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

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KECK GEOLOGY CONSORTIUM
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2013-2014 PROJECTS

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TECTONIC EVOLUTION OF THE FLYSCH OF THE CHUGACH TERRANE ON BARANOF ISLAND, ALASKA*:*
Faculty: *JOHN GARVER*, Union College, *CAMERON DAVIDSON*, Carleton College
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EVALUATING EXTREME WEATHER RESPONSE IN CONNECTICUT RIVER FLOODPLAIN ENVIRONMENT*:*
Faculty: *ROBERT NEWTON*, Smith College, *ANNA MARTINI*, Amherst College, *JON WOODRUFF*, Univ. Massachusetts, Amherst, BRIAN YELLEN, University of Massachusetts
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ANNA MARTINI, Amherst College
BRIAN YELLEN, University of Massachusetts

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Research Advisor: Anna M. Martini

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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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IMPACTS OF EXTREME PRECIPITATION ON SEDIMENT YIELDS FOR POST GLACIAL UPLANDS OF THE NORTHEAST

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Research Advisor: Jon Woodruff

INTRODUCTION

Previous work on the effects of extreme precipitation events (Yellen et al., in review) documented the crucial role that hurricanes play in making upland sediment available for transport. During Hurricane Irene, high precipitation intensities led to landslides, gully erosion, and channel incision, mobilizing indurated glacial deposits. Observations of up to 40 years of mean annual sediment yield exported from the Deerfield River during a one-day event led Yellen et al., (in Review) to conclude that extreme precipitation events like Irene are the main contributors to the erosion of sediment from upland tributaries**.** It was found that even though the Deerfield watershed is only 5% of the size of the Connecticut River watershed it still contributed about 40% of the sediment that was transported to the mouth of the Connecticut River. It is suggested that lack of flood control dams in the Deerfield watershed contributed to this extraordinary sediment yield. Alternatively, perhaps unique geomorphic characteristics made this watershed more susceptible to erosion and therefore high sediment yields. It is unclear what effect the network of 16 major flood control dams in the Connecticut River watershed had on the total sediment load that reached the Atlantic Ocean during Irene flooding. Furthermore Yellen et al., (in Review) found that turbidity measurements at the mouth of the Connecticut River have been significantly higher in the two years following Irene. It is suggested that Irene drastically changed the erosion mechanics of upland glacial deposits by exposing glacial fines, causing a higher suspended sediment concentration for any given discharge.

This project is focused on a flood control reservoir behind Ball Mountain Dam on the West River in Jamaica, Vermont (43.127729°, -72.774130°). The goals of this project are to examine the sedimentary fingerprint of the Hurricane Irene layer in an upland flood control dam and evaluate what role flood control played in modifying the sedimentary imprint of the event. Furthermore, to what extent do event layer characteristics in the uplands resemble that which were observed at the mouth of the Connecticut River. We compare the sediment yield for tropical storm Irene in the West River watershed to those of other watersheds affected by the storm to determine what role flood control dams have on sediment loads observed at the mouth of the Connecticut River. Lastly this project seeks to gain insight into the question of where this extra sediment in suspension, that has been present at the mouth of the Connecticut River since tropical storm Irene, is coming from. Did Irene change the erosion rate of upland deposits?

SITE DESCRIPTION

Ball Mountain Reservoir forms behind Ball Mountain Dam (BMD) on the West River in Jamaica, Vermont (Fig. 1). The West River is a tributary of the Connecticut River, has a length of 68 km, and drains a watershed area of 1096 km^2. The portion of river above Ball Mountain Dam has a watershed area of 445 km^2. Ball Mountain Dam was built in 1961 for flood management; according to the US Army Corps of Engineers it has a maximum capacity of 64,696,122 m^3. Due to management of the reservoir the pool height is not kept at a stationary elevation. The pool stage is measured from the base of the dam. The reservoir is kept at around 19.8 m in the summer, 10.7 m in the winter, and 7.6 m in the spring. When the water level is lowered most of the reservoir bottom is exposed and a river forms. During Hurricane Irene the inflow to the reservoir reached 793 m^3/s, causing the water to rise to 52.3 m. To put this into perspective the average inflow during the month of August from 2006 to 2012 was 7.1 m^3/s, and the average annual peak flow during that time was 284 m^3/s.

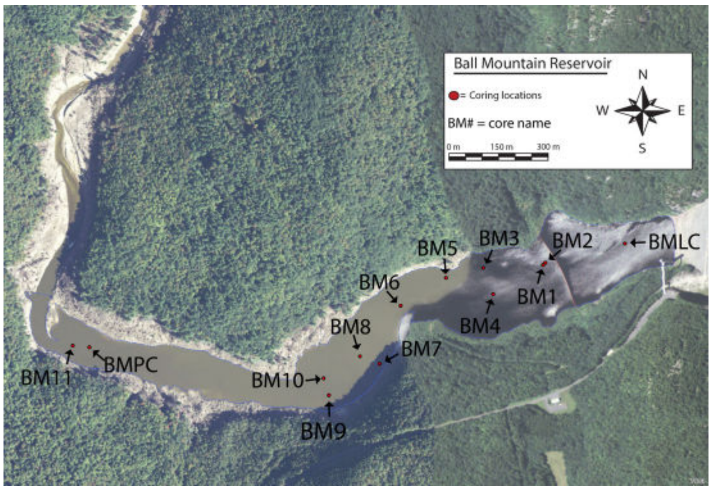

Figure 1. Map of Ball Mountain Reservoir in Jamaica, Vermont (43.127729°, -72.774130°). Figure details the location of each core site. Aerial photograph from the Vermont Center for Geographic Information.

Table 1. Information detailing cores collected from Ball Mountain Reservoir.

Core	Latitude	Longitude	Date Collected	Coring Method
BM1	43.12686°	-72.7805°	July 19th, 2013	Push Core
BM2	43.126917°	-72.780417°	August 26th ,2013	Uwitec
BM3	43.12677°	-72.78272°	August 26th ,2013	Uwitec
BM4	43.12606°	-72.78235°	August 30th, 2013	Uwitec
BM5	43.12650°	-72.78410°	August 30th, 2013	Uwitec
BM6	43.12574°	-72.78578°	August 30th, 2013	Uwitec
BM7	43.12416°	-72.78655°	August 30th, 2013	Uwitec
BM8	43.12436°	-72.78728°	August 30th, 2013	Uwitec
BM9	43.12330°	-72.78843°	August 30th, 2013	Uwitec
BM10	43.12376°	-72.78863°	August 30th, 2013	Uwitec
BM11	43.12458°	-72.79732°	August 30th, 2013	Uwitec
BMLC	43.12744°	-72.77747°	August 30th, 2013	Push Core

SAMPLE COLLECTION

Nine sediment cores were collected at BMD to enable us to construct an Irene event layer isopach map across the reservoir. On July 19th 2013, we collected a 7.6 cm outside diameter push core abbreviated BM1, see figure 1 for location of cores and table 1 for core information. On August 26th 2013, two additional cores were collected (BM2 and BM3) using a Uwitec Gravity corer with hammer attachment (Fig. 1, Tab. 1). On August 30th 2013, we collected four more cores, again using the Uwitec. These cores are labeled BM4, BM5, BM8, and BM11 (Fig. 1, Tab. 1). Each of these cores was extruded on the deck of the boat where we recorded the thickness of the Irene layer and post-Irene sediment. Three samples were taken from each core; a pre Irene sample, an Irene sample, and a post Irene sample. That same day we took a push core labeled BMLC (Fig. 1, Tab. 1) using the same push core setup. Additionally, there were four cores we attempted to collect using the Uwitec that day, BM6, BM7, BM9 and BM10 (Fig. 1, Tab. 1). At BM6 we collected a core that was mostly river sediment with no fine-grained lake deposits. At BM7 we collected a core that was entirely river sand. At site BM9 we were unsuccessful in collecting a core due to the Uwitec Barrel shattering upon impact with the bottom of the reservoir. This suggests the bottom at this location was rocky with little to no sediment deposited there. Like BM6 and BM7, BM10 had no fine grained lake deposits, only sand. Sites BM6, BM7, and BM9 all were taken close to the south shore of reservoir (Fig. 1). The river sand and the rocky bottom at all of these locations suggest when the reservoir is drawn down, the river forms and runs through these locations. When the reservoir stage is lowered, the river presumably scours any sediment that had been deposited there during peak pool height.

SEDIMENT ANALYSIS

Methods

Back in the Sedimentology Lab at the University of Massachusetts each core was sampled. During sampling, 2 cm samples were taken in roughly 4 cm to 7 cm intervals through the pre- and post-Irene sediment from cores BM1, BM2, BM3, and BMLC. Sand layers at these distal locations were presumed to be bedload transport by the river during low reservoir pool stage. These coarse layers were therefore not sampled as they capture anthropogenic reservoir management dynamics rather than natural depositional characteristics of the short-lived Irene event. Through the Irene sediment, 1 cm samples were taken every centimeter. At UMass, cores were run through an ITRAX x-ray fluorescence core scanner to obtain a radiograph image and elemental abundance profiles of various elements through each core. Tests for porosity, loss on ignition (organic content), and grain size were also performed. These will provide the sediment characteristics that will be used to identify the Hurricane Irene event layer. Yellen et al., (in Review) shows that the Hurricane Irene deposits are grey in color, lower in organic content, finer grained, higher in potassium content, and lower in Zirconium content.

RESULTS

The various sedimentary characteristics that we examined can be compared to results from Yellen et al., (in review) to verify identification of the Irene event layer. Grain size and loss on ignition data for BMLC can be seen in Figure 2. The graph shows a drop in the D_{50} grain size to under 15 µm (D_{50} meaning the grain size at which 50% of the grains are finer than). This decrease in grain size occurs at approximately 63 - 77cm in depth. A drop in organic content at approximately 67 – 77 cm in depth is also shown. Figure 3 shows a profile through BMLC of the elemental abundances, x-radiograph and an optical image of the core. As you can see there is a strong increase in potassium and a corresponding drop in zirconium from 62 – 72 cm, with a peak at a depth of 67 cm. The average ratio of K/Zr through the Irene Layer was measured to be just over 5. This value corresponds perfectly within the range of K/Zr ratios calculated by Yellen et al., (in Review) for Hurricane Irene sediment found within the lower Connecticut River. Peak values within the Irene sediment in BMLC even equal those found in glacial winter varve sediments taken from the uplands of the Deerfield River watershed by Yellen et al., (in Review). The distinctive sediment characteristics seen in BMLC are consistent with the rest of the cores taken from Ball Mountain Dam. Based the physical and chemical properties of the event layer preserved behind Ball Mountain Dam, it is clear that this is the same material that was deposited in the off-river water bodies near the mouth of the Connecticut River.

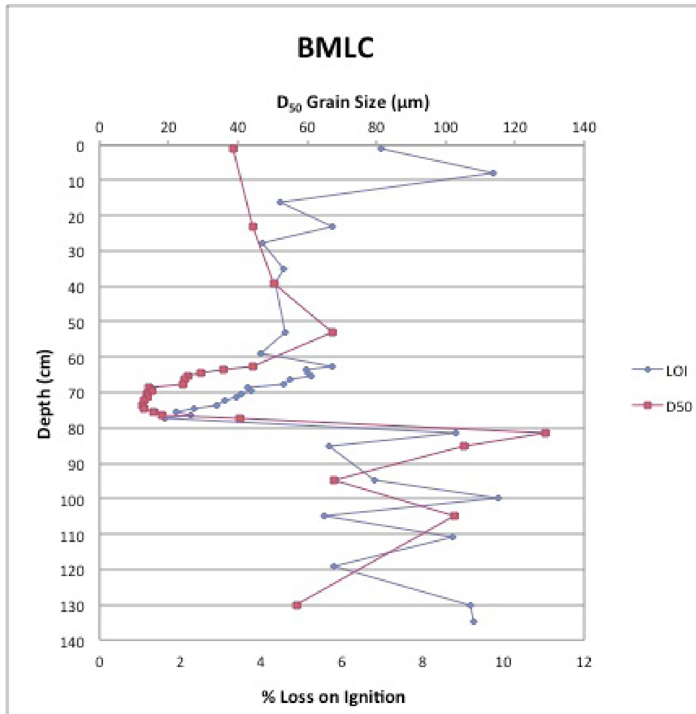

Figure 2. D_{50} grain size and loss on ignition (organic content) in a depth profile through core BMLC.

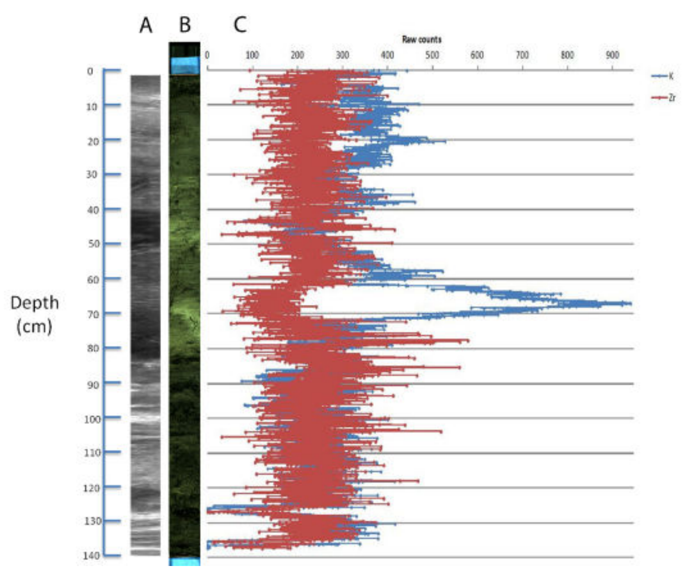

Figure 3. X-radiograph profile (A), elemental abundance profile (C) of Potassium and Zirconium, and an optical image (B) of core BMLC. The x-radiograph is showing a density profile. Light corresponds to less dense layers and dark corresponds to higher density layers. In the elemental abundance profile red represents concentrations of Zirconium (Zr) and blue represents concentrations of Potassium (K). A higher raw count represents a higher concentration of the element.

WATERSHED ANALYSIS

When studying the Hurricane Irene event, it is important to determine the sediment yield. To calculate sediment yield, an interpolation of the thickness of the Irene sediment was done in ArcMap using an inverse distance weighting interpolation method. Figure 4 shows spatial variation in the Irene deposit thickness. Generally, Irene's deposit was slightly thicker closer to the dam and has been removed from the course of the West River at low reservoir pool. Using porosity and density of the sediment, this interpolation was used to calculate a total mass of 13,767 tonnes of Irene sediments trapped within the reservoir. The watershed area above Ball Mountain Dam is 445 km^2, which gives a sediment yield during Irene of 31 tonnes/km^2. This value is slightly less than the sediment yield for the much larger Connecticut River watershed which had a sediment yield of 48 tonnes/km^2, and much lower than the yield for the Deerfield River watershed which had a sediment yield of 350 tonnes/km^2. It is important to note that the value for the sediment yield calculated in this study is likely an underestimate. This is because to calculate the yield of the watershed we need to know the trapping efficiency of the dam. We have no way of knowing what this value actually is so we make an assumption that the dam trapped 100% of the Irene sediment that entered the reservoir. This means this watershed was not nearly as active during the storm as the Deerfield was. We could also make the opposite assumption that the two watersheds were of equal yield. This would mean that the trapping efficiency of the dam was only about 9%. The actual value is going to be somewhere between these two extremes. Either way, this data suggests that flood control dams of the upper Connecticut River did not significantly affect the amount of sediment that reached the mouth of the river. Furthermore, this also suggests lack of flood control on the Deerfield River was not the driving factor in the extraordinarily high suspended sediment concentrations measured.

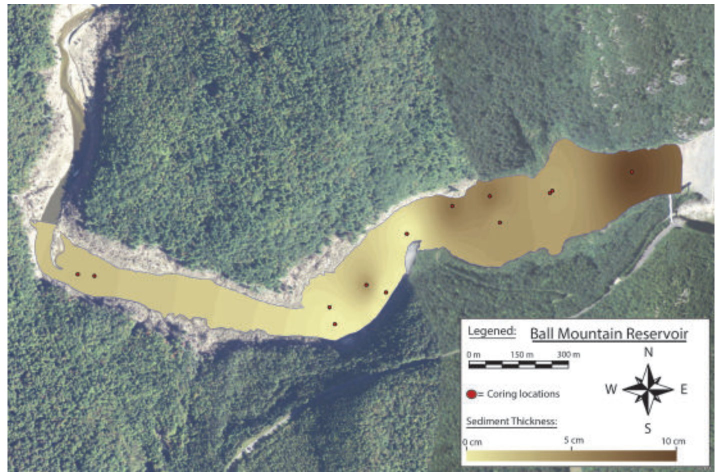

Figure 4. Isopach map of Ball Mountain reservoir showing the variation in thickness of the Irene event layer. Lighter color represents a thinner Irene layer, and darker colors represent a thicker Irene layer. Aerial photograph from the Vermont Center for Geographic Information.

The same interpretation method was used to calculate the sediment yield of post Irene deposits. This was done in order to calculate the mean annual sediment yield since Hurricane Irene. The total mass of post Irene sediment without organics was calculated to be 72,698 tonnes. With the watershed area being 445 km^2, and a depositional time span of 2 years, this gives us a sediment yield of 82 tonnes/km^2/yr. Once again this is an underestimate due to post-depositional erosion and the assumption that the trapping efficiency of the dam is 100%. However, trapping efficiency in the last two years has likely been much higher than that for the Irene event because reservoir residence time was anomalously short during the extreme flooding of TS Irene. Ideally we could then compare this post Irene mean annual yield to the mean annual yield of pre Irene deposition to understand how this extreme event might have changed the rate of erosion in postglacial upland tributaries. However, none of the cores from Ball Mountain are long enough to reach the bottom of the reservoir. Therefore, we are unable to calculate a pre Irene mean annual yield. We can still compare our post Irene sediment yield to those of some other small watersheds around the Connecticut River. The average sediment yield for watersheds around the Connecticut River is 16 tonnes/km^2/yr (Yellen et al. in review). As you can see the post Irene mean annual yield in the Ball Mountain watershed is considerably higher than that average. Is this disparity due to an increase in the rate of erosion in the uplands since Irene or is the pre Irene mean annual yield for Ball Mountain also considerably higher than that of the other watersheds?

In an attempt to get some idea of what affect Irene had, we can look at the sedimentation rate at BMLC for pre-Irene and post-Irene. BMLC is directly in front of the dam, so we can use the elevation data for the bottom of dam, the pool height, and the year the dam was constructed along with our own coring data to calculate the pre Irene deposition rate. The sedimentation rate for pre Irene was calculated to be 13 cm/yr, and the sedimentation rate for post-Irene was calculated to be 32 cm/yr. This means that at BMLC the rate of deposition of post-Irene sediment is 2.45 times greater than the rate of pre Irene deposition. This increase is similar to the increase in the turbidity since Irene (about double), observed at the mouth of the Connecticut River, measured by Yellen et al., (in Review). This suggests that Hurricane Irene did cause an increase in mean annual sediment yield by exposing glacial fines to later high frequency low discharge events.

FUTURE WORK

Work that still needs to be done includes the calculation of volume of pre Irene sediment behind Ball Mountain Dam and the calculation of the mean annual yield. This can be done either by dating pre Irene sediment across the reservoir or coring to the bottom of the reservoir. This needs to be done to more accurately assess whether the sediment yields of the watershed have been changed by the tropical storm Irene. Lastly more work needs to be done at other field sights around the Connecticut River uplands to see if the data found at this site are consistent across other upland tributaries.

REFERENCES

Yellen et al., Geomorphic Impacts of Extreme Precipitation on Post-glacial Rivers: Insights from Hurricane Irene. *Geomorphology*, in review.