SEDIMENTS OF THE MISSISSIPPI, ALABAMA, AND FLORIDA (MAFLA) CONTINENTAL SHELF[1]

LARRY J. DOYLE
University of South Florida
Department of Marine Science
830 First Street South
St. Petersburg, Florida
AND
THOMAS N. SPARKS[2]
Duke University
Department of Geology
Box 6665
College Station
Durham, North Carolina

ABSTRACT: The eastern Gulf (MAFLA) continental margin may be conveniently divided into two parts of opposing history and character. West of Cape San Blas lies the eastern limb of the Gulf Coast Geosyncline whose surface expression is a clastic sand body, called the MAFLA Sand Sheet, grading westward into the muds of the Mississippi pro-delta. These sediments have a clay mineral suite dominated by smectite. East of Cape San Blas lies the West Florida Margin, a sequence of carbonate and evaporitic rocks which has been cut off from a major clastic source since Jurassic time. The surface expression of this sequence is the West Florida Sand Sheet, predominantly a patchy veneer of shell hash and foraminiferal, algal, and even oolitic sands which is subjected to periodic reworking by frontal system storms and hurricanes. Kaolinite dominates its clay mineralogy. Seaward of the carbonate sands lies the West Florida Lime Mud facies, slope sediments composed of planktonic foraminifera and coccoliths.

Inshore of the carbonate sands and separated from them by a zone of mixed composition lies a mature quartz fine sand, which also makes up the beaches of Southwest Florida. West Florida shelf quartz sands appear to have been deposited at lower sea level stands and to have been transported back and forth with no net drift in a longshore current system which changes seasonally from north to south.

Clay mineralogy in portions of the MAFLA region shows distinct changes in composition over a period of a year in the benthos and over periods as short as a few hours in the water column. These changes reflect contribution from two distinct provenances. Benthic variation probably results from occasional intrusion of smectite laden Mississippi River or Loop Current water into the eastern zone. Water column variation may be the result of seiching of the Gulf or the pulsing movement of kaolinite laden eastern shelf water to the west.

INTRODUCTION

Purpose

The continental margin of the Gulf of Mexico is one of the most intensely explored in the world and is dealt with in literally thousands of publications (Braunstein, 1970). Most research efforts have been concentrated on the oil rich northern Gulf, while the margin east of the Mississippi passes and north of Cape Romano (Fig. 1) has been relatively neglected. It is the purpose of this paper to provide a regional overview of the surface sediments based upon the results of a four year study integrated with data from the pertinent literature.

Approach

Because it lies adjacent to the states of Mississippi, Alabama, and Florida, the continental margin of the Gulf of Mexico, shown in Figure 1 has become known by the acronym MAFLA. This study is but a portion of a grand scale seasonal survey of the sediments, chemistry, and biology of the MAFLA region sponsored by the Bureau of Land Management. Each of the stations shown in Figure 1 was sampled for grain

[1]Manuscript received May 16, 1979; revised December 10, 1979.

[2]Present address: Texaco, Inc., 1501 Canal Street, New Orleans, La.

JOURNAL OF SEDIMENTARY PETROLOGY, VOL. 50, NO. 3, SEPTEMBER, 1980, P. 0905–0916.
 0022-4472/80/0050-0905/$03.00

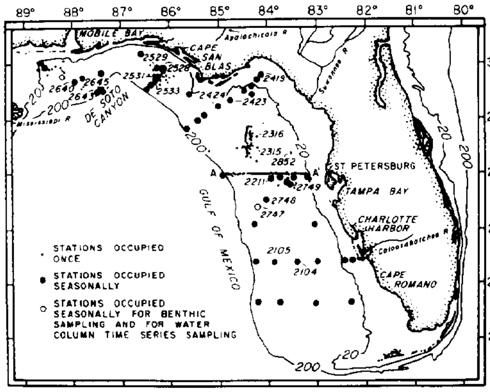

FIG. 1.—Station locations.

size analysis and carbonate content. Stations represented by large closed circles have been repeatedly occupied and were sampled for total organic carbon and clay mineralogy as well as grain size and carbonate content.

In addition to the benthic stations, time series sampling for clay mineralogy was conducted at a station south of Mobile Bay, Alabama, and due west of Tampa Bay as part of a water chemistry program during the fall of 1977 and the winter of 1978. Stations so sampled are depicted by open circles in Figure 1. Four samples per day over a five day period were taken near the surface and near the bottom.

Standard laboratory methods were used throughout. Texture of bottom sediments was determined by standard sieve and pipette analysis. The sand and gravel fractions were sieved at one phi intervals and the <63 micrometer fraction was broken down into percent silt and percent clay. Carbonate content was determined by acid leaching, gas displacement as described by Ireland (1971). Total carbon was determined, after dissolution of the carbonate fraction, by direct measurement in an Angstrom model 7000 carbon combustion analyzer. Relative percentages of smectite, illite, kaolinite, chlorite, vermiculite, and mixed-layer minerals were calculated by comparing the areas of the basal peaks. Benthic clay mineralogy was determined with a Norelco x-ray diffraction system following the techniques of Griffin (1962) and Grim (1968).

Suspended particulates were collected on 47 mm Millipore HA filters (0.45 micrometer pore diameter). They were then treated to remove calcium carbonate and organics and transferred to 0.2 micrometer pore size, 25 mm diameter Selas Flotronics silver filters. With sediments now on silver filters, the samples were clipped into a sample holder and x-rayed at 2.0° 2θ per minute from 3° 2θ to 30° 2θ on a Rigaku "Miniflex" Model 2005 x-ray diffractometer. Mounts with measurable amounts of clay present were treated with ethylene glycol fumes at 60–80° C for at least twelve hours and were immediately x-rayed from 3° 2θ to 15° 2θ to check for expansion of the smectite peak. A final heat treatment at 550° C for one hour followed by x-ray analysis from 3° 2θ to 15° 2θ was performed. Methods of identification and quantification of clay minerals followed those for benthic clay mineralogy.

Geologic Setting

Summarized by Martin (1976), the geology of the continental margin of the MAFLA region may be divided into two basic provinces. The transition zone between them trends southwest from Cape San Blas to the DeSoto Canyon. West of the transition lies the Gulf Coast Geosyncline which deepens to the west, attaining a thickness of over 30 kilometers. This massive section of clastic rocks, the accumulation of the Mississippi River system, is mostly Cenozoic in age and is underlain by Triassic-Jurassic salt measures which are the source beds for the numerous diapirs which characterize the area. East of the transition zone the nature of the rocks changes dramatically. The region has been cut off from major clastic provenance since Jurassic time, which has led to the accumulation of over 4600 meters of carbonates and evaporites, the former of which are still being slowly deposited. These rocks have accumulated behind a series of shelf edge algal reef dams which at various times in the geologic past have restricted circulation (Bryant and others, 1969; Pyle and Antonine, 1973; and Antoine and others, 1974). Pyle and others (1977) have found vestiges of reef dams on the present shelf edge; but the original reefs, of the Albian/Aptian stages, have subsided over 1800 meters and now make up the Florida Escarpment.

Uniboom and side scan sonar surveys conducted by Pyle and others (1977) have shown that east of Cape San Blas a veneer of Holocene sediments only a meter or two thick overlies a ubiquitous reflector which they identified as the top of the Miocene. Cropping out often on the shelf, this reflector forms ledges distinguishable in seismic and bathymetric profiles. Regions of karst collapse features have also been identified. The sediment veneer has large fields of small to giant sand waves which suggest that much of the surface of the wide shallow shelf is mobile, at least under the severe storm and hurricane conditions to which it is periodically subjected.

Gould and Stewart (1955), Shepard (1956), Ludwick (1964), and Grady (1972) have conducted studies of portions of the surface sediments of the region; and Shepard (1956) and Ludwick (1964) have described the sediments of the Mississippi River Delta east to Cape San Blas as a number of clastic sand, mud, and transitional facies. Gould and Stewart (1955) investigated the central portion of the West Florida Shelf and described it as covered by a series of sediment bands distinguishable by texture, carbonate constituents, and mineralogy. Van Andel and Poole (1960) and Fairbank (1962) described the distribution of heavy minerals in the study area. Griffin (1962) first described the clay mineralogy of the northeastern Gulf of Mexico, including the West Florida Shelf where his only samples were estuarine, as being dominated by smectite. Huang and others (1975), based on 1974 MAFLA sampling, showed that east of Cape San Blas, kaolinite rather than smectite was the dominant clay mineral.

RESULTS AND DISCUSSION

Texture and Carbonate Content

The two parameters which are most diagnostic in describing the surface sediments are texture and carbonate content. Figure 2A is a map of the distribution of the sand fraction (>63μ) in the sediments of the Eastern Gulf shelf. Figure 2B shows the percent of carbonate in the study area. Averages of all replicates from all sampling periods have been contoured to produce the figures.

Figure 2A shows that sands dominate the study area except for a large patch of sediments with an elevated amount of fines which lies to the west of Tampa Bay in the central shelf region. Highest values in the center of the patch exceed 40 percent fines. The 80 percent sand fraction contour lies well out on the shelf edge. Even many upper slope sediments of the region contain up to 50 percent sand, almost entirely composed of the tests of planktonic foraminifera. The sand fraction decreases rapidly west of Mobile Bay as the Mississippi Delta is approached and fine grained sediments also lie in the head of DeSoto Canyon. Deeper water, finer grained sediments in the study area are generally poorly sorted ($\sigma 1.0$–2.0ϕ) while those

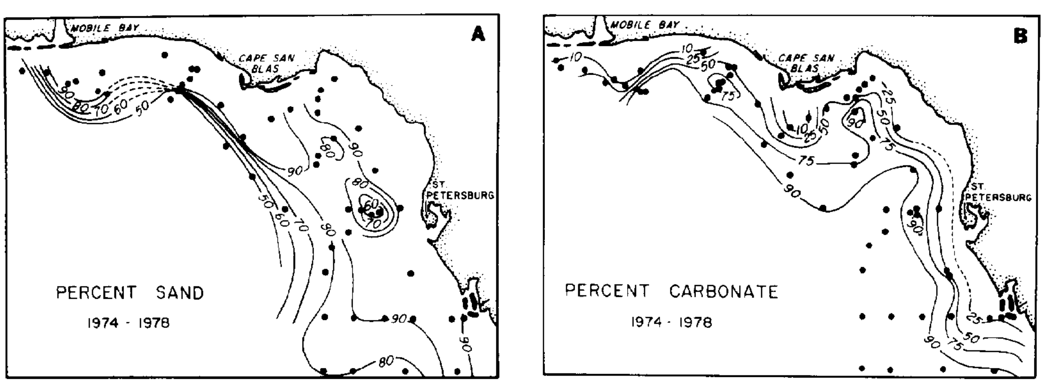

FIG. 2.—A) Average percent greater than 63μ fraction surface sediments. Contour interval—10%. Averages based upon repeated occupation of stations with replicate sampling over the period 1974–1978. B) Average percent carbonate content of surface sediments. Contour interval—10%. Averages are based upon repeated occupation of stations with replicate sampling over the period 1974–1978.

sands and muds lying on the shelf are generally very poorly sorted (σ2.0–4.0ϕ) according to Folk's (1965) classification.

Although carbonate and quartz sands dominate the MAFLA shelf a textural chart based upon a finer interval than that of Figure 2A would be misleading. Closely spaced sampling reveals that the detailed sediment distribution is patchy. For example, Figure 3, based upon a series of samples at one mile intervals across the shelf west of Tarpon Springs (see Fig. 1) shows that patches of much finer than sand sized sediment occur frequently, probably related to shadow zones caused by local bathymetry. Carbonate content for that transest (Fig. 3) is much more constant.

In addition to the geographically controlled variation in sediment texture, our data indicate during hurricanes and even during the passage of storms associated with winter fronts which move through the area from north to south, the bottom sediments are effectively winnowed. The 29 stations shown as large closed circles in Figure 1 were sampled with between 11 and 16 separate box core drops per station during each period of the summer of 1976, summer of 1977, fall of 1977, and winter of 1978. Navigation back to the same point was precise. Figure 4, a plot of the box core drops on one station of four cruises, illustrates the navigational accuracy. High standard deviation of mean grain size shown in Table I for most of the stations illustrates the changes in the sediments. A coefficient of variation calculated

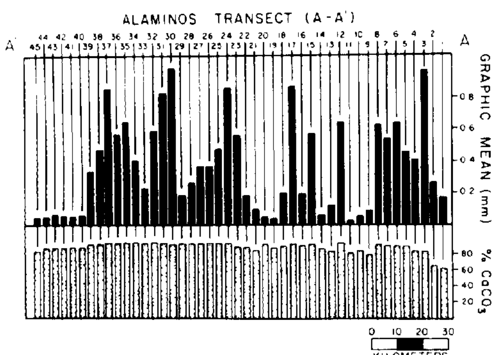

FIG. 3.—Texture and calcium carbonate percentages on one mile station intervals along transect A-A taken from the R/V ALAMINOS across the west Florida shelf.

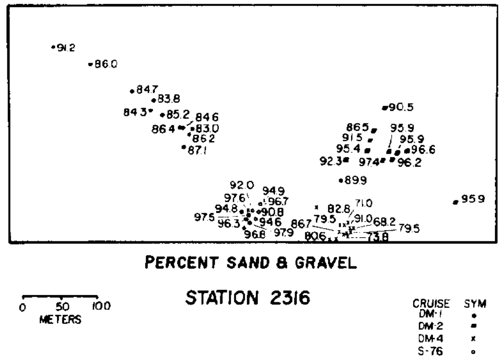

FIG. 4.—Spread of box core samples over four cruises and their sand and gravel percentages.

by dividing the grand mean grain size for each station by its standard deviation for each station is also shown in Table I. All but two are 33% or above, further illustrating the temporal variability in sediment characteristics.

While the shelf sand sheets on both sides of Cape San Blas are texturally similar, Figure 2B shows there is a major compositional break trending slightly east of south from the Cape. The low carbonate content contours which correspond to high quartz content, form a bulge out onto the shelf which marks the transition between western and eastern facies. The eastern portion is dominated by up to 90 percent carbonate components while the western portion is predomi-

TABLE I.—*Stations which showed relatively high textural variability*

Station	ϕ $\bar{X}$D	ϕ SD	Coefficient of Variation	No. of Samples
2104	1.38	0.52	0.38	55
2105	1.58	0.70	0.44	25
2211	1.20	0.76	0.63	57
2315	2.30	2.00	0.87	14
2316	2.00	1.13	0.57	56
2419	1.83	0.70	0.38	44
2423	1.32	0.67	0.51	54
2528	0.50	0.46	0.92	53
2529	0.49	0.30	0.61	26
2531	0.56	0.23	0.41	54
2533	1.00	0.75	0.75	28
2640	1.11	0.74	0.67	56
2643	1.34	0.49	0.37	26
2645	1.06	0.37	0.35	54
2747	2.34	0.93	0.40	49
2748	1.13	0.46	0.41	49
2749	1.04	0.38	0.37	4
2852	1.04	0.40	0.38	16

nantly quartz sand. A band of quartz sand also lies inshore to the east of Cape San Blas and makes up the western beaches of the Florida peninsula. Perusal of Figure 2B shows a gradational transition between the nearshore quartz band and open shelf carbonate sediments, and the abrupt narrowing of the quartz band just south of Charlotte Harbor and the mouth of the Caloosahatchee River, the southern-most transportation system for sands from the Florida Terraces.

As is normally the case in marine sediments, total organic carbon content follows the grain size trends and increases with increasing fine fraction. Values vary from about 1.0% to less than 0.1%, and most correspond with those of Emery and Uchupi (1972) for sandy shelf sediments.

Benthic Clay Mineralogy

Smectite and kaolinite are the predominant clay minerals in Eastern Gulf margin sediments. Illite is present in most samples, ranging from trace amounts to about 16 percent, and shows a random pattern of distribution within the study area. Mixed layer clays and chlorite are rare and scattered in benthic samples.

Distribution of the dominant clay minerals smectite and kaolinite are shown in Figures 5A and 5B. Values are averaged for the summer of 1976, and the fall of 1977. Smectite, characteristic of the Mississippi drainage system, dominates west of Cape San Blas. Relative percentages of kaolinite increase toward the Cape. East of San Blas kaolinite becomes more important, and over large portions of the area is the dominant clay mineral. Kaolinite values are somewhat lower and smectite correspondingly higher than those reported by Huang and others (1975) and Huang (1977). This suggestion of variability in the benthic clay mineral suite is reinforced by apparent changes in relative

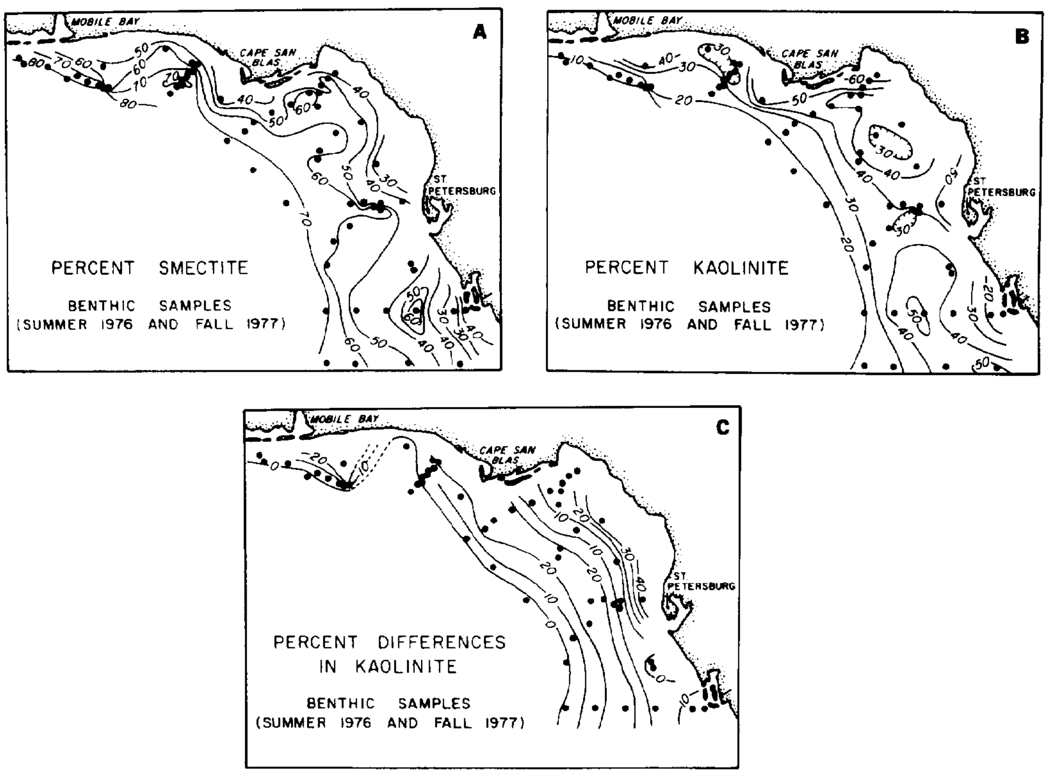

FIG. 5.—A, B) Kaolinite and smectite contents averaged for summer 1976 and fall 1977 sampling periods. Contour interval—10%. Percentages are of the total clay mineral fraction. C) Differences in percentages of kaolinite in the clay mineral fraction between summer 1976 and fall 1977 sampling periods.

percentages of kaolinite and smectite between summer 1976 and fall 1977. Over most of the shelf smectite decreased dramatically and regularly toward the shore. Where smectite decreased, corresponding increases in relative amounts of kaolinite occurred as shown in Figure 5C.

Significant variation in relative amounts of clay minerals in the benthic sediments over as short a period as one year is an exciting prospect. Since clay mineralogy is a semi-quantitative method, differences in measurements must be judged conservatively. However, several factors support the veracity of the relative differences shown in Figure 5C. Analyses for summer 1976 and fall 1977 samples were done in the same laboratory by the same personnel using the same methods over a relatively short time period measured in months. Secondly, variations are not random nor are they either larger or smaller by a constant amount. They increase or decrease regularly toward shore. These factors indicate that the trends are real.

Several provenance areas feed sediments to the Eastern Gulf margin. The Mississippi drainage basin is characterized by a clay mineral suite dominated by smectite (Griffin, 1962). Like the coastal plain of the southeastern United States to the north, smectite also dominates the clay mineralogy of those rivers which rise in the Tertiary rocks of peninsular Florida (Huang and others, 1975). With the possible exception of the Caloosahatchee River, which empties into Port Charlotte Harbor, where a bulge in smectite values is noticeable, these rivers contribute little to even the fine fraction of Gulf sediments. Kaolinite dominates the Appalachicola River system, while the Mobile River system has a mixed smectite / kaolinite suite. These latter two river systems must be the ultimate source of kaolinite in the Eastern Gulf margin, a conclusion reinforced by Figures 6A and 6B which show the crystallinity of kaolinite and smectite in the study area, a determination arrived at by evaluation of the x-ray peak of the basal reflector. Samples with sharp, well defined peaks are interpreted as exhibiting very good crystallinity, while broad low peaks are interpreted as exhibiting poor crystallinity. Degradation of crystallinity is a function of weathering changes in the water column and diagenesis in the benthic sediments and is thus an indicator of distance in space and time from source. The further from a source, the longer time would be available for changes in crystallinity to occur. Probably even more important, the farther from the source the less dilution with fresh clays would be expected. Therefore, old partially degraded clays would become increasingly prevalent away from the source. Based upon this rather subjective measure, kaolinite crystallinites are best in the northwestern part of the Gulf and decline to the south and east, suggesting that the kaolinite source was to the north. Smectite crystallinity in the study area generally declines away from the delta and to the south and the Mississippi provenance is apparent.

Seasonal or annual variation in kaolinite / smectite ratios on the west Florida shelf

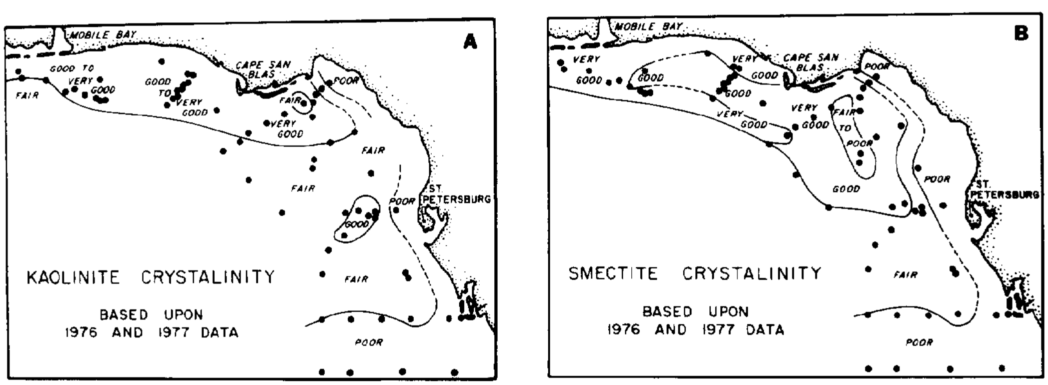

FIG. 6.—A, B) Kaolinite and smectite crystallinity based upon sharpness of basal peak.

is probably the result of varying influence of Mississippi River water which occasionally intrudes upon the area, and the Loop Current which often sweeps through the Yucatan channel up into the DeSoto Canyon where it may winnow smectite laden sediment from the western rim. When it is present as far north as the canyon, the current loops back south along the West Florida slope and outer shelf. Since the shelf floor is subject to severe winnowing during major storms, smectite pulses in the benthos may be transient because of resuspension of smectite.

Rivers of West Florida carry little suspended sediment; those of western peninsular Florida carry practically none. Most of what is brought in is trapped in lagoons or estuaries. These factors suggest that much of the comparatively small clay mineral fraction of the West Florida shelf east of Cape San Blas may be relict. In that event juxtaposition of kaolinite rich shelf sediments with the smectite dominated sediments of peninsular Florida as well as the pattern of decreasing crystallinity of clay minerals to the south and southeast suggests that the northern Florida rivers, the Appalachicola and perhaps the Suwannee, may have been major contributors to the nearshore quartz sand band compared to most of smaller Coastal Plain rivers of the peninsula. The bulge in smectite and quartz off the mouth of the Caloosahatchee River suggests it is an exception and that this peninsular river was a major contributor to the quartz band during lowered sea level periods.

Alternatively, essentially all original clay minerals transported to the sea by peninsular rivers during lowered sea level may have been winnowed from quartz sands by the latest sea level rise. A small clay mineral fraction may have then been added during the last few thousand years chiefly from northern river sources and the Caloosahatchee River by flow escape from estuaries and lagoons.

Suspended Clay Mineralogy

The suspended clay mineral suite is similar to that of the benthos with the addition of trace to minor amounts of talc which is present in the summer of 1976 samples. Talc is not present in the fall 1977 samples, but is found in surface samples in winter 1978, where it varies in quantity from trace amounts to dominant. Talc does not show up in benthic clay mineral analysis. Manheim (pers. comm.) has pointed out that talc is widely used as a dispersing agent in crop dusting and, as such, finds its way into the suspended particulates in the water column through runoff.

Variation in clay mineralogy was even more startling in some of the time series stations occupied in the fall of 1977 and the winter of 1978 than in the benthos. Figure 7A shows the variation in near bottom waters at a station south of Mobile Bay over a five day period. Regular and marked fluctuations of clay mineralogy are present with peaks of smectite and kaolinite alternating on a 12 to 18 hour period. High concentrations of

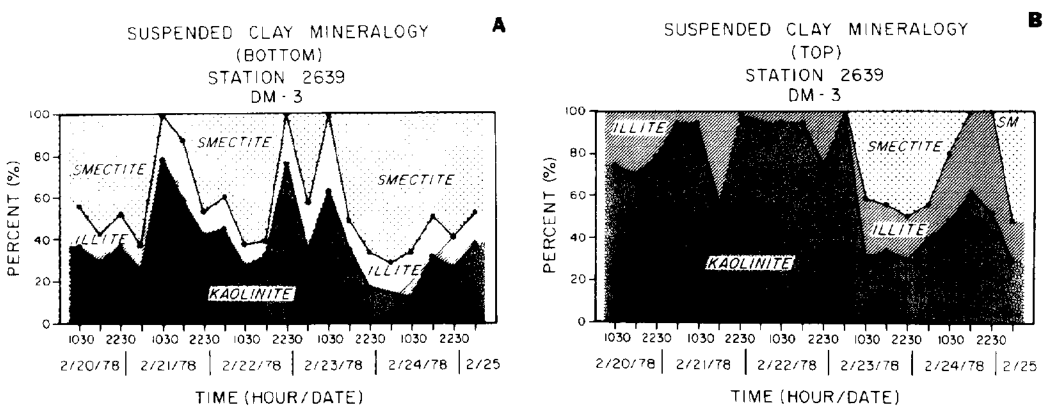

FIG. 7.—A, B) Variations over a five-day interval in the suspended clay mineralogy in near bottom and near surface waters off Mobile Bay along with total suspended load numbers from Betzer and others (1978).

smectite correspond with high total suspended load measured by Betzer and others (1977) while high relative percentages of kaolinite correspond with relatively low suspended loads (also measured by Betzer and others, 1977). Pulsations may be due to the passage of a seich moving the same water mass first to the east then to the west, to the tides, or to a periodic pumping of water laden with kaolinite from east to west. Unfortunately, very little of the current structure of the shelf of the eastern Gulf is known.

Surface fluctuations (Fig. 7B) were present but subdued and mineralogy differed from that of the near bottom samples. Only illite and kaolinite were present in surface samples for the first three days of the time-series. A bolus of smectite rich sediments passed through on the 23rd, and was replaced by kaolinite and illite rich sediments on the 25th.

Figure 8 shows a profile of the salinity values of the water column during the time-series sampling. The picnocline varies dramatically at about the same period as do the fluctuations in clay mineralogy.

To the authors' knowledge, pulsations in mineralogy of the type shown have not been previously reported.

Eastern Gulf Shelf-Surface Sediment Facies

Present day expression of the surficial sediments of the Eastern Gulf margin reflects that of the subsurface geology; that is, it may be roughly divided at Cape San Blas into a western region of clastics and an eastern region dominated by carbonates. Figure 9 shows the facies distribution of surface sediments in the study area.

Since most of the load of the Mississippi River is delivered directly to the shelf edge or is carried west due to the distribution of

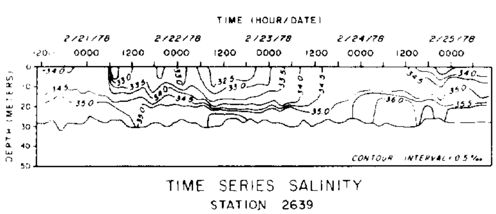

FIG. 8.—Variations in salinity off Mobile Bay over the same time period over which clay mineralogy varied. Data courtesy of Dames and Moore, Inc.

major distributaries and the Coriolis force acting on the plume, sediments on the eastern margin of the delta change rapidly from the St. Bernard Prodelta facies (Ludwick, 1964) dominated by mud to an open shelf clastic facies, which we call the MAFLA sand sheet. Sediments within this sheet are quartz sands with carbonate percentages of generally less than 25%. Van Andel and Poole (1960) and Fairbank (1962) characterize the heavy mineral suite of the area encompassed by the MAFLA sand sheet as reflecting a southern Appalachian provenance. Kyanite and staurolite are diagnostic, with ilmenite, zircon, and tourmaline common. Hematite, pyroxenes, and amphiboles which dominate the Mississippi suite are present, suggesting some contribution from the river.

Within the MAFLA sand sheet adjacent to the Eastern margin of DeSoto Canyon lies the rather geographically limited Destin Carbonate Facies with carbonate percentages over 75. Wanless (1977) shows this zone to be a combination of shell hash, lithothamnion algae, and foraminifera. Since the Loop Current turns to the east then south at the DeSoto Canyon, it may serve to block transport of clastic sediments into this zone, resulting in the accumulation of carbonate sediments similar to those of the West Florida carbonate sand sheet.

East of Cape San Blas lies the West Florida shelf which may be divided mineralogically into two facies, described by Gould and Stewart (1955), with a rather broad transition zone between (see Fig. 9). A carbonate sand facies dominates the outer and middle shelf. However, rather than being banded with regard to texture and carbonate constituents as described by Gould and Stewart (1955), sediments within it are of patchy distribution. Carbonate content, arbitrarily at over 75 percent, defines the boundary. Patches of shell hash, foraminifera, lithothamnion algae, and even oolites locally dominate (Gould and Stewart, 1955; Wanless, 1977). As expected, detrital heavy minerals are essentially absent in the carbonate facies. Phosphorite associated with outcrops of probably Miocene Age is present in some locations.

Shoreward of the carbonate facies lies the transition zone shown in Figure 9, which includes ever increasing amounts of quartz to the east. The transition is gradual and

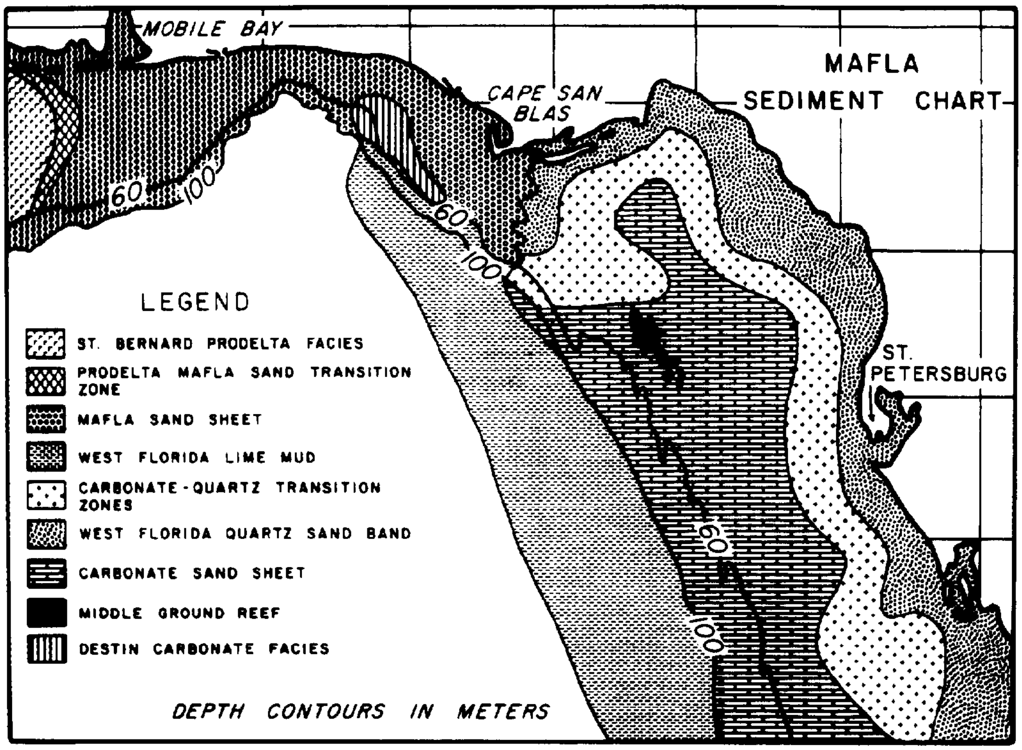

FIG. 9.—Sedimentary facies of the MAFLA margin.

the shoreward boundary is arbitrarily placed at 25 percent carbonate. Shoreward of the transition zone lies a quartz sand facies. This facies is a mature very fine to fine sand. The heavy mineral suite is characterized by the resistant minerals zircon, tourmaline, garnet, and staurolite (Fairbank, 1962). The inshore quartz band also makes up West Florida's beaches and is significant for several reasons.

The rivers of Florida carry little suspended load and even less bed load. The quartz sand band is bordered on the west and south by carbonates. Heavy mineral and clay mineral suites within it are distinct from the sediments to the west of Cape San Blas suggesting that there is little sediment exchange between the two. The question then arises, that without a constant source for replenishment, why is the band still there? Why hasn't longshore drift removed the quartz to be replaced by carbonate sand? Northerly winds dominate during late fall and winter, while southerly winds predominate the rest of the year (Jordan, 1973). This alternating wind pattern leads to a southerly longshore drift in late fall and winter and a northerly drift during the remainder of the year. These two patterns must roughly balance so that there is essentially no net drift and sediments tend to migrate back and forth; otherwise, since there is no active source for clastics, the quartz sand should have been transported from the system and the beach should be composed of carbonates. The result is an exceedingly mature sediment.

Since quartz is not being fed to the system at present, it must be relict from an earlier time. It may be the result of quartz sands being brought down from the Tertiary clastic terraces of peninsular Florida during lowered stands of sea level or it may represent the surface of a partially drowned terrace. A third alternative is, that since clay mineralogy of the shelf is dominated by kaolinite and the coastal plain sediments of peninsular Florida by smectite, the northern Appalachicola and Suwannee Rivers may have been the most significant source.

Seaward of the carbonate sand facies lies the West Florida Lime Muds (Ludwick, 1964). This facies lies on the continental slope. In many places it may contain large amounts of sand sized planktonic foraminifera. Clay minerals are dominated by smectite, probably the result of Loop Current transport and fine grained carbonates, mostly of coccoliths, are also important.

CONCLUSIONS

1) Sediments of the Eastern Gulf of Mexico continental margin may be divided into a number of facies which are the latest expressions of the history of the geologic column below. West of Cape San Blas are the MAFLA sand sheet and the Mississippi Delta, the surface expression of the eastern limb of the Gulf Coast Geosyncline. These sediments get finer to the west and have Mississippi River type heavy mineral and clay mineral suites, the latter dominated by smectite. A patch of high carbonate sediments, possibly the results of winnowing and/or blocking of clastic input by the Loop Current, lies on the outer shelf adjacent to the eastern rim of DeSoto Canyon.

2) East of Cape San Blas is the West Florida Sand Sheet, the outer and middle portion of which is made up predominantly of carbonate sands, the surface expression of a thick section of carbonates and evaporites which have been accumulating since the Jurassic. Inshore of the carbonates lies a mature quartz band surrounded by carbonates and cut off at Cape San Blas. Originally deposited at lower stands of sea level, it maintains itself by shifting alternately north then south about equal distances under the pressure of seasonal variations in the wind induced longshore current system. A quartz/carbonate transition lies between the carbonate and quartz sands. Clay mineralogy is dominated by kaolinite, originating from north Florida river systems while the heavy mineral suite in the clastics has lost its Mississippi diagnostics and is composed of the most durable species.

3) Dominated by planktonic foraminifera and fine carbonate nannoplankton, a slope lime mud facies occurs seaward of the West Florida Sand Sheet.

4) Variation within sand sheets is patchy both in texture and composition. Data suggest that considerable storm driven winnowing occurs and sediments can undergo considerable textural change during severe weather periods.

5) Clay mineralogy shows distinct temporal variation over the course of a year in the bottom sediments and over a period of a few hours in the suspended sediments. In the latter case, these changes are the dramatic result of variations in transport of clear eastern Gulf water characterized by kaolinite westward past Mobile Bay either in pulses or by seiching. Bottom sediment variations are the result of the occasional intrusion of smectite rich Mississippi or Loop Current water east of Cape San Blas and of major storm systems.

ACKNOWLEDGMENTS

We wish to acknowledge James Alexander and Murice Rinkel of SUSIO and Tom Scanland of Dames and Moore for their efforts in organizing and managing the overall program of which this work represents but a small part. Chris Tsokos of the Department of Mathematics, University of South Florida, and Peter Feldhausen of Dames and Moore provided valuable data management services. Bart Birdsall and Gary Hayward were invaluable in data collection and sample analysis. This work was supported by the Bureau of Land Management through contracts numbered 08550-CT4-11 and 08550-CT5-30 to the State University System Institute of Oceanography of Florida (SUSIO) and AA550-CT7-34 to Dames and Moore, Inc., and by those institutions through subcontract. BLM has verbally requested that the following statement be made:

> This report has not been reviewed by BLM and approved for publication. This does not signify that the contents necessarily reflect the views and policies of the Bureau, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

REFERENCES

Antoine, J. W., Martin, R. G., Pyle, T. E., and Bryant, W. R., 1974, Continental margins of the Gulf of

Mexico, *in* Burk, C. A., and Drake, C. L., eds., The Geology of Continental Margins: New York, Springer-Verlag, p. 683–693.

Betzer, P. R., Peacock, M. A., and Jolley, R. R., 1978, Trace metals in suspended matter and zooplankton of the northeastern Gulf of Mexico MAFLA survey, 1976–78: Rept Bureau Land Management, Contract No. AA550-CT7-34, 50 p.

Bryant, W. R., Meyerhoff, A. A., Brown, N. K., Jr., Furrer, M. A., Pyle, T. E., and Antoine, J. W., 1969, Escarpments, reef trends and diapiric structures, Eastern Gulf of Mexico: Am. Assoc. Petroleum Geologists Bull., v. 53, no. 12, p. 2506–2542.

Doyle, L. J., Birdsall, B., Hayward, G., Lehman, L., Szydlik, S., and Warren, E., III, 1977, Baseline monitoring studies, Mississippi, Alabama, Florida outer continental shelf, 1975–1976: Rept Bureau Land Management, Contract No. 08550-CT5-30, 14 p.

Emery, K. O., and Uchipi, E., 1972, Western North Atlantic Ocean: Am. Assoc. Petroleum Geologists Mem. No. 17, 532 p.

Fairbank, N. C., 1962, Heavy minerals from the Eastern Gulf of Mexico: Deep Sea Research, v. 9, p. 307–338.

Folk, R. L., 1965, Petrology of Sedimentary Rocks: Austin, Hemphills, 152 p.

Gould, H. R., and Stewart, H. R., 1955, Continental terrace sediments in the northeastern Gulf of Mexico: Soc. Econ. Paleontologists Mineralogists Spec. Pub. No. 3, 129 p.

Grady, J. R., 1972, Reconnaissance Survey; Bottom sediments on the continental shelf, *in* Report of the National Marine Fisheries Services: Gulf Coastal Fisheries Center for fiscal years 1970, 1971, p. 15-A.

Griffen, G. M., 1962, Regional clay mineral facies—products of weathering intensity in the northeastern Gulf of Mexico: Geol. Soc. America Bull., v. 73, p. 737–768.

Huang, W. H., Doyle, L. J., and Chiou, Wen-An, 1975, Clay mineral studies of surface sediments from the shelf of the northeastern Gulf of Mexico, *in* Bailey, W. W., ed., Proc. 1975 Internat. Clay Conf., Mexico, p. 55–70.

Jordan, C. L., 1973, The physical environment: climate, *in* the Eastern Gulf of Mexico: SUSIO, St. Petersburg, Florida, p. IIA-1–IIA-22.

Ludwick, J. C., 1964, Sediments in the northeastern Gulf of Mexico, *in* Papers in Marine Geology: New York, MacMillan, p. 204–238.

Martin, R. G., 1976, Geologic Framework of northern and eastern continental margins, Gulf of Mexico, *in* Bouma, A. H., Moore, G. T., and Coleman, J. M., eds., Beyond the Shelf Break: Am. Assoc. Petroleum Geologists, Short Course, p. A-1–A-28.

Pilkey, O. H., and Field, M., 1972, Onshore transportation of continental shelf sediment: Atlantic Southern United States, *in* Swift, D. J. P., Duane, D. B., and Pilkey, O. H., eds., Shelf Sediment Transport: Stroudsburg, Dowden, Hutchinson and Ross, p. 429–447.

Shepard, F. P., 1956, Marginal Sediments of the Mississippi Delta: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 11, p. 2537–2618.

VanAndel, T. H., and Poole, D. M., 1960, Sources of Recent Sediments in the Northern Gulf of Mexico: Jour. Sed. Petrology, v. 30, p. 91–122.

Wanless, H., 1977, Baseline monitoring studies, Mississippi, Alabama, Florida outer continental shelf, 1975–1976: Rept Bureau of Land Management, Contract No. 08550-CT5-30, 14 p.