

# Continuation of Bedrock Geologic Mapping of Matinicus Quadrangle

PI: Martha Growdon, SUNY Oneonta

Funded by: United States Geological Survey, ED MAP, 2012

**U.S. DEPARTMENT OF THE INTERIOR  
U.S. GEOLOGICAL SURVEY**

**Continuation of Bedrock Geologic Mapping of Matinicus Quadrangle**

*Principal Investigator:* Dr. Martha Growdon  
State University of New York College at Oneonta (SUNY Oneonta)

**Introduction and Results of Prior Support**

Matinicus Island is the largest of eight islands located approximately 23 miles south of Penobscot Bay, and the mainland, in the Gulf of Maine. Matinicus Island has a year-round population of 47 residents (U.S. Census Bureau) that swells to almost four times that during the summer tourist season. The bean-shaped island is approximately two miles (3 km) long by one mile (1.6 km) wide, and covers an area of about 750 acres (Penobscot Bay Chamber of Commerce).

The bedrock geology of Matinicus Island is generalized on the 1:500,000-scale Maine State map (Osberg et al., 1985), but interpretations made from the mapped relationships are problematic. On the map, older, Ordovician sedimentary units are shown in intrusive contact with younger, Devonian granites, yet no fault is mapped between the units, and the rocks that should be metamorphic are mapped as sedimentary.

Previous field work, funded by EDMAP grant #G11AC20116, revealed the following important relationships on Matinicus Island:

- 1) Amphibolite-facies metasedimentary units are intruded by coarse-grained undeformed granite. The contact zone between the granite and the metamorphic rocks is characterized by angular clasts of metasedimentary rock rafted into fingers of granite.
- 2) The rocks on the southwestern point of Matinicus Island exhibit quartz rodding lineations and quartz ribbons with muscovite streaks, characteristic of greenschist-facies mylonites. Overprinting foliations in the metamorphic rocks suggest multiple deformation events, probably at different metamorphic grades.
- 3) Ochre-colored stained zones along the contact between the granite and metasediments and also within some metasedimentary lithologies were identified as likely source zones of elevated levels of arsenic present in many islanders' well water.

These relationships, in addition to mapping completed during the summer 2011 (Figure 1), suggest that bedrock geology of the Matinicus Quadrangle is more complex than previously documented (Osberg et al., 1985) and merits further investigation. The detailed bedrock geologic mapping proposed for the four remaining islands on the quadrangle will identify focused areas for more detailed investigation of metamorphic, structural, and groundwater problems.

Figure 1. 7.5-minute Matinicus Quadrangle topographic map.

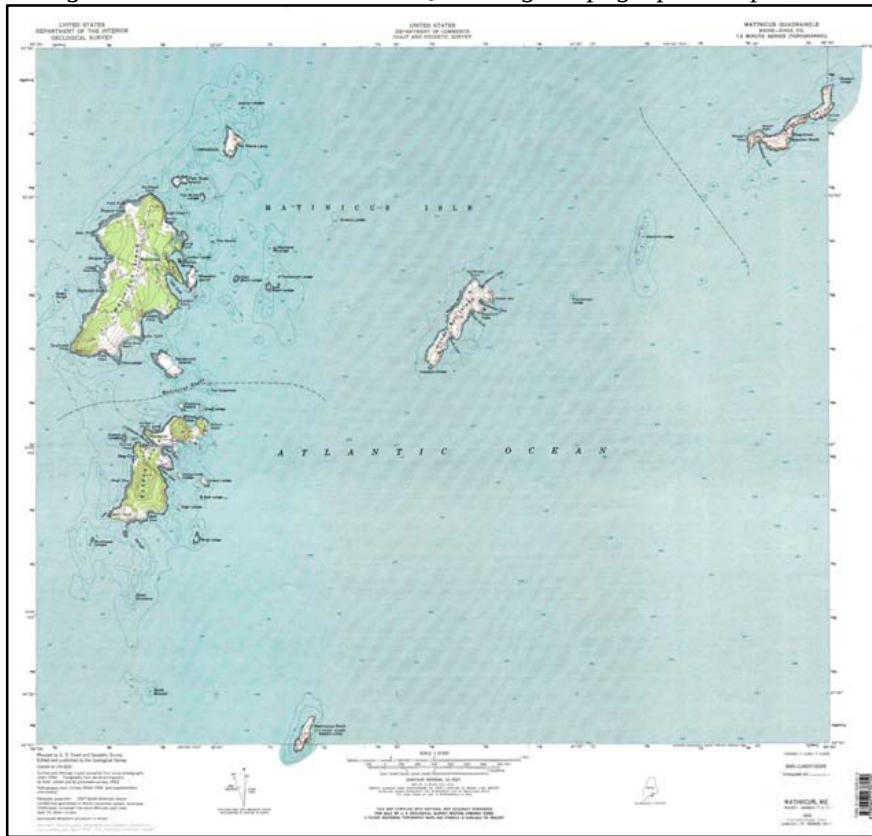


Figure 2. Preliminary field map completed in summer 2011.



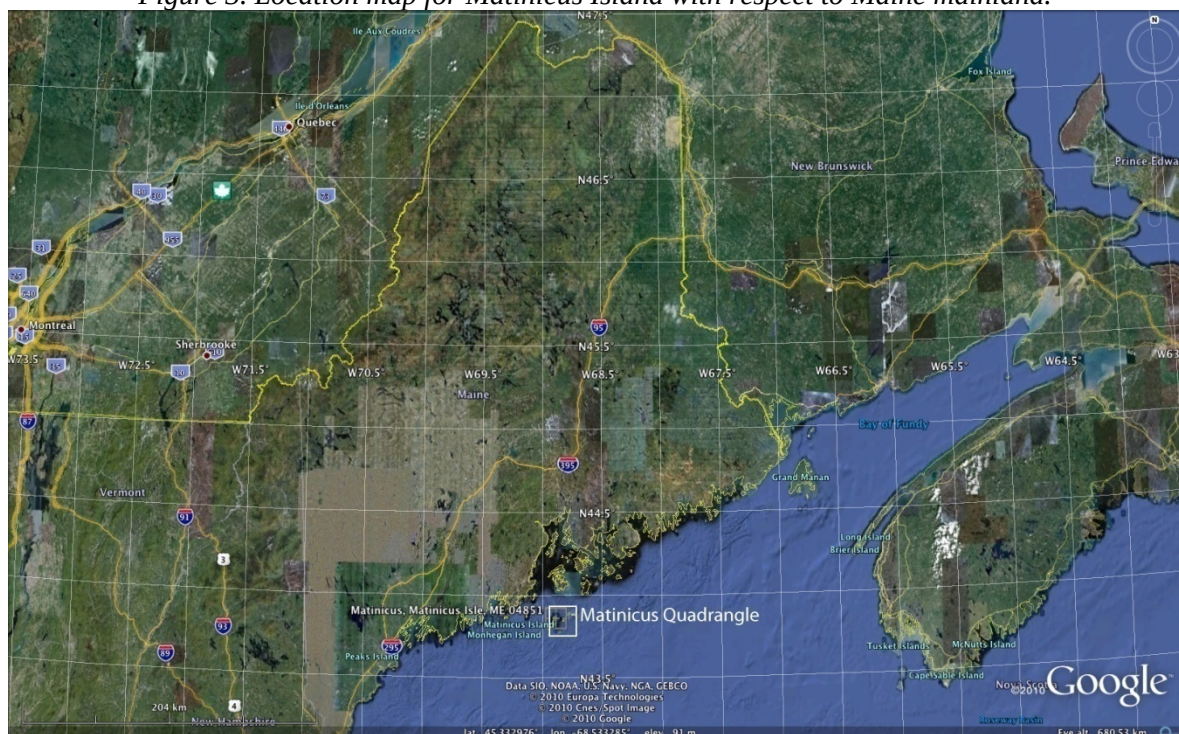
The Maine State Geological Survey supports ongoing bedrock geologic mapping at the quadrangle scale to update and complete the 7.5-minute, 1:24,000-scale bedrock geological map coverage of Maine. Discussions with Robert Marvinney of the Maine State Geological Survey, and with several residents of Matinicus Island during 2010-2011, helped identify the Matinicus Quadrangle as a target for detailed bedrock mapping at the 1:24,000 scale. EDMAP-funded mapping of Matinicus Island, Two Bush Island, Two Bush Ledge, No Man's Land, and Wooden Ball Island was completed in the summer of 2011; a preliminary field map (see Figure 2) was presented at the national Geological Society of America meeting in October 2011. The islands' small sizes, and the nearly 100% outcrop coverage around their perimeters, make the project perfect for student mappers, as relationships between units can be directly observed along the Islands' coasts. We anticipate that mapping of Ragged, Tenpound, and Seal Islands, as well as Matinicus Rock, will be completed within a single summer of EDMAP-funded field work.

Bedrock mapping in the field and supporting laboratory investigations will form the core of the proposed student researcher's Master's thesis. The results of these investigations will also be presented at the Northeast section (NE) and Annual Geological Society of America (GSA) meetings.

### **Location and Geologic Setting**

The proposed field site is located in central coastal Maine, south of Penobscot Bay and about 60 miles south of Bangor, Maine, at 43°51'42"N, 68°52'49"W. Matinicus and associated islands are shown on the 7.5-minute quadrangle map in Figure 1. A map of the Island with respect to mainland Maine is provided in Figure 3.

*Figure 3. Location map for Matinicus Island with respect to Maine mainland.*



### **Purpose and Justification**

Although the geologic issues hinted at by the summer 2011 mapping of Matinicus Island are sufficient to pique an academic interest in this small coastal island, the societal issues that would be addressed by completed, detailed mapping of the Matinicus 7.5-Minute Quadrangle (Survey, 1953) (see



Figure 1) also justify the required time and effort. A detailed knowledge of the bedrock geology on any remote island is critical for maintaining the well-being of residents and island ecosystems. The characteristics of the bedrock units control the flow of water through aquifers, as well as the occurrence and transport of natural or anthropogenic contaminants. Groundwater is the only source of fresh water on Matinicus and Ragged Islands. Most residents report elevated arsenic levels, some >400 ppb, in their drinking water. We believe the As is leaching from several of the metasedimentary units as residents whose wells were hydrofractured for higher flow volume report substantially higher levels of arsenic after the hydrofracturing. Accurate mapping of bedrock units is therefore critical for locating uncontaminated freshwater aquifers for these island communities. The field mapping and subsequent laboratory investigations required for publication of a full bedrock geologic map of Matinicus Quadrangle will identify aquifer units and conduits for groundwater flow and will flag units that could cause groundwater contamination. It is impossible to understate the importance of available freshwater resources for isolated communities; the efficient harvesting of this water is critical to the ongoing lives of island residents. Accurate information about groundwater reservoirs on the inhabited islands is essential to residents who are planning for future changes, both within their community and on Earth as a whole.

Bedrock mapping in Maine is notoriously difficult due to the paucity of outcrop exposure; the correlation between the well-documented sequence of terranes in Québec and those in the southern Appalachians is often convoluted in Maine. The Norumbega fault zone in south-central Maine has been argued to be the locus of minor and extreme dextral displacement of terranes; however, research into this problem is often stymied due to the lack of correlation with other bedrock units along strike of the fault zone. It may, however, be possible to resolve the question instead through detailed mapping of bedrock units and structures along Maine's coastal islands, which often have nearly 100 percent bedrock exposure along shorelines, and where faults, contacts and shear zones are well exposed. These features provide a wealth of information about structural, stratigraphic, and age relationships between bedrock units. Coastal mapping will aid interpretations of regional geology through interpolation to areas where the contact relationships between units are not so clearly exposed.

Basement irregularities, remnants of rift-transform sequences along active margins, are often re-used during each orogenic cycle, and substantially affect both the types of structures that develop and the preservation of multiple metamorphic events (Growdon, 2010; Thomas, 2006). Intense deformation and shearing accompany overprinting episodes of metamorphism along basement promontories, but relatively little deformation and only weak metamorphism (typically from single events) is most often preserved along basement recesses. The Québec Recess, a basement salient underlying northwestern Maine, allowed geologists to recognize at least four distinct Phanerozoic orogenic episodes in the northern Appalachians in Québec and Maine. Bedrock exposures in Maine should show evidence for accretion of exotic terranes in this recess, where the thin terranes mapped through southern New England expand across strike and where primary metamorphism can be preserved without overprinting by later events.

Several specific problems will be addressed by the full bedrock geologic mapping of the Matinicus 7.5-Minute Quadrangle. First, no existing detailed bedrock geologic map covers the Matinicus Island Quadrangle. This proposed project will complete work begun in 2011 on a detailed bedrock geologic map of the Matinicus Island Quadrangle that will complement the growing inventory of 7.5-minute-quadrangle-scale bedrock geologic maps in Maine. In addition, the timing and grade of metamorphic and/or deformation events will be documented through outcrop and micro-scale investigations.

Previous work (Ludman and West, 1999) identifies Matinicus and other coastal islands as part of the Coastal Lithotectonic belt south of the Norumbega fault zone in Maine. Matinicus Island, in particular, falls in the region of generically mapped upper amphibolite facies polydeformed rocks. Observations of several overprinting fabrics and amphibolite-grade mineral assemblages on Matinicus Island during mapping in 2011 corroborate Ludman and West's general mapping. These observations are inconsistent with the regional setting in the Québec Recess; the results of the proposed investigation will

help answer the long-standing question of the degree of lateral terrane transposition along the dextral Norumbega fault zone.

A resident of Matinicus Island planted the idea for this mapping project nearly six years ago, when the author was approached during preliminary field work and asked about the possibility of making a bedrock geologic map of Matinicus Island available to the residents. A reconnaissance map of surficial materials on the Matinicus Island Quadrangle was published in 1977 (Thompson, 1977) and work on a bedrock geologic map of the Matinicus Island Quadrangle began last summer (2011). This work was warmly received by the islanders and will continue to have a resounding effect upon them. Bedrock mapping of the Matinicus Island Quadrangle has the potential to show the residents how the Maine Geological Survey actively serves the public; it also has very real potential to identify the bedrock aquifers that are essential for the island community's health, growth, and long-term sustainability. Finally, most "Mainers" have a real interest in the geologic story of the rocks beneath them. Matinicus Island is a popular summer destination; this mapping can identify outdoor classrooms—locations where interesting geological relationships can be directly observed—that can be used to educate the public about local geological processes and problems.

### **Strategy for Performing the Geologic Mapping**

The problems presented above will be addressed with outcrop-scale mapping on Matinicus, Ragged and surrounding Islands during the summer of 2012, along with subsequent work necessary to generate a full bedrock map. The first goal in the field will be to locate and map in detail the exposures of, and contacts between bedrock units on Ragged, Seal, Tenpound and Matinicus Rock Islands. Mapping on these uninhabited islands requires charter service transport to the vicinity of the islands and an inflatable dingy to transport field participants to the islands from the charter boat. Mapping will proceed around the shores of the islands to differentiate bedrock units and to compile mineralogical and structural information within the units. Mapping will proceed inland to available outcrops upon completion of shoreline work. Grapefruit-sized samples will be collected from each outcrop that appears petrologically or structurally different from others. These samples will be transported back to SUNY Oneonta, where the student will prepare oriented billets and thin sections for further investigation. A preliminary base-map of the Matinicus Island Quadrangle will be completed before leaving the field during the summer of 2012.

Although most of the first-order research questions outlined above can be addressed at the outcrop scale, additional investigations at the micro-scale will be needed to answer secondary questions that stem from the field research. Following the field season, the student researcher will prepare thin sections for petrography and scanning electron microscopy. Samples will also be prepared for X-ray fluorescence (XRF) analysis, to identify units with elevated arsenic concentrations. The student will complete petrography and XRF investigations over the winter months and will present her findings at NE GSA, 2013. She will also present a poster or oral presentation on the petrographic and geochemical results, and will participate in the "Map Blast" session during the meeting, in which field mappers display and discuss their preliminary maps. The results of the mapping and lab research will be published following completion of field and lab investigations.

### **Timetable and Mentoring Strategy**

Preliminary meetings between the faculty advisor and the student are underway. In these meetings, the student and faculty mentor review literature of coastal Maine geology, discuss the specific problems to be addressed and how they will be addressed in the field, identify classes to be taken by the student, and discuss avenues for funding the student's research. The student takes notes during these meetings and keeps an organized library of files for easy reference. Literature review and mapping strategy planning will continue until July 2012. Field research will take place August 1-20, 2012. During this time the student and faculty will catalogue and distinguish rock types at outcrops and map faults, contacts, and structures including fabrics, bedding, and folds. The responsibility of the faculty mentor in the field

includes teaching the student to take detailed field notes through the use of a template developed in the summer of 2011 and helping the student identify areas where more investigation may be necessary, due to odd mineral assemblages or interesting structures. The goal of the project is to map all units, contacts, and major structures on a preliminary draft map by August 20, 2012 and to take samples of relevant materials, which may number up to one hundred, depending upon findings in the field.

Following field work and after the beginning of the school semester (third week of August 2012), the student will begin cutting billets (for oriented thin sections) and preparing powders (for XRF geochemistry). This preparation should take one month, after which billets will be selected for in-house and external thin-section production. The student will have completed the in-house thin sections and received the externally produced ones by the middle of October 2011, at which point she will work on one sample a day to catalogue minerals and textures. The faculty mentor will coach her through the processing of these samples by working through several initial samples with her and providing a template for her notes. Following the initial launch, the faculty mentor will meet weekly with the student to review her progress on the thin sections and double check her petrography. In addition to petrography, specialized training sessions will be arranged, to teach the student to use the XRF to analyze and reduce the data from her samples. This teaching process will require at least two hours per week of the faculty mentor's time outside of the normal meetings. By early December 2012, the student will have collected enough observational and chemical data to write an abstract for the NE GSA 2013 meeting.

Between the fall and spring semesters we will analyze the detailed nano-textures of selected samples. The College's winter break provides an ideal time for such work, since no other students are on campus and the external humidity and temperature are relatively stable. It is hoped that the analysis will be done with an in-house scanning electron microscope (SEM) to be requested from the National Science Foundation's Major Research Instrumentation program. If the award is not received, arrangements can be made with regional SUNY institutions, such as Binghamton University, to use existing equipment.

The student will spend the spring semesters of 2013 in petrographic, structural, or groundwater investigations pertinent to preparing the final quadrangle bedrock geologic map, as well as preparing the written portion of her Master's thesis. The student and faculty mentor will meet for weekly post-field-work progress report meetings to set deadlines, discuss strategies and troubleshoot ongoing work. While it is the student's responsibility to complete the work in a timely manner, it will be the responsibility of the faculty mentor to set reasonable deadlines to keep the student on target toward project completion.

*Table 1. Detailed Timeline.*

| <b>Timeline</b>        | <b>Activity</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                       |
|------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| March 2012             | Technical report and preliminary map will be sent to EDMAP for previous research.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |
| April 2012 – July 2012 | Library and background research to guide student through the basics of New England Appalachian and specifically Maine coastal geology. Student will keep a folder file of Maine research, including detailed notes from meetings and literature review. <ul style="list-style-type: none"> <li>• Review of past New England Intercollegiate Geological Conference field trip guides for Maine that may pertain to coastal Maine geology.</li> <li>• Review of notes from Dr. Arthur Hussey, professor emeritus at Bowdoin College, who has visited Matinicus with students.</li> <li>• Review of thin sections from Matinicus Island rocks mapped Aug. '11</li> </ul> |
| August 1 – 20, 2012    | Field work on Ragged, Seal, and Tenpound Islands and Matinicus Rock, with a goal to have all contacts between rock units identified and traced on draft                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |

| Timeline                   | Activity                                                                                                                                                                                                                                                                                                                              |
|----------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                            | base map by Aug 20, 2012. <ul style="list-style-type: none"> <li>• Field team will catalog rock types at the outcrop scale.</li> <li>• Faculty mentor will guide student through outcrop identification of rocks and minerals and measurements of structural and sedimentary features (cleavages, faults, folds, bedding).</li> </ul> |
| August 25 – Sept. 30, 2012 | Cutting and preparation of necessary billets for polished thin sections for petrography and SEM work; preparation of powders for in-house XRF work. A number of billets will be sent out for external thin section processing; thin sectioning instructions will be given to student for in-house sample processing.                  |
| Sept. 30 – Oct. 31, 2012   | XRF processing of selected samples, following one-on-one coaching of student on in-house XRF machine, including data reduction processes (including Gresen's style analysis) and plotting components on ternary diagrams.                                                                                                             |
| Early November, 2012       | Receive thin sections and begin petrography of selected samples.                                                                                                                                                                                                                                                                      |
| Nov. – Dec. 11, 2012       | Petrography continues at the rate of one sample per day, to catalog initial observations of textures and mineralogy. A template thin section note page will be provided to the student by the faculty mentor.                                                                                                                         |
| Early December, 2012       | Submit abstract for presentation at NE GSA 2013.                                                                                                                                                                                                                                                                                      |
| January, 2013              | SEM processing of samples                                                                                                                                                                                                                                                                                                             |
| Jan. – March, 2013         | Compilation of map for presentation at NE GSA Map Blast and poster sessions. Presentation of preliminary results.                                                                                                                                                                                                                     |
| March – April, 2013        | Student continues work to complete compilation of data of all eight islands; the faculty mentor intends to continue separately funded research with student to produce maps ready for digitization by April 2013 in conjunction with the Maine Bureau of Geology and Natural Areas.                                                   |

### **Deliverables**

This project will result in a 1:24,000-scale, 7.5-minute quadrangle bedrock geologic map of the Matinicus Quadrangle, Maine, with cross sections. Maps will initially be produced in paper format, and later digitized with the assistance of the Maine Bureau of Geology and Natural Areas, at no cost to the PI. The project will be presented at national and local Geological Society of America meetings.

### **Project Personnel**

#### **PI/Supervising Professor: Martha Growdon, Ph.D.**

Dr. Growdon is an assistant professor of structural geology at SUNY Oneonta. She has taught Structural Geology and Earth Materials (mineralogy + petrology for Earth Science majors). Last year she mentored a very successful EDMAP grant program on Matinicus Island. She was an Associate Instructor at Indiana University from 2005 to 2007, teaching coursework in mineralogy, petrology and structure, and has conducted geology field work since 2003. Dr. Growdon's current field work, since 2006, focuses on the Orange-Milford belt, in Connecticut. She also conducted field work in the Kiseynew Domain, Manitoba, Canada, as part of Canada's Targeted Geoscience Initiative (TGI3) from 2006 to 2008. She has participated in the New England Intercollegiate Geological Conference since 2005. She mentored two undergraduate students as field assistants, and later their senior theses, at Indiana University; both students presented results at GSA meetings.



### Student: Ellyse Powers

Ellyse is currently a senior in Earth Science Adolescence Education at SUNY Oneonta, and expects to graduate in spring of 2012. She will enter our graduate program in the Fall of 2012 as a Master's student. This research would form the core of her Master's study. Ellyse's completed undergraduate coursework (shown in Table 2) includes field and laboratory courses that will support field-based petrologic observations. Ellyse plans to complement her research during her MS with advanced petrology and structural geology studies that will enable her to successfully complete her research agenda. In addition to her course work, Ellyse presented two very successful undergraduate research endeavors at regional and national conferences.

Ellyse is the brightest student in the SUNY Oneonta Earth & Atmospheric Sciences Department. Her untarnished 4.0 GPA and her ability to challenge herself to achieve beyond expectations make her a prime candidate for Master's work in mapping and field geology. It is the opinion of the faculty mentor that Ellyse would surpass the expectations for the research outlined in this proposal.

*Table 2. Student's Completed Geology Coursework and Research*

| <b>Course</b>                                                                                                                                                                                                                                             |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Anza Borrego Geology Field Trip                                                                                                                                                                                                                           |
| Earth Materials                                                                                                                                                                                                                                           |
| Hydrogeology                                                                                                                                                                                                                                              |
| Earth History and the Fossil Record                                                                                                                                                                                                                       |
| <b>Undergraduate Research</b>                                                                                                                                                                                                                             |
| Lyell Rides Again in Upstate New York: A Pedagogical Virtual Expedition to Explore the Past Based on Modern Fluvial Processes and Deposits. Anna Downey, Ellyse Powers, and Leslie Hasbargen. <i>GSA Abstracts with Programs</i> , Vol. 43, No. 5, p. 476 |
| Counteracting Student Misconceptions Regarding Formation of Sedimentary Rocks. Colleen Rappa, Cailey Wood, Ellyse Powers, Anna Downey and Jim Ebert. <i>GSA Abstracts with Programs</i> , Vol. 43, No. 1, p. 146                                          |

### Other Support

To supplement EDMAP funding, the proposed student researcher will apply for a Billings Fund grant through the New England Intercollegiate Geological Conference for her field work component. The PI will apply for a Faculty Research and Creative Activities grant through SUNY Oneonta. Should these grant proposals be funded, the budget for this grant proposal will be modified.

## **References Cited**

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**ATTACHMENT B**

University: State University of New York College at Oneonta (SUNY Oneonta)  
The Research Foundation of SUNY (applicant) for SUNY Oneonta

Proposal Short Title: Cont. of Bedrock Geologic Mapping of Matinicus Quadrangle

**National Cooperative Geologic Mapping Program  
 Educational Geologic Mapping Program Element  
Proposed Total Budget**

**(revised 3/26/2012)**

Note: Must include totals of all requests for MS and PhD funded students from a University or College.

| Budget Category                                                                                                                                                                                                  | Amount Requested | Proposed University Amount |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------|----------------------------|
| <b>SALARIES:</b>                                                                                                                                                                                                 |                  |                            |
| <i>Graduate Student – Ellyse Powers<br/>(fellowship: equivalent to 250 hours @ \$14/hour)</i>                                                                                                                    | \$3,500.00       | \$0                        |
| <i>Faculty Supervisor – Martha Growdon<br/>(six weeks' summer salary equivalent)</i>                                                                                                                             | \$0              | ████████                   |
| <b>Total Salaries:</b>                                                                                                                                                                                           | \$3,500.00       | ████████                   |
| <b>FRINGE BENEFITS:</b>                                                                                                                                                                                          |                  |                            |
| Supported by negotiated rate agreement check one:<br>(X)yes ( )no [50.16% NYS rate for faculty salary cost share]                                                                                                | \$0              | ████████                   |
| <b>Total Fringes:</b>                                                                                                                                                                                            | \$0              | ████████                   |
| <b>FIELD EXPENSES</b>                                                                                                                                                                                            |                  |                            |
| <i>Per Diem – 2 people x 20 days x \$46 (standard Maine meals &amp; incidental expenses CONUS rate); NOTE: lodging will be provided pro bono by an Island resident, and therefore no costs will be incurred.</i> | \$1,840.00       | \$0                        |
| <i>Vehicle cost – Round trip charter ferry from Rockport to Matinicus Island (4 x \$55/way)</i>                                                                                                                  | \$220.00         | \$0                        |
| <i>Vehicle cost – Round trip charter service – Matinicus Rock</i>                                                                                                                                                | \$400.00         | \$0                        |
| <i>Vehicle cost – Round trip charter service – Seal Island</i>                                                                                                                                                   | \$500.00         | \$0                        |
| <i>Mileage – 867 miles round trip (Oneonta, NY to Rockport, ME) x \$.555/mile</i>                                                                                                                                | \$481.19         | \$0                        |
| <b>Total Field Expenses</b>                                                                                                                                                                                      | \$3,441.19       | \$0                        |
| <b>MISCELLANEOUS SUPPLIES</b>                                                                                                                                                                                    |                  |                            |
| <i>Office and laboratory supplies (itemize)</i>                                                                                                                                                                  | \$0              | \$0                        |
| <i>Other – External thin section preparation (40 samples x \$32 per sample)</i>                                                                                                                                  | \$1,280.00       | \$0                        |
| <b>Total Miscellaneous Supplies</b>                                                                                                                                                                              | \$1,280.00       | \$0                        |
| <b>Total Direct Cost</b>                                                                                                                                                                                         | \$8,221.19       | ████████                   |
| <b>Indirect Cost (18%)*</b>                                                                                                                                                                                      | \$1,479.81       | ████████                   |
| <b>Uncollected Indirect Cost</b>                                                                                                                                                                                 | \$0              | \$0                        |
| <b>TOTALS</b>                                                                                                                                                                                                    | \$9,701.00       | ████████                   |

\*Not to exceed 18%