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Physiography, texture, and bedforms during June-July 1981 in Turnagain Arm estuary, upper Cook Inlet, Alaska

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INTRODUCTION

Turnagain Arm estuary is the southeast-trending extremity of upper Cook Inlet near Anchorage, Alaska, which extends from Fire Island to Portage, a distance of approximately 85 km (fig. 1). The estuary is macrotidal, with a maximum semidiurnal tidal range of at least 11.4 m. Like Upper Cook Inlet (Sharma and Burrell, 1970) and Knik Arm (Bartsch-Winkler, 1982), Turnagain Arm is an area of contemporary sand deposition (Bartsch-Winkler and Ovenshine, 1984). At low tide, it is mostly intertidal, with approximately 70 percent exposed as elongate bars composed of fine sand and silt, dissected by braided tidal channels of unknown depth and textural morphology. Glacial deposits border the mouth at the Anchorage Lowlands, Fire Island and Chickaloon, but most of the estuary is surrounded by bedrock ridges that rise to 1,200 m less than 2 km from shoreline.

This study on the texture of the sediments comprising the intertidal zone represents baseline information which may be useful to developers and planners in the future. The estuary is proximal to the largest metropolitan area in Alaska (Anchorage) and, even though most of the shoreline is protected from environmental encroachment by being within National Forest and State Park boundaries, parts of the shoreline are within the Anchorage and Kenai Boroughs, and careful monitoring of the Arm is essential. Facilities introduced into the estuarine system by man prior to the time the study began included a gas pipeline crossing near Potter, and the Seward Highway abutments built at stream mouths and near marshes. There is no dredging carried out in Turnagain Arm, nor any boat harbors or marinas, and the estuary is relatively pristine.

As part of the macrotidal setting, a tidal bore occurs during the incoming tide; the solitary waves form near the limit of the intertidal zone near Fire Island, and flow up non-draining tidal channels. As many as four tidal bores have been witnessed at a single low tide occurring in separate channels. Since the larger tidal channels never drain completely, their depths are unknown. This report excludes information obtained at Portage at the head of the Arm; Portage-area data are reported by Ovenshine and others (1976) and Bartsch-Winkler and others (1978).

Data presented here on the physiography, texture, and measurement of bedforms were collected during June and July, 1981. Vertical aerial photographs (scale 1:24,000) of Turnagain Arm were taken in the early spring at low tide. These photographs were utilized in mapping and sampling surface sediments (pl. 1) and were the basis for the physiographic map (pl. 2).

SAMPLING AND LABORATORY PROCEDURES

The high liquefaction potential of Turnagain Arm sediment is a well-publicized deterrent to foot travel. In addition, most tidal channels never drain, and have unstable banks and bottoms, making them impassable.

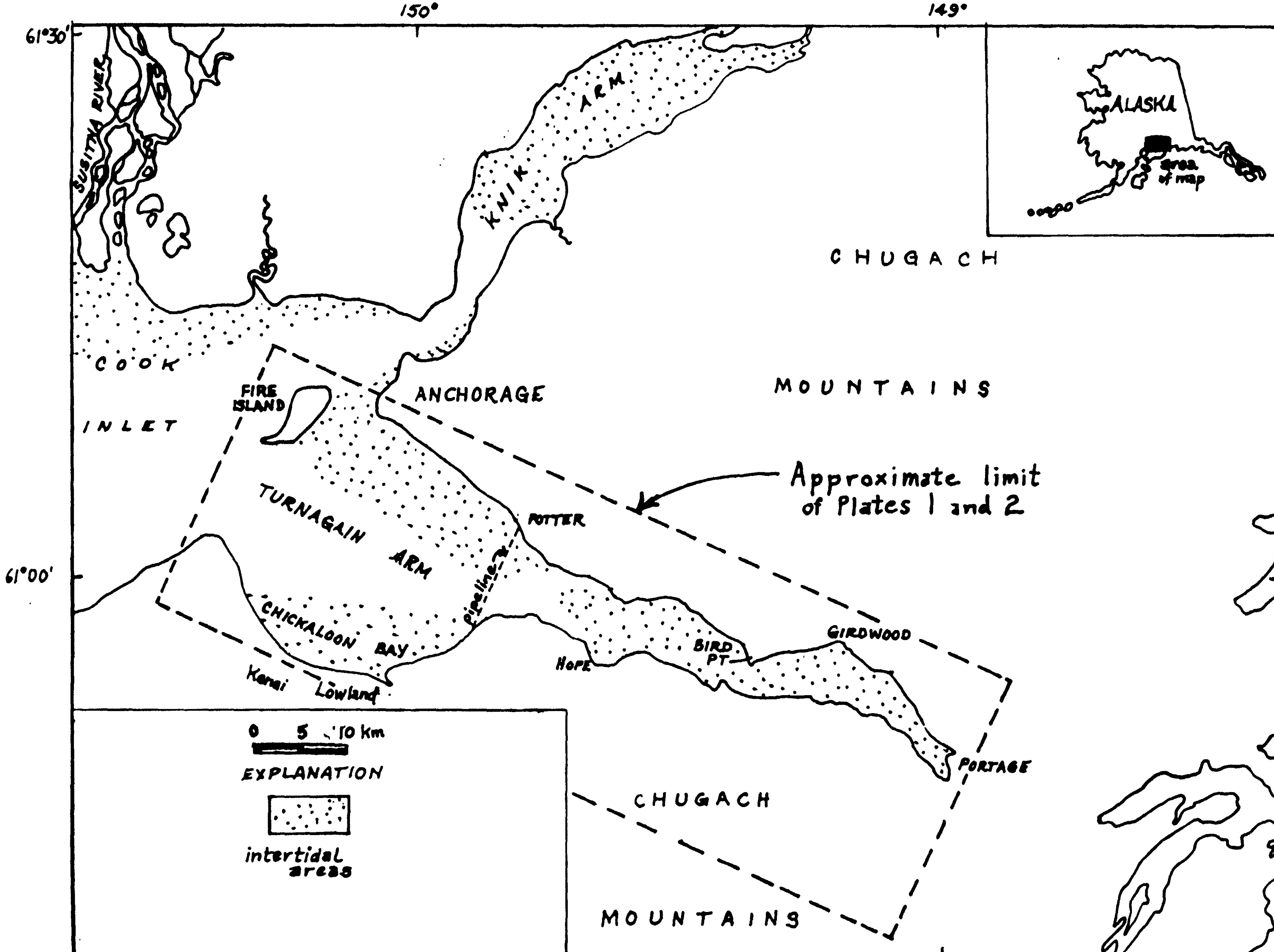

Figure 1. Index map of Turnagain Arm and vicinity showing intertidal areas.

Therefore, helicopter transportation was utilized in sampling and was limited to areas exposed at low tide during July and August, 1981. A 80 cm^3 grab sample was collected from the surface sediment at each station, estimates of relative liquefiability and water saturation were made, and the surface bedforms measured. At some sites, boxcores were taken and notes on vertical textural changes and sedimentary structures were noted and analyzed by x-radiography. The results of these observations were used to determine the facies present. Steps in the textural analysis were: (1) drying at $60^{o}C$, (2) weighing, (3) wet-sieving to remove the fraction less than 44 microns, (4) drying, (5) weighing to determine the percent finer than 44 microns, (6) dry-sieving at half-phi intervals, and (7) weighing sieve fractions to an accuracy of 1 mg. The percentage of sand in each sample was then calculated.

TEXTURE OF SEDIMENT

Longitudinal bars consisting of very well sorted silt and sand with crests which parallel the trend of the estuary fill Turnagain Arm (pl. 1). The lower reaches (toward the mouth of the estuary and in areas adjacent to major tidal channels) have the highest percentage of sand, and textures fine upward toward the head of the estuary and toward the crests of intertidal bars. Though the Arm was carved by glaciers (Karlstrom, 1964), there is little evidence in Turnagain Arm sediment of glacial events that predate the last glacial maximum (glaciers probably occurred there as recently as 14,000 yr B.P.; Kachadoorian and others, 1977; Bartsch-Winkler and others, 1983; Bartsch-Winkler and Schmoll, 1984). Glacial deposits are not common along the shoreline, so lag gravel is not prevalent within Turnagain Arm sediment, though small stream gravel deposits do occur at the margin of the Turnagain Arm deposit where creeks and rivers drain into the arm. Clay size material is rare in all samples, constituting less than 1 percent of any sediment sampled. This may be due to the high-energy environment which does not allow deposition of finer grained sediment, and to the relative lack of clay in the presumed source areas (in part, large glacial deposits found near the mouth of the estuary; H. R. Schmoll, oral communication, 1983). Textural patterns reflect relative tidal current energies, with coarser material deposited by stronger currents occurring along the flanks of channels and in the lower reaches. Finer grain sizes deposited by low-flow velocities at slack water high tide occur on the crests of bars and on the higher flats.

BEDFORMS

Ripple marks are typical bedforms over most of intertidal surface sediment in Turnagain Arm, and indicate various current regimes and current directions of the previous ebb tide (pl. 2). This bedform data in combination with boxcore information and the textural map resulted in interpretation of the sedimentological units of Turnagain Arm. Measurements of ripple mark amplitudes indicate minimum dimensions, since the ripples are postdepositionally altered (tops truncated) by subsequent ebb tide (shallowing water level and lagging current velocity, which superimposes bedforms of a lower current regime).

Megaripples. The largest bedforms present in Turnagain Arm are assymetric megaripples which occur at the seaward limit of the intertidal deposit. They are composed of sand. Most of the measurements on these bedforms were only estimated, due to the high liquefaction potential of the sediment, making on-site measurement difficult. The high liquefiability indicates the sediment to be well-sorted and highly saturated. The megaripples range in height from approximately 1.5m to 0.2 m, with a mean of 0.7 m; their estimated wavelengths vary from 12 m to 3 m, with a mean of 7 m. The orientations of the megaripples on the surface sediment reflect their formation both in the direction of the highest current velocity, and in the deepest water of the falling tide. Because they are formed in relatively deep water, they result from circulation patterns not as directly affected by bottom morphology as are the smaller scaled bedforms described here.

Straight-crested or sinuous ripple marks. Straight-crested or sinuous ripple marks (Ovenshine and others, 1976) represent the next highest current regime to the megaripples. They are often superimposed on or found associated with megaripples, or in the areas nearest the intertidal channels. Straight-crested ripple marks have amplitudes which range from 4.0 to 0.25 cm and wavelengths of 17.0-3.5 cm. Mean amplitude is 1.3 cm, and mean wavelength is 9.7 cm. Although they may also be found higher on the tidal flat in association with lunate-linguoid ripples, this bedform type is most typical of the lower flat areas. Straight-crested ripple marks are characteristically asymmetrical and their orientations reflect small variation in topography of the lower tidal flat, forming in water depths of 0.75 m or more (Ovenshine and others, 1975).

Lunate-linguoid ripple marks. Lunate and linguoid ripple marks (or combinations of both forms) (Ovenshine and others, 1976) are found throughout the tidal flat, and are the most prevalent bedform measured in Knik Arm. Their highest concentration is intermediate between the lowest, most saturated, active mudflat and the upper, drier, lesser active flat. Lunate-linguoid wavelengths are commonly difficult to measure due to their complex morphology; often they are transitional forms from straight-crested ripple marks. Where measureable, they have wavelengths ranging from 26.0 to 7.5 cm, averaging 18.8 cm. They have amplitudes ranging from 5.0 to 0.5 cm, averaging 3.3 cm. Lunate-linguoid ripple marks reflect the moderate to low current regimes of the falling tide in water depths of 0.25 m or less (Ovenshine and others, 1976), and are therefore found superimposed on higher-regime bedforms of the lower flat and as remnants of higher flow regimes on the lower part of the upper mudflat.

CONCLUSIONS

Turnagain Arm contains three sedimentary facies with similar characteristics to those described from Knik Arm (Bartsch-Winkler, 1982); i.e., (1) a lower flat facies which is saturated, composed of liquefiable sand, and containing megaripples; (2) an upper active flat facies, typically composed of less than 30 percent sand, liquefiable sand and silt, relatively small ephemeral drainage channels, and no megaripple occurrences; and (3) an upper "inactive" flat area facies composed predominantly of silt (sand percentages less than 10 percent). Details of this third facies at Portage have been reported by Ovenshine and others (1976) and Bartsch-Winkler and others (1982). On the upper reaches of Turnagain Arm composed of facies 3 sediment, significant subsidence occurred during the great Alaska Earthquake of 1964, lowering the sediment into the tidal zone. Sediment in these areas has been prograding from this subsidence, and the land is regenerating to pre-earthquake conditions (Ovenshine and Kachadoorian, 1976; Bartsch-Winkler and Garrow, 1982; Kachadoorian and Ovenshine, 1984).

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