KECK GEOLOGY CONSORTIUM

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

April 2011
Union College, Schenectady, NY

Dr. Robert J. Varga, Editor
Director, Keck Geology Consortium
Pomona College

Dr. Holli Frey
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Union College

Carol Morgan
Keck Geology Consortium Administrative Assistant

Diane Kadyk
Symposium Proceedings Layout & Design
Department of Earth & Environment
Franklin & Marshall College

Keck Geology Consortium
Geology Department, Pomona College
185 E. 6th St., Claremont, CA 91711
(909) 607-0651, keckgeology@pomona.edu, keckgeology.org

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Robert J. Varga Editor and Keck Director Pomona College	Keck Geology Consortium Pomona College 185 E 6th St., Claremont, CA 91711	Diane Kadyk Proceedings Layout & Design Franklin & Marshall College

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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
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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.

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Faculty: *DAVID P. DETHIER*, Williams College, *WILL OUIMET*. University of Connecticut
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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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Faculty: *KARL W. WEGMANN*, North Carolina State University, *TSALMAN AMGAA*, Mongolian University of Science and Technology, *KURT L. FRANKEL*, Georgia Institute of Technology, *ANDREW P. deWET*, Franklin & Marshall College, *AMGALAN BAYASAGALN*, Mongolian University of Science and Technology.
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.

LATE PLEISTOCENE EDIFICE FAILURE AND SECTOR COLLAPSE OF VOLCÁN BARÚ, PANAMA

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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

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LYNN M. GEIGER, Wellesley College
Research Advisor: Dr. Brittina A. Argow

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Research Advisor: Jonathan Woodruff

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

Keck Geology Consortium
Pomona College
185 E. 6th St., Claremont, CA 91711
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SEDIMENT DYNAMICS & ENVIRONMENTS IN THE LOWER CONNECTICUT RIVER

SUZANNE O'CONNELL, Wesleyan University

INTRODUCTION

The Connecticut River extends from the Canadian border in Quebec, 650 km to Long Island Sound. (LIS). It is the longest river in New England and the main source of fresh water (70%) to LIS. Almost 400 towns and cities, with a population of approximately 2.3 million lie in its 29,000 km 2 (7.2 million acre) watershed. In the northern reaches, were it forms the border between Vermont and the Green Mountains and New Hampshire and the White Mountains, forests dominate the landscape. Roughly 35,000 acres, mostly in Vermont, but extending into Massachusetts and Connecticut are preserved from development by the Nature Conservancy, local land trusts and as part of the Silvio Conte National Fish and Wildlife refuge. In northern Massachusetts, suburbia and agriculture comprise the watershed. Then, beginning in Holyoke, MA and continuing through Springfield and Hartford, CT, most of the watershed is urban or densely populated suburban. During much of the 19th and 20th centuries, the Connecticut River, especially the Massachusetts and Connecticut portions were extensively used to generate energy and receive waste.

Flow rates for the Connecticut River vary seasonally, with highest usually flows in the late spring and early fall (Fig. 1A). In any year, water flow velocities between Hartford and Middletown (Fig. 1B) vary between about < 0.1 and 3.0 m/s. The lower 90 km of the river, including Hartford are a tidal estuary. The tidal range in Hartford is about ten centimeter and increases towards LIS were averages one and a half meters.

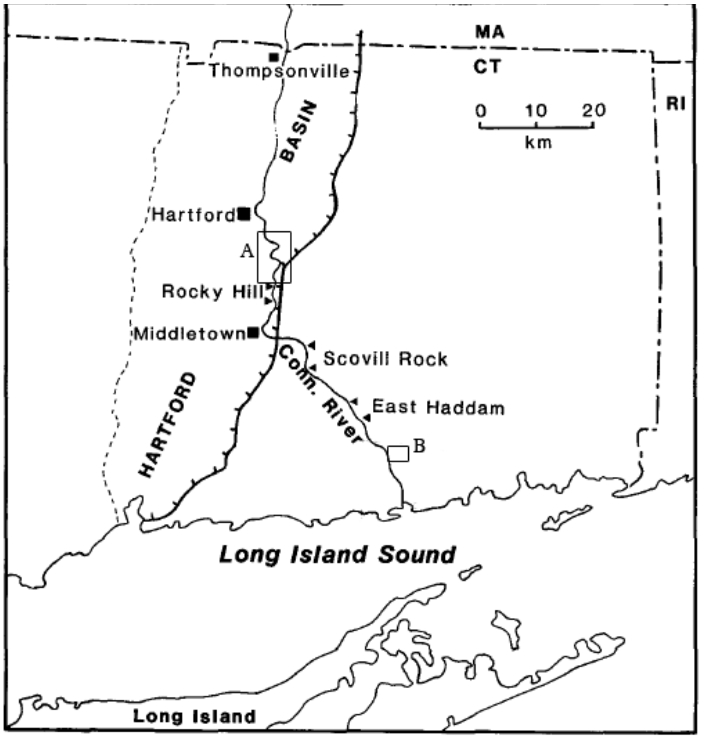

Figure 1A. Location map of the lower Connecticut River. The areas of interest in this report include Hartford to Long Island Sound, Romero's examination of grain size and composition, between Hartford and Rocky Hill (box A) where an extensive sand wave reach exists (Geiger study) and between East Haddam and Long Island Sound where Selden Pond and Creek (box B) connect with the Connecticut River (Jacobacci study). Thompsonville is the location of the only gagging station on the Connecticut River in CT. The hatched line is the location of the Eastern Border Fault, marking the eastern edge of the Hartford Basin. (Figure from Horne and Patton, 1989).

RESULTS

Three independent research projects were conducted as part of the Connecticut River sediment dynamics and environments study.

A) Sediment dynamics in the Glastonbury Meanders, Lynn Geiger, Wellesley College

B) Survey of grain size and composition for the entire lower Connecticut River, Gabe Romero, Pomona College

C) Contaminant storage in Selden Cove, a flood plain tidal pond, Kara Jacobacci, University of Massachusetts

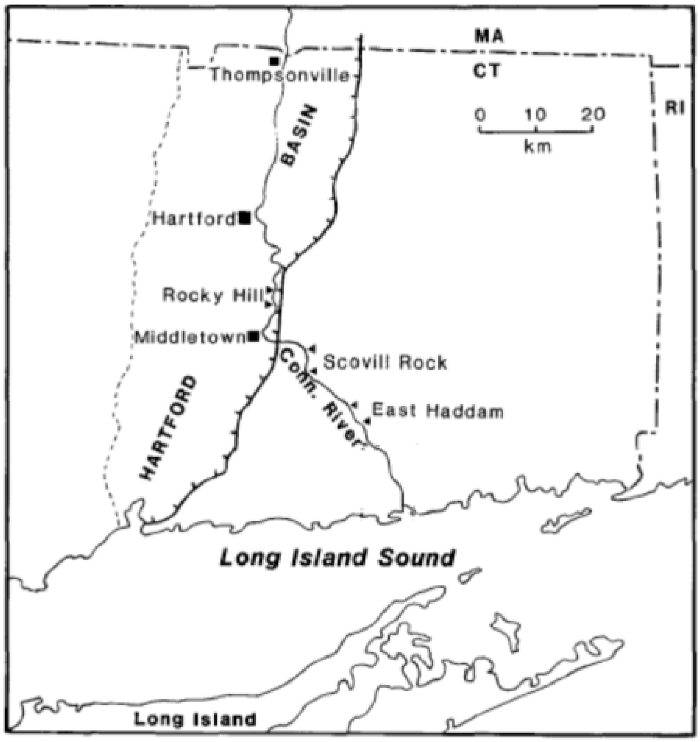

Figure 1B. Average daily discharge at Thompsonville, CT, north of survey area. Two rivers enter the Connecticut River between this gaging station and Hartford. The Farmington River with discharge an order of magnitude less and the Hockanum River, with discharge two orders of magnitude less than the Connecticut River. Diamonds mark sampling events (see Table 1A).

SEDIMENT DYNAMICS IN THE GLASTONBURY MEANDERS

A 2002 multibeam survey of the Glastonbury Meanders, between Hartford, and Middletown, CT (Fig. 1B), funded by NSF-OEDG grant 703737, showed clearly defined bedforms, sandwaves along the river bottom. A few grab samples recovered sediment with a distribution of size ranges in the fine to coarse sand range. The goal of this study was to measure velocities, bedforms and grain size under different flow conditions and use this information to model the river dynamics (Fig. 1B). Specifically; under what conditions do the sandwaves form, are they a relict from a different flow regime, and how much sand is moving through the river towards Long Island Sound. In addition, we are interested in how these results will impact the interpretation of bedforms in the stratigraphic record.

Date	Discharge Thomp-sonville	aDcp Measured Discharge	aDcp Total Discharge	Mean Gauge Ht Hartford	Mean Gauge Ht Middletown	River Slope
7/29/2009	523 m^3/s	499 m^3/s	692 m^3/s	1.76 m	0.93 m	0.0000263
4/18/2010	886 m^3/s	601 m^3/s	855 m^3/s	2.16 m	1.06 m	0.0000346
7/6/2010	195 m^3/s	203 m^3/s	324 m^3/s	0.66 m	0.54 m	3.84E-06
9/13/2010	79 m^3/s	--	--	0.65 m	0.58 m	2.21E-06
11/15/2010	473 m^3/s	355 m^3/s	529 m^3/s	1.45 m	0.89 m	0.0000175

Table 1A. River flow information by date of measurement.

	Bedfield 1 (Geiger 19)	Bedfield 2 (Geiger 15)	Bedfield 3 (Geiger 8)	Bedfield 4 (Geiger 7)
	April			
Bedform Class	Large Dunes	Washed out	Washed out	Washed out
Wavelength (m)	40	N/A	N/A	N/A
Bedform Ht (m)	1.50	N/A	N/A	N/A
Max Vel (m/s)	1.61	1.71	1.71	1.84
Ave Vel (m/s)	0.71	0.68	0.73	0.87
Discharge (m3/s)	846	862	906	869
	September			
Crest mean (range) um	625 (599-649)	544 (486-582)	*364 (354-372)*	420 (378-467)
Crest (mean ave. difference) um	50	96	18	89
Trough mean (range)um	630 (509-781)	578 (530-630)	469 (329-620)	450 (392-506)
Trough (mean ave. difference) um	272	100	291	114
	July			
Bedform Class	Large Dunes	Small Dunes	Med. Dunes	Large Dunes
Wavelength (m)	50	8	10	20
Bedform Ht (m)	1.50	<0.5	1.00	1.00
Max Vel (m/s)	1.17	1.39	1.23	1.16
Ave Vel (m/s)	0.32	0.29	0.33	0.37
Discharge (m3/s)	142	207	235	213

Table 1B. Bedform field information for April and July and mean grain size measurements. Sample locations have been renamed. Both the Geiger (this volume) renamed locations are given.

To accomplish this goal, measurements were made before, during and after the Keck program (Table 1A). Most of the bedforms were absent during high flow conditions in April 2010 (Table 1B), but were present in July, when discharge was lower (Fig. 2). In September when samples were collected and videos taken of the sampling process, ripples, too small to be see with acoustic measurements were visible on top of the sand waves.

Six bedform (sandwave) fields were sampled by scuba divers in September, when discharge was similar to discharge in July. They used a cup scoop and placed the sediment in a plastic bag. The sandwaves were sampled at the crest, tough and approximately halfway down the lee and stoss side. Two samples were taken from each sandwave and three sandwaves

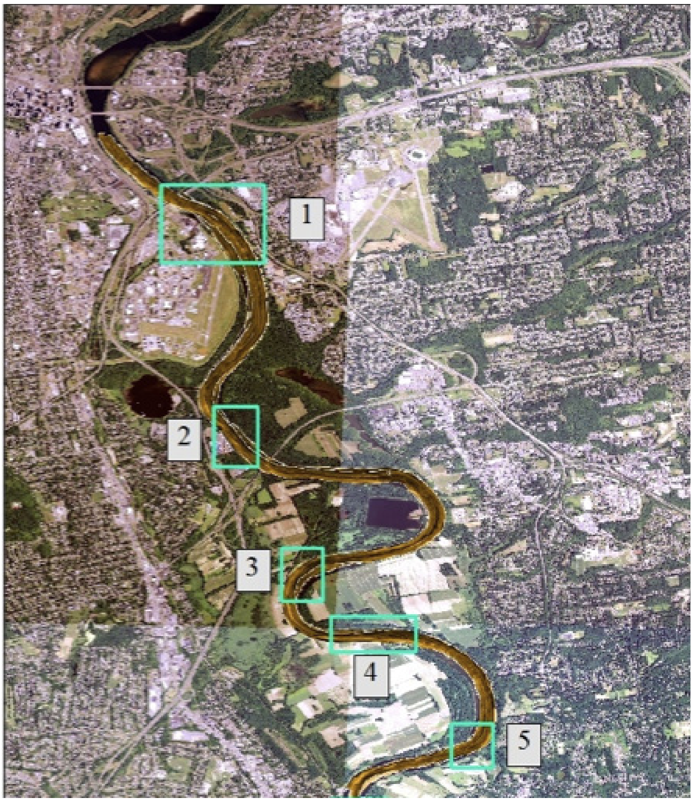

Figure 2A. Location of sampled bedform fields between Rocky Hill and Hartford (Fig. 1A).

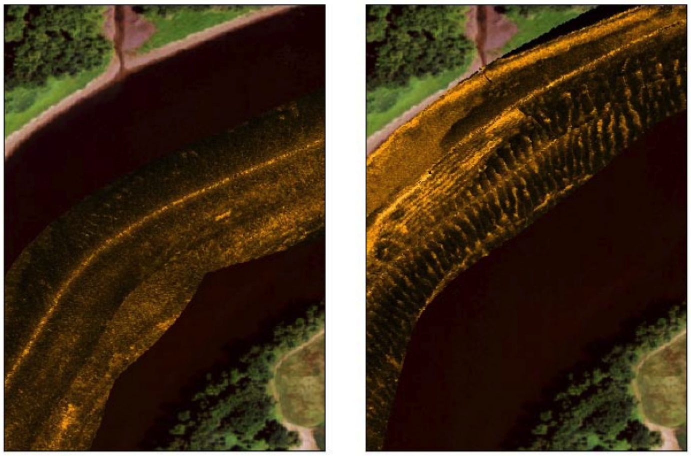

Figure 2B. Example of change in bedform between April, high discharge and July, low discharge.

were sampled in each bedform field. The scuba divers also took videos of the river bottom, revealing wooden sticks and logs in the trough, extensive plant growth and smaller bedforms (ripples) on the crest of the sandwaves.

Table 1B and Figure 5 of Geiger summarize the results of the bedform, velocity and grain size measurement analysis. There were several surprising results:

1) Grain size for each bedform was different, even if from the same bedform field.
2) Average (mean) grain size of the trough was coarser than the crest in four bedform fields and roughly equal in the two bedform fields with the largest average grain size.
3) Mean grain size for trough and crest range from 364-730 um or 1.5 to 0.0 phi.
4) As grain size increases, crests become more coarsely skewed and troughs become more finely skewed
5) Average grain size did not determine whether or not a bedform fields was washed out during high flow conditions.
6) The variation in grain size between crests and troughs in the same bedform field was as large as or larger than between different bedform fields.
7) For each bedform pair, 80% of crests are coarser and better sorted than troughs.
8) Three distinct groups are identified based on grain size characteristics of the crest and trough. These are described more fully in Geiger's contribution.

SURVEY OF GRAIN SIZE AND COMPOSITION FOR THE LOWER CONNECTICUT RIVER

Gabe Romero analyzed a suite of grab samples along a 90 km stretch of the Connecticut River from Hartford to Long Island Sound (Romero, Figure 1). In light of the findings of the detailed grain-size analysis study of Geiger in the Glastonbury Meanders, it is not surprising that Romero found consistent grain size distributions in grab samples from three different areas (Table 2). The sizes, determined by visual inspection, are coarser than those measured by Geiger with a Beckmann-Coulter Laser Diffraction Particle Size Analyzer. Furthermore Romero found that there is no down-stream change in sediment size within the navigation channel, but that sediment coarsens towards LIS outside of the channel (Table 2). As the river in the lowest stretch (samples 1-10, Table 2) are in a much wider river, it is possible that winnowing is producing the coarser grain size. Roundness was also determined by visual inspection. Grains became more rounded downstream as subrounded grains replaced subangular grains.

Smp ID	Envir.	Ch. Loc.	Distance to LIS (km)	W. D. (m)	Mixed Hg (ppb)	Clay Hg (ppb)	Modal Grain Size (um)	Maturity	Roun-ding
26	C	Low	90.2	0.5	182.42	262.53	710-1000	8.09	SR
25	C	Low	89.9	0.75	680.39	1388.9	1000-1410	5.25	SA
24	C	Low	89.6	1	249.11		710-1000	6.14	SR
23	C	Low	88.2	2	572.75		710-1000	4.55	SA
27	C	Low	86.6	0.75	1186.28		1000-1410	11.5	SA
28	C	Low	85.2	2	995.64		710-1000	3.34	SA
29	C	Low	84.5	2	135.95	209.1	350-500	4	R
30	C	Low	84.5	3	711.09		710-1000	4.12	SA
32	C	Low	83.8	3					
31	C	Low	83.5	1.25	334.09				
11	B	Out	72.3	2.5	204.74	404.88	710-1000	4	SA
12	B	In	71.1	6	34.74	50.725	710-1000	4.55	SR
13	B		*70.5*		176.37	246.62			
14	B	In	69.9	5		243.42	710-1000	5.25	SR
15	B		69.5		846.29				
16	B		*69*		14.58	22.605			
17	B	Out	68.4	2.5	251.38	223.26	710-1000	3.54	SR
18	B	Out	67.6	7	499.82		1000-1410	4.55	SA
19	B	Out	67.5	3	115.31	114.52	350-500	13.28	R
20	B	In	66.8	7	235.66		710-1000	3.76	SA
21	B	Out	66.8	2.5	334.59	453.27	1000-1410	4.88	SA
22			*65*		171.32	282.72			
6	A	Edge	15	8	374.15		710-1000	8.32	SA
5	A	In	14.7	8			710-1000	11.5	SA
4	A	Edge	13.9	7			1000-1410	4.55	SA
3	A	In	13.6	6.5	3575.74		710-1000	9	SA
2	A	Out	13.3	5			710-1000	5.66	SA
1	A	In	12	7	4907.91		710-1000	6.69	SR
7	A	Out	12.5	1	178.38		1000-1410	4.88	SA
8	A	In	9.9	5	559.43		710-1000	7.33	SR
9	A	In	9	5	418.73		710-1000	9	SR
10	A	Out	9	5	412.29		710-1000	9	SR

Table 2. Sediment characteristics in the Connecticut River from Hartford to Long Island Sound (Modified from Romero, 2011, Hg from C. Brennan). See Romero, Figure 1 for locations. All sample IDs begin with 10KCRP and have been eliminated. Env. = environment, A=lower estuary, B= Glastonbury Meanders (Geiger study), C=near and south of Hartford. "Ch. Loc". refers to the sample location with respect to the navigation channel. Modal grain size and roundness were determined visually, (R= rounded, SR = subrounded, SA=subangular) Compositional maturity index is modified from Pettijohn (1957). (Romero study)

Romero also looked at sediment composition chemically (X-ray diffraction) and mineralogically. Mineralogy was used to determine maturity using a modified Pettijohn (1957) equation. Quartz dominated all samples (Romero, Figure 2). Within the navigation channel, rounding increases downstream, but actually increases for sediment outside the channel. This suggests that outside of the channel, in the shallower areas, sediment may not have travelled as far and is more likely to be sourced from the adjacent river edges. Alternatively, or in combination, during high flow conditions coarser sediment is deposited in the shallower areas and remains there until another high velocity flow is capable of resuspending the larger grains.

CONTAMINANT STORAGE IN SELDEN COVE, A FLOOD PLAIN TIDAL POND

Several lakes, ponds and coves are connected to the east side of the Connecticut River between Massachusetts and Long Island Sound. These include Oxbow Lake, Pecausett Pond, Chapman Pond, and Hamburg Cove (Jacobacci, Figure 1). Selden Pond, located 16 km north of Long Island Sound, with a tidal range of about 1.1 m, is such a pond and the focus of the Jacobacci study.

What is now Selden Pond connected to the Connecticut River in about 1854. The connection is marked with a decrease in organic content (Jacobacci, Figure 2). At roughly the same time, mercury and lead abundance increases rapidly and is interpreted to identify the beginning of industrialization in the Connecticut River watershed. Mercury levels reached as high as 1300 ppb in Selden Pond. This is mid range between Hamburg Cove to the south, with values over 2000 ppb and Pecausett Pond to the north, where the highest values are a little over 1000 ppb. The metal abundance begins to decrease after 1975 (Jacobacci, Figure 5). A surprising result of these studies is that the mercury levels in the ponds, in ppb, are so much higher than in the adjacent marshes where mercury levels never reached 500 ppb (Varekamp et al., 2003) In addition to coring, a ground penetrating radar (GPR) survey was done in Selden Pond. The 1854 transition was located at 160 cm in the core. Extrapolating the mercury measurements over the Pond area, Jacobacci calculated the amount of mercury stored in Selden Pond as 20 kg. Great Island, the saltwater

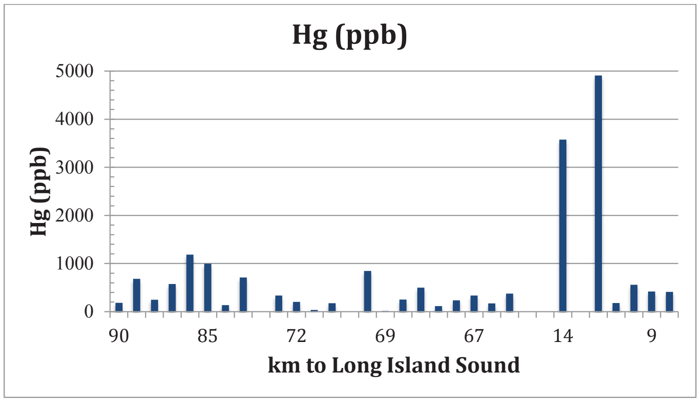

Figure 3. Mercury concentration in fine grain sediments (PPB) in the Connecticut River from Hartford to Long Island Sound.

marsh to the south, contains lower levels of mercury, but extends for a much larger area. Jacobacci calculated the mercury stored there as 70 kg. Thus even though Seldon Pond is 2% of the surface area of Great Island Marsh, it contains almost a third of the mercury contamination.

Mercury levels in the surface of the pond are much lower, less than 200 ppb. But the question remains, what is the source of the mercury? Mercury content in the fine fraction of the Romero samples ranged from less than 100 ppb to over 1000 ppb (Table 2, Fig. 3). The relationship of the river samples to those deposited in the adjacent ponds and coves is not known. Modern surface and near-surface river sediment contain high concentrations of mercury of mercury, the mercury-laden sediments will be found where fine-sediment is concentrated, such as in ponds and coves connected to the Connecticut River.

CONCLUSIONS

The three Connecticut River studies provide evidence for questioning past assumptions and generating new ideas in interpreting depositional processes. Geiger shows that the relationship between grain size and location in a sandwave is highly variable. Quite possibly, coarse sediment that falls over the crest and intro the trough remains there for many years until a large increase in discharge is capable of resuspension. Even after the resuspension, possibly during decelerating flow, coarser grains are trapped in the trough. The Jacobacci study of mercury contamination in Selden Pond shows that a process, other than simple deposition, must be invoked to explain the very high contamination levels in the small ponds, which is much higher than the adjacent marshes. The ponds must be concentrating the fine-sediment fraction and with that, the contaminants.

All of the studies contributed to this project raise multiple additional questions, some of which will be addressed during the 2011 Keck Connecticut River Project.

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