SEDIMENT CHARACTERISTICS OF THE INNER SHELF AND ENVIRONMENTAL GEOLOGIC MAP, PORT ARANSAS AREA, TEXAS: PRELIMINARY RESULTS

PART I - Sediments of the Inner Shelf
Prepared by
Henry Berryhill, Jr.
assisted by
Gary Hill, Charles Holmes, Michael Dorsey,
and Roderick Harwood*

Part II - Environmental Geologic Map
Prepared by
Susan Casby

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*Graduate Student, University of Texas, Austin

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SEDIMENT CHARACTERISTICS OF THE INNER SHELF AND ENVIRONMENTAL GEOLOGIC MAP, PORT ARANSAS AREA, TEXAS: PRELIMINARY RESULTS

Introduction

Port Aransas is located at the north end of Mustang Island on the coastline of south-central Texas. Water exchange between the Gulf of Mexico and Copano, Aransas, and Corpus Christi Bays takes place principally through Aransas Pass, which also serves as the ship channel entrance for Port Aransas and Corpus Christi.

The principal area of study covered by the report is a part of the Inner Continental Shelf, extending approximately five and a half miles (8.9 km) north and south of Aransas Pass and 16 miles (25.8 km) seaward from shoreline to the general position of the 100 ft (30.3 m) isobath. In addition the report includes water current data for a larger segment of the Continental Shelf and an environmental geologic map for a 10 (16.1 km) by 6 (9.7 km) mile area that extends inland from shoreline and includes a segment of Mustang and San Josê Islands plus adjacent inshore waters of Redfish Bay. The geography of the south-central Texas coast and the location of the three study areas covered by the report are shown by figure A.

The purpose of the study is to determine the textural composition, depositional pattern and trace element geochemistry of the surficial sea floor sediments, the textural composition, stratigraphy and degree of consolidation of Holocene and upper Pleistocene sediments beneath the sea floor to the extent possible, to summarize the possible influence of water current movement on sediment dispersal patterns in the principal study area (A), and to classify the geologic environments of the inland area adjacent to Port Aransas.

Data for area A were gathered during periods of field investigation in November, 1973 and in March and April, 1974. The water current data are synoptic for four years beginning in early 1970, and compilation of the environmental geologic data began in January, 1974. Results and interpretations presented herein are preliminary. Formal publication is planned after further integration and synthesis of data both within this area and from adjacent areas now under investigation.

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his time to pilot the ANOMALY; and Dr. Joseph McGowen of the Bureau of Economic Geology, University of Texas, Austin, participated as a member of the scientific crew during the first of three sampling cruises.

Each of the individuals and institutions contributed substantially to the study and a large measure of thanks and appreciation is extended.

Bathymetry and Sea Floor Topography

The progression of water depth seaward to 100 ft (30.3 m) at the outer edge of study area A is generally uniform at a rate of about 5 ft (1.5 m) per mile seaward of the 55 ft (16.8 m) isobath. Near shore beyond the surf zone the sea floor gradient is approximately 30 ft (9.1 m) per mile across the shoreface to 35 ft (10.7 m) water depth and about 8 ft (2.4 m) per mile from there to the 55 ft (16.8 m) isobath.

During the sampling of bottom sediments, eleven bathymetric profiles were run across study area A and the bathymetric map (fig. 1) has been constructed from those readings. Comparison of the 1973 bathymetry with that of 1938 made by the Coast and Geodetic Survey suggests some slight changes in sea floor topography over the past 36 years (fig. 2). The changes suggested, though slight, are important in understanding long term mass movement of sediment and a new survey made with more precise navigation would be highly desirable in understanding this problem. The implications of the indicated changes in sea floor topography is discussed in the section of the report on surficial sea floor sediments.

The sea floor over study area A is relatively smooth and of low gradient with no indicated prominences

Sediments, Sea Floor

Methods of Study

Surface grab samples were obtained for study area A at one-mile (1.6 km) intervals and a total of 175 samples were collected. Samples were taken with a Shipek sampler of .1 m^3 capacity and 4-inch (10.2 cm) penetration capability. Shipboard navigation for locating sample stations consisted of a combination of Loran C and radar. The navigation plots of the 175 sample stations are shown by figure 3.

The surficial sediment samples were analyzed in the laboratory for texture, trace element and benthic fauna content. Particle size distribution and proportions of sand-silt-clay in each sample was determined by a combination of settling tube and hydrometer: particle size of the fraction above 0.062 mm diameter ($>4.00\phi$) was determined by settling tube; that below 0.062 mm by hydrometer. Particle size distribution of the greater than 0.062 mm fraction was subdivided on the basis of particle size range into: very fine (0.062-0.105 mm); fine (0.125-0.210 mm); medium (0.250-0.42 mm); and coarse (0.50-0.71 mm) sand.

Trace element composition for each sample was analyzed by the 30 element semiquantitative spectrographic method to determine gross distribution and to determine which elements might be present in significantly high concentrations. Further analyses were made of copper, lead, zinc and mercury content by the Atomic Absorption method (Perkin-Elmer Model 303) for quantitative refinement of the concentrations of these elements. In addition, trace element concentrations in the benthonic polychaetes (worms) were analyzed for correlation with the trace element concentrations in the host sediments. Total organic carbon in percent was determined for each sample by the Atomic Absorption method.

Gross faunal determinations were made from the sediment samples collected for textural analysis.

Texture

Over-all the texture of the surficial sea floor sediments in area A is fine grained. Grain size of the sand fraction, with the exception of the shell remains, in the majority of samples is in the very fine and fine categories. Proportions of silt and clay increase seaward; the clay fraction is predominate over silt. Coarse sand was found in only five samples: 42, 44, 63, 86, and 106 and, of these, sample 63 contained the largest grains. Sand of medium grain size is present in 36 samples, including several at the seaward edge of the study area.

As a means of determining dispersal and depositional patterns, the textural data have been compiled in two forms: percentage of the sand fraction in the total sample (fig. 4); and the proportions of sand-silt-clay in each sample (fig. 5). The percent sand data on figure 4 are based on analysis of all samples collected; the data showing relative proportions of sand-silt-clay on figure 5 are as yet incomplete, but the spread of data on the map is sufficient to give a representative pattern for the over-all area. The relative proportions of sand-silt-clay for those samples for which analyses have been completed are shown on the triangular diagram (fig. 6). As noted above, the diagram shows that silt is the predominant constituent in relatively few samples and that only one sample consists of more than 75 percent clay-sized particles.

Sand Dispersal Patterns

The sand component of the surficial bottom sediments is distributed in an irregularly banded to branching pattern that reflects at least in part the directions of sediment movement along the sea floor. The major zone of sand lies, as expected, along and parallel to the shoreline. The outer or seaward boundary of this zone is highly irregular and consists of a series of fingers of sandy sediments separated by re-entrants of fine grained material. The interfingering pattern of the seaward edge of the sandy zone with finer sediments is shown best by the 90 and 60 percent isopleths. If the 50 percent isopleth is used as the seaward boundary of the inner shelf or near shoreline sandy zone, it outlines a sizable seaward bulge northeast of Aransas Pass and a southward-trending smaller bulge or large finger southeast of the Pass. Farther seaward a narrow crescent-shaped sandy zone trends generally northeastward. The rather broad nose of sandy sediment at the south-central edge of the study area seems to lie along this same trend, but neither its geometry nor extent is known beyond the area studied. The crescent-shaped patch of sandy sediments almost coincides with the seaward bulge of the 70 ft (21.3 m) isobath shown on the bathymetric maps, figures 1 and 2.

The patterns just described are believed to represent general directions of sediment movement and deposition across area A. Two prevailing long-term directions of sediment movement are suggested by the 50 percent isopleth that marks the seaward boundary of the sandier sediments of the near shore band. The large bulge northeast of Aransas Pass probably represents sand that is swept seaward from the barrier island and shoreface during ebbing storm surges that follow hurricanes. The southern end of San José Island, which lies but a few feet above sea level for a distance of several miles, is usually swept by storm surges during both rise and ebb. Much of the sand in the bulge probably came from San José Island and from the bays beyond. The nose of sandy sediment southeast of Aransas Pass seems to be a southward extension from the bulge area to the north. The southward trend of this extension probably represents sand that is being carried by southward-flowing longshore currents plus additional material carried out of Aransas Pass principally by normal ebbing tides. The southeastward orientation of the fingers of sand and clayey sand outlined by the 90 and 60 percent isopleths northeast and east of Aransas Pass seem to confirm this trend. The sandy sediments farther out probably represent material initially carried seaward during major storms. Their arrangement in crude bands parallel to the shoreline may represent later modification during periods of strong wind-driven wave action.

As noted previously, several samples at the outer edge of area A have grains of medium size. The presence of this material 16 miles from shore could represent reworking in place of relict sands during the post Wisconsin glacial stage rise in sea level. However, the branchlike connection of the several bands of sandy sediment argues for seaward transport of the sand. Another possible explanation is that the connecting branch pattern represents shoreward migration of relict sands during Holocene sea level rise. In conclusion it can be stated with a fair degree of certainty that within five to six miles of the shoreline, sediments are being carried both seaward and southerly. The quantity of sediment being carried southward over a given period of time is not known. Beyond six miles the mechanism by which the sandy sediments reached their present position is conjectural. However, the suggested changes in sea floor topography shown on figure 2 seem to indicate net seaward movement of sediment over the entire northern half of area A during the past 36 years.

Trace Element Content

Semiquantitative spectrographic analysis of the sediments in area A for trace elements indicate no anomalously high concentrations. However, values for zinc over the seaward third of the area are higher than that normally found in continental shelf sediments. So that results offshore could be compared with studies made earlier in Corpus Christi Bay and also for greater quantitative accuracy, additional analyses of the samples by Atomic Absorption were made for copper, lead, zinc, mercury and also for total organic carbon. The results of these analyses are shown by figures 7a-e.

Concentration values generally considered beyond the normal range for sediments for the four trace metals analyzed by AA are as follows: cu, >25 parts per million; Pb, >25 parts per million; Zn, >50 parts per million; and Hg, >500 parts per billion. Copper values in area A, with the exception of sample station 54 which has an indicated value of 40 ppm, are not significant. Lead concentrations also are below significant values except at station 54 where the indicated concentration is 25 ppm, or at the lowest end of the significant value range. Zinc concentrations are above 50 ppm over the seaward third of area A and in patches nearer shore (see figure 7a). Mercury concentrations are very low over the entire area.

The concentrations of trace metals in the sediments bear a very close relationship to the sediment texture, as would be expected because of the complexing of the metallic ions with the clay minerals. Trace element concentrations are higher in the finer-grained sediments. This relationship can be seen by comparing the sediment texture and trace element maps. Thus trace metal concentrations over area A are very low in the sands, becoming progressively increased with increase in the <.062 micron fraction in the sediment sample.

Benthic Fauna

Methods of Study.--Biological data for each station includes a list of all identifiable living organisms or remains of organisms derived from the sample and how many of each were present. The biological material was derived from a split of the sediment sample at each station. After material for the other analyses was scooped out of the grabs, the remaining bulk sediment was put into zip-lock plastic bags and stored in a cooler (without ice). Within 24 hours these samples were washed through a window screen sieve box with a water spray and the residual material placed in new zip-lock plastic bags with 95% isopropyl alcohol.

In the laboratory each sample was sorted into "living" organisms, whole identifiable remains of organisms ("shell"), and broken mostly unidentifiable fragments. The "living" specimens and dead shell were then identified, counted, and tabulated; fragments were not further examined.

Ideally a biological sample should provide a quantitative representation of the biotic community from which it is taken. The methods used for this survey fall short of this ideal on several counts and must therefore be regarded as semiquantitative. First of all the methods discriminate against certain organisms: those smaller than the ~1.5 mm mesh of the sieve box; those too fragile to withstand the water spray (e.g., small thin shelled bivalves, some worms); and those so large or motile that it is unlikely that they would be caught by the sampler even if they are actually abundant (e.g., sand dollars, shrimp). Second, the sample volumes ranged from about 1/2 to 2 liters, the smaller samples coming from the harder to penetrate sandy areas where 2 and 3 grabs per station were sometimes necessary. No attempt was made to correct the data for this irregularity. Finally, it must be recognized that these data represent the situation for a short space of time (vis., 3 days in November) and do not therefore reveal seasonal or successional variations in the shell community.

Despite these shortcomings these data provide some valuable insights about the shelf benthos, particularly their diversity (a community characteristic that is less strongly affected by the sampling methods than is the absolute number of specimens) and the population distributions of the more common species. These aspects of the molluscan community are discussed below.

Results of Study and Discussion.--Although the small sample size obtained did not allow for a systematic or quantitative study of the macrobenthic organisms (with the exception of very small molluscs) in this study, general observations indicate that the benthonic fauna in the study area is both abundant and diverse.

General familiarity with the near continental shelf in the Port Aransas area has demonstrated that the common benthic fauna fall into the following major taxa:

A. Vertebrata

1. Rajiformes
2. Pleuronectiformes
3. Anguilliformes

B. Echinodermata

1. Holothuroidea
2. Asteroidea (Astropecten, Luidia)
3. Ophiuroidea
4. Echinoidea

C. Crustacea

1. Malacostraca

    a. Stomatopoda (Squilla)
    b. Decapoda

        (1) Natantia (Penaeus, Sicyonia)
        (2) Reptantia

            (a) Anomura (Thalassinidae, Paguridae)
            (b) Pinnotheridae, Goneplacidae)

D. Mollusca

1. Gastropoda
2. Bivalvia
3. Scaphopoda

E. Polychaeta (Onuphidae, Glyceridae, Capitellidae, Lumbrineridae, Maldanidae, Cirratulidae)

F. Coelenterata (Cerianthidae, Renilla)

The vast majority of the identifiable organisms in this set of samples are molluscs, with only scattered occurrences of coelenterates, echinoderms, and crustaceans. Among the molluscs few taxa are abundant enough to draw meaningful conclusions about their individual distributions although all contribute to community diversity. Altogether, 65 mollusc taxa were differentiated, including 49 to species, 12 to genus, and 4 to family level. Of these taxa 39 were bivalves, 23 were gastropods, and 3 were scaphopods. Of these, 13 bivalves and 6 gastropods occur at more than 10 stations.

Shelf mollusc diversity in the Port Aransas area seems to be profoundly influenced by the inlet (Aransas Pass). The diversity distribution (fig. 8a) shows a striking concentric pattern around the inlet opening with high diversity immediately around the inlet, decreasing in all directions away from the pass. This pattern begins to break down at the northeast and southwest edges of the map, suggesting that the inlet-influenced area is giving way to a more "normal" shelf diversity distribution. A continuation of sampling along the coast above and below the pass would be extremely valuable in confirming that this area is anomalous.

Another generalization arises when diversity distribution is compared to sediment distribution: that, except for the area immediately around the inlet, the highest diversity occurs in areas where sand and mud are mixed, decreasing markedly where percent sand gets above about 80 or below 40-50. For example along the northeast edge of the map diversity is relatively high on the muddy sand lobe shown on the percent sand map (fig. 5) but decreases toward the beach and seaward. Further seaward there is a sandy patch indicated, with a corresponding increase in diversity. Again, extending the study area would confirm this relationship.

One curious feature of the diversity map is the tongue of higher diversity in the middle of the southeast edge of the area. It is perhaps related to the small sandy area shown on the percent sand map. Examination of the more seaward samples may elucidate this point.

Although quite a large amount of shell was collected, there seemed to be relatively few living molluscs. This may be due in part to the delay between sampling and actual preservation of the biological material (i.e., some animals may have died and become disarticulated between sampling and preservation). But primarily it indicates a relatively low population density for most forms. Of the 231 living individuals collected, 207 were bivalves (12 different species) and 24 were gastropods (6 different species).

Three bivalves, Mulinia, Abra, and Lucina, were particularly well represented by living as well as dead specimens. Although not enough living specimens were recovered to make a meaningful living distribution map, maps of total shell distribution were constructed for these three forms which reveal trends in their population distribution, even if the numbers used in their construction are only approximately quantitative.

Mulinia lateralis is a small (up to 15 mm) shallow-burrowing filter feeder that likes to live in non-shifting sandy sediment. Except for the extremely high population density patch located about 4 miles south of the jetties (fig. 8b; no explanation can be found for this unusual occurrence), its distribution fits well with its mode of life. In the sandy areas both above and below the inlet (cf. fig. 5) density is high, particularly below the inlet just seaward of the swash zone. These areas are also where all the living specimens of Mulinia were found (circled numbers on map). The higher productivity south of the inlet is probably related to the nutrient supply swept southward from the inlet by the predominantly southward longshore drift. Conversely population density is low, with no living specimens in the spoil area and southward from the jetties. Here the deposition of materials from the channel make life hard on Mulinia. Further seaward it is clearly too muddy for Mulinia.

Abra aequalis, about the same size as Mulinia, has a mode of life quite different. It is a relatively deep burrowing deposit feeder that prefers soft muddy sediment. Like Mulinia, Abra's distribution (fig. 8c) fits its mode of life. The two areas of highest density correspond to pockets of muddy sediment located east and southwest of the inlet opening (see fig. 5). Its particularly high density in these two areas probably also reflects the larger contribution of organic detritus from the inlet (see fig. 7d). At the top and bottom edges of the map a perhaps more normal pattern is developing with Abra abundance increasing seaward as the sediment becomes less sandy, then decreasing farther out in deeper water.

Lucina amiantus and Lucina multilineata are so similar that they have been lumped together for discussion. Both are small (up to 7 mm) deep burrowing filter feeders that prefer clean sand substrate. Lucina was an order of magnitude less common than Mulinia and Abra but there were a relatively large number of living specimens. It is found almost exclusively in areas of greater than 70% sand (cf. figs. 8d and 5), being much more sensitive to muddiness than Mulinia. For example the muddy sediment fringes that extend shoreward on either side of the channel are strikingly devoid of Lucina. The high density patch just seaward of the channel is a bit of a puzzle but since Lucina shells are relatively stout this is perhaps a lag accumulation of dead shells.

Finally it should be mentioned that in almost all samples in muddy sediment, an abundance of polychaete worms is indicated by intensive burrowing. While quantitative data on density and distribution of polychaetes were not ascertained in this study, two species were sufficiently common to be collected for trace metal analysis: *Diopatra cuprea*, a raptorial feeder, was collected from 18 samples and *Nereis* sp., a deposit feeder, was found in 11 samples. Each worm and its host sediment were analyzed by Atomic Absorption spectrophotometry for copper, lead, and zinc content to determine if a correlation existed between trace metal concentrations in the worms and trace metal concentrations in their host sediment; i.e., does trace metal concentrations in the polychaetes increase as concentrations of trace metals in the sediment increase.

Preliminary analyses strongly suggest that a correlation does exist between trace metal concentrations in the polychaetes and their host sediment (fig. 8e). A correlation coefficient (r) above .5 shows good corelation while values of .75 and higher are considered excellent correlation. *Nereis*, which ingests sediment, showed a better correlation of trace metal concentration with its host sediment than *Diopatra*, which ingests both benthic and planktonic organisms. Zinc concentrations were 2 to 11 times greater in the worms than in the sediment but these concentrations did not correlate with zinc concentrations in the sediment (*Nereis*, r = .20; *Diopatra*, r = .18). However, previous studies have shown that zinc does not concentrate in the marine food chain. Copper concentrations in the polychaetes and their host sediment were poorly correlated in *Diopatra* (r = .41) while *Nereis* showed excellent correlation (r = .87). Concentrations of copper were 2 to 15 times greater in the worms than in the sediment. Lead, considered to be among the more toxic trace metals, exhibited the best over-all correlation (Nereis, r = .83; Diopatra, r = .70) with concentrations 1 to 7 times higher in the worms than in the sediment.

Sediments, Subsea Floor

Methods of Study

The sediments beneath the surficial four inches were studied by interpretation of their acoustical characteristics and by coring. The acoustical method used for the survey of the area was continuous seismic reflection profiling using as a sound source a sparker having a capacity of 1,500 Joules. The sound source was fired at one-half second intervals. The sound return was filtered in the 320-810 HZ range and recorded on an EPC recorder employing a one-fourth second sweep rate. The recorder was set for maximum speed of paper flow so as to expand the analog record and show as much internal detail within the sediment sequence as possible. Coring was done by two methods: divers working on the sea floor in water depths of less than 50 feet (15.1 m) and gravity corer of 10 ft (3 m) barrel length from shipboard in water depth greater than 50 feet.

Approximately 110 miles of seismic reflection profiles were obtained and the layout of the traverse lines over the area is shown by figure 10. A total of 29 cores were obtained: 13 by the diver method and the remainder from shipboard. The locations of the core stations are shown by figure 3. The cores were capped in the field and returned to the laboratory in the upright position. In the laboratory the cores were cut into halves lengthwise, faced, described, sampled and X-rayed for study of internal sedimentary structures.

Interpretation of Seismic Reflection Profiles

The acoustical patterns recorded suggest, on the basis of preliminary examination, that approximately the upper 300 ft (90 m) of the subsea sedimentary sequence is divisible into three general stratigraphic units of probable different depositional environments and lithologic nature. Interpretation of the seismic profiles for this report was confined to approximately the upper 300 ft (90 m).

The rationale for dividing the recorded sequence into units is based first on certain key reflecting horizons that seem to persist beneath the total area studied and second on over-all differences in the acoustical analog patterns between the key reflecting horizons. Three principal reflecting horizons are recognized; these are, with increasing depth beneath the sea floor, A, A' and B. The subsurface positions of these reflectors are shown on the cross sections, figures 11-2 through 11-9, and on the copies of the analog profiles for traverses four, five and seven.

Reflector A, the shallowest of the three horizons, lies within a few feet of the sea floor at the shoreward ends of the traverses and becomes deeper seaward at a gradual and generally uniform rate to a maximum recorded depth of 66 ft (20 m) at the outer edge of the surveyed area. Characteristically the internal subreflectors above horizon A are uniformly nearly parallel to both the sea floor and horizon A. The nearness of horizon A on the analog records to the sound reflection along the sea floor on the shoreward parts of the profile obliterates details of the sequence above horizon A in those areas, but elsewhere the sound analog above A suggests generally flat-lying beds or layers and uninterrupted sedimentation. No irregularities or areas of hard subreflectors within the sequence above A are evident. The sequence above horizon A most likely represents transgressive deposition of sands and muds landward across the continental shelf as sea level has risen since the last withdrawal during the Wisconsin glacial stage. An isopach or thickness map contoured on one meter intervals for the sequence above A has been prepared from thickness plots taken from the seismic profiles at five-minute intervals. The thickness pattern for the sequence above A is shown by figure 11a. Subtle but nevertheless obvious variations in thickness are indicated. The thickness patterns over the outer half of area A reveal a thicker lobe that trends southeastward and subsidiary thicker lobes that also trend southeastward and seem to be tributaries to the principal lobe. This dendritic pattern suggests that the material above A has covered and filled a part of an older southeastward trending drainage system. Shoreward, the sequence thins abruptly in the west-central part of area A about five miles from shore. South of the mid point of area A, reflector A seems to almost truncate a fish-hook shaped high area and then thickens for a mile or so before rising shoreward. This elongate and curved thin part of the sequence and the elongate-thicker area adjacent to and shoreward of it may represent a segment of an older barrier island and adjacent accompanying lagoon that has been buried by the sediments above A. High areas that seem to be truncated by the sequence above A are marked on the copies of records for lines 4, 5 and 7. These highs line up parallel to present shoreline and may represent an older barrier island or other shoreline feature that is now buried by the sequence above A.

Reflector A', the next continuous reflector below reflector A, has considerably more variation in subsea floor depth. At the shoreward ends of the seismic reflection profiles, the average subsea floor depth of reflector A' is about 99 ft (30 m). Seaward the subsurface depth increases abruptly to form a channel-shaped depression that parallels the present shoreline, and from there rises to within 59 ft (18 m) of the surface at one point across a high area that parallels the shoreline before continuing a progressive but somewhat irregular deepening to about 264 ft (80 m) at the seaward edge of the study area. The position and configuration of reflector A' are shown in cross section by figures 11-2 through 11-9 and its thickness pattern is shown by figure 11b.

The configuration of reflector A' suggests that it represents in part an erosion surface of probable Pleistocene age and in part depositional features along an old shoreline. The prominent channel is an erosional feature and very likely is a buried tributary of the Pleistocene Nueces River whose buried channel crosses from beneath Corpus Christi Bay onto the continental shelf about 10 miles south of area A. The high area adjacent to the buried channel has the width, form and trend of a barrier island similar to those along the present coastline. The sequence of events suggested by reflector A' is formation of a barrier island and adjacent lagoon during a rise in sea level during the Pleistocene and subsequent withdrawal of the sea followed by erosion and entrenchment of a stream tributary along the shoreline-trending axis of the lagoon into soft lagoonal muds.

The internal subreflectors between reflectors A and A' are characteristically irregular and lenticular. The irregular pattern of these subreflectors as they appear on copies of the seismic profiles for lines 4, 5 and 7 suggest that they represent a combination of coastline deposits that probably include lagoonal, barrier island, fluvial and deltaic sediments that probably are in part interfingered and in part overlapping. The Holocene-Pleistocene time boundary probably lies somewhere in the upper part of the sequence between reflectors A and A'.

Reflector B is a prominent reflector beneath the entire area of study (figs. 11-2 to 11-9). Its average depth below sea floor some three miles seaward of the present shoreline is 149 ft (45 m). From there it drops progressively seaward at a generally uniform rate to a depth of 297 to 330 ft (90 to 100 m) at the outer edge of the study area. Reflector B is truncated by reflector A' in two parts of area A: along the channel outlined by reflector A and at the southeast corner. Reflector B is a strong reflectoring horizon that may represent the top of more consolidated sediments than those above reflector A'. The nature of the lithologic sequence beneath B is unknown. The reflection patterns were not analyzed in detail for the sequence between A' and B. On the basis of a preliminary examination, the reflection patterns are more regular than between A' and A, but some irregularities are present, including some evidence of channeling.

Description of cored sediments

The upper part of the sequence of sediments above reflector A was sampled by coring at the stations shown on figure 3. The depth of penetration of the cores ranged up to one and a half meters. Two bore holes made for the Corps of Engineers, numbers 126 and 127, penetrated the entire sequence above reflector A and into the upper part of the sequence above reflector A'. Diagrammatic logs of the cores are shown on figures 9 through 9c and logs of the two bore holes are shown by figure 9d.

The diver and gravity cores indicate that the sediments in the upper part of the sequence above reflector A are characteristically interbedded and intermixed muds and loose sands that are very similar to the surficial deposits on the sea floor in area A. In bore holes 126 and 127 (fig. 9d), which penetrated the entire sequence above reflector A, these sediments are loose sands and muds. The thickness of the sequence in hole 126 is six feet and in 127 ten and a half feet. The position of the base of the sequence in the two bore holes confirmed the position interpreted from the acoustical reflection patterns previously drawn on the seismic reflection profile for line 5. On the basis of the core data in hand and the analog pattern of the sound reflections in the profiles it can be reasonably assumed that the entire sequence above reflector A is made up of intermixed relatively loose sands and soft muds throughout area A.

The vertical distribution of sand and mud and the seaward variations in the proportions of sand and mud are readily apparent in the diagrammatic logs of the diver and gravity cores (figs. 9-9c). The amount of sand is generally largest in the cores from nearer shoreline and becomes progressively less seaward, but these patterns are by no means regular. Sand makes up most of the cores nearest shoreline at the north and south boundaries of area A, but approaching the ship channel jetties at Aransas Pass from both north and south, the mud content increases and mud and sand are interlayered. The larger amount of interlayered mud nearer the jetties probably comes in part from bay outflow through Aransas Pass and in part from reworking of the spoil bank off the south jetty by wave action and currents. The higher content of sand relative to mud in cores 41, A and 69 seems to confirm in vertical dimension a longshore southward component of sediment movement as suggested by the distribution of the sand-sized fraction in the surficial seafloor sediments. Additional coring plus quantitative studies of sand movement are needed to refine the longshore trend pattern and to make volumetric estimates.

Internally the cored sediments have two prevailing characteristic structures: sharp basal contacts of many of the sand units in the cores from nearer shore; and a highly mottled appearance of both sand and mud and mud itself farther offshore. The sharp basal contacts suggest that the thicker sand layers nearer shore and their probable thinner equivalents farther offshore were transported under high energy conditions. The concentration of shell remains at the base of these layers and the typical graded structure (i.e., a gradual upward decrease in grain size) of the layers substantiate this interpretation. The most likely mechanism for movement of the bulk of the sand is the strong currents associated with hurricanes. The correlateable thin sand layers near the tops of cores 38, 36, 34, 139, 137, 73, 75, 151, 153 and 155 suggest that these currents have swept sand as far as 16 miles offshore. This particular layer may represent a single storm deposit.

The widespread mottling in the cored sediments has been caused by benthic burrowing organisms. The degree of bioturbation or churning of the sediments by bottom dwelling animals is typically high except in the sandy cores near shore and in those farthest from shore. In many of the cores, the layering of the sand has been destroyed entirely by burrowing activity.

The sediments in bore holes 126 and 127 below subseafloor depths of six and ten and a half feet respectively are distinctly different from those above. Typically, the sediments below the depths stated are largely sand that is firmer than that in the unit above; layers of well bedded shell fragments are numerous. In both holes a stiff greenish-gray clay was penetrated: at 26.5 ft (7.9 m) in 126, and at 32.5 ft (9.4 m) in 127. In 126 the clay contains calcareous nodules and seems to be a single unit 3.5 ft (1.1 m) thick, but in 127 the clay is not calcareous and occurs in thinner layers between layers of sand. The sand beneath the stiff clay in 126 and that associated with it in 127 is in large part almost white; some layers are almost pure quartz.

The gray shelly sand above the stiff greenish-gray clay is very similar if not identical to beach and near beach sand deposits; the greenish-gray clay is probably a lagoonal or bay deposit and the associated nearly white to white well-sorted sand probably is dune sand that migrated into the lagoon and became interlayered with the lagoonal mud. In terms of paleo-depositional environments, a progressive upward change with time is demonstrated by the sediments sampled in holes 126 and 127: lagoonal clay and dune sand overlain by beach deposits which are in turn overlain by inner continental shelf sands and muds. This progression probably represents the deposits laid down during the Holocene sea level rise. The shelly sands may represent barrier island and associated sands that were reworked and pushed shoreward over the lagoonal clay as sea level rose. The greenish clay may mark the top of the Pleistocene sequence, but age dating is needed to confirm this assumption.

Water Movement Patterns

In conjunction with studies of depositional processes and the movement of sedimentary material on barrier islands, and along the inner continental shelf, an investigation of the rates and directions of drift in the Gulf of Mexico off the Texas coast was initiated in January 1970. The drift of surface water was measured by the net movement of carded and ballasted drift bottles, and bottom drift was charted by use of plastic sealed drifters of the Woodhead type.

From January 1970 to April 1974 five surface drifters and five bottom drifters were released at each of 48 stations by drop from a Coast Guard airplane whose location at each station was fixed by Loran A or by Tacan. The release points were 12 nautical miles apart along four lines paralleling the coast between Port Aransas, Texas and the mouth of the Rio Grande.

These lines were 1, 10, 20, and 30 nautical miles offshore in water depths averaging about 20, 90, 130, and 180 feet.

In July 1973 the study was extended to include the coast between San Luis Pass and Port Aransas, Texas. The number and types of drifters released at each station and the number and spacing of release points remained the same as for the first study area. Drops have been made seasonally since January 1970, with the exception of a gap in the winter and early spring of 1971. A drop was made in September 1971, but the recovery data are not included because recoveries were few and erratic due to the passage of hurricanes Edith and Fern over the area shortly after the drop.

Results of the study to date for area B (see fig. A) are summarized on figures 12, 12a and 12b.

The summary plots of the drifter data show that the cumulative long term direction of water movement on both seasonal and annual bases is southerly, both for surface and bottom currents. However, some seasonal differences are obvious. Also, it is apparent from the drifter maps that the percentage of returns of surface drifters has been consistently larger than that for bottom drifters, indicating a strong response of the surface drifters to the prevailing onshore wind directions of this area. The smaller return percentages for the bottom drifters suggests that the movement of bottom waters is in general away from the shoreline farther offshore in deeper water and parallel to the shoreline in the nearshore zone in shallow water. A definite longshore movement of bottom water with both southerly and northerly components is indicated on an annual basis.

In using the drifter data, two qualifications should be kept in mind: 1) in plotting the returns equal weight has been given to each drifter recovered, which may cause some bias because larger numbers of drifters were recovered following some releases than others; and 2) the direction of drifter movement from point of release to point of pick up is assumed to have been a straight line when in actuality it may not have been.

The generally southerly pattern of water movement within area A fits generally well with the dispersal pattern of the sand component of the bottom surficial sediments. The pattern for the sand seems to represent the cumulative response to the water movement on annual bases. Overriding the seasonal patterns of water movement, of course, are the high currents that accompany hurricanes. The high energy currents that occur during hurricanes are believed to be the principal movers of sand.

Environmental Geologic Map

The environmental geologic map has been compiled largely from both high and low level color aerial photographs furnished by NASA. In addition it includes the compilation for the area north of Aransas Channel made by R. A. Hoover as a doctoral dissertation while studying at the University of Texas, Austin.

The over-all area covered by the environmental geologic map extends from Shamrock Cove north to Mud Island and from Ingleside on the west across Redfish Bay and Mustang Island and San José Islands to the east. The map has been compiled at a scale of 1:24,000 and consists of four sheets: parts of the USGS, Port Ingleside, Port Aransas, Estes and Aransas Pass Quadrangles.

The various depositional environments of the areahave been classified and the areal extent and interrelationships of the various environments are shown on the two sheets. An accompanying legend summarizes the characteristics of the environments.

The maps are self-explanatory but several summary statements are pertinent. Comparison of photographs made in 1968 and 1972 indicate the following changes. Substantial increases in grass cover over the area have occurred both below and above tide level since 1968. Areas of spoil coverage also have been increased substantially by dredging activity. The magnitude of black mangrove coverage over the area has increased slightly. Areas of older dredge spoil along Aransas Channel have been substantially reworked and are becoming revegetated rapidly. The predominant environment in the mapped area in terms of total area covered is the subtidal grass flats. The part of San José Island covered by the environmental map consists of sand lying little more than a few feet above sea level. Vegetation cover over this part of San José Island is very light and it has been swept over repeatedly in the past by both rising and ebbing storm surges that accompanied hurricanes.

Summary Conclusions

1. Water movement--The cumulative direction of water movement both surface and along shore over area A, as indicated by drifter studies, is southerly on an annual basis with seasonal variations and reversals. The patterns of movement within a few miles of shoreline seem to be fairly regular from year to year; farther offshore, bottom water movement is not well documented.

2. Sea floor sediment dispersal patterns--Movement of sediment along the inner several miles of area A, as indicated by the sand fraction of the sediment, is southerly and this pattern most probably reflects the prevailing longshore southerly drift of the water. The trend of the seaward bulge of sandier sediments north of Aransas Pass normal to shoreline is believed to represent sand swept onto the continental shelf from the adjacent barrier island and shoreface during hurricanes. The sand layer in the gravity cores from the outer 8 miles of area A strongly suggest that the currents that accompany ebbing storm surges following hurricanes can carry sand at least as far as 16 miles offshore. Whether or not the sand carried seaward by the storm-generated currents is eventually carried southerly is not conclusively demonstrated by the sediment map. However, the lobe of thicker sediment in the sequence above reflector A (fig. 11a) beneath the southeastern part of area A suggests an elongate northwestward-trending focus of deposition where the rate of sediment accumulation during the Holocene rise in sea level may have been higher than elsewhere

in area A. If the pattern of deposition so suggested is correct, then it can be reasonably assumed that inner shelf sediment movement across area A has a long term southerly drift. No quantitative estimate of sediment movement by volume is possible on the basis of the studies made to date. Determination of rates and volume of sediment movement will require further study utilizing tracer material, bottom sediment traps, and frequent measurements of suspended sediment concentrations. Analysis of long shore drift of sediment plumes over the inner shelf off Texas, in part on a time sequence basis, using ERTS and aircraft photography now being conducted by Ralph Hunter will aid substantially in assessing patterns of suspended sediment movement over the shelf.

3. Benthic fauna--1) the benthic fauna in area A is both abundant and diverse; 2) the benthos is zoned relative to sediment type and proximity to the inlet; and 3) preliminary analysis strongly suggests that the concentrations of trace metals in the polychaetes is closely tied to trace metals concentration in the host sediments. In all cases the concentrations are higher in the worms than in the host sediments, indicating active concentration by the worms as a living process.

4. Nature and competence of sediments with depth--The sediments above reflector A are characteristically interlayered soft muds and relatively loose sands, except nearer shore where sand predominates. Neither the core samples nor the sound reflection patterns on the seismic profiles indicate hard material within the sequence. The sequence thickens gradually seaward to about 66 ft (20 m) at the outer edge of area A.

The sequence beneath reflector A and above A', as represented by the sound analog, seems to be principally a series of older and now buried shoreline and near shoreline deposits, although fluvial and deltaic deposits likely are present. The Corps of Engineers bore holes bear this out to the degree that the holes penetrated into the upper part of the sequence. The logs of the bore holes indicate largely sand and shelly sand somewhat firmer than the sand above A. Also present in the holes nearer shore is a stiff greenish gray clay that may represent the top of the Pleistocene sequence.

The top of the sequence above reflector A' is truncated at several places by basal sediments above reflector A. These localities lie between the Corps of Engineers bore holes. They are probably older shoreline features and they possibly represent reworked upper parts of older barrier island and associated deposits. In summary, deposits above reflector A are relatively soft muds and loose sands that increase in thickness seaward; those between A and A' seem to be largely shelly sand a bit more compact than the sand above A.