KECK GEOLOGY CONSORTIUM

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

April 2011
Union College, Schenectady, NY

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2010-2011 PROJECTS

FORMATION OF BASEMENT-INVOLVED FORELAND ARCHES: INTEGRATED STRUCTURAL AND SEISMOLOGICAL RESEARCH IN THE BIGHORN MOUNTAINS, WYOMING
Faculty: *CHRISTINE SIDDOWAY, MEGAN ANDERSON*, Colorado College, *ERIC ERSLEV*, University of Wyoming
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EXPLORING THE PROTEROZOIC BIG SKY OROGENY IN SOUTHWEST MONTANA
Faculty: *TEKLA A. HARMS, JOHN T. CHENEY*, Amherst College, *JOHN BRADY*, Smith College
Students: *JESSE DAVENPORT*, College of Wooster, *KRISTINA DOYLE*, Amherst College, *B. PARKER HAYNES*, University of North Carolina - Chapel Hill, *DANIELLE LERNER*, Mount Holyoke College, *CALEB O. LUCY*, Williams College, *ALIANORA WALKER*, Smith College.

INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO
Faculty: *DAVID P. DETHIER*, Williams College, *WILL OUIMET*. University of Connecticut
Students: *ERIN CAMP*, Amherst College, *EVAN N. DETHIER*, Williams College, *HAYLEY CORSON-RIKERT*, Wesleyan University, *KEITH M. KANTACK*, Williams College, *ELLEN M. MALEY*, Smith College, *JAMES A. MCCARTHY*, Williams College, *COREY SHIRCLIFF*, Beloit College, *KATHLEEN WARRELL*, Georgia Tech University, *CIANNA E. WYSHNYSZKY*, Amherst College.

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Students: LYNN M. GEIGER, Wellesley College, KARA JACOBACCI, University of Massachusetts (Amherst), GABRIEL ROMERO, Pomona College.

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Faculty: *KELLY MACGREGOR*, Macalester College, *CATHERINE RIIHIMAKI*, Drew University, *AMY MYRBO*, LacCore Lab, University of Minnesota, *KRISTINA BRADY*, LacCore Lab, University of Minnesota

Students: *HANNAH BOURNE*, Wesleyan University, *JONATHAN GRIFFITH*, Union College, *JACQUELINE KUTVIRT*, Macalester College, *EMMA LOCATELLI*, Macalester College, *SARAH MATTESON*, Bryn Mawr College, *PERRY ODDO*, Franklin and Marshall College, *CLARK BRUNSON SIMCOE*, Washington and Lee University.

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Students: *BRIANA BERKOWITZ*, Beloit College, *DAENA CHARLES*, Union College, *MELLISSA CROSS*, Colgate University, *JOHN MICHAELS*, North Carolina State University, *ERDENEBAYAR TSAGAANNARAN*, Mongolian University of Science and Technology, *BATTOGTOH DAMDINSUREN*, Mongolian University of Science and Technology, *DANIEL ROTHBERG*, Colorado College, *ESUGEI GANBOLD, ARANZAL ERDENE*, Mongolian University of Science and Technology, *AFSHAN SHAIKH*, Georgia Institute of Technology, *KRISTIN TADDEI*, Franklin and Marshall College, *GABRIELLE VANCE*, Whitman College, *ANDREW ZUZA*, Cornell University.

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Students: *SHANNON BRADY*, Union College. *LOGAN SCHUMACHER*, Pomona College, *HANNAH ZELLNER*, Trinity University.

KECK SIERRA: MAGMA-WALLROCK INTERACTIONS IN THE SEQUOIA REGION
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EOCENE TECTONIC EVOLUTION OF THE TETONS-ABSAROKA RANGES, WYOMING
Faculty: *JOHN CRADDOCK*, Macalester College, *DAVE MALONE*, Illinois State University
Students: *JESSE GEARY*, Macalester College, *KATHERINE KRAVITZ*, Smith College, *RAY MCGAUGHEY*, Carleton College.

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Keck Geology Consortium: Projects 2010-2011
Short Contributions— Connecticut River

SEDIMENT DYNAMICS & ENVIRONMENTS IN THE LOWER CONNECTICUT RIVER
Project Faculty: SUZANNE O'CONNELL, Wesleyan University

INVESTIGATION ON TROUGH CREST RELATIONSHIP OF BEDFORMS IN THE CONNECTICUT RIVER
LYNN M. GEIGER, Wellesley College
Research Advisor: Dr. Brittina A. Argow

A CASE STUDY FOR SEDIMENT AND CONTAMINATION IN FLOOD PLAIN TIDAL PONDS: SELDEN COVE, CONNECTICUT RIVER
KARA JACOBACCI, University of Massachusetts (Amherst)
Research Advisor: Jonathan Woodruff

COMPOSITIONAL AND TEXTURAL CHARACTERIZATION OF BOTTOM SEDIMENTS FROM THE LOWER CONNECTICUT RIVER
GABRIEL ROMERO, Pomona College
Research Advisor: Robert Gaines

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A CASE STUDY FOR SEDIMENT AND CONTAMINANT STORAGE IN FLOOD PLAIN TIDAL PONDS: SELDEN COVE, CONNECTICUT RIVER

KARA JACOBACCI, University of Massachusetts (Amherst)
Research Advisor: Jonathan Woodruff

ABSTRACT

The Connecticut River Estuary has inherited a legacy of contamination since the onset of industrialization. Tidal ponds and coves along the river provide ample storage space for the deposition of fine-grained sediment and likely serve as a primary depocenter for contaminants introduced to the river over the last few centuries. Here we present sedimentological and geophysical data from Selden Cove, a fresh water tidal pond located along the floodplain of the Connecticut River, in order to assess the inventories of sediment and heavy metal contaminants. Using ground-penetrating radar surveys, we are able to determine patterns and spatial distributions of depositional units within the sub-bottom. Cesium-137 is used to evaluate decadal rates of deposition as well as define temporal stratigraphic horizons. Mercury analyses indicate sediments deposited since industrialization and provide an additional chronological constraint for evaluating centennial rates of deposition. Using these tools, we are able to determine the total volume of contaminated sediment stored within the cove as well as an inventory for the total amount of mercury which

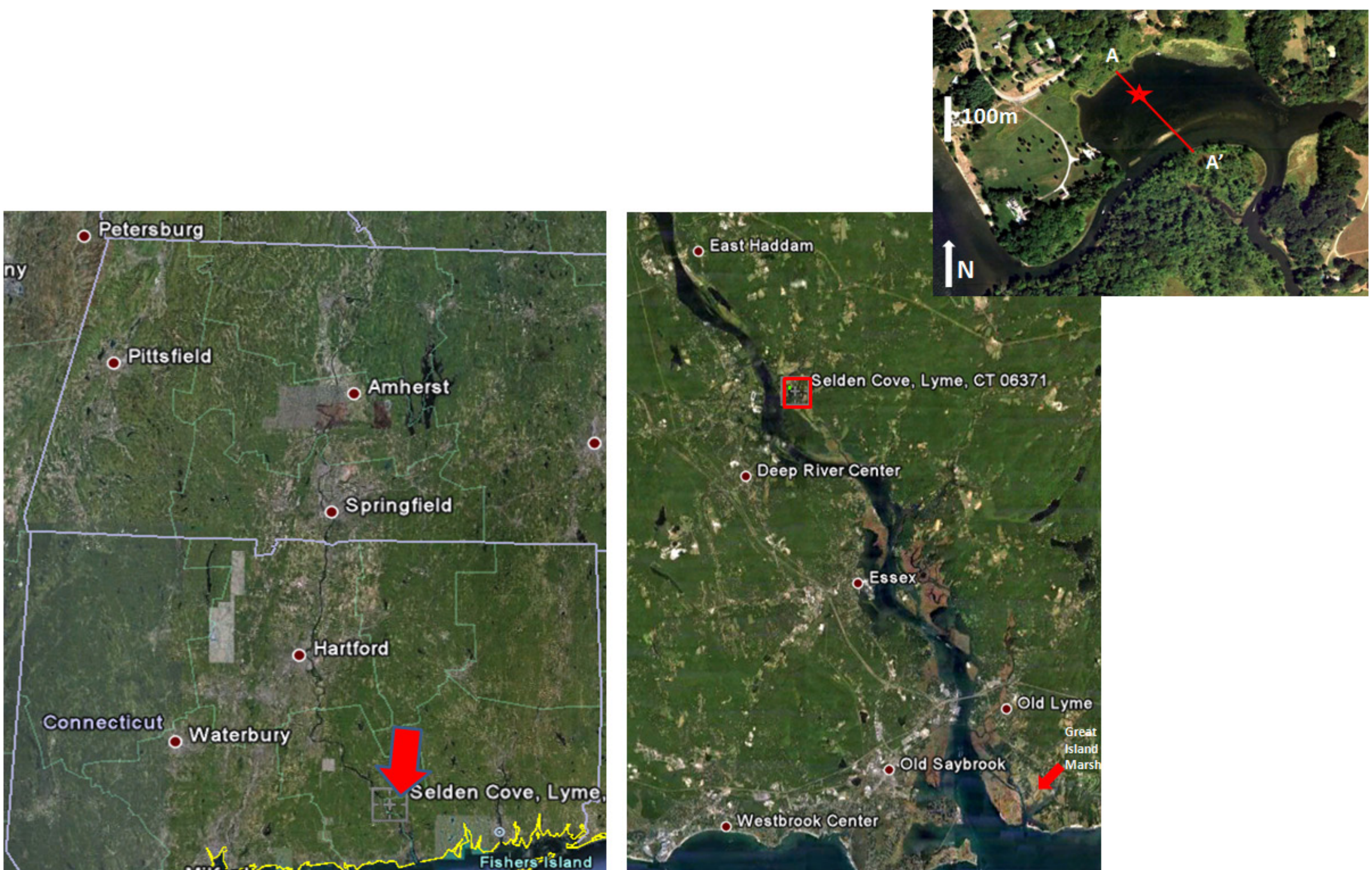

Figure 1. Site map showing the location of Selden Cove in the state of Connecticut as well as its proximity to Long Island Sound. The location of previous work conducted on Great Island Marsh by Varekamp et al. (2003) is indicated with an arrow.

has accumulated in the pond since the mid-1800s. These inventories are then compared to previous published results for neighboring marsh locations in order to assess the relative role floodplain tidal ponds play in the storage of contaminated sediment.

SITE LOCATION

Selden Cove is located along the eastern floodplain of the tidally influenced reach of the Connecticut River, approximately 16 kilometers (10 miles) from the mouth. The average tidal range at the site is approximately 1.1m, with a maximum range of 1.3 m during the spring freshet. The Connecticut River has a relatively short salinity reach, extending to an annual maximum of 15 km from the mouth during periods of low discharge. (Horne and Patton, 1991). Typically Selden cove is located above the salinity reach; it experiences freshwater conditions except potentially for periods of extremely low discharge on the river. Average water depths at the site are about 1 – 1.5m, with a small submerged levee separating it from a deeper ~ 3m tidal channel to the south. Cores collected previously in a nearby tidal marsh (Great Island Marsh), indicate anomalously high mercury concentrations in excess of 300 ppb down to a depth of 35 cm. (Varekamp et. al 2003) These concentrations exceed background levels of 50-100 ppb, and likely reflect anthropogenic mercury introduced into the river following the onset of industrialization around 1850 C.E.

HISTORY

Until the mid-1800s, Selden Cove was influenced tidally by the Connecticut River through a small tidal creek to the southeast of the site. In May of 1854 a severe flood, the 5th largest discharge event on record for the Connecticut River, eroded a shorter, additional 350 m long inlet to the east of the cove that remains today. (Maloney 2001)

SUBBOTTOM STRATIGRAPHY

Ground penetrating radar surveys identify a reflector layer likely representing the cove's bottom just prior to the 1854 flood. The data suggests that the cove was around 3m deep at this time. Today, the cove is between 1 – 1.5m in depth, indicating that the site has experienced high sedimentation rates and rapid deposition following the formation of the second inlet in 1854.

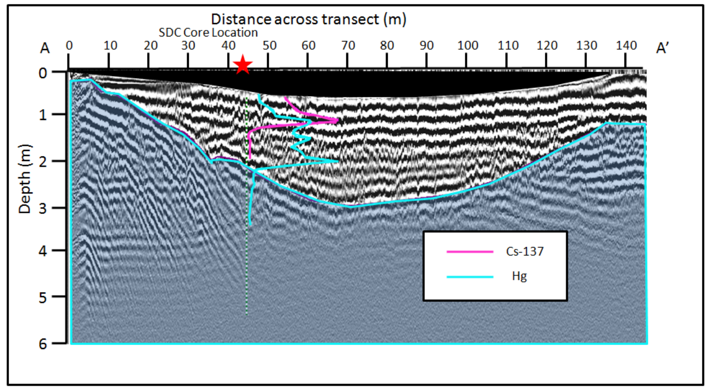

Figure 2. Ground-penetrating radar data showing the sub-bottom profile and reflector occurring at a similar depth to the 1850 onset for Hg pollution.

SAMPLE COLLECTION

In addition to the GPR survey a 4.95 m core was collected towards the pond's depocenter. Two drives were collected at the SDC site indicated with a star on the satellite image. SDC1, collected using the push coring method, was given to Amherst College for use in their porosity and Hg measurements. SDC3, collected using the vibracoring method, was used for all other analyses. The cores were taken side by side to allow near complete records from present day down to 4.95 meters

AGE CONSTRAINTS

Age constraints were obtained with Cesium-137 and bulk Hg and Pb analyses. Average deposition rates over the last few decades were calculated based on the advent and subsequent peak of Cs-137, which likely occurs contemporaneously with the advent of nuclear weapons testing in 1954 C.E. and the later moratorium in 1963. (Pennington et al. 1973) The onset and subsequent peak in Cs-137 activity occurs at depths of 52cm and 76cm respectively, yielding a deposition rate of roughly 1.1-1.4cm/yr. The onset of Hg and Pb in the core occurs around 160cm, resulting in a similar deposition rate of about 1.0 cm/yr, assuming that the onset of Hg and Pb reflect the year 1850 C.E. (Varekamp et al. 2003, Varekamp et al

2005) Recent decreases in Pb within sediment in the region have been linked to the transition of unleaded gasoline in the 1970s. Selden Cove shows a drop in bulk Pb at a depth of 50cm that is consistent with a deposition rate of 1.4cm/yr. Cs-137 and bulk Hg and Pb concentrations suggest that the rate of deposition has been relatively steady, with a slight increase towards modern day that can potentially be attributed to increased compaction within the lower sediments of the core.

BATHYMETRY AND DEPTH

Current bathymetry for Selden Cove is fairly uniform in depth, ranging between 1-1.5 meters throughout the pond. We used the prominent 1854 reflector evident in the GPR stratigraphy to reconstruct the bathymetry of Selden Cove just prior to the opening of the southern inlet in 1854 C.E. (figure 2), and correlated it roughly to the ~1850 C.E. onset for Hg pollution. At this time, Selden Cove was a bowl shaped depression with a maximum depth of 3 meters deep in the center and gradually shallower towards the shore.

PHYSICAL CHARACTERISTICS OF SEDIMENT

The sediment recovered from the cores is approximately 70% silt with the remaining 30% primarily clay. Little sand is evident in the core with the exception of deposits potentially attributable to high energy events. A noticeable decrease in organic content is evident at the 1854 C.E. horizon, where the lithology shifts from highly organic sediment below this transition to the less organic sediment above as seen in Figure 3b. This pattern is consistent with the opening of the tidal inlet to the south and subsequent transport of predominantly clastic inorganic material into the cove. Dry bulk density measurements for sediments above the 1854 C.E. horizon are consistent up to a core depth of 30 cm, followed by a decrease in density towards the surface to a minimum of ~0. 26 g/cm^3 at the sediment – water interface. Using an average of dry bulk density for the sediments above the 1854 horizon (~0.7g/cm^3) and the estimated total for deposited sediment within this timeframe, we find that a mass of roughly $3.6*10^7$ kg of sediment has been

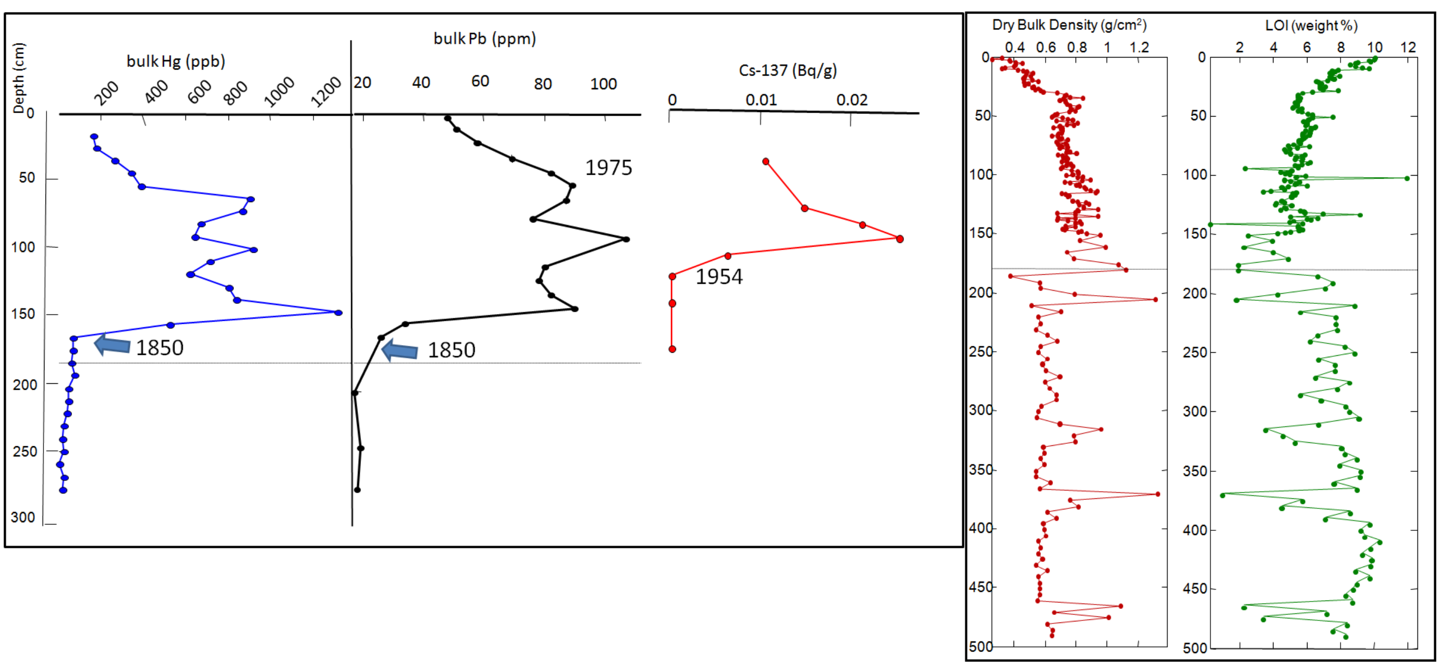

Figure 3. 3a. Down core profiles of bulk Hg, Bulk Pb, and Cs-137 from Selden Cove. These provide an age constraint for the upper portion of the core as well as an approximate deposition rate of 1.0-1.4cm/year. The Hg peak is roughly equivalent to the year 1850. The onset of Cesium-137 corresponds to the year 1954 and the peak is the year 1963. 3b. Down core profiles for dry bulk density (left) and loss on ignition (right). Profiles indicate a change in lithology at a depth of around 160 cm, dating to roughly 1850 based on heavy metal chronologies.

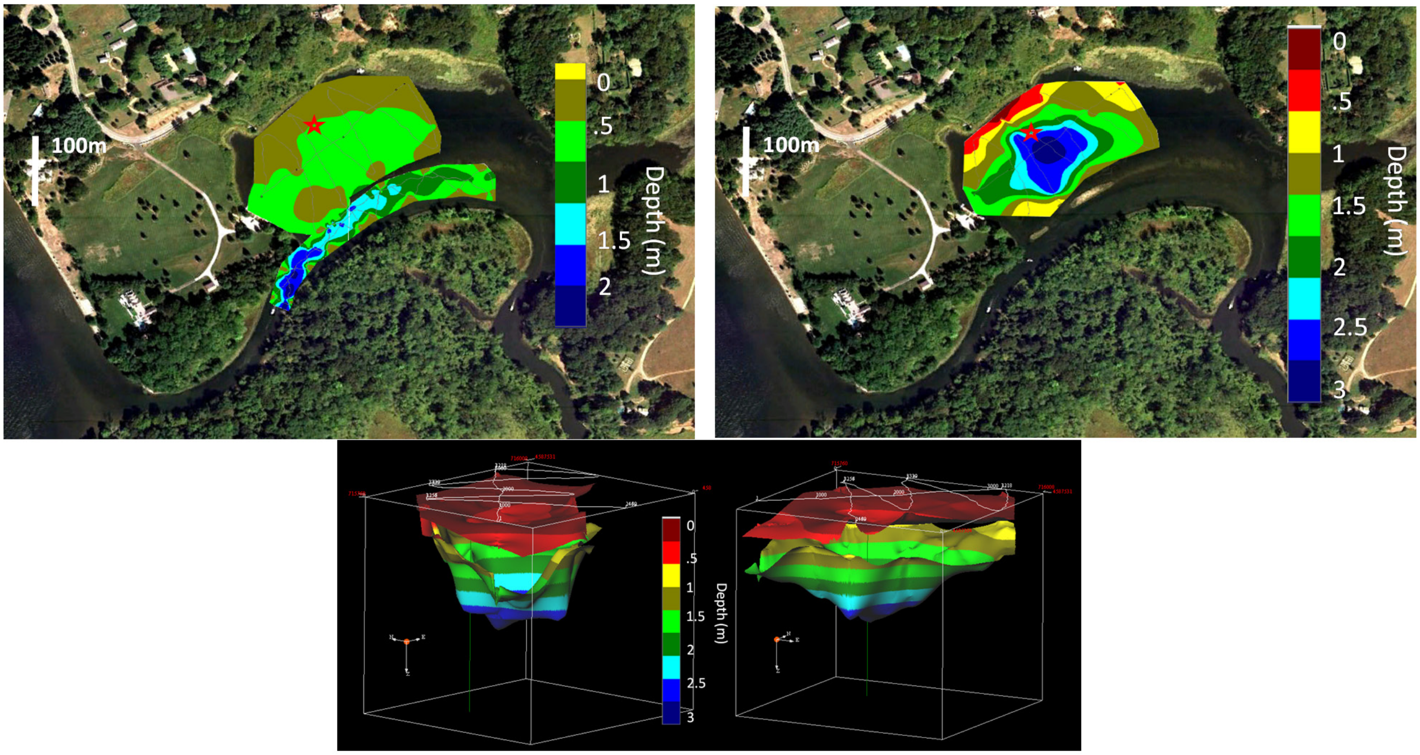

Figure 4. 4a. Bathymetric profile of Selden Cove compiled from GPR data. Star indicates core location. 4b. Reconstruction of 1854 CE bathymetry based on depth to 1854 sub-bottom reflector (Figure 2), superimposed on a satellite image. Star indicates core location. 4c. 3-Dimensional distribution of bathymetry (top profile) and depth to Hg onset in ~ 1850 (lower profile).

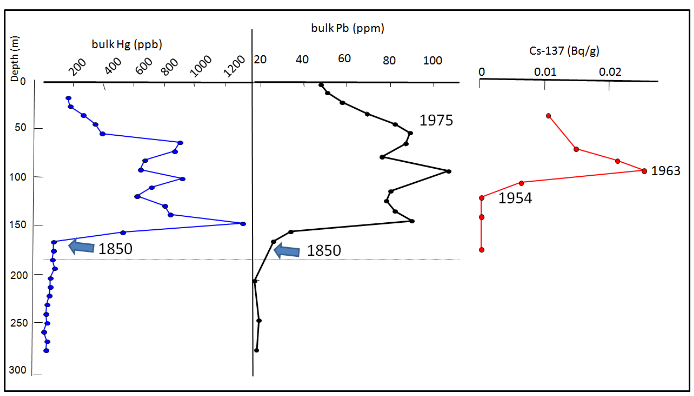

Figure 5. Relative areas (left) and Hg inventories (right) for Selden Cove and Great Island Marsh.

deposited in the cove since 1854 C.E., or approximately at a rate of 2.3*105 kg/yr.

HG INVENTORIES

After obtaining average masses for 10cm intervals of sediment, we factored in the Hg concentrations in ppb to determine a total mass of Hg over each 10 cm interval. We added the Hg masses together over the 150 cm interval to obtain a total amount of 7.0* 10^4 ng/cm2 for the location of the SDC core. After accounting for the bathymetry of the cove, we determined that the average inventory of Hg per unit area is $4.0*10^4$ ng/cm^2.

Core SDC3 depth to onset= 1.6 m	Hg Inventory at SDC3= 73,300 ng/cm^2	Maximum depth to Hg onset = 2.5 m
Maximum Hg Inventory= 100,000 ng/cm^2	Volume of Hg laden sediment= 50,500 m^2	Area of Pond= 4.04 *10^4 m^2
Average Depth to Hg onset= 1.25 m	Average Hg Inventory= 42,000 ng/cm^2	Total Hg Inventory ≈ 20 kg

Hg Inventory at Great Island Marsh= 3000 ng/cm^2	Area of Great Island Marsh= $2*10^6$ m^2	Total Hg Inventory ~= 60 kg

DISCUSSION

Great Island Marsh, shown on Site Location figure, is the nearest saltwater marsh used in Varekamp et al 2003 to assess the role that marshes play in storage of contaminated sediment. Hg profiles from Great Island Marsh show cumulative inventories of 3000 ng/cm^2, about 3% of the maximum inventory calculated for the center of Selden Cove. However, the square area of Great Island Marsh is two orders of magnitude larger than the cove at about $2*10^6$ m^2. The total cumulative Hg inventories for Great Island Marh and Selden Cove are on the same order of magnitude at 60kg and 20kg respectively. While Selden Cove is only 2% of the surface area compared to Great Island Marsh, it accommodates a third of the total Hg contamination. The amount of Hg (ng/cm^2) per unit area on average, at SDC core location, and cumulatively is an order of magnitude higher than measurements from any of the salt marshes. On average, Selden Cove has 14 times the Hg inventory/area compared to Great Island Marsh. At maximum, Selden Cove contains 33 times the inventory/square area compared to Great Island Marsh. This indicates that while the marshes may store more sediment, the contamination is focused in the coves along the river at significantly higher concentrations.