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The Geomorphology of Teshekpuk Lake in Relation to Coastline Configuration of Alaska's Coastal Plain

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ABSTRACT. Observations on a drained and a partially drained lake basin adjacent to Teshekpuk Lake led to the conclusion that the drainage was a result of erosion produced by the moat-current phenomenon of Teshekpul Lake. The processes of shoreline erosion and lake-capture seem to be responsible for the growth and configuration of Teshekpuk Lake. Similar phenomena between large lakes and the Beaufort Sea may also have influenced the shoreline configuration of vast coastal areas such as Admiralty Bay, Dease Inlet and Harrison Bay.

INTRODUCTION

Teshekpuk is an Eskimo name meaning "the largest lake of all," and it refers to the largest lake on Alaska's Coastal Plain. Teshekpuk Lake (70° 35' N, 153° 30' W) is about 33 by 44 km, with a maximum depth of 10 m. The lake is surrounded and presumably underlain with Pleistocene alluvial silt and sand and has an ancient beach deposit on the north shore (Williams *et al.*, 1978). According to the National Aeronautic and Space Administration's (NASA) LANDSAT imagery for 1971-77, the lake is ice-free for only about 6 weeks, from late July or early August to mid-September. A shifting cake of ice surrounded by a moat is common during July and sometimes early August (Fig. 1). Ice thickness ranges from 1.8 to 2.4 m in winter (unpublished data from Husky Oil Co.).

These observations and interpretations on the morphometry of Teshekpuk Lake are a result of an inquiry into the causes of the complete drainage of one lake and the partial drainage of an associated basin near the northwestern shore of Teshekpuk Lake. These newly drained basins were discovered during explorations on 15-18 July 1976 of sites needed to measure impacts of petroleum exploration and development on wildlife in National Petroleum Reserve — Alaska. Additional observations were made on 13 July 1977.

BACKGROUND OBSERVATIONS

Approximately 1 km north of the Naval Arctic Research Lab's Teshekpuk Lake field camp, is a lake approximately 1.3 x 2.1 km separated from Teshekpuk Lake on the south by a narrow strip of land. This basin which we

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FIG. 1. View to the east, showing the partially drained North Lake at left and Teshekpuk Lake at right, with drainage point between (13 July 1977).

named North Lake, had a low water level produced by recent drainage into Teshekpuk Lake (Fig. 1), and its shallow waters and broad mud flats were attractive to brant [*Branta bernicla* (Linnaeus)], whitefronted goose [*Anser albifrons* (Scopoli)], pintail (*Anas acuta* Linnaeus), oldsquaw [*Clanqula hyemalis* (Linnaeus)] and shorebirds. We suspect that the very turbid water does not exceed 30 cm in depth. Mud flats showed polygonal patterns produced by frost action, and pioneer plant associations were evident. Presumably, these polygons were a product of frost action under the former lake, because such patterns are visible underwater in lakes. Moreover, this lake clearly is part of a secondary lake system lying in an ancient basin.

At the west edge of North lake is an abrupt shelf of peat that once formed the sweeping, squared shoreline of the full lake basin. This bar, similar to those described by Carson and Hussey (1960), is 28 m wide and is underlain by permafrost at a depth of 7 cm. About 22 m west of this shelf is a much smaller (325 m in diameter) and shallower lake basin lying above the level of North Lake. This basin, which we called Dry Lake, was connected to North Lake by a channel 2 m deep containing several large ice wedges.

OBJECTIVES AND METHODS

Although drainage is a well-recognized phenomenon of tundra lake systems, the drainage of these two basins, Dry Lake and North Lake, raises several specific questions of significance in understanding lake-basin dynamics and ecological succession in this region of large lakes: 1) When and why did these lakes drain?; 2) What will be the rate of tertiary lake formation in these basins?; 3) What will be the direction and rate of plant and animal succession in these basins?; and 4) What will be the influence of oil development on such aquatic systems?

In addition to onsite observations and photographs, aerial photographs of the northwestern section of Teshekpuk Lake were accumulated from various sources for the years 1948 (U.S. Navy), 1955 (U.S. Geological Survey), 1975 (North Pacific Aerial Survey, Anchorage, Alaska), and 1976 (Bureau of Land Management). Less detailed but more frequent coverage of Teshekpuk Lake was available from NASA's LANDSAT imagery for 1971-1977. The most detailed coverage that allowed examination of even plant succession was from 1:3000 and 1:6000 low-level 35mm infrared photos of North Lake which we took during 1977. Based on these aerial photos, an effort was made to assess changes in lake-basin size, to examine drainage patterns, and to examine overlap in ancient lake basins demonstrated by frost-feature patterns, intersecting shorelines, plant communities and drainage patterns.

INTERPRETATION

There were no major changes between 1948 and 1955 in the shoreline of adjacent lakes in the northwestern portion of Teshekpuk Lake. The lake configuration shown in the U.S. Geological Survey topographic 1:250,000 series (Teshekpuk Quadrangle) was based on the 1955 photos. Unfortunately, no photographs from intervening years have been found that might better date the drainage of these lakes, and we can only conclude that drainage occurred between 1955 and 1975. Aerial reconnaissance of the coastal area between Cape Halkett and Point Barrow resulted in observations of numerous sizable, recently drained or partially drained basins. There seems to be little evidence of major land uplift, suggesting that the extensive lake drainage merely reflects the dynamics of numerous lake life histories as described by Carson and Hussey (1960).

Our identification of the cause of the drainage of North and Dry Lakes at first centered on how North Lake breached the narrow land mass between it and Teshekpuk Lake. Aerial photos showing the configuration of the neck of land between Teshekpuk Lake and North Lake indicate that Teshekpuk Lake had enlarged northward, reducing the width of the inter-lake isthmus and thereby allowing one or several ice wedges to thaw, resulting in a channel between the two lakes (Fig. 2). The channel, now 84 m wide and partially sealed by a newly formed beach on the Teshekpuk lake side occurred at the narrowest point and where a surface pond already existed. The vertical

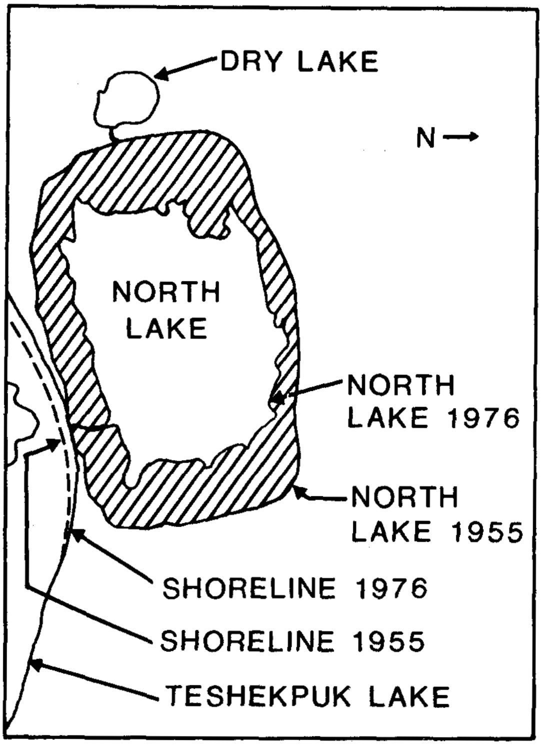

FIG. 2. Locations of Dry and North Lakes, with a comparison of lake and isthmus size of North Lake from 1955-1976, based on aerial photographs.

face of the entire north shore of Teshekpuk Lake and numerous exposed ice wedges demonstrate recent cutting. The erosion may have been caused partially by movement of cake ice but more probably resulted from erosion produced by the current in the channel between the ice mass and abrupt shoreline, as discussed by Carson and Hussey (1960) for smaller lakes.

Dry Lake is about 2 m above North Lake. The vertically cut bank and exposed permafrost lenses in the drainage of Dry Lake in 1976 suggested that the drainage into North Lake was very recent. In fact, these lenses had melted and the sod had collapsed by 1977.

Aerial photos of several other basins, both east and west of North Lake, show the elimination of shorelines separating them from Teshekpuk Lake, and drainage into the larger lake. Several of the basins remain unflooded but, because of their low elevation, only a minor increase in the level of Teshekpuk Lake would cause them to become "captured lakes."

The shoreline of Teshekpuk Lake is complex, particularly along the western edge, and obviously has resulted from the coalescence of many sizable lakes (Fig. 3). Several islands help delineate former individual basins. Teshekpuk Lake seems to be expanding as it has many times in the past, and these partially or fully drained basins may one day be portions of the main lake. Topographically, Teshekpuk Lake seems to be a low basin with drainage from

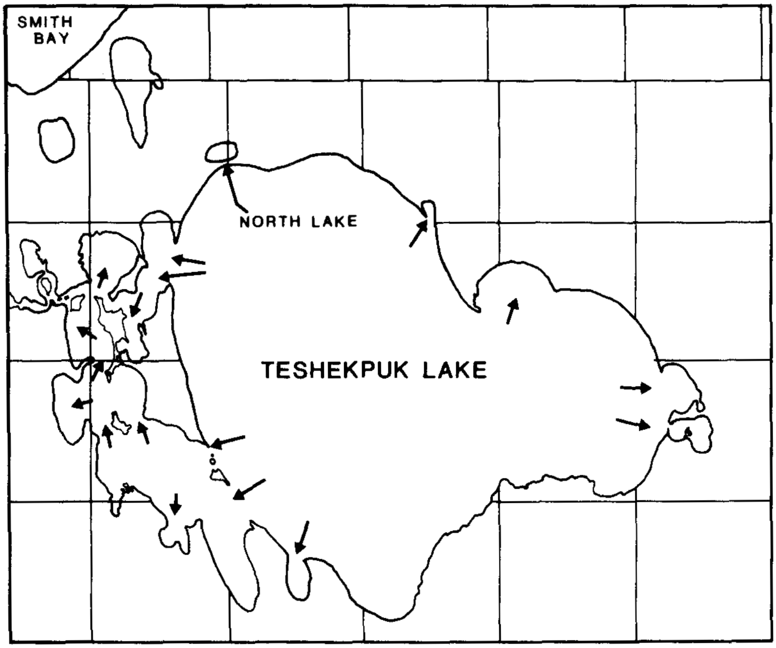

FIG. 3. Shoreline configuration of Teshekpuk Lake with arrows indicating "captured lakes" that have been flooded. At least those in the northwest corner are very shallow, and use of a motorboat is difficult.

all directions. The rate of flow at the outlet will influence whether water levels eventually rise or fall in relation to newly captured basins, but it appears that the only outlet is northwesterly through the Miguakiak River — and the volume of this flowage is uncertain. Moreover, the direction of flow probably reverses with varying ice conditions and water levels.

DISCUSSION

Lake dynamics in relation to coastal geomorphology

Growth of lakes, changes in lake shape, and breaching of basin shorelines have been described in Black and Barksdale (1958), Livingstone *et al.* (1958), Black (1969), Carson and Hussey (1960), and others. Based on differences in size and shape among thaw lakes, Carson and Hussey (1962) divided the coastal plain into eastern and western sections, separated by a boundary paralleling the Colville River at approximately longitude 152° W. In the eastern section, wetlands rarely exceed 1.6 km in length. In the western section, wetlands frequently exceed 1.6 km, and some are over 10 km. These differences may be related to age of the sediments and to the slope (Sellman *et al.*, 1975), but it is obvious that shoreline configurations have been more dynamic in the western area. Our observations on lake-basin capture demonstrate that the shoreline of Teshekpuk Lake is changing actively.

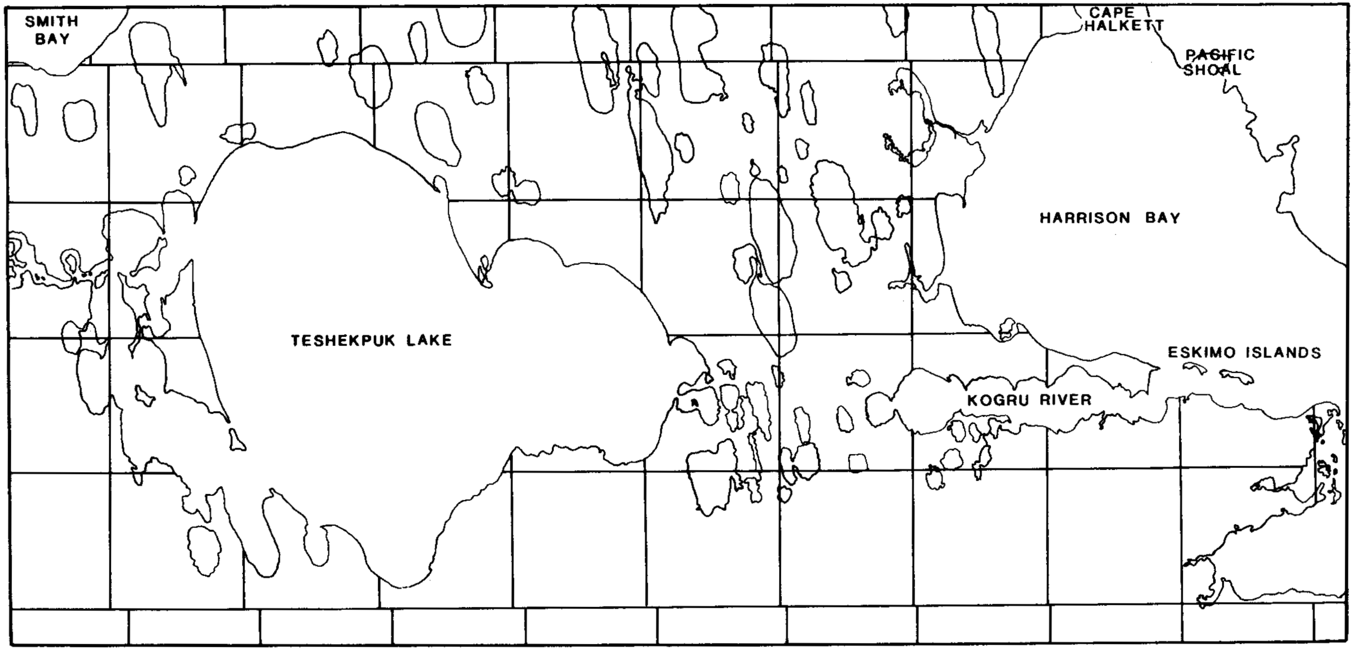

FIG. 4. Location of: a) Teshekpuk Lake in relation to Smith's Bay to the northwest and Harrison Bay to the east; b) Outline of Pacific Shoal that may have been the ancient shoreline of a large, freshwater lake.

The Arctic coastline of the Beaufort Sea is equally dynamic and the processes of melting of permafrost, slumping of soil and transport by water movements resemble the smaller scale process on lakes (MacCarthy, 1953; Rex, 1964; Hume, Schalk and Hume, 1972). Shorelines are being eroded at surprisingly rapid rates with the general effect being a shifting of the shoreline southward. Such erosion has transected numerous lakes along the coast east of Barrow as mapped by MacCarthy (1953). Similar ocean-lake coalescence along the shoreline north of Teshekpuk Lake also is evident, such as at Ross Bay and Iko Bay west of Dease Inlet, and Kurgorak Bay and McKay Inlet east of Dease Inlet (Fig. 4).

Major interactions between lake, sea, and possibly river processes probably were responsible for the irregular configuration of the Beaufort Sea shoreline between Barrow and Harrison Bay. The shape of Admiralty Bay, its islands, and its irregular shoreline, indicate that it was once a huge lake that joined with Dease Inlet — itself possibly another lake — and the Beaufort Sea (Fig. 5). The role of the Meade River drainage in modifying the topography of that region is uncertain. The western part of Harrison Bay (Fig. 4) between Cape Halkett, the Pacific Shoal and the Eskimo Islands also may have been a large freshwater lake rivaling Teshekpuk Lake in size. Given thousands of years, Teshekpuk Lake could cut northwesterly to join Smith's Bay of the Beaufort Sea or eastward to the Kogru River and Harrison Bay by this process of erosion, melting, drainage, and (presumably) increased water volume (Fig. 4). Dependent upon topography, it could cut both directions, leaving a huge island north of Teshekpuk Lake. Or, more likely, it may eventually cut its own drainage to a point where "the largest lake of all" will become a partially drained basin that is once again a number of coalescent basins. Some huge lakes exceeding 10 km occur northeast of Teshekpuk Lake; yet they are obviously secondary basins lying in once still larger basins.

Biotic changes resulting from lake drainage

The drainage of North Lake and Dry Lake provides baselines from which to measure the rate of change in these permafrost lake ecosystems. Black and Barksdale (1958) and Carson and Hussey (1960, 1962) discussed the process of lake formation, and various basins were dated by Livingstone *et al.* (1958), who used the ages of willows, and by Carson (1968) who used radiocarbon techniques. Not only is there a unique opportunity to observe changes in physical characteristics of these newly drained basins, but it also will be possible to assess floral and faunal succession in relation to secondary lake formation. The importance of mature secondary lakes in production of invertebrates and waterbirds has been established (Bergman *et al.* 1977), but study of a newly drained system would allow a better understanding of the reasons for the richness and the successional events that influence water-related organisms. Although the slowness of the process may reduce the feasibility of a chronological and observational study in North Lake, the availability of this stage will permit comparison of this basin with more advanced lake stages that can be found in the area.

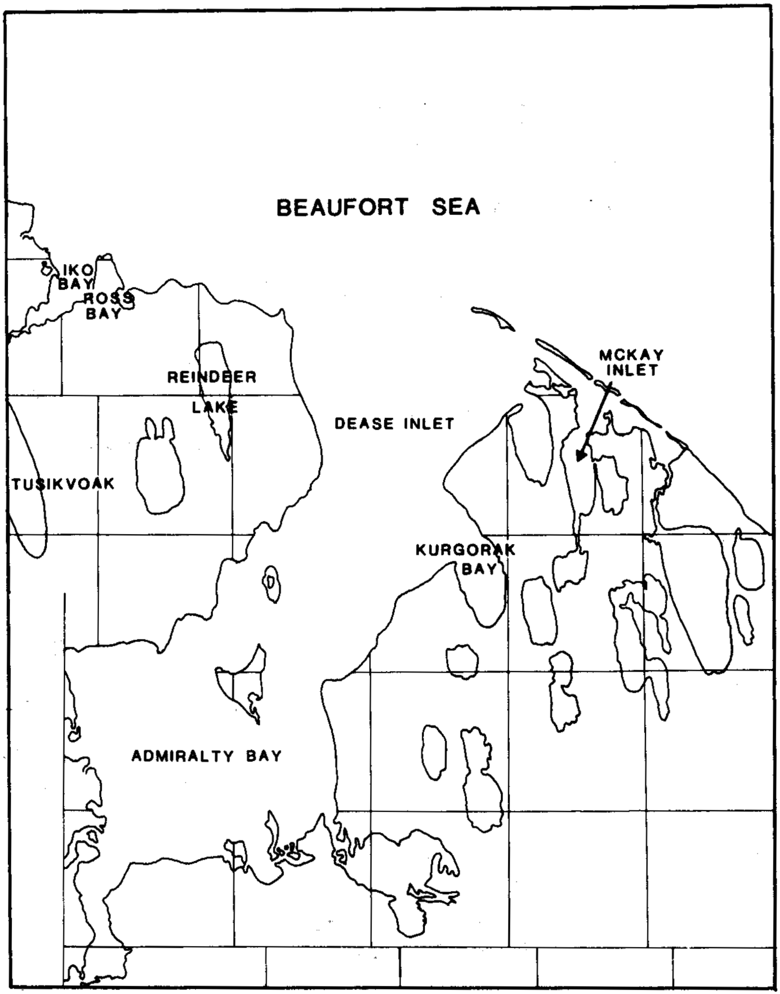

FIG. 5. Shoreline topography and island structure in Admiralty Bay and Dease Inlet suggesting fusion of former lake basins.

Relationship to oil development

If these speculations on lake dynamics are true, the potential of oil pollution raises additional major concerns. Teshekpuk Lake is in a potential oil leasing area; an exploratory well was drilled on the east shore in 1975, with some accidental spillage of drilling muds into the lake. What will be the impacts of pipelines, roads, accidental spillage or dumping of wastes, and heating of waters on Teshekpuk and the many smaller lakes? Proposed removal of gravel from bars along Teshekpuk Lake would facilitate cutting action by water. Use of water for drilling could modify lake levels and create secondary cutting and thawing. Even more serious would be possible effects on drainage. Modification of drainage of the Miguakiak River that drains Teshekpuk Lake to the west could have serious implications on water levels and flooding of basins of the Teshekpuk Lake system. What minor changes in water volumes or temperature may influence the rate of change of these lakes? Drainage systems have already been modified in the oil-development area near Prudhoe Bay due to roads and other structures. In view of the apparent patterns of permafrost melt, lake coalescence, erosion and other actions in large lakes, the potential that human activity will induce major morphological changes in these tundra lake systems is great.

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