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Spring Meeting

April 24, 2010, 8:30 AM
McCardell Bicentennial Hall, Room 417
Middlebury College, Middlebury, Vermont

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* Speaker

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ABSTRACTS

A GEOCHEMICAL AND PETROGRAPHIC ANALYSIS OF THE ECHO POND PLUTON, VERMONT

Victor Guevara, Geology Department, Middlebury College, Middlebury, VT 05753

A group of syn- to post-collisional Devonian plutons in the Northeast Kingdom of Vermont is representative of a significant period of magmatism that occurred after the main phase of the Acadian Orogeny between approximately 390 and 360 Ma. The dates of the Acadian Orogeny are poorly constrained and the tectonic history near the end of the Acadian Orogeny is poorly understood. The study of these plutons using modern techniques of geochemistry and age-dating is an important step toward gaining a better understanding of the tectonic processes occurring at the end of the Acadian Orogeny.

The focus of this study is the Echo Pond Pluton, a member of a group of plutons collectively known as the Northeast Kingdom Batholith. Our work has confirmed the presence of four distinct zones in the Echo Pond Pluton, based on rock type: mafic zones in the southern and northeastern areas of the pluton containing quartz-amphibole gabbro and diorite, a zone of granodiorite and granite that constitutes the central portion of the pluton, and a small zone of porphyritic granodiorite and granite containing rounded quartz grains in the east-central part of the pluton. The pluton intrudes the meta-sedimentary rocks of the Gile Mountain Formation. Quartz veins, granite dikes, and xenoliths are common at gradational contacts with the surrounding country rock. Previous workers used isotopic data to suggest that both mantle and crustal components played a role in the evolution of the Echo Pond Pluton. ICP-AES analysis of major, minor, and trace elements and ICP-MS analysis of rare earth elements will build upon this work, leading to more detailed conclusions about the magmatic evolution of the pluton.

Few studies have addressed the Echo Pond Pluton specifically, and little is known about its magmatic origin. Moreover, a precise age for the Echo Pond Pluton has not been obtained. The use of U-Pb dating of zircon, petrography, and modern methods of geochemical analysis will further constrain the dates of Acadian magmatism in Vermont and contribute to a more complete understanding of the magmatic origin and tectonic processes that led to the emplacement of the Echo Pond Pluton. This study hopes to accomplish this and provide a foundation for future study of the final stages of the Acadian Orogeny in Vermont.

SEISMIC EXPLORATION OF THE PORT HENRY WATER PLANE IN LAKE CHAMPLAIN

Robert Athan, Geology Department, Middlebury College, Middlebury, VT 05753

The Port Henry water plane, located below the current water level of Lake Champlain, is examined through a series of seismic profiles gathered from 2003 to 2009. The increase in technology throughout the years has enabled the gathering of higher resolution profiles than those captured during previous studies in the 1930's. The water plane is identified through erosional terraces found within these high-resolution seismic profiles. Mapping of these terraces allows the creation of digital models of the Port Henry water plane using the program

EarthVisions. The terraces in these models have revealed that the Port Henry water plane is bowl shaped in nature as opposed to flat lying and is located at a depth within the range of 80 to 95 feet. These features are attributed to the effects of isostatic rebound since the retreat of the Laurentide ice sheet as well as the effects from rising lake level over time.

ECOLOGIC SUCCESSION IN THE VALCOUR FORMATION REEFS (MIDDLE ORDOVICIAN, CHAZY GROUP) OF VERMONT AND NEW YORK

Lauren Chrapowitzky and Charlotte Mehrtens, Department of Geology, University of Vermont, Burlington, VT 05405

The Chazy Group (Mid. Ord.) of the northern Appalachians has been the focus of numerous reef surveys since the early 20th century. It was deposited syn-tectonically on the eastward-dipping margin of Laurentia during the Taconic Orogeny, and comprises part of a major Ordovician carbonate sequence found throughout the Appalachians. The Chazy Group consists of 3 reef-bearing units. The uppermost Valcour Fm. contains reef horizons constructed by distinctly different framebuilders than the older Chazy Group units (Day Point and Crown Point Fms.), as well as strata elsewhere in the Appalachians. This study seeks to identify how and why the composition of the framebuilders changed over time.

The reefs are lensoid to circular in shape and can be up to 4m in cross-section. Lithofacies composition, size and shape of mounds, and subaerial exposure surfaces have allowed for identification of up- and downslope reefs. Stringline sampling was used to identify major framework organisms in the reefs in the field, followed by thin section point counting. In downslope reefs, the trepestome bryozoan *Batostoma* dominates the pioneer organisms (up to 40% of framebuilders), which passes vertically into tabulate algae dominated climax organisms (20-80%). Elsewhere, the *Batostoma* base transitions upwards through an intermediate stage of *Batostoma, Billingsaria,* and tabulate algae, and finally a tabulate algae dominated climax layer. Downslope reefs are commonly flanked by crinoid-dominated wackestones-packstones, but are capped by cross-bedded grainstones. In contrast, upslope reefs are a maximum of 2m thick in cross-section, and are pioneered by tabulate algae, and *Billingsaria*, diversify vertically in the composition of the framebuilders, and in the climax stage, tabulate algae is replaced by stromatolites and stromatoporoids.

These horizons contain evidence of firmgrounds. Upslope reefs are most commonly capped and flanked by cross-bedded crinoidal grainstones. Two primary lithofacies comprise the reefs and adjacent environments. The cores themselves are typically *Batostoma* (downslope) and tabulate algae (upslope) cruststones, Surrounding the cores are wacke-pack-rudstones of varying compositions, but generally contain bioclastic debris of bryozoa, coral, sponges, algae, brachiopods and crinoids. Upslope reefs are most commonly capped and flanked by cross-bedded crinoidal grainstones.

ANALYSIS OF THRUST RELATED STRUCTURES IN THE CHAMPLAIN VALLEY OF VERMONT

Halen Earle[1], Jonathan Kim[2], and Keith Klepeis[1], (1) Department of Geology, University of Vermont, Burlington, VT 05405; (2) Vermont Geological Survey, 103 South Main Street, Logue Cottage, Waterbury, VT 05671-2420

Our field area consists of the towns of Williston, Charlotte, and Hinesburg, Vermont, and contains portions of the Champlain and Hinesburg thrusts (CT and HT, respectively). We defined three structural domains within the field area: the lower plate of the CT, the upper plate of the CT (both consisting of Cambrian–Ordovician sedimentary rocks), and the upper plate of the HT, consisting of chlorite-sericite grade metamorphic rocks. These thrust slices were imbricated during the Ordovician Taconian Orogeny.

The oldest structures in the field area are related to thrusting along the HT and CT. Near the HT, these include mylonites and F1 isoclinal folds of bedding that are deformed by F2 folds with asymmetric shear bands. Above the CT, syn-thrusting responses in the Monkton Quartzite include extensive fracturing, open folding, and thrust duplexing. Directly below the CT, within Stony Point Fm. shales, structures include large open-tight reclined folds (F1), intraformational thrusts, and axial planar cleavage. Across the field area, deformation style appears to have been influenced by rock unit rheology.

All syn-thrust structures throughout the field area are deformed by N-S trending asymmetric folds (F3) and E-W trending open folds (F4). These fold sets create a dome and basin pattern across the region, which is visible at outcrop and map scale. Presence of the fold sets was confirmed by field mapping throughout the region. Above the HT domestic well logs and LIDAR slope maps were used as well.

Our analyses suggest that structural variations within each thrust slice are caused by rheological contrasts between rock units during top-to-the-northwest motion. The data also suggest that some structural variability is related to the magnitude of strain, which is controlled by proximity to major thrust faults. The dome-and-basin interference pattern created by Acadian (Devonian) F3 and F4 fold sets is kinematically compatible with either two discrete orthogonal fold sets or simultaneous development of both fold sets during constriction. We favor an interpretation involving constriction strains whereby the interference pattern was created during a reactivation of pre-Taconic E-W trending basement ramps.

ARSENIC IN GROUNDWATER WELLS IN GLACIAL DRIFT, NORTH-CENTRAL VERMONT

Lilly Corenthal, Geology Department, Middlebury College, Middlebury, VT 05753

Groundwater wells in glacial drift in north-central Vermont contain arsenic concentrations above the EPA maximum contaminant level (MCL) of 10 ppb. These wells are situated within or adjacent to the Rowe-Hawley Belt (RHB), a sequence of early Paleozoic metasedimentary and metaigneous rocks in the suture zone of the Ordovician Taconian Orogeny. Whole rock As concentrations of the dominant rock units in the RHB, in order of decreasing as concentration, include (1) meta-ultramafic (UM) rocks (serpentinites and talc-magnesites) with As values as high as 1104 ppm in talc-magnesite and 449 ppm in serpentinite (mean As = 93 ppm, n = 41), (2) phyllites with a mean As concentration of 22 ppm (n = 34), including two isolated occurrences of 101 and 190 ppm As from below As-rich talc-magnesite, and (3) greenstones (n = 33) with a mean As concentration of 4.1 ppm. Elevated As in wells glacially down-gradient from UM in the RHB raises the possibility that the As is derived from UM components in the till and outwash, a hypothesis that has also been suggested for the original source of As in the Bengal fan (Guillot and Charlet, 2007). Accordingly, this study aims to evaluate the origins of As in glacial drift and groundwater through a combined geochemical, mineralogical and spatial analysis of glacial drift aquifer materials, well water chemistry and historic well records. While surficial wells in New England are generally thought to not be elevated in naturally-derived As, approximately 40% (7 out of 17) of the surficial wells tested in the RHB contain As exceeding 10 ppb. Analyses of drift and groundwater composition reveal possible variation in As sources. XRD and ICP-MS data suggest a partial ultramafic signature to As in down-gradient glacial drift, with phyllite from the Ottaquechee Fm. responsible for additional inputs. Weathering of talc-magnesite concentrates As in iron-hydroxide weathering products, confirming the hypothesis that UMs contribute As to down-gradient surficial deposits. Closer to ultramafics, a higher percentage of residential surficial wells contain elevated As, but the sample set is small and suggests the need for future work. The presence of chlorinated solvents and pesticides in one well permits the hypothesis that the elevated As levels in that well are either anthropogenically-derived or modified.

ANALYSIS OF ARSENIC SPECIATION IN ULTRAMAFIC ROCKS BY SEQUENTIAL CHEMICAL EXTRACTION

Jonathan Moen, Geology Department, Middlebury College, Middlebury, VT 05753

Arsenic-enriched ultramafic rocks from northern Vermont were studied using a sequential extraction process to determine arsenic speciation. Attention was brought to high arsenic levels in these rocks when groundwater with elevated arsenic (above the EPA MCL of 10 ppb) was discovered in bedrock wells in north-central Vermont. Previous work suggests that the arsenic source is metasomatized ultramafic rocks, specifically serpentinites and talc-carbonates found within Rowe-Hawley Belt, a tectonic assemblage of thrust slices in the suture zone of the Taconian Orogeny. Arsenic levels in these rocks are highly elevated, with concentrations up to 450 ppm in serpentinites and up to 1104 ppm in talc-carbonates. Arsenides, sulfides and other minerals frequently associated with arsenic were not detected in these samples, indicating that other minerals host the arsenic. It was predicted that arsenic would instead be hosted in tetrahedral sites of antigorite or talc as As(V) substituted for Si, in magnesite as arsenate anions substituted for carbonate anions, or adsorbed onto mineral surfaces. A 3-step sequential extraction is being applied to determine arsenic speciation, using 1 M ammonium nitrate (pH = 4.7) to extract exchangeable ions, 0.11 M acetic acid (pH = 2.6) to dissolve carbonates, and aqua regia to dissolve antigorite and talc. At each extraction step, ICP-MS, XRD and FTIR were used to determine geochemistry, mineral content, and bond configurations, respectively, in remaining pulps and extracted solutions. Sequential extraction results suggest that arsenic in the Vermont rocks is securely bound within crystal structures of antigorite, talc, and magnesite. Surface sorption was not found to play a significant role in arsenic content, except in one sample. FTIR

and XRD data indicate disorder in antigorite crystallographic structures; this may be the result of arsenic substitution in tetrahedral sites. Electron microprobe data from a collaborating lab (personal correspondence, Keiko Hattori, March 2010) indicate the presence of highly arsenic-enriched magnetite in one antigorite sample; this suggests that substitution of As(III) for Fe(III) in minute grains of magnetite may be another major As host site. Future work is needed to disambiguate the As contributions of magnetite and other stable mineral sites.

MINERALOGY OF VERMONT ASBESTOS GROUP MINE WASTE, EDEN, VERMONT

Alyssa Findlay and Greg Druschel, Department of Geology, University of Vermont, Burlington, VT 05405

The Vermont Asbestos Group (VAG) mine in Eden, Vermont was one of the largest national producers of chrysotile asbestos and was active from 1900 until 1993. As a result of the extent of the operation, there exist large piles of waste rock containing remnant asbestos fibers. The serpentinized ultramafic rock deposit from which the asbestos was mined also contains high concentrations of nickel and chromium. Elevated concentrations of these elements and the presence of asbestiform mineral fibers have been observed in sediments from rivers surrounding the area (ANR, 2008), suggesting contamination by the erosion of the mine waste pile. Metal concentrations are not reflected in the water column (Piatek, 2009). Chrysotile is often enriched in metals compared to the surrounding rock (Barbeau and Dupuis, 1985), however small quantities of heazelwoodite (Ni_3S_2), and chromite ($FeCr_2O_4$) are present within the waste piles (ANR, 2008).

Samples were collected by John Schmeltzer (VT Agency of Natural Resources) from the VAG site. Samples were obtained from the mine waste pile and from a settling pond within Hutchins Brook, downstream of the tailings pile. Additional samples include a piece of magnetite from within the mine, and examples of chrysotile fibers produced by the mine.

Preliminary analysis of samples by X-ray diffraction shows the dominant mineral species to be serpentine and spinel. Further XRD work is in progress in order to determine mineralogy more specifically. Bulk chemical composition obtained by X-ray fluorescence spectroscopy shows high concentrations of iron, nickel, and chromium within samples. SEM-EDS X-ray element mapping suggests that significant quantities of these metals may be present in concentrated amounts within specific mineral grains. Metal sulfide species appear to be the primary phase containing nickel, while chromium appears to be incorporated with iron into oxides. Work is in progress to further determine the extent to which nickel and chromium are present in the chrysotile fibers; however the data collected thus far suggest the presence of primary nickel and chromium mineral phases is a significant source of nickel and chromium in sediments working their way offsite. Metals contained in these phases will be transported and solubilized via very different paths than chrysotile asbestos fibers.

ANR-DEC Memorandum (2008). Vermont asbestos group mine site. Eden-Lowell: Vermont Agency of Natural Resources.
Barbeau, C., Dupuis, M., et al. (1985). Metallic elements in crude and milled chrysotile asbestos from Quebec. Environmental Research 38(2): 275-282.
Piatak, N. M. (2009). Geochemistry of mine waste, drainage, and stream sediments from the Vermont Asbestos Group mine, northern Vermont, USA: United States Geologic Survey.
Levitan, D. M., Hammarstrom, J. M., Gunter, M. E., Seal, R. R., II, Chou, I.-M., and Piatak, N. M. (2009). Mineralogy of mine waste at the Vermont Asbestos Group mine, Belvidere Mountain, Vermont: American Mineralogist, 94(7), 1063-1066.

FOSSIL EARTHQUAKES IN SOUTH-CENTRAL MAINE: PSEUDOTACHYLITES IN THE JONES CORNER FAULT ZONE

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Pseudotachylites are rare fault rocks formed only through extraterrestrial impacts (i.e., meteorites) or extremely high-velocity seismic events. They are typically dark, microcrystalline to glassy veins, of varying width, interpreted to have formed via frictional melt. While the processes of pseudotachylite generation are frequently disputed, it is agreed upon that seismogenic pseudotachylite is unique in being the only known rock that forms exclusively at seismic slip rates. As such, seismogenic pseudotachylite is able to preserve the many dynamic processes of paleoearthquakes and can itself be considered a fossil earthquake.

The Jones Corner fault zone is a previously unrecognized and unmapped zone of brittle and ductile deformation in south-central Maine containing a variety of fault-generated rocks, including mylonite, cataclasite, and multiple generations of seismogenic pseudotachylite. The zone is located roughly 3.5 kilometers southeast of the Sandhill Corner mylonite belt, a zone associated with the regional Norumbega fault system. The Jones Corner zone, as currently mapped, trends approximately N55ºE and is at least 3 kilometers long and up to 250 meters wide. Pseudotachylite in the zone occurs as fault and injection veins with thicknesses of up to 5 centimeters. These rocks exhibit a variety of structures, including flow banding and folding, microlitic textures, and cross-cutting veins. Bulk geochemistry of pseudotachylite suggests that they originated locally within the amphibolite facies quartzofeldspathic gneiss and biotite schist of the Ordovician Cape Elizabeth Formation.

Using field observations, thin section petrography, and whole-rock geochemical analysis, the Jones Corner pseudotachylite has been comprehensively characterized, and interpretations have been made concerning the conditions of faulting and seismicity responsible for the generation of the Jones Corner pseudotachylite.

A MULTI-PROXY STUDY OF A POST-GLACIAL SEDIMENTARY RECORD FROM OVERLAND LAKE, NEVADA

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Overland Lake is a tarn at 2880 m asl in the Ruby Mountains of northeastern Nevada. A core was retrieved from the lake in July, 2009 in order to develop a record of post-glacial environmental change. The core extended from the sediment-water interface to a depth of 4.7 m. A layer of tephra encountered at a depth of 328 cm is believed to be Mazama based on the presence of similar ash in nearby Angel Lake for which radiocarbon age control is available. Several proxies were considered including: water content, loss on ignition (LOI), magnetic susceptibility (MS), reflected light color spectrophotometry (CSP), grain size distribution (GS), dry bulk density (BD), biogenic silica content (bSi), and carbon to nitrogen ratios (C/N). LOI and water content both rise rapidly in the basal sediment, but then fall and rise again through a long oscillation that spans ~1.5 m. The ash is located at the low-point of this interval, but the falling LOI values begin ~50 cm deeper, indicating that the ash alone is not responsible for the LOI decrease. Analysis of bSi and C/N will shed light on whether this oscillation represents a change in aquatic or productivity or in the inwashing of terrestrial organic matter. The luminosity component of the CSP (L*) is strongly correlated with LOI, indicating that organic matter is primarily responsible for the darkness of the sediment. Mean clastic grain size exhibits notable cyclic variability throughout the record, with values oscillating between 10 and 40 µm. Given the setting of the lake in a cirque surrounded by steep slopes with two major fluvial inputs, these variations likely indicate changes in the amount of precipitation resulting in fluctuations in clastic input. Values of MS are greatest in the tephra layer, but lower-amplitude variability exhibits a pattern similar to the trends in mean grain size, which is consistent with inwashing of iron-bearing minerals. Radiocarbon dating and geochemical fingerprinting of the tephra supported construction of a depth-age model allowing comparison of these time series with other dated paleoenvironmental records from the region.

NEOGLACIAL EPISODES RECORDED IN A LAKE SEDIMENT CORE FROM THE UINTA MOUNTAINS, UTAH

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Considerable paleoclimate research is focused on climatic variability during the Holocene, including the enigmatic period of renewed glaciations known as the Neoglaciation. Alpine lake sedimentary records are particularly useful in Neoglacial studies because they can provide uninterrupted, high-resolution records of environmental changes. This study focused on analysis of biogenic silica, phosphorus, and carbon/nitrogen from an alpine lake sediment record collected in northeastern Utah, adding to an extensive dataset that suggests several periods of Neoglacial activity in the Uinta Mountains. The sediment core, which spans the past 5300 years, was taken from EJOD Lake, a small lake with a maximum depth of 4.3 m, and a surface area of 2.7 ha, located above modern treeline at 3323m. The lake is situated in a large glacial cirque ~500 m downslope from a complex of Neoglacial end moraines. Dry meltwater channels run from these moraines directly into EJOD Lake establishing a clear connection between glacial activity and the lake sediment record. The biogenic silica, LOI, and clastic flux time series all exhibit an overall decreasing trend over the past 5000 years suggesting a gradual shift of the lake environment towards a colder, harsher climate. Superimposed on this downward trend are smaller-scale fluctuations characterized by intervals of notably low values in biogenic silica and LOI, and high values in C:N. These intervals suggest episodes of Neoglacial advance at 3600-3400, 2500-2300, and 2000-1600 BP. Subsequent increases in mineral P and clastic flux and decreases in median grain size at 3000-2900, 2300-2000, and 1400-1200 BP mark times when glacial retreat washed fine-grained rock flour stored in the moraines into the lake. Less pronounced variability at 809-560 and 395-182 BP show similar trends which may indicate two episodes of Neoglacial advance associated with the Little Ice Age. The dating of these episodes shows some synchronicity with periods of Neoglacial advance in western North America, but also indicates that such advances were extremely regionally variable. A dramatic shift in proxies indicates a change towards warmer climates and less soil development between 182 BP and AD 2005.

TIMING AND SIGNIFICANCE OF LARGE-SCALE FOLDING IN THE TAVAN HAR BASEMENT BLOCK IN SOUTHEASTERN MONGOLIA RELATIVE TO LATE TRIASSIC SINISTRAL SHEAR

Graham Hagen-Peter, Laura E. Webb, and Merril Stypula, Department of Geology, University of Vermont, Burlington, VT 05405

The East Gobi Fault Zone (EGFZ) in southeastern Mongolia is part of the Central Asian Orogenic Belt and has experienced a complex history of deformation subsequent to continental accretion during the Paleozoic. Several phases of deformation have been identified in the Tavan Har region including Late Triassic sinistral shear, Late Jurassic–Early Cretaceous rift basin development, mid Cretaceous basin inversion, and early Cenozoic sinistral strike-slip faulting. The lithologic units of northern Tavan Har consist of amphibolite–upper greenschist-facies metamorphic rocks with variable lower greenschist-facies overprints, a granitic gneiss body, and higher-grade migmatites. An ENE-striking, near-vertical S1 foliation, associated with the Triassic shear zone, is well developed across the region, with some outcrops displaying a strong mylonitic fabric. In northern Tavan Har the S1 foliations define large scale (~200 m wavelength), shallow-plunging, isoclinal folds that are observable in satellite imagery. Axial planar S2 is not seen at outcrop scale within the folded unit observable in satellite imagery, but is observed in nearby outcrops in Tavan Har. Smaller-scale folding was also observed in southern Tavan Har with an axial planar S2 cleavage. Measured parasitic fold axes, as well as π-axes calculated for the large-scale folds, are near parallel to mineral lineations associated with the Late Triassic shear zone fabric. Preliminary interpretations of the available data suggest that the large-scale folding is kinematically related to shear zone development. This presentation will integrate the results of microstructural analyses with field and petrological observations to test this hypothesis. The results of this project have implications for unraveling the history of polyphase deformation in the EGFZ and for the dynamics of large-scale intracontinental deformation.

PETROGRAPHIC AND GEOCHEMICAL ANALYSIS OF BASEMENT ROCKS IN THE EAST GOBI FAULT ZONE, MONGOLIA

Donald Hefferon, Department of Geology, University of Vermont, Burlington, VT 05405

The East Gobi Fault Zone (EGFZ) is NE-striking structural corridor in southeastern Mongolia. Rocks in region record the history of the amalgamation of Asia via collision and accretion in which microcontinental blocks are proposed to have played a significant role as a site of nucleation. Metamorphic tectonites of basement blocks in the EGFZ have been traditionally mapped as Precambrian based on their relatively high metamorphic grade and high strain, however, these associations are largely speculative with few isotopic age constraints from the region. Field, petrographic, and new geochronological data support the interpretation that the high strain/high grade rocks have Paleozoic protoliths rather than Precambrian. This study will test this hypothesis through geochemical correlations of the metamorphic tectonites and rocks of known Paleozoic or Mesozoic age.

Correlations investigated as part of this study include: 1) a sill within an Upper Permian–Lower Triassic clastic sedimentary sequence and a boudinaged dike/sill in paragneiss. Both samples are mafic intrusions in (meta)sedimentary rocks and, based on field and geochronological constraints, possibly represent different structural levels in the lower plate beneath a carbonate nappe in the Bulgan Uul region. 2) an Early Permian volcanic unit and mylonitized metavolcanic rocks from different structural levels of a Late Triassic ductile shear zone in the Tavan Har region. Data presented from geochemical analyses will include trace and REE analyses conducted via ICP-OES. In addition to petrographic analyses, spider diagrams and discrimination diagrams will be compared with each other, published data from the region, and standard values for igneous rocks of various tectonic settings to assess correlations between the metamorphic tectonites and rocks of known Paleozoic age. Geochemical and petrographic assessments will be linked to sample position within the structural corridor to compare sample deformation histories on a larger scale. The results of this study bear on the role that Precambrian crust plays in continental growth and the tectonic evolution of the region.

SYNTHESIZING SOUTHERN ANDEAN OROGENESIS FROM THE EVOLUTION OF THE MAGALLANES FORELAND BASIN, SOUTHERN PATAGONIA, CHILE

Janelle McAtamney, Keith Klepeis, and Charlotte Mehrtens, Department of Geology, University of Vermont, Burlington, VT 05405

South of 51ºS latitude, in the southernmost Andes, the Cretaceous inversion of the Late Jurassic Rocas Verdes rift basin created the Cretaceous-Neogene Magallanes foreland basin between an active volcanic arc and the South American craton. I studied the Lower and Upper Cretaceous sedimentary units, known as the Zapata Formation and Punta Barrosa Formation, that record this tectonic transition to test previous models of rift basin inversion and foreland sedimentation patterns. I describe sandstone petrography, detrital modes, and detrital zircon ages from pre- and post-inversion sediments within both units in two previously unstudied parts of the foreland basin. My results constrain the timing of uplift and denudation of source terrane in the internal part of the orogen and characterize the depositional setting and provenance during the transition from back-arc to foreland basin sedimentation in the southernmost Andes.

Three kilometers of measured section record the stratigraphic transition from the Zapata Formation to the Punta Barrosa Formation. Thinly bedded shallow marine mud and incomplete Bouma sequences characterize the Zapata Formation. Fining-upward packages of thickly bedded coarse-grained sand mark the onset of deposition of the Punta Barrosa Formation. Complex paleocurrent patterns from both units support a sedimentation model of multiple back-arc submarine fans during the initiation of the foreland basin. Modal analysis and petrography of sandstone from both units shows sediments are compositionally immature, highly feldspathic, and derived from a volcanic arc. Detrital modes record the transition from dominantly volcanic lithic fragments in the Zapata Formation to dominantly metamorphic lithic fragments in the Punta Barrosa Formation. Detrital zircon age spectra yielded maximum depositional ages between ~88 Ma and ~82 Ma through the stratigraphic transition interval which is younger than previously interpreted depositional ages for these units.

Andean orogenesis began as a submarine thrust wedge behind an active Late Cretaceous volcanic arc. Foreland basin infill was sourced from uplifted horst-and-graben style blocks

proximal to an active volcanic arc. Uplift and erosion of pre-rift basement schists and Upper Jurassic volcanic rocks occurred after about ~82 Ma.

TECTONIC TRANSITION FROM BACKARC RIFT BASIN TO COMPRESSIONAL FORELAND BASIN IN THE SOUTHERNMOST ANDES: ITS GEOCHEMICAL EXPRESSION

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The southernmost Andes record the formation of a Jurassic oceanic rift called the Rocas Verdes basin. By the late Cretaceous this rift inverted under compression, forming the Magallanes foreland basin. In this study I examined the REE characteristics of mudstones from stratigraphic sections exposed in two localities to determine temporal changes in sediment composition during this tectonic transition and to evaluate possible differences in sediment provenance along the strike of the belt. Rocks of the Lower Cretaceous Zapata Formation fill the Rocas Verdes basin; rocks of the Upper Cretaceous Punta Barrosa Formation mark the initiation of the Magallanes foreland basin. Distinguishing between these two units has been difficult to interpret in most localities. To solve this problem, we investigated REE data from a sequence of 12 mudstones from the central part of the Rocas Verdes and Magallanes basins and compared them to two other sequences located 300 km along the strike of the orogen to the southeast and the northwest, respectively. Our results indicate that rocks of the Punta Barrosa Formation are more enriched in the light REE and more fractionated than rocks of the Zapata Formation. The latter are more enriched in the heavy REE, most likely reflecting a mafic source. In addition, the base of the Zapata Formation is characterized by a strong negative Eu anomaly that gradually becomes less pronounced at the top of this unit and into the Punta Barrosa sequences. We interpret these patterns to reflect an increase in the contribution of eroded upper crustal continental arc material during the compressional inversion of the Rocas Verdes basin. In addition, a comparison between the geochemical signature of these two units along the strike of the basin suggest that, in the south, basaltic crust and rift mudstones preferentially were recycled into the first foreland basin sediments whereas in the north they were not. This heterogeneous pattern can be explained if the southern part of the Rocas Verdes basin was wider than that in the north and accumulated a much thicker mudstone section prior to inversion. The patterns suggest that the REE composition of Magallanes foreland basin sediments that mark the initiation of Andean orogenesis was strongly influenced by the preexisting architecture of the Rocas Verdes rift basin.

PRESIDENT'S LETTER

The Big Picture

Most geologists spend their working days immersed in the details of their specialty. Although this is necessary in order to advance our knowledge, this focus on the details makes it easy to lose track of the broader context that our specialties are part of. It seems to take a rare sort of author to combine a knowledge of earth science with a knowledge of how to tell a story. Many of us are familiar with the writings of Stephen Jay Gould and John McPhee. After reading

Earth: An Intimate History, by Richard Fortey (Alfred A. Knopf, New York, 429 p., 2005), I would argue that Fortey should be added to this select few.

Earth is a travelogue to some of the geologic high-points of the planet, a history of the development of geological thought, and an exploration of how science gets accomplished in the real world. It is a story of visionary thinkers, plodding realists, grand ideas, and the testing of those ideas in the harsh light of accumulating facts.

Besides helping us to understand the contributions of Hutton, Lyell, Harry Hess, and J. Tuzo Wilson (a story that many of us know tolerably well already), he introduces us to some of the now lesser-known names, such as Léonce Elie de Beaumont, Eduard Suess, and G. Steinman.

Plate tectonics is the glue that holds his story together. I think what is particularly fine about the book is that he doesn't just tell us the current plate-tectonic explanation for the features of the Earth, he describes quite a bit of the story of how, over the last century, geologists and geophysicists figured it out. In the last chapters of the book he tries to make the case that just about everything about the world around us can, in some more or less fundamental way, be related to plate tectonics. On first encountering some of these statements, I wanted to find fault with them, but then, as I thought about them, I had to largely give in to his argument; it really is all about the plates!

Although plate tectonics is used as an organizing principle in the book, Fortey does a particularly fine job of reminding us that the great geologic theories of today may sound extremely dated and quaint in only 25 or 50 or 100 years. We need to remember that the geologist of a couple generations back were at least as good at observing as we are today—they were just working from different paradigms.

Fortey is not quite as skilled a writer as Gould or McPhee. Indeed, in the early chapters I found several spots where I thought he lacked the perfect phrase. However, as I read deeper into the book, I was caught up in the story he was telling and no longer noticed the occasional clumsy sentence (if they were even there). I highly recommend this book to any amateurs or professionals who are interested in how the planet works.

Sincerely,
George Springston, President

WINTER MEETING MINUTES

The meeting of the Executive Committee followed the Society's Winter Meeting held on February 6, 2010 at Norwich University. Present at the meeting were George Springston, John Van Hoesen, Rick Dunn, Les Kanat, Jon Kim, Larry Becker, and Kristen Underwood. Steve Howe and Dave West were unable to attend the meeting. Steve sent a report by e-mail to the members of the Executive Committee prior to the meeting detailing the financial condition of the Society and the status of membership renewals and the Spring Meeting. He also introduced three proposals concerning research grant funding levels, electronic balloting, and the establishment of an Election/Nominating Committee. George Springston took the minutes for Dave West.

Research Grant funding: The Executive Committee voted to table a proposal to establish a cap of $1,100.00 on the total amount of funds that can be awarded for research grants during each of the two semiannual rounds, while still maintaining a maximum award per grant of $700.00, for the calendar year 2010. Committee members would like to get more information from the Treasurer regarding the need for this cap. The Committee would like to discuss this issue at the next meeting, with a balance sheet in hand, to help it understand how this impacts the Society's finances.

Electronic balloting: The Executive Committee discussed the idea of electronic balloting as the preferred method of balloting for future elections. John Van Hoesen will research the idea of using SurveyMonkey to accomplish this.

Election/Nominating Committee: The Executive Committee felt that an Election/Nominating Committee might not be needed presently.

VGS Lecturer: Stephen Wright was not present at the meeting, so Committee members did not discuss with him the idea of continuing as Lecturer for 2010. George Springston will contact Stephen to discuss this with him.

Vermont Geological Survey: The Executive Committee discussed the proposal in the Governor's budget to shift the Vermont Geological Survey to an educational institution such as the University of Vermont extensively. It was deemed appropriate to prepare a letter of support. The members not directly involved with the Survey will work with John Van Hoesen to draft a letter of support for the work of the Vermont Geological Survey. This will be sent to members of the Administration and the Legislature.

Outreach to other geological societies: In order to promote wider participation in Society activities, Committee members voted to have the *Green Mountain Geologist* sent electronically to the secretaries of other geological societies in the region, including New Hampshire, Maine, and New York.

Analysis of the Winter Meeting: The Executive Committee expressed satisfaction at the attendance and the range of discussions that resulted from this very successful Winter Meeting. It extended its appreciation to John Field for his excellent keynote presentation, to Kristen Underwood for her help organizing the meeting, and to John Van Hoesen for his help publicizing the event. A tentative topic for the Winter 2011 Meeting, "Geology and Public Health," was proposed.

Summer Field Trip: Jon Kim and George Springston will lead a field trip to the Knox Mountains area of Marshfield and Groton. Date still to be decided.

Respectfully submitted,
George Springston, President

TREASURER'S REPORT

The financial condition of the Society continues to be very strong. As of April 3, 2010, the Society's checking account balance was $6,767.41. One Research Grant proposal was submitted by the April 1, 2010 deadline and is currently under review by the Advancement of Science Committee. The amount of the funding awarded during this round will be reported in the Treasurer's Report in the Summer 2010 *Green Mountain Geologist*. To my knowledge, there are no outstanding bills.

The following members have joined the Society since the last report: Don Hill, Swanton, Vermont, and Daniel Ruddell, Tunbridge, Vermont.

The Treasurer gratefully acknowledges the contributions to the Society's Research Grant Program by the following members:

Laurence R. Becker
Ray Coish
Jeanne C. Detenbeck
Barry Doolan
Albert W. Gilbert, Jr.
Timothy W. Grover
Craig Heindel
Barbara L. Hennig
Jefferson P. Hoffer
Stephen S. Howe
Jon Kim
Ronald B. and Anita H. Krauth
Frederick D. Larsen
J. Gregory and Nancy W. McHone
Alexis P. Nason
George Springston
Sharon Strassner
Peter J. and Thelma B. Thompson
Roger and Terry Thompson
David West
Stephen F. Wright

Respectfully submitted,
Stephen S. Howe, Treasurer

ADVANCEMENT OF SCIENCE COMMITTEE REPORT

The Advancement of Science Committee received one application for research grant support prior to the April 1, 2010 deadline and will evaluate this proposal in the near future. We are hoping to hear talks by recent VGS Research Grant awardees at the student meeting on Saturday, April 24th, at Middlebury College: Lauren Chrapowitzky (UVM), Hal Earle (UVM), Lilly Corenthal (Middlebury College), Victor Guevara (Middlebury College), and Kyle Ashley (UVM).

Respectfully submitted,
Jon Kim, Chair

VERMONT STATE GEOLOGIST'S REPORT

Governor Proposes Moving the Vermont Geological Survey to the University of Vermont

On January 19, 2010, Governor Douglas released his fiscal year '11 budget that will begin on July 1, 2010. Under key Department of Environmental Conservation (DEC) budget issues the narrative states:

"In FY'11 the Division of Geology (Vermont Geological Survey) is proposed to be transferred to the University of Vermont along with its three positions. This will allow the Program to better leverage research funds while continuing to provide geological mapping services to Vermonters."

The Commissioner of DEC and the State Geologist have met with the UVM Vice President for State and Federal Relations, the UVM Chief Financial Officer, both the Deans of Arts and Sciences and Extension, and the Chair of the Geology Department. Chair [Char] Mehrtens has been most helpful in moving this issue forward to the UVM administration.

These discussions are on-going. As members of the geological community in Vermont, if you would like to learn more about this issue, please contact me at (802) 241-3496 in my role as the Chair of the Society's Public Issues Committee.

Respectfully submitted,
Laurence R. Becker, State Geologist
Chair, Public Issues Committee

ANNOUNCEMENTS

FRIENDS OF THE PLEISTOCENE MEETING

The Northeastern Friends of the Pleistocene will hold its 2010 meeting, entitled "Deglaciation of the Connecticut River Valley—Hanover, Lyme, Lebanon, and Claremont, New Hampshire," on June 4-6, 2010 in Hanover, New Hampshire.

Field trip leaders include Carol Hildreth, CTH Enterprizes; Meredith Kelley, Dartmouth College; Jack Ridge, Tufts University; and Erich Osterberg, Dartmouth College.

Some of the sites we will visit include:
- *A sub-till varve site in the Sugar River valley just east of Claremont, with paleomag results*
- *Landslide scars along the Mascoma River Gorge*
- *A long (10-m) core from Occum Pond on the Dartmouth College campus* [the lowest radiocarbon age is ~13.1 14C ka, from within varved sediment, and the core apparently has a continuous record since then]
- *Exposures in the large esker in the Hanover area*
- *Varve deposits of glacial Lake Hitchcock in West Lebanon*
- *Stream-terrace levels and associated deposits in Connecticut River tributary valleys*

For further information, contact: Carol Hildreth at hildrethcr@comcast.net

Registration information, the trip schedule, and other details will be posted on the Friends of the Pleistocene website at http://www.geology.um.maine.edu/friends/

STUDENT RESEARCH GRANT APPLICATIONS

Students and secondary school teachers are encouraged to apply to the VGS Research Grant Program by **October 1, 2010**. Downloadable Research Grant Program applications are available from the Society's website at http://www.uvm.org/vtgeologicalsociety/. For those without Internet access, forms may be obtained by writing to Jon Kim at the Vermont Geological Survey, 103 South Main Street, Logue Cottage, Waterbury, VT 05671, e-mail: jon.kim@state.vt.us, or by calling (802) 241-3469.

VERMONT GEOLOGICAL SOCIETY CALENDAR

April 24:	VGS Spring Meeting, Bicentennial Hall, Middlebury College
June 4-6:	Friends of the Pleistocene Meeting, Hanover, New Hampshire
June 7-8:	Lake Champlain 2010 Conference, Burlington, Vermont
Sept. 24-26:	NYSGA Meeting, Staten Island, New York
Oct. 1:	VGS Research Grant Program applications due
Oct. 1-3:	NEIGC Conference, Orono, Maine
Oct. 31-Nov. 3:	Geological Society of America Annual Meeting, Portland, Oregon

Vermont Geological Society
P.O. Box 1224
Saint Albans, VT 05478-1224

ADDRESS CHANGE?
Please send it to the Treasurer at the above address

Vermont Geological Society
Spring Meeting
April 24, 2010, 8:30 AM
McCardell Bicentennial Hall, Room 417
Middlebury College, Middlebury, Vermont

Directions to Middlebury College:

From the town green in Middlebury, take Route 125 west, past the Catholic Church, and up the hill through the College. Go over the crest to the bottom of the hill as it flattens to a valley. Turn right onto Bicentennial Drive and follow the winding driveway to the large parking lot on the west side of McCardell Bicentennial Hall. The meeting will be held in Room 417.