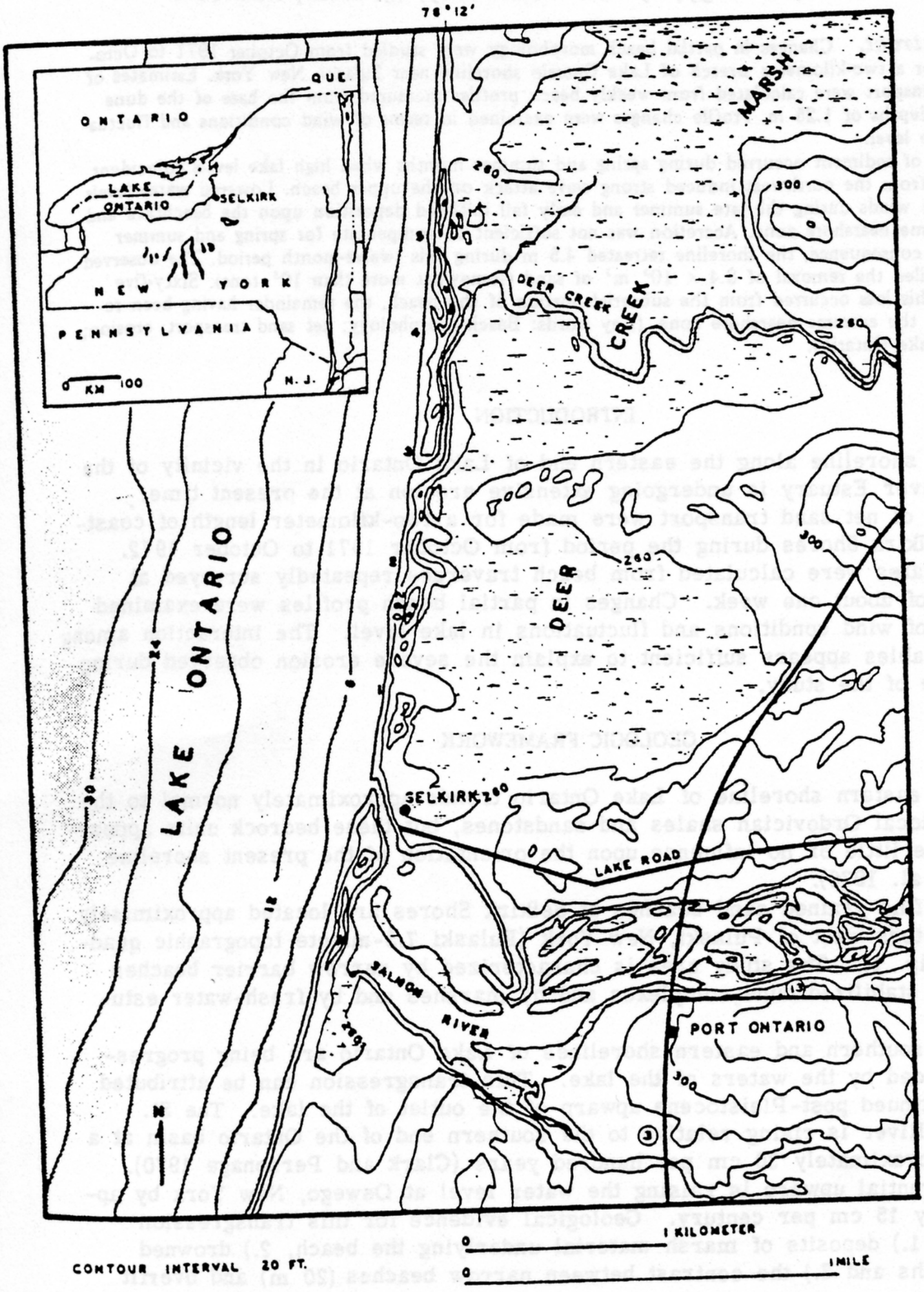

FIG. 1. Topographic map showing shoreline features and locating profiling stations.

dunes (15 m high). The potential for flooding and erosion in these areas is enhanced by periodic high water levels.

Profiling stations were established at five locations along the two-kilometer baseline (Fig. 2). The profiling, repeated at weekly intervals, employed the stake and-horizon method of Emery (1961). Profiles extend from the base of the dune across the subaerial portion of the beach into the nearshore zone to water depths of approximately 1.25 m. Representative profiles for station one are shown in Fig. 2. The net volume of sediment transported in or out of the system was determined by superimposing profiles to generate a sediment envelope. The difference between two profiles, representing fields of net erosion or accretion, was calculated by computer. The cross-sectional changes were integrated over the length of the study area to yield an estimate of the amount of sediment gained or lost for the twelve-month period.

Recordings of wind azimuths, durations and intensities, obtained from a monitoring station in Oswego, New York, were used to determine the effect of these variables upon beach morphology. The station, approximately 20 km southwest of Selkirk provides an adequate picture of weather conditions in the study area. Monthly wind rose diagrams were constructed from observations taken at four-hour intervals. A wind rose for the year is shown in Fig. 3a. The wind data were computer analyzed to determine whether the distribution was circular normal or whether preferential directional tendencies existed.

Wave height, wavelength and direction of wave approach to the coast are principal controlling factors determining direction and rate of longshore sand transport. Fetch lengths (Fig. 3b), durations, orientations and intensities of

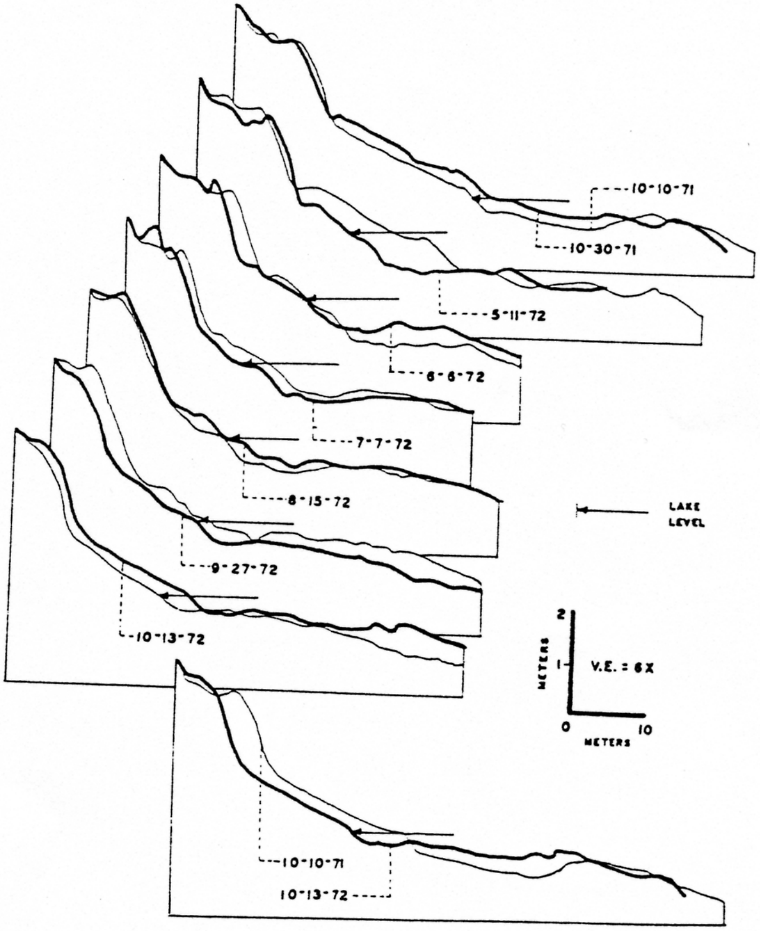

FIG. 2. Beach profiles measured at station one, October 1971 to October 1972.

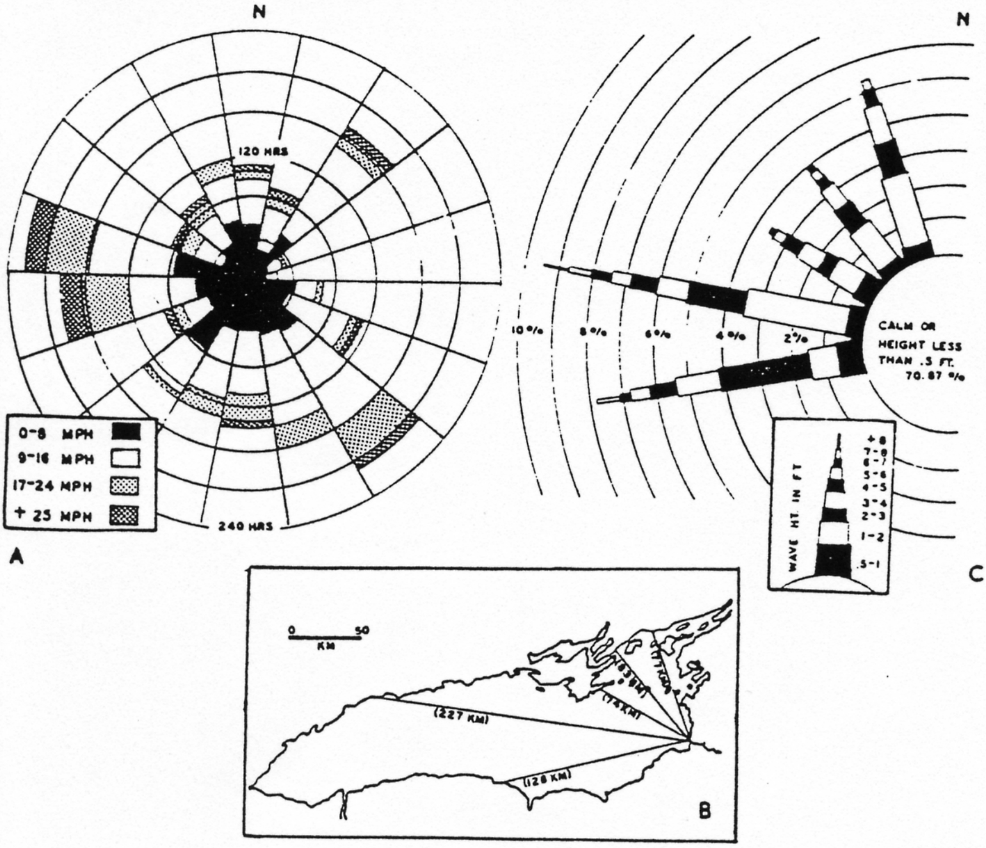

FIG. 3a. Rose diagram indicating number of hours winds of different intensities occurred from each direction. b. Exposure of Selkirk Shores, showing fetch lengths. c. Rose diagram indicating percent of time waves of different amplitudes were hindcast from each direction.

wind govern wave amplitude and angle of coastal approach. Hindcasts of wave height and period were determined using empirical curves presented by Bretschneider (1951). Surface friction experienced by the wind blowing over land can significantly reduce wind velocity below values that would occur over open water. To compensate for the fact that wind records used in this study were obtained from a land-based station, the top wave values predicted by the hindcasting curves were selected. This kind of velocity correction follows the practice of Saville (1953). The waye characteristics determined in this way are the period and amplitude of the predominating wave. The wave height established by this method is the average of the higher one-third of these predominating waves. These values are plotted on a wave rose (Fig. 3c) to show the percent of time a deep water wave of a given amplitude approached the shore from a particular direction. During much of the winter, large areas of the lake are normally covered with ice. This effectively shortens fetch lengths. For an even longer period each winter, the shoreline is protected by a thick shelf of ice terminating lakeward in an ice ridge (Zumberge and Wilson 1953). Incoming waves are therefore unable to affect the beach itself, expending their energies against this ice barrier. The beach undergoes minimal modification by waves during this time.

Drift bottle studies conducted by Harrington (1895) indicate that currents along the eastern shoreline flow predominantly northward. Consistent with this and with observed directions of wave approach, littoral drift within the study area is predominantly south to north. The drift direction is indicated by the piling up of sediment against the south side of groins located near the study area. The progressive northward displacement of the mouth of the Salmon River Estuary appears also to be a function of this drift movement.

Lake level has been monitored in Oswego, New York since 1860. A summary of average monthly water level elevations for the period October 1971 to October 1972 is shown in Fig. 4. Also shown in this figure are monthly average elevations for the last ten years and for the entire period of record. The pattern of seasonal variation shows over a century of observations that the highest water levels occur during summer and lowest levels during winter months. During the period of the present study, highest monthly levels were recorded during July 1972 and the lowest levels during February 1971. Figure 4 shows that water levels during the study period were higher than the average levels monitored over the last ten years and average levels for the entire period on record.

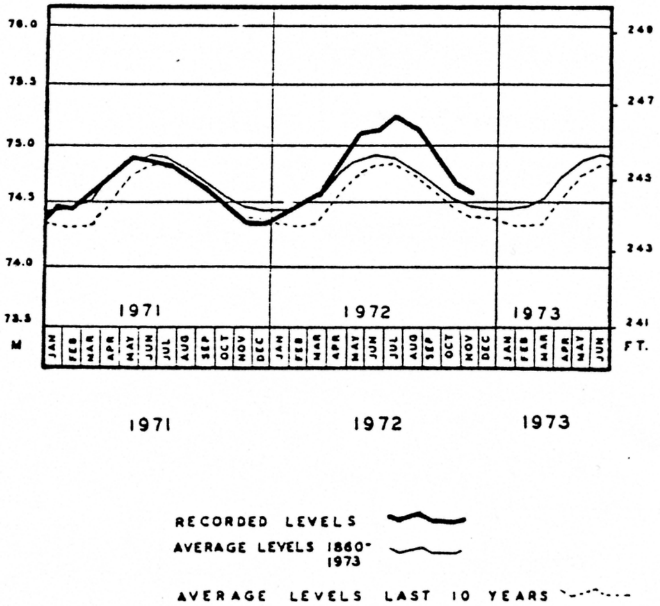

FIG. 4. Monthly mean lake levels during study period compared with long-term average levels and average levels for the last ten-year period (U.S. Dept. of Commerce, Lake Survey Center, Detroit, Michigan).

The observed water level fluctuations within Lake Ontario can be attributed to several causes. Seasonal fluctuations depend upon changes in water volume within the basin. These in turn depend upon variations in precipitation, evaporation and outflow.

In addition to seasonal variations in water level, the lake is subject to fluctuations of irregular magnitude and duration. Variations in barometric pressure can produce changes in water levels that in extreme cases can range up to a meter or more. Such short-term effects may continue for periods of several hours to several days (Hough 1958). Winds of sufficient velocity to drive the surface waters forward in greater volume than can be carried by return currents affect the lake by raising the water elevation on the weather shore and lowering it on the lee shore.

SAND MOVEMENT

Waves approaching the beach at an angle produce a transverse swash running diagonally up the beach and a backwash that retreats directly lakeward. Beach drifting is caused by waves breaking in this manner edging sand along the shore (King 1972). Wave-induced littoral currents in the nearshore zone transport sediment along the lake bottom. These processes produce longshore drift with the direction being dependent upon the angle of wave approach. Maximum wave heights hindcast by the SMB method were less than three meters.

Parameters such as wave height, duration, wavelength and wave steepness govern the rate of sand transport. Volume of sediment entrainment by any particular wave increases rapidly with wave height. The volume of sediment moved by a particular wave also increases as the period lengthens (Sverdrup et al. 1942). Large waves thereby remove greater volumes of sediment from the beach. The most destructive waves are associated with high wind velocities accompanying storms. The erosional effectiveness of large waves produced by strong winds blowing onshore is enhanced by the direct consequence of these winds. Portions of the beach high enough to escape wave attack under normal conditions become subject to erosion. Steep waves attacking a sand beach are destructive in that they cause erosion of the shoreline, moving sand to deeper water offshore.

Longshore drift may transport a portion of the sand removed from the beach face along the coast and out of the study area. An additional quantity of sand may be transported offshore to depths below normal wave base. Sediment removed in this way is effectively lost to the active beach system, since a mechanism to remobilize it shoreward is lacking. The present study appears to show that up to 25% of the material eroded from the beach face is stored temporarily in the offshore zone in the form of submarine bars trending subparallel to the coast. During periods of low wave activity, these bars migrate landward eventually becoming welded to the beach. A portion of the sand previously removed from the shore can in this manner be returned to the beach face.

Model experiments have been conducted by Schwartz (1965, 1967) to test Bruun's theory of the relation between sea level rise and shoreline erosion. Bruun's model proposes that should a profile of equilibrium exist, rising water levels will cause material eroded from the upper beach to be deposited on the nearshore bottom down to depths approximating wave base. This will result in the upper beach being displaced landward as material is moved seaward. The volume of sediment displaced seaward must equal the volume of material eroded from the shore. The equilibrium profile will be maintained by accretion on the offshore bottom equalling the rise in water level. The landward displacement of the beach at Selkirk can be documented by the described marsh deposits beneath the beach.

SUMMARY

Loss of sediment from the beach and extreme nearshore zone occurred during spring and summer 1972. Beach erosion in this area is a consequence of winds blowing from the northwest. The erosional effectiveness of these winds is enhanced by their coincidence with the major fetch direction and further amplified during this year by unusually high lake levels. Higher lake levels allow direct wave attack upon the upper portions of the beach. In contrast, late summer and early fall were times of beach accretion. These period coincided with episodes of lowered lake levels and strong winds blowing from th land. Winds from the east depress lake level, thereby placing the upper beach beyond the limit of wave attack. A further effect of offshore winds is to reduce the amplitude of the approaching waves. Such flattened waves tend to be constructional in that they sweep sand landward and onto the beach (King 1972).

During the study, beach accretion occuring during late summer and fall was not sufficient to compensate for losses incurred during spring and early summer. As a consequence, the shoreline retreated an average of 4.5 m landward during this twelve-month period. The observed beach erosion entailed the removal from the study area of some 8400 m^3 of sand, somewhat more than 1000 tons of sediment. Sixty-five percent of this loss occurred from the subaerial portion of the beach, the remainder having been removed from the submerged nearshore zone.

CONCLUSION

Differential upwarp of the lake outlet continues to effect the long-term wate levels along the eastern shore of Lake Ontario. The transgression resulting from this uplift has long-term implications in regard to increased shoreline erosion. Winds blowing along the greatest fetch coupled with elevated water levels generate high seas which have induced severe conditions of beach erosion.

It is unlikely that uplift of the outlet will cease in the immediate future. Nor is there much reason to expect an increase in beach nourishment or a reduction of the strong northwest winds. It follows that erosion along the eastern shoreline of Lake Ontario must be considered a chronic condition.

ACKNOWLEDGMENTS

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REFERENCES

Bretschneider, C. L. 1951. *Revised wave forecasting curves and procedures.* Tech. Rpt. He:155047. Berkeley, California: Institute of Engineering Research.

Clark, R. H., and Personage, N. P. 1970. Some implications of crustal movement in engineering planning. *Can. J. Earth Sci.* 7:628-633.

Emery, K. O. 1961. A simple method for measuring beach profiles. *Limnol. Oceanog.* 6:90-93.

Harrington, M. W. 1895. *Bull. B,* Washington: U.S. Weather Bureau.

Hough, J. L. 1958. *Geology of the Great Lakes.* Urbana, Illinois; University of Illinois Press.

King, C. A. M. 1972. *Beaches and coasts.* New York: St. Martin's Press.

Saville, T. 1953. *Wave and lake level statistics for Lake Ontario.* Tech. Memo. No. 38. Washington, D.C.: Beach Erosion Board, U.S. Army Corps of Engineers.

Schwartz, M. L. 1965. Laboratory study of sea level rise as a cause of shore erosion. *J. Geol.* 73:528-34.

__________. 1967. The Brunn theory of sea level rise as a cause of shore erosion. *J. Geol.* 75:76-92.

Sutton, R. G.; Thomas, L. L.; and Woodrow, D. L. 1970. Nearshore sediments in southern Lake Ontario, their dispersal and economic potential. In *Proc. 13th Conf. Great Lakes Res.*, pp. 308-318. Ann Arbor: Internat. Assoc. Great Lakes Res.

Sverdrup, H. U.; Johnson, M. W.; and Fleming, R. H. 1942. *The Oceans, their physics, chemistry and general biology.* New York: Prentice-Hall.

Zumberge, J. H., and Wilson, J. T. 1953. Effect of ice on shore development. In *Proc. 4th Conf. Coastal Engineering,* ed. J. W. Johnson, pp. 201-205. Berkley, California: University of California Press.