KECK GEOLOGY CONSORTIUM

PROCEEDINGS OF THE TWENTY-SECOND ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2009
Franklin & Marshall College, Lancaster PA.

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ISSN # 1528-7491

The Consortium Colleges National Science Foundation

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BLOCK ISLAND, RI: A MICROCOSM FOR THE STUDY OF ANTHROPOGENIC & NATURAL ENVIRONMENTAL CHANGE

Faculty: *JOHAN C. VAREKAMP*: Wesleyan University and *ELLEN THOMAS*: Yale University & Wesleyan University
Students: *ALANA BARTOLAI*: Macalester College; *EMMA KRAVET and CONOR VEENEMAN*: Wesleyan University; *RACHEL NEURATH*: Smith College; *JESSICA SCHEICK*: Bryn Mawr College; *DAVID JAKIM*: SUNY.

Funding Provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)

Keck Geology Consortium: Projects 2008-2009
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Project Director: ***JOHAN C. VAREKAMP***: Wesleyan University
Project Faculty: ***ELLEN THOMAS*****:** Yale University & Wesleyan University

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Research Advisor: Donald Barber

A 3.5 KY SEDIMENTARY RECORD OF THE GREAT SALT POND ON BLOCK ISLAND, RI
CONOR VEENEMAN: Wesleyan University
Research Advisor: Johan Varekamp

Funding provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)

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A 3.5 KY SEDIMENTARY RECORD OF THE GREAT SALT POND ON BLOCK ISLAND, RI

CONOR VEENEMAN: Wesleyan University
Research Advisor: Joop Varekamp

INTRODUCTION

Block Island was created as part of the Outer Lands during the last glacial maximum ~20,000 years BP, and has been the home of various settlements including a colony of Narragansett Indians, English settlers, and the current island community.
One of Block Island's most prominent and recognizable features is its Great Salt Pond (GSP), a large, central water basin, currently in exchange with the ocean through a narrow connecting channel. Numerous scientific studies have been conducted on Block Island and GSP (Sirkin, 1976; Coleman & McBride, 2008), but details of the formational and depositional history of the pond are still largely unknown. Earlier reports and historical evidence suggest a cyclical history of the connection of GSP with Block Island Sound, resulting in transitions from saltwater to fresh/brackish water within the pond (Livermore, 1876). We analyzed sediment core samples collected from various locations and depths of GSP, and reconstructed the pond's paleoenvironments over time. We interpret these data within the context of the last deglaciation, associated sealevel rise and rebound history.

Core	Date Extracted	Water Depth (m)	Core Depth (cm)
GSP2	6/26/2008	10.0	59
GSP3	6/26/2008	9.1	112
GSP11	7/8/2008	5.5	71
GSP12	7/8/2008	6.2	40
GSPV1	7/8/2008	6.7	225
GSPV2	7/10/2008	5.8	108
GSPV3	7/10/2008	7.3	181
GSPV4	7/10/2008	5.0	138

Table A: Cores, core length (recovered cm in core, strongly compacted in vibracores) and bathymetry of coring sites.

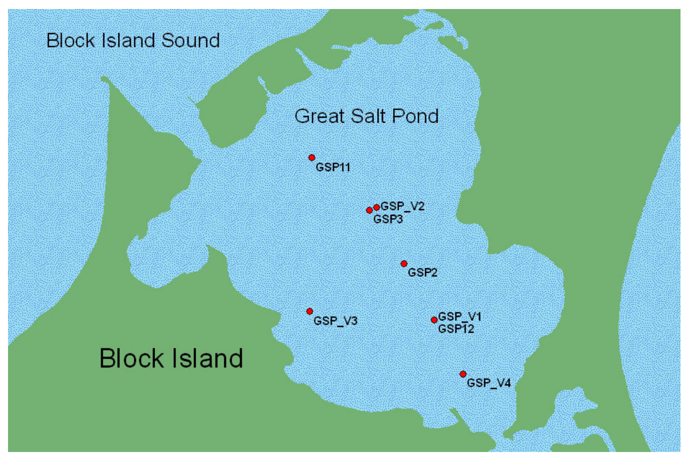

Figure 1: Core locations in Great Salt Pond.

METHODS

Cores from GSP were retrieved using standard hammer core and vibracore techniques deployed from small boats. Locations for core sampling were chosen based on bathymetry and evidence from earlier exploratory sediment grab samples. Ideal locations for coring were defined as having adequate water depth (>5m) and consisting of surface sediment without a thick layer of surface shells or rocks (to allow for easier coring). Core data is shown in Table 1. Locations of cores discussed here are shown in Figure 1.

After extraction, the cores were sealed for laboratory analysis at Wesleyan University. Vibracores were split with a circular saw in the lab and core photos were photo-stitched to construct core-length photographic records. Sediment from hammer cores was removed from the coring tubes using an extruder, so no whole-core descriptions are available. Sediment color and relative ratios of clay/sand/silt were noted, along with the presence of shells/shell fragments, pebbles/rocks, and plant matter/wood fragments. The mass of each core section was weighed before and after drying. The water percentages were used to calculate bulk dry densities, which were used to estimate the compaction during vibracoring and calculate mass accumulation rates.

Oyster shells were collected from the cores for radiocarbon dating. Shells were selected if they appeared to be in situ e.g., whole shells taken in vivo position from oyster beds. Oyster shells from the cores GSP3, GSPV3, and GSPV4 were used for dating purposes. The oysters were analyzed at NOSAMS, Woods Hole, MA for ^{14}C contents and $\delta^{13}C$. Radiocarbon ages were converted to calendar dates using the Calib 5.0.1 program of Stuiver & Reimer (1993).

Core GSPV3 had the greatest number of radiocarbon-dated shells and contained the most intricate stratigraphy, so that core was chosen for foraminiferal sampling. Core GSPV3 was sub-sectioned into 5cm intervals and from each of the thirty-eight intervals, tests of the benthic foraminifera species Elphidium excavatum (E.ex.) were collected to be used for stable isotope analyses (Thomas, 2000). Over 1,500 E.ex. individuals were collected from core GSPV3, on which $\delta^{13}C$ and $\delta^{18}O$ were measured with a mass spectrometer at Yale University, New Haven CT.

RESULTS

Calendar calibration of measured oyster radiocarbon data revealed that the sediment near the bottom of core GSPV3 was deposited 3450±30 BP, which is the oldest calibrated date from our sample suite. With the four dates available for core GSPV3, an age-depth curve was created to develop an age model for the 38 core slices (Figure 2). Other cores had fewer dates but also were shorter and individual and integrated age models were developed from all available data. The depth-in-core for the various samples was restored using a water expulsion model, comparing the water contents of the hammer cores (non-compacted) and the vibracores (de-watered). From the age models and the bulk dry densities, we

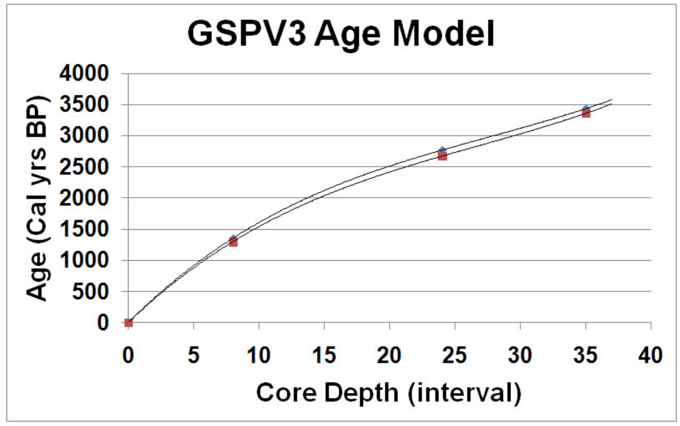

Figure 2: The GSPV3 age model with upper and lower error limits.

computed mass accumulation rates (MAR) of sediment for cores GSP3, GSPV3, GSPV4.

Stable isotope data from foraminifera extracted from core GSPV3 were used as proxies for temperature and salinity estimates of GSP over the last 3.5 ky. Temperature and salinity both influence the $\delta^{18}O$ in calcite, and without additional data, we can not constrain both environmental variables. We used the following approach: initially we kept salinity constant at 35 ppt and then calculated the apparent temperature variations over time. In a second set of calculations, we kept the temperature constant and calculated apparent paleo salinities. We then evaluated the strength of these two signals as independent variables. Small variations in salinity have a large effect on the $\delta^{18}O$ in calcite, so we proceeded with using an external temperature data reference set and then calculated paleosalinities.

The Greenland Ice Sheet Project 2 (GISP2) has resulted in a wealth of climate data, including a surface temperature record for Greenland's ice sheet over the past 5,000 years (Stuiver & Goodes, 2000). These high-latitude temperatures cannot be used directly as a record for the GSP water temperatures, but we can transfer the deviations in temperature from a mean GISP2 value as indicative of the temperature trends at lower latitudes. The GSP constant-salinity 'apparent paleotemperature' record was compared with moving averages of the GISP2 temperature record for alignment of major anomalies, and minor adjustments in the age model for GSP were applied to match the major wiggles. The GISP2 ΔT values were then applied to an estimated mean temperature of GSP, creating a local paleo temperature record. With those temperature data as input, paleosalinities were calculated for GSP based on the stable isotope data of core GSPV3. The record was calibrated by obtaining the observed GSP salinity for the core top sample. The resulting paleosalinity record shows three noticeable peaks in salinity and two noticeable troughs (Figure 3).

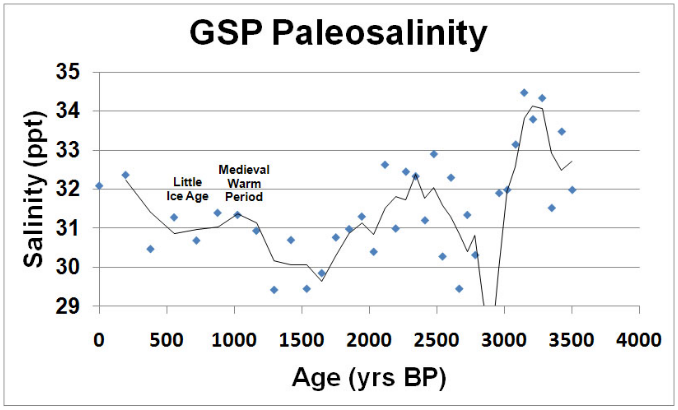

Figure 3: Paleosalinity record of the Great Salt Pond, reconstructed from oxygen isotope data from Elphidium excavatum tests collected from core GSPV3.

Salinity is at a record high of 34 ppt around 3.2 ky BP. It then experiences a steep decline, and reaches below 31 ppt by 2.8 ky BP. The interval 2800-2900 BP had no foraminifera and was presumably too fresh for their survival. Salinity increases again, reaching 32 ppt by 2.4 ky BP. A gradual decrease ends with salinity below 30 ppt by 1.5 ky BP. From this last trough salinity experiences an increase, reaching the 32 ppt present day value at the top. The small salinity high at ~ 1000 BP and the following low at 500 BP may be representative of the Medieval Warm Period and Little Ice Age respectively (see Bartolai - this volume).

DISCUSSION

The calculated sediment MARs for cores GSP3, GSPV3 and GSPV4 show strong variations in space and time in GSP (Figure 4).

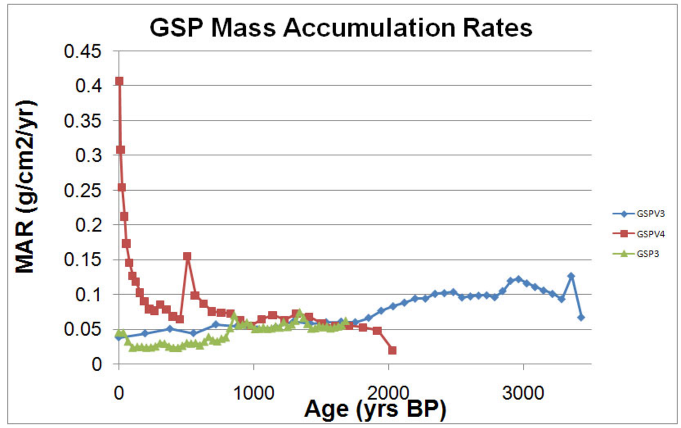

Figure 4: Sediment mass accumulation rates (g/cm2/yr) for three GSP cores.

The interpretation of the MARs is still open to debate. The MARs at Block Island are not very different from those in Long Island Sound (Varekamp et al., 2009), and given the extremely small watershed surrounding the Pond, much of the sediment may be brought in through the connecting breach from the open marine environment. The broad decrease in MARs in GSPV3 and GSP3 over the last 3000 years may be related to the size of the breach and the overall openness of GSP to the surrounding sea. The paleosalinity and MAR record of GSPV3 show a broad correlation with lower MARs during periods of lower paleosalinity, suggesting a relationship between 'connectedness with the sea' with paleosalinity and sediment import. In how far landuse changes have impacted the sediment budget of the Pond remains to be determined, but sharp increases in MAR in GSPV4 and GSP3 since colonial times suggest that the colonial deforestation of the island has impacted sediment delivery to the Pond.

The paleoenvironmental record of GSP reveals that GSP has undergone significant salinity changes, with values from 29.5 to 34.5 ppt, dependent on the connectedness of the Pond with the sea. The historical records of the connection between GSP and the ocean goes back about 200 years, but the resolution of our salinity data does not allow for a direct comparison with that historical record. During periods of very low salinity, forams cease to exist in the Pond, which occurred in core interval 28-29 (2900-

2840 yBP), where forams are absent in the central part and we see two steep salinity gradients on each side.

The overall evolution of Block Island is the result of interplay between rebound and absolute rates of sea level rise. The modern salt marshes in GSP suggest a rate of relative sea level rise of 3 mm/year, which is similar to estimates of the modern eustatic rate (~3mm/yr; Kravet, this volume). Our ^{14}C age index points can be used to extend the relative SLR record back in time, with the condition that we have to know the depth below MSL that the oysters were living at the time. Combination of the ^{14}C age sea level index points (with compaction corrected depths) with the short salt marsh record suggests that the oysters lived at 3-4m water depth. The SL elevation data versus time plot than provides a rate of RSLR of about 1.5mm/yr over the last 3000 years, which is slightly faster than rates during that period in central Long Island Sound (~1mm/yr).

Dated freshwater marshes provide constraints on the relative position of paleo sea level during the last stages of deglaciation and the obtained ages (~12,000-14,400 BP) provide information on the rebound history of the island. Freshwater ponds on Block Island most likely formed as kettle lakes left by retreating glaciers. Sediment analysis of Fresh Pond reveals that the water within the pond has remained fresh, indicating that the island has never been fully inundated. Thus we know that the elevation of the bottom of Fresh Pond has always been above the elevation of the surrounding seawater.

CONCLUSIONS

- Sediment records from the Great Salt Pond date back to 3450±30 BP.

- Sediment mass accumulation rates in Great Salt Pond vary, and may broadly scale with the ‘openness’ of the Pond to the sea. The impact of colonial deforestation may show up in the MARs of several cores.

- A reconstructed “constant salinity” apparent temperature record for GSP reveals similar trends of warming and cooling to existing hemispherical temperature records.

- A temperature-corrected paleo salinity record shows the degree of openness to the sea, in one case leading to almost complete closure with disappearance of marine foram faunas.

- Dates from basal freshwater marshes on Block Island suggest that Block Island was above sea level at 14,400-12000 BP.

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