THE
GREEN MOUNTAIN GEOLOGIST

QUARTERLY NEWSLETTER OF THE VERMONT GEOLOGICAL SOCIETY

SPRING 1999 VOLUME 26 NUMBER 2

The Vermont Geological Society's Spring Meeting

Presentation of Student Papers

Room 4, Kalkin Hall

University of Vermont

Burlington, Vermont

Saturday April 17th

Directions: Kalkin Hall is immediately behind the Perkins Geology Building on the north side of campus. Parking is available in the lot adjacent to Perkins. Access is from Colchester Avenue. Construction along Main Street (Route 2, the main Burlington exit off I-89) has been slowing and rerouting traffic during the week. Weekend travel into and out of the city should be relatively easy.

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VERMONT GEOLOGICAL SOCIETY
DEPARTMENT OF GEOLOGY
UNIVERSITY OF VERMONT
BURLINGTON, VERMONT 05405-0122

The *GREEN MOUNTAIN GEOLOGIST* is published quarterly by the Vermont Geological Society, a non-profit educational corporation.

Vermont Geological Survey Summer Field Trip

Danby Marble Quarry

Mount Tabor, Vermont

Saturday July 17th

Contact Shelley Snyder by July 1st to make reservations (ssnyder@mtabe.k12.vt.us or 658-0575).

Directions to Quarry:

Follow Rt. 7 south from Rutland through Wallingford and South Wallingford to Danby. Approximately 10 miles south of the point where Rt. drops to two lanes just north of Wallingford, take a right to Mount Tabor Road to Danby Four Corners. At Danby Four Corners (less than a quarter mile from Rt. 7) take a left on to Fire Station Road. Follow for 0.6 miles to Quarry Hill Road. Take a right onto Quarry Hill Road. Follow for 0.4 miles to Quarry Road. Take a right onto Quarry Road and follow through gates and keep a steep hill to quarry entrance. Park on the right before the quarry entrance.

New England Intercollegiate Geological Conference (NEIGC)

Hosted by UVM Geology Department

October 1–3, 1999

Field Trips in Northern Vermont and adjacent New York State

A Complete schedule of trips will be published in the Summer GMG.

SPRING MEETING PROGRAM

University of Vermont
Kalkin Hall
April 17, 1999

8:30 **Coffee**

9:00 **Adam R. Consigli:** *GEOCHEMISTRY AND TECTONIC SETTING OF A SUITE OF DIKES NEAR VICTORY, VERMONT*

9:15 **Elizabeth R. Goeke:** *PRESSURE AND TEMPERATURE STUDIES IN THE EASTERN AUREOLE OF THE VICTORY PLUTON, NORTHEASTERN VERMONT*

9:30 **Carey A. Hengstenberg:** *REGIONAL SIGNIFICANCE OF THE AVERILL PLUTON, NORTHEAST KINGDOM, VERMONT: A SYN-TECTONIC PLUTON?*

9:45 **Myrth T. Anderson:** *DEPTH CONSTRAINTS ON THE ORIGIN OF NORTHEAST KINGDOM GRANITES, VERMONT*

10:00 **Brian Totten:** *ANALYSIS OF IRON OXIDE COATINGS THAT HAVE FORMED AS A RESULT OF ACID MINE DRAINAGE FROM THE PIKE HILL COPPER MINE IN NORTHEASTERN VERMONT*

10:15 **Scot Wiercinski:** *GEOCHEMICAL AND MINERALOGICAL ANALYSIS OF THE PIKE HILL MINE TAILINGS, CORINTH, VERMONT*

10:30 **Break: Recent Surficial Maps of the Montpelier and Barre West 7.5-Minute Quadrangles by F.D. Larsen and S.F. Wright, respectively, will be on display as will the northern section of the new Vermont State Bedrock Map**

10:40 **Darrin L. Santos:** *THE EFFECTS OF TWO YEARS OF INTENSE MILITARY ACTIVITY ON THE SOURCE AREAS, SOURCE-BASIN LENGTHS, AND INITIATION OF CHANNELS IN THE U.S. ARMY'S FORMER DESERT TRAINING CENTER, MOJAVE DESERT, CA.*

10:55 **Bryan A. Hopping:** *GEOCHEMICAL ANALYSIS OF MID-TERTIARY SEDIMENTS FOR EVIDENCE OF PALEOCLIMATE CHANGE, MISSION AND JACKO VALLEYS, MONTANA*

11:10 **Brad E. Rosenheim:** *FRESHWATER DILUTION OBSERVED IN STABLE OXYGEN ISOTOPE RECORD OF SCLERACTINIAN CORAL MONTASTREA ANNULARIS: ROATAN, HONDURAS*

11:25 **Megan Duni:** *SEDIMENT CHARACTERIZATION OF ROATAN ISLANDÍS REEFS AND BEACHES, PRE-HURRICANE MITCH, BAY ISLANDS, HONDURAS*

11:40 **Andrew J. Wall:** *CORRELATION BETWEEN FROG MALFORMITIES AND HEAVY METALS IN WARD MARSH, WEST HAVEN, VT, AND MUD CREEK, ALBURG, VT.*

11:55 **Timothy L. Morse**: *GEOPYSICAL PROPERTIES OF SURFICIAL SEDIMENTS ALONG THE ANTARCTIC PENINSULA AND IMPLICATIONS FOR PALEOCLIMATE CHANGE*

12:10 **Lunch Break: VGS Business Meeting will take place during the lunch break**

12:40 **Megan Hofeller:** *DETENTION POND INFLOW AND OUTFLOW: WATER QUALITY SAMPLING OF CENTENNIAL BROOK, BURLINGTON, VERMONT*

12:55 **Krista R. Polley:** *WATER QUALITY OF CENTENNIAL BROOK, BURLINGTON, VERMONT*

1:10 **Erich C. Osterberg:** *HYDRODYNAMICS OF THE SOUTH MAIN LAKE OF LAKE CHAMPLAIN*

1:25 **David B. Sardilli:** *OBSERVATION AND ANALYSIS OF THE INTERNAL SEICHE IN LAKE CHAMPLAIN, SHELBURNE BAY, VERMONT*

1:40 **Billie-Jo L. Gauley:** *A STUDY OF THE UNDERWATER FAULT SYSTEM OF LAKE CHAMPLAIN NEAR PORT KENT, NEW YORK*

1:55 **Break followed by announcement of awards.**

SPRING MEETING ABSTRACTS
University of Vermont
April 17, 1999

DEPTH CONSTRAINTS ON THE ORIGIN OF NORTHEAST KINGDOM GRANITES, VERMONT

Anderson, Myrth T., Geology Department, Middlebury College, Middlebury, VT 05753

Central and eastern Vermont record evidence of collisional processes during the Taconian and Acadian orogenies. During late and post Acadian time, the bedrock of eastern Vermont and adjoining New Hampshire was intruded by a suite of Devonian plutons. Several of these plutons in Vermont have been grouped together under the name of the Northeast Kingdom batholith. The batholith consists of several gabbroic to granitic plutons that intrude the Devonian Waits River and Gile Mountain formations. It is presently thought that these plutons were emplaced in a syn- to post-tectonic collisional environment, and Devonian Rb-Sr dates (370-390 Ma) place the batholith intrusion around the time of the Acadian Orogeny.

This study examines the West Charleston, Nulhegan, and Victory plutons. The West Charleston pluton is gabbro, diorite, and granodiorite containing hornblende, biotite, plagioclase, pyroxene, quartz, and K-feldspar. The Nulhegan pluton is quartz monzodiorite and leucogranite, with hornblende, plagioclase, biotite, quartz, and k-feldspar. The Victory pluton consists of granite and granodiorite with biotite, plagioclase, quartz, k-feldspar, and hornblende. Minor and accessory minerals present throughout the plutons include sphene, muscovite, chlorite, ilmenite, magnetite, apatite, and epidote.

Some of the samples contain the mineral assemblage hornblende, biotite, two feldspars, quartz, sphene, and ilmenite or magnetite, and have been used to determine the depth of emplacement using aluminium-in-hornblende barometry. Application of Anderson and Smith's (1995) geobarometer yields an average depth of 9.3 km for the Nulhegan pluton, and 13.8 for the Victory pluton. Ayuso and Arth (1992) estimated a depth of emplacement of < 12 km for the Nulhegan pluton. Hannula et al., (in press) have determined the depth of metamorphism of the country rock around the Victory pluton to be between 15-18 km. Similar depths of emplacement for the granite are consistent with pluton emplacement while the country rocks were being metamorphosed.

GEOCHEMISTRY AND TECTONIC SETTING OF A SUITE OF DIKES NEAR VICTORY, VERMONT

Consigli, Adam R., Dept. of Geology, Middlebury College, Middlebury, VT 05753

Many mafic dikes intruded into northeastern Vermont between the Taconian Orogeny (460-440 Ma) and the Acadian Orogeny (400-360 Ma). Rouff (1998) analyzed a suite of dikes (420 Ma) found near the Comerford Dam in northeastern Vermont, and concluded they represented depleted tholeiites formed in a mid-ocean ridge or back-arc basin setting. A set of dikes northeast of Rouff's area is the focus of this study. Using geochemical and petrological analyses, the tectonic origin of these intrusive rocks can be obtained.

East of the Victory Pluton, on the east side of the Monroe Fault, a set of mafic dikes crops out in the towns of Victory, Concord, and Granby, Vermont. These dikes intrude the Albee Formation and vary in size from coarse to fine grained. Several of the dikes preserve evidence of chilled margins. Mafic rocks closer to the Monroe Fault are highly deformed; in contrast, rocks farther from the fault are mostly undeformed. All the dikes have a metamorphic assemblage of amphibole and plagioclase ±epidote ±biotite ±chlorite ±sphene and ±calcite.

Ternary, binary, and rare earth element (REE) diagrams were utilized to classify and distinguish the rocks that were studied. Most dikes have a tholeiitic composition, but there are some outliers that have a more alkalic composition. The majority of the dikes are basaltic in nature. Others vary from andesitic to basanitic. Tectonic discriminant diagrams of the dikes show the majority of the rocks are like mid-ocean ridge basalts (MORB) in composition. REE patterns are slightly enriched in LREE- similar to basalts from some continental extensional environments.

Chemical analyses show that a majority of the studied rocks are similar in nature to Rouff's dikes. They are mostly tholeiitic basalts that were intruded in an extensional environment. Thus, the dikes in this study could be derived by melting asthenospheric mantle, similar to the Comerford intrusive suite.

SEDIMENT CHARACTERIZATION OF ROATAN ISLANDÍS REEFS AND BEACHES, PRE-HURRICANE MITCH, BAY ISLANDS, HONDURAS

Duni, Megan, Department of Geology, University of Vermont, Burlington, VT 05405

Roatan, one of three islands comprising the Bay Islands, lies in the Carribbean Sea approximately 50 km north of Honduras. The fringing reef surrounding much of the island is the southernmost extension of the Belize reef system, the second largest reef system in the world. Though annual visitors to Roatan have been increasing dramatically over the past decade, the islandís tropical ecosystem is considered one of the very last remaining pristine reef systems in the world, yet no descriptive studies regarding Roatan Islandís coral reef have been preformed. In an effort to produce a comprehensive starting point from which future studies monitoring pertenent environmental changes will evolve, I am characterizing sediments at eleven beach sites and seven reef sites surrounding Roatan Island. Sediment characteristics measured at every site include 1) mean grain size, 2) the degree of sediment sorting, 3) biogenic to terrestrial sediment ratios, and 4) mineralogy of terrestrial sediment present.

During the summer of 1998, grab samples were collected from the back reef by Charlotte Mehrtens and Robert Young, and from the islandís beaches by David Bush. Reef samples were wet sieved on location and beach samples were wet sieved at the University of Vermont, Fall 1998. From Fall 1998 to Spring 1999, the degree of sorting and mean grain size of the sieved sediment were determined, insoluble material was isolated, and percent insoluble sediment present was then calculated. X-Ray Diffraction was used to determine mineralogy for all samples smaller than 3.0 phi. Quartz, feldspar, and amphibole were the dominant minerals. Significantly, no terrigenous clays were identified. For coarser-grained samples, mineralogy will be determined using a binocular microscope this spring.

Data is being interpreted using existing maps of shoreline properties, watershed boundaries, human development, and bedrock geology to yield a description of factors that are prominent influences controlling the sediment characteristics at each site. Generally, beaches (n=11) showed very high insoluble residue values, an average of 69.11%, and smaller grain sizes, an average of 1.42 phi (medium sand), while the reefs (n=7) showed extremely low insoluble residue values, an average of 9.85%, and larger grain sizes, an average of 0.17 phi (coarse sand). On average, both reefs and beaches are poorly sorted with an Inclusive Graphic Standard Deviation of 1.68 phi and 1.28 phi, respectively. The evidence of the lack of transport from land to reef or vice versa is supported by what appears to be a lack of impact on the reefs offshore of the sediment plumes observed on the island. Either the sediment composing the plumes settles out before reaching the reef, or it continues traveling into the open sea without settling on the reef. One apparent exception to this generalization is the impact that a dredged inlet has on the Key Hole site. While reefs on this island have an percent insoluble residue not exceeding 6%, the sediments of Key Hole, just offshore of a dredged inlet, rise to 35% insoluble.

A STUDY OF THE UNDERWATER FAULT SYSTEM OF LAKE CHAMPLAIN NEAR PORT KENT, NEW YORK

Gauley, Billie-Jo L., Geology Department, Middlebury, VT 05753

The fault system beneath Lake Champlain is based on the projection into the lake of well-studied land based faults in New York and Vermont. Due to the limited access, little direct study of the underwater faults has been made until now. In western Lake Champlain, underwater faults may explain topographic anomalies such as Ferris Rock. In order to study the faults, we have to rely on instruments that can illustrate the bottom topography. The data consists of 6.8 square miles of side-scan records, taken during the 1997 Lake Survey, and 22.7 nautical miles of Precision Depth Recorder (PDR) tracts. Topographic escarpments on the lake bottom may represent faults. The alignment of escarpments along neighboring PDR tracks gives us the orientation of the fault. The PDR tracts indicate the existence of one fault directly northwest of Schuyler Island as well as one northeast of Trembleau Point. A final side-scan mosaic demonstrates the relationship of the underwater faults to those observed on land. The combination of PDR records and the side-scan mosaic allows us to define the underwater fault system of Lake Champlain near Port Kent in a more detailed manner than previous studies.

PRESSURE AND TEMPERATURE STUDIES IN THE EASTERN AUREOLE OF THE VICTORY PLUTON, NORTHEASTERN VERMONT

Goeke, Elizabeth R., Geology Department, Middlebury College, Middlebury, VT 05753

The Ordovician or Silurian New Hampshire series metasediments are separated from the Silurian-Devonian Vermont series metasediments by the Monroe Fault. In northeastern Vermont, the Devonian Victory Pluton straddles the thrust fault and has long been assumed to be post-tectonic, though recent studies suggest it intruded during fault movement.

In the garnet zone east of the fault peak pressures and temperatures are 4.6–5.6 kbar and 515–575° Celsius. Peak pressures and temperatures in the garnet zone west of the fault are 5.0 kbar and 515–525° Celsius. The nearly equal peak pressures and temperatures indicate that the final garnet growth occurred after all deformation along the fault took place.

In sillimanite grade rocks east of the fault, one sample contains the assemblage staurolite + sillimanite + garnet + cordierite + ilmenite + rutile + plagioclase + biotite + chlorite. Reaction textures in the thin section suggest that cordierite and garnet were replaced by biotite and sillimanite; staurolite has reacted with biotite, sillimanite and garnet; and ilmenite was replaced by rutile. These reactions are consistent with an increase in pressure or a decrease in temperature.

A pressure increase during contact metamorphism in the eastern (upper) plate of the fault could be explained in several ways. There are several possible explanations: the pluton may have been emplaced above part of its eastern aureole, another thrust fault to the east may have slipped concurrently with the Monroe Fault, or pressure may have increased for some other reason not related to the pluton or the Monroe Fault.

REGIONAL SIGNIFICANCE OF THE AVERILL PLUTON, NORTHEAST KINGDOM, VERMONT: A SYN-TECTONIC PLUTON?

Hengstenberg, Carey A., Geology Dept., University of Vermont, Burlington, VT 05405

The Averill pluton is a medium to coarse-grained biotite granite which intrudes Early to Middle Devonian metasedimentary rocks of the Gile Mountain and Ironbound Mountain Formations. This and related plutons in northeastern Vermont have been previously interpreted as post-tectonic plutons that mark the end of the Acadian Orogeny in Vermont. These interpretations are based on evidence from the contact metamorphic aureoles, apparent lack of foliation within the bodies

of the plutons and discordant map patterns. However, recent studies indicate that significant ambiguities are inherent in the interpretation of emplacement related structures (Karlstrom and Williams, 1995). For example, Hannula et al., (1999) suggest that the Victory Pluton, which was originally described as a post-tectonic pluton in northeast Vermont, was actually emplaced along an active thrust during orogenesis. The focus of this study is to determine the emplacement history of the Averill Pluton as pre-, syn- or post-tectonic by investigating: (1) deformation textures within the body of the pluton, (2) the metamorphic history in the contact aureole and (3) the pluton's relationship to regional metamorphism and deformation.

Field data collected along the contact of the granite in the eastern and western portions of the pluton show folded granitoid dikes in the country rock and a weak foliation defined by aligned biotite and feldspar grains. In the area very proximal to the contact within the body, hand sample specimens of granite appear deformed, with a weak fabric defined by elongate quartz, feldspar and biotite grains. Petrographic textures indicative of deformation occur throughout the pluton but are more apparent near the pluton margin. This is especially noticeable along the northern contact in Quebec and the eastern contact in Vermont where pervasive deformation textures have been observed. These features include: strong muscovite foliations, recrystallized and biaxial quartz, myrmekite and deformed feldspar grains in all thin sections studied thus far. This preliminary data suggests that at least a portion of the body has been deformed during or after emplacement. Pegmatite dikes also occur in both country rock and pluton and are late, cross-cutting all features. These relationships imply that deformation ceased before final emplacement of the Averill pluton.

To determine if the observed deformation relationships are associated with emplacement-related deformation or regional deformation, it is necessary to examine metamorphic history and textural relationships on the country rocks. The country rock shows several generations of metamorphic mineral growth which include, staurolite, sillimanite, biotite and muscovite. In all instances these porphyroblasts appear to have formed prior to foliation development in the rock because the fabric defining the foliation wraps around these porphyroblasts. Foliations in the granite are sometimes parallel to the country rock foliation, and this may suggest an interaction between regional and emplacement-related strain but the effect of regional deformation in the contact aureole cannot be determined completely until regional P–T conditions and foliation trends are defined. Based on metamorphic reactions in the contact aureole, temperatures and pressures of likely emplacement conditions of the Averill pluton are mid-crustal, approximately 550–650°C and 3–7 kbar.

DETENTION POND INFLOW AND OUTFLOW: WATER QUALITY SAMPLING OF CENTENNIAL BROOK, BURLINGTON, VERMONT

Hofeller, Megan, Department of Geology, University of Vermont, Burlington, VT 05405

Human activities have a large impact upon our environment. The use of urban stormwater detention ponds has become a practice to improve the water quality of urbanized streams such as Centennial Brook. This brook, in Burlington, Vermont, is adjacent to the University of Vermont campus and flows through Centennial Woods Natural Area. Three detention ponds are located along the drainageway of Centennial Brook to collect stormwater runoff from campus storm drains, surrounding parking lots, a hospital, hotel, and two gas stations. Two ponds are located downstream from the brookís headwaters, and the other is further downstream. All three are specifically designed to reduce the amount of suspended solids entering the brook and control the discharge into the brook. Stormwater moves through the detention ponds and eventually discharges into Centennial Brook.

The performance of these detention ponds is evaluated by sampling six different locations along the stormwater flow path to the brook. Site 1 was the untreated water entering the first detention pond. The water sampled at Site 2 was the outflow of the first detention pond at times of high flow and low flow. Site 3 was the inflow to the second detention pond. Site 4 was the outflow of the second detention pond. Site 5 was the water that is being discharged into Centennial Brook. Site 6 was the water being discharged into Centennial Brook from the third detention pond. Each site was sampled for pH, conductivity, chloride ion concentration, and suspended solids during high flow, normal flow and low flow. Each site was sampled six times from February through April 1999.

General trends are made for the analyzed samples from the brook. Surprisingly, the average total suspended solid values were higher at the detention pond outflows than the inflows by a factor of ten. Total suspended solids (TSS) ranged from 6.22 mg/L at Site 1 to 40.40 mg/L at Site 6. Conductivity and chloride ion concentrations corresponded to the high and low flow; there were high conductivity and high chloride concentration values for low flow days and low values for high flow days. The minimum values for both parameters were at Site 1 with a conductivity of 1.39 mmhos and Cl concentration of 0.0137 moles/L; higher values were apparent at Site 4 with a conductivity of 4.58 mmhos and a Cl concentration of 0.0408 moles/L. The pH values ranged from 7.93 to 8.11 and had no temporal or spatial relationship to the drainageway.

Detention ponds in the Centennial Woods Natural Area are not effective at settling out solids during high flows. The high flow days increase the turbulence within the detention ponds and, as a result, increase the suspended solids in the river. In addition, the higher flows dilute the concentrations of ions in the water. Conductivity and chloride ion concentrations corresponded to the amount of water flowing through the drainageway.

GEOCHEMICAL ANALYSIS OF MID-TERTIARY SEDIMENTS FOR EVIDENCE OF PALEOCLIMATE CHANGE, MISSION AND JACKO VALLEYS, MONTANA

Hopping, Bryan A., Geology Department, Middlebury College, Middlebury, Vermont

In the Mission and Jacko Valleys of western Montana there exist depositions of lateritic mid-Tertiary sediments. Study of these sediments is important in gaining an understanding of paleoclimate conditions during the time of deposition. Past study has shown that these sediments were deposited in a semi-arid to arid environment, mainly in the form of fans on the floors of the valleys. Dating of volcanic ash puts these sediments at 32± 1.4 Ma. Analysis of the clay mineralogy of these sediments shows that kaolin minerals dominate in the northern sediments, and more smectite is seen in the more southern deposits. This difference in mineralogy suggests a change in the climate from semi-tropical to semi-arid.

This study continues previous work on these deposits by performing a bulk chemical analysis of these sediments using ICP analysis. Using the known clay mineralogy the samples are roughly ranked from less to more weathered. The rankings are supported by plots of the ratio of soluble to insoluble elements. Preliminary plots of the major and trace elements generally show the expected trends based on the ranking. As expected, weight percent of some of the more soluble elements, magnesium and calcium, decreases from less to more weathered sediments.

Geochemical analysis of these sediments shows a change in chemistry which would suggest a change in climate around the time of deposition. The dating of these sediments puts them near the Eocene-Oligocene boundary. The subtropical climate prior to this boundary is responsible for the higher degree of weathering found in some of the sediments. The sediments which show less weathering, as well as the fan-like deposits, were formed when the climate changed from subtropic to semi-arid.

GEOPYSICAL PROPERTIES OF SURFICIAL SEDIMENTS ALONG THE ANTARCTIC PENINSULA AND IMPLICATIONS FOR PALEOCLIMATE CHANGE

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The Antarctic Peninsula continental shelf is located within the transition from subpolar to polar climate regimes. Increased temperature effects along the AP (increase of 2.5{symbol 176 \f "Symbol" \s 10}C recorded at Faraday Station) include increases in surface melting across ice shelves, smaller coverage of annual sea ice, and related increases of sediment influx and deposition within the basins and fjords. Climatic related events and sediment deposition patterns make this region a sensitive indicator of paleoclimate. Prior investigations have seen varied sediments along the peninsula shelf and fjords indicating extended development of glaciers, glacial recession, and subsequent paleoclimate evolution during the Holocene.

High-resolution geophysical properties including bulk density, water content, electrical resistivity and magnetic susceptibility were measured on 3-meter kasten and gravity cores from three locations along the Antarctic Peninsula. Relationships between geophysical properties and core lithology are used to describe paleoclimate change.

Geophysical reflectors have been associated with sand lenses and small scale variations in bulk density and water content of hemipelagic/pelagic sediments. Resistivity measurements indicate a negative correlation with water content and may be a good indicator of paleoclimate change. Magnetic susceptibility shows an inverse profile of biogenic silica and is useful in interpreting regional climate.

HYDRODYNAMICS OF THE SOUTH MAIN LAKE OF LAKE CHAMPLAIN

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Lake Champlain provides an outstanding opportunity to further understand internal seiche dynamics of long and narrow stratified lakes. The wind-driven internal seiche has been shown to dominate Lake Champlain's circulation, and is known to have dramatic effects on the lake's thermal structure. Five subsurface moorings equipped with temperature sensors and self-contained Acoustic Doppler Current Profilers (ADCPs) were positioned in areas of varying depth within the South Main Lake of Lake Champlain (between Thompsons Point and Potash Point). From May 14, 1997 to October 14, 1997, the moorings measured current velocity and backscatter every hour in one-meter cells, and measured temperature every hour in four-meter cells, throughout the water column. The data were quality controlled, modeled and analyzed.

During this study period, the South Main Lake was dominated by oscillating north-south currents driven by the internal seiche. At any given time, hypolimnic flow was opposite to that of the epilimnion, although maximum velocities were consistently observed in the epilimnion over the five sites. North-south maximum velocities ranged from 10–47 cm/s, while east–west maximum velocities ranged from and 5–27 cm/s. Auto- and cross-spectral analyses indicate that the first, second and wind-forced modes of the lake were 4.3–5.3 days, 2.6–3.0 days and 10.7 days, respectively. Shorter observed periods of 0.89–1.5 days may reflect an internal seiche system bounded within the study area itself. The varying thickness of the metalimnion revealed the second vertical mode with dominant spectral peaks at 5.3 days and 2.7–3.0 days. Backscatter intensity, however, displays a strong diurnal oscillation, which suggests that the majority of reflecting material was phytoplankton and/or zooplankton.

Gradient Richardson Numbers indicate that the thermocline was characterized by a zone of stability. Mixing across the metalimnion dramatically increased during the initial, downward tilting of the thermocline associated with high-amplitude seiche oscillations, suggesting that epilimnion renutrification may have occurred during these times. Contrary to the northward direction of the lake's drainage, the net transport of water had a dominant southerly component at all but the southernmost mooring (Potash Point). This can be attributed to the internal seiche's Kelvin wave structure and the position of these moorings to the west of the lake's thalweg. This further suggests that a net counter-clockwise circulation cell may exist south of Thompsons Point.

WATER QUALITY OF CENTENNIAL BROOK, BURLINGTON, VERMONT

Polley, Krista R., Department of Geology, University of Vermont, Burlington, VT 05405

Increased chemicals and runoff in surface water due to urbanization effect the chemical composition of natural streams. In order to evaluate these effects, pH, conductivity, chloride concentrations and suspended solids were measured in Centennial Brook. Centennial Brook flows through the Centennial Woods natural area, adjacent to the University of Vermont. The headwaters of Centennial Brook originate from two detention ponds that are outside the natural area. These detention ponds capture runoff and help remove pollutants before they enter Centennial Brook. Runoff from surrounding forested areas and roads enters directly into the brook.

This study evaluated seven locations along Centennial Brook. At each location, two 900-ml samples were taken twice a week from February 11th 1999 to March 22nd 1999. Samples were taken to the lab to be analyzed for pH, conductivity, chloride ion concentrations and total suspended solids.

The highest pH (8.33) was upstream at site 2, while the lowest pH (7.64) was downstream at site 7. The weathering of the dolostone bedrock found in Centennial Woods helps maintain the slightly basic pH of the stream. Chloride ions, pH and conductivity decreased in concentrations as sites progressed downstream and away from the detention ponds. The chemicals causing the raised values closer to the detention ponds are being diluted as they are carried down stream. During the week before and including March 2nd, snow melt and heavy storm discharge occurred. No significant increase in chloride ion concentration was present at any of the sites during this time. However, conductivity was found to increase dramatically during this period of high discharge. Upstream at sites 1–3 conductivity values were all above 5 milli mhos. Conductivity values on March 2nd decreased progressively downstream but the values were still higher than other sample days respective to the sites. The rise in conductivity did not relate to chloride ion concentration; therefore, conductivity values were not representing the chloride from the street salt but from other unknown ions. Downstream at site 5 average values for conductivity and chloride ions all exceeded the values found upstream at site 4. Site 5 crosses a path in the natural area increasing the amount of foreign materials entering the stream. During times of melt and rain the amounts of suspended solids increased respectively with discharge.

In the month of February, snow is still accumulating and pollutants are trapped in the snow resulting in the similar values of conductivity, and chloride ion concentration for the month of February. These pollutants were released during the melt causing the higher concentrations of conductivity. On March 2nd a rainstorm increased the discharge of the area. Both the melt and the storm increased the runoff entering Centennial Brook thereby increasing the concentration of pollutants. On March 2nd, pH, and chloride ion values remained similar to the samples taken in February, but conductivity values increased suggesting that other ions besides chloride ions were present in the stream. Suspended solids also increased over other sample days from the higher discharge. On March 22nd values for conductivity, pH, chloride ions and suspended solids all dropped below the values seen in February; indicating the contribution due to the snow melt and increase runoff had ended for the Centennial Brook region.

FRESHWATER DILUTION OBSERVED IN STABLE OXYGEN ISOTOPE RECORD OF SCLERACTINIAN CORAL MONTASTREA ANNULARIS: ROATAN, HONDURAS

Rosenheim, Brad E., Dept. of Geology, Univ. of Vermont, Burlington, VT, 05405, brosenhe@zoo.uvm.edu

Roatan, Honduras, is a steep-sided island under high development pressures resulting in deforestation and increased runoff. Local concerns for the health of the island's reef have emerged recently as live coral coverage has decreased and brown and green algae coverage has increased in certain areas. In an attempt to correlate these changes with deforestation and increased runoff, we are analyzing three specimens of M. annularis for trends in oxygen isotope ratios over space and time.

Three corals have been sampled from areas of the reef representing long-established development, recently filled wetland, and pristine offshore patch reef, respectively. X-radiography has concluded that each coral is 5–7 years old. Thus far, stable isotope data has been obtained for the specimen collected adjacent to the recently filled wetland. Each growth band was sub-sampled according to the X-radiograph to observe the coral's seasonal $\delta^{18}O$ variability. Besides seasonal variance, this coral shows a decrease of 0.75‰ (four times larger than the mean annual standard deviation) in $\delta^{18}O$ values over the previous six years. We do not expect to see any temporal trends other than seasonal variation in the other two specimens due to the unaltered geohydrology of the adjacent coast during the life of the corals. It is hypothesized that the offshore patch reef coral should be, on average, more enriched in $\delta^{18}O$ than the coral sampled adjacent to the long-established development.

The results of this project represent the first quantification of reef quality on the island of Roatan. They offer a geohydrologic interpretation to accompany climatic discussion of $\delta^{18}O$ values in modern scleractinian corals as an indicator of anthropogenic environmental effects.

THE EFFECTS OF TWO YEARS OF INTENSE MILITARY ACTIVITY ON THE SOURCE AREAS, SOURCE-BASIN LENGTHS, AND INITIATION OF CHANNELS IN THE U.S. ARMY'S FORMER DESERT TRAINING CENTER, MOJAVE DESERT, CA.

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During World War II the U.S. Army established twelve 'tent cities' used as base camps for housing troops and equipment during training exercises in the Mojave and Sonoran Deserts of California and Arizona. The Desert Training Center was used intensively for two years as over one million American troops and support personal filtered through. The base camps were partially dismantled 54 years ago, but road berms and stone walkway alignments are still intact today. The road berms act as local stream barriers, diverting streams from their natural path down the steepest gradient. The diversion of streams has created zones (5 to 40 m) void of channels down slope of roads. Compacted soil surfaces also remain within the camps, and have yet to recover even after 50 years of camp abandonment.

Camp Iron Mountain, one of the Desert Training Center base camps, is located east of the Iron Mountains on a flat, gently sloping alluvial plain (also known as a bajada) in the Mojave Desert of southern California. The climate is arid, receiving less than 7.87 cm of rainfall annually, and is sparsely vegetated, dominated by creosote bush (Larrea tridentata). I show that the military's modification of the surface hydrology (by leaving road berms intact) and modification of the soil surface (by compaction) has altered the location of channel heads inside Camp Iron Mountain, as compared to the location of channel heads on the bajada surface outside and surrounding Camp Iron Mountain. The differences between channel head locations is determined by calculating the source area (area of ground surface where rainfall will collect to form overland flow) and source-basin length (distance from the channel head to the local drainage divide) of each channel head. The channel heads in areas inside the camp that are affected by road berms, express larger source areas and source-basin lengths than the source areas and source-basin lengths of channel heads occurring outside the camp in areas not impacted by military activity. The areas inside the camp affected by considerable soil compaction have channel heads that express smaller source areas and source-basin lengths as compared to the channel heads outside of the camp.

OBSERVATION AND ANALYSIS OF THE INTERNAL SEICHE IN LAKE CHAMPLAIN, SHELBURNE BAY, VERMONT

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The Champlain Water District (CWD), located on the eastern shore of Shelburne Bay, Vermont, is a facility used for water collection, purification, and distribution to a total of twelve communities including South Burlington and Shelburne. In total, the facility is responsible for providing roughly 60,000 people and many local businesses in these areas with a high quality water supply. Additionally, the facility is dedicated to a thorough understanding and optimization of the intake water characteristics so that it may provide its customers with the best quality water available. In order to better understand the circulation characteristics of Shelburne Bay, the CWD supported a pilot study of current and temperature observations in the near vicinity of its intake pipe from July of 1997 through June of 1998. The presence of two effluent pipes on the southeastern shore of Shelburne Bay and the newly completed Burlington Bay effluent piper were factors in launching the study.

Using an acoustic doppler current profiler and seven temperature sensors, data sets were analyzed using a combination of statistics, spectral analysis, hodographs and two dimensional computer visualization. Observed data suggests that the main lake seiche with a period of 4.5 days is not present in Shelburne Bay. This is most likely due to the bottom topography in the area which contains a ridge line serving to isolate the Shelburne Bay- Burlington Bay system. Rather, data analysis indicates the presence of a diurnal seiche operating in the area. Whether or not the lateral boundaries for this seiche include Burlington Bay is under evaluation. Additional studies concerning backscatter intensity, wind forcing, and mean circulation are also explored.

ANALYSIS OF IRON OXIDE COATINGS THAT HAVE FORMED AS A RESULT OF ACID MINE DRAINAGE FROM THE PIKE HILL COPPER MINE IN NORTHEASTERN VERMONT

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A study was done in order to analyze the metals content of iron oxide coatings that have formed in a small stream bed as a result of acid mine drainage from the Pike Hill Mine. The Pike Hill Mine was actively mined for copper up to 1919 and is located near Cornith, Vermont at the headwaters of Pike Hill Brook which is a component of the Waits River watershed. As the Pike Hill Brook flows through several hundred yards of tailings it oxidizes sulfide minerals and becomes highly acidic. The highly acidic water dissolves metals from the tailings and transports them downstream where they precipitate out of solution as iron oxide coatings on the stream bed as pH increases. By studying the content of these coatings using XRD, ICP, and SEM analysis, it can be estimated what environmentally detrimental metals are present in the system and how mobile these metals are.

Solid iron oxide coatings were taken from the surfaces of rocks and tailings in the stream bed, and were prepared for XRD analysis using a sonifier. XRD analysis showed that the samples obtained are almost pure iron oxide and have little mica or quartz which would be indicative of the surrounding country rock. ICP analysis

has shown changing concentrations of metals downstream which appear to be a result of acid/metal rich or acid/metal poor influxes of water into the stream. Iron concentrations range from 83,950 ppm to 1,000,000 ppm and copper concentrations range from 749 ppm and 10,540 ppm. By comparing variations in concentration downstream, it appears that the Pike Hill Brook system can be subdivided into groups of elements with similar geochemical behavior. These groupings are (Ni, Cr and Ag), (Cu, Co), and (Ti, Zn and Mn). SEM analysis has shown several crystal forms of iron oxide.

CORRELATION BETWEEN FROG MALFORMITIES AND HEAVY METALS IN WARD MARSH, WEST HAVEN, VT, AND MUD CREEK, ALBURG, VT.

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Studies performed by the Vermont Agency of Natural Resources (VTANR) and Jim Andrews of Middlebury College have found frog malformations in a number of sites across the Lake Champlain Basin. The surveys documented rates of morphological abnormalities in the Northern Leopard frog (*Rana pipiens*) ranging from 2% to 45% depending on the site (VTANR, 1998). Further laboratory research by VTANR, using the Frog Embryo Teratogenesis Assay: Xenopus (FETAX), showed that frog embryos grown in *water* from Ward Marsh WMA, in West Haven, VT, had an 89% malformity rate with a 6.6% mortality rate. In the assays using *sediment* from Ward Marsh, there was a 100% malformity rate and a 38.3% mortality rate (VTANR, 1997). This evidence indicates that the sediment is a potential source of teratogens. Mud Creek, in Alburg, VT, which was used as a control in this study, has very little evidence of malformities in the field and laboratory FETAX assays.

In other studies, frogs exposed to Cu^{2+}, Zn^{2+}, Co^{2+}, Ni^{2+}, Cd^{2+} in FETAX assays have shown these metals to be teratogens, causing malformities and mortality. The malformities of frogs exposed to these metals include retinal depigmentation and pelvic and hind limb malformities (Plowman et al., 1991,1994; Luo et al, 1993). These types of malformities have been found in Ward Marsh by VTANR, which leads us to suspect that the frog malformities may be related to high concentrations of metals in the sediment.

EPA method 200.2 for total recoverable analytes was used to prepare sediment samples from Ward Marsh and Mud Creek for ICAP analysis. Samples at Ward Marsh and Mud Creek were collected in transects ranging from subaerially exposed soils adjacent to the marsh to subaqueous sediment in the marsh, including all levels in between. Concentrations of Cu^{2+}, Zn^{2+}, Co^{2+}, Ni^{2+}, Cr^{2+} in the sediment at the two sites were determined using the ICP, with replicate runs.

Sediment samples from Ward Marsh contain statistically higher concentrations of Zn^{2+} (mean = 103 $\pm$ 34 mg/kg), Co^{2+} (mean = 18.3 $\pm$ 3 mg/kg), Ni^{2+} (mean = 39.4 $\pm$ 7.7 mg/kg), and Cr^{2+} (mean = 43.4 $\pm$ 11.8 mg/kg), than Mud Creek. Cu^{2+} concentrations were similar between the two sites. Furthermore, metal concentrations in Ward Marsh indicate a trend ranging from low concentrations in soils farther from East Bay to higher concentrations in subaqueous sediment closer to the bay. This relationship implies that East Bay is a potential source of heavy metals, which are accumulating in the sediment and that elevated metals concentrations could be responsible for frog malformities observed in the field at Ward Marsh.

GEOCHEMICAL AND MINERALOGICAL ANALYSIS OF THE PIKE HILL MINE TAILINGS, CORINTH, VERMONT

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The Pike Hill Mine is an abandoned copper mine located in east central Vermont. The northernmost of a series of copper mines in the Orange Country Copper District of the state, the mine lies in the Waits River Formation. Mined sporadically between the 1850's and the 1910's, the mine was active long before

regulations on waste rock disposal were in place. Consequently, the oxidation of many of the remaining primary minerals (pyrite, chalcopyrite, and sphalerite) has lead to the creation of acid mine drainage. X-Ray diffraction (XRD), scanning electron microscopy (SEM), inductively-coupled plasma atomic emission spectroscopy (ICP), and pH analysis of the tailings were conducted to determine the tailings chemistry and mineralogy. Secondary and tertiary minerals like jarosite, various iron oxyhydroxide phases, and gypsum were recognized in XRD and SEM analysis, and no sulfides were detected, indicating that a high degree of sulfide oxidation has occurred. The presence of gypsum, a highly soluble phase, indicates that wet/dry cycles play an important role in metals cycling.

ICP and pH analysis demonstrate that the intense oxidation and high metals content of the tailings will continue to produce acidic drainage into the future. ICP analysis showed very high concentrations of Fe which ranged from 2 to 33% while Cu concentrations ranged from 170-48,030 ppm. Concentrations of many toxic elements (Ni and Cr) were consistently below dangerous levels (<185 ppm), and other toxic elements (Co, Zn, and Mn) were also consistently low, but exhibited some high values in one or two samples. The pH analysis yielded values which were also very low. All but two samples had a value less than 3, and some had values below 2. Changes of pH over time demonstrate a kinetic effect relative to the amount of acidity produced. Present in the Waits River Formation are various carbonaceous materials which were expected to buffer some of the acidic drainage; the low pH values, however, suggest this is not occurring.