

Quaternary Coastal History, Basin Geometry and Assumed Evidence for Hurricane Activity, Northeastern Gulf of Mexico Coastal Plain

Ervin G. Otvos

Gulf Coast Research Laboratory
USM Institute of Marine Sciences
Ocean Springs, MS 39566, U.S.A.

ABSTRACT

OTVOS, E.G., 1999. Quaternary Coastal History, Basin Geometry and Assumed Evidence for Hurricane Activity, Northeastern Gulf of Mexico Coastal Plain. *Journal of Coastal Research*, 15(2), 438-443. Royal Palm Beach (Florida), ISSN 0749-0208.



Detailed aspects of the mid-to-late Holocene coastal evolution including identification of the transgressive and/or regressive character of shore-oblique estuarine valley-fill and/or shore-parallel lagoonal and lake deposits are important on the northeastern Gulf of Mexico coast. Evaluation of the valley-fill or lagoonal nature of these depositional basins in southeast Alabama and elsewhere is crucial in deciding the nature of multiple sand layers enclosed in such estuarine sequences. Multiple sand laminae, enclosed in organic-rich estuarine-lagoonal and lacustrine clays and muds beneath Gulf coastal lakes have been presented as proxy indicators of cyclically recurring Category 4 and 5 hurricanes, believed to have struck the coast periodically, following subdued hurricane activity before 3.2 ka BP (LIU and FEARN, 1993, 1997).

Subsurface data, combined with those of Liu and Fern indicate that most of the sand laminae cited from sediments beneath Shelby Lakes were deposited in an estuarine valley fill, *not* lagoonal deposits. This occurred well before the original Shelby Lakes formed by prograding late Holocene strandplain ridges that mark the progressively seaward shifting Gulf of Mexico shoreline positions. Marsh islands in western Lake Shelby indicate that erosion of beach ridges around the originally smaller lagoons has gradually expanded them. Distances of probable storm overwash from the Gulf even into these early lagoons thus are not comparable with those that occasionally take place at the present time. In addition to providing important data for coastal evolution, the morphological and stratigraphic evaluation of coastal water bodies illustrate constraints in the reconstruction of prehistoric hurricane activity.

ADDITIONAL INDEX WORDS: Coastal evolution, lagoon, estuary, strandplain, storm cyclicality, Holocene.

INTRODUCTION

Newly evaluated subsurface data in combination with data by LIU and FEARN (1993) provided new insights for the understanding of the mid-to-late Holocene events in the Shelby Lakes region of southeastern Alabama. Beyond the detailed reconstruction of coastal history in the area, it is also important to establish the lagoonal or estuarine valley-fill character of lithosomes that have been associated with present coastal water bodies by the two authors. Nationwide professional, even public interest had been drawn to their suggestion of cyclic "extreme" events (Hurricane Category 4 and 5 storms) during the past three millenia and their expected return in the near future. A recent publication (LIU and FEARN, 1997) cited similar evidence from adjacent northwest Florida. More papers were expected to follow along these lines.

Our drillcore samples and surface field work from the Shelby lakes area indicated the thin nature of Holocene deposits that overlie the Pleistocene at shallow depths. Between our drillhole locations, LIU and FEARN (1993) encountered a much thicker unconsolidated Holocene sequence in cores drilled. They identified these muds that enclose numerous

sand laminae and thin beds as having been deposited in the ancestral Shelby Lakes. Comparing present storm deposits with those of the past, LIU and FEARN recounted that while Category 3 Hurricane Frederic deposited a 9 cm thick wash-over bed along Lake Shelby's south shore in 1979, Core E and short cores in the central and northern lake areas contained no laminae attributable to Frederic's overwash (Figure 1). Because the distance from the present Gulf shoreline to the Core E drill site is much greater than to the Frederic's wash-over location, overwash of an extreme hurricane was claimed as the mechanism to emplace sand laminae in the 9 m thick clay sequence of Core E.

Five of the six radiocarbon dates from disseminated organic matter in bulk samples in Core E suggested a recurrence interval of *c.* 600 yr for Category 4 and 5 Gulf hurricanes to Liu and Fearn. A review of the radiocarbon dates and our own subsurface and surface data compelled me to reexamine the nature and formation history of this coastal area, including that of the pertinent coastal water bodies, in view of what is now known about the Quaternary deposits beneath and in the vicinity of the lake.

Study Methods

Relevant lithologic and microfossil data, published and/or provided by LIU and FEARN (1993; FEARN, *written comm.*,

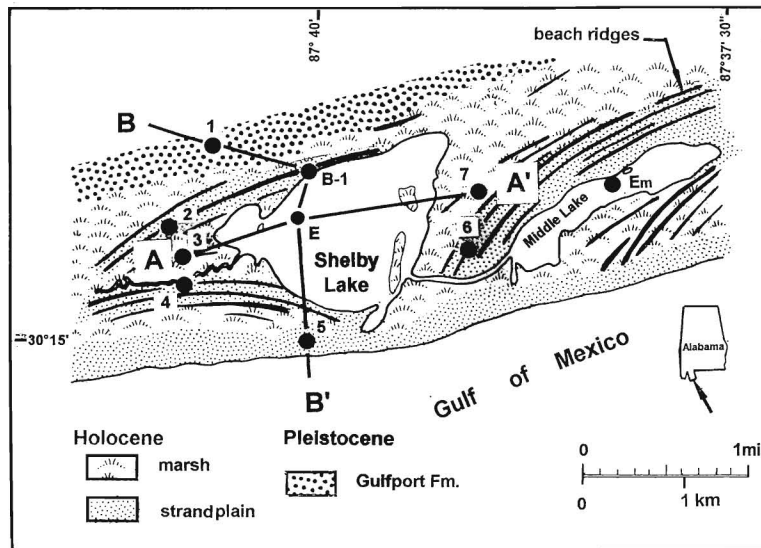


Figure 1. General geology and GCRL drillhole locations in Gulf State Park, Shelby Lake-Middle Lake area, Alabama (Otvos, 1985). Lake corehole location after Liu and Fearn (1993). Cross sections: Figures 2a,b.

1997), from nine of our own Alabama-Florida coreholes (Otvos, 1997) and my field work, including several publications, have been utilized in reconstructing the Quaternary local geological history.

In referring to the lakes I follow Liu and Fearn's changed designations and use the name "Shelby" for the western one of two Shelby Lakes (Gulf Shores 7.5 min. USGS topographic quadrangle). East Shelby Lake is cited as "Middle Lake".

QUATERNARY EVENTS, LAKE SHELBY AREA, ALABAMA

Late Pleistocene

Three distinct formations, widespread along most of the northern Gulf coast represent the late Pleistocene coastal plain interval (Otvos, 1991). The Sangamonian transgressive hemicycle emplaced muddy-sandy sediments of the Biloxi Formation in a series nearshore-inshore depositional facies. The Biloxi, underlain by earlier Sangamonian fossil-free alluvial Prairie deposits locally is covered by the Gulfport coastal barrier, in turn capped by steep dune ridges, probably of Wisconsinan full-glacial age. With their addition, the ridge reaches +12 m (+40 ft) maximum elevation (Otvos, 1991, 1997).

Muddy sands of the alluvial Prairie regressive phase underlie the Pleistocene land surface north of the Pleistocene barrier. Post-Sangamonian surface erosion seaward of the Gulfport barrier eliminated Prairie deposits above the Biloxi Formation. The Pleistocene surface deposits became oxidized during the long Wisconsinan-early Holocene marine lowstand. Highly oxidized, dark yellowish-orange (10YR6/6), fossil-free, and undifferentiated Neogene sediments consist of granular sands and sandy clays beneath the Pleistocene units in two coreholes.

The Pleistocene coastal plain in Alabama and northwest Florida, directly underlain by the three late Pleistocene formations, had been referred to as the "Pamlico terrace". This term, first used on the Carolina coast, was imported to the Gulf by COOKE (1945). Originally, it designated a young Pleistocene coastal marine surface on the Atlantic seaboard. Because of the Prairie's alluvial origins and questions regarding the long-distance morphostratigraphic correlation of the Pamlico, that term's further use on the Gulf coast is not advisable (Otvos, 1997).

The buried Pleistocene land surface displays a marked southwesterly-southerly slope (Figure 1). Thick Holocene "lagoonal" clays under Shelby and Middle Lakes (LIU and FEARN, 1993), surrounded by Pleistocene deposits (Otvos, 1985) reveal the deep incision in the Pleistocene land surface. Headward eroding steep-walled creek valleys formed during the Wisconsinan lowstand (Figures 2a,b, and 3). With the inadequate constraint imposed by our limited drillcore coverage, the configuration of the incised valley network is still largely conjectural (Figure 3).

An analogue of this deeply cut valley system, formed not by major streams, only sizable large creeks, is represented by landward-elongated, estuarine pond-filled narrow valleys in the Destin-Point Washington area of the Florida Panhandle (Figure 4; Alligator, Big and Little Redfish and a host of other lakes; USGS Grayton Beach and adjacent quadrangles). These subsequently drowned valleys end on high ground a short distance inland. Several of the Destin-Grayton Beach area lagoon/lake basins were incised 13-to-20.0 m (40-to-60 ft) below the Gulfport barrier surface.

HOLOCENE

(a) Estuarine Stage

LIU and FEARN (1993) described homogeneous, gray lagoonal deposits with 95-98% clay and little fine sand content.

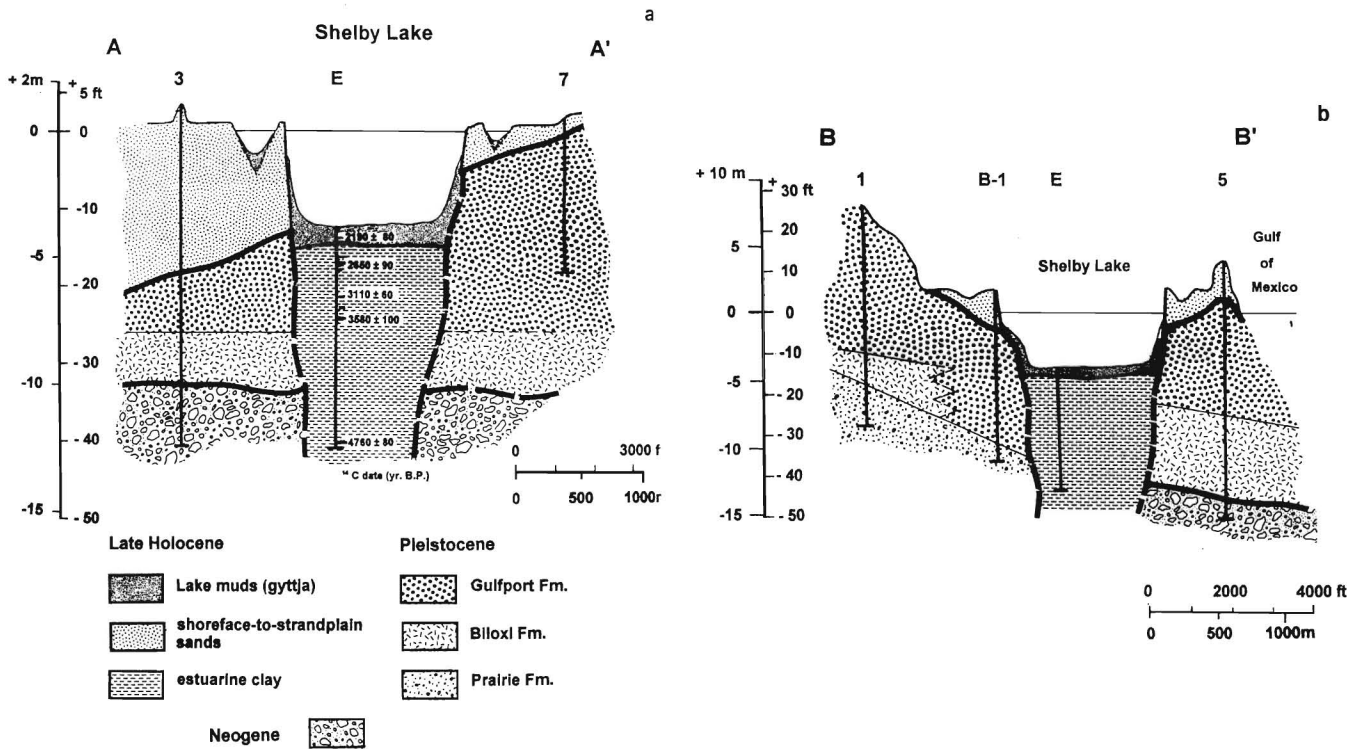


Figure 2. Geologic cross sections across Shelby Lake. Core E, with radiocarbon dates of Liu and Fearn (1993). (a)-West-East; b-North-South cross sections (see: Figure 1).

The combined subsurface data now shows that the receiving basin was not a relatively shallow shore-parallel lagoon but a deep, essentially shore-normal or shore-oblique, narrow valley, the total length and exact position of which to be established in the future. (Figures 1–3). The overwhelmingly clayey composition of the estuarine fill indicates that landward-

directed tidal and storm-tidal sand transport and deposition may not have played a noticeable role until the shoreline gradually reached the vicinity of the present Shelby Lake area. This landward extended, elongated water body presumably was well sheltered and out of reach of hurricane washovers. The source of the enclosed sand laminae appear to

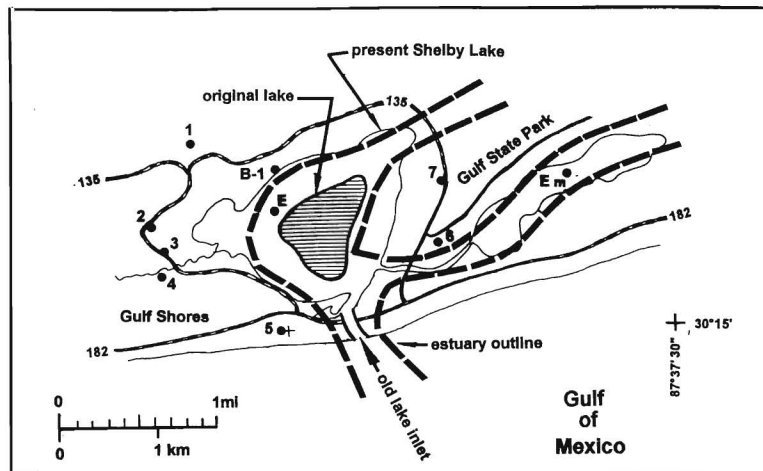


Figure 3. Conceptualized outline of pre-lacustrine Late Holocene estuary and initial Shelby Lake cusped lagoon in Shelby-Middle Lake area, Gulf Shores, Alabama.

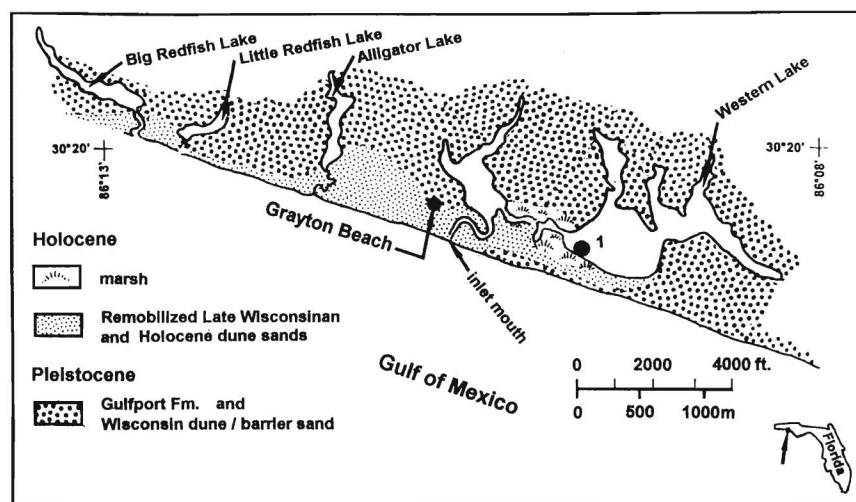


Figure 4. Geological setting of Western Lake area, northwest Florida. GCRL corehole: Grayton Beach. Lake Core #1 position provided by Liu and Fearn (*written commun.*).

have been bank erosion and storm tidal flow, including winnowing.

With the steady approach of the Gulf shoreline during later stages of the late Holocene transgression, salinities first gradually rose in the estuarine arms. Core E was too short to include most of this stage. With increased local runoff salinities may then decrease. Lacking foraminifer data, the diatom floras (FEARN, *written comm.*) only hint at such trends in Core E. Salinities abruptly declined above the "3580 yr level", to peak again before the end of the estuarine phase. A single maize pollen in Core E was claimed as the earliest (3500 yr BP) indication of corn cultivation in eastern North America (FEARN and LIU, 1995, 1997).

LIU and FEARN (1993) suggested a 4.8–2.2 ka BP age range for their 815-cm interval in Core E, assumed to be of lagoonal origin. In excess of ten, 0.1–1 cm thick sand laminae, distributed throughout this "lagoonal" interval suggested to them landfall by numerous Category 4 and/or 5 extreme hurricanes within 50 km of Lake Shelby. Lithologic, stratigraphic data and radiocarbon dates were not available from the 9.34-m Middle Lake core.

(b) Marine Highstand, Strandplain Progradation

As rising Gulf waters gradually covered the Pleistocene land surface and the clayey valley-fill, a Holocene seashore was established along the foot of the Gulfport barrier. A 2 km wide strandplain prograded between the Gulfport barrier and the present beach backshore during the ensuing depositional regression (OTVOS, 1985, 1997). Several beach ridge generations defined the shores of the original, triangular-shaped Lake Shelby lagoon in the center of a large cusped spit. In contrast, ancestral Middle Lake occupied a low between two parallel beach ridge generations (Figure 1).

(c) Lake Formation and Expansion

A transgressing surf zone is assumed to have formed a ravinement surface as it overrode and beveled the surficial Holocene estuarine beds. LIU and FEARN (1993) did not notice an erosional unconformity at the interface between the thin lake sediment interval and the underlying gray estuarine clays. However, the early estuarine and the much younger lake shores clearly represent two separate stages of events. The presence of Recent hurricane overwash deposits in the lake has no bearing on assumed overwash events into the ancient estuarine body.

Remnants of sandy shoreface deposits and the underlying ravinement surface that formed during the transgression may be preserved in the subsurface. The 55–85 cm thick, organic-rich "lake" muck, its diatom fauna including fresh water, brackish, and marine taxa (FEARN, *written comm.*), post-dates 2.2 ka BP (LIU and FEARN, 1993). Multiple sand laminae were reported from this "gyttja" interval in the short Shelby Lake cores as well.

Marshes developed along the lake shores, covering inter-ridge lows and lower beach ridges. Several remnant marsh islands appear to outline the early Shelby lagoon, with directly overlying shallow Holocene beach ridges. Erosion of the marsh and beach ridge shores in the past two millennia have gradually expanded Shelby, Middle, and the other lakes (Figure 3).

SAND LAMINAE IN ESTUARINE AND LACUSTRINE DEPOSITS—MARKERS OF CYCLICALLY RECURRING EXTREME HURRICANES OR OTHER EVENTS?

Liu and Fearn assume that sand laminae represent wash-over deposits by extreme hurricanes in a preexisting lagoon and lakes. However, the absence or relative scarcity of sand

laminae and thicker layers in estuarine lithosomes is not necessarily a proof for "fewer and weaker hurricanes before 3.2 ka". Instead, it should be attributed to the greater distance of a sheltered, low-energy, upper estuarine reach from its associated, coeval Gulf shoreline. The varied sources and emplacement conditions of sand laminae in the lacustrine sediments is another matter. They hardly present incontrovertible proof for extreme hurricane activity.

Beach ridge shores contributed sand to the lake bottom during periods of wave-induced shore erosion and lake expansion. Sparsely vegetated barrier surfaces and dunes, eroded by rainstorm wash may also provide sand sources in the periphery of lakes and tidal estuaries. Wind-induced current-winnowing of sandy bottom muds would also produce sand laminae. Wave fetch and with it wave dimensions increase with expanding lake areas. Without having to assume direct storm overwash, recurring tidal and storm-tidal currents through Gulf-connected inlets may represent another sand source.

Deposits, such as the 9 cm thick, laterally extensive sand layers, produced by Hurricane Frederic and emplaced in lake muds along Lake Shelby's south shore (LIU and FEARN, 1993) would provide the strongest evidence yet for hurricane overwash. However, it is impossible to distinguish between sand laminae from the direct "hit" by a Stage 1 hurricane, on one hand, and on the other, the powerful glancing effect of an extreme hurricane; its center passing at some distance from the lake basin. Another vital factor is the pre-landfall path of a given hurricane. The cyclone quadrants that pass over a given lake or estuary do determine landward- or Gulfward oriented wind- and overwash directions and the location of the resulting washover. Because two millenia ago both the lake and Gulf shores had been located much closer to the cited Shelby and Middle Lake core sites than presently, sand sources for storm overwash and transport through passes were much closer to the depositional sites than the 1.5 km distance between Corehole E and the present Gulf shore. For example, the initial horizontal distance between newly formed Middle Lake, site of another Liu and Fearn-long piston core, and the regressing coeval Gulf shoreline, backed by periodically overwashed foredune ridges seaward of the Lake, may not have exceeded two hundred meters.

SEA-LEVEL POSITION AND RADIOCARBON DATES OF SAND LAMINAE

The Late Holocene Gulf level curve is essential in evaluating the validity of claims by Liu and Fearn. In very close agreement with the sea-level curve of NELSON and BRAY (1970, p.66) that itself conforms with other eustatic curves for the last few millenia, our peat date from the nearby Back Bay of Biloxi estuarine sequence places the 5700 yr BP sea-level at -6.9-7.5 m (23-to-25 ft; OTVOS, 1985, p. 37). The 3500 yr BP, time point on the curve provided a -1.5 m (-5 ft) sea-level position from a wood or peat sample. Except in the Mississippi delta region, the Gulf level is generally accepted as having been essentially unchanged or very close to the present during the last two millenia. That time interval coincided with progradation of the Alabama-northwest Flor-

ida strandplains and their sharp erosional truncation by the present straight Gulf shoreline in most recent times (OTVOS, 1985, 1991).

LIU and FERN accumulated a large number of radiocarbon dates from numerous lake cores. Unfortunately, nearly all Core E (Shelby Lake, AL) and Core #1 dates (Western Lake, Grayton Beach, FL) were based on very few bulk samples, composed of finely disseminated organic matter, prone to contamination by admixed older organics (Figure 2a). These samples came from <10 cm core intervals (LIU, *written comm.*, 1997). This precludes a reliable age interpolation by finely tuned dates that bracket sand laminae.

A mere six unevenly spaced radiocarbon dates were accepted as valid by LIU and FEARN from Core E. An example for inconsistent dates comes from the comparison of the 4760 yr BP date, at c. 12.5 m (c. 41 ft) below present sea-level (Figure 2a). Because sea-level reached -12.5 m by c. 6200 yr BP and rose to c. -3.6 m (12 ft) by 4760 yr BP (NELSON and BRAY, 1970), this would mean that no deposition took place in the estuary for a period of 1400 years. Alternately, it would indicate the subsequent total removal of the accumulated sediments by some unknown process. One may regard the date as suspect. Another questionable date, 4930 yr. BP, came from Liu and Fearn's Western Lake Core #1 at 6.0-6.3 m (20-21 ft) below sea-level (Figure 4). According to the Nelson-Bray curve, the Gulf level exceeded this elevation approximately a millennium earlier.

WESTERN LAKE, GRAYTON BEACH, NORTHWEST FLORIDA

This estuarine lake occupies the upper reach of a branching valley network, incised in the Gulfport barrier. A c. 18 m (60 ft) thick, moderate yellowish-brown, very light tan, to humate bearing dusky yellowish brown moderately well, well-to-moderately-poorly sorted medium sands represented the Gulfport Formation in our Grayton Beach drillhole (Figure 4). The Gulfport land surface rises to 7.5-to-9 m (25-30 ft). Steep Wisconsinan dune ridges locally overlie the barrier surface and reach 15-to-23 m elevation (50-to-74 ft; OTVOS, 1997).

Western Lake is connected to the Gulf by a meandering inlet that may have repeatedly switched its position in the past. A wide, active dune zone provides the barrier with abundant sand supply and blocks the inlet entrance periodically. Storm overwash, as during Stage 3 Hurricane Opal in 1995, may repeatedly reopen it. Pertinent stratigraphy, depositional facies, and lithologic information are not yet available from the lake cores. No mention was made of earlier estuarine beds, resembling those beneath Shelby Lake.

45 m (145 ft) north of the southern lake shore LIU and FEARN (1997) noted numerous sand laminae emplaced in the organic lake mud in Core #1 (Figure 4). Core #1 was drilled prior to Hurricane Opal, 25 m north of a post-Opal core that *did* include sand laminae from Opal's overwash. In the author's words, "if sea level was not drastically different from the present, this implies that during 5000-3400 yr BP hurricanes affecting the Grayton Beach area were less intense and probably less frequent than in the subsequent period".

LIU and FEARN (1997) assumed that sand laminae, attrib-

utable to the Hurricane Opal overwash were *not* deposited at the Core #1 site and laminae found in Core #1 are attributable to extreme hurricanes, more intense than Opal. No cores were obtained after Opal at the Core #1 site to test this assumption.

The source of the sand laminae, just as in the Lake Shelby area, may have been related to diverse factors other than rare extreme hurricanes. In the 5–3 ka BP interval the Gulf barrier beach and the inlet entrance existed significantly seaward of their most recent positions. Sand transport to the lake would have been facilitated by rainwash-related dune erosion, different inlet positions and dimensions, and lower dune crest elevation Gulfward to promote storm overwash.

CONCLUSION

The detailed study of Holocene coastal plain stratigraphy, primarily including the outline and position of pertinent estuarine water bodies and associated sedimentary sequences may be vital in for judging Holocene storm frequencies and intensities in certain coastal sectors. This evaluation helps to establish restraints in providing evidence for alleged tropical storm overwash episodes and their suggested long-term cyclicity, reflected by these sediment sequences.

A critical review of late Quaternary evolution and sea-level history, employing subsurface stratigraphy of the estuarine and lake basins in the Alabama and Florida coastal areas provides no compelling proof to suggest that multiple sand laminae found in valley-fill and lacustrine clay and mud lithosomes resulted from recurring extreme hurricane events. These sediment units may be attributed to a number of common processes.

LIU and FEARN (1993, 1997) based their assumptions of past extreme hurricanes on the position of Lake Shelby and recent hurricane washover deposits encountered on the southern lake bottom. However, the landward elongated, pre-existing valley network and the estuary that subsequently filled it were unrelated to ancestral Lake Shelby and Middle Lake, let alone present-day Lake Shelby. The shore positions around ancestral Lake Shelby and Middle Lake had been determined by strandplain ridges that formed during the late Holocene depositional regression.

Sand laminae and thin layers enclosed in estuarine and lacustrine muddy sediment sequences may owe their source material and development to sedimentary processes other than very rare extreme hurricane overwash events. Dating

of finely disseminated organic matter, open to contamination by reworked and admixed substances creates another problem. The handful of unevenly distributed dates, mostly from disseminated organic matter and of questionable accuracy, were insufficient for establishing the exact age of bracketed sand laminae and their suggested 600-yr cyclicity.

In all, the geometric configuration and presented history of small coastal sedimentary basins provided no compelling evidence for increased and cyclically recurring tropical cyclonic activity in the Gulf during the past 3400-to-3200 yrs and for a projected "600-year storm" to impact the northern Gulf coast in coming decades.

ACKNOWLEDGMENTS

Mr. Wade E. Howat conducted our core drilling operations in the Lake Shelby and Grayton Beach areas and analyzed sediment and microfossil samples. He also drew the present illustrations and helped to correct the manuscript. I thank Drs. Kam-biu Liu and Miriam Fearn for kindly providing information on their diatom and radiocarbon data.

LITERATURE CITED

- COOKE, C.W., 1945. Geology of Florida. *Florida Geological Survey Bulletin*, 29, 339 p.
- FEARN, M.L. and LIU, KAM-BIU, 1995. Maize pollen of 3500 B.P. from southern Alabama. *American Antiquity*, 60, 109–117.
- FEARN, M.L. and LIU, KAM-BIU, 1997. Identification of maize pollen: Reply to Eubanks. *American Antiquity*, 62, 146–148.
- LIU, KAM-BIU and FEARN, M.L., 1993. Lake-sediment record of late Holocene hurricane activities from coastal Alabama. *Geology*, 21, 793–796.
- LIU, KAM-BIU and FEARN, M.L., 1997. Lake sediment record of Hurricane Opal and prehistorical hurricanes from the Florida Panhandle. 22nd Conference on Hurricanes. *American Meteorological Society*, May 19–23, 1997, Fort Collins, Colorado. Preprint #9c.5, p. 397–398.
- NELSON, H.F. and BRAY, E.E., 1970. Stratigraphy and history of the Holocene sediments in the Sabine-High Island area. Gulf of Mexico: Deltaic Sedimentation, *SEPM Special Publication*, 15, 48–77.
- OTVOS, E.G., 1985. Coastal Evolution: Louisiana to Northwest Florida: Guidebook. *New Orleans Geological Society*, 91p.
- OTVOS, E.G., 1991. Quaternary Geology of the Gulf of Mexico Coastal Plain (with J.R. DUBAR and others). The Geology of North America, *Decade of North American Geology*, v. K-2. *Geological Society of America*, p. 583–610.
- OTVOS, E.G., 1997. Northeastern Gulf Coastal Plain Revisited. Neogene and Quaternary Units and Events—Old and New Concepts. *New Orleans Geological Society-Gulf Coast Association Geological Societies*, Field Trip Guidebook, 143p.