Marine Geology, 90 (1989) 51–57
Elsevier Science Publishers B.V., Amsterdam — Printed in The Netherlands

HEAVY-MINERAL RECONNAISSANCE OFF THE COAST OF THE APALACHICOLA RIVER DELTA, NORTHWEST FLORIDA: A SUMMARY AND NEW INTERPRETATIONS

JONATHAN D. ARTHUR[1], SHEKHAR MELKOTE[2], JOSEPH APPLEGATE[2] and THOMAS M. SCOTT[1]

[1]*Florida Geological Survey, 903 West Tennessee Street, Tallahassee, FL 32304 (U.S.A.)*
[2]*Department of Environmental Regulation, 2600 Blairstone Road, Tallahassee, FL 32399 (U.S.A.)*

(Revised and accepted April 14, 1989)

Abstract

Arthur, J.D., Melkote, S., Applegate, J. and Scott, T.M., 1989. Heavy-mineral reconnaissance off the coast of the Apalachicola river delta, northwest Florida: A summary and new interpretations. In: M.C. Hunt and S.V. Doenges (Editors), Studies Related to Continental Margins. Mar. Geol., 90: 51–57.

Two-hundred-and-fifty sediment samples were collected for heavy-mineral and textural analysis along the northwest Florida coastline from approximately 24 km offshore of Apalachee Bay to the same distance offshore of Pensacola Bay. The heavy-mineral suite characterizing sediments within this region consists of opaque minerals, kyanite, staurolite, tourmaline, zircon and rutile. Minor constituents of this suite include epidote, sphene, amphibole, sillimanite, garnet and leucoxene. The average heavy-mineral concentration within these sediments is approximately 0.12 wt.%. Specifically, the 2 to 3ϕ grain-size interval contains an average of 0.51 wt.%, whereas the 3 to 4ϕ interval contains an average of 4.39 wt.% heavy minerals. Note that the 3 to 4ϕ interval typically represents only 4% of the sample volume. There is a general westward increase in heavy-mineral concentrations throughout the study area. Superimposed on this regional trend, areas of maximum heavy-mineral concentration occur within sediments offshore of St. George and Santa Rosa islands. The primary source of sediments in the region is the crystalline rocks of the southern Appalachians.

Granulometric analyses of these sediments reveal a westward increase in values of sample mean grain size, and decrease in standard deviation, and percent fines. It is postulated from these data, in addition to the interpretation of sample grain-size distributions, skewness, and kurtosis, that these inner continental shelf sediments are primarily fluvial in origin. These sediments have been transported to the shelf by the Apalachicola and surrounding major rivers during Pleistocene low sea-level stands. Data also indicate evidence of reworking by coastal or marine offshore wave processes.

Introduction

In May 1985, 250 surface samples were collected offshore of the Florida panhandle to assess the heavy-mineral resource potential and textural characteristics of the region. The data and results of this investigation were published by Arthur et al. (1985). The following report is primarily a summary of that study. Because the initial report was written as a sedimentologic heavy-mineral investigation, this report will also emphasize recalculated data, allowing a better economic evaluation of sediments in the region. New discussion of heavy-mineral species distribution within sediment grain-size intervals is also presented in this report.

Sampling and analytical methods

The study area consists of an 18.5 km wide belt that parallels the northwest Florida coastline from Apalachee Bay to Pensacola Bay (from 83°50′W to 87°20′W). Systematic collection of samples was accomplished by dividing the study area into 32 N–S transects spaced approximately 11 km apart. An average of eight surface grab samples was collected along each transect from the R.V. *Wolf*. Figure 1 shows sample locations and coastal morphologic features within the study area. Deviations from the general sampling pattern occurred near shoals (e.g., Dog Island Reef, Fig.1), where heavy-mineral deposits may be located (Tanner et al., 1961).

Samples were split to yield approximately 100 g for granulometric analysis. Each split was wet-sieved at 4.5ϕ, dried, and sieved at quarter-ϕ intervals from -1.0 to $+4.0$ ϕ (2–0.063 mm). Weight percent, cumulative weight percent, and four moment measures (skewness, kurtosis, and mean and standard deviation) were computed using a granulometric program (Kirkpatrick, 1982).

Sediments within the fine sand (2–3 ϕ) and very fine sand (3–4 ϕ) intervals were combined to form two groups. As suggested by Carver (1971), all samples within the 2–3 ϕ fraction were analyzed for heavy-mineral content. An average of 10 g was split from the 2–3 ϕ fraction for each sample and centrifuged (20 min at 2000 rpm) in tetrabromoethane to separate heavy minerals. For the 3–4 ϕ fraction, one sample from the middle of each transect was separated in the same manner. Note, however, that only 2–4 g of the finer fraction was available for separation.

Weight percent heavy-minerals was determined for each grain-size fraction separated utilizing 250 samples in the 2–3 ϕ interval and 32 samples in the 3–4 ϕ interval. The proportion of heavy-mineral species within the heavy-mineral fraction was estimated by point counting (200 counts/slide).

Regional geology and morphology

The study area consists of the inner continental shelf of the northeast Gulf of Mexico, a portion of the Gulf Coast sedimentological province. The province has an areal extent of 388,500 km^2 and contains a thick section of arenaceous–argillaceous marine to shallow-marine strata (Murray, 1960). Pleistocene and Recent surface sediments in the study area are predominantly coastal marine or alluvial in origin (Schnable and Goodell, 1968).

The northeast Gulf of Mexico is a large depositional basin that receives an influx of sediments from several rivers that drain the Coastal Plain of the southeast United States. Covering an area of about 50,800 km^2, the three-state drainage system of the Apalachicola River system is the largest in the region (Leitman et al., 1983). It is composed of the Flint, Chattahoochee, and Chipola Rivers, all of which flow into Apalachicola Bay via the Apalachicola River. Donoghue and Bedosky (1985) reported that the mouth of the Apalachicola River is a prograding delta. Numerous other bays exist within the study area. From east to west, these include the Apalachee, Ochlockonee, St. Josephs, St. Andrews, Choctawhatchee, and Pensacola Bays. Like the Apalachicola Bay, the St. Andrews, Choctawhatchee, and Pensacola Bays are bound by barrier islands. A large spit encloses the St. Josephs Bay. All rivers that flow into bays in the area drain the Coastal Plain.

Figure 1 also shows the location of several offshore sand bars or shoals in the vicinity of St. George Island, Dog Island, and Cape San Blas. West of the Cape, the study area does not contain any major bars or shoals. Schnable and Goodell (1968) suggested that the Dog Island Reef, South Shoal, and Ochlockonee Shoal are drowned barrier islands. The origin of St. George and Cape San Blas Shoals is unresolved.

Textural data

Granulometric parameters are discussed in this section in terms of average values, ranges,

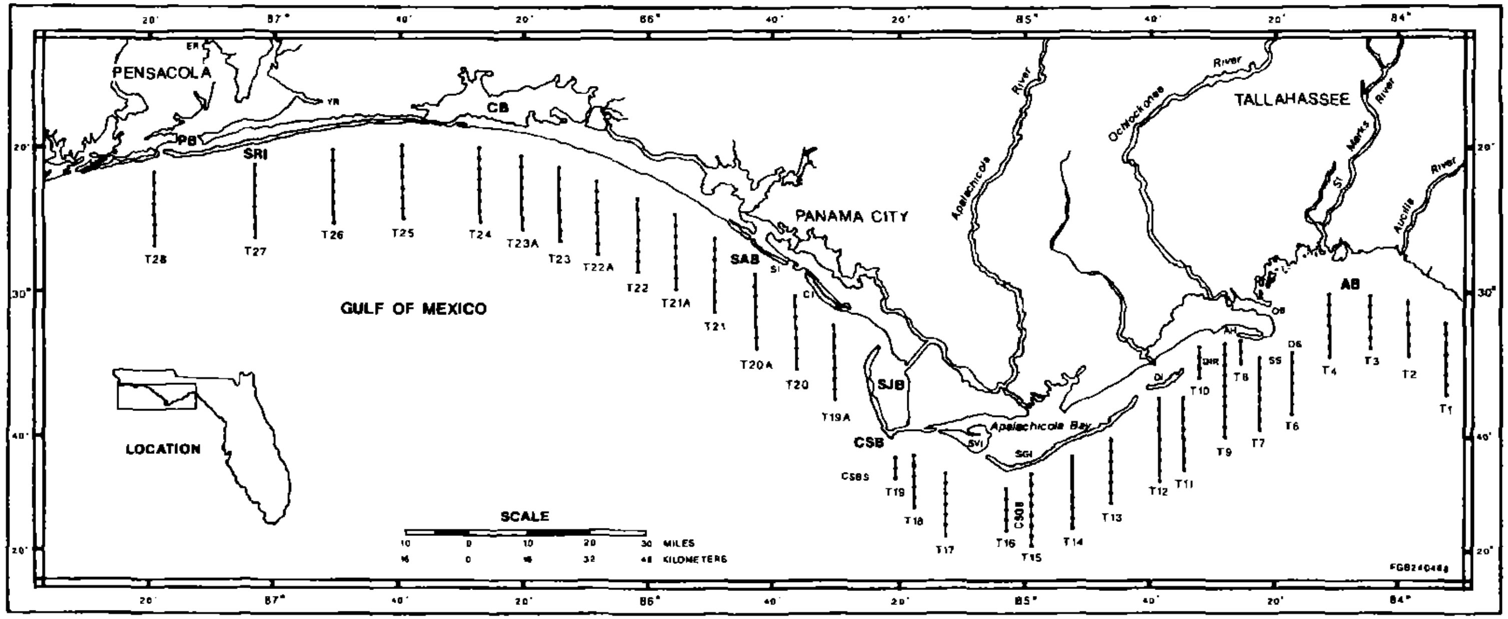

Fig.1. Study area and sample location map showing morphological features: *PB* — Pensacola Bay; *ER* — Escambia River; *YR* — Yellow River; *SRI* — Santa Rosa Island; *CB* — Choctawhatchee Bay; *SAB* — St. Andrews Bay; *SI* — Shell Island; *CI* — Crooked Island; *SJB* — St. Josephs Bay; *CSB* — Cape San Blas; *CSBS* — Cape San Blas Shoal; *SVI* — St. Vincent Island; *SGI* — St. George Island; *CSGS* — Cape St. George Shoal; *DI* — Dog Island; *DIR* — Dog Island Reef; *AH* — Alligator Harbor; *OB* — Ochlockonee Bay; *OS* — Ochlockonee Shoal; *SS* — South Shoal; and *AB* — Apalachee Bay. Continuous lines with dots indicate transect and sample locations.

and regional trends within the study area. For a more complete discussion and interpretation of these parameters, the reader is referred to Arthur et al. (1985) and Melkote et al. (1986).

The average sediment mean grain size is 1.62 ϕ (0.325 mm). This parameter ranges from 2.87 ϕ (0.137 mm) to 0.33 ϕ (0.796 mm), or fine to coarse sand. Grain-size standard deviation, an indicator of the degree of sorting, ranges from 1.35 ϕ to 0.18 ϕ and averages 0.79 ϕ within the study area. Weight percent fines ($\geqslant 4.0\ \phi$, 0.063 mm) within the sediments is highly variable. The values range from trace amounts (< 0.01 wt.%) to almost 25% of the sample. The average value of weight percent fines is 2.02. Thus, inner continental shelf sediments in the region are typically within the medium sand-size grade, moderately to moderately well sorted (based on scale of Friedman, 1961) and contain, on average, approximately 2% silt- and clay-size particles.

The use of moving averages is an effective technique that enables "noise–free" interpretation of a given variable (Davis, 1973). This method is applied to various textural parameters to observe regional and semiregional trends within the study area. Figure 2 is a stacked plot of four-point moving averages of the transect averages for mean grain size, standard deviation of mean grain size, and weight percent fines versus longitude. From east to west, sediment mean grain size coarsens from roughly 1.8 ϕ (0.29 mm) to 1.35 ϕ (0.39 mm), sorting generally improves, and the weight percent of silt and clay decreases.

Two prominent semiregional trends are observed in the textural data (Fig.2). The most dominant trend represents the area centered between St. Andrews Bay and Cape San Blas, where a sharp decrease in mean grain size (increase in phi units, Fig.2) and standard deviation corresponds to an increase in weight percent fines. In other words, the sediments become finer, the weight percent silt and clay increases, and the sediments are relatively better sorted. Textural data for the area centered offshore and east of Choctawhatchee Bay (86°10′W) reveal a marked semiregional

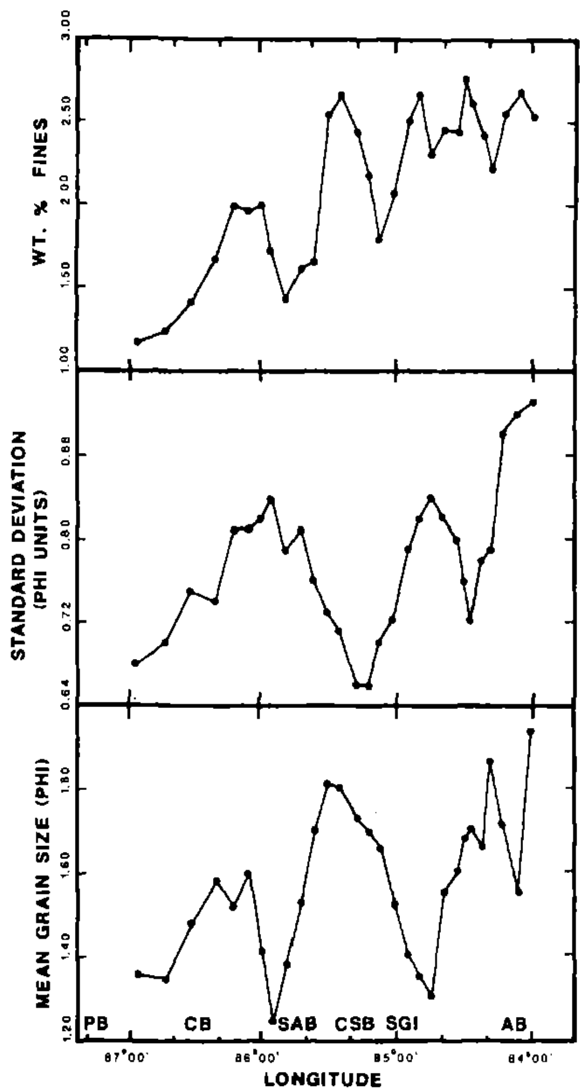

Fig.2. Four-point (transect average) moving averages of sample mean grain size (ϕ), standard deviation (ϕ), and weight percent fines (> 4.5 ϕ) versus longitude. *PB* — Pensacola Bay; *CB* — Choctawhatchee Bay; *SAB* — St. Andrews Bay; *CSB* — Cape San Blas; *SGI* — St. George Island; and *AB* — Apalachee Bay.

trend where sediment mean grain size becomes finer, sorting becomes relatively poor, and percent fines increases.

Skewness, kurtosis and bivariate plots of the above parameters indicate that the sediments are primarily fluvial in origin despite their present location within a coastal marine environment. Reworking of these sediments during Pleistocene sea-level fluctuations was not sufficiently efficient to remove fluvial textural characteristics (Arthur et al., 1985; Melkote et al., 1986). Some samples, however, do reveal the expected beach or coastal marine textural characteristics.

Heavy-mineral data

Results of the heavy-mineral analyses are presented here in the following order: (1) weight percent data and regional distribution for each grain-size interval analyzed; (2) proportions of heavy-mineral species for each grain-size interval analyzed; and (3) weight percent heavy minerals within the total sample. Data mentioned in (1) and (2) are tabulated in Arthur et al. (1985). Total sample heavy-mineral concentrations, both real and projected, are recalculated data, presented herein as averages due to space limitations.

In the 2–3 ϕ (fine sand) fraction, the average heavy-mineral content is 0.51 wt.%. This grain-size interval averages 28.8% of the total sediment sample. An average of 4.68% of the total sample accounts for the 3–4 ϕ (very fine sand) fraction. Average heavy-mineral content in this finer size class is 4.39 wt.%. Figure 3 shows the regional distribution of heavy minerals within both grain-size intervals as four-point moving averages (transect averages, 2–3 ϕ; one sample/transect, 3–4 ϕ) versus longitude. The regional pattern shows a general westward increase in heavy-mineral content for both grain-size fractions (Fig.3). Semi-regional patterns, however, are similar to those observed in the textural data: sediments offshore of the western end of St. George Island contain relatively large amounts of heavy minerals for the 2–3 ϕ and 3–4 ϕ size fractions (up to 0.9% and 11.0%, respectively).

The heavy-mineral suite within the study area includes opaques (i.e., magnetite, ilmenite, rutile, and leucoxene), kyanite, staurolite, tourmaline, and zircon with minor amounts of epidote, sphene, amphibole, sillimanite, garnet, and possibly monazite. Almost identical heavy-mineral suites are reported for coastal sedi-

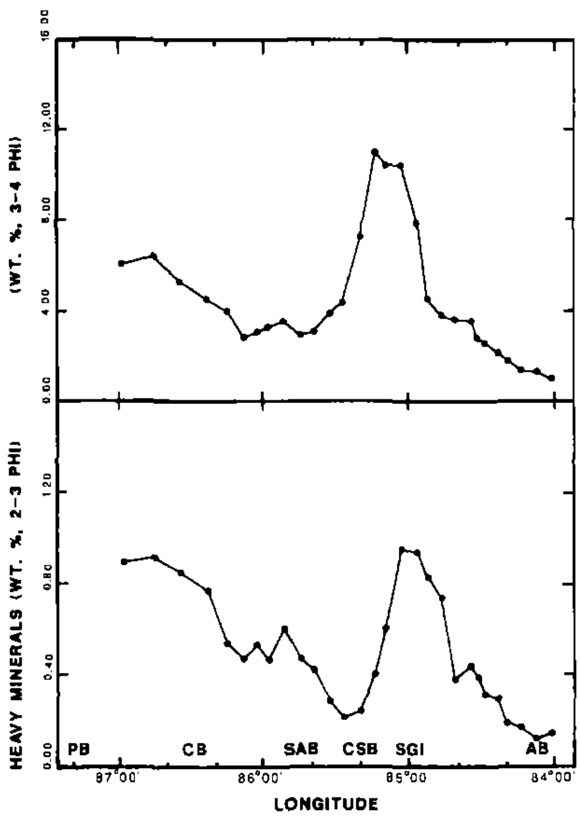

Fig.3. Four-point moving averages (2–3 ϕ, transect averages; 3–4 ϕ, individual samples) of weight percent heavy minerals versus longitude. *PB* — Pensacola Bay; *CB* — Choctawhatchee Bay; *SAB* — St. Andrews Bay; *CSB* — Cape San Blas; *SGI* — St. George Island; and *AB* — Apalachee Bay.

ments from Mississippi to Florida by Goldstein (1942), Harding (1960), Foxworth et al. (1962), and Drummond and Stow (1979). Based on river drainage systems within the eastern half of the Gulf Coast Province, as well as similar heavy-mineral suites, numerous studies (e.g., Goldstein, 1942; Hsü, 1960; Van Andel and Poole, 1960; Foxworth et al., 1962; Drummond and Stow, 1979; Arthur et al., 1985) have agreed upon the crystalline rocks of the southern Appalachian Piedmont as the ultimate source of heavy minerals within the region. These sediments were probably deposited at low sea-level stands during the Pleistocene.

The volumetric proportions of heavy-mineral species within the 2–3 ϕ and 3–4 ϕ heavy-mineral grain-size intervals are shown in a

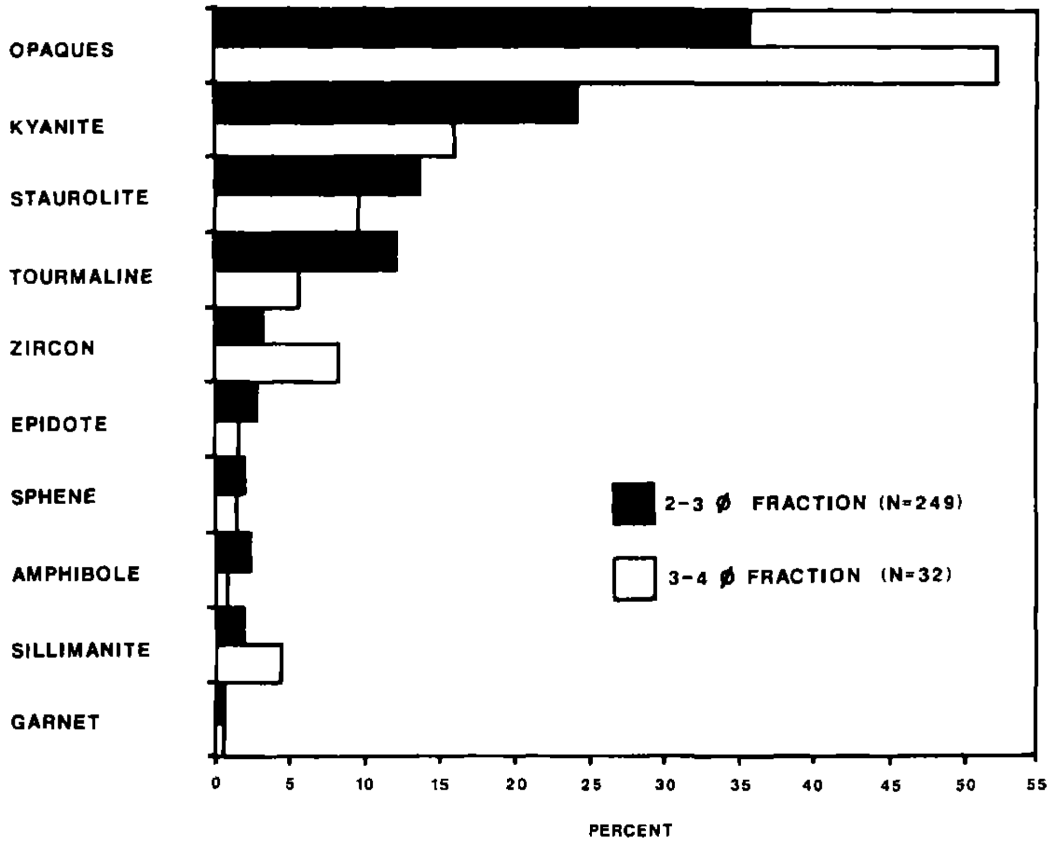

Fig.4. Histogram of modal analyses for the 2–3 ϕ and 3–4 ϕ heavy-mineral fractions.

histogram (Fig.4). In comparing the two size fractions, the most notable observation is the preferential concentration of opaques, zircon, and sillimanite within the 3–4 ϕ interval. This finding is in general agreement with the results of Schuiling et al. (1985), who found a relationship between particle size and heavy-mineral species density. Of the minerals they investigated, garnet, epidote, and tourmaline (densities <4.2 g/cm^3) were concentrated in the 2–3 ϕ fraction, whereas rutile, magnetite, ilmenite, and zircon (densities >4.2 g/cm^3) were more prevalent in the 3–4 ϕ fraction. Sillimanite (density = 3.24 g/cm^3), the exception to the "rule" with respect to our samples, should be more abundant in the 2–3 ϕ fraction. Schuiling et al. (1985), however, also noted that particle shape may affect the size versus density correlation: during sieving, elongate minerals may fall into a smaller than expected size class. On the basis of this and the high standard deviation for sillimanite modal data ($s = 5.53$) within the 3–4 ϕ interval, the unexpected sillimanite distribution is resolved. The lower density heavy minerals, kyanite and staurolite, are more abundant in the 2–3 ϕ fraction, as expected.

Total sample heavy-mineral content can be determined from data accumulated by Arthur et al. (1985). These concentrations are, of course, based on certain assumptions, the first being that all heavy minerals within a given sample are within the 2–4 ϕ (0.25–0.063 mm) interval. Thirty-two samples were separated for heavy-mineral content within both the 2–3 ϕ and 3–4 ϕ intervals. Calculated total heavy-mineral content for these samples averages 0.13 wt.%. Projected heavy-mineral concentrations for the remaining samples were calculated by adding an estimated amount of 3–4 ϕ heavy minerals to the known 2–3 ϕ heavy-mineral content. The estimate is based on the assumption that the average proportion of heavy minerals in the 3–4 ϕ fraction (36.2% of the total heavy-mineral content) is a reasonable estimate for the study area. The projected heavy-mineral concentration within the study area, averaging 0.12 wt.% (A.E. Grosz, pers. commun., 1987), is well within one standard deviation of actual values. Although the average projected and actual heavy-mineral contents are similar, projected values for individual samples may not be this accurate (e.g., sample 2–5; actual = 0.365 wt.%, projected = 0.113 wt.%).

It is apparent from these data that the pre-investigation assumptions made in this study, which were based on Carver's (1971) review of the literature, are not ideal for Gulf Coast economic heavy-mineral studies. Specifically, if one were to analyze only the 2–3 ϕ fraction, the calculated weight percent heavy minerals and relative proportions of heavy-mineral species may not accurately reflect that of the total sample. Fortunately, this study analyzed enough 3–4 ϕ sediment fractions to allow for estimation of total sample heavy-mineral content.

Acknowledgements

The new data were developed in cooperation with the Branch of Eastern Mineral Resources, U.S. Geological Survey. A co-operative agreement between the Florida Geological Survey and the Minerals Management Service (contract no. 14-12-0001-30115) provided funding for the initial investigation on which this report is based.

References

Arthur, J.D., Melkote, S., Applegate, J. and Scott, T.M., 1985. Heavy mineral reconnaissance off the coast of the Apalachicola River Delta, northwest Florida. Fla. Bur. Geol. Rep. Invest. 95, 61 pp.

Carver, R.E., 1971. Procedures in Sedimentary Petrology. Wiley–Interscience, New York, 653 pp.

Davis, J.C., 1973. Statistics and Data Analysis in Geology. Wiley, New York, 550 pp.

Donoghue, J.F. and Bedosky, S.J., 1985. Recent sediments of a delta complex, Apalachicola River, Florida. Geol. Soc. Am. Abstr. Programs, 17: 110.

Drummond, S.E. and Stow, H.S., 1979. Hydraulic differentiation of heavy minerals, offshore Alabama and Mississippi. Geol. Soc. Am. Bull., 90: 1429–1457.

Foxworth, R.D., Priddy, R.R., Wendell, B.J. and Moore, W.S., 1962. Heavy minerals of sand from recent beaches of the Gulf Coast of Mississippi and associated islands. Miss. Geol. Surv. Bull., 93: 92 pp.

Friedman, G.M., 1961. On sorting, sorting coefficients and lognormality of the grain size distribution of sandstone. J. Geol., 70: 737–753.

Goldstein, Jr., A., 1942. Sedimentary petrologic provinces of the northern Gulf of Mexico. J. Sediment. Petrol., 12: 77–84.

Harding, J.L., 1960. Heavy mineral occurrences on islands of the Mississippi Sound and adjacent areas of the mainland. Geol. Soc. Am. Southeast. Sect., Abstr. Programs, pp.9–10.

Hsü, K.J., 1960. Texture and mineralogy of the recent sands of the Gulf Coast. J. Sediment. Petrol., 30: 380–403.

Kirkpatrick, G.L., 1982. Statistical analysis of grain size as a possible key to ancient depositional environments. M.S. Thesis, Florida State Univ., Tallahassee, 181 pp.

Leitman, H.M., Sohm, J.E. and Franklin, M.A., 1983. Wetland hydrology and tree distribution of the Apalachicola River flood plain, Florida. U.S. Geol. Surv. Water Supply Pap., 2196-A: 1–20.

Melkote, S.R., Arthur, J.D., Applegate, J.L. and Scott, T.M., 1986. Sediments of the inner continental shelf, northwest Florida. In: W.F. Tanner (Editor), Suite Statistics and Sediment History. Florida State Univ., Tallahassee, pp.22–34.

Murray, G.E., 1960. Geologic framework of Gulf Coastal Province of United States. In: F.P. Shepard, F.B. Phelger and T.H. Van Andel (Editors), Recent Sediments, Northwest Gulf of Mexico. Am. Assoc. Pet. Geol., Tulsa, Okla., pp.5–33.

Schnable, J.E. and Goodell, H.G., 1968. Pleistocene–Recent stratigraphy, evolution and development of the Apalachicola coast, Florida. Geol. Soc. Am. Spec. Pap., 112: 72 pp.

Schuiling, R.D., de Meiser, R.J., Riezebos, H.J. and Scholten, M.J., 1985. Grain size distribution of different minerals in a sediment as a function of their specific density. Geol. Mijnbouw, 64: 199–203.

Tanner, W.F., Mullins, A. and Bates, J.D., 1961. Possible masked heavy mineral deposit, Florida panhandle. Econ. Geol., 56: 1079–1087.

Van Andel, R.H. and Poole, D.M., 1960. Sources of recent sediments in the northern Gulf of Mexico. J. Sediment. Petrol., 30: 91–122.