PELAGIC TROPICAL TO SUBTROPICAL FORAMINIFERA IN THE HUDSON RIVER: WHAT IS THEIR SOURCE?

A Final Report of the Tibor T. Polgar Fellowship Program

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Monahan, K. M. and D. H. Abbott. 2015. Reconstructing Hudson River Sedimentary Signals. Section I: 1-19 pp. *In* D.J. Yozzo, S.H. Fernald and H. Andreyko (eds.), Final Reports of the Polgar Fellowship Program, 2013. Hudson River Foundation.

ABSTRACT

Reconstruction of past climate events in the Hudson River basin is useful to calibrate historical records, and increasingly important in light of recent hurricane impacts on the area. The concentration of radiogenic nuclides such as Cs-137 and Pb-210 can be used as a sediment dating technique (Bopp and Simpson 1989), but do not provide historical climate data intrinsically. Microfossil identification was used, which provides $\delta^{18}O$ reconstructions and species specific tolerance ranges. Sediment samples from three Hudson River sediment cores were sieved and picked for microfossils. Discrete layers of marine pelagic foraminifera were found in one core, CD02-29A and replicated in CD02-13. Tropical foraminifera species such as *Globigerinoides ruber (pink)* dominate the assemblages from CD02-29A. Dating estimates of the cores were provided by Pb-210 and Cs-137 profiles. Pending carbon-14 dates from CD02-29A and CD02-13 will provide more robust sedimentation rate assessments, and future hurricane event correlations.

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INTRODUCTION

Reconstruction of past climate events is useful both for calibration of historical records and providing a better baseline for comparing current atmospheric phenomena. Identifying and developing sedimentary proxies can help ascertain the past intensity and frequency of large drought and hurricane events, and help inform planning and adaption to future events. Sediment dating techniques using the concentration of radiogenic nuclides such as Cs-137 and byproducts of Pb-210 have been very successful in providing sediment dates (Bopp and Simpson 1989), but do not provide historical climate data. The use of microfossils in sediments for climate analysis is one method for gathering climate data, through either $\delta^{18}O$ measurement or through species specific climatic tolerance ranges (Cronin et al. 2005).

In previous work, analysis of three sediment cores from the Hudson River from off Manhattan Island to Piermont (shown in Fig. 2) determined that these cores contained calcareous shells of marine organisms (Table 1).

When examining core CD02-29A, pelagic foraminifera were found in discrete layers. *Globigerinoides ruber* (pink) and other tropical species dominate the assemblages. None of these marine species could live in the Hudson River at normal salinity and temperature values (Weiss et al. 1978).

These tropical foraminifera were examined with a scanning electron microscope and have been shown to contain cocoliths cemented into their pore structure (Fig. 1). Cocoliths are small carbonate plates produced by marine cocolithophore organisms (Ramsey 1974).

Table 1. Species of Foraminifera in Hudson River core CD2-29A

Species	**Classification**	***Salinity Range, ppt**	***Temperature Range, °C**
G. ruber (pink)	tropical	22-49	18-32
G. ruber (white)	temperate to subtropical	22-49	14-32
G. sacculifer	tropical	24-47	16-31
Orbulina universa	cosmopolitan	23-46	10-30
Neogloboquadrina. dutertrei	tropical to subtropical	25-46	15-30
Globorotalia inflata	temperate	33-38*	5-27
Globorotalia tumida	tropical to subtropical	34-38*	16-29

*Tolerance data from (Bijima et al. 1990) and (Tolderlund and Be 1971)

Cocolithophores are unilocular marine algae which live in marine environments and appear in the sediment record in the Upper Triassic (Bown et al. 2004). These plates suggest an open ocean source for these tropical foraminifera. The tropical and subtropical foraminifera were found in seven distinct layers in the sediment core, which suggests a unique transport mechanism.

The observed distinct layers of tropical marine foraminifera may have been deposited during a hurricane event which created a storm surge. A storm surge forms when a low pressure weather system with high winds piles up water near the coast, and can flood areas close by, especially if the storm occurs during high tide conditions.

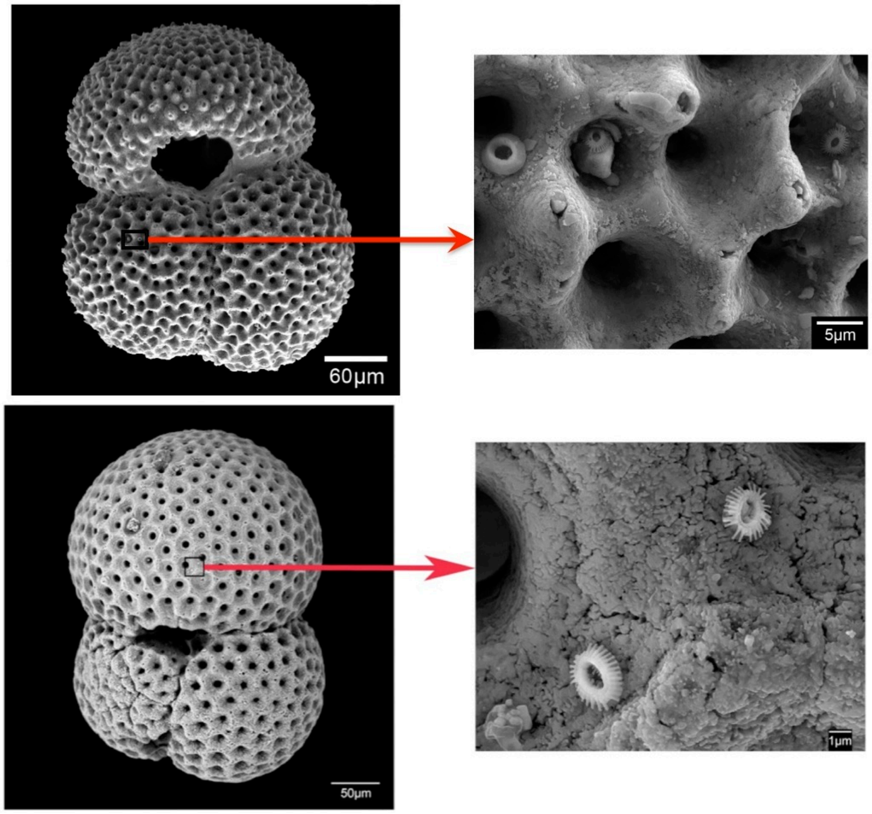


Figure 1. SEM photomicrographs of pelagic foraminifera from Hudson River cores. Top left: *G. ruber* (pink) from CD2-29A. Top right: Magnification of the black box in the figure to the left, showing coccoliths cemented onto the foraminiferal test. Bottom left: pelagic marine foraminifer from VM32-2. Bottom right: two coccoliths from area of foraminifer in box. *Photo credits: Dee Breger, Micrographic Arts, Greenfield, NY.*

Storm surges can form from both Nor'easters and hurricanes (tropical cyclones). Warm core rings from the Gulf Stream travel to 40°N and contain tropical foraminifera (Ruddiman 1969). Under most circumstances, warm core rings stay on the outer shelf. The strong onshore winds and less intense rainfall produced by a hurricane whose eye has its landfall south of the Hudson River (like Hurricane Sandy), could help to move warm core rings from the outer shelf onto the inner shelf and subsequently into the Hudson. In this case, the foraminifera were most likely dead by the time they reached the Hudson River.

Another possible transport mechanism is through drought conditions, which would be evident in the movement northward of the “salt wedge” that is formed in an estuary like the Hudson, where the dense salt water flows below the freshwater. This would allow the foraminifera to live further up the river than the salinity tolerances of the foraminifera species would originally suggest, and could result in such depositional layers as the drought seasons come and go. This effect would be most likely to occur in midsummer, a time when tropical to subtropical foraminifera would find it easier to thrive in the offshore ocean, and may be exacerbated by strong offshore winds.

In this study, goals were to check the reproducibility of foraminifera bearing layers in CD02-29A by re-sieving samples from the core, and to provide higher resolution Cs-137 and Pb-210 dating of CD02-29A to further constrain the sedimentation rate. Another objective was to process another similar core titled CD02-13 for Cs-137 concentration to assess sedimentation rate and sieve this core for microfossils. Constraining the spatial distribution and absolute ages of the stratigraphic microfossil layers is the first step to developing a useful paleoclimatic proxy.

METHODS

Core Sampling

Sediment cores CD02-29A and CD02-13 were kept in refrigerated storage at Lamont Doherty Earth Observatory. Samples were taken from different depths in core in 2 cm^3 sizes for analysis. Sampling depths in both cores were selected using lows in acoustic impedance as a proxy for incursions of marine, clay-rich sediment. Some depths in core CD02-29 where foraminifera had been found previously were resampled to check on the reproducibility of the prior results. The sediment core CD02-29A was originally recovered during the “Can-Do” cruise on June 3rd, 2002 using a vibracore mechanism at 8.2 m water depth. Similarly, CD02-13 was taken on May 31st, 2002 at 11 m water depth, also a vibracore. Core locations are shown in Figure 2.

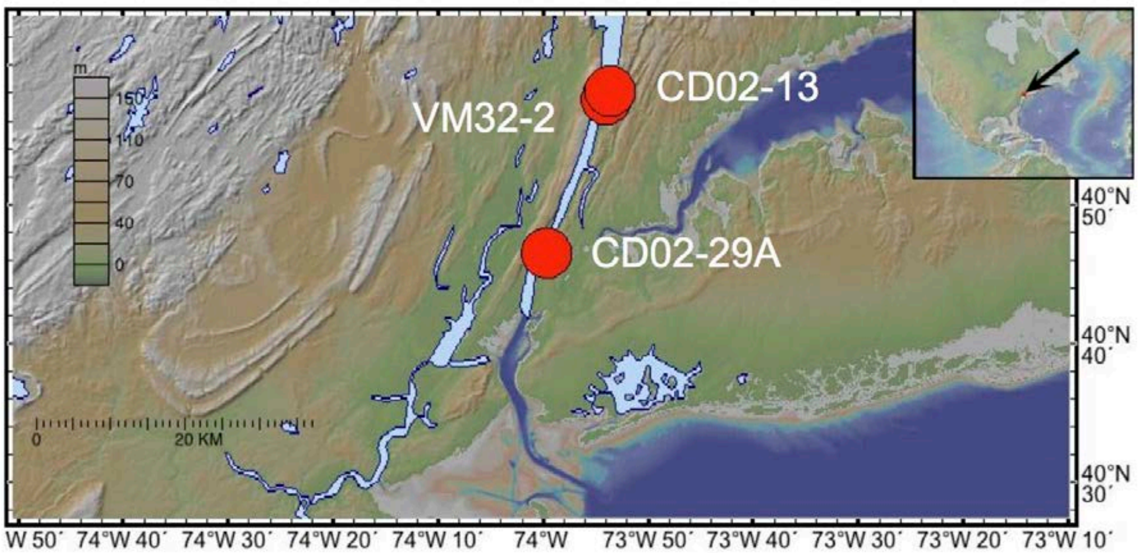


Figure 2. Map of the three sediment cores used in this study. VM32-2 is a piston core, CD02-13 and CD02-29A are vibracores.

Sample Collection

Sediment core samples were processed using wet sieving methods. Small subsamples were weighed and then dried in a sealed oven at 23° C for two days, and the weight was again recorded.

Next, the original sample was disaggregated in de-ionized water. The sample was sonified for 15 minutes, and allowed to settle overnight. This sonification step was repeated three times. In order to segregate different test size fractions, the samples were washed through stacked 250μm, 125μm, 63μm, and 38μm sieve sizes, and rinsed with de-ionized water. Stacked sieves with samples were covered with a watch-glass and dried overnight. Sieves were cleaned through ultra-sonification in a water bath between each sample.

Fossil Picking

Fossil picking was accomplished with a Herrbrugg Wild MSA stereographic microscope for each size fraction at each depth sampled. The number and species of fossils were recorded and tests were stored in slides for reference and possible future isotopic analysis.

RESULTS

Multiple layers containing tropical planktonic foraminifera including a large number of *G. ruber* (pink) were recovered after sieving and fossil picking in CD02-13 (Fig 3, Fig 4). These assemblages were very similar in abundance and species distribution to CD02-29A.

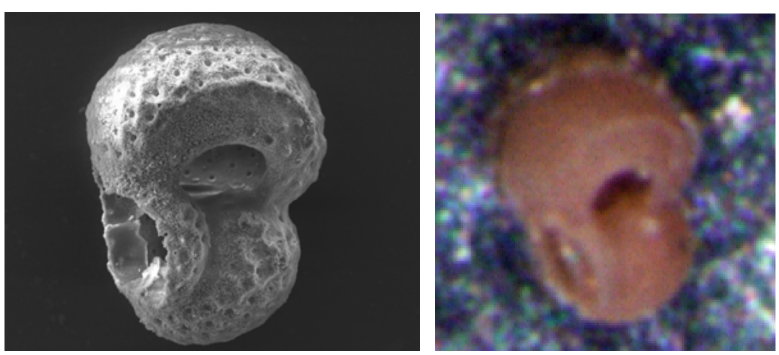


Figure 3. SEM and visual light image of a *G. ruber (pink)* test from CD02-13, 100-102cm. *Photo credits: Dee Breger, Micrographic Arts, Greenfield, NY.*

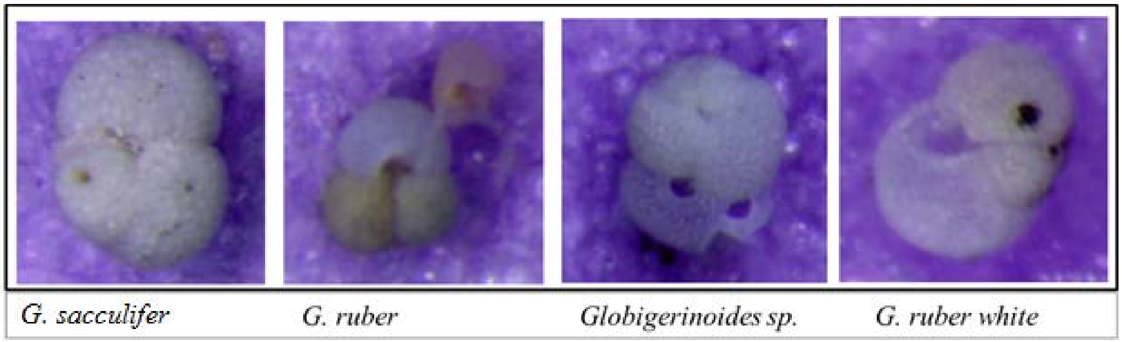
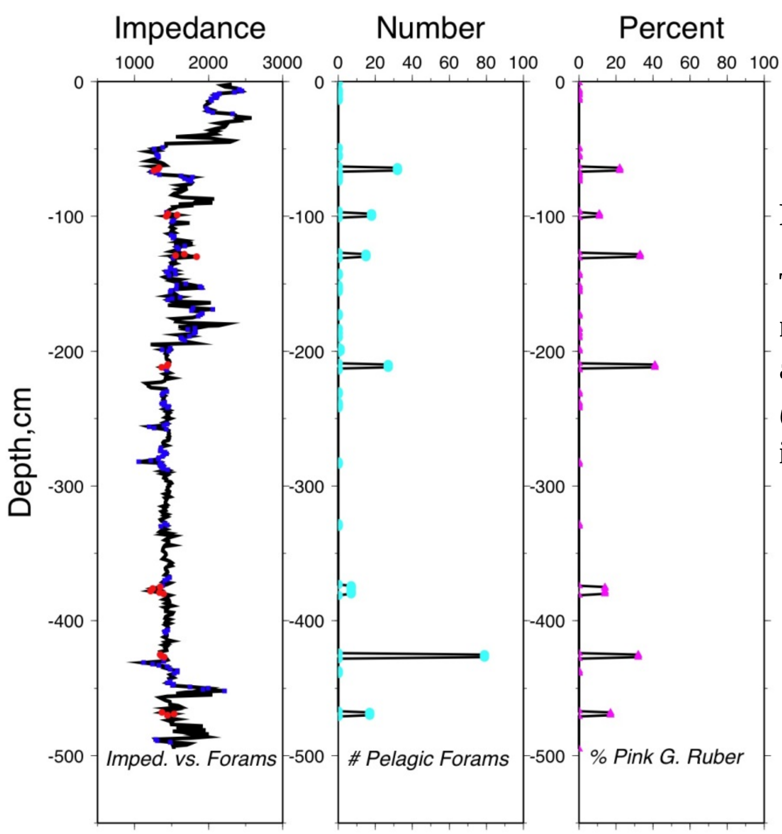


Figure 4. Visual light images of other marine planktonic foraminifera tests from CD02-13.

Layers containing marine planktonic foraminifera were replicated in CD02-29A, and the core profile was updated to reflect the new values. Acoustic impedance was a good predictor of carbonate bearing layers (Fig. 5). New layers containing benthic foraminifera were also found in CD02-29A.



CD02-29A
Updated Core Profile

Figure 5.

The acoustic impedance, number of pelagic forams, and the percent *G. ruber (pink)* is provided by depth in core.

Refined radiogenic isotope data for CD02-29A provided a higher resolution dating profile for Cs-137. Peaks were resolved at 1971 for the Indian Point nuclear power plant leak of radioactive material, in 1963 for the fallout maximum, and a final drop-off in 1954 (Fig 6). For CD02-13, post-1954 Cs-137-bearing sediment was only detected in the first 2 cm, and mixed with post-1954 level sediment until 6cm. Below this line, Cs-137 was inconclusive for CD02-13 (Fig 7).

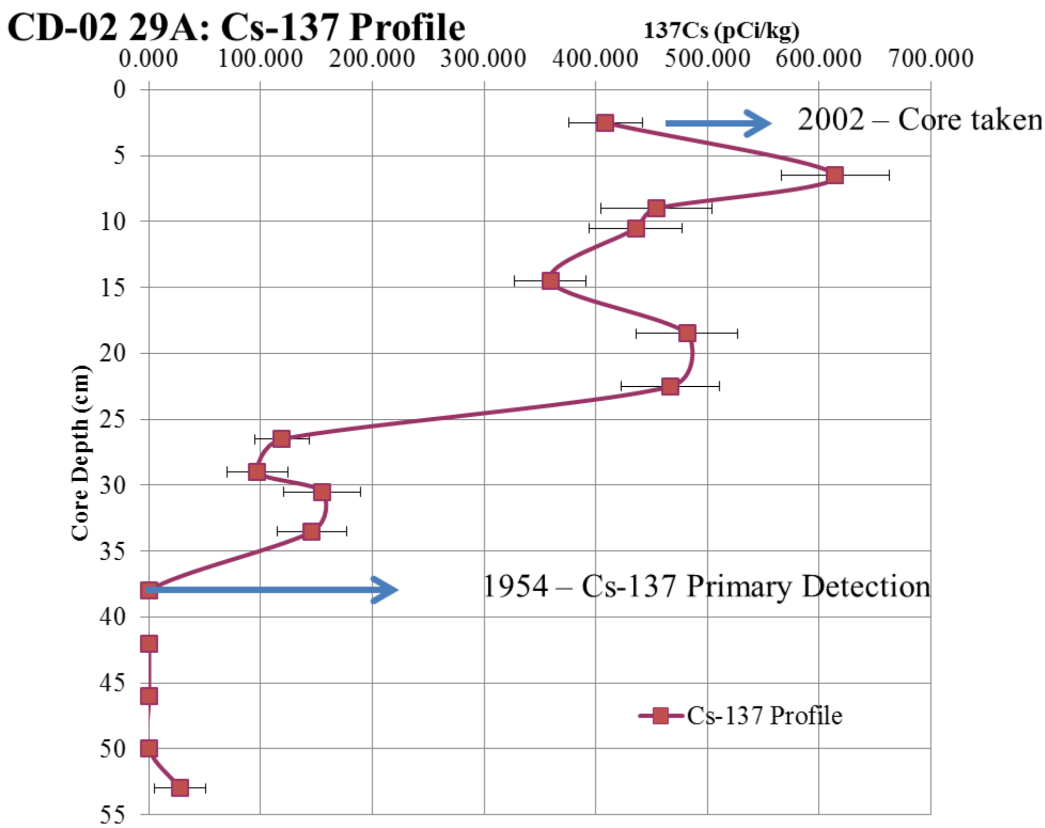


Figure 6. **The Cs-137 profile for CD02-29A shows a peak at 1971, during the leak at Indian Point, another fallout peak in 1963, and a final drop-off at 1954, all of which can be used as stratigraphic markers (Levinton and Waldman 2006).**

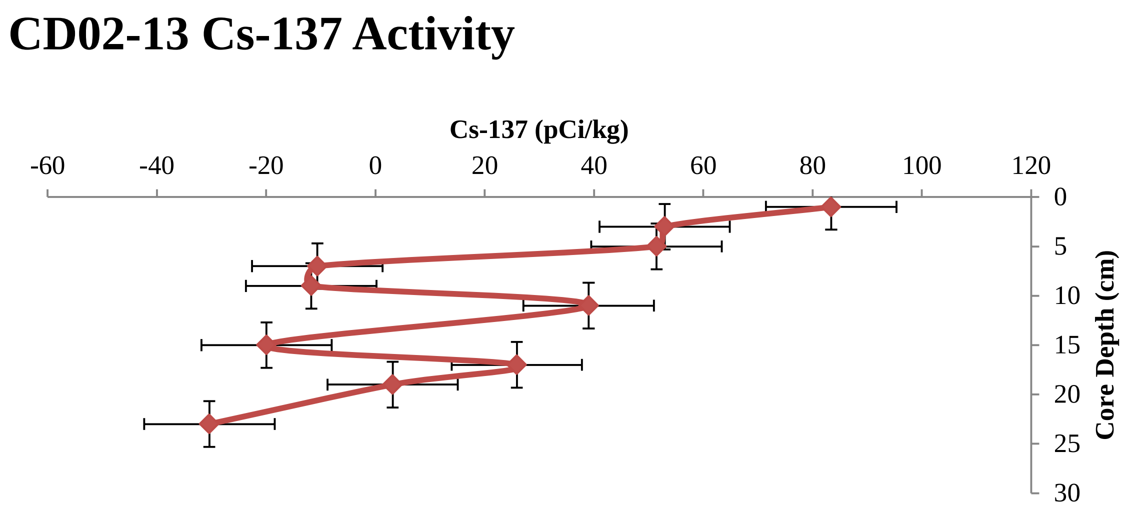


Figure 7. **The Cs-137 profile for CD02-13 shows a slight increase at the beginning of the core of post-1954 Cs-137 and mixing down to 6cm, but lower values are within standard error variation.**

Assuming a constant influx of sediment to the core location, an estimate of the sedimentation rate can be provided from the Cs-137 values. For CD02-29A, the estimated sedimentation rate is between 0.5 cm/year and 1.5 cm/year. Total Pb-210 activity from CD02-13 was inconclusive.

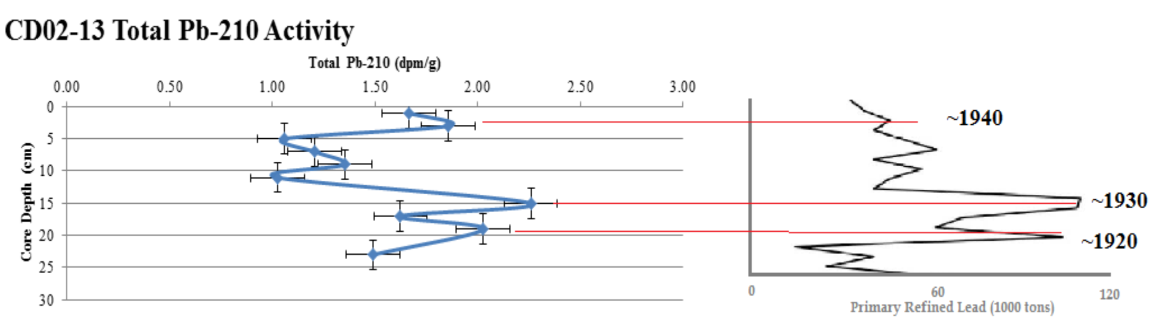


Figure 8. **The total Pb-210 data from CD02-13 with the production of refined lead in the Hudson Basin adjacent (Nelson, 2011).**

DISCUSSION

Previously suggested pelagic foraminifera-bearing layers were confirmed by repeat core sampling and sieving of CD02-29A. This result supports the previous layer identifications, and sampling at many depth levels corroborated the hypothesis that these are the main stratigraphic foram-bearing layers.

Similar assemblages of sub-tropical and tropical planktonic foraminifera were found in core CD02-13, located upriver from CD02-29A. This replicates the findings in CD02-29A and suggests that deposits of pelagic foraminifera may occur throughout the lower Hudson River. However, abundances of the fossils found were much lower than in CD02-29A. Issues of possible contamination of the sieves by entrapped foraminiferal tests were addressed through sonification of sieves between each use, as in Green (2001). In the future, methylene blue treatment of the sieves could provide a more robust protection against contamination, due to the low abundances present in CD02-13.

Radiogenic sediment dating for CD02-29A and CD02-13 provides valuable temporal parameters for the former, but for the latter core the Cs-137 peaks were not resolved. This is likely due to sedimentation rate changes or local dredging, as depositional patterns are very spatially dynamic within the Hudson River Estuary (McHugh et al. 2004). Common influences on the resolution of Cs-137 profiles within sediment cores include: reworking of sediment (re-suspension and bioturbation), diffusional movement of Cs-137 through pore waters, and particle size of sediments, which impacts particle association (Ritchie and McHenry 1990). The most likely influence on the difference between resolved Cs-137 horizons between CD02-29A and CD02-13 is changes in the sedimentation rate.

Sedimentation rates can vary seasonally, and commonly sedimentation in the Hudson occurs both due to mechanisms of flocculation from an increase in salinity downstream and kinetic settling of suspended matter in lower flow conditions (Woodruff et al. 2001). High levels of rapid sediment deposition can occur in the estuarine turbidity maximum (ETM) zone (Meade 1969). In this area, physical sediment trapping mechanisms such as salinity-inducted flocculation and tidal effects cause a focusing and concentration of suspended sediment (Nitsche et al. 2010).

The collection of these suspended particles acts as a sediment trap at the marine-freshwater water interface, creating high sedimentation rates through rapid sheer velocity changes, salinity gradients, and spatial stratification gradients (Ralston et al. 2013). The depositional profiles at the ETM can change as the fluxes of freshwater from upriver flow seasonally change (Woodruff et al. 2001). During times of high flow during snowmelt or storm events, the increase in freshwater can push the ETM downstream, changing the salinity gradients in the Hudson and allowing for higher rates of sediment deposition downriver (Woodruff et al, 2001). Gathering bathymetric and seismic data can help to address accumulation rates and depositional profiles (Nitsche et al. 2010), which may help understand the dynamics of sediment deposition in the range of CD02-29A and CD02-13.

A hurricane event could re-suspend sediment containing planktonic foraminifera tests deposited from a tropical source (likely the Gulf Stream) which are then deposited once the tests reach the depositional area of the ETM within the Hudson River. This resuspended material could be deposited further upriver in the event of a storm surge. One such storm surge event occurred in 1998 when high winds from the East produced water surface elevations into the Battery as far North as Albany, NY (Blumberg and Hellweger 2006). The well-preserved nature of the tests suggests a rapid depositional profile without post-depositional suspension, such as would be common in the ETM. This assemblage of foraminifera from this paper is quite characteristic of the Gulf Stream, as *G. sacculifer* has its highest abundances within the Gulf Steam, which was another tropical foraminifera identified as a component of the tropical assemblage (Balsam and Felssa et al. 1978). The high levels of fine-grained materials in the depositional layers and correlation with acoustic impedance are consistent with high depositional rate event sediment profiles in the Hudson, monitored by both sediment core and optical acoustic measurements (Traykovski et al. 2004).

An external check for the climatic signal could be obtained through use of carbon-14 dating. Using this method in estuaries can be complex due to re-suspension and incorporation of old carbon sources into shell material, however it has been used in the past (Pekar et al. 2004) for this area in the Hudson. Pending carbon-14 dates from CD02-29A and CD02-13 will provide more robust sedimentation rate assessments, and future hurricane event correlations.

In the future, collection of another sediment vibracore in the depositional area near CD02-29A would provide for replication of depositional layers in the sediment. Review of other core candidates near CD02-13 which have a higher resolution Cs-137 profile is suggested as well. Though greater levels of replication in identified stratigraphic layers are needed, the implications of current results still suggest a unique depositional mechanism and climatic signal, possibly due to storm surges.

ACKNOWLEGMENTS

We would like to thank the Tibor T. Polgar Fellowship program and the Hudson River Foundation for funding and support of this project. Thank you to Dee Breger for her SEM images and workup of the images in Figure 1. Thank you to Richard Bopp and Miriam Katz at Rensselaer Polytechnic Institute for their support and continued advice, along with Bärbel Hönisch, Nichole Anest and Jon Stelling at LDEO.

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