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SEDIMENTARY FRAMEWORK OF THE
ERODING BEACH-SHOREFACE SYSTEM,
ADJACENT TO TYBEE ISLAND, GEORGIA

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INTRODUCTION

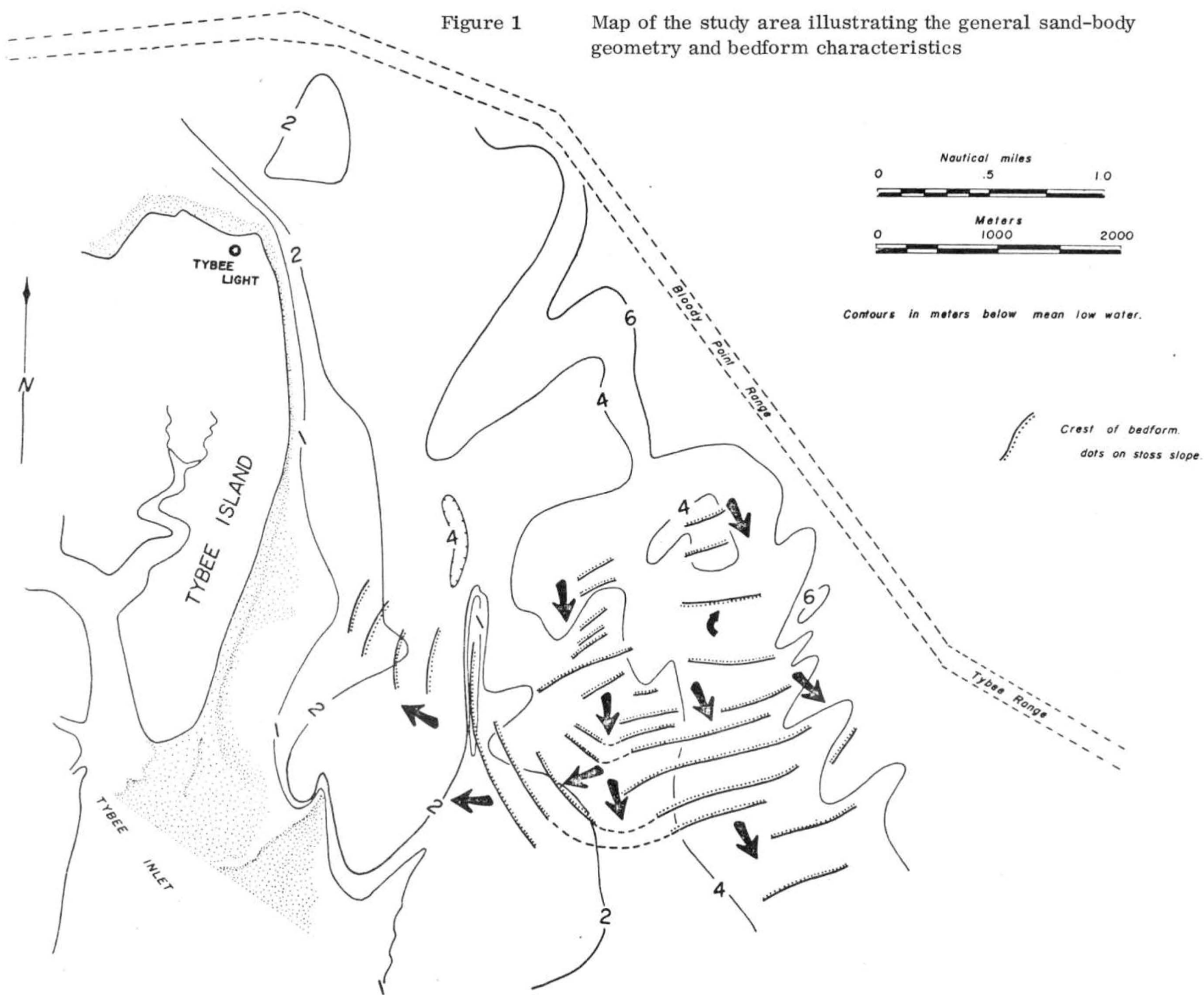
Tybee Island is located just south of the Savannah River entrance, and approximately 20 miles east of the city of Savannah. The submarine topography and facies distribution patterns at the shoreface adjacent to Tybee Island have been studied in order to construct a sedimentary framework. This report is a description of some of the fundamental data needed to understand the sediment budget of the Savannah Beach area. At present, a deficit in the sediment budget of Tybee Island has created severe erosion along the beaches, and erosion has already threatened much of the island's commercial and private property.

Detailed topographic surveys of the shoreface were conducted in order to determine the general sand-body geometry and the characteristics of the larger bedforms. From these data a topographic and bedform map was effected (fig. 1).

Over a period of three months, seventy-three box cores were taken in a sample grid located between Savannah Beach and Tybee Roads (fig. 2). The coring device took relatively undisturbed sediment samples that could be analyzed for primary and biogenic sedimentary structures and textures. Sediment samples were extruded from the core cans and trimmed to 1" thick wafers. Wafers were then x-ray radiographed and treated with epoxy for preservation. The characteristics of the sediment illustrated on the x-ray radiographs and the epoxy peels were observed and described in the laboratory. Percentages of the constituent portions of each core were approximated by estimating the areal distributions of the constituent portions of sand, mud and shell fragments. Sand was analyzed further by considering the coarse, medium and fine fractions. The relative stability or mobility of the bottom sediments was also estimated by comparing the

Figure 1

Map of the study area illustrating the general sand-body geometry and bedform characteristics



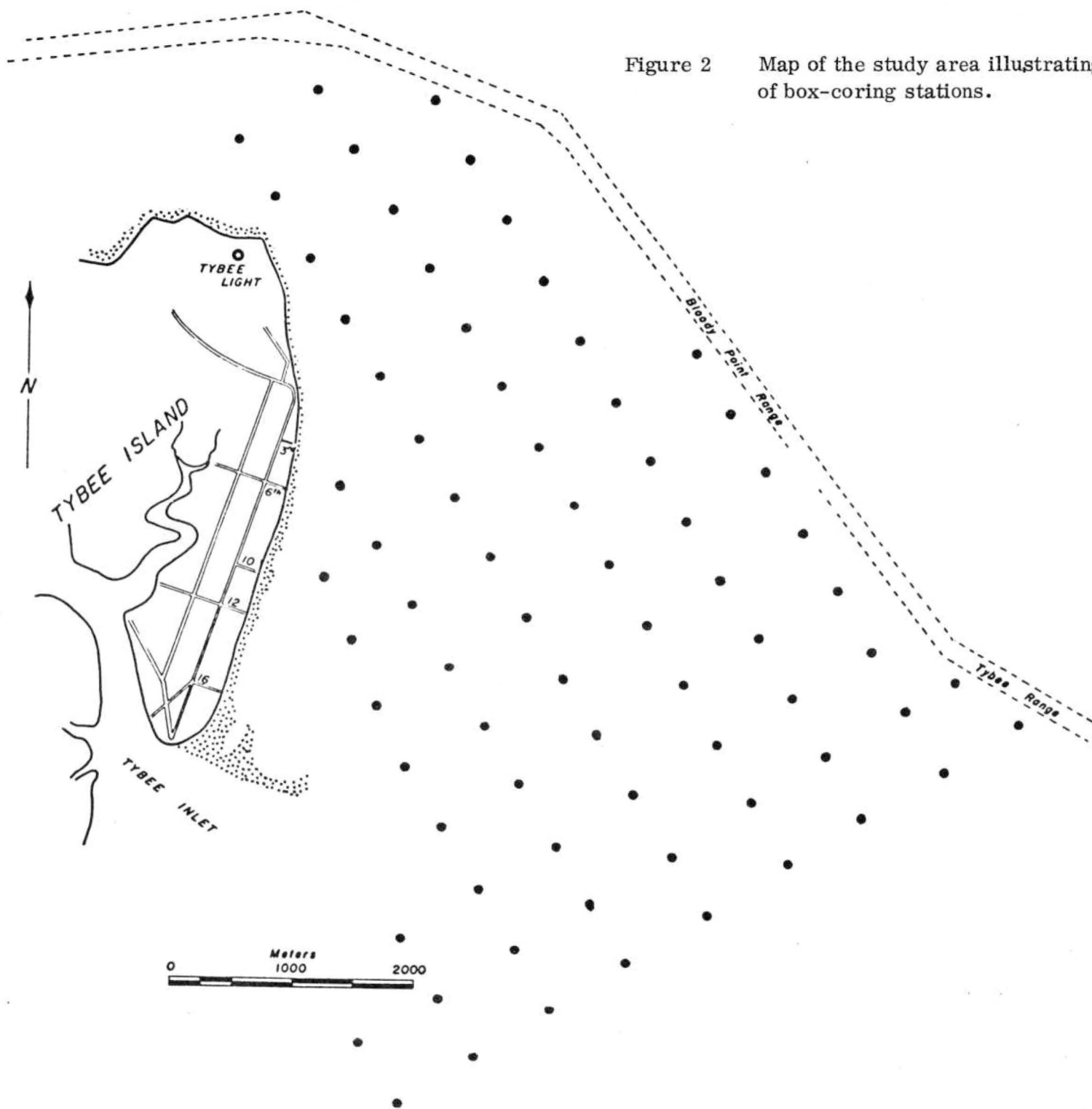


Figure 2 Map of the study area illustrating the locations of box-coring stations.

aereal-distribution percentages of primary sedimentary structures and bioturbid sedimentary structures.

Submarine Topography

The undulating topography in the study area illustrated numerous large, asymmetrical bedforms. Interpretations of bottom soundings also indicated a small, terminal channel in the northeast portion of the study area and northerly trending spit in the south central portion of the study area. This channel originates on the shoreface approximately one half mile east of the Third Street beach and extends northeasterly toward the Savannah River channel. The channel is slightly funnel-shaped and opens toward the margin of Bloody Point Range. In the southeastern portion of the study area, the residual movement of the large asymmetrical bedforms (sand waves) illustrated a centripetal pattern. Although many of the sand-wave crests were continuous for several miles, the orientations of the bedform slip faces were variable. The crests that were within one and one quarter miles from Bloody Point Range generally had slip faces on the southeast sides of the bedform. The sand-wave crests that were within one and three tenths miles from the beach generally were on the southwest or west sides of the bedforms. The residual movement of sediment in these bedforms appears to be from the margin of the seaward portion of Bloody Point Range toward the sand shoals at the south end of Tybee Island. However, adjacent to Bloody Point Range the residual movement appears to be in an offshore direction, whereas bedforms closer to shore are

asymmetrical on the landward side (indicating an onshore residual movement). In light of the above discussion, it must be pointed out that bedforms were only slightly asymmetrical, and residual movements were only minor. In this area, the surges of refracted waves may play a greater role in shaping the crests of these bedforms, than the shearing flow of tidal currents.

In the south central portion of the study area, a submerged spit extends in a northerly direction from the seaward end of the sand shoal at Tybee Inlet. The spit is built along the crest of a coarse grained, longitudinal sand wave. This sand body absorbs a great deal of the wave energy which would normally be dissipated on the beach at the southern end of Tybee Island. Waves touch bottom as they approach the sand body and produce an onshore, turbulent surge of water that passes across the spit. Turbulent wave surge is able to transport relatively large quantities of sediment short distances; however, once sediment is suspended by wave surge, then tidal currents may transport grains great distances. On the landward and leeward side of the spit, slightly deeper water is embayed to the south by the shoreline of Tybee Island and to the west by the Tybee Inlet sand shoal.

Facies Description and Distribution

Sediments of the shoreface and upper offshore areas are composed of varying concentrations of coarse sand, medium sand, fine sand, silt and clay. A portion of these grain-size fractions are shell fragments and heavy minerals, and although each of these constitute sediment types were present in many of the cores, the

percentages of the sediment types varied. In order to analyze the variance, the percentages of sediment types that were recorded on radiographs and peels were plotted on base maps. From these maps, the spatial distribution of sediment types became readily apparent.

In general, sand composed the largest portion of the substrate, followed by shell fragments and mud.

Distribution of Sand

Coarse Sand

The percentages of constituent sand grain sizes were estimated from the approximate amount of sand present on a longitudinal cross section of each core. Cores with high percentages of coarse sand (.5 to 1.0 mm) generally also contained relatively high percentages of shell fragments. Spatially, the highest concentrations of coarse sand appeared to correspond to the undulating sand wave topography. The bedding type associated with the coarse sand was readily discernible in the x-ray radiographs and relief peels. Coarse sand was generally stratified in relatively large foresets of undisturbed (non-bioturbated) strata.

The distribution pattern of coarse sand illustrated an oblique trend that extended from the Tybee Roads channel to an area of the foreshore between 6th Street and 12th Street (fig. 3). The highest concentration occurred in a sand wave field approximately one thousand meters seaward of the beach at 12th Street. Apparently the finer sand sizes are winnowed out of these large bedforms (sand waves), leaving a lag of coarse sand and shell fragments. Transport of the coarse lag by tidal currents is minor and grains are moved only as dunes migrate. Therefore, the

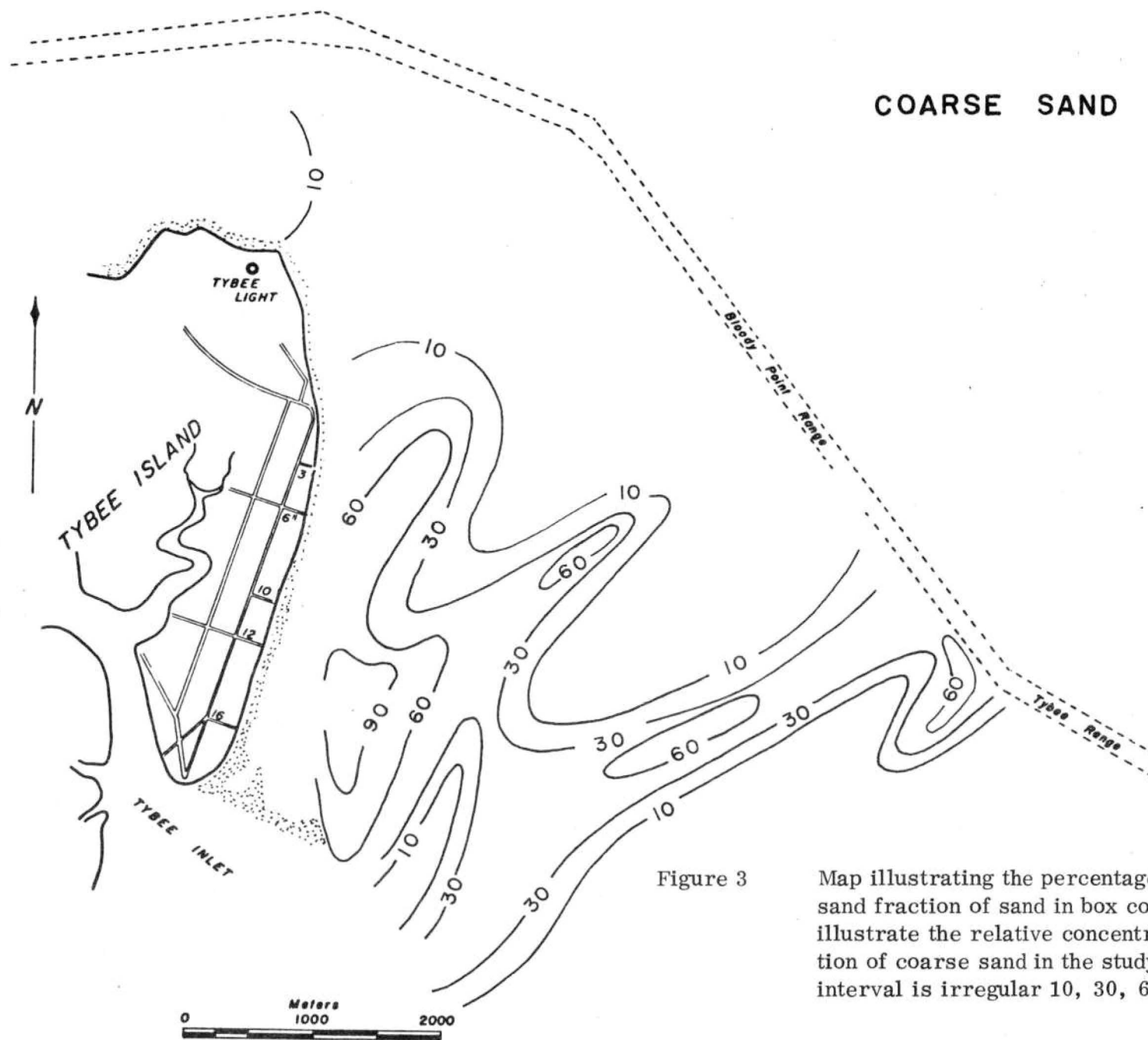


Figure 3

Map illustrating the percentages of the coarse-sand fraction of sand in box cores. Contours illustrate the relative concentration and distribution of coarse sand in the study area. The contour interval is irregular 10, 30, 60 and 90 percent.

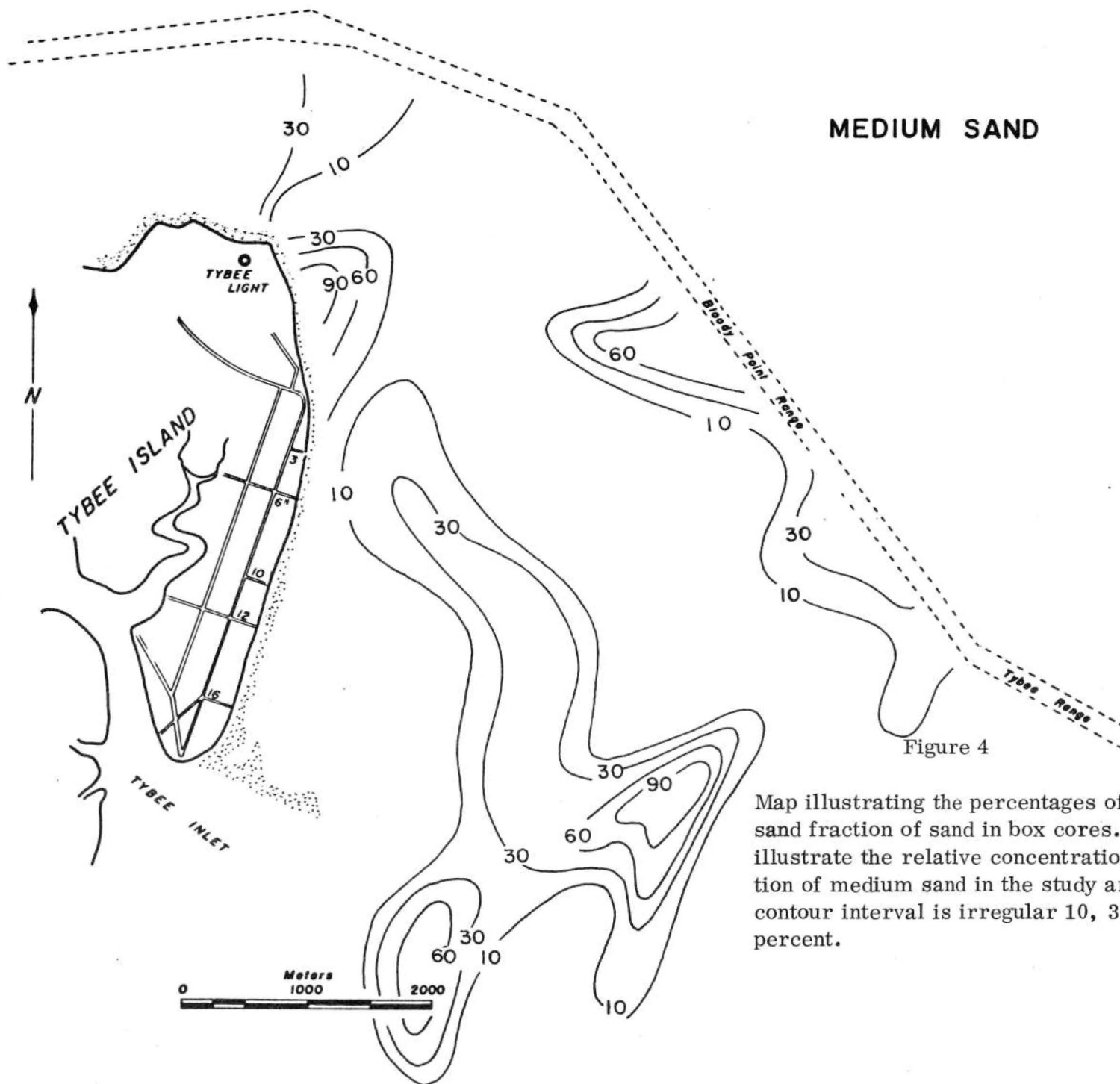
concentrations of coarse sand on the shoreface are relatively stable, and bedform trends only illustrate the centripetal flow patterns of the ebbing and flooding tidal currents.

Medium Sand

High percentages of medium sand (.25 to .50 mm) appeared in three separate portions of the study area (fig. 4). In the northern portion of the study area a relatively high percentage of medium sand occurred with fine sand (0.125 to 0.25 mm) in a moderately to highly bioturbated substrate. Adjacent to the Savannah River channel along Bloody Point Range, medium sand was found intermixed with a relatively high concentration of mud and shell fragments. In the central and southern portions of the study area, medium sand occurred with coarse sand in an undulating topography. In general, the highest concentrations of medium sand appeared to correspond to the areas on the seaward sides of the major sand wave fields.

Fine Sand

The study area adjacent to Savannah Beach is predominantly composed of fine sand. Cores that contained greater than 90% fine sand were collected from three separate portions of the shoreface (fig. 5). In the southern portions of the study area, fine sand is present in the embayment behind the sand wave spit described above. The sand was generally thinly laminated with relatively high concentrations of heavy minerals in some laminations. The fine sand in this embayment



MEDIUM SAND

Figure 4

Map illustrating the percentages of the medium-sand fraction of sand in box cores. Contours illustrate the relative concentration and distribution of medium sand in the study area. The contour interval is irregular 10, 30, 60 and 90 percent.

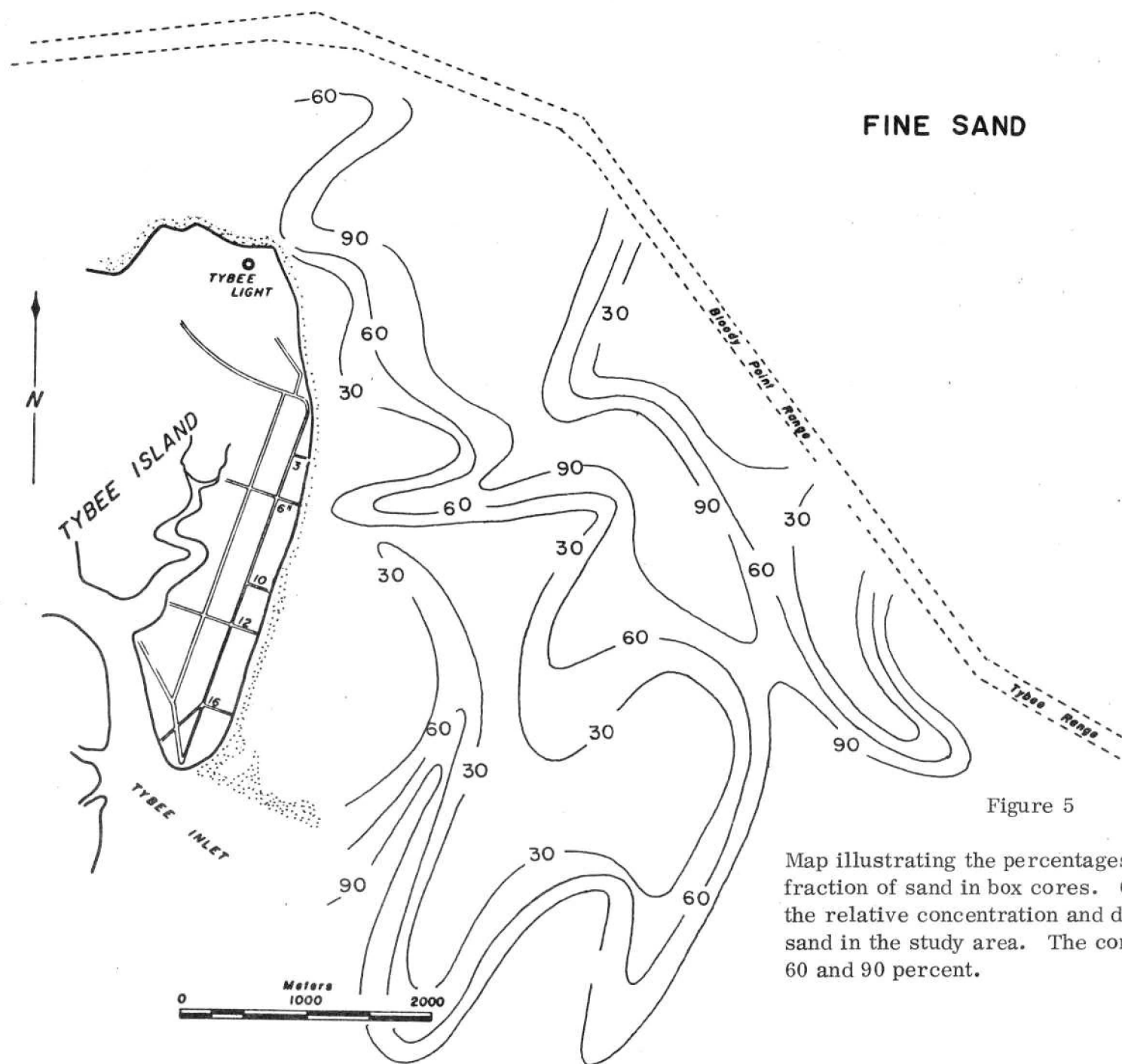


Figure 5

Map illustrating the percentages of the fine-sand fraction of sand in box cores. Contours illustrate the relative concentration and distribution of medium sand in the study area. The contour-interval is 30, 60 and 90 percent.

was probably suspended and winnowed out of the sand wave spit by turbulent wave processes.

High concentrations of fine sand (greater than 90% of the sample) also occurred along the seaward edge of the study area approximately 2 miles offshore. This portion of the study area was also generally highly bioturbated and the mixed sediments of the substrate are believed to be relatively stable under the normal physical conditions for the area.

A third tongue of fine sand extends parallel to the southern margin of Bloody Point Range. This zone of fine sand appears to begin at the entrance of the Savannah River, and protrudes in a southeastern direction to a point approximately 6 miles offshore. The configuration of this trend generally corresponds to the expected position of a ramp margin shoal. Ramp margin shoals are large sand bodies which commonly border the seaward channels of many of the other Georgia inlets. However, over the years, the ramp margin shoals at the north end of Tybee Island have continuously decreased in size.

Distribution of Mud

Relatively high concentrations of mud were present along the southern margin of the Bloody Point Range (fig. 6). Core samples that contained approximately 50% mud were generally mixed with shell fragments and had no indication of any primary sedimentary structures. The mixing of the substrate was produced almost completely by the infaunal population. Bioturbation of this type generally occurs in a relatively stable bottom, (i. e. the substrate is undisturbed by physical

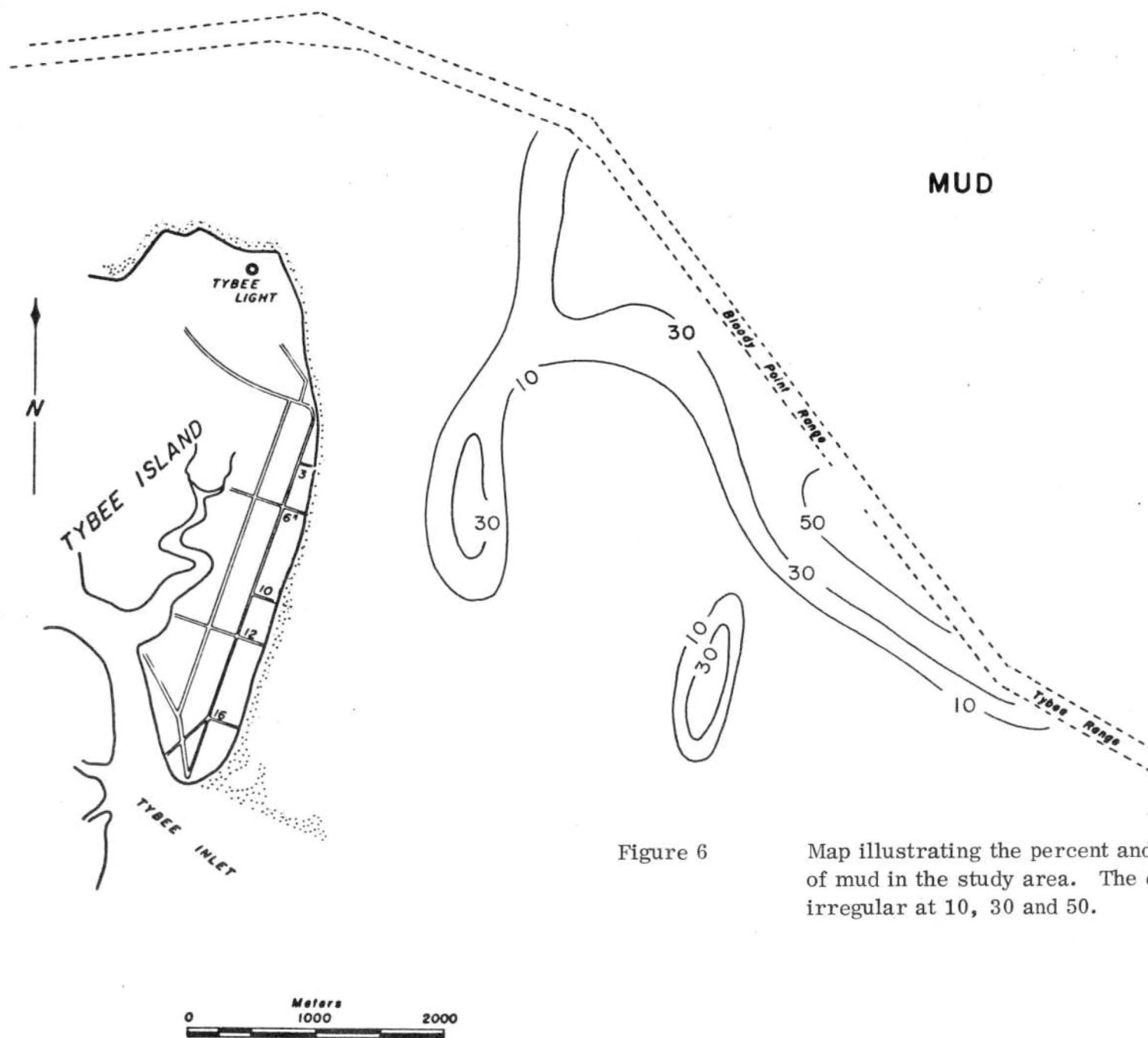


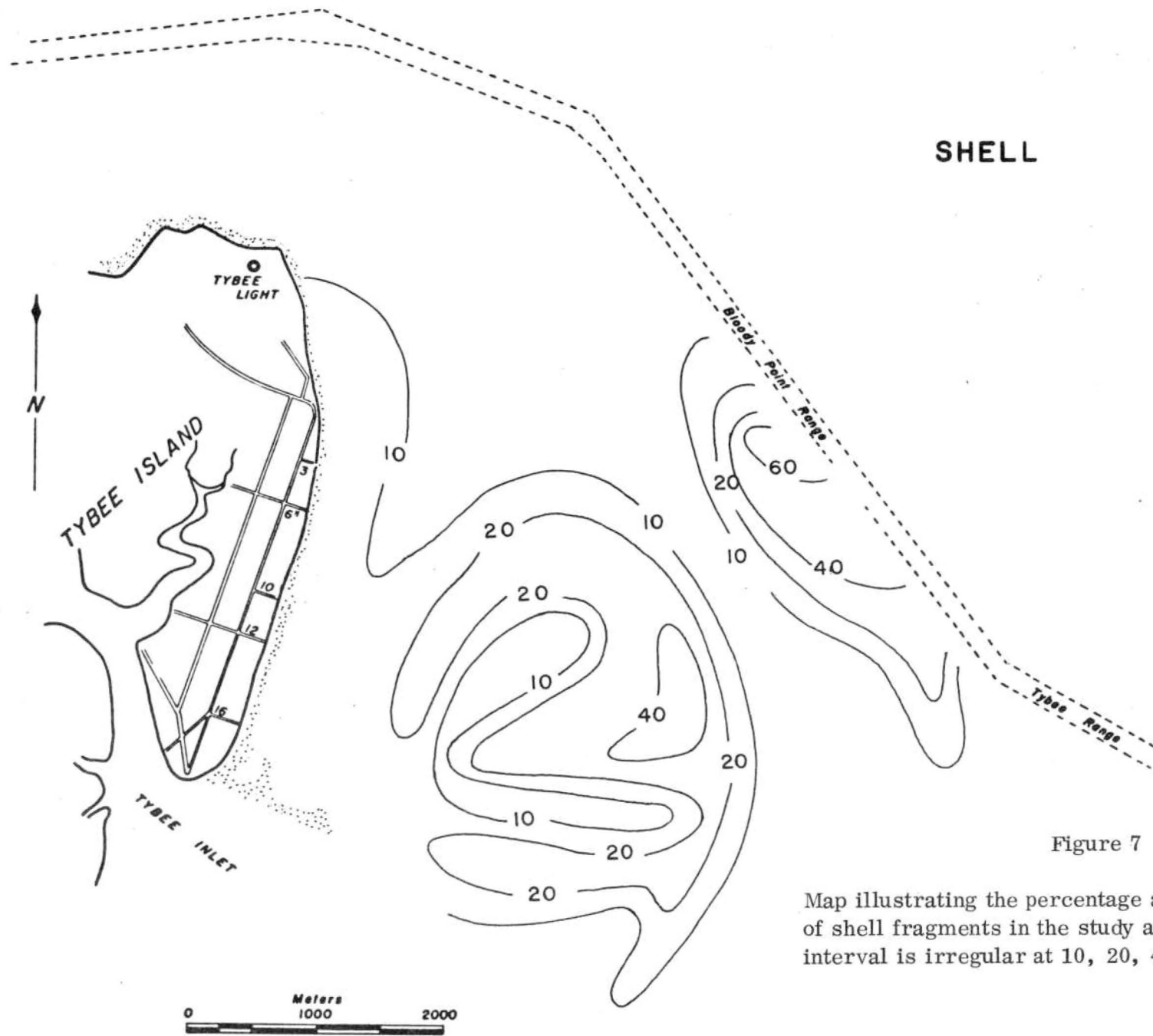
Figure 6

Map illustrating the percent and distribution of mud in the study area. The contour is irregular at 10, 30 and 50.

processes long enough for organisms to move into and live in the sediments). The percentage of mud appears to decrease away from the margin of the channel. The textures of the cores that contain between ten and thirty percent mud were different than the cores with higher percentages of mud. Samples composed of between ten and thirty percent mud had interbedded layers of sand and mud. These textures have been referred to as flaser bedding and their occurrence has been documented in the tidal flats, marshes and estuaries (Reineck and Wunderlich, 1968). Flasers at the margin of the channel were composed of Type 1 (thinly laminated mud) and Type II (fecal-mud lamina) (Oertel, 1973). Burrowing of these interbedded units by the infaunal population also provide for some mud pebbles that were formed in situ in the substrate (Rhoads, 1970). These mud pebbles were not rounded and were not part of a hydrodynamically deposited bed. However, local shifts in the topographic configurations of the sediment-water interface may expose these mud pebbles to local erosional and depositional processes. In general, mud represented only a small percentage of the total sediments of the study area.

Shell Fragments

Shell fragments occurred in two zones within the study area (fig. 7). One area mentioned above corresponded to a zone of high mud accumulation in a bio-turbated substrate. The other zone corresponded to the undulating sand wave topography that was located in the middle of the study area. In this area, the medium and coarse sand concentrations were relatively high and the fine sand and mud concentrations were low. Shell fragments were generally from small bivalves,



SHELL

Figure 7

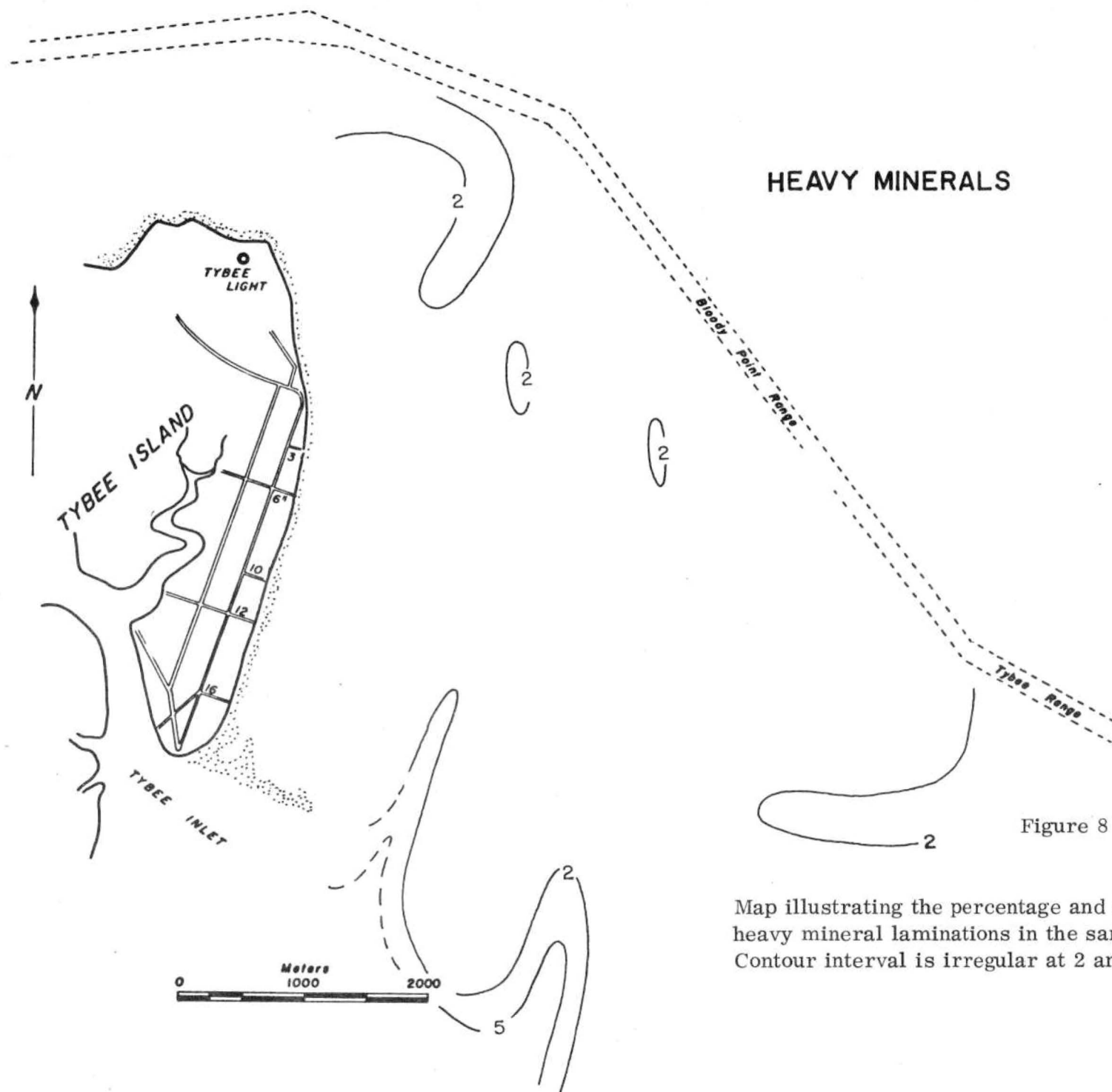
Map illustrating the percentage and distribution of shell fragments in the study area. Contour interval is irregular at 10, 20, 40 and 60.

and fragments were between five and ten millimeters in length. Many of the shells appeared to be from the bivalves Mulinia lateralis and Donax variabilis; however, numerous other shell fragments from gastropods and other bivalves were present. Although the dense matrix of shell fragment makes it almost impossible to discern bedding planes, a large percentage of concave shell fragments generally shared the same orientations. Apparently these sediments are not bioturbated although bedding planes are vague because of the overlapping arrangements of shell fragments. The shelly deposits generally occurred in inclined foreset beds of sand waves. The relatively loose packing of shell fragments and coarse sand makes a relatively mobile or unstable substrate; however, the average tidal current velocity for this area is insufficient to transport the coarse fractions long distances. The coarse sand and shell fragments generally are transported within the dune-shaped bedforms rather than being continuously entrained along a mobile boundary layer.

Heavy Minerals

The concentration of heavy mineral grains were generally very low. Dark laminations containing between 20 and 40 percent heavy minerals were present in some cores; however, these laminations generally made up less than five percent of the core. Thus, the total amount of heavy minerals in the box cores was generally less than four-tenths of one percent (two percent of a 20 percent lamination). Lamination concentrations greater than two percent were located in portions of the substrate that were horizontally laminated or had small scale ripple laminations and horizontal laminations.

The horizontal laminations in the shallower areas were deposited by turbulent wave processes. In the deeper-water areas, local areas existed where vortical flow may have been the dominant mechanism in producing concentrations of heavy minerals.



HEAVY MINERALS

Figure 8

Map illustrating the percentage and distribution of heavy mineral laminations in the sand fraction. Contour interval is irregular at 2 and 5.

However, heavy minerals were concentrated only in horizontal laminations in the upper portion of the substrate.

Without exception, the concentrations of heavy mineral laminations occurred in fine sand. Mud, shell fragments, medium and coarse sand were not associated with heavy mineral laminations.

Bioturbation

In each core sample, a certain percentage of the primary textures and structures was secondarily disturbed by organic reworking. This type of secondary mixing was sometimes in the form of stationary dwelling tubes (as the tubes of the sand shrimp Callianassa and the polychaetes Onuphis and Diapatra), locomotion traces by mobile macro-infauna (as the heart urchin Moira, the olive snail Oliva, the mole crab Lepidopa, the surf clam Donax) or mixing by mobile micro-infauna (as isopods). If we assume that over a period of time the local faunal community will completely disrupt all of the primary sedimentary textures and structures in the upper substrate, then relative degrees of bioturbation versus the preserved primary structure and texture is a crude measure of surficial seabed stability. That is, if the substrate is left stationary long enough to have been bioturbated, then it must have been unaffected by physical processes for a relatively long period of time. In contrast, relatively unstable or mobile areas of substrate would have high percentages of primary texture and structure. The degree of bioturbation may therefore be an indication of the relative duration that sediment has been physically quiescent and exposed to organic reworking. The key used as a standard for determining the total amount of bioturbation

in a sample is illustrated in figure 9.

In that bioturbation generally affects the upper portions of substrate, maps were made depicting both the upper and lower portions of each core sample.

In general, the upper portions of the samples had slightly lower degrees of bioturbation than the lower portions (fig. 10 and fig. 11). This indicates that the upper 75 centimeters is slightly more mobile and unstable and stability increased with depth. The areal distributions of intensely bioturbated substrate was similar for the upper and lower portions of the shoreface samples. The maximum degree of bioturbation was along the margin of Bloody Point Range and along the seaward edge of the study area. The bioturbation in this area was predominantly locomotion traces, and may have occurred during a very short interval of time. This intense zone of bioturbation was breached just seaward of the small, "funnel shaped" channel that opens toward the margin of Bloody Point Range (described above, fig. 1). Apparently the funnel shaped channel has a relatively mobile sea bed.

A portion of the substrate was also intensely bioturbated in an area approximately 500 meters seaward of the 6th Street beach. The substrate in this area is predominantly fine sand, and the bioturbation was predominantly produced by dwelling tubes. These dwelling tubes generally occur in relatively stable areas of substrate. The presence of dwelling tubes indicates that this area of the shoreface was relatively stable and was not experiencing rapid erosion or accretion.

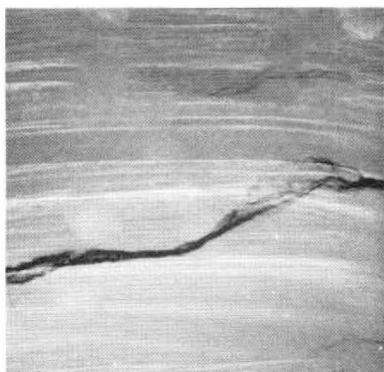
The relatively high degree of bioturbation observed in many of the other samples were generally of the dwelling tube type.

Figure 9

Key used for determining percentages of total bioturbation.

No attempt is made to differentiate between different types of bioturbation.

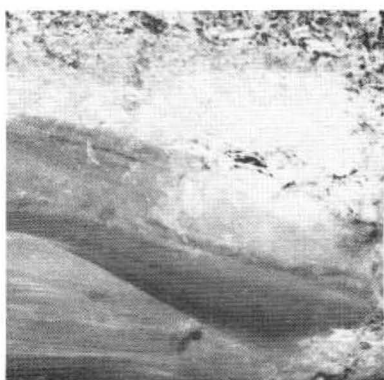
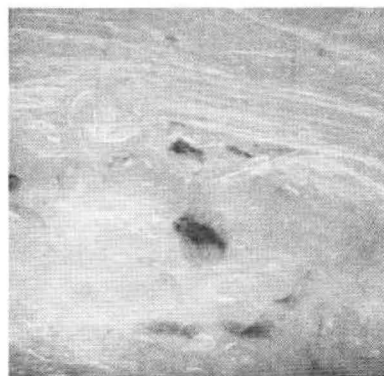
20
PERCENT OF BIOTURBATION



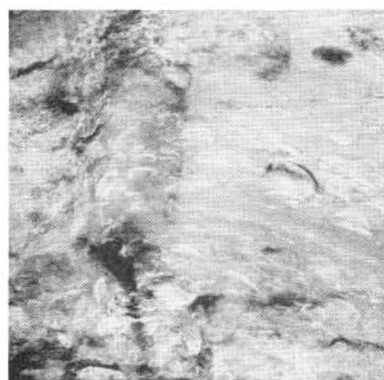
0-10%



10-40%



40-80%



80-100%

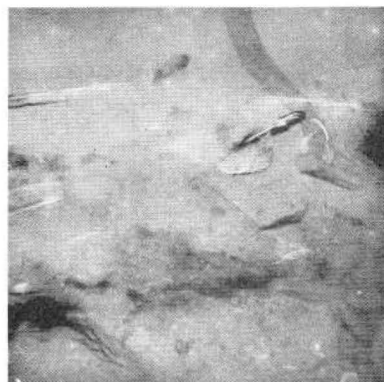


Figure 10

Map illustrating the degree of bioturbation in the upper seventy-five centimeters of the substrate. The question mark is in an area that was inaccessible to sampling.

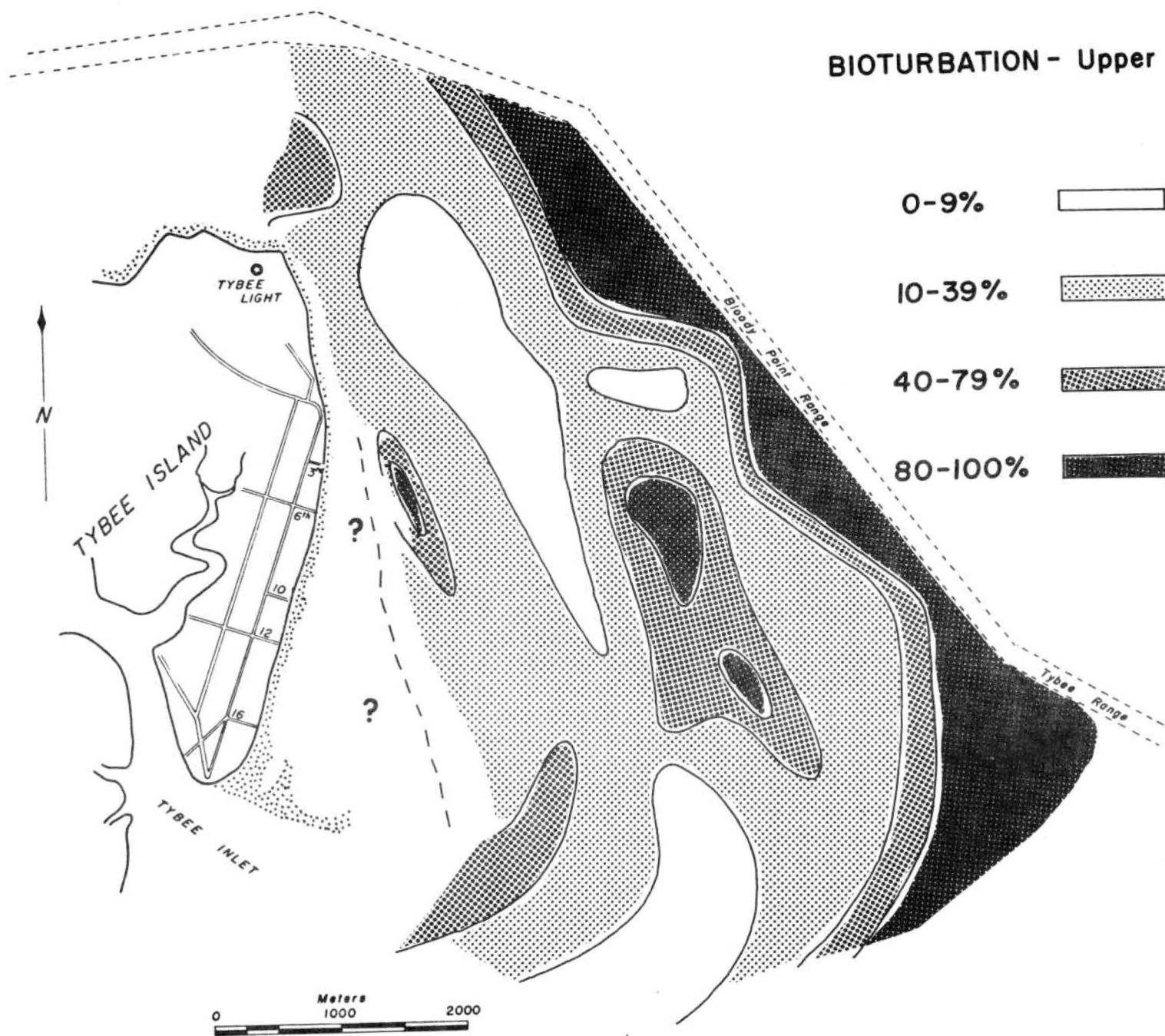
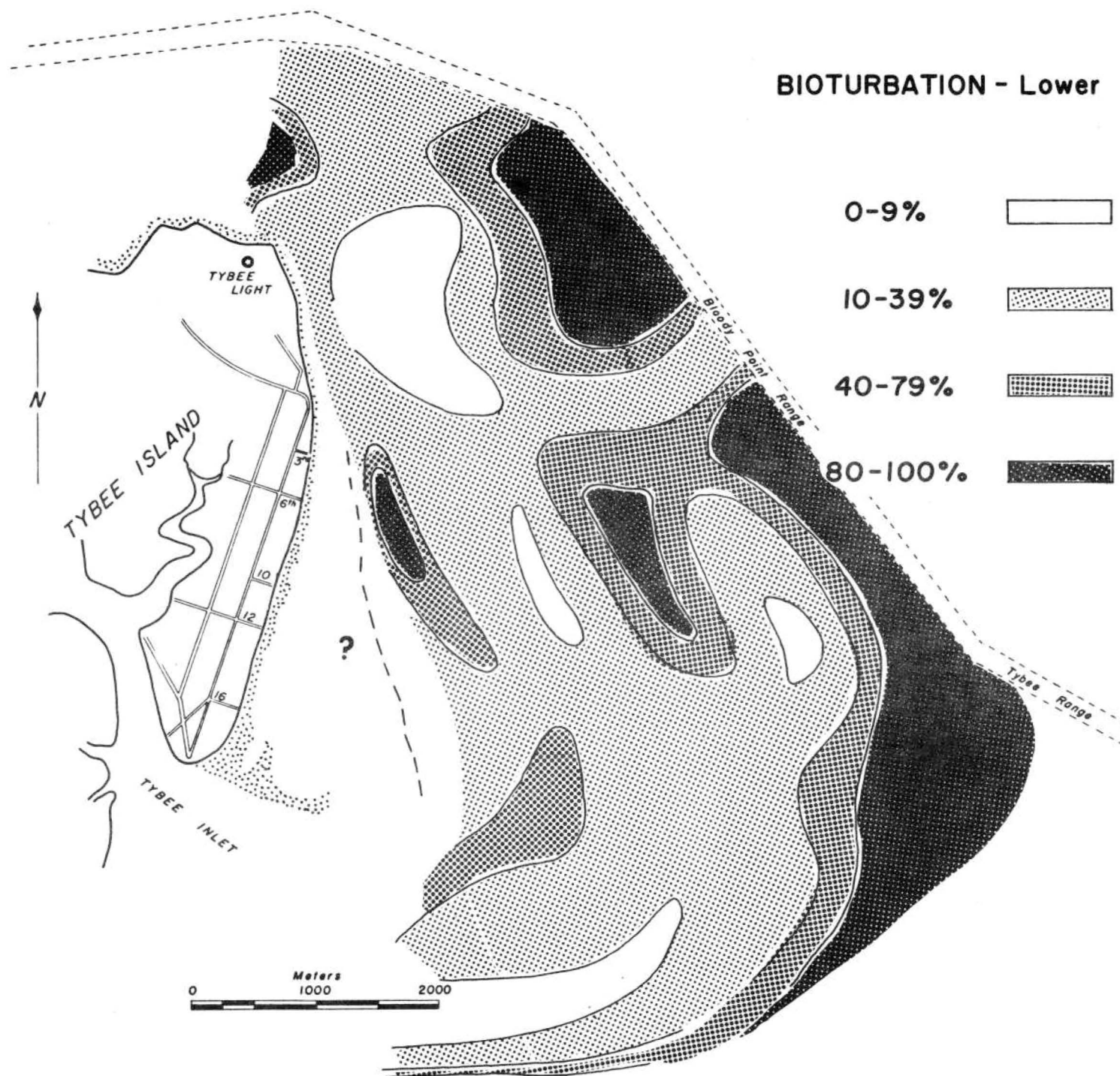


Figure 11

Map illustrating the degree of bioturbation in the substrate below seventy-five centimeters. The question mark is in an area that was inaccessible to sampling.



The trends on the bioturbation maps that illustrate minimum bioturbation are potential sites of highly mobile sediment at the sea bed. However, when the substrate is composed of coarse grain sizes (greater than .5 mm) sediment is generally "locked" into relatively slowly moving sand waves. The finer grain sizes that are winnowed out of these bedforms probably are initially very mobile. Bioturbation in laminated, fine grained sand was generally in the form of locomotion traces by isopods. Although these traces disrupted the laminations, the bedding planes were still discernible. Adjacent to the Tybee Inlet, horizontally laminated beds with isopod bioturbation generally experienced long durations of turbulent wave forces, and the sea bed was very mobile. The northwest-southeast trending "low bioturbation zone" in the north central portion of the study was generally composed of small scale ripple laminations and also has a relatively mobile sea bed.

In general, the degree of bioturbation on the Tybee shoreface is not an indicator of erosion or accretion but rather a relative measure of the durations between sediment reworking by physical or biological processes. Intensely bioturbated areas indicate relatively long durations between periods of sediment reworking by physical processes. Portions of substrate that were not extensively bioturbated were unstable areas of the sea bed and could be subjected to rapid sedimentary changes. However, change may take place in the form of rapid erosion or rapid accretion. Erosional and depositional patterns are dependant upon the patterns of sediment transport. Adjacent to Tybee Island, patterns of sediment transport are dependant upon the nature of the centripetal inlet drain (of the Savannah River) that floods and ebbs over the sea bed. Descriptions of sediment dispersion patterns and tidal flow

patterns will be described in forth coming reports.

Acknowledgements

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