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Coastal and Marine Geology Program

Early Results from the Northern Gulf of Mexico Ecosystem Change and Hazard Susceptibility Project

Summary

The northern Gulf of Mexico coastal region and its diverse ecosystems are threatened by population and development pressure and by the impacts of rising sea level and severe storms such as the series of hurricanes that has impacted the northern Gulf in recent years. In response to the complex management issues facing the region, the U.S. Geological Survey (USGS) organized a multidisciplinary research program to coordinate the activities of USGS and other scientists working in the northern Gulf of Mexico region (fig. 1). The Northern Gulf of Mexico (NGOM) Ecosystem Change and Hazard Susceptibility Project aims to develop a thorough understanding of the dynamic coastal ecosystems on the northern Gulf coast, the impact of human activities on these ecosystems, and the vulnerability of ecosystems and human communities to more frequent and more intense hurricanes in the future. A special issue of Geo-Marine Letters published in December 2009 is devoted to early results of studies completed as part of this project. These studies, which have been conducted at sites throughout the northern Gulf region, from the Chandeleur Islands to Apalachicola Bay, have focused on three themes:

- The underlying geologic framework that exerts controls over coastal processes
- The impact of human activities on nearshore water quality
- Hurricanes and associated effects

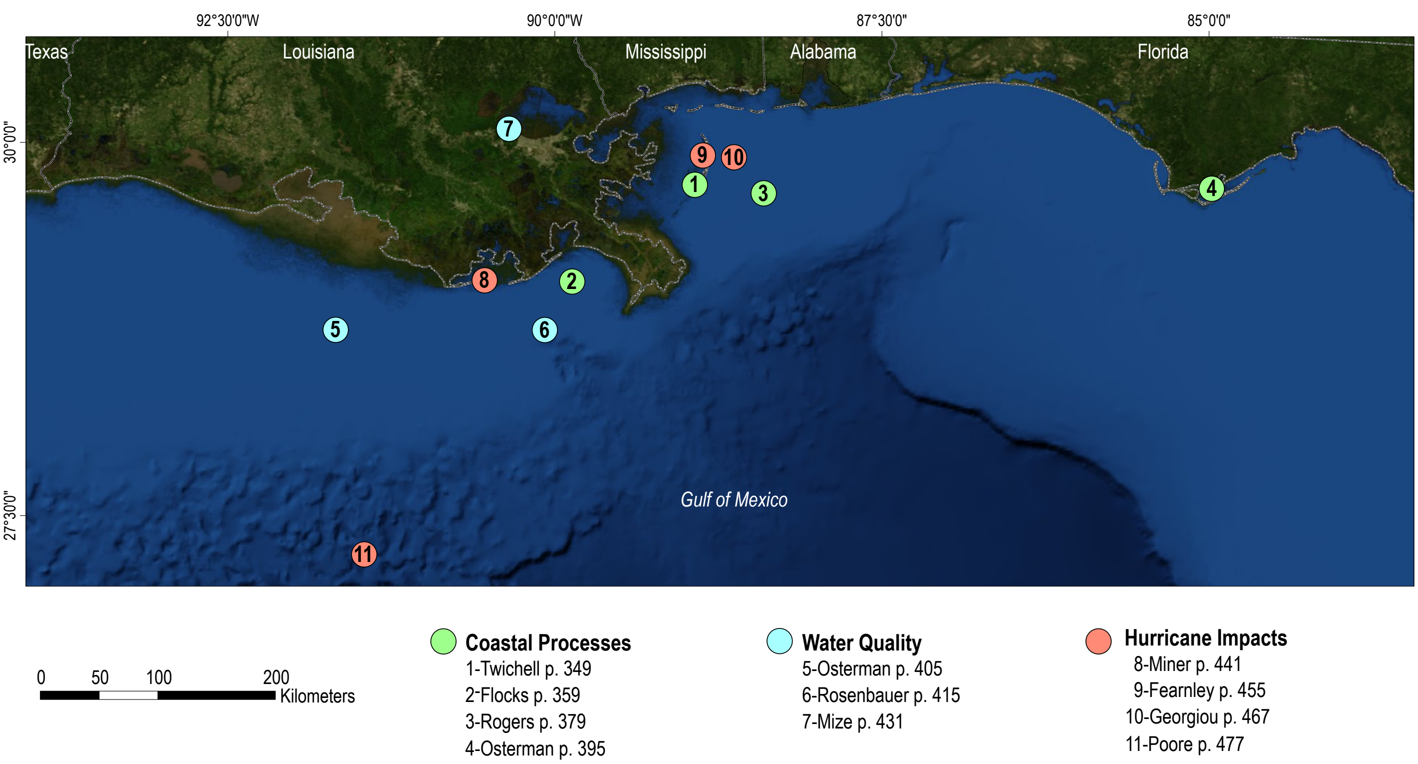

Figure 1. Northern Gulf of Mexico (NGOM) study sites cover the coastal margins of Louisiana, Mississippi, Alabama and the Florida panhandle. Scientists from the U.S. Geological Survey and partner organizations working on the NGOM Ecosystem Change and Hazard Susceptibility project have focused their early efforts on the underlying geologic framework that influences coastal processes (green circles), the effects of nutrient loading and other pollutants on water quality (blue circles), and the impacts of hurricanes (red circles) in the coastal zone. Each numbered circle corresponds to an article (listed by first author and page number) published in Volume 29, Number 6, of Geo-Marine Letters.

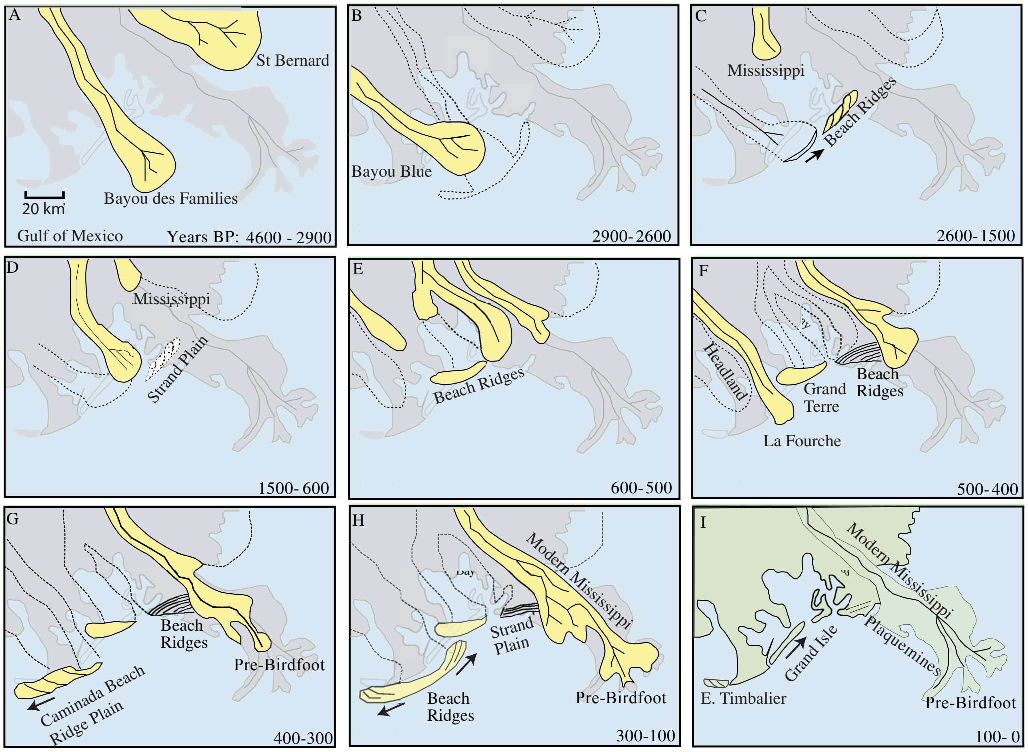

Figure 2. Map sequence illustrating coastal evolution in the Barataria Basin from 5,000 years B.P. to the present. Yellow shading in panels A-H shows extent of sandy distributary channels and beach ridge deposits. Purple shading outlines extent of modern delta. Green shading in panel I outlines extent of subaerial exposure of modern delta (Flocks and others, 2009).

Coastal Processes

Several studies have established the importance of the geologic framework in determining how the northern Gulf coastal region responds to storms and sea-level changes. Offshore from the Chandeleur Islands, USGS researchers have identified two types of erosion patterns, linear and subcircular in shape, that result from differing seafloor geology responding to wave and current energy on the inner shelf. Their observations suggest that the morphology of the inner continental shelf is continuously evolving and controlled by the underlying stratigraphy. Nearby, research on the barrier-island systems of the Mississippi River Delta plain, which experiences some of the highest rates of shoreline retreat in the world, further identifies the underlying geologic framework that controls the evolution of various coastal features. USGS scientists have created a chronology of coastal evolution in the Barataria Basin from 5,000 years B.P. to the present (fig. 2), which shows how cycles of delta progradations and erosion can create strand plains, beach ridges, and ultimately the modern shoreline.

Effective management of the Chandeleur Islands, which comprise the Breton National Wildlife Refuge, includes replenishing sediment loss through the placement of similar material. Finding appropriate sand resources requires an understanding of the processes that formed the barrier islands, because the placement and fate of the sand bodies are determined by the same cyclical processes that form the islands. A group of researchers at the University of New Orleans, who are collaborators on this project, have reconstructed the Holocene chronology of the St. Bernard Shoals, which is a group of discrete sand bodies that may provide an appropriate sediment resource for Chandeleur Islands.

At the far eastern end of the northern Gulf of Mexico study region, USGS scientists have reconstructed the geological evolution of Apalachicola Bay based on sediment cores. The advance of deltas into the bay introduced the sandy substrate that provides the requisite habitat for present-day oyster colonization. The time of occurrence of barrier-island formation, inferred from the establishment of estuarine conditions in Apalachicola Bay, was as early as 6,400 ^{14}C years B.P. The faunal assemblage documented supports the interpretation that St. George Island formed as rising sea level flooded an inter-stream divide on the incised continental shelf.

Water Quality

During normal summers, about 25 percent of the northern Gulf of Mexico shell-fishing grounds is closed due to pollution; increased nutrient loading of the Mississippi River results in a hypoxic zone covering ~7,000 square miles, and chronic algal blooms occur in many of the region's inshore waters. USGS and University of New Orleans scientists have documented the effects of freshwater and nutrient influx to the coast from the Mississippi River, which results in the well-known "dead zone" on the Louisiana shelf, and also have described the effects of the periodic opening of the Bonnet Carré Spillway, which results in algal blooms and related ecosystem changes in Lake Pontchartrain. The standard explanation of the dead zone phenomenon is that spring flood waters of the Mississippi River and Bonnet Carré Spillway spread over more dense saline water. In this stratified region, eutrophication fueled by excess dissolved nutrients stimulates algal blooms that subsequently die. During their decomposition, most of the dissolved oxygen is consumed, resulting in the formation of a low-oxygen or dead zone.

USGS scientists utilized a specific low-oxygen foraminiferal faunal proxy, the PEB index (i.e., % *Protononion atlanticum* + % *Epistominella vitrea* + % *Buliminella morgani*), to trace the development of low-oxygen bottom waters and hypoxic conditions over the Louisiana shelf over the last 100 years. The PEB index record indicates that areas of low-oxygen bottom water began to appear in the early 1910s in isolated hotspots near the Mississippi Delta and rapidly expanded across the entire Louisiana shelf beginning in the 1950s (fig. 3). These results are supported by a separate study that used stable isotope analyses from core samples to assess the sediment record for evidence of hypoxic events. The stable isotope analyses demonstrated that the sediment on the northern Gulf of Mexico shelf offshore from the Mississippi River is a complex mixture of marine and terrestrial material and that these mixtures are spatially dependent and subject to change over time. Together, these two studies outline the history of the development of hypoxia on the Louisiana shelf prior to the beginning of monitoring studies in 1985. In a third study, USGS researchers have found that Lake Ponchartrain exhibits a very similar response to freshwater and nutrient increases.

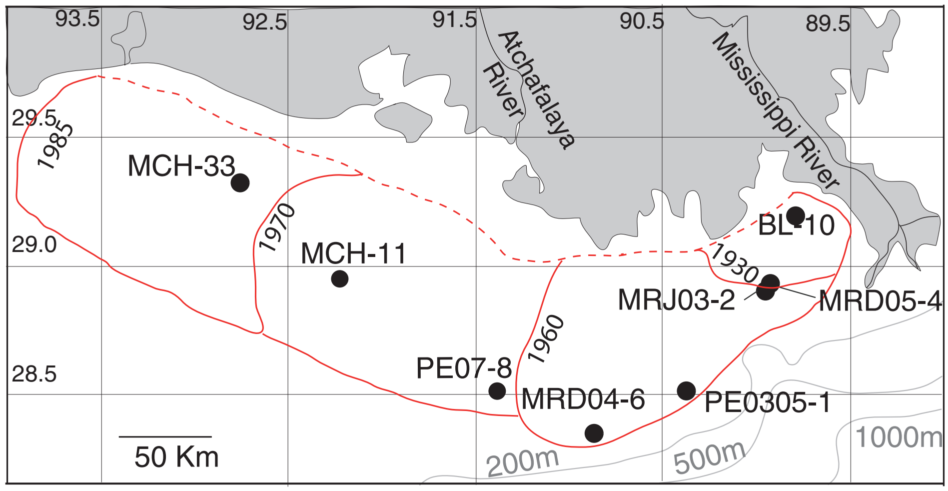

Figure 3. Map of hypoxia study area showing spread of low-oxygen bottom water over the Louisiana shelf from 1930 to present day (Osterman, Poore, and others, 2009).

Hurricane Impacts

In comparison to long-term background coastal processes, episodic events such as hurricanes have enormous impacts on coastal regions. Results from shoreline change analyses done from 1855 to 2005, using early ground survey data and maps, demonstrate that tropical cyclone frequency dominates the long-term evolution of the Chandeleur Islands off the Mississippi Delta. This observation is consistent with other USGS research conducted on the Chandeleur Islands. For example, Sallenger and others (2007) noted immediate and significant degradation of the subaerial portion of the Chandeleur Islands following Hurricane Katrina's landfall in 2005. In comparison, as part of the NGOM project, University of New Orleans scientists constructed digital elevation models from modern and historical bathymetric surveys for three time intervals extending back to the late 1800s (fig. 4). They calculated large sediment volume changes and defined long-term erosion and deposition trends. They further documented the effects on shoreface retreat caused by the large deficit in the coastal sediment budget, high rates of relative sea-level rise, and storm-induced current and wave erosion. A companion study documented the scope of shoreline change related to intervals of hurricane frequency and focuses on the erosional impacts associated with the passage of Hurricane Katrina in 2005. Taken together, the two studies show that rates of shoreface erosion vary significantly through time, and the average rates are driven by processes linked to major hurricane impacts.

In a separate study, University of New Orleans researchers conducted a modeling experiment that used observed wind fields to generate wind-driven longshore transport rates for the Chandeleur Islands. The results show that overall northward sediment transport dominates due to stronger winds during the April through October "storm season." Although there are large errors associated with the model, the results compare well with field observations and overall trends from studies based on changes in seafloor morphology, historic-shoreline trends, and aerial photography.

Given evidence that hurricanes have the ability to radically alter coastal morphology and that such changes persist through time, predicting hurricane frequency and intensity has become increasingly important. Several studies suggest that decadal-scale oscillations in an average North Atlantic sea-surface temperature (SST) known as the Atlantic Multidecadal Oscillation (AMO) influ-

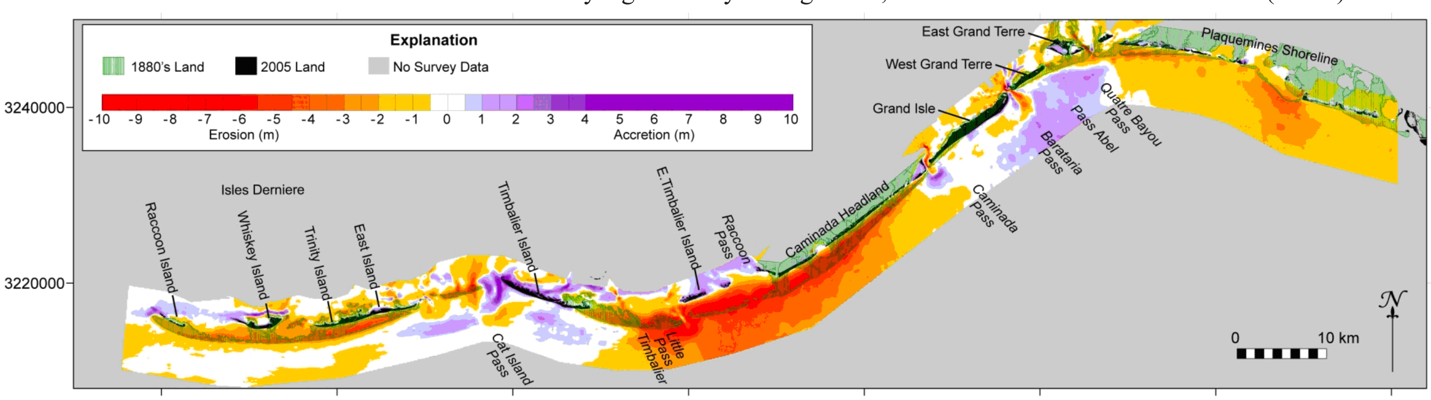

Figure 4. Map identifying 1880s to 2005 seafloor change along a Louisiana barrier island chain from Raccoon Point to Sandy Point (Miner and others, 2009).

ence the landfall of hurricanes on North America, with warmer SSTs correlating with more hurricane landfalls. USGS scientists found decadal-scale variability in a 450-year proxy SST record from the northern Gulf of Mexico and showed that it tracks AMO known from the historical record. The northern Gulf of Mexico SST record indicates decadal-scale variability of North Atlantic SSTs, and perhaps alternating periods of more and less active hurricane activity have occurred for the last few centuries and will likely continue into the future.

Implications

The future evolution, health, and resilience of ecosystems in the northern Gulf of Mexico will be influenced by a blend of natural and anthropogenic factors and processes. Future work will continue to provide improved information to anticipate changes and help manage the natural and human resources of the northern Gulf of Mexico.

Reference Cited

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