REPLY

Lake Sediment Evidence of Coastal Geologic Evolution and Hurricane History from Western Lake, Florida: Reply to Otvos

Otvos questions our interpretation of the overwash origin of the sand layers we found in the sediment cores of Lake Shelby and Western Lake and raises six questions about our reconstructed history of late-Holocene hurricane landfalls in the Gulf Coast. Although most of his questions were addressed in our paper (Liu and Fearn, 2000a), we welcome the opportunity to provide a point-by-point reply to them.

**Questions 1, 3: Where was the sand barrier beside Western Lake during the late Holocene?** By citing a shoreline recession rate of 0.5–1.0 m/yr for 1868–1935, Otvos implies that the shoreline (hence the sand barrier) could have been 1.5–3.0 km away from the lake 3000 14C years ago. If he is correct, then where was the lake? One possibility is that the lake has shifted landward during the late Holocene, generally following the re-treating shoreline. In this case, the lake would not have occupied its present location 3000 years ago. Another possibility is that the lake has not moved, but the shoreline has gradually approached it. In this case, the lake might once have been freshwater due to its inland location. A third possibility is that the lake has always been close to the sand barrier, but was larger 3000 years ago. In this case, the coring sites would have been farther away from the sand barrier than they are today.

None of these scenarios is supported by the data from the cores. The fairly uniform loss-on-ignition curves from core 1 above 3.2 m show that the depositional environment of the lake has changed little over the past 5000 years. These sedimentological data, plus biostratigraphic data from diatoms and pollen, also suggest that Western Lake was never freshwater (Liu and Fearn, 2000a, pp. 242–243). In addition, during 1000–3400 14C yr B.P. there were more, not fewer, overwash sand layers deposited at the coring site. Thus, the site could not have been farther away from the sand barrier 3000 years ago than it is today, unless the hurricanes then were even stronger than we have inferred in our reconstruction.

Therefore, while it is likely that there were minor sea-level fluctuations and shoreline changes during the late Holocene, these changes were probably inadequate to alter drastically the depositional environment of the lake basin and hence the sensitivity of Western Lake in recording prehistoric hurricanes. The position of the sand barrier, although not fixed, probably has not shifted significantly during the late Holocene.

**Question 2: Could minor hurricanes have breached the dune barrier and deposited the sand layers?** Liu and Fearn (2000a, pp. 242–243) did consider the possibility that the differences in the frequency of sand layers in the core may be due to long-term changes in the height of the barrier ridge. We rejected this explanation because the same pattern of change in sand-layer frequency was also found in the 5000-year sedimentary record from coastal Lake Shelby, 150 km west of Western Lake (Liu and Fearn, 1993). In fact, similar temporal patterns of storm surge deposits have been documented from the sedimentary records of Pascagoula Marsh, Mississippi, and Pearl River Marsh, Louisiana, two estuarine marshes along the northern Gulf Coast (Liu, 1999; Liu and Fearn, 2000b; Elsner et al., 2000).

The emergence of a regionally coherent chronological pattern of hurricane-induced sedimentation in coastal lakes and marshes over the last 5000 years argues against any explanation that invokes local factors or stochastic processes such as the opening and closure of low pathway gaps or tidal inlets. Instead, a regional factor, most likely climatic change, must have been responsible for the millennial-scale variations in the frequency of overwash sand layers in the core.

Otvos speculates that minor hurricanes could have breached low barrier-dune sectors and caused overwash sand deposition into Western Lake. During the past 100 years, the Western Lake area was affected by at least 20 hurricanes that came within a 139-km radius of the site (Neumann et al., 1999). Of these, at least six minor (category 1 or 2) and four major hurricanes (category 3) made landfall near Western Lake and directly affected the coastal environment there. However, in none of these did storm surges breach the dune ridge barrier and cause overwash into the lake. In the cores from Western Lake, Liu and Fearn (2000a) dated the youngest overwash sand layer to 1170 ± 50 14C yr B.P. The absence of recent overwash sand layers suggests that Otvos’ speculation is unfounded.

Otvos’ “previously active Gulf inlet, now buried beneath the transgressive barrier dune ridge” is a conjecture unsupported except by a map of the modern coastline near Western Lake (Otvos, 1999, Fig. 4). If such an inlet had existed and had “provided a ready conduit for sand from the Gulf to Western Lake,” this would have been reflected in the Western Lake cores, probably as sandy or silty gyttja low in organic matter. This might have been the case for Western Lake during its formative phase between 5000 and 7000 14C yr B.P. (Liu and Fearn, 2000a, 241). For this reason, we did not use this section of the core in our reconstruction of hurricane history. However, no evidence of such
active tidal connection is found in the loss-on-ignition data for the past 5000 years. Our cores from Western Lake and three other coastal lakes nearby (Camp Creek Lake, Campbell Lake, Morris Lake) contain discreet overwash sand layers embedded by organic lake mud with sharp stratigraphic contacts, again indicating that no “active Gulf inlet” existed during the past 5000 years.

**Question 4: Is there an alternative to the overwash or storm-surge origin of the sand layers?** Otvos asks why the sand layer occurring at the top of core 11 must be attributed to Opal and why it was absent in other cores. Liu and Fearn (2000a: 238) addressed these questions, stating that although the dune ridges were not overwashed by Opal, “sand was introduced into the lake by saltwater invading through the tidal channel from the west.” According to field observations made during and after Opal, the paved roads and parking lots at the southwestern corner of Western Lake were inundated and, after the floodwater had receded, were covered with a layer of sand eroded from the adjacent sand dunes and beaches. These field observations led us to infer that the sand layer at the top of core 11 “must have been deposited by floodwater that invaded the tidal channel and eroded the base of the dunes and beaches along the south shore” (p. 240). Because this sand was derived from more limited sources (the base of sand dunes rather than the entire dune ridge) and was transported by lower-energy currents and waves than would have been the case for overwash processes, it was not transported very far beyond the lakeshore before it was deposited. This explains why the Opal sand layer was present only in core 11, which was taken at a site only 20 m from the south shore, and absent in more-distant cores 8, 9, 12, and 13.

Otvos invokes “simple intralacustrine sand redeposition from sandy lake bottoms” as the origin of the sand layer that we attributed to Opal. What “simple” mechanism could mobilize sand to deposit in a 1.5-cm-thick layer at a site that normally accumulates only organic lake sediment, and only once in 1000 years? The only logical and parsimonious explanation for the Gulf Coast is storm surge and overwash processes due to intense hurricane strikes, as we postulated.

**Question 5: Does a positive relationship exist between hurricane intensity and the size of the overwash sand body?** The relationships between hurricane intensity and the size of the overwash sand body deposited in a coastal back-barrier lake are complex. We have acknowledged some of these confounding factors, including abundance of sand supply, emphasizing that our working hypothesis is subject to the assumption that “the geomorphic setting remains the same for any given lake and that hurricane landfall conditions (e.g., timing, duration, angle of approach) occur randomly over time” (Liu and Fearn, 2000a, 239; see also Liu and Fearn, 1993, 2000b). However, recognizing these complexities does not prevent us from generalizing that a positive relation exists among hurricane intensity, storm-surge height, and size of the overwash sand body.

Donnelly et al. (2001a, 2001b) demonstrates that recent and historic major hurricanes on the Atlantic coast caused significantly higher storm surges than minor hurricanes and winter storms, and that over the past several centuries only the major hurricanes left a stratigraphically distinct and regionally consistent record of overwash sand layers in the sediments of the coastal marshes.

Otvos cites the differential sedimentary impacts of category-3 Hurricane Frederic on Dauphin Island and Lake Shelby as an example of the unpredictable relationship between hurricane intensity and the size of the overwash sand body. This example fails to illustrate Otvos’ point. The greater impact of Frederic on Dauphin Island than on Lake Shelby can be explained simply by the decay of wind with distance from the eye of the landfalling storm—Frederic made landfall directly over Dauphin Island, whereas Lake Shelby was 50 km to the east (U.S. Army Corps of Engineers, 1981).

**Question 6: Details of coastal geologic history can be reconstructed from coastal lake-sediment records.** We agree with Otvos’ statement that details of coastal geologic history must be carefully considered before reaching conclusions on the frequency and intensity of prehistoric hurricanes. The only question is how such coastal geologic history can be reconstructed. Coastal geologists have typically based their scenarios on interpretations of lithological cross sections constructed from undated boreholes drilled through rock formations on land (Otvos, 1999). We argue that sediments from coastal lakes, if available, are important archives of information not only on prehistoric hurricane activity, as we have demonstrated, but also on the history of sea-level fluctuations and coastal morphological changes. The paleoenvironmental information contained in these archives should not be overlooked by traditional coastal geologists. With regard to Otvos’ questions about the geological context of our reconstructed late-Holocene hurricane history, the answer is not only blowing in the wind, but also buried in the mud of these coastal lakes, waiting to be deciphered.

**REFERENCES**


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