35th Annual

FIVE COLLEGE GEOLOGY
UNDERGRADUATE
RESEARCH
POSTER SYMPOSIUM

THURSDAY, APRIL 17 2014

BENESKI MUSEUM OF NATURAL HISTORY
AMHERST COLLEGE
Exploring the Morphometry of Martian Valley Networks Using the MARSSIM Landform Evolution Model

Benjamin Boatwright, Amherst College

Advisors: Caleb Fassett, Mount Holyoke College; Anna Martini, Amherst College

The existence of ancient valley networks and drainage basins on Mars suggests that fluvial activity once played a significant role in shaping the surface of the planet. This likely required a wetter and warmer climate than exists today. Several studies have demonstrated that the morphometric characteristics of valley networks on Mars differ from those on Earth. Among these is a power law relationship between stream length and drainage area, known as Hack’s law. The exponent for Hack’s law is observed to be higher on Mars than on Earth, suggesting that Martian valley networks of a given length will have smaller, more elongate drainage areas than terrestrial valleys. It is not completely known why this discrepancy exists, although many possible reasons relate to valley maturity and differences in erosive potential.

This study used the MARSSIM landform evolution model to simulate a number of geomorphic processes on digital elevation models (DEMs) taken from the Mars Orbiter Laser Altimeter (MOLA) and High Resolution Stereo Camera (HRSC) in order to determine which, if any, of these processes might have affected the Hack’s law relationship on Mars. Measurements of the Hack’s law exponent on MOLA and HRSC DEMs yielded values similar to those cited in previous studies. Actual simulation exercises involved the variance of discharge and impact cratering rates on synthetic and real topography. Increases in discharge over several 100,000-year simulation periods produced an overall lowering trend in Hack’s exponent, suggesting that the higher Hack’s exponents observed on Mars may be mutually compatible with a lower average discharge. Moderate to heavy impact cratering resulted in trends not observed on the real Martian terrain, which reaffirms previous proposals that cratering rates would have been negligible over the timescales involved in valley network formation. Our computations were complicated significantly by inconsistencies in the model architecture, and further work will be necessary to alleviate these issues.
Paleoproterozoic metamorphosed mafic dikes and sills (MMDS), Highland Mountains, southwestern Montana

Adrian Castro
Amherst College

Paleoproterozoic metamorphosed mafic dikes and sills (MMDS) crosscut much of the suite of quartzofeldspathic gneisses that characterize the Precambrian core of the Highland Mountains in southwestern Montana. The Highland Mountains MMDS are garnet-clinopyroxene-hornblende-plagioclase-quartz amphibolites that have a relict igneous fabric. The MMDS are recognized as dikes, although they crosscut the gneissic fabric with a very low angle of obliquity, and are commonly aphanitic and weathered to a red-brown color. Garnet-hornblende and garnet-clinopyroxene thermobarometry shows that the MMDS fall in the upper amphibolite-lower granulite facies, with temperatures between 600-800°C and pressures between 0.7-0.9 Kbar. Major and trace element geochemical analysis shows that the MMDS are subalkaline basalts, while Harker and Fenner plots show that there has been very little major element mobility due to metamorphism. Basalt discriminant diagrams plotted with MMDS trace element data are indeterminate, as they show these MMDS to have ocean floor and ocean island affinities, while field evidence demonstrates that these basalts are continental in origin. Chondrite normalized spider diagrams reveal the MMDS to be enriched in most REEs, while MORB normalized spider diagrams show enrichment just in LREEs. Similar MMDS’ in the neighboring Tobacco Root Mountains intruded at 2.1 Ga, and were metamorphosed to upper amphibolite grade about 1.77 Ga (Cheney et al. 2004b) The major and trace element geochemistry of the Highland Mountains MMDS is very similar to that of the Tobacco Root Mountains MMDS, which points at a possible cogenetic nature of the two suites of MMDS.
Climate and land use: unraveling forcing factors in lake productivity from a lacustrine sediment core record in western Ireland

Mollie McDowell
Amherst College

The value of lake sediments for historiography lies in their propensity to produce continuous records of natural and anthropogenic changes. Multi-proxy paleolimnological studies, therefore, can provide detailed insight into various aspects of an area’s environmental history, such as long-term climate patterns, individual climatic events, land use changes, and ecosystem perturbations. In this study, we examine a lake in western Ireland with a catchment composed entirely of Carboniferous limestone. Lough Carra, a polymictic marl lake in Mayo County, Ireland, is large, spanning 14.4km², yet has an average depth of only 1.7m. However, a number of deep basins and sinkholes are present, reaching up to 18m in depth.

An 8m core was collected from the easternmost basin of Lough Carra near the mouth of the River Annies at a depth of 14m. The bottom 6.5m is well laminated. It is composed of a continuous ~2000 year sediment record as determined from preliminary $^{14}$C and $^{210}$Pb analyses. Large carbon isotope shifts are present in the bulk organic and inorganic phases, from -30 to -33 and from -2 to -5, respectively. The shift occurs right after a ~1852 “marker” bed resulting from a flooding event in the catchment that destroyed drainage works built two years prior. In addition, steady increases towards the modern occur in PO$_4$ concentrations and Hg within the sediment, indicating anthropogenic input. To further constrain nutrient dynamics in the lake, XRF core scanning analysis and ICP-MS analysis are being employed. Both will be useful in determining the catchment’s environmental history in terms of natural and anthropogenic changes.
Aida Orozco
Anna M Martini
Amherst College

Geochemical and Microfossil Record of Mass Hemlock Declines in the Sediment of Lily Pond in Barton’s Cove, Western Massachusetts: Implication on the Current Hemlock Die-off

ABSTRACT

In recent years, the Hemlock Woolly Adelgid (HWA) has aggressively infested a large portion of the American hemlock (*Tsuga canadensis*) population. This infestation has led to a massive decline, and the transformation of forest ecosystems in the region (Hessl and Pederson, 2012). One consequence is that local watersheds are being loaded with extra dissolved organic matter and nutrients, promoting the eutrophication of lakes and ponds. Around 6000 – 4800 years before present, the pollen record in lake sediments in the northeastern region of North America indicates a series of declines in the hemlock population, comparable to the decline we see today. Three-ring analysis suggests that these declines were the result of a series of droughts in the mid-Holocene (Foster et al., 2006; Shuman et al., 2004; Hessl and Pederson, 2012).

Today, the effects of the current hemlock decline are being accentuated by the rebound of earthworm populations in the region, after their decimation during the Last Glacial Maximum. These worms are cycling dissolved nutrients out of the soil organic matter faster than the biota can recycle them (Hale, 2006). This culminates in large amounts of nutrients flushed into nearby bodies of water, leading to further eutrophication (Templer, 2001; Templer, 2004; Hale, 2006). The process is also likely magnified by global warming, as reaction rates (often stemming from microbial processes) increase with soil temperature. In this study we will examine a deep, Hemlock surrounded plunge pool in Barton’s Cove, Gill, MA, to look for signals of past Hemlock declines using geochemical analysis and the microfossil record. We will also examine experimental data on hemlock and deciduous forest soils to quantify the additional nutrient release to be expected by worm colonization of these forests.
Stable isotope data from carbonate rocks are key to understanding paleoenvironmental conditions. However, syndepositional and early diagenetic processes can alter these geochemical proxies in modern environments; such variability might be predicted in the geologic record. Ordovician-Silurian limestones from Anticosti Island, Québec are used to test the hypothesis that δ^{13}C_{carb} and δ^{18}O_{carb} variability may be due to a) syndepositional processes in different depositional environments within the basin and b) differing diagenetic regimes across the basin. Two sample sets are examined: one time series from a single stratigraphic section, and another set of coeval samples deposited in a range of paleoenvironments across the island. Transmitted light petrography constrains diagenetic history and supplements field-based interpretations of depositional environment. Variability of δ^{13}C, δ^{18}O, and trace elements (Sr, Mn, Mg, Fe) in primary and diagenetic textures is statistically analyzed to characterize the effect of each on the bulk sample value. The time series records variation in δ^{13}C and δ^{18}O but little environmental variation, the samples having been deposited almost entirely on the outer ramp, below storm wave base. The coeval sample set records a progressive shallowing associated with the ascending limb of the end-Ordovician δ^{13}C/δ^{18}O excursion, the achievement of maximum shallowing at the peak of the excursion, and deepening thereafter in association with the excursion’s descending limb. Within the coeval sample set, the δ^{13}C record is largely invariant across the island and appears to record a primary signal; the δ^{18}O record does vary spatially and is aberrant in samples from the eastern end of the island, suggesting that there are multiple diagenetic provinces on the island. The results will inform the interpretation of basin-scale variability in the stable isotope record through space and time.
Magnesium isotope records associated with dolomite formation in a modern alkaline lake

PESSOA, Cecilia K. ¹, JONES, David S. ¹, and HIGGINS, John A. ²

¹Geology Department, Amherst College, 11 Barrett Hill Road, Amherst, MA 01002, cpessoa14@amherst.edu
²Geo sciences Department, Princeton University, Guyot Hall, Princeton, NJ 08540

The occurrence of dolomite in modern sediments of Deep Springs Lake (DSL), an alkaline playa lake in eastern California, provides an opportunity to study magnesium isotope systematics associated with dolomite formation. DSL is recharged by seasonal melt water from surrounding mountains and is fed by a network of springs discharging into the lakebed. We collected push cores of sediment from two lake bottom sites and five sites adjacent to springs. Pore water was collected by field-deployed peepers and centrifugation of sub-sampled sediment cores. Sediment was washed, dried, and homogenized before dissolution in weak acid. Magnesium isotope ratios (δ²⁶Mg) of pore waters adjacent to springs are isotopically enriched (~0.0‰ DSM). These spring pore water values are significantly heavier than silicate source material, suggesting loss of isotopically depleted Mg to carbonate minerals prior to discharge into DSL. Pore water δ²⁶Mg profiles vary <0.1‰ in the 40 cm below the sediment surface, indicating that little dolomite precipitation or dissolution is occurring within the sediment; this observation is consistent with the hypothesis that dolomite precipitates directly from DSL lake water. Sediment δ²⁶Mg is depleted from the pore water (~-1.8‰ DSM). If this dolomite is derived from waters with δ²⁶Mg of spring pore waters, the fractionation factor for these terrestrial lacustrine dolomites is ~1.8‰, which is similar to previously reported fractionation factors measured in marine systems.
Geologic Controls on the Stream Water Chemistry of the Berkshires of Western Massachusetts

Collier, Nicole R. and Newton, Robert M., Department of Geosciences, Smith College, Northampton, MA 01063

Stream water chemistry in undisturbed forested catchments is controlled primarily by the watershed’s surficial and bedrock geology. This study examines the relative importance of these two factors in determining the chemistry of small headwater streams within the Berkshires of Western Massachusetts. Sample sites were chosen to reflect various types of bedrock and surficial geology. Samples were taken from 14 headwater streams at least 1 km in length, that were primarily located within a single rock type during winter low flow period. Samples were analyzed for base cations (Ca$^{2+}$, Mg$^{2+}$, Na$^+$, K$^+$), trace metals (Fe, Al$^{3+}$), anions (Cl$^-$, NO$_3^-$, SO$_4^{2-}$), alkalinity, pH, and dissolved organic carbon. Winter sampling reflected high concentrations of sodium and chloride from the dissolution of road salt (NaCl, MgCl$_2$). The molar ratio of sodium to chloride in the samples is not the expected value of 1, suggesting cation exchange occurring in the samples, substituting sodium with calcium from soil mineral exchange sites. Out of 14 samples, WM02 is the only sample whose stream chemistry is controlled by surficial geology. Controls of stream chemistry are indicated by high concentrations of ions as a product of high residence time in highly permeable sand and gravel deposited by melt water streams. At this site, groundwater occurs between grains of sand and gravel, which leads to greater porosity, holding groundwater reserves. Low concentrations of ions were present in most waters, indicating slow reaction rates and residence times due to the more stable nature of silicate-bearing minerals, which dominant in granite, basalt, and other Mesozoic Basin sediments that occupy much of this area. Highest total ion concentrations were seen in areas of carbonate bedrock, where the bedrock is highly reactive and significant to water chemistry. In all samples, calcium was the dominant cation, indicating the presence of microcrystalline calcite veins throughout this area of Western Massachusetts, and the dominance of bedrock geology on the stream water chemistry.
Post-Sturtian Microfossils from Zambia and Namibia

Moore, Kelsey R. And Pruss, Sara B., Department of Geosciences, Smith College, Northampton, MA 01063

The fossil record of the Neoproterozoic has to date been scarce, with most examples of fossil material coming from shales and cherts. In recent analyses, several fossil groups have been identified in carbonates, particularly those that cap glacial deposits during Snowball Earth events (Bosak et al., 2011a, 2011b, 2012; Dalton et al., 2013). Neoproterozoic (~720 to 580 million year old) limestone and dolomitic shale drillcore samples were recently collected in Zambia (by F. Macdonald, Harvard University). These drillcore samples were collected from strata that record the Sturtian and Marinoan Snowball Earth glaciations (e.g., Hoffman et al., 1998), including the Kakontwe and Calcaire Rose formations, which cap glacial strata. These samples, along with samples of equivalent age collected in Namibia of the Rasthof Formation, produce eukaryotic microfossils of possible agglutinated testate amoebae. These discoveries contribute to our knowledge of post-Snowball marine microbial ecosystems and demonstrate that testate microfossil were widespread in the glacial aftermath. This study provides insight into the morphology and composition of the Zambian and Namibia microfossils and allow for comparisons of similarly aged rocks from various localities.

References


Chile lies on a subduction zone, a convergent plate boundary at which the relatively dense Nazca Plate subducts beneath the overlying South American plate. Historically, interactions between these tectonic plates have ruptured many earthquakes (Mw≥7), some as recently as the catastrophic 2010 Maule earthquake (Mw=8.8) and the 2014 Tarapaca earthquakes (Mw=8.2 and 7.6). Recent studies have shown evidence for segmentation of rupture areas along the Chilean coastline. The orientation of well-preserved reverse faults is consistent with the location of segments. (Loveless et al., 2009). A key concept in understanding the orientations of the faults is the orientations of the main principal stresses, maximum compressional (σ₁) and maximum extensional (σ₃), in which their orientations depend on the style of deformation. In our study, we began a quantitative exploration of this phenomenon, using MATLAB to simulate 88 earthquakes (Mw≥7), the magnitudes and locations of which were taken from a National Atmospheric and Oceanic Administration (NOAA) database. From this information, we calculated the stress fields induced by the slip between tectonic plates for each seismic event. If in reality the selected 88 earthquakes ruptured the coastal normal faults, we would expect the trend of σ₃ to be roughly perpendicular (or at least greater than 45˚) to the strike of these faults. Our study has shown that many areas along the coastline exhibit low proportions of differences between σ₃ trends and fault strikes greater than 45˚. This suggests that if these faults were indeed formed by the σ₃ in question, very few of them exhibit perfect normal faulting and rather, the majority have a strong strike-slip component. This result indicates that, overall, our record is not necessarily representative of the seismic pattern that ruptured the coastal faults of northern Chile. However, we observed a spatial variation along the coastline, near the Mejillones peninsula, where normal faulting is concentrated, suggesting that the 500-year seismic record we incorporated in our study is representative of the extensive history of surficial deformation for that specific region. Overall, we were able to obtain a first-order estimate for overall slip distribution, as well as recognize patterns in faulting style and a rough idea of the stresses induced by major Andean earthquakes that were potentially responsible for the formation of current day geologic features.
High Precision, High Spatial Resolution Laser Refractometer for Measurement of Mineral Refractive Indices

Wanda Feng, John Brady, and Doreen Weinberger
Departments of Geosciences and Physics, Smith College, Northampton, MA 01063

Optical refractometers were developed in the 19th century, used primarily to identify materials. The advent of lasers has opened possibilities for measuring the refractive indices accurately and precisely. The work presented here involves the instrument design and calibration of a refractometer to measure refractive indices of small crystals (d>20 µm) in polished thin section accurately within ±0.0001 error. A red HeNe (λ=632.8 nm) laser has been carefully directed to a high index glass hemisphere (n_{hemisphere} =1.78472). A calcite polarizer and quarter wave plate are placed in the path of the laser to linearly polarize and rotate the light, respectively. Subsequently, a beam expander and achromatic lens focus the incident beam to a spot size of 3.5 µm. When a mineral sample with an index less than that of the hemisphere is placed onto the plane of the hemisphere with a high index liquid between, the light is refracted or totally internally reflected at a critical angle (θ_C). For a known n_{hemisphere} and observed θ_C, the sample index (n_{sample}) may be determined (equation 1).

\[ n_{sample} = n_{hemisphere} \sin \theta_C \]  

[1]

The reflected light is projected onto a CCD line detector, which records the reflected ray intensity vs. angle, where the observed θ_C manifests as a shadow edge. To translate the pixel scale to refractive index measurements, a set of glass standards with well-known indices has been procured and polished for calibration. A series of olivine crystals with a range of indices from the Kiglapait layered mafic intrusion will also be studied to investigate refractive index as a function of chemical composition.
Hurricane Sandy formed on October 22, 2012 in the western Caribbean Sea and, as it moved north, it began to intensify. Sandy reached New York City on October 29, 2012 as a Category 1 storm. Sediment cores were taken from coastal back barrier ponds on the southern coast of Staten Island, post-Hurricane Sandy. Multiple coarse grained deposits, consistent with storm surge inundation, are found in the upper two meters of the core but very few are found in the lower section. A distinct change in lithology, which dates to the 1750s, separates these sections. Additionally, the sediment above the transition is coarser and less organic than the sediment below. We hypothesize that oyster beds, which were abundant in this area before the 1750s, protected the back barrier ponds from being inundated by major storm surge events but trapped fine grained, more organic sediment from the Hudson River. Overharvesting of the oyster beds and land clearance of the area by European settlers in the eighteenth century may have increased erosion of the coast. This erosion could create the spits of land which closed the ponds and shut off sediment supply from the Hudson River and the Atlantic Ocean.
Classification and Volatile Concentrations in a Chondritic Meteorite
Nolan Fonda and Sheila Seamen
Department of Geosciences, University of Massachusetts-Amherst

Chondritic meteorites are thought to have contributed to Earth’s volatile content. Volatile rich asteroids and meteorites impacted early Earth, possibly supplying it with volatiles such as H₂O and CO₂. The purpose of this study was to classify a chondritic meteorite, to identify and quantify volatile concentrations in the meteorite, and to compare its properties with those of previously studied meteorites. Chondrules make up about 20% of the meteorite. Mineral compositions were determined by electron microprobe analysis. The meteorite is composed of 0.25-0.5 mm grains of 76.9% enstatite, 21.5% ferrosilite, and 1.6% wollastonite composition Orthopyroxene and is surrounded by metallic minerals. Fourier transform infrared (FTIR) spectra were collected from orthopyroxene crystals to identify water and carbon dioxide. Water concentrations were calculated on the basis of peak areas on the FTIR spectra. Water concentrations in orthopyroxene crystals range from 0.33 to 1.095 weight percent. Without a bulk rock analysis, a definite classification of the meteorite is not possible, but on the basis of mineral assemblage and chondrule preservation, the meteorite is tentatively classified as an L2 chondrite. L2 chondrites have low Fe contents and have experienced extensive aqueous alteration but still contain recognizable chondrules as well as unaltered pyroxene.
IMPACTS OF EXTREME PRECIPITATION ON SEDIMENT YIELDS FOR POST GLACIAL UPLANDS OF THE NORTHEAST

Wesley Johnson, Brian Yellen, Jon Woodruff, Anna Martini, Robert Newton
Department of Geosciences, University of Massachusetts-Amherst

Abstract

This study uses deposits within Ball Mountain flood control reservoir (Jamaica Vt), to examine sediment yield in a postglacial upland tributary of the Connecticut River. The goals of this study are to examine the sedimentary fingerprint of an event layer corresponding to flooding during Hurricane Irene in Late August 2011 to evaluate what role flood control played in modifying the downstream sedimentary imprint of the event. In addition, 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 study seeks to understand what lasting effect Hurricane Irene flood-related land disturbances had on the erosion rate of upland deposits in years since the storm.

Nine sediment cores were taken from Ball Mountain Reservoir in Jamaica, Vermont. Grain size, porosity, organic content, elemental abundance, and x-radiographs were used to analyze the sediment. This study suggests that Irene sediment trapped behind Ball Mountain Dam is consistent with Irene sediment observed at the mouth of the Connecticut River. Also, that the West River watershed had relatively low sediment yields for the Hurricane Irene event. Lastly, Irene caused an increase in the erosion rate of upland glacial deposits, likely due to continued incision of hill slope gullies formed during the event.
A Sedimentary Record of 3,000 years of Coastal Change on Staten Island
Melanie Koerth
Department of Geosciences, University of Massachusetts-Amherst

Sediment cores contain extremely valuable information on the coastal environment such as deposition rate, storm surge occurrence, and sediment source. Cores taken from Arbutus Lake, a coastal, back-barrier lake on Staten Island’s southern coast are analyzed for elemental abundance, magnetic susceptibility, and grain size. A distinct change in lithology, corresponding to a decrease in zircon abundance and increases in magnetic susceptibility, percentage of coarse grained (i.e. sand) material, and frequency of storm surge deposits is observed and radiometrically dates to ~1750 CE. These results are consistent with a transition from a tidal marsh environment to a closed back-barrier lake. Historical maps show the formation of a barrier system between 1775 and 1859 CE which may be the result of removal of the widespread oyster beds from New York Harbor.