Journal of Coastal Research	14	2	669–674	Royal Palm Beach, Florida	Spring 1998

DISCUSSION

Discussion of: Otvos, E.G., 1995. Multiple Pliocene-Quaternary Marine Highstands, Northeast Gulf Coastal Plain—Fallacies and Facts. *Journal of Coastal Research*, 11, 984–1002

Joseph F. Donoghue, Frank W. Stapor, and William F. Tanner

Department of Geology
Florida State University
Tallahassee, FL 32306
(phone: 904/644-2703)
(email: donoghue@gly.fsu.edu)

Department of Earth Sciences
Tennessee Technological
University
Cookeville, TN 38505

Department of Geology
Florida State University
Tallahassee, FL 32306

ABSTRACT

DONOGHUE, J.F., STAPOR, F.W., and TANNER, W.F., 1998, Discussion of: Otvos, E.G., 1995. Multiple Pliocene-Quaternary Marine Highstands, Northeast Gulf Coastal Plain—Fallacies and Facts. *Journal of Coastal Research,* 14(2), 669–674. Royal Palm Beach (Florida), ISSN 0749-0208.

This paper discusses a manuscript by Otvos (1995). The original paper attempts to draw parallels between Mississippi–Alabama Neogene units and those of north Florida, despite significant differences in depositional setting and style. The original paper additionally presents some arguments regarding sea-level history and terrace origins which we consider to be tenuous. We present here various lines of evidence which were not considered in the paper and which led to quite different interpretations of the sedimentologic history of north Florida.

INTRODUCTION

Depositional styles on the margins of the northern Gulf of Mexico basin vary considerably from west to east. The Texas coast is dominated by small to medium-size rivers and their deltaic deposits. Sedimentologic development of the Louisiana–Mississippi–Alabama coast has been heavily influenced by the Mississippi River and the sequence of deltas that it has occupied throughout its history. The Florida Panhandle coast is influenced by small rivers and deltas to the west and one large river to the east, the Apalachicola. The Florida peninsula is a stable carbonate platform, with sediments becoming more calcareous with distance south.

The significant difference in depositional regimes from west to east is manifest in various ways. Modern subsidence rates and coastal sediment deposition rates are probably representative of the long-term Neogene rates that have influenced the lithology and thickness of coastal sediment units. Geodetically-measured subsidence rates on the Mississippi delta region are high—4–5 mm/yr. In contrast, subsidence rates on the north Florida coast are 1 mm/yr or less (HOLDAHL and MORRISON, 1974). Modern coastal sedimentation rates are likewise high along the Mississippi Delta coast, typically 10–25 mm/yr (CAHOON *et al.,* 1995). Coastal sedimentation rates on the north Florida coast are considerably less, typically 1–10 mm/yr (DONOGHUE, 1993; HESS, 1995; HIGHLEY, 1995; CAHOON *et al.,* 1995).

Comparing the Mississippi River coast and the coast of north Florida, it is difficult to conceive of two sedimentologically more disparate coastal regions on the margins of the same basin: to the west in Louisiana and Mississippi a rapidly subsiding coast dominated by the deposits of the largest river on the continent; to the east in Florida a relatively sediment-starved and stable coast on the flanks of a carbonate platform. OTVOS (1995) attempts to draw parallels between the Neogene of Mississippi-Alabama and that of north Florida despite these substantial differences. For the reasons stated above, the two coastal regions vary considerably in depositional history and the correlations must therefore be considered tenuous. Otvos additionally has put forth some arguments regarding sea-level history and terrace origins which we consider to be equally tenuous. We welcome this opportunity to discuss what we believe are some factual and philosophical flaws in those arguments.

PLEISTOCENE TERRACES

Pre-Sangamonian Barrier Deposits

One of the major points made by Otvos (OTVOS, 1995, Pp. 987–992) is that arcuate sand bodies found at elevations of 6

97086 Received and accepted in revision 23 May 1997.

meters and 9 meters MSL in the Apalachicola Delta region of north Florida are not terrace deposits representing possible pre-Sangamonian barrier islands. BRENNEMAN (1957) and BRENNEMAN and TANNER (1958) had identified them as such, on the basis of texture, size, shape, elevation, and geographic location. Additionally, an ionium-disequilibrium date from one of the terraces indicated that the deposits were older than Sangamonian (MAXWELL, 1971a, 1971b).

Otvos attributes the origin of the terraces, in part, to railroad beds (OTVOS, 1995, p. 988). Abandoned logging railroad beds do in fact follow parts of the terraces, which would make sense in building a railroad through a swamp. The railroad beds and the terraces diverge, however. This raises the question as to why the railroad builders would have built embankments and then not put railroads on them. Also, why lay out a railroad in an arc through a swamp? All of the logging roads in the area (as seen in OTVOS' Figure 4) are straight. Only the path of the railroad bed is curved, and it is the only arcuate feature in the region.

As seen on black-and-white vertical aerial photography (Edgar Tobin aerial survey, 1941; scale 1:24,000), these sand bodies are typically 200–300 meters wide, which would represent a tremendous waste of effort if they had been created solely by loggers. Furthermore, where relatively wide swamps interrupt the continuity of each ridge, the true constructed width can be seen: less than 10 m. Otvos assumed that the builders constructed some stretches of embankment 200–300 m wide, where clearly (in other places, nearby) a width of 10 m or less was sufficient. The correct interpretation is that loggers used as much of a preexisting feature as they could; hence that feature is not a railroad embankment.

Otvos' alternative explanation for how these arcs came to be formed by dissolution of the underlying carbonates (OTVOS, 1995, Pp. 988–991) is tortured. If this mechanism is important in the geomorphologic development of the region, there should certainly be many of these such features. There are not.

Otvos also invokes tectonics and related karst processes as contributing to the formation of the ridges (OTVOS, 1995, Pp. 990–992). The explanation is tenuous, requiring parallel sets of hypothetical fractures. There is no documentation for the existence of such fractures. None of them apparently showed up in Otvos' dozens of boreholes in the region, nor in the dozens of stratigraphic core tests described by SCHMIDT (1984) and HUDDLESTUN (1976).

There is a major point regarding the terraces which Otvos has ignored. They have been field-mapped by MACNEILL (1949), SCHMIDT (1984), and most recently by SCHUSTER (in press), as discrete units that are sedimentologically and geomorphologically distinct from the surrounding deposits. MACNEILL'S (1949) publication is a USGS Professional Paper on Florida Pleistocene shorelines. SCHMIDT'S (1984) publication is a Ph.D. dissertation on the Florida Neogene by the State Geologist of Florida. The last reference is the USDA Soil Survey of Franklin County, Florida, the county in which the terraces occur. Draft versions of it have been available for many years. None of the above three references is cited by Otvos.

Tectonism

OTVOS (1995) states that no pre-Sangamonian Pleistocene coastal deposits are found on the northeastern Gulf Coastal Plain. Tectonic uplift and erosion are given as the reason for the absence of deposits older than Sangamon. The paper implies (OTVOS, 1995, p. 987) that geodetic leveling surveys indicate that uplift continues to the present day, as described by HOLDAHL and MORRISON (1974). In reality, HOLDAHL and MORRISON'S evidence shows that there is no ongoing uplift in the northeastern Gulf Coastal Plain, and in fact slight subsidence is occurring.

ORIGIN OF NORTH FLORIDA TERRACES

Otvos states that the work of GOETSCHIUS (1971) on the sedimentology and origin of northwest Florida terraces was "unsuccessful", and implies that the "poor" results were due to lack of stratigraphic control (OTVOS, 1995, p. 986). In fact, the work of Goetschius was based on samples all of which were taken from individual sand bodies, and the procedure was granulometric. Furthermore, the work of Goetschius was replicated in a later project, which produced essentially the same results (Outler, B., and Tanner, W.F., unpublished data). Therefore the work of Goetschius has been verified independently, and was successful.

The sediment texture data in Goetschius' study (GOETSCHIUS, 1971) show, for example, that the NW Florida terrace at 50 meters MSL had a primarily marine origin. The "surf break" on the granulometric probability plots is reliable evidence for surf-and-swash work (first reported by Fuller, 1961, and confirmed in field experiments by TANNER, 1966). The fourth moment measure (kurtosis), examined in terms of the mean value of this parameter, as well as its standard deviation, indicated moderate-to-high wave energy (TANNER, 1995, p. 131; the 50-meter terrace plots at kurtosis mean of 4.28, and standard deviation of 1.18). There is no significant support in the granulometric data for any other origin.

Otvos continues to promote his unique hypothesis that linear features in the Florida Panhandle, including the terraces, had a tectonic origin. His evidence is that "continuity, linearity and relatively fresh appearance . . . suggest their tectonic origin" (OTVOS, 1995, p. 986). By these criteria, almost all of the beaches, individual beach ridges and marine terraces around the Gulf of Mexico would have had a tectonic origin, which clearly is not the case.

Peculiar hypotheses abound in the paper by Otvos: for example, the reference to "coast-parallel terraces of alluvial origin" (OTVOS, 1995, p. 987). The terraces studied by GOETSCHIUS (1971) are "coast-parallel," but they are clearly not of alluvial origin. Their location on both sides of the earlier mouth of the Apalachicola River, in a well-known "cuspate foreland" coastal pattern, should make this clear. However, the granulometric work is definitive as to the origin.

IDENTIFICATION OF HIGHSTAND DEPOSITS

Facies Identification by Sedimentary Structures

OTVOS (1995, Pp. 994–995) states that the *strike or transport perpendicular view* of coastal dune slip-face deposits may mimic the semiparallel horizontal and low-angle cross laminations characteristic of swash zone deposits. He implies that this *two-dimensional geometry* is therefore suspect as an indicator of an intertidal, swash-zone origin. This argument is most puzzling because any confusion as to a structure's actual three-dimensional geometry can be resolved simply by cutting an additional "view" or section perpendicular to the first. This is a trivial matter in unconsolidated sand, although a more difficult task in lithified material.

Of course, the easiest solution is to look at transport-parallel sections where slip-face laminations are readily discernible from swash-zone laminations by both the angle and direction of inclination. Because the transport direction in a coastal sand ridge is basically perpendicular to its crest—which is aligned essentially parallel to the shoreline—transport-parallel sections are not common even on eroding coasts. The identification in a coastal sand ridge of semiparallel horizontal laminations and, especially, seaward-dipping, low-angle cross laminations are compelling arguments for an intertidal, swash-zone origin. These two sedimentary structures overwhelmingly characterize beach ridges described by STAPOR (1975) in the Florida Panhandle and by STAPOR *et al.* (1991) in southwest Florida.

Geomorphic Argument, Origins of the Shell Component

OTVOS (1995, p. 995) argues that narrow, 2–4 m high sand ridges are beach foredunes because of their height and steep slopes. He illustrates this contention with photographs of ridge roadcuts from Cape San Blas (his Figure 7A) and St. Joseph Spit (his Figure 7B), both in Gulf County, Florida, but does not provide any additional data to support his foredune origin. STAPOR (1975) was able to differentiate among beach, dune, and ridge sands on the basis of granulometric characteristics (the first four moment measures); furthermore, the ridge sands were granulometrically more similar to beaches than they were to dunes. The ridge internal-structure data presented by STAPOR (1975) is overwhelmingly dominated by low-angle, seaward inclined, planar laminations that extend horizontally for several meters. The linear, continuous, symmetric, and smooth or non-hummocky gross geomorphology argues against an eolian origin. STAPOR (1975) concluded that these sand ridges were primarily marine in origin and are beach ridges (see TAYLOR and STONE, 1996, for a comprehensive review of beach ridges).

It is somewhat ironic that the ridge shown by OTVOS (1995) in his Figure 7A is the only example in which STAPOR (1975; the Embankment Ridge in his Figure 2) found evidence to support a "mixed" origin involving both eolian and marine processes. Clearly then, coastal sand ridges can be eolian, marine, or "mixed" in origin. However, because eolian and marine processes result in markedly different granulometries, geomorphologies, and internal structures, a marine-formed ridge should and can be distinguished from an eolian-formed ridge.

Granulometric Methods

Otvos objects to the use of granulometric methods because of the "lack of objective, empirical field comparison and verification, based on a sufficiently large number of samples, obtained from a variety of modern depositional environments" (OTVOS, 1995, p. 994). The granulometric procedures on which this type of analysis is based, come from the study of thousands of samples from modern environments, including various beaches having different wave energy levels, sand dunes, rivers, and others (TANNER, 1995).

EVIDENCE FOR HOLOCENE HIGHSTANDS AT NORTHEAST GULF COASTAL SITES

Holocene Scarp and Terrace Pairs

OTVOS (1995, Pp. 992–993) considers the suite of elevated scarp and terrace pairs, cut into Pleistocene coastal deposits, that occur scattered along the entire length of the Florida Panhandle coast to have resulted from storm surges. He rejects the marine highstand interpretation of STAPOR (1975). Both agree that their "fresh appearance" necessitates a Holocene rather than a Pleistocene age. Otvos invokes a storm-surge origin, which is attractive in its simplicity. Certain factors are troublesome to a storm-surge hypothesis, however: (1) the existence of these scarp and terrace pairs within bays sheltered by Pleistocene barriers, *i.e.* Apalachicola Bay (East Point); (2) their restricted range in elevation, about 1.5 to 2.0 m; (3) their occurrence adjacent to narrow lagoons fronted by modern barriers, *i.e.,* Alligator Harbor in Franklin County and the Pensacola Navy Base area in Escambia County; and (4) their complete absence on any of the Holocene barriers.

How is the storm-surge elevation maintained long enough in the sheltered bays for their much less energetic waves to carve a terrace many meters wide? Are the scarps and terraces which are also adjacent to narrow lagoons older than the Holocene barriers? If not, then the previous sheltered-bay concern applies. Why is there only this narrow range of terrace elevations, given the potentially much greater range of surge elevations? Why have the Holocene barriers been spared this type of geologic activity over the past 2,000 to 3,000 years? These concerns—in addition to the observation that at the seaward end of every Florida Panhandle locality there was a modern cliff with a toe elevation at or very near MLW (see Figure 9 of STAPOR, 1975)—call into question any storm-surge hypothesis.

An erosional geomorphic feature is younger than the material it truncates and older than a truncating feature or blanketing deposit. Datable materials from a blanketing deposit provide the best minimum-age estimate for the erosion. Scarp cutting can be no younger than the age of the blanketing deposit. Along the Florida Panhandle coast the only potentially blanketing deposits that contain datable materials are aboriginal shell middens. However, whether a midden actually blankets a terrace or has been truncated by the terrace, as argued by OTVOS (1995, p. 992), can be a difficult question to resolve. It should be expected that midden material will extend down into the substrate as well as incorporate substrate material in its matrix. The upper surface is the critical one: is there evidence of wave-reworking and/or submergence in addition to the expected disturbance produced by subaerial exposure?

Water-worn sherd artifacts in the context of an original subaerial midden would be a convincing argument; the presence of significant quantities of non-food, marine shells would be indicative of submergence (Marquardt, W.H., Florida Museum of Natural History, personal communication). WILLEY (1949) does not report any water-worn sherds from his examination of 106 sherds from the Nine-Mile midden (9 miles west of Apalachicola, Florida, immediately adjacent to St. Vincent Sound) nor does PHELPS (1966) from his examination of 3,001 sherds from the Tucker midden at Alligator Harbor, Franklin Co., Florida (20 miles east of Apalachicola); both of these middens were interpreted by STAPOR (1975) to blanket and hence post-date a terrace.

Clearly, these scarp and terrace pairs are (1) Holocene in age and (2) the result of wave action at a higher-than-present, sea-level position. The previously mentioned four concerns or observations about their geologic/stratigraphic, geographic, and topographic distributions cannot be explained by the storm-surge hypothesis of OTVOS (1995). Conversely, these four concerns are readily addressed by the sea-level highstand hypothesis of STAPOR (1975) that interprets these scarp and terrace pairs to be remnant relicts that predate barrier island formation along the Florida Panhandle coast.

Central West Florida Barrier Islands

Otvos's discussion and dismissal of the increasing amount of evidence for late Holocene high stands (OTVOS, 1995, Pp. 992–995) on the Gulf of Mexico coast is equally unconvincing. He misinterprets STAPOR *et al.*'s (1991) evidence for multiple high stands; the latter used approximately 300 shell dates from ridges in the Captiva/La Costa (Lee County, Florida) area to document the existence of late Holocene high stands in SW Florida.

OTVOS (1995, p. 995) states that ridges making up the Lee County barrier islands are capped with eolian sand, and that their crest elevations are therefore unrelated to MSL. This conclusion is based largely, if not entirely, on their appearance in a cross-section with a 100:1 vertical exaggeration. MISSIMER (1973) and STAPOR *et al.* (1991) found that these features are beach ridges of marine origin based on (1) their internal structure of planar laminae with a gentle seaward dip, (2) their geographic and geometric characteristics (each is a shore parallel, curvilinear, continuous, and symmetric ridge of a uniform crest elevation) and (3) the occurrence of pebble-size mollusk shells approximately 3 m above present MSL deposited in planar laminae with a gentle seaward dip—the Wulfert Ridge on Sanibel Island. These ridges are further organized into distinct sets defined by erosional boundaries with older, landward sets truncated by younger, seaward sets. Each set has a uniform elevation that is different from its neighbors. The highstanding Wulfert set is 3 m in elevation and stands at least a meter above ridges formed over the past hundred or so years. We reject Otvos' unfounded assertion that these ridges are capped with eolian sand and his conclusion that their crest elevations are therefore unrelated to sea level.

Immediately landward of the Wulfert set on Sanibel Island is an archaeologic site that contains an Indian midden buried by estuarine/washover deposits that now are at least 70 cm above MSL. WALKER *et al.* (1994) describe in detail the stratigraphic sequence at this site and conclude that sea level rose at least 120 cm to a height 70 to 80 cm above present MSL 1600 to 1400 yr B.P. This represents an independent confirmation of the existence and magnitude of the Wulfert highstand proposed by STAPOR *et al.* (1991) from beach-ridge set elevation and a narrowing of the time estimate to the younger end of the 2000–1500 BP range indicated by radio-carbon dates of individual, reworked shells present within this ridge set.

Holocene Sea-Level Curve

Otvos cites NELSON and BRAY's (1971) Texas sea level curve as evidence against the existence of Holocene highstands (OTVOS, 1995, p. 1000). He describes the curve as "well documented mid-to-late Holocene Gulf sea level positions." The curve is in fact not well documented. It is defined by only about a dozen wood and peat dates for the entire Holocene. Moreover, most of the dates are from offshore boreholes, precluding the possibility of dating highstands.

Almost all Holocene sea-level curves are based on subsurface materials collected by coring, for example, inter- to supratidal peats and depth-restricted corals. This approach is inherently biased toward lower-than-present sea-level events and away from higher-than-present events. However, if (1) the cores are taken over a wide enough geographic range to recover the shoreward shift of depth-sensitive units and (2) the dating technique is sufficiently sensitive to identify discontinuities of several hundred years in what appears to be a sequence of conformable, superposed deposits, then higher-than-present events should be detectable. It is the dating technique that is deficient in that the analytical error of Holocene radiocarbon determinations is commonly plus or minus 50 to 150 years. Thus subsurface coring combined with radiometric dating should not be expected to find Holocene higher-than-present sea-level events, and it hasn't.

Mobile Bay Sea Level Data

Otvos discusses HOLMES and TRICKEY's (1974) study of inundated middens in Mobile Bay (OTVOS, 1995, p. 1000). Those authors had interpreted the stratigraphy found at Bryants Landing, Alabama, as being the result of multiple inundations during the period 4100 yr BP to present. The inundations (represented by 6–18 inch-thick mud layers) ended midden occupation (represented by layers of shell and artifacts) on three occasions, for periods of 500–1000 years. Otvos calls the mud layers storm or flood deposits. According to the authors, the evidence indicates otherwise. Also, there were three mud layers reported, the last one at +1.4 m. Otvos refers to only two of them.

St. Vincent Island, FL, Strandplain, Ridge Elevations, Ages and Island Genesis

In his discussion of the St. Vincent Island beach ridge plain and its possible relation to Holocene sea level history, Otvos has not carefully examined the field data (OTVOS, 1995, Pp. 995–997). He attributes the differences in height among sets of beach ridges to localized subsidence. In fact, some of the highest beach ridge sets (4+ meters) are among the oldest (northernmost) sets—sets A through E. These ridges are approximately 2,000 to 3,000 years old. If subsidence of the ridges is occurring, it should be progressively greater with time. This is not the case.

St. Vincent is an example of a progradational strandplain island. Such islands are composed of curvilinear, shore-parallel ridges and are the sites most likely to preserve the greatest amount of potential highstand deposits: they record a long-term history of *subaerial,* net deposition. Sand ridges are the predominant deposit and we assert that internal structure, geomorphology, and granulometry characteristics are sufficient to distinguish wave-built *beach ridges* from back-beach *dune ridges.* Beach-ridge crest elevation is initially a function of sea-level position and/or wave climate and secondarily of any subsidence (compaction) or uplift (tectonic). The independent recognition of elevated, contemporaneous sea levels from archaeologic sites strongly supports our hypothesis that beach-ridge crest elevations on the progradational islands of the Florida Gulf coast is in large part a function of sea-level position.

The discussion of BRALEY's (1982) postulated late Holocene highstand evidence from the Paradise Point shell mound archaeological site on St. Vincent Island is likewise based on misinterpretation of field data collected by others (OTVOS, 1995, p. 997). Braley found a lagoonal mud layer overlying a midden deposit (with ceramic artifacts) dated at 1710 yr BP. Immediately overlying the mud layer was another, younger midden deposit with associated ceramics. The mud deposit is *above* present sea level, leading Braley to infer a highstand. Otvos has misinterpreted Figure 4 of BRALEY (1982), which does not give any vertical elevation relative to modern sea level.

There has been no mud discovered to date beneath the Paradise Point shell mound (STAPOR, 1975; BRALEY, 1982; WALKER *et al.,* 1995). However, the sea-level sensitive marsh deposit at this site is located well above its expected elevation relative to present-day MSL (BRALEY, 1982; WALKER *et al.,* 1995) and would have been originally deposited at an even higher MSL if the 5 m thick, Mallard Slough clay layer were to extend north beneath Paradise Point. The presence of underlying, compactable clays would only serve to magnify the sea-level estimate of the elevated shell layer along the Mallard Slough shoreline reported by STAPOR (1975). WALKER *et al.* (1995) discovered additional archaeologic and geologic strata at Paradise Point beneath those examined by BRALEY (1982). Their additional radiometric dates on the clay-rich midden immediately beneath the marsh deposit indicate a 1300 to 1500 BP age, essentially coeval with the 1500 BP of the Wightman site's drowned midden on Sanibel Island (WALKER *et al.,* 1994).

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