Undergraduate Research Experience in Ocean, Marine, and Polar Science

Survey of Post Last Glacial Maximum Environment: Unusual Soil Constituents in Rockyhock Bay Stratigraphy

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Abstract

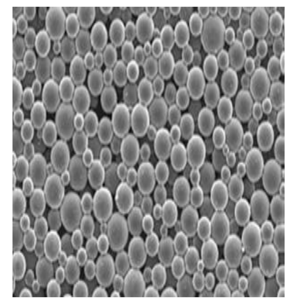
Throughout North America's eastern coastal plain are found a variety of features attributed to ice age climate. These include many elliptical, shallow depressions collectively called Carolina Bays, hypothesized to have been formed by the strong, sustained winds and arid, cold climate characteristic of glacial epochs (Raisz, 1934, Johnson, 1942 and Kaczorowski, 1977). This view eclipsed the 1933 proposition by Melton and Schriever, and expanded by Prouty (1934, 1953), that extraterrestrial debris produced by an aerial meteorite or comet explosion in the vicinity of the Great Lakes during the late Pleistocene formed the bays. Recent discovery that a number of the bays were found to contain material associated with extraterrestrial impacts including carbon and magnetic spherules, glass-like carbon, charcoal and nanodiamonds reinvigorated the debate over the bay's origins (Firestone, et. al. 2007).

To confirm the bays were receptacles for impact material, soil samples were previously taken from Rockyhock Bay in Edenton, NC. Sequential soil samples were excavated near the bay's center and core samples extracted near the bay's rim. The samples were examined to determine the presence of carbon-associated markers and to measure the density of magnetic grains and grain-size distribution. Magnetic spherules were found among the smaller size portions of the magnetic grains and spherule density estimated. The geochemistry of a magnetic spherule was determined using scanning electron microscopic energy dispersive x-ray spectroscopy (SEM-EDS).

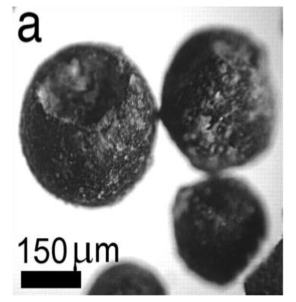
Evidential Markers: Soil Constituents

Charcoal

Glass-like Carbon



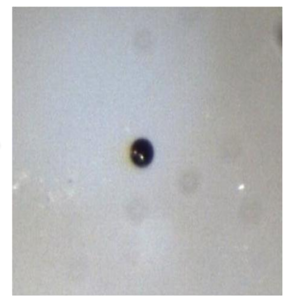
Carbon Spherule



Nanodiamonds

Magnetic Grains

Magnetic Spherule



Introduction

Evidence for the harsh climate prevalent during the Last Glacial Maximum (LGM) are seen in topographical features visible south of the ice sheet margin in the uplands and coastal regions of the eastern United States.

Among these are many elliptical, shallow depressions called collectively Carolina Bays, hypothesized to have been formed by "blow outs" of loose sediment by the strong, sustained winds and arid, cold climate characteristic of glacial epochs (Raisz, 1934, Johnson, 1942 and Kaczorowski, 1977).

12,900 years ago, post-LGM warming was interrupted by a return to a glacial climate that persisted for over 1,000 years. The events precipitating the cooling, known as the Younger Dryas (YD), are the subject of debate. Recently Firestone proposed that an impact in the Laurentide ice sheet by a fragmented comet might have simultaneously initiated the YD and formed the Carolina Bays [4]. Carbon 14 dating and pollen analysis of core samples taken from Rocky Hock Bay (RHB, in Chowan County, NC, by Whitehead [5] indicate a pre-YD genesis. However, a number of the bays have been found to contain materiel associated with extraterrestrial impacts including carbon and magnetic spherules, glass-like carbon, charcoal and nanodiamonds [4]). The discovery reinvigorated the debate over the bay's origins.

If created before the YD, the bays would have experienced episodic post-formation modification due to cold, dry, windy periods alternating with warm, moist and calmer climatic conditions. Carolina Bays would thus episodically fill with wind-blown or water-borne sediment or water. Some evidence of bay history should be evident in their stratigraphy. Whitehead's correlation of depth to date at Rocky Hock Bay, shown in figure 1, makes it possible to establish a chrono-stratigraphic context for potential impact markers found in bay sediments and also provide and opportunity to confirm Whitehead's inferred bay-structure and age.

Rockyhock Bay: Soil Sample Source

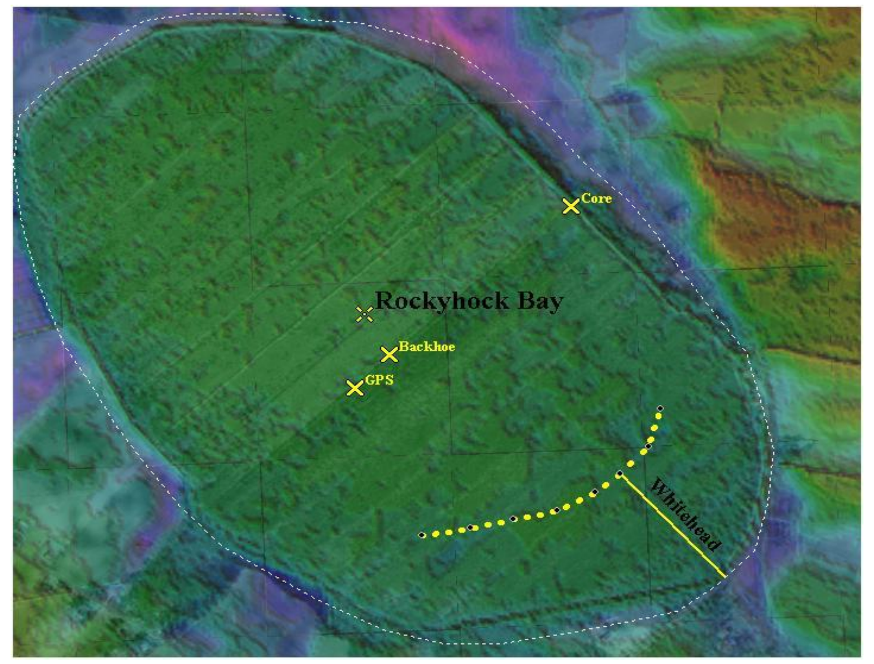


Figure 1. Rocky Hock Bay sample locations for Whitehead depth-to-date correlation and URE OMPS 2009 Gambit Team coring and backhoe.

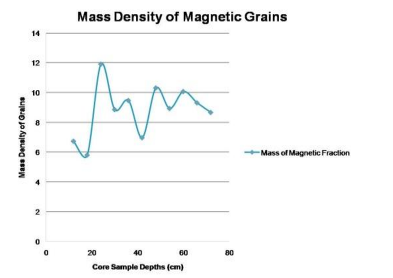


Figure 12. Mass density of all soil depths analyzed.
Note: There are four bulk grain peaks.

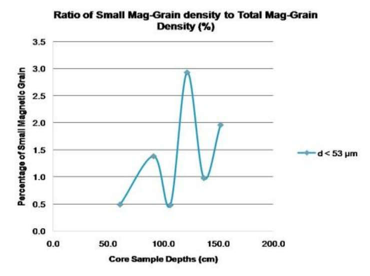


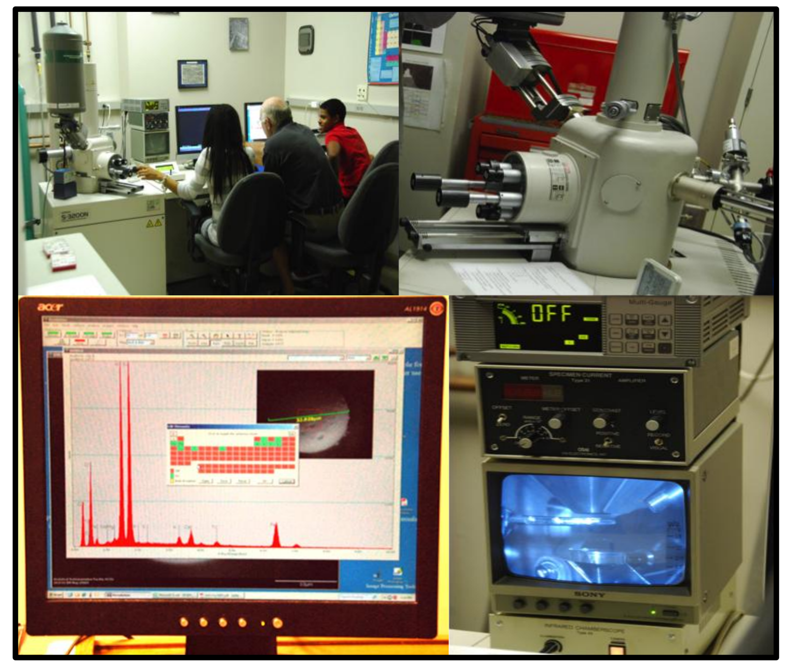
Figure 13. Mass density percent of small magnetic grains from the samples containing peaks and those surrounding them.

Analysis Materials

Figure 2. Some of the materials used for the analysis of the soil samples.

Scanning Electron Microscope

Hitachi S-3200N SEM at the North Carolina State's Analytical Instrumentation Facility



Procedure

Figure 3. Weighing of a sample to 300 grams

Figure 4. Slurry being filtered through a 20-micron mesh filter

Figure 5. Two filters containing the floating material extracted

Figure 6. Magnet being moved around the slurry

Figure 7. Rinsing the magnetic grains

Figure 8. Size sorting of magnetic grains

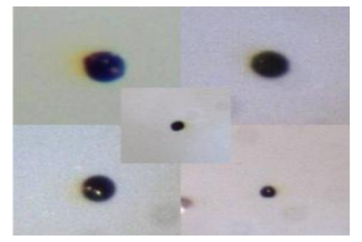


Figure 9. Possible magnetic spherules

Figure 10. SEM stubs containing possible magnetic spherules

Peak Depths (cm)	Mass of Magnetic Grains (g/kg)	Mass of Smallest Magnetic Grains (d < 53 µm) (g/kg)	Percent of Smallest Magnetic Grains
61	11.914	0.057	0.48%
91.4	9.473	0.127	1.34%
121.9	10.313	0.297	2.87%
152.4	10.070	0.197	1.96%

Figure 14. Bulk magnetic grain peaks and their percentages of the smallest grain size.

Geo-chemistry of Magnetic Spherule (48")	
Elements	Percent (%)
Oxygen	29.9
Silicon	16.54
Aluminum	14.83
Iron	3.05
Magnesium	0.42
Calcium	1.02
Potassium	0.57

Figure 15. Composition of the magnetic spherule from 121.9 cm sample depth.

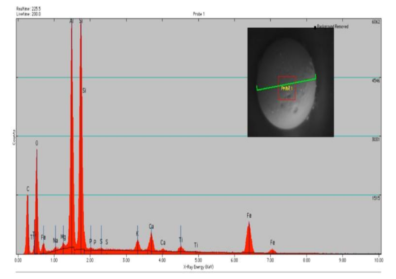


Figure 16. EDS of magnetic spherule found from 121.9 cm depth.

Results

There were four peaks in the bulk magnetic material: (1) 61 cm, (2) 91.5 cm, (3) 121.9 cm, and (4) 152.4 cm depths (Fig. 12 & Fig. 13). Each of the peaks were ~ 30.5 cm apart. Each peak was size sorted and its mass was measured and density calculated. The ratio of the smallest size fraction's density to that of the sum of the three size portions was calculated and tabulated as a percent of the total (Fig. 14). The largest bulk peak was found in sample 61 cm depth. The smallest grains (d < µm 53) were most abundant in the core-sample from 121.9 cm depth.The largest bulk peak was found in sample 61 cm depth Suspected spherules were founded in 61 cm and 121.9 cm depths, but not in any of the depths surrounding them. However, only the sample at 121.9cm depth revealed the presence of magnetic spherules at an abundance of about 60 spherules/kilogram.

The EDS showed that the geo-chemical composition of the 32 µm magnetic spherule found in the 121.9 cm depth: oxygen (29.9%), silicon (16.54%), aluminum (14.83%), iron (3.05%), magnesium (0.42%), calcium (1.02%), and potassium (0.52%), as shown in figure 15. There were trace amounts of other elements found (Fig. 16).

The Rockyhock bay spherule was found to possess similar soil constituents to spherules found in other Carolina Bays, (Fig. 17). There were small amounts of all the markers found in RHB, except for carbon spherules. Since no carbon spherules were found, no tests were run for the presence of nanodiamonds.

Conclusions

There was no significant indication of biomass burning beyond small fragments of charcoal and glass-like carbon. This can be attributed to the geography of Rocky Hock Bay, which was probably a lake during the late-Pleistocene. Therefore, there was mostly water present and no biomass-forest or trees. Also, multiple bulk magnetic grain peaks were found in 30.5 cm intervals beginning at 61 cm. There is only one significant small grain diameter that produced magnetic spherules, which was at 121.9 cm. Firestone concluded that peaks found in bulk grain materials indicated the YD layer [4]. However, it was discovered that the peaks in size d < 53 µm spherules showed the true layer.

The SEM confirmed the grain's spherulitic nature and the EDS results indicated similar geo-chemistry to other spherules taken from distant sites. Spherule chemical composition appears to be very similar to that of the Earth's crust but not of either volcanic or anthropogenic or biogenic origin. The chemistry appears to be very similar to microtektites found around the world and attributed to extraterrestrial impact (Glass, 1974 and Koeberl, 1986).

Markers	RHB	Other Bays
Amber Spherules	small amounts	varying amounts
Carbon Spherules	none	varying amounts
Charcoal	small amounts	varying amounts
Glass-like Carbon	small amounts	varying amounts
Nano-diamonds	untested	varying amounts
Magnetic Grains (Peak)	multiple peaks	single & multi-peaked
Magnetic Spherules	small amounts	varying amounts

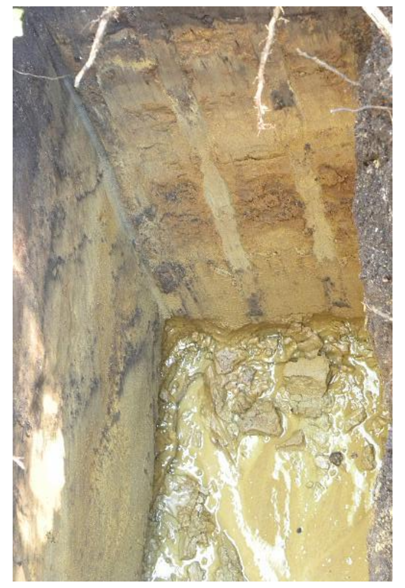
Figure 17. Comparison of the soil constituents found in RHB to other bays.

Future Work

Soil samples analyzed from Rock Hock Bay contained soil constituents that correlate with an extraterrestrial impact. Further research should be done by taking new core samples from just inside of the bay. It is also suggested that core samples at 7.6 cm intervals beginning at 61 cm to 167.6 cm to confirm the YD impact layer and obtain more accurate results.

The URE OMPS 2009 Gambit Team previously took and analyzed soil samples from Sandra Kimbel Bay (SKB) [1]. It is recommended that processed samples from (SKB) with peaks in bulk magnetic grain density are size sorted (d > 250 µm, 53 µm < d < 250 µm, and d < 53 µm) and calculate the percentages of each. Afterwards, analyze the sample with the peak in d < 53 µm. Any possible spherules found should have the same SEM-EDS work that was done on the spherules found in RHB. In doing so, the spherulitic nature and chemical composition of the possible magnetic spherules can be determined. Afterwards, those magnetic spherules should be compared to spherules from other impact sites.

Future Lacustrine-history bays should be surveyed and soil analyzed for impact markers including: charcoal, carbon spherules, glass-like carbon, and magnetic spherules. If magnetic spherules are found, SEM-EDS should be performed. If carbon spherules are found, Transmission Electron Microscopic (TEM) analysis should be performed to reveal the presence of nanodiamonds should be performed.



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