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***THE VERMONT GEOLOGICAL SOCIETY ANNUAL
SPRING STUDENT PRESENTATION MEETING
April 18, 2015, 8:30 am
Room 219, Delehanty Hall, UVM, Burlington, VT***

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PRESIDENT'S LETTER

The Vermont Geological Society held its annual winter meeting on Saturday January 24, 2015 at the Cider House Restaurant in Waterbury. This meeting, which was attended by 48, commemorated the recent retirement of Vermont State Geologist Larry Becker (1995-2014). The meeting started with a "happy hour" of appetizers and a cash bar, was followed by a buffet feast, and concluded with applied geology talks by Bob Marvinney, Rick Chormann, and Steve Mabee, the current state geologists of Maine, New Hampshire, and Massachusetts, respectively. Larry Becker spoke last and recapped the highlights of his career and thanked all the attendees. Because of this special event, the Vermont Geological Society covered the full cost of dinners for some special guests as well as ~50% of these costs for all attending members.

Respectfully submitted,
Jon Kim, President



State Geologists (left to right): Steve Mabee (MA), Marjorie Gale (VT), Laurence Becker (retired VT), Rick Chorman (NH) and Bob Marvinney (ME)



Greg Walsh and John Van Hoesen enjoying the gathering at the Cider House.



Cheryl Marvinney and Kate Ross

Heartfelt Thanks for the Event

With admiration for the Society, I want to thank the Executive Committee and the Membership for the sendoff at the VGS winter meeting. The Executive Committee put time and energy into the event with many arrangements made by Jon Kim, Society President. The gifts are special: The 2011 bedrock state map framed; the glass version of the simplified 1961 map of

On March 13, 2015 the House and Senate adopted S.C.R. 10 honoring the work and contributions of Laurence R. Becker as Vermont State Geologist.

Larry is working as a temporary employee in our office through June. He is working on a special project for strengthening the role of science in ANR. Work groups are discussing “Asking and Answering Natural Resource/Environmental Questions” and “Personnel and Science Expertise” and working towards recommendations for processes to be established in ANR.

Many thanks to Jon Kim for organizing a wonderful retirement celebration for Larry Becker.

Vermont and the plaque from USGS. My state geologist colleagues from Maine, Massachusetts, and New Hampshire ably supported the geology and public-policy theme – the applied geology our surveys all perform. For those that attended and to the membership, we have a special group that continues to show how a vibrant community meets, greets, and shares the joys of our science. All in all, a very gratifying evening.

Sincerely,
Larry

STATE GEOLOGIST’S REPORT

From water chemistry to tectonics, Lidar and drones, there were 52 Vermont-specific presentations by our geoscience community at the Northeast Section Annual Meeting of the Geological Society of America in Bretton Woods, NH this past March. Jon Kim, George Springston, and our soon-to-graduate student intern Christina Strathearn were co-authors on several abstracts:

Connard, C., Coish, R., Kim, J., and Amidon, W., 2015, U-PB dating of detrital zircons in the Cram Hill Formation, Vermont: implications for paleogeography and orogenesis.

Dunn, R.K., Springston, G.E., Hermanson, T., and Thomas, E., 2015, Interbedded subaqueous debris and turbidity flows; a thick and laterally extensive ice-proximal facies preserved in isolated proglacial basins.

Kanat, L.H., Springston, G.E., and Sevi, A., 2015, Complex earth slide-flows in glaciolacustrine deposits over the past 100 years in Jeffersonville, Vermont.

Kim, J., Romanowicz, E., Dorsey, M., and Strathearn, C., 2015, Hydrogeological analysis of a complexly folded and faulted bedrock aquifer in the Champlain Valley of west-central Vermont.

Kim, J., 2015, The along-strike context of the Richardson Memorial Contact (RMC) in the town of Craftsbury, north-central Vermont.

Ryan, P., Kim, J., and West, P., 2015, Along strike variation in arsenic and other trace elements in metapelites of the Connecticut Valley/Gaspe sequence (NE Vermont and SE Quebec).

Springston, G.E., and Underwood, K.L., 2015, Landslide and alluvial fan activity due to Tropical Storm Irene: Examples from Money Brook, Black River watershed, Vermont.

Springston, G.E., and Kim, J., 2015, Surficial features and bedrock structures revealed by lidar in western Vermont.

Strathearn, C., Klepeis, K., Kim, J., Gombosi, A., Langworthy, M., Johnson, E., and Schachner, B., 2015, Detailed analyses of structures in the footwall of the Champlain Thrust at Lone Rock Point, Burlington, Vermont.

In the meantime, I have been transitioning to my new role as State Geologist, a role significantly different than bedrock mapping. I'm working on how to best explain and deliver our science and its applications to the public, particularly within 3-5 year time constraints and in tight budget years. We developed results-based accountability measures (RBA) and in that context our focus is earth science as applied to environmental and human health, hazards, and groundwater. We are now tying the RBAs to our Strategic Plan and developing specific annual goals and strategies to address how Vermont is better off due to our work and to illustrate our contributions to ANR. "Actionable research" and "timeliness" needs for policy makers are terms recurring in conversations.

Other items on our radar are Act 250 applications for both sand and gravel pits and rock quarries, re-design of the Environmental Conservation (includes the Geological Survey) web site, landslide hazard mapping, and planning for the ROVER (Rapid Observation of Vulnerability and Estimation of Risk) analyses of selected critical facilities in Vermont this summer. That work, conducted in coordination with NESEC and FEMA, is focused on an evaluation of buildings and their potential response to seismic events. NESEC hopes to employ ROVER at National Guard facilities, the DEMHS building in Waterbury, and are possibly the Vermont Statehouse. A trained group of volunteers, the FEMA Volunteer Corps, will conduct the facility evaluations.

Lastly, with Spring finally upon us we are planning for STATEMAP-funded surficial geology projects in Cabot and Monkton. Also, George Springston and I will collect more till samples for geochemical analyses and mineralogy (Pete Ryan and students) in the Montpelier one-degree sheet before the end of June. Jon Kim will be in the field focused on groundwater in fractured bedrock projects in conjunction with his powerhouse informal consortium of Keith Klepeis (UVM), Pete Ryan (Middlebury), and Ed Romanowicz (SUNY Plattsburgh).

Respectfully submitted,
Marjorie Gale, Vermont State Geologist

ADVANCEMENT OF SCIENCE COMMITTEE REPORT

The committee did not receive any applications to the Vermont Geological Society Research Grant Program by the April 1st deadline. However, recent discussions by the VGS Executive Committee recommended that the spring deadline be extended to May 1st to better accommodate students, who have recently been selected for upcoming field projects, but are not “up to speed” enough yet to write a research grant. Because of the late notice of this extension, **I will accept research grant applications for the new May 1st deadline that are postmarked by Monday May 11th.** Send grant applications to Jon Kim, Vermont Geological Survey, 1 National Life Drive, Main 2, Montpelier, VT 05620-3902.

REQUESTS - 3 judges are needed for the VGS Student Meeting on Saturday April 18th. Last year, Craig Heindel, Larry Becker, and Peter Gale were judges so I would appreciate some other volunteers. Please contact me if you are willing to judge (jon.kim@state.vt.us). Also, please let me know if you have an idea for the summer field trip.

Respectfully submitted,
Jon Kim, Chair

TREASURER’S REPORT

Finances: The Society remains in good financial health. Since the last report we have not incurred expenses, but Spring Meeting expenses are pending. These will include cash prizes to the winner of the Doll Award and to the second and third place finishers, as well as upcoming expenses from the next round of Student Research Awards.

Expenses:

Dinner guests and member subsidy	\$1220.88
Speaker expenses	\$411.99
Gift expenses	\$427.82

Balance: Our balance as of April 1, 2015 is \$11,758, with most of 2015 dues having been received. To date for 2015, we have received \$1,648 in dues and \$1,112 in gifts toward the Research fund.

New Member:

Chris Koteas, Department of Earth and Environmental Sciences, Norwich University

Respectfully submitted,
David S. Westerman, Treasurer

2015 SPRING MEETING PROGRAM

8:30 AM COFFEE & REFRESHMENTS

9:00 AM RILEY EBEL: Colloidal sediment in the Uinta Range, Utah

9:15 AM BRENT NIXON: A study of salinization dynamics on a ranch in eastern Montana: characterizing the source, production and transport of dissolved sodium and sulfate in surface water in three first-order catchments

9:30 AM JENNIFER BOWER: Impacts of competitive sorption processes on Pb bioavailability in urban soils

9:45 AM NICHOLAS BACHMAN: Origin and speciation of uranium in the Clarendon Springs Formation, Milton and Colchester, Vermont

10:00 AM CYNTHIA CONNARD: U-Pb dating of detrital zircons in the Cram Hill and Umbrella Hill formations, Vermont

10:15 AM SAM LAGOR: The relationship between magmatism, deformation and metamorphism during the Acadian Orogeny: evidence for syntectonic intrusion of the Knox Mountain Pluton in the Connecticut Valley-Gaspé Trough, Central Vermont

10:30 AM BREAK, COFFEE & REFRESHMENTS

11:00 AM LOGAN MILLER: Stratigraphy, structure and volcanic rock geochemistry in the Little Jarvis area of the Palmer Property, southeast Alaska

11:15 AM ABRA ATWOOD: Cosmogenic ^3He paleo-seismology of an active normal fault, northern California

11:30 AM CHRISTINA STRATHEARN: Detailed analysis of structures in the foot wall of the Champlain Thrust at Lone Rock Point, Burlington, Vermont

11:45 PM PIPER ROSALES: Analysis of multiple slumps in Lake Champlain, Vermont from Juniper Island to Quaker Smith Point

12:00 PM ELLEN TAYLOR: Palynological analysis of a Champlain Sea peat layer, St. Albans Bay, Vermont

12:15 PM JUDGING, REFRESHMENTS & AWARDS CEREMONY

2015 ABSTRACTS**COLLOIDAL SEDIMENT IN THE UINTA RANGE, UTAH**

Riley Ebel and Jeff Munroe, Middlebury College

Weathering of earth materials in high alpine environments is usually considered a slow process because rates of chemical reactions are known to be inhibited by low temperatures. However, physical weathering driven by freeze/thaw oscillations is efficient at reducing rock to fine sediment, and most chemical weathering processes continue to operate as long as liquid water is present. Thus at high elevations above the reach of alpine glaciers the combination of physical and chemical weathering could be expected to produce pedogenic minerals over long time periods. The Uinta Mountains of northeastern Utah provide a setting in which this prediction can be tested. Alpine uplands of the Uintas were not directly impacted by glacial ice during the Pleistocene, and soils in these landscape positions presumably began forming long before the current interglaciation. Previous studies have noted that clay minerals and colloidal (submicron) material are abundant in these soils. Other work has documented the presence of abundant colloidal material in sediment cores from lakes in landscape positions below the unglaciated alpine uplands. This project was designed to test the inter-related theories that a) the submicron material in the soils is pedogenic, reflecting long-term weathering during the Quaternary, and b) the submicron material in the lakes was derived from the alpine soils by erosion. Linking the colloidal sediments identified in alpine soils with those in lacustrine records may provide valuable information about chemical and physical weathering in alpine settings, as well as the source and fate of alpine sediment on both short and long term scales. Submicron material was isolated from previously collected soil and lake sediment samples through centrifuging. Results of XRD analyses indicate that the submicron material is predominantly composed of clay minerals. Lake sediment samples are strikingly monomineralic, containing only illite, whereas alpine soil samples contain both illite and smectite in varying amounts; some soils contain solely illite, some contain solely smectite, and some are a mixture. Illite-rich soils are more abundant in the eastern Uintas, with smectite-rich samples dominant to the west. SEM analysis demonstrates the presence of platy crystals, in some cases with wavy or curled edges, that are consistent with a pedogenic origin. Variation in K from 0.3 to 0.7 atoms per unit cell reflects smectite and illite end-members. Ubiquitous presence of secondary minerals in upland soils supports the theory of active pedogenesis in the uplands; in addition, similarities between lake and soil illites support the initial hypothesis that there is likely a connection between lake and soil material via erosion. Geochemical results from ICP-MS will be used to evaluate the similarity between the submicron material from the soils and lakes using ratios of immobile trace elements and rare earth element abundances.

**A STUDY OF SALINIZATION DYNAMICS ON A RANCH IN EASTERN MONTANA:
CHARACTERIZING THE SOURCE, PRODUCTION AND TRANSPORT OF
DISSOLVED SODIUM AND SULFATE IN SURFACE WATER IN THREE FIRST-**

ORDER CATCHMENTS

Brent Nixon, Middlebury College

Salinization in the Northern Great Plains (NGP) of North America has been studied both in the context of saline seeps in cultivated farmland and in high solute content in rivers. The study area, three first-order catchments on a ranch in a semi-arid, sparsely vegetated prairie landscape in eastern Montana, is underlain by gently dipping marine and non-marine Cretaceous and Tertiary sedimentary rocks, including black marine shales, sandstone, and coal/lignite. The locally derived surficial sediment incised by ephemeral streams fed by seasonal precipitation.

To test the hypothesis that Cretaceous marine shales are the source of sulfur and sodium in dissolved reservoir water, the geochemistry of water and non-water materials was studied. In general, the objective was to determine the original geologic source and production/transport dynamics of sulfur and sodium within these catchments.

Within three different catchments on a 160 km² ranch, three reservoirs with high, medium, and low salinity were the main study sites. Samples of overland storm flow were taken once, and reservoir water samples were taken twice, once when the reservoir was freshly filled with spring runoff and then two months later after significant evaporation and seepage loss. Non-water samples were bedrock, alluvium, and evaporite deposits from reservoir margins. Detailed geochemistry of all samples was determined using ICP-MS and XRD.

ICP shows reservoir waters to have very high levels of sulfate (1050 – 6900 mg/L) and sodium (400 – 2900 mg/L) and elevated concentrations of trace elements such as arsenic, strontium and uranium. ICP reveals a near one-to-one positive correlation of sodium with sulfate in shales, alluvium, coal, and evaporites in these watersheds. XRD indicates presence of thenardite (NaSO₄), smectite, calcite, pyrite, chlorite, illite, quartz, and feldspar. Together with the high levels of sulfate and sodium, the presence of calcite, smectite, and pyrite suggests a geochemical model of production and release of sulfate and sodium from rock and sediment to shallow groundwater and surface water. In this model, calcite weathering produces calcium ions, which exchange with sodium ions adsorbed to smectite, releasing Na into solution. Oxidation of pyrite produces sulfate ions, which go into solution. This mechanism appears to be responsible for the dominance of sodium sulfate waters and thenardite in reservoir evaporite deposits.

IMPACTS OF COMPETITIVE SORPTION PROCESSES ON Pb BIOAVAILABILITY IN URBAN SOILS

Jennifer Bower, Chandler Noyes, and Nicolas Perdrial, University of Vermont

The presence of contaminant metals in soils is a worldwide and widespread issue of concern, but in-situ remediation efforts are often hindered by the complexity and heterogeneity of soil systems. Through multiscale analysis of column experiments, this project aims to model

competitive sorption dynamics, using Pb as an element of concern, with the goal of constructing a quantitative, predictive tool for soil competitive sorption to be applied toward soil remediation. Representative soil samples containing as much as 12,000 mg kg⁻¹ Pb were sourced from a Burlington, VT site contaminated with legacy Pb from exterior paint. A series of column experiments is then conducted, testing the mobility of Pb as a function of the pH of rainwater, before beginning column experiments investigating multiscale expressions of competitive processes influencing Pb speciation and bioavailability. Next, amendments of goethite (FeO[OH]) and PO₄ in specific ratios are added to soil columns and leached with synthesized rainwater in order to examine the speciation and bioavailability of Pb using molecular, micro- and macro-scale tools (XAS, XRD, SEM, XRF and elemental analysis). Coupling the experimental evaluation of Pb bioavailability as a function of the presence of competitive sorbents with numerical prediction of sorption behavior using the reactive transport model CRUNCHFLOW will contribute to the development of a quantitative, predictive tool relevant to the remediation of Pb-affected systems. Eventually, the goal of this research is to help generate sustainable Pb remediation techniques that are effective in a diversity of soil types.

ORIGIN AND SPECIATION OF URANIUM IN THE CLARENDON SPRINGS FORMATION, MILTON AND COLCHESTER, VERMONT

Nick Bachman¹, Peter Ryan¹, and Jonathan Kim²

¹Middlebury College, ²Vermont Geological Survey

The purpose of this thesis is to (1) determine the origins and diagenetic history of the phosphoritic material within the Clarendon Springs Formation, (2) model the uptake and fixation of uranium within Clarendon Springs Formation with specific focus on the phosphoritic horizons, and (3) identify the hydrological and mineralogical weathering processes causing the uranium to mobilize into groundwater. The background and impetus for this study are that groundwater produced from the Clarendon Springs Formation in Milton and Colchester is known to contain elevated uranium and alpha radiation. Radioactivity is high enough that the average alpha radiation from 131 domestic bedrock wells tested in a 12 km² area is 32 picocuries per liter (pCi/L) and 22 % of these wells produce concentrations of alpha radiation above the EPA's maximum contaminant level (MCL) of 15 pCi/L. Furthermore, the three most contaminated wells, which occur within a kilometer of each other, average 841 pCi/L, and the bedrock of this sub-area is the focus of this study.

Dark grey to black phosphorites are sporadically distributed throughout the region that contains elevated radionuclides in well water. Phosphorite-rich beds are interbedded with massive dolostone beds that lack phosphorite. The phosphatic material typically occurs as subangular, pebble-sized clasts in a dolostone matrix, and wispy beds of dark grey phosphorite (possibly "hardground") are also observed. These textures are consistent with a syndepositional origin of the phosphorite. Rock samples collected from outcrops up-dip of the most highly contaminated

wells were categorized based on structure and composition and analyzed for mineralogical and chemical content using ICP-MS, XRD and SEM-EDS. ICP-MS analysis shows that the phosphorites contain 80-210 mg/kg uranium while the dolostone matrix contains less than 10 mg/kg U. XRD indicates that the phosphorite mineral is fluoroapatite. SEM-EDS element maps show that phosphorite clasts and layers lacking significant post-depositional deformation contain the highest levels of uranium; U appears to occur diffusely in cryptocrystalline fluoroapatite, but perhaps more importantly, U is concentrated in microcrystalline pyrite (with associated Fe-hydroxide) scattered throughout the phosphorite. This may suggest that uranium was substituted into Ca sites in fluoroapatite upon crystallization on the seafloor (consistent with literature reports), but also that U was also incorporated into sulfides during very early diagenesis or during recrystallization associated with dolomitization. The role of pyrite as uranium host is significant because it weathers much more rapidly than apatite, and this may be an important factor controlling the high amounts of U and alpha radiation in well water.

**THE RELATIONSHIP BETWEEN MAGMATISM, DEFORMATION AND
METAMORPHISM DURING THE ACADIAN OROGENY: EVIDENCE FOR
SYNTECTONIC INTRUSION OF THE KNOX MOUNTAIN PLUTON IN THE
CONNECTICUT VALLEY-GASPÉ TROUGH, CENTRAL VERMONT**

Sam Lagor and Laura Webb, University of Vermont

The Silurian–Devonian metasedimentary rocks of the Connecticut Valley-Gaspé trough (CVGT) were subjected to multiple fabric-forming deformational and metamorphic events throughout the course of the Acadian orogeny. Plutons intruding the metasediments have been considered post-tectonic, but microstructural studies of the intrusions and their metamorphic aureoles indicate some of these plutons have intruded syntectonically. This study investigates the relationship between Acadian deformation and intrusion of the Knox Mountain pluton (KMP) of central Vermont via an integrated structural and geochronological study along a transect across rocks of the CVGT. The transect begins at the western limit of the CVGT at a faulted unconformity, the Richardson Memorial Contact, and passes into the margin of the KMP in the east. Our observations confirm previous findings of three documented Acadian foliations (S1-S3) in the CVGT, where S1 fabrics typically dominate and closely parallel original bedding, S2 is a crenulation cleavage, and S3 is only locally apparent. However, we have also identified localities where S2 is associated with compositional banding in outcrop, S3 defines a strong crenulation cleavage, and S1 is preserved only in S2 microlithons. Field and microstructural observations indicate that the KMP intruded syntectonically. Evidence includes folded and boudinaged granitic dikes at the margin of the KMP, and microstructures such as flame perthite, myrmekite, deformation twins, and textures associated with grain-boundary migration recrystallization in the granite. In the metamorphic aureole, biotite porphyroblasts overgrew S1 and were deformed during S2 crenulation cleavage development. Pluton crystallization has been dated at 371 ± 4 Ma using U-Th-total Pb dating of monazite, an age concordant with the published age of the nearby

Barre Granite. The timing of S2 fabric development in the CVGT is constrained by $^{40}\text{Ar}/^{39}\text{Ar}$ geochronology at ~365 Ma, consistent with microstructural evidence that suggests the KMP intruded just prior to S2 development. Plateau and weighted mean ages from across the transect, as well as minimum ages from argon loss profiles, show a general trend of younging towards the east, suggesting these rocks have been affected by Alleghanian and Mesozoic deformation and exhumation.

U-PB DATING OF DETRITAL ZIRCONS IN THE CRAM HILL AND UMBRELLA HILL FORMATIONS, VERMONT

Cynthia Connard and Ray Coish, Middlebury College

The tectonic history of the Vermont Appalachians can be further understood with the aid of geochronological data from detrital zircons. The Rowe-Hawley Belt in central Vermont is a critical tectonic zone because it contains a major suture formed during closure of the Early Paleozoic Iapetan Ocean. The Hawley slices within this belt in Vermont include the Moretown and Cram Hill formations. These formations have been interpreted as metamorphosed fore-arc sediments of a late Cambrian - early Ordovician volcanic arc (the Shelburne Falls Arc) in the Iapetan Ocean. Recent data have identified the provenance of metasediments within the Moretown Formation as Gondwanan, contrary to previous work which suggested a peri-Laurentian source. To follow up on this work, the current study focuses on the Cram Hill Formation, which lies immediately above the Moretown and just below Silurian-aged rocks. In particular, we use detrital zircon ages to provide new information on the provenance of the Cram Hill metasediments by comparing those ages to known age signatures of possible source regions. Zircons from samples of the Cram Hill near Montpelier and Craftsbury, Vermont have been separated and analyzed on the LA-ICP-MS at Rensselaer Polytechnic Institute. Preliminary results show a prominent age peak at ~600Ma, which suggests a Gondwanan zircon source, and several less prominent peaks around 1,000-1,200 Ma, which imply a Laurentian zircon source. Another peak at 1,500-1,600 Ma is of uncertain origin. These data suggest that there were several available sources, consistent with deposition of the Cram Hill sediments as western parts of the Iapetan basin closed. A sample of the Umbrella Hill Formation near Craftsbury was also analyzed to give the first-ever detrital zircon ages for this unit. Results for this sample show prominent peaks at ~460-500 Ma, which suggests an Ordovician arc source. All results are used to further refine our understanding of the northeast Appalachian orogenic model.

STRATIGRAPHY, STRUCTURE AND VOLCANIC ROCK GEOCHEMISTRY IN THE LITTLE JARVIS AREA OF THE PALMER PROPERTY, SOUTHEAST ALASKA

Logan Miller, Middlebury College

The Little Jarvis area of the Palmer property is located approximately 55 kilometers northwest of Haines, Alaska and is host to several distinct occurrences of volcanogenic massive sulfide

mineralization. The approximately 1.5 km² study area is within the Alexander Terrane which contains accreted, arc-related rocks of Precambrian to Triassic age. This relatively unstudied field area is separated from more extensively explored and locally mineralized portions of the property by what has been interpreted to be a large east-west striking, north-dipping normal fault (LJ fault).

Detailed bedrock mapping of the field area has resulted in the delineation of the following lithologic units (described from north to south): (1) a thick sequence of deformed calcareous argillite, (2) mafic lapilli tuff interbedded with argillites and deformed basalt, (3) massive to fragmental, strongly foliated basalt, (4) a thick deformed sequence of amygdaloidal pillow basalt, intercalated with thin beds of argillite, tuff, and limestone, and (5) a generally undeformed gabbro that intrudes and thus post-dates movement on the LJ fault. Numerous thin dykes and sills ranging from mafic to felsic in composition are found throughout the study area.

The units in the Little Jarvis area have been subjected to both ductile and brittle deformation, and metamorphism to greenschist facies conditions. Deformation in the area north of the LJ fault is characterized by a sequence of gentle to open, upright folds with wavelengths of several hundred meters, as well as numerous small-scale north-west dipping normal faults. Foliation in the stratified rocks is variable depending on rock type, but locally well-developed.

Whole rock geochemical analyses of basalts in the study area reveal relatively consistent sub-alkaline compositions. Trace element analyses show primarily MORB-type signatures, confirming previous work that suggests a back-arc rift tectonic environment. Although it is difficult to directly correlate stratigraphic units from the field area with previously studied units south of the LJ fault, this work does not preclude correlations. The characterization of stratigraphy and structure in the field area provides a valuable contribution to the development of a regional model that will guide future economic mineral exploration in the area.

COSMOGENIC ³HE PALEO-SEISMOLOGY OF AN ACTIVE NORMAL FAULT, NORTHERN CALIFORNIA

Abra Atwood and William Amidon, Middlebury College

Over 100,000 earthquakes are felt each year around the world, 100 of which can cause significant damage to people; the human and financial cost of earthquakes underscores the need for improved understanding of how earthquakes on normal fault systems work. The Hat Creek Fault in northern California is a world class example of a segmented normal fault that cuts through a 24 ka basalt with an estimated slip rate of 2.2-3.6 mm/yr (Blakeslee and Kattenhorn, 2012). It is part of a system of normal faults that threatens local infrastructure, including a hydroelectric dam on the Pit River. Very little is known about its seismic hazard, although estimates based on the characteristic earthquake model have predicted a ~Mw 6.7 event with a

recurrence interval of ~700 years (Blakeslee and Kattenhorn, 2012). A better understanding of its paleo-seismic history will inform regional seismic hazard models, while also providing a test of common assumptions used when applying the characteristic earthquake model to normal faults. One major assumption is that a fault will rupture at a consistent magnitude and recurrence interval over time. Another assumption, used by previous seismic analyses, is that all sections rupture in tandem, which would lead to over-estimates of earthquake magnitude. This study develops a paleo-seismic history by using cosmogenic ^3He in pyroxene and olivine to date exposure ages of co-seismically toppled blocks and corresponding scarp faces to determine the timing of major seismic events. Three of the eight fault sections were sampled in this study to assess whether the sections rupture in tandem or separately. Preliminary results suggest that different segments may have ruptured in distinct events, an emerging chronology that will be clarified by forthcoming results.

**DETAILED ANALYSIS OF STRUCTURES IN THE FOOT WALL OF THE
CHAMPLAIN THRUST AT LONE ROCK POINT, BURLINGTON, VERMONT**

Christina Strathearn¹, Keith Klepeis¹, Jon Kim², Anne Gombosi¹, Max Longworthy¹, Eleanor Johnson¹, and Ben Schachner¹,

¹ University of Vermont, ² Vermont Geological Survey

Between Burlington, VT and the Quebec border, the Champlain Thrust (CT) juxtaposed massive dolostones of the Cambrian Dunham Fm (hanging wall) with calcareous shales of the Ordovician Iberville Fm (foot wall), during the Ordovician Taconian Orogeny. After this orogeny, the CT was deformed by open folds of possible Devonian (Acadian) age. In southern Quebec, the CT maps continuously into the Rosenberg Thrust/ Logan's Line. South of Burlington, the CT cuts up section into red quartzites of the Cambrian Monkton Fm via a presumed lateral ramp, and continues into New York. Published estimates of displacement along the CT range from 60-100 km.

Although the CT has been studied previously at Lone Rock Point, the multiple generations of ductile (low, moderate, high strain) and brittle structure in shales of the footwall have never been systematically defined. We present the following relative chronology of structures:

- 1) Formation of bedding planes (S0), characterized by thin layers of carbonate within black shale.
- 2) Formation of rootless isoclinal folds (F1) of brittle carbonate layers and the development of a spaced pressure solution cleavage (S1) that parallels the axial planes of the folds.
- 3) The S1 cleavage is deformed into asymmetric S-C shear bands that merge into parallelism with, and are cut by, intraformational thrusts. The thrusts form oblate, eye-shaped structures that are stacked on top of one another forming horse duplexes. A second cleavage (S2) defines a part of the S-C fabric and is intensified in thrust zones.

Calcite slickenlines on fault surfaces plunge to the SE and NW and slip directions fan up to 40 degrees with respect to one another.

4) Formation of sets of upright, north (F3) and east-striking (F4) folds of S2 warping the CT.

5) Formation of conjugate sets of normal faults that record top-down-to-the-north and -south kinematics.

6) Formation of the steeply-dipping fracture sets (N-S and E-W striking) that cut across competent lithologies.

Preliminary interpretations suggest that simple and pure shear components of deformation in the foot wall are partitioned into thrusts and SE-plunging isoclinal folds, respectively. Ongoing research seeks to correlate this relative structural chronology along strike.

ANALYSIS OF MULTIPLE SLUMPS IN LAKE CHAMPLAIN, VERMONT FROM JUNIPER ISLAND TO QUAKER SMITH POINT

Piper Rosales, Patricia Manley, and Tom Manley, Middlebury College

Lake Champlain has three depositional layers that occurred as this body of water went from a proglacial lake to a saline oceanic extension and back to a freshwater lake. Marine debris flows are mass wasting events where the sediment is transported down slope and does not retain its original composition. Marine debris flows, when studied, have been known to give insight into the regions past natural disasters, temperature changes, and sediment distribution. Recent analysis has shown multiple debris flows as well as slumps east of the Four Brother's Islands and west of Juniper Island. This large cluster of debris flows in Lake Champlain is unusual because of their size and frequency. The size of the debris flow and location was deduced through seismic profiles gathered with the CHIRP sub-bottom profiler. Multibeam sonar generated a new bathymetric map allowing for location of failed scarps where the debris flows originated from. In addition three core samples of the three main debris flows in the study area were used to determine the sediment type and age of these debris flows. This thesis was focused on discovering the size and number of the debris flows, the direction and orientation of the debris flows, the different origins, and the time of failure. These processes help in the understanding of the layers of weakness in the region and give us a possible seismic history of the region.

PALYNOLOGICAL ANALYSIS OF A CHAMPLAIN SEA PEAT LAYER, ST. ALBANS BAY, VERMONT

Ellen Taylor, Patricia Manley, and Tom Manley, Middlebury College

Palynology can provide information about past climates by revealing how vegetation changed over time. This thesis uses the pollen record from a St. Albans Bay, Lake Champlain, sediment core to study climate and vegetation succession approximately 8-9 kya. After the Laurentide Ice Sheet receded from Vermont 13.4 kya, the isostatically depressed land allowed the Atlantic

Ocean to flow into the Champlain Valley, creating the Champlain Sea. As the glacier's isostatic influence on the land receded into the past, the land rebounded, severing the Atlantic Ocean's connection to the Champlain Sea. Rain and river water freshened the Champlain Sea into modern-day Lake Champlain. This project seeks to understand how the vegetation and climate changed as the Champlain Sea transitioned into Lake Champlain. Core sediment samples were processed by a lab at the US Geological Survey, where the pollen was extracted and made into slides. At least 300 pollen grains (with a minimum of 100 non-pine grains) were counted per slide and identified to the lowest possible taxonomic level. Preliminary analysis indicates that St. Albans Bay may have become fresh much earlier than the rest of the lake, and that the early pine-dominated community became a hemlock-northern hardwood-dominated community, then returned to a pine dominated community.

CALENDAR

Middlebury College, Geology Seminar Series

Date: April 24, 2015

Time: 12:30 pm

Location: Room 417, Bicentennial Hall, Middlebury College, Middlebury, VT

Information: Rich Goldfarb of USGS will present a talk about tectonics and ore deposits. Title TBA.

78th Reunion of the Friends of the Pleistocene

Date: June 5-7, 2015

Location: Dinosaur State Park, Rocky Hill, CT

Host: FOP, Geological Society of Connecticut, and the Connecticut Geological and Natural History Survey

Information: This year's fieldtrip is "Glacial Lake Hitchcock and the Champlain Sea" led by Janet Stone, Jack Ridge, Ralph Lewis and Mary DiGiacomo-Cohen.

For information visit the web site: <http://www2.newpaltz.edu/fop/>

2015 EarthScope National Meeting

Date: June 14 - 17, 2015

Location: Stowe Mountain Lodge, Stowe, Vermont

Information: The main meeting program will have 5 themes as plenary sessions: Dynamics and evolution of the North American continent: crust, lithosphere, and deep mantle; From Groundwater to the Ionosphere; Active tectonics and modern earth processes of North America; Advances in understanding and forecasting hazards; and EarthScope innovations and looking into the future.

66th Highway Geology Symposium

Date: September 14-17, 2015

Location: Sturbridge Host Hotel and Conference Center, Sturbridge, MA

Host: Massachusetts Dept of Transportation and the UMASS Amherst.

Information: There will be a half day TRB session titled "Geotechnical Risk Assessment and Performance Management" on Monday afternoon, September 14th. Technical sessions of the Symposium will start on Tuesday morning, September 15th.

More information is at: <http://www.highwaygeologysymposium.org/>

2015 NGWA Conference on Groundwater in Fractured Rock

Date: September 28-29, 2015

Location: Hilton Hotel, 60 Battery St., Burlington, Vermont

Host: National Ground Water Association

Information: Visit the web site: <http://info.ngwa.org/servicecenter/Meetings/Index.cfm>

2015 Geological Society of America Annual Meeting & Exposition

Date: November 1-4, 2015

Location: Baltimore, Maryland

2016 Geological Society of America Annual Meeting & Exposition

Date: September 25-28, 2016

Location: Denver, Colorado

Host: Geological Society of America

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**Vermont Geological Society
Norwich University, Dept. of Geology
158 Harmon Drive
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