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Holocene environmental and parasequence development of the St. Jones Estuary, Delaware (USA): Foraminiferal proxies of natural climatic and anthropogenic change

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Abstract

The benthic foraminiferal record of marshes located along western Delaware Bay (St. Jones Estuary, USA) reflects the response of estuaries to sea-level and paleoclimate change during the Holocene. System tracts are recognized and within them parasequences based on sedimentological and foraminiferal assemblages identification. The parasequences defined by foraminiferal assemblages appear correlative with rapid Holocene climate changes that are of worldwide significance: 6000–5000, 4200–3800, 3500–2500, 1200–1000, and 600 cal years BP.

Following postglacial sea-level rise, modern subestuaries and marshes in the region began to develop between 6000 and 4000 years BP, depending on their proximity to the mouth of Delaware Bay and coastal geomorphology. Initial sediments were fluvial in origin, with freshwater marshes established around 4000 years BP. The subsequent sea-level transgression occurred sufficiently slowly that freshwater marshes alternated with salt marshes at the same sites to around 3000 years BP. Locally another two transgressions are identified at 1800 and 1000 years BP respectively. Marine influence increased in the estuaries until 600 years BP (Little Ice Age), when regression occurred. Sea-level began to rise again during the mid-19th Century at the end of the Little Ice Age, when marshes became established.

The presence of a sand lens in the upper and middle estuary and the reduction in the number of tests in the top samples in cores from the same area also suggest an anthropogenic influence. The estuary infill resulted in a sharp transgressive sequence, represented by salt marsh foraminiferal assemblages in the upper part of the cores. The increase in marsh foraminifera in both areas suggests an increase in marine influence that might be due to the transgression beginning at the end of the Little Ice Age about 150–180 years ago coupled with anthropogenic straightening of the channel in 1913.

Keywords: Foraminifera; Estuaries; Holocene; Marine transgression; Sequence stratigraphy; Delaware

1. Introduction

The past range of variation of an ecosystem in response to natural and anthropogenic variation is a scientific basis for predicting the ecosystem's response to future perturbations and making sound management decisions. However, because they assess the environment as it is now, typical biological or chemical surveys are unlikely to reveal the full spectrum of environmental change and biologic response through time (Wolfe et al., 1987). This means that monitoring programs must continue for many years before any meaningful trends

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can be inferred. One way to address this issue is to assess the changes in paleoenvironments that can be inferred from a sedimentary succession, together with its preserved fossils, with an established geological time frame. This is feasible in estuarine systems because tidal marsh ecosystems are very sensitive to environmental changes (Temmerman et al., 2004).

Foraminiferal assemblages are ideal indicators of environmental change through time (Murray, 2003). Foraminifera inhabit a wide range of sedimentary environments, from fresh to brackish to fully marine. They reproduce rapidly (months to about a year) so populations react quickly to environmental change, usually responding before populations of larger taxa (Schindler, 1987). Because they are small, they are abundant in small samples, the preparation and analysis of which requires simple and inexpensive techniques. Finally, the same or similar species have long been used in a wide variety of (paleo)environmental studies all over the world (e.g., Murray, 1991; Scott and Medioli, 1980), facilitating the transfer of the basic methodology to other locales and the intersite comparison of environmental perturbations (Yanko et al., 1999).

The overall objectives of our study were to use foraminifera to infer natural paleoenvironmental changes during the Holocene and to evaluate the severity of anthropogenic environmental changes over the past 500 years (i.e., relative to pre-Colonial natural baseline conditions) in the St. Jones Estuary (Dover, DE, USA; Fig. 1). The morphology and extent of different estuarine sedimentary environments are constantly altered by erosion and deposition of sediments, and are sensitive to even small changes in sea level. These studies allowed us to address the environmental evolution of the St. Jones Estuary following Holocene sea-level rise, to identify the environmental baseline conditions prior to European settlement, to assess the relative impacts of anthropogenic activities through time on the health of the St. Jones River watershed, and to support planning of future monitoring and habitat restoration efforts.

1.1. Background: Holocene sea-level rise, coastal evolution, and climate variability

In the late 1960s, J. C. Kraft (Professor Emeritus of Geology, University of Delaware) and students began intensive studies of the barrier–lagoon–marsh systems located along Delaware Bay and the open coast (e.g., Kraft, 1971; Kraft et al., 1979; Belknap and Kraft, 1985;

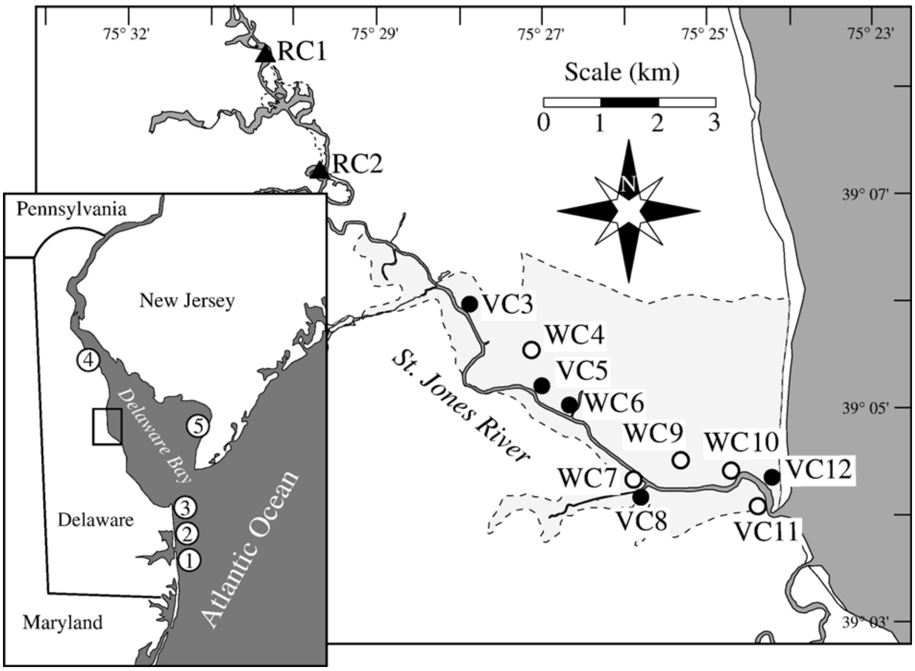

Fig. 1. Location of the St. Jones Estuary in Delaware Bay (USA), core sites, and localities referred to in the text. Key: 1—Indian River Bay; 2—Rehoboth Bay; 3—Wolfe Glade-Cape Henlopen; 4—Leipsic River; 5—Dennis Creek, New Jersey; RC: Russian peat core; VC: vibracores taken in this study; WC: vibracores taken in previous work (Wilson, 2005). Black dots indicate vibracores analyzed for foraminifera. Black triangles indicate Russian peat cores analyzed for foraminifera. White dots indicate vibracores not analyzed for microfossils. Dashed lines represent the extent of St. Jones Estuary Reserve. Dark gray indicates sea.