THE GREEN MOUNTAIN GEOLOGIST
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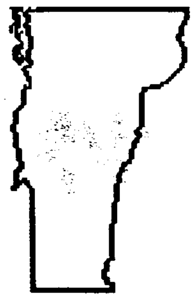

QUARTERLY NEWSLETTER OF THE VERMONT GEOLOGICAL SOCIETY

SPRING 2003 VOLUME 30 NUMBER 2

The Vermont Geological Society's Spring Meeting

Presentation of Student Papers
April 26, 2003, 8:30 am
Middlebury College

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Directions to the Spring VGS Meeting
Middlebury College
April 26, 2003
8:30 am

Take Rte. 125 west, past the Catholic Church, up hill through the college. Go over the crest to the bottom of the hill as it flattens to a valley; turn right onto the winding driveway and park in the large parking lot on the west side of Bicentennial Hall.

Meeting is in Bicentennial Hall, Room 104 (NOT Room 220).

CALENDAR

April 26	VGS Spring Meeting, Middlebury College
May 16	The Adirondack Section Of The Society Of Mining Engineers field trip, Albany, NY*
July 19	VGS Summer Field Trip, Colchester, VT; Contact: Jon Kim @ 241-3469**
Sept. 24-26	54TH Annual Highway Geology Symposium Burlington, VT; Contact: Tom Eliassen @ 828-6916
July 26-27	24th Annual Champlain Valley Gem, Mineral And Fossil Show, Tuttle Middle School, Dorset St., South Burlington, VT. Contact: 802- 863-5980
Oct. 10-12	NEIGC 2003, Amherst College and Smith College.

*Tour of the Lafarge cement operation just south of Albany, NY including the limestone quarry (fossils!), the aggregate plant, and the explosives operation. Information and directions can be found at the Pittsburgh SME section's website: http://www.smepittsburgh.org/calendar.htm

**Jon Kim, VT Geological Survey, will lead a bedrock and environmental geology field trip in the Colchester area. Meet at 9:30 am at the Park and Ride on the east side of the intersection of Routes 2 and 7, Exit 17 off I-89. Trip runs rain or shine. Bring lunch. For details contact Jon at 241-3469.

SPRING MEETING PROGRAM
Annual Presentation of Student Papers
Bicentennial Hall, Room 104
Middlebury College, Middlebury, Vermont

April 26, 2003

8:30	COFFEE
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10:45 D. Anderson: PETROGRAPHIC CORRELATION OF DIKES AND LEUCOGRANITE FROM THE NORTHFIELD IGNEOUS COMPLEX, VERMONT

11:00 D. Byrne: GEOCHEMISTRY OF THE FERNANDEZ PLUTON AND ASSOCIATED DIKES, AND THEIR CORRELATION WITH OTHER ROCKS OF THE NORTHFIELD IGNEOUS COMPLEX, VERMONT

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11:30 L. Fernandes: GEOLOGY OF THE WEEKS MILLS QUADRANGLE, EAST-CENTRAL MAINE

11:45 H. Beal, M. Swanson & M. Bampton: INTEGRATED PRECISION DIGITAL MAPPING AND STRAIN ANALYSIS OF SYNTECTONIC GRANITE INTRUSIONS WITHIN THE NORUMBEGA FAULT SYSTEM, CASCO BAY REGION, MAINE

12:00 M. Reilly: PETROGENESIS OF THE LATE SILURIAN-EARLY DEVONIAN LINCOLN SHONKINITE, SOUTH-CENTRAL MAINE

12:15 W.C. Simonson: CRETACEOUS AGE EXTENSIONAL DEFORMATION IN WESTERN NEW ZEALAND *

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* Graduate research project

ABSTRACTS

GEOCHEMICAL ANALYSIS OF SOILS AND SURFACE WATER DERIVED FROM CHEMICAL WEATHERING OF ULTRAMAFIC ROCK, CORNWALL, ENGLAND: SPECIATION AND ECOLOGICAL CONSEQUENCES

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Ultramafic rocks are known to possess exceptionally high metal concentrations, which are often reflected in their weathering products. The focus of this study is the Lizard Complex of Cornwall, England, an ophiolite sequence containing variably serpentinized peridotite and dunite that contain high concentrations of Cr, Ni (~3000 mg/kg each) and Co (~150 mg/kg), which have the potential to migrate into surface or groundwater and pose ecological and health concerns. The purpose of this investigation is to quantitatively determine the speciation and availability of these metals and to better understand their fate and transport from serpentinite parent material. Rock, soil, surface and ground water samples were collected from freshly exposed soil profiles and streams. Analyses included sequential chemical extraction (SCE) coupled with quantitative X-ray diffraction (Q-XRD) of bulk soil and rock samples; XRD of the <2 μm clay fraction; and the chemical comparison of rocks, soils and waters by Inductively Coupled Plasma-Atomic Emission (ICP-AES) and ICP-Mass Spectroscopy (ICP-MS).

Metal concentrations in water samples reflect significant natural enrichment, but are within common ultramafic ranges. Selected samples contained Co, Cr, and Ni concentrations above those of safe drinking water levels. For example, two separate ambient shallow groundwater samples sites produced elevated Ni concentrations of 153 and 288 ppb, Cr values of 28 and 90 ppb, and Co concentrations of ~5 ppb. Al, Fe, and Mg also exceed UK standards at some sites. SCE data reveal significant Co and Ni liberation from the reducible fraction (e.g. ~1500 mg Ni per kg of soil) and chemical and XRD data support the presence of Ni and Co in trioctahedral smectite and vermiculite as well as poorly crystalline Fe hydroxides. The liberation of significant amounts of Al, Si and Mg in the reduction stage is also consistent with smectite and vermiculite as sources of Ni and Co. Cr

liberation is primarily from the oxidizable fraction (~100 mg Cr per kg soil), suggesting that Cr occurs in organic material or Cr-bearing oxides such as chromite, where Cr may oxidize from Cr^{+3} to Cr^{+6} during the extraction. Approximately 50% of Ni in the soils occurs in easily extractable clays, oxides, and exchange sites, which helps to explain the higher concentrations of Ni in shallow ground water as compared to Cr, which is likely contained in more resistant oxides.

GIS ANALYSIS OF THE RECENT RETREAT OF GLACIERS IN THE TANGGULA SHAN, TIBETAN PLATEAU

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Glaciers exist in a sensitive state of equilibrium and are therefore good indicators of climate change. The slightest changes in atmospheric conditions can affect temperature and precipitation, thus affecting the overall mass balance of the glacier. Globally, the retreat of glaciers began at the end of the Little Ice Age in the 19th century when temperatures began to increase. In the past 50 years, however, the rate of retreat has accelerated, indicating the link between anthropogenic activities, climate change and glacial recession.

The objective of this study is to quantify recent glacial recession in the Tanggula Shan, Tibetan Plateau. A Geographic Information System (GIS) was used collect and analyze the data from four satellite images from 1976, 1977, 1989 and 2001. In the IDRISI program, the images were registered, resampled and manipulated into false infared composites used for unsupervised cluster analysis. The ARC GIS program was used to digitize thirty glaciers and calculate their area. The analysis conducted with the GIS provides evidence that glaciers in the Tanggula Shan have decreased in area from 1976 to 2001, with an average percent change of –21.

These results are supported by ice-core analysis and climate trends. Ice-core data from central Asia records provide evidence of warming associated with low-latitudes and high altitudes suggesting that tropical and subtropical glaciers may be more sensitive to climate change. Moreover, temperature data from weather stations near the site of the coring show a 1.2°C warming trend since the 1950s. The conclusions from the ice-core analysis support results from the Tanggula Shan where high

elevation and relatively low latitude glaciers have lost considerable area in 25 years. In the Tian Shan of Western China, meteorological data show a warming of 0.5-1.6°C over the past 60 years. Given their proximity, temperature changes have also likely occurred in the areas of the Tanggula Shan. By comparing the results of the GIS analysis of the Tanggula Shan to previous research, it is evident that these glaciers have been retreating in accordance with recent climate changes over the past 25 years.

GEOCHEMISTRY AND MINERALOGY OF VOLCANIC PALEOSOLS FROM CHILE'S TENTH REGION: IMPLICATIONS FOR VOLCANIC FINGERPRINTS, HOLOCENE CLIMATE CHANGE, AND TRACE METAL AVAILABILITY

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Subduction of the Nazca plate under the South American plate has produced a very active volcanic arc in the Andes Mountains of southern Chile. In Chile's tenth region, La Región de los Lagos, there are over twenty stratovolcanoes of basaltic to andesitic composition that have formed an impressive series of post-glacial volcanic ash-derived paleosols. Three paleosol sequences were sampled along a north-south transect across the tenth region. Samples were collected for chemical and mineralogical analysis at 5cm intervals from trail and road cuts.

Although color and texture were often the only characteristics needed to distinguish volcanic ash depositional events, in some cases field observations are unable to distinguish between successive paleosols. Initial analysis of soil geochemistry by ICAP shows that a molar ratio of Bases:R_2O_3 (in weight percent of major element composition, where R = Al, Fe and Ti) accurately describes transitions from one volcanic event to another. Values ranged from 0.11 in the upper layers of paleosol profiles to approximately 0.5 in underlying, unaltered ash. Once fresh parent materials had been identified by major element chemical analysis, lowermost layers (mainly ash and tephra) from each paleosol were analyzed for rare earth element (REE) compositions to provide more complete chemical fingerprints for the magma sources.

XRD studies were conducted on the less than 5μm size fraction from the uppermost layers of paleosols to assess mineralogical content. The

presence of halloysite, imogolite and allophane reflects the intense weathering environment and rapid crystallization characteristic of high precipitation (2 – 5 m MAP) and relatively high temperature. The presence of smectite in some samples is interpreted to represent less intense weathering, shorter time intervals of weathering exposure, or possibly periods of drier Holocene climate. The northernmost profile, Marífilo, had previously been studied, and therefore had C^{14} dates for individual volcanic layers. The remaining two paleosols, Ensenada and Cochamó, did not have dates, and ages were estimated by comparisons to the mineral alterations of the Marífilo profile.

Concerns about mobile heavy metals stemmed from other research showing elevated concentrations of chromium in many of the local lakes. Ongoing analyses of acetic-acid extractable and bulk trace metal concentrations will be applied to an evaluation of trace metal mobility in these environments with pronounced soil leaching.

ORIGIN AND TRANSPORT OF NATURALLY OCCURRING METALS IN GROUND WATER, NORTHERN ADDISON COUNTY, VERMONT

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Middlebury College, Middlebury, VT 05753

Concentrations of lead and uranium in excess of EPA maximum contaminant levels have been detected in ground water derived from the late Cambrian-early Ordovican dolomitic Clarendon Springs Formation (CSF) in northern Addison County, Vermont. Analysis by inductively coupled plasma-atomic emission spectrometry (ICP-AES) was performed on ground water derived from 20 wells drilled into the CSF and other members of the regional siliciclastic-carbonate sequence. Preliminary results indicate that 11 of 20 ground water samples contain Pb concentrations above the MCL (15 ppb); 5 of these samples had Pb concentrations greater than 150 ppb. Seven of these 11 wells are drilled into the CSF. The remaining four wells draw ground water from the Monkton Quartzite or Ordovician carbonates, and are located within approximately 3 km to the west and east of the assumed position of the CSF. Analysis of additional ground water samples by both ICP-AES and ICP-mass spectrometry will further delimit the concentration and geographic extent of both lead and uranium in ground water in northern Addison County.

Brittle-fracture and photolineament analyses was undertaken to determine structural controls on the transport of metal-bearing ground water. Dominant fracture orientations within the CSF trend approximately N45°W, N10°W, and N30°E, reflecting regional Taconic and Acadian deformation. Local ground water flow converges in an aquifer situated within the carbonate sequence, including the CSF. Thus, ground water is exposed to CSF rocks bearing Pb and U, and is then directed by fractures throughout the region. Carbonate dissolution and subsequent whole-rock geochemical analysis will determine where Pb and U are sequestered within the CSF dolomite. Lead in the CSF may have been deposited contemporaneously with early-Ordovician epigenetic dolomitization by low to moderate temperature, hypersaline basinal brines, in a process analogous to the formation of Mississippi Valley Type Pb-Zn deposits. Previous ICP-MS analysis of the CSF and associated ground water indicates that areas of uranium concentration are highly localized, and may have been formed by roll-front deposition in organic-rich breccia zones formed by karst dissolution in a shallow-sea or sub-aerial environment.

LAST GLACIAL MAXIMUM EQUILIBRIUM-LINE ALTITUDES IN NORTHEASTERN UTAH, U.S.A.

Jeremy Shakun, Geology Department
Middlebury College, Middlebury, VT 05753

Thirty Last Glacial Maximum (LGM) alpine glaciers from the Uinta and Wasatch Mountains of northeastern Utah were reconstructed. Their equilibrium-line altitudes (ELAs) were determined using four methods: accumulation-area ratio (of 0.65), toe-headwall altitude ratio (of 0.4), highest extent of lateral moraines, and the lowest cirque-floor method. The ELA estimates from each of these four methods were combined in a weighted average to yield an LGM ELA for each of these glaciers. ELAs rise steadily eastward from 2460 m on the Wasatch Front to 3120 m at the eastern end of the Uintas. This significant westward ELA depression is likely due to pluvial Lake Bonneville-enhanced snow precipitating over the Wasatch Range and western Uintas leaving areas further downwind (i.e., east) of Lake Bonneville progressively snow-starved. LGM ELAs were also determined for five valley glaciers from the Stansbury Range of north-central Utah, and the East Humboldt Range and Ruby Mountains of

northeastern Nevada, these latter two ranges being just west of Lake Bonneville. ELAs in these ranges are somewhat higher than those in the Wasatch and western Uintas (2540 m to 2730 m), despite their relative proximity to the major moisture source of the Pacific Ocean, reflecting the influence of Lake Bonneville on ELAs in the mountains of northeastern Utah. ELAs on the south slope of the Uintas are ~50 m lower than those on the Uinta north slope. This is likely due to lake-effect snow coming from southwest of the Uintas at times. The lateral moraine method appears to have been the most accurate in reconstructing ELAs. The lowest cirque-floor method yielded the highest ELAs and was likely the least accurate. The accumulation-area ratio likely underestimated and the toe-headwall altitude ratio overestimated LGM ELA depression for the seven, extremely large Uinta south slope glaciers because of their geometry and non-uniform area-altitude distribution. Accordingly, a higher accumulation-area ratio and toe-headwall altitude ratio should have been used for these seven, complex glaciers.

ANALYSIS OF SPATIAL VARIABILITY OF PRECIPITATION AND SNOW ACCUMULATION ON MOUNT MANSFIELD, STOWE, VERMONT

Keith N. Musselman, Department of Geology
University of Vermont, Burlington, VT 05405

Recent research on two upper watersheds of the West Branch Little River (West Branch) and Ranch Brook, both located on the eastern side of Mount Mansfield in the town of Stowe, Vermont, indicates substantial differences in unit area runoff between the two basins. These disparities may be explained in part by spatial variability of precipitation inputs. This study seeks to better understand the microclimatology of these upper elevation watersheds. The costs and difficulties in maintaining an adequate network of upper elevation weather stations have limited research focused on spatial precipitation patterns. Forecasting these small-scale precipitation patterns in mountainous regions is a difficult undertaking due to the insufficient density of recording stations and the variable effects of terrain and elevation on storm behavior. This study obtains large quantities of precipitation data (13 stations) over a 22.5-km^2 study area. Rainfall occurring between August 10th and October 30th, 2002 was documented using a network of thirteen automated recording rain gauges recently installed throughout the two watersheds. The network is designed to create three transects of individual mountain slopes; the Gondola Transect, running the length of the eight-passenger gondola, the Spruce Peak Transect, and Ranch Brook Transect.

Each transect is composed of five gauges, spaced at relatively equal elevation intervals. Snowfall from December 12, 2002 through the end of the 2003 snow season was monitored along the Ranch Brook Transect with a network of three snow gauges and NWS station data from the summit. These snow data were complimented by repeated snow pack analyses using coring techniques, conducted along the Ranch Brook transect. These precipitation data are used to map, document, and increase understanding of small-scale precipitation trends in the region. They are analyzed for average elevation/precipitation regressions. The study is geared toward proving a direct correlation between increases in precipitation with elevation as well as understanding the effect of azimuth and large topographic features such as ridgelines and prominent summits. Preliminary results of this study suggest an average positive linear precipitation/elevation relationship of 3cm/250m. A significant increase in precipitation is also observed in close proximity to major ridgelines and summits. During a single widespread rain event in late September, 2002, the West Brach station *'Gondola 750m'* located in the shadow of a 450m ridge recorded 1.5cm more rain than the Ranch Brook station *'Ranch 820m'* located in a col of the same ridge. This storm event loaded the West Branch watershed with 38% more rain than fell within the Ranch Brook watershed. These findings are possible contributors to the runoff discrepancy observed between the upper elevation watersheds of Ranch Brook and West Branch of the Little River.

USING DISCUSSION SECTIONS AND OTHER EFFECTIVE TEACHING METHODS TO IMPROVE A LARGE INTRODUCTORY GEOSCIENCE COURSE

Eric Butler, Paul Bierman, & Joanna Reuter, Department of Geology
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Teaching large introductory geoscience classes presents many challenges to faculty attempting to make such classes interesting, educational, and enjoyable to students. Educational research suggests that students learn best when they are involved with the material being taught and can build connections with their own lives and interests. At the University of Vermont, we have used personal experience and educational research to develop a large introductory geoscience class, Earth Hazards (GEOL 007) that uses effective lecturing techniques and weekly discussion sections to build student interest and learning. Interactive, student-centered lecture periods build student interest and knowledge, and are complemented by discussion sections in which hands-on activities and proper discussion

facilitation help non-science students experience the material first-hand and build links between science and the real world. Our experiences teaching this class have helped us determine what works and what does not at the university level, and we feel that our curriculum and methods can be applied in many university settings to enhance student learning and enjoyment of geoscience.

Please see our web site: http://geology.uvm.edu/morphwww/classes/ehaz/hazards_site/Front.html

PETROGRAPHIC CORRELATION OF DIKES AND LEUCOGRANITE FROM THE NORTHFIELD IGNEOUS COMPLEX, VERMONT

Daniel J. Anderson, Geology Department
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The Fernandez pluton, a peraluminous leucocratic tonalite, crosscuts six associated dikes that intruded parallel to the foliation of the surrounding metasediments of the Moretown Formation. These intrusive units were investigated to determine their relationship with a more widespread series of north-northeast trending intrusions west of Northfield, Vermont, referred to here as the Northfield Igneous Complex. Petrographic analyses were conducted on selected samples of both pluton and dike material. In the pluton, plagioclase feldspar is the most abundant mineral with compositions near Ab_{90} - An_{10}; alkali feldspar occurs in minor amounts. Quartz and muscovite are present as euhedral to subhedral crystals, as well as in the matrix. Muscovite also occurred with chlorite, epidote, calcite, and rarely biotite as alteration products on the plagioclase. The dikes have similar plagioclase and quartz as euhedral or fragmented phenocrysts. Crosscutting relationships show that the pluton post-dates the dikes, but their geochemical and mineralogical similarities suggest they are both derived from the same melt. These relationships suggest all these magmas were fed from a deeper source where quartz and plagioclase growth was underway prior to emplacement. Intrusion parallel to folded layers of country rock, combined with post-emplacement alteration, is compatible with emplacement that post-dated the Taconic orogeny and pre-dated the Acadian orogeny.

GEOCHEMISTRY OF THE FERNANDEZ PLUTON AND ASSOCIATED DIKES, AND THEIR CORRELATION WITH OTHER ROCKS OF THE NORTHFIELD IGNEOUS COMPLEX, VERMONT

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The Fernandez pluton, a member of the Northfield Igneous Complex, is located within the Moretown Formation west of Northfield, Vermont. The Moretown Formation was deformed and metamorphosed during both the late Ordovician Taconic orogeny and the Devonian Acadian orogeny. Beds in the Moretown Formation are preserved in nearly vertical isoclinal folds. Contacts of the igneous body cut across the bedding and subparallel cleavage of the Moretown Formation, showing that the pluton intruded the Moretown following its deformation. Further constraint on the time of emplacement of the pluton comes from evidence of its weak metamorphism that suggests emplacement prior to the Acadian orogeny. Geochemical analyses of six samples, four from the main body and two from associated dikes, show these rocks to overlap in composition with SiO_2 values ranging from 72.03-74.49 wt% and combined alkalis ranging from 7.62-9.03 wt%. The rocks are peraluminous with aluminum saturation index values from 1.1-1.2, and all samples are corundum normative. Similar values were found in previous studies for other members of the Northfield Igneous Complex. In addition, all members are muscovite-bearing, leucocratic S-type granites. Their magmatic origin is interpreted to result from partial melting of Al-rich continental crust during post-Taconic extension. However, the rocks of different plutons tested in prior studies plot separately in AFM and granite ternary plots, suggesting each intrusion had a unique fractionation history.

TECTONIC SETTINGS OF ORDOVICIAN AND DEVONIAN MAFIC ROCKS NEAR CHESUNCOOK LAKE, NORTHERN MAINE

Adam Schoonmaker & W.S.F. Kidd
University at Albany, Albany, NY 01222

Field relationships and geochemistry of the Bean Brook Gabbro and equivalents ("Boom House" Gabbro) indicate a correlation with the Ordovician Dry Way Volcanics at the Ripogenus Dam, northern Maine. The gabbros (K/Ar age 472.5 Ma) intrude the Hurricane Mountain Mélange and related Cambrian sedimentary strata, but are conspicuously absent

above the Taconic unconformity at the base of the Siluro-Devonian. This temporal distribution of gabbros is similar to that seen in the Ordovician section of the Exploits Terrane and Dunnage Melange in Newfoundland. Geochemical tectonic discrimination and trace element patterns of Ordovician and Devonian mafic rocks indicate that they have been either geochemically influenced by subduction-related sources or contaminated by the assimilation of upper continental crust.

Ordovician basalts and gabbros range from tholeiitic arc to calc-alkaline arc on Th/Ta/Hf/3 and Ta/Yb vs Th/Yb diagrams. Trace element diagrams of the Ordovician lavas and gabbros show low amounts of enrichment of the incompatible trace elements (relative to N-MORB) with a consistent Nb-anomaly suggesting that the Bean Brook and Boom House Gabbros are genetically related to the nearby Dry Way volcanics. REE patterns for the Bean Brook and Boom House gabbros and Ordovician Dry Way volcanics all show similar flat patterns, although at elevated concentrations (relative to chondrite), inconsistent with a direct MORB origin. These magmas could be the result of a ridge subduction event, or the formation of a back-arc basin.

The Devonian volcanics were erupted in a rapidly subsiding basin dominated by fine-grained mudrocks and subsequently overlain by the Acadian Seboomook Flysch. This suggests that these basalts may have been erupted on the outer trench slope of a subducting plate. The basalts show a significant Nb-anomaly but are strongly calc-alkaline-to-shoshonitic, consistent with either a volcanic arc or a within-plate origin. REE patterns are highly elevated (relative to chondrite) and show a negative slope also consistent with a volcanic arc or within-plate setting, or with melting of a slab-enriched lithosphere source during an early stage of the Acadian collision.

GEOLOGY OF THE WEEKS MILLS QUADRANGLE, EAST-CENTRAL MAINE

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The Weeks Mills quadrangle is located in east-central Maine along the contact between the Central Maine sequence and the Falmouth-Brunswick sequence. The rocks in this region have experienced several periods of metamorphism and deformation associated with multiple orogenic events related to Appalachian Mountain building. The area consists predominantly of southwest-trending, northwest-dipping metasedimentary and metavolcanic units, all of which have been variably intruded by pegmatite. The structurally lowest point in the southeast corner of the map area consists of garnet-andalusite schist, gray-green schist, and garnet-coticule schist tentatively correlated with the Scarboro Fm. Structurally above these units to the west, is a mylonite over 100m thick. The mylonite represents the Sand Hill Corner Fault, part of the Norumbega Fault System. Sillimanite is found in the rocks northwest of the mylonite, while andalusite is abundant in rocks to the southeast of the mylonite. To the west, the mylonite gradually changes to a protomylonite, with feldspar and muscovite porphyroclasts. The Cape Elizabeth Fm., a light gray quartz-plagioclase-mica granofels and schist, is the next unit to the northeast. Structurally above the Cape Elizabeth Fm. are well-laminated plagioclase-quartz-biotite-hornblende gneisses of the Nehumkeag Pond Fm., which locally contain 2 cm – 2 m amphibolite layers. The Beaver Ridge Fm., a dark gray to black, sulphidic and graphitic, quartz-plagioclase-mica schist recognized by its thoroughly rusty-weathered appearance, lies structurally above the Nehumkeag Pond Fm. The Hutchins Corner Formation, an interlayered, well laminated calc-silicate and biotite-quartz granofels, is separated from the Beaver Ridge Formation by the Hackmatack Pond Fault. One lens of the Sandy Pond Fm., a lithologically diverse unit containing garnet amphibolite, feldspathic schists and pelitic schists with staurolite, kyanite, cordierite, and sillimanite, was found on the east side of the Hackmatack Pond Fault. The northwest corner of the study area consists of the felsic intrusive rocks of the Three-Mile Pond Pluton.

Two phases of folding are recognized. The first set of folds (F2 on the basis of regional correlation) are upright isoclinal folds with fold axes that

plunge shallowly to the northeast. The F2 foliation is overprinted by F3 Z-folds with variably plunging, north-trending fold axis. Dextral shear kinematic indicators are found throughout the area.

INTEGRATED PRECISION DIGITAL MAPPING AND STRAIN ANALYSIS OF SYNTECTONIC GRANITE INTRUSIONS WITHIN THE NORUMBEGA FAULT SYSTEM, CASCO BAY REGION, MAINE

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Casco Bay, Maine is composed of steeply-dipping and strongly-lineated metamorphic rocks and deformed granite intrusions resulting from transpression associated with shearing on the Norumbega Fault Zone. Within the three study sites of Merepoint, Wood Island, and Hermit Island, strain partitioning during dextral transpression resulted in initial intrusions orthogonal to the shear direction and continued shearing resulted in CW rotation and elongation into strings of granite boudin pods oblique to the host rock flow layering. To conduct strain analysis, the sites were digitally mapped using the precision techniques of Trimble 5700 dual frequency GPS receivers, Spectra Precision Geodimeter 608 series total stations, Excel, and Arc View GIS. These techniques were able to capture fine-scale detail over large areas, providing insight into structural processes. By using geometric analysis of the boudin strings and foliation, surface area reconstruction of boudin pods, and a line length technique for folded intrusions, the γ-shear strain, elongation, and shortening values were determined to estimate the pure and simple shear components to the deformation. In close proximity to the main Norumbega shear zone in inner Casco Bay, Merepoint produced γ-values of 11.6 and 12.6 (assuming simple shear) with elongation of 316-610%. Farther to the east in outer Casco Bay, Wood and Hermit Islands show γ-values ranging from 1.3-10.7 for simple shear and elongation values from 45-220%. These values appear to be independent of the bedrock structure, with variably dipping folded layers at Wood and steeply dipping limb layers at Hermit along the eastern flank of the Hen Cove anticline and an interpreted "Phippsburg Shear Zone". All sites also display a significant pure shear layer-normal shortening component to the deformation as seen in crumpled orthogonal granite intrusions with shortening values from 25 to 66 % that reduces the apparent simple shear values calculated from the boudin string-foliation geometry.

PETROGENESIS OF THE LATE SILURIAN-EARLY DEVONIAN LINCOLN SHONKINITE, SOUTH-CENTRAL MAINE

Michael J. Reilly, Geology Department
Middlebury College, Middlebury, VT 05753

Highly distinctive rocks of the Lincoln shonkinite (a.k.a. Lincoln Sill) are exposed discontinuously over a distance of nearly 75 kilometers, from Boothbay Harbor in south-coastal Maine to near Liberty in south-central Maine. The 418 +/- 1 Ma (Tucker et al., 2001) shonkinite intrudes rocks of both the Liberty-Orrington and Fredericton lithotectonic belts and has been variably sheared and metamorphosed during Middle to Late Devonian orogenic activity. In south-central Maine, where the width of the intrusive body is greatest, the effects of this subsequent tectonism are minimal and pristine igneous mineralogies and textures are well preserved. This study presents field, petrographic and geochemical data from these pristine igneous rocks and interpretations of this data will provide much needed information on the tectonic setting of this region during the early stages of the Acadian orogeny.

Field work in south-central Maine revealed only subtle compositional and textural variability within the undeformed portions of the shonkinite intrusion. The dominant rock type is highly porphyritic, containing megacrysts of alkali feldspar up to 6 cm in length set in a finer-grained matrix dominated by clinopyroxene, orthopyroxene and biotite. Plagioclase and quartz is rare to absent in most samples and olivine (Mg-rich) has been found at only one locality. Minor accessory minerals include apatite, zircon and Fe-Ti oxide minerals. Fine-grained mafic enclaves can be observed at most localities, although they are not overly abundant. Alkali feldspar megacrysts often show a preferred orientation within a given outcrop, although there appear to be no systematic trends within the intrusive body as a whole.

Whole rock geochemistry from samples unaffected by metamorphism reveals highly unusual igneous rock compositions. SiO_2 contents range

from 55-60% and the rocks are noticeably rich in alkalis (K_2O = 6.0 to 7.5% and Na_2O = 1.5 to 2.5%) and magnesium (7-9%). Trace element analyses yield relatively high abundances of both compatible and incompatible elements (e.g., Cr = 419 to 729 ppm and Ba = 1500 to 2000 ppm). Rare earth element plots reveal LREE enrichment (200-300 times chondrites) as compared to the HREE (10 times chrondrites). Future work, including mineral chemistry and isotope geochemistry will further characterize the Lincoln Shonkinite and provide information on the tectonic setting of the region during Late Silurian-Early Devonian time.

CRETACEOUS AGE EXTENSIONAL DEFORMATION IN WESTERN NEW ZEALAND

W. Corey Simonson & Keith A. Klepeis, Department of Geology, University of Vermont, Burlington, VT 05405

Previous field work in extensional terranes around the globe has allowed geologists to link particular styles of deformation to specific extensional environments e.g. continental rifting, back arc basin development, intra-arc extension, syn and late orogenic extension etc. One distinctive style of deformation associated with extensional metamorphic core complexes has been well documented based on examples from western North America, the Aegean, and elsewhere.

Detailed structural mapping within the Paparoa metamorphic core complex, northwest South Island, New Zealand, indicates an extensional system characterized by two major conjugate detachment surfaces, intense asymmetric ductile deformation including the development of mylonitic and ultramylonitic shear zones, semi-brittle shear zones and conjugate brittle normal faulting. Based on cross-cutting relationships, we have established a sequence of at least four events beginning with the formation of ductile fabrics and high temperature folding in metamorphic and plutonic rocks at depth on both the northern and southern ends of the system. In the south, this resulted in protomylonite, mylonite, and ultramylonite rocks interfolded with variably deformed host rocks. In the north, well developed S-C fabrics are preserved in megacrystic granites. As extension continued, a series of lower temperature kink folds affected the southern half of the core penecontemporaneous with semi-brittle normal faults in the north. Finally, conjugate brittle normal faults cut all previous fabrics and structures within the core complex. This sequence records the

progressive evolution of the extensional system as deforming continental crust passed through the brittle-ductile transition zone.

The contrasting style of deformation and structural geometry among the Paparoa metamorphic core complex and North American core complexes is related, we believe, to the mechanism or cause of extension in each case. Some North American core complexes are thought to be strongly influenced by gravitational forces acting on overthickened crust. In New Zealand, extensional structures formed during the fragmentation of Gondwana. Thus, the driving force behind the formation of an extensional metamorphic core complex strongly influences the style of deformation produced during extension.

PRESIDENT'S LETTER

Dear Members,

Wow! What a great winter meeting! Thank you to all the presenters, who brought us a diverse and very interesting group of topics. Thank you also to Norwich University for hosting the meeting, and providing us with such an ample supply of Box o' Joe. I was also pleased to see current and former geology students from several campuses. This is something we need to encourage!

At the Executive Committee meeting afterwards, we discussed the VGS by-laws and focused on several places where changes may need to be made regarding payment of dues, membership, etc. If you have any proposed changes, please bring them to the spring meeting so that we can put them into shape so that they can be properly warned for the annual meeting. The complete by-laws can be found on the VGS web page:

http://www.uvm.org/vtgeologicalsociety

Thanks again to Steve Howe for developing and maintaining this site. Also, if you know of field trips or other events of potential interest to the VGS membership, please let me know the details so that they can be advertised on our website and in the GMG calendar.

It looks like our spring student presentations meeting will be another success, with fourteen submitted talks. Please encourage other students to attend, especially those who may wish to do thesis or independent study work of their own. Seeing what other students have done can be very motivating!

Our summer plans are shaping up as well, with Jonathan Kim offering to help lead a trip on Saturday, July 19, in the Colchester area, including information on the radioactivity map he's been working on. Details are elsewhere in this publication.

See you in Middlebury!

Sincerely,

Helen Mango
Department of Natural Sciences
Castleton State College, Castleton, VT 05735
(802) 468-1478; helen.mango@castleton.edu

WINTER MEETING MINUTES

Saturday, February 8, 2003
Northfield, Vermont

Present were Helen Mango (President), Tim Grover (Vice President), Dave West (Secretary), Steve Howe (Treasurer); also Peter Ryan, Dave Westerman, Larry Becker, Rick Dunn.

President Helen Mango opened the meeting. It was agreed that it would be all right to advertise field trips and meetings associated with other geological organizations in the GMG and on the Society Website. Steve Howe indicated that the website is being expanded and updated regularly. Steve Howe (as Treasurer) reported that the financial status of the Society remains strong and about two-thirds of the members have paid their dues. The committee then discussed reducing the grace period for members with delinquent dues and it was agreed this issue should be discussed more widely at the annual meeting, perhaps involving a change to the bylaws. Any proposed change would be warned at least one month in advance for possible action at the fall annual meeting. The bylaws concerning who may be a Society member (as opposed to an associate member) also need review. Increasing the number of student members

was also discussed. Larry Becker thanked the Vermont Geological Society on behalf of the Vermont Geological Survey for the letter sent to the state Legislature indicating the Society's support of the State Survey and the description of the services the Survey provides on behalf of the State of Vermont. Larry also provided an update on attempts to initiate an aquifer-mapping program in the state. Members of the Executive Committee pledged support for such a program and asked to be kept informed of progress.

Arrangements had been made for the Spring VGS meeting in Middlebury on April 26th. It was also reported that Jon Kim of the Vermont Survey offered to lead the summer VGS field trip on July 19. The focus of the trip would be the bedrock and environmental geology of the Colchester quadrangle.

Respectively submitted,
Dave West, Secretary

ADVANCEMENT OF SCIENCE COMMITTEE REPORT

The Society's Winter Meeting was an unqualified success, with some of the most interesting talks we have ever had at a winter meeting. Members are encouraged to contact me with any suggestions they may have for a theme for next year's meeting.

The Committee did not receive any applications for the Society's Research Grant Program by the due date of April 1, 2003. I will recommend to the Executive Committee that a due date of October 1, 2003 be established for a second round of applications. The Committee will strengthen its efforts to advertise the Program .

The Committee gratefully acknowledges the contributions to the Society's Research Grant Program by the following members:
Laurence R. Becker
Jeanne C. Detenbeck
Lawrence W. Gatto
Arthur W. Gilbert, Jr.
Barbara L. Hennig
Jefferson P. Hoffer
Carl Koteff
Eric Lapp
Frederick D. Larsen

John A. Malter
Alexis P. Nason
Ileene Schmidt
Ethel M. & William J. Schuele
Sharon Strassner
Peter J. & Thelma B. Thompson
Roger & Terry Thompson
Richard & Susy Ziegler

Finally, the Committee continues to add content to the Society's website. Members' contributions are always welcome.

Respectfully submitted,
Stephen S. Howe, Chair, Advancement of Science Committee

VERMONT GEOLOGICAL SOCIETY TREASURER'S REPORT

The financial condition of the Society continues to be strong. As of April 3, 2003, the checking account balance was $5,170.54. To my knowledge, there are no outstanding bills.

I would like to thank the large majority of members who promptly renewed their membership by the due date of February 15, 2003. However, about 15 members have not paid their dues. Please send your check and green membership directory form to me at the address indicated on the form, not to the University of Vermont

The following members have been approved for membership in the Society since the last report: John Carmola, St. Albans, VT; Keith Musselman, Burlington, VT; Adam Schoonmaker, Albany, NY; Matthew Stein, Windsor, VT;Bryan and Beverley Wemple, Burlington, VT

Respectfully submitted,
Stephen S. Howe, Treasurer

STATE GEOLOGIST'S REPORT AND PUBLIC ISSUES

With a new administration, the Vermont Survey sponsored a map showing for the Agency of Natural Resources. More than 50 people came to view maps and meet the geologists working on the projects. The maps addressed the naturally occurring radionuclide issue, landslides,

erosion, groundwater recharge mapping, and basic bedrock and surficial geology.

The Division of Geology and the Division of Water Supply formally transferred a "A Report on the Status of Groundwater and Aquifer Mapping in the State of Vermont" to the chairs of the Natural Resource committees in the Legislature. The report, developed by the two Divisions, is intended to meet the reporting requirements of Act 133 of the Adjourned 2001 Legislative Session.

Two recent requests for aquifer information came from Castleton and Woodstock. The Northeast Rural Water Association (NRWA) is working with Castleton to combine planning approaches for groundwater protection and stormwater discharges. The town wants to look at existing groundwater supplies and the nature of the aquifer. The State Geologist is advising the NRWA in their effort to develop a groundwater protection ordinance. The Woodstock Conservation Commission wants to better understand groundwater on a town wide basis. The State Geologist will visit Woodstock in May and make a presentation to the Commission.

Water Quality Division is requesting advice on the potential collapse of a 60-100' Lamoille Valley RR embankment in Morrisville. The embankment started sliding this past fall. Stormwater impounding behind the embankment may be the cause due to a clogged stone box culvert.

Two years ago, the Vermont Survey began working with the Vermont Dept. of Agriculture to understand the geologic basis for nitrate contamination of bedrock wells in the vicinity of a farm in East Montpelier. Geologic mapping was completed in the vicinity of the East Montpelier farm by Jon Kim and two undergraduate student assistants from the University of Vermont. The Div. of Geology, in cooperation with Water Supply Division, submitted a 319 non-point source grant application to the Water Quality Division to further address the problem. The proposal is entitled: A Role of Geologic and Hydrologic Setting in the Development of Effective Nutrient Management Plans at Vermont Farms.

Respectfully Submitted,
Laurence Becker, State Geologist and Chair, Public issues Committee