New Hampshire Geological Survey's Annual
Geologic Mapping Workshop 2018

Thursday April 5, 2018
9:00 AM – 12:30 PM*
NHDES Auditorium, NHDES, Concord
29 Hazen Drive, Concord, New Hampshire 03302-0095

Public Session Agenda

8:30 – 9:00 AM **Coffee and Poster Session in Auditorium Anteroom****

9:00 – 9:10 **Welcome and NHGS Program Update**
Rick Chormann, NH State Geologist

Guest speakers:

9:10 – 9:30 **Neil Olson, NH Department of Transportation** – ***"Use of 3D point cloud data for rock slope assessment."***

The use of detailed 3D models allows geologist to make better-informed decisions regarding geologic hazards. This talk will cover two case studies of the use of Structure from Motion (SfM) to collect structural information of rock slopes. The New Hampshire Department of Transportation (NHDOT) maintains a Rockfall Hazard Rating System (RHRS) that seeks to quantify the hazard posed by rock cuts over 20ft high adjacent to state roads. The current hazard rating is based on a number of field observations including geologic structure. These structural measurements are limited to the area accessible by foot because of limitations on rope access by NHDOT staff, thereby excluding a number of important structural measurements. In July 2017, NHDOT was able to work with the University of Vermont (UVM) to fly an Unmanned Aerial System (UAS) equipped with a global positioning system (GPS) and camera to acquire a series of images and video of a rock cut in Crawford Notch, New Hampshire. These pictures, in conjunction with ground control points collected by NHDOT using survey grade GPS during the flight, were used with commercial SfM software to create a 3D point cloud model of the rock cut. The resulting point cloud allowed for an exponential increase in the number of structural measurements and greatly improved the stability analysis of the cut, the highest rated in the RHRS. Additionally, the point cloud model allows for measurement of volumes, future change detection, and increased time and detail working on the cut and the identification of potential stabilization methods. Following the success of the UAS flight by UVM, a second cut in Warner, NH was visited and photographed with a GPS enabled smartphone, ground control points collected using a mapping grade GPS and the photographs processed using SfM freeware. This talk will share the process of collecting a 3D point cloud for a near vertical rock face as well as the additional analysis that is capable with such a rich data set. Some pros and cons of each method will be discussed as well as potential future applications of this technology within NHDOT.

9:30 – 9:50 **Lindsay Spigel, Maine Geological Survey** – ***"Characterization of large landslides related to the Presumpscot Formation, southern Maine."***

Maine's glacial marine clay unit, the Presumpscot Formation, is present throughout southern Maine and presents challenges to development, infrastructure, and public safety in the most populated area of the state. Landslides associated with the Presumpscot Formation have occurred in river corridor and coastal bluff areas of southern and coastal Maine throughout historical and modern times. The largest recorded historical landslide (about 15 ha) happened along the Presumpscot River in 1868, but most of these known landslides have been relatively small (<10 ha). LiDAR topographic data recently revealed over 100 large landslides in southern Maine, ranging from tens to hundreds of hectares. The Maine Geological Survey has been working with assistance from the Maine Emergency Management Agency to determine the characteristics of these large landslides. A subset of landslides was chosen for more detailed investigation, in which vegetation that was buried by, caught up in, or deposited on the landslides was sought for radiocarbon dating of the features. Prior to this study, only one pre-historic landslide had been dated to about 13,500 cal yrs BP. Improved understanding of the timing and potential triggers of these previously unknown landslides that were revealed by LiDAR will help guide disaster preparedness.

9:50 – 10:10 **P. Thompson Davis, Department of Natural and Applied Sciences**, **Bentley University** – ***"Boise Rock, not the glacial erratic that we thought, but rather part of the landslide history of Franconia Notch, New Hampshire."***

Boise Rock (41.15313 °N, 71.67812 °W, 595 m a.s.l.), a large boulder composed of Conway Granite, lies on the northbound side of Franconia Notch Parkway (I-93), directly across the highway from Cannon cliff, from which the "Old Man of the Mountain'' met his demise on 3 May 2003. Perhaps because of its size (~14 m across and 1 to 6 m high), odd sub-angular shape, and composition, Boise Rock has long been considered an archetype glacial erratic. The rock derives its name from a teamster, Tom Boise, who barely survived a mid-winter snowstorm during the early 1800s under the boulder's overhang.

As part of an effort to determine the rate of vertical lowering of the last waning ice sheet to cover the New England area, we analyzed ^{10}Be from a sample collected atop Boise Rock with the desire to provide a lower anchor point for our cosmogenic nuclide glacial dipstick reconstruction in Franconia Notch. Our surprising result was an age of 7.1 ± 0.4 ka, almost 6 ka younger than expected, based on ^{14}C ages on organic material from lake sediment cores in the area. Profile Lake at the head of Franconia Notch, about 1 km north of Boise Rock, provides two calibrated ^{14}C ages of 12.83 ka and 12.77 ka on wood and bulk organic matter at just above the transition from glaciolascustrine sediment to gyttja in two of several sediment cores (Rogers et al., 2010).

Although not useful for our glacial dipstick study, the likely Conway Granite bedrock cliff source for Boise Rock about 400 vertical meters directly upslope provides important information on the prehistoric landslide history in Franconia Notch. Of 20 landslides (debris flows) from the eastern slope of Franconia Notch as recorded by clastic lenses measured in Profile Lake sediment cores, six of the debris flows originated from the southern track zone between about 8.5 and 4.0 ka (Rogers et al., 2010). Although historic rock falls from nearby Cannon cliff, including the collapse of the Old Man of the Mountain, are not associated with extreme precipitation events, historic debris flows in Franconia Notch recorded by documentary data and clastic lenses in Profile Lake are. Precipitation-triggered debris flows and rock slides in Franconia Notch during the early Holocene are also consistent with pollen records from the White Mountains that indicate increased warmth and storminess beginning about 8.5 ka.

10:10 – 10:30 **J. Dykstra Eusden, Department of Geology, Bates College** – ***"ME-NH transect from the migmatized Central Maine Belt in western Maine to the Bronson Hill Anticlinorium in northern New Hampshire."***

This talk is imbued with the spirit of the "NH-VT" transect across the northern Appalachians annually led by Jo Laird, Pete Thompson, and Wally Bothner and enjoyed by legions of UNH grad students. New 7.5' bedrock quadrangle mapping, supported by the Maine and New Hampshire Geological Surveys through the U.S.G.S. StateMap program, forms a near continuous E-W transect of updated bedrock geology across the Central Maine Belt (CMB) to the Bronson Hill Anticlinorium (BHA) along the U.S Rte. 2 corridor; the "ME-NH" transect.

In the Gilead and Bethel, Maine quads, a highly migmatized CMB Rangeley stratigraphy has been defined with poor topping control that is intruded by diorites, granites, and pegmatites. Detrital zircons yield maximum depositional ages of circa 422-433 Ma while crystallization ages for two-mica granites yield ages of 349-355 Ma. The sequence of events in this part of the CMB is: (1) end of Rangeley Stratigraphy deposition at 422-433 Ma; (2) Acadian nappe-stage folding and the onset of regional metamorphism; (3) widespread migmatization occurring around 376 Ma; (4) Neoacadian open, reclined refolding: (5) Neoacadian emplacement of the Songo Pluton and associated diorites at 364 Ma; (6) Neoacadian two-mica granite emplacement at circa 350 Ma; (7) Alleghanian emplacement of the Sebago-type plutons at 294; and (8) intrusion of pegmatites around 260 Ma.

In the NH quadrangles the Mahoosuc Fault separates migmatized CMB Silurian Rangeley Formation from the BHA Ordovician Ammonoosuc Volcanics. The Moose River Fault separates the Ammonoosuc Volcanics from the Oliverian Jefferson Dome. Internal to the Dome are several dip-slip ductile shear zones. The BHA sequence sits unconformably (Penobscot?) above the Cambrian Albee Formation. Detrital zircons for the Albee yielded maximum depositional ages of 522 Ma and 545 Ma. Jefferson Dome gneisses yielded Ordovician crystallization zircon ages of 440 Ma and 447 Ma with one unexpectedly yielding a Carboniferous age of 334 Ma. Detrital zircon ages of a metasedimentary xenolith within the Jefferson Dome gave a maximum sedimentation age of 429 Ma suggesting the enveloping intrusion is no older than Silurian. Though we have improved our understanding of the "ME-NH" transect we have also uncovered many new areas of future work that the next generation of students will enjoy.

10:30 – 11:00 **Break (Posters)**

Kurt A. Niiler, J. Dykstra Eusden, Thorn K. Merrill, Bates College –***"New geochronology and bedrock mapping of the southern portion of the 7.5-minute Mt. Crescent quadrangle, northern New Hampshire."***

New bedrock 1:24,000 mapping and complementary zircon geochronology in the southern half of the Pliny East 7.5' quadrangle in northern NH along the Bronson Hill Anticlinorium and within the Jefferson Dome was completed as part of the USGS/NHGS StateMap program. The mapping reveals the following: 1) a variety of gray to pink, variably foliated Ordovician Oliverian granites; 2) several narrow, highly sheared lenses of Ordovician Ammonoosuc Volcanics within the Oilverian suite; 3) a previously undiscovered metasedimentary xenolith; 4) Ordovician weakly to non-foliated syenite; and 5) the crescentic-shaped Jurassic Mt. Crescent ring dike. Regions of silicified zones marking late brittle faults were also found and correlate to those found in the SW adjacent Mt. Dartmouth 7.5' quadrangle. Rare Jurassic mafic and rhyolitic dikes were also mapped and correlate to those found in the nearby Jefferson 7.5' quadrangle.

Crystallization and detrital zircon U-Th-Pb ages were determined for five samples from the study area. These five samples included three from the Oliverian granites, one from the granite porphyry of the Mt. Crescent ring dike and one from the metasedimentary xenolith found in the southwest corner of the quadrangle. Two of the three samples believed to be part of the Oliverian yielded concordant zircon ages of 440.1 +/- 2.6 Ma and 447.2 +/- 2.5 Ma, supporting their inclusion as part of the Ordovician Jefferson Dome. The third Oliverian sample yielded a concordant zircon age of 334.0 +/- 2.2 Ma, surprisingly indicating a Carboniferous age of intrusion. This sample also contained older zircons that were Ordovician in age, suggesting that it inherited them from the surrounding Oliverian Jefferson Dome rocks during intrusion. The sample of the Mt. Crescent ring dike yielded a concordant zircon age of 178.4 +/- 1.1 Ma, supporting its previous age designation. The metasedimentary xenolith yielded a maximum depositional age of 429.3 +/- 7.0 Ma, suggesting that it is Silurian and further that the enveloping coarse granite, previously designated as Ordovician, is no older than Silurian in age.

Hazel M. Cashman and J. Dykstra Eusden, Bates College; Richard A. Boisvert, NH Division of Historical Resources; Woodrow B. Thompson, Maine Geological Survey (retired) – *"The postglacial Riverton Stage of Glacial Lake Israel: An important feature for the occupants of the Israel River Complex."*

This study focuses on the relationship of the proposed postglacial Riverton Stage of glacial Lake Israel in the Israel River Valley of New Hampshire to the Israel River Complex (IRC) archaeological sites on/among till hummocks overlooking the valley (Boisvert et al., 2017). Maps were made in GIS of the Riverton stage and the three previously mapped stages, called Bowman, Pine Knob, and Bailey's (Thompson et al., 2017), using LiDAR (from the Lancaster E and Jefferson 7.5' quadrangles) obtained through NH Granit. A wave-cut bench found in the field further confirms the elevation of the Bailey's Stage spillway and its respective shoreline (Thompson et al., 2017).

Mapping of geomorphologic landscape units in the study area showed three classes: hummocky till (stagnation moraine), smooth till, and what is referred to as lake bottom (even topography in the floor of the Israel River Valley, overlain by alluvium). Spatial patterning of the units was compared to models of Bailey's and Riverton Stage shorelines made using LiDAR in GIS. Good correlation was found between boundaries of hummocky till and smooth lake bottom and the Riverton shoreline model, while the correlation with the modeled Bailey's stage shoreline is weaker.

Riverton Stage shorelines were modeled using elevations from a spillway at Riverton, NH, (Thompson, pers comm) after digital extraction of overlying postglacial and anthropogenic gravels from the DEM. Lower and upper spillway elevations bracket the minimum and maximum areal extent of this stage. Radiocarbon dates were obtained from organic material at the top of a layer of postglacial lake sediment and from wood at the bottom of an unknown layer, either postglacial pond deposits or glacial lake clays, (Thompson, pers comm) as well as from cervid bone fragments excavated by Dr. Richard Boisvert from the Jefferson VI site in 2013. These dates help constrain timing of the disappearance of Glacial Lake Israel and determine the relationship of the postglacial Riverton Stage to the occupation of the IRC sites. Riverton Stage models made from the upper spillway elevation show the lake as proximal to the IRC. The existence of this feature in the Israel River Valley had impacts on caribou migration routes, hunting patterns/strategies, and on site usage and material culture at IRC sites (Boisvert, 2012; Boisvert et al., 2017).

11:00 – 11:20 **Vadim Levin, Department of Earth and Planetary Sciences, Rutgers University (via GoToWebinar) – *"Upper mantle dynamics beneath New England and eastern New York: Rising currents and falling fragments."***

The upper mantle beneath the Appalachian Orogen in eastern North America contains regions where seismic waves speed are significantly reduced compared to the craton to the west. They are hundreds of kilometers across, cut across the trend of the Appalachian terranes and likely post-date the Paleozoic assembly of Pangea. The most prominent of these anomalies, the North Appalachian Anomaly (NAA) beneath southern New England, has been alternatively explained as a localized disruption of lithospheric fabric, the after-effects of the Great Meteor Hot Spot passage, and present day asthenospheric upwelling due to edge-driven convection.

Seismological observations accumulated over the last decade offer improved constraints on the geometry and the properties of the NAA. Tomographic images based on EarthScope TA data Identify a compact NAA, anout 400 km across, that is largely limited to the volume east of the Appalachian Front and place it mostly beneath the relatively thin lithosphere of the northern Appalachian Orogen.

Nearly 10% shear wave speed reduction relative to the values in the stable craton is required to explain the observed lateral variation in travel times of teleseismic S waves. Amplitudes of co-located anomalies in shear and compressional speed at depth require the NAA to have a thermal origin. Furthermore, a comparison of spectra of teleseismic shear waves shows that seismic attenuation is considerably higher beneath the NAA, also implying high temperature within it. The short lateral scale of heterogeneities in attenuation values requires a highly heterogeneous asthenosphere with large differences over distances of ~100 km and suggests interaction with, and possibly erosion of, the overlying lithosphere. Indicators of upper mantle anisotropy suggest a regionally consistent pattern of deformation, with ~N80E orientation, in good agreement with the absolute plate motion. A clear departure from this pattern is seen beneath the NAA where subvertical asthenospheric flow disrupts the pattern. Taken together, new constraints on the upper mantle structure and texture characterize northeastern North America as a highly heterogeneous volume where elevated temperature in sublithospheric mantle likely drives localized upwellings and promotes small-scale unrooting of the overlying lithosphere.

11:20 – 11:40 **Peter Thompson, University of New Hampshire (retired) – *"Reevaluation after 50 years of nappes in western New Hampshire: Are Skitchewaug and Cornish Nappes one and the same?"***

Recent detailed mapping in west-central New Hampshire demands a reevaluation of regional nappe-stage structures in the Bronson Hill anticlinorium (BHA). In the Smith Pond area, between the Mascoma and Croydon domes, schist layers formerly interpreted as infolds of Littleton and Partridge Fms alternating with Clough Quartzite are more likely schist intervals within the Clough, and a single F1 isocline of Fitch Fm. Samples have been collected for U-Pb detrital zircon analysis to test this hypothesis. The 1.5-km-amplitude syncline of Fitch opens westward and is deformed by a large overturned F2 anticline plunging SE, by upright F3 dome-stage folds, and locally by minor kinks associated with the nearby Mesozoic Grantham fault. The F1 fold appears to be a minor fold on the upright limb of the much larger westward-opening, recumbent Garnet Hill syncline (GHS), above the autochthonous Bronson Hill sequence, and not the "root zone" of the Skitchewaug nappe. A closer look at other purported extremely attenuated repetitions between Clough and interbedded schist units (e.g. Croydon Mountain, Surry Mountain) is warranted.

The Bethlehem Gneiss, presumably part of the Fall Mountain thrust nappe (FMTN), cuts obliquely across nappe-stage folds. The upper, overturned limb of the F1 GHS is preserved farther west as the lower limb of the Cornish nappe (CN), where it was dropped down along the Northey Hill shear zone. Facies changes between Littleton, Gile Mountain and Waits River Fms must occur beneath the CN. South of the Croydon dome, and east of the Grantham fault, the overturned limb of a westward-closing anticline is also preserved, there called the Skitchewaug nappe (SN), truncated above by the Brennan Hill thrust and Bethlehem Gneiss in the FMTN. The implication of these structural relationships is that CN = SN, rooted east of the BHA and below the FMTN. The upright limb of this nappe is preserved in a small graben at Skitchewaug Mountain and also north of the Lebanon dome. Farther north, the nappe is truncated above by the Piermont allochthon in a position analogous to the FMTN. Rocks NW of the Keene dome, supposedly in a deeper Bernardston nappe, may be a case of metavolcanics within the Littleton having been misinterpreted as a tight isocline of Ordovician units. Samples for U-Pb geochronology have been collected to resolve this question.

11:40 – 12:00 **Brian Fowler, NH Geologic Resource Advisory Committee** – ***"Post-Laurentide deglaciation of the middle Swift River basin, Bartlett and Chocorua 7.5-minute quadrangles, New Hampshire."***

The Middle Swift River Basin lies on flat terrain that stretches west to east in Albany, New Hampshire. Mountain ridges flanking the basin to the south are formed by Mts. Passaconaway, Paugus, and Chocorua and on its north by Owl Cliff, Bear Mt. and Table Mt. These ridges direct the Swift River to the east into the Saco Valley at Conway. During deglaciation, the basin initially contained a +/-12 sq. mi. +/- 2,000-ft. thick mass of wasting glacial ice that had been isolated from the rest of the downwasting ice sheet as its thinned and separated around the region's higher terrain. The initial stage of its disintegration within the basin involved extensive meltwater flowing to the south off its high surface through the 2,200-ft. cols at the heads of the Kelly and Paugus Brook valleys. After the ice surface lowered below these cols, deposits on the basin's north-facing slopes show small lakes locally ponded into progressively lower elevation pockets variously trapped between raggedly disintegrating ice and the north facing slopes. As the ice surface continued to lower and the basin became ice-free, these small lakes progressively drained and then coalesced into Glacial Lake Passaconaway, which was dammed by a cross-valley morainal "plug" at the present location of the Rocky Gorge Upper Falls on the Swift River. Several abandoned progressively lower and heavily eroded meltwater channels there show the lake drained in several stages until the plug was breached and the bedrock threshold exposed.

12:00 – 12:20 **Greg Barker, NH Geological Survey** – ***"Surficial Geology of the New London 7.5' Quadrangle, New Hampshire."***

This talk will highlight the surficial geologic units identified from desktop analysis of LiDAR terrain and field investigations of these features. The LiDAR data was a key component to tentatively identify features and target areas for concentrated field efforts. The LiDAR was also used to subsequently compile these field observations into map units. The mapped units allowed for the re-construction of a likely deglaciation sequence. Some of the key findings were: 1) the Mount Kearsarge edifice played a large role in controlling how the Laurentide Glacier retreated from the area, 2) shallowness of bedrock in many portions of the quadrangle largely controlled how meltwater moved through the quadrangle. 3) large areas of ice contact deposits and high elevation cross (modern day) topography would likely indicate the mode of deglaciation was largely down-wasting and not active retreat. This conclusion would seem to be further bolstered by a lack of morainal features and classic glaciofluvial sequences.

12:20 **Questions and closing remarks**

Rick Chormann, NH State Geologist

Private Working Session for NHGS Mappers in the Anteroom

1:15 – 3:15 Mapping contractor meeting for those who map for the NHGS under the STATEMAP program.

Directions to NH Department of Environmental Services
The main offices of DES (including the New Hampshire Geological Survey) are located at 29 Hazen Drive, Concord, NH.

From the South and West

Take I-93 north to Exit 14 turning right at the end of the exit ramp. At the third light (at top of the hill), turn left onto Hazen Drive. Turn left at sign for Health & Human Services. Visitor parking is available in front of building.

From the North

Take I-93 south to Exit 15E onto I-393. Take Exit 2 and turn left at end of exit ramp (East Side Drive). Stay to the right and turn right at light onto Hazen Drive. Turn right at sign for Health & Human Services. Visitor parking is available in front of building.

From the East

Take Route 4 west to Concord (Route 4 becomes I-393 in Concord). Take Exit 2 and turn left at end of exit ramp. Stay to the right and turn right at second light onto Hazen Drive. Turn right at sign for Health & Human Services. Visitor parking is available in front of building.

Note: If you have not already done so, please respond by email if you plan to attend so that we can anticipate the number of attendees. If you need further information on the program or **to R.S.V.P., please contact the NH Geological Survey at: geology@des.nh.gov**

Attendance at the entire public session part of the workshop qualifies for 3.5 CEU's

Please bring photographic identification (*e.g.* driver's license) in order to be admitted to the DES Building. Thank you.

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* NHDES employees should confirm their attendance and schedule of the workshop with their supervisors.

** Posters will be on display until the end of the public session of the workshop.