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KECK GEOLOGY CONSORTIUM
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CLAY MINERALOGY FINGERPRINTING OF SEDIMENTS DEPOSITED FROM TROPICAL STORM IRENE IN THE CONNECTICUT RIVER WATERSHED

JULIA SEIDENSTEIN, Lafayette College
Research Advisor: Dru Germanoski

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SCOTT KUGEL, The College Of Wooster
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INTRODUCTION

Along the Connecticut River, Hurricane Irene was responsible for many unusual events with the most notable being a large amount of flooding in the upland areas surrounding the river and its tributaries (Avila and Cangialosi, 2011). Among these tributaries, the Deerfield River, in southwestern Vermont and western Massachusetts, contributed 40% of the total sediment load of the Connecticut River, while only comprising five percent of the watershed (Yellen et al., 2014).

This flooding mobilized large amounts of lacustrine sediments that were deposited shortly after the last glacial maximum in glacial Lake Hitchcock (Ashley, 1972). Yellen et al. (2014) notes that accumulations of this glacial sediment can be characterized as incongruous, inorganic, and fine-grained layers that have a low elemental abundance. Stream gauge data shows that there was a delay in the movement of this sediment from the Deerfield River into the Connecticut River of 1.4 days due to the flood control measures on the river (Yellen et al., 2014, Fig. 1).

This study seeks to 1) identify these layers in multiple flood control reservoirs and dams of the Connecticut River and its tributaries, 2) develop a template that distinguishes storm events like Hurricane Irene from normal deposition within the sediment record, and 3) identify previous storm events within the sediment record that are similar to Hurricane Irene.

Our analysis focuses on the organic content, grain size, and mercury concentration of the cores that were collected. We found that the samples that were collected from the four upland flood control reservoirs of the Connecticut River, do not match the expected characteristics of sediment deposited by Hurricane Irene as described by Yellen et al. (2014).

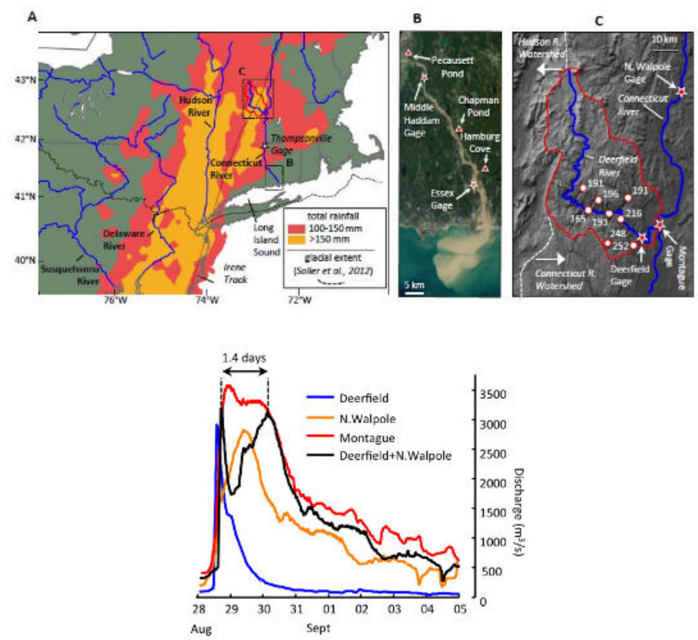

Figure 1: Maps of the location of USGS discharge gauges on the Deerfield River, the Upper Connecticut River at North Walpole, NH, and the Connecticut River below the confluence with the Deerfield at Montague, MA and a graph of their data during and directly after Hurricane Irene (Yellen et al., 2014, fig 1 and 2).

STUDY LOCATION

Four locations on tributaries of the Connecticut River in western Massachusetts and southern Vermont were chosen as the primary sites for sample collection. Littleville Lake and Knightville Dam are two flood control reservoirs that are located on the Middle and East Branch of the Westfield River in Hampden and Hampshire Counties, Massachusetts. Sherman Reservoir is a hydroelectric and flood control reservoir located on the Deerfield River on the border of Massachusetts and Vermont. Conway Electric Dam is a decommissioned hydroelectric dam located on the South River, a tributary of the Deerfield River, in Franklin County, Massachusetts.

METHODS

This study focuses on four cores, one from each of the locations, that typifies the data found at each location: 1) L1D1, a 60 cm long push core that was collected from the northern delta of Littleville Lake, two kilometers away from the dam, 2) SR-1, a 120 cm long gravity core that was collected from the northwestern side of the lake, two kilometers from the dam, 3) KDRC 3, a 150 cm long Russian Peat Core, and 4) CER VC4, a 150 cm long vibracore that was collected from the reed covered embankment on the northern side of the river, 60 m from the dam.

Push cores were collected using a polycarbonate core barrel that was pushed into the sediment using a piston. Gravity cores were collected using a UWITEC gravity corer. Russian Peat Cores were collected using an Aquatic Research Instruments Russian Peat Corer. Vibracores were collected in a similar method as used by Smith (1996). Grain size testing was completed with a Horiba Camsizer and a Coulter LS 200 laser particle size analyzer at the University of Massachusetts Amherst. Organic content was determined using loss on ignition (LOI) techniques. Mercury concentration was tested using the Teledyne Leman Labs HYDRA II_c mercury analyzers in Amherst College's Geology Department and Smith College's Center for Aqueous Biogeochemical Research.

RESULTS

L1D1

The organic content of L1D1 is stable for the lower half of the core but fluctuates in the upper half of the core (Fig 2A). Organic levels begin at 1.6% at 60 cm and hover there for the next 34 cm. During the next 12 cm, the LOI spikes to 33% and falls to 14% at a depth of six centimeters. Over the next three centimeters, organic levels spike to 54% and fall to 19% before gradually rising to 21% at the surface.

The mercury concentration is stable for the lower half of the core but fluctuates in the upper half (Fig 2B). Mercury concentration begins at 10 nanograms

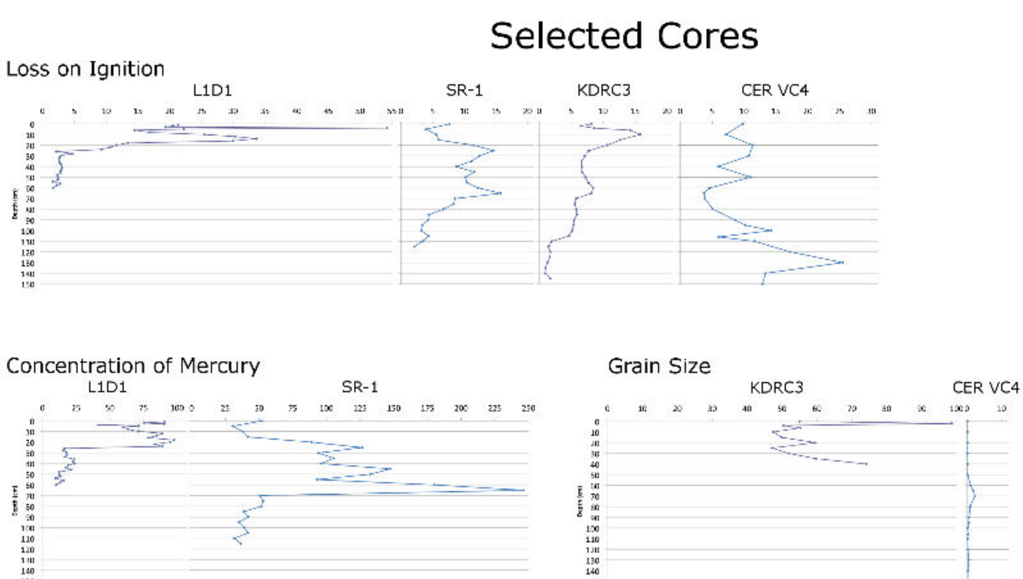

Figure 2: (A) Loss on ignition, (B) concentration of mercury, and (C) grain size analyses of cores L1D1, SR-1, KDRC3, and CER VC4. Red dashed lines denote the location of the possible Irene layers.

per gram (ng/g) at a depth of 60 cm and fluctuates between nine nanograms per gram and 23 ng/g over the next 34 cm. At a depth of six centimeters, mercury concentration rises to 89 ng/g and falls to 59 ng/g. Three centimeters later, mercury concentration rises to 90 ng/g, which it remains at until the surface.

SR-1

The organic content of SR-1 is stable and low for the majority of the core. The organic content begins at three percent at 120 cm, rising to eight percent over the next 45 cm (Fig 2A). At 70 cm, the LOI jumps to 15% but declines to 10 % over the next 10 cm where it holds steady until a depth of 45 cm. From 45 cm to 30 cm, the organic content rises to 14% but falls to five percent at the surface.

The mercury concentration oscillates for much of the core with a peak at 65 cm (Fig 2B). Mercury concentration starts at 36 ng/g at 120 cm and oscillates between 31 ng/g and 50 ng/g over the next 30 cm. The mercury concentration rises to 196 ng/g at 65 cm. From 60 cm to 30 cm, the mercury concentration falls to 93 ng/g and begins to oscillate between 90 ng/g and 50 ng/g. At five centimeters, the mercury concentration falls to 30 ng/g but rises to 52 ng/g at the surface.

KDRC 3

The organic content of this core steadily rise, as it gets closer to the surface (Fig 2A). The organic content starts at one percent at a depth of 145 cm. Over the next 115 cm, the LOI rises to eight percent. From 25 cm to 10 cm, the organic content rises to 15%. The organic content then falls to six percent at two centimeters and rises slightly to eight percent at the surface.

The grain size of KDRC 3 fluctuate greatly throughout the core, starting at 40 cm with a D90 of 74 µm (Fig 2C). Over the next 15 cm, the D90 falls to 47 µm. At 20 cm, the D90 rises to 59 µm but then falls again to 47 µm 10 cm later. Over the next 10 cm, the D90 of the core rises sharply to 98 µm at two centimeters and then falls to 55 µm at the surface.

CER VC 4

The organic content of CER VC4 has a trend of increasing organics, as the core gets deeper. The organic content starts with a LOI of 12% at 150 cm. At 130 cm, the LOI rises to 25%. Over the next 65 cm, the LOI steadily falls to three percent at 65 cm. At 50 cm, the organic content rises to 11% and begins to oscillate between 11% and five percent until the surface.

The grain size of CER VC4 remains stable throughout the majority of the core except for a spike at 70 cm (Fig 2C). The D90 of this core starts at 0.2 µm at 150 cm (Fig 2A). Over the next 70 cm, the D90 remains stable until it rises to 2.2% at 70 cm. By 50 cm, the organic content has fallen again to 0.2%, a level that remains constant through the rest of the core.

DISCUSSION

Yellen et al. (2014) proposes that the characteristics of an Irene layer are "anomalously fine grained and inorganic" sediment that contain and elemental abundance that "exhibit a preserved sedimentary imprint consistent with the enrichment of glacial fines introduced from upland catchments". The majority of the cores examined in this study have a noteworthy change in grain size, organic content, or mercury concentration within the first 15 cm. Also, due to Hurricane Irene being the most recent event of this nature in the area, we can infer that it is responsible for the changes. However, the samples that were collected do not always replicate the proposed characteristics.

Littleville Lake

The first 10 cm of L1D1 contains one of the trends that Yellen et al. (2014) suggests denote an Irene layer: low mercury concentration (Fig 3). This is indicative of glacial sediments. However, it also contains a high organic content, which does not match this trend. This is most likely due to the close proximity the lake has to organic rich terrestrial areas, which can contribute their organic content to the system.

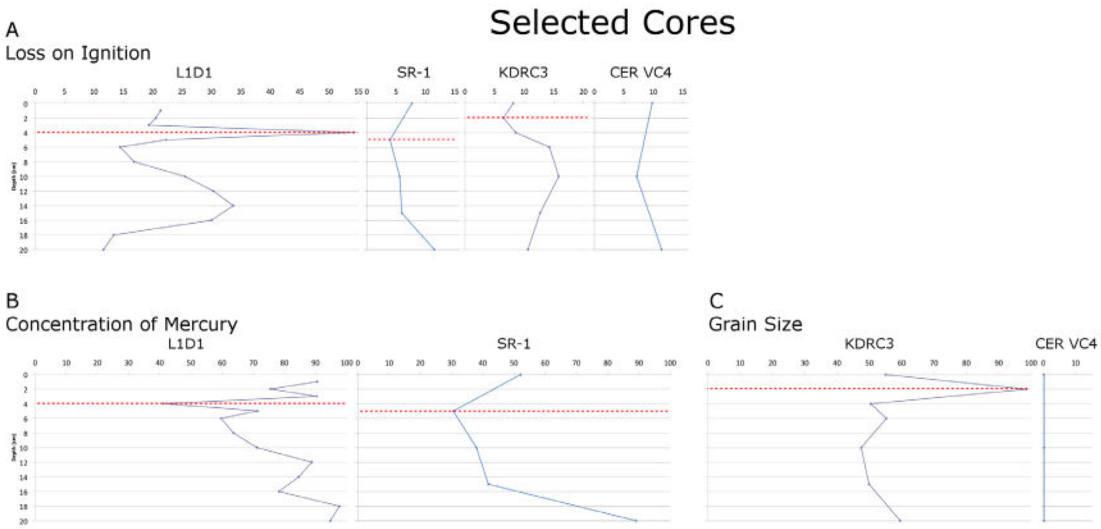

Figure 3: (A) Loss on ignition, (B) concentration of mercury, and (C) grain size analyses of the first 20 cm of cores L1D1, SR-1, KDRC3, and CER VC4. Red dashed lines denote the location of the possible Irene layers.

Knightville Dam

Within the first few centimeters of core KDRC3 only one of the proposed characteristics of an Irene layer is present: low organic content. At the same place in the cores, a high grain size is also expressed, directly contradicting what is anticipated of an Irene layer. In addition, a possible Irene layer was visually observed in the core, as it was being collected in the field at the same location as these trends (Fig. 4). These trends may indicate that there is less time for the larger grains to settle out naturally at the upstream locations than the downstream locations, implying that the source material is located significantly closer to the sites that are examined in this research than the location that Yellen et al. (2014) analyzed. This is supported by the fact that the sites that were examined by Yellen et al. (2014) were from the lower portion of the Connecticut River; however, in this study, all locations are in the upland areas that are further upstream.

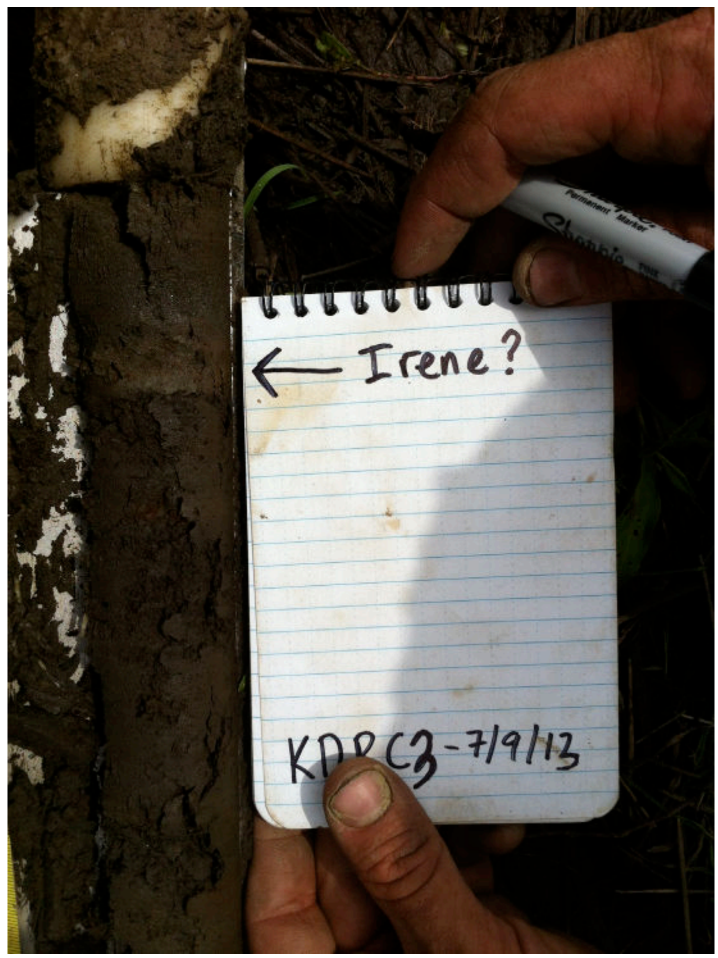

Figure 4: Possible Irene layer that was identified in core KDRC3 as it was being collected in the field.

Despite Littleville Lake and Knightville Dam being proximally located, at about 2.5 km apart they contradictorily exhibit the potential Irene layer. Littleville Lake displays a high LOI and a low concentration of mercury, while Knightville Dam exhibits a low LOI and high grain size. This can possibly be explained by multiple factors. Littleville Lake immediately floods into a forested area, however at Knightville Dam, flood waters must rise 36 m before reaching any substantial forest growth due to the area being dry the majority of the year. Also, the samples from Littleville Lake were collected between two and three kilometers away from the dam, from the sediment-water interface while the samples from Knightville Dam were collected between 100 m and 500 m away from the dam from the dry water holding area. This could make a difference because, in areas very near the dam, like where the cores from Knightville Reservoir were collected, the water that is already present is trapped by the dam causing it to begin deposition of the larger particles it is transporting. However, in areas that are much further away from the dam, like where the cores from Littleville Lake were collected, the water is not as directly constrained by the dam, allowing it to continue to retain its sediment load.

Sherman Reservoir

The first 10 cm of core SR-1 displays two of the characteristics of a deposit left by Hurricane Irene: low organic content and low mercury concentration (Fig 3). SR-1 shows these trends because, like Littleville Lake, the cores come from the end of the reservoir furthest away from the dam. This allowed the water to pass through and deposit the heavier organic and elementaly rich particles nearer the dam.

Conway Electric Dam

The first few centimeters of core CER VC 4 exhibits one of the characteristics that denote an Irene layer: a low organic content (Fig 3). However, CER VC 4 does not have any change in grain size at that same depth. The other cores that were collected from this location also do not exhibit any changes in organic content or grain size at these depths.

The cores from Conway Electric Dam do not resemble those from other locations. This is most likely because Conway Electric Dam acts more like a river in these circumstances than a dam. This is because the dam has had sediment amassing at it for the past 80 or more years filling in most of the space behind it. This leaves no room for water to be stored behind it creating a preserved sediment record for the past 80 or more years but not for recent events.

Irene Layer

Many of the samples that we have collected do not match what Yellen et al. (2014) has prescribed as characteristic of an Irene layer. Grain size differences like those in the cores collected from Knightville Dam can be explained by the differing locations of the sample collection. However, the other characteristics of an Irene layer do not appear to form any distinguishable trend between locations.

From these data, we can infer that the Hurricane Irene signal in the sediment layers is not as well expressed in the upland flood-controlled tributaries of western Massachusetts and southern Vermont as it is in the off river water bodies of the southern Connecticut River. This is because of the difference in hydrologic processes that occurred between the locations from this study and those from Yellen et al. (2014). As part of the flood control system for the Connecticut River, the dams and reservoirs that were examined in this study stored the majority of the water and sediment that was mobilized during the storm. As the storm passed over the area on August 28, 2011, the discharge of the upland tributaries dramatically increased, but successful flood control measures prevented that water from immediately flowing downstream. The water captured in these reservoirs, was effectively stagnant and began to deposit the coarser grained particles. Over the next several weeks after the storm, the water level was drawn down to normal stages, releasing the finer grained particles that have yet to settle out, creating the deposits that are observed by Yellen et al. (2014; Fig 1).

CONCLUSION

Organic content, mercury concentration, and grain size analyses of sediment cores taken from four upland flood control reservoirs of the Connecticut River do not match the expected characteristics of sediment deposited by Hurricane Irene as described by Yellen et al. (2014). Furthermore, the analyses demonstrate no discernable patterns between locations. Therefore, a new template of a Hurricane Irene deposit could not be developed for upland flood control reservoirs.

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