2010-2011 PROJECTS

FORMATION OF BASEMENT-INVOLVED FORELAND ARCHES: INTEGRATED STRUCTURAL AND SEISMOLOGICAL RESEARCH IN THE BIGHORN MOUNTAINS, WYOMING
Faculty: CHRISTINE SIDDOWAY, MEGAN ANDERSON, Colorado College, ERIC ERSLEV, University of Wyoming
Students: MOLLY CHAMBERLIN, Texas A&M University, ELIZABETH DALLEY, Oberlin College, JOHN SPENCE HORNBUCKLE III, Washington and Lee University, BRYAN MCKEE, Lafayette College, DAVID OAKLEY, Williams College, DREW C. THAYER, Colorado College, CHAD TREXLER, Whitman College, TRIANA N. UFRET, University of Puerto Rico, BRENNAN YOUNG, Utah State University.

EXPLORING THE PROTEROZOIC BIG SKY OROGENY IN SOUTHWEST MONTANA
Faculty: TEKKA A. HARMS, JOHN T. CHENEY, Amherst College, JOHN BRADY, Smith College
Students: JESSE DAVENPORT, College of Wooster, KRISTINA DOYLE, Amherst College, B. PARKER HAYNES, University of North Carolina - Chapel Hill, DANIELLE LERNER, Mount Holyoke College, CALEB O. LUCY, Williams College, ALIANORA WALKER, Smith College.

INTERDISCIPLINARY STUDIES IN THE CRITICAL ZONE, BOULDER CREEK CATCHMENT, FRONT RANGE, COLORADO
Faculty: DAVID P. DETHIER, Williams College, WILL OUMET, University of Connecticut
Students: ERIN CAMP, Amherst College, EVAN N. DETHIER, Williams College, HAYLEY CORSON-RIKERT, Wesleyan University, KEITH M. KANTACK, Williams College, ELLEN M. MALEY, Smith College, JAMES A. MCCARTHY, Williams College, COREY SHIRCLIFF, Beloit College, KATHLEEN WARRELL, Georgia Tech University, CIANNA E. WYSHNYSZKY, Amherst College.

SEDIMENT DYNAMICS & ENVIRONMENTS IN THE LOWER CONNECTICUT RIVER
Faculty: SUZANNE O’CONNELL, Wesleyan University
Students: LYNN M. GEIGER, Wellesley College, KARA JACOBACCI, University of Massachusetts (Amherst), GABRIEL ROMERO, Pomona College.

GEOMORPHIC AND PALEOENVIRONMENTAL CHANGE IN GLACIER NATIONAL PARK, MONTANA, U.S.A.
Faculty: KELLY MACGREGOR, Macalester College, CATHERINE RIHIKIMAKI, Drew University, AMY MYRBO, LacCore Lab, University of Minnesota, KRISTINA BRADY, LacCore Lab, University of Minnesota
Students: HANNAH BOURNE, Wesleyan University, JONATHAN GRIFFITH, Union College, JACQUELINE KUTVIRT, Macalester College, EMMA LOCATELLI, Macalester College, SARAH MATTESON, Bryn Mawr College, PERRY ODDO, Franklin and Marshall College, CLARK BRUNSON SIMCOE, Washington and Lee University.

GEOLOGIC, GEOMORPHIC, AND ENVIRONMENTAL CHANGE AT THE NORTHERN TERMINATION OF THE LAKE HÖVSGÖL RIFT, MONGOLIA
Faculty: KARL W. WEGMANN, North Carolina State University, TSALMAN AMGAA, Mongolian University of Science and Technology, KURT L. FRANKEL, Georgia Institute of Technology, ANDREW P. deWET, Franklin & Marshall College, AMGALAN BAYASAGALN, Mongolian University of Science and Technology.
Students: BRIANA BERKOWITZ, Beloit College, DAENA CHARLES, Union College, MELLISSA CROSS, Colgate University, JOHN MICHAELS, North Carolina State University, ERDENEBAATAR TSAGAANNARAN, Mongolian University of Science and Technology, BATTTOGTOH DAMDINSUREN, Mongolian University of Science and Technology, DANIEL ROTHBERG, Colorado College, ESUGEI GANBOLD, ARANZAL ERDENE, Mongolian University of Science and Technology, AFSHAN SHAIKH, Georgia Institute of Technology, KRISTIN TADDEI, Franklin and Marshall College, GABRIELLE VANCE, Whitman College, ANDREW ZUZA, Cornell University.

LATE PLEISTOCENE EDIFICE FAILURE AND SECTOR COLLAPSE OF VOLCÁN BARÚ, PANAMA
Faculty: THOMAS GARDNER, Trinity University, KRISTIN MORELL, Penn State University
Students: SHANNON BRADY, Union College. LOGAN SCHUMACHER, Pomona College, HANNAH ZELLNER, Trinity University.

KECK SIERRA: MAGMA-WALLROCK INTERACTIONS IN THE SEQUOIA REGION
Faculty: JADE STAR LACKEY, Pomona College, STACI L. LOEWY, California State University-Bakersfield
Students: MARY BADAME, Oberlin College, MEGAN D’ERRICO, Trinity University, STANLEY HENSLEY, California State University, Bakersfield, JULIA HOLLAND, Trinity University, JESSLYN STARNES, Denison University, JULIANNE M. WALLAN, Colgate University.

EOCENE TECTONIC EVOLUTION OF THE TETONS-ABSORA RANGES, WYOMING
Faculty: JOHN CRADDOCK, Macalester College, DAVE MALONE, Illinois State University
Students: JESSE GEARY, Macalester College, KATHERINE KRAVITZ, Smith College, RAY MCGAUGHEY, Carleton College.

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EXPLORING THE PROTEROZOIC BIG SKY OROGENY IN SOUTHWEST MONTANA
Project Faculty: TEKLA A. HARMS, JOHN T. CHENEY, Amherst College, JOHN BRADY, Smith College

PROTOLITH DETERMINATION OF PRECAMBRIAN MYLONITIC ROCKS ADJACENT TO THE MADISON MYLONITE ZONE, HENRYS LAKE MOUNTAINS, SOUTHWEST MONTANA AND IDAHO
JESSE DAVENPORT, College of Wooster
Research Advisor: Shelley Judge

PETROGRAPHIC AND GEOTHERMOBAROMETRIC ANALYSES OF METASEDIMENTARY ROCKS IN THE HENRYS LAKE MOUNTAINS, IDAHO AND MONTANA
KRISTINA DOYLE, Amherst College
Research Advisor: Tekla Harms

GEOCHRONOLOGY OF PRECAMBRIAN META-GABBRO IN THE HENRYS LAKE MOUNTAINS, SOUTHWEST MONTANA AND IDAHO
B. PARKER HAYNES, University of North Carolina - Chapel Hill
Research Advisor: Drew S. Coleman

PETROGENESIS AND DEFORMATION OF PRECAMBRIAN QTZ-DOL MARBLE UNITS IN THE GRAVELLY RANGE AND REYNOLDS PASS, HENRYS LAKE MTNS, SW MT AND ID
DANIELLE LERNER, Mount Holyoke College
Research Advisor: Steve Dunn and Michelle Markley

PETROGENESIS OF PRECAMBRIAN IGNEOUS AND META-IGNEOUS ROCKS SOUTH OF THE MADISON MYLONITE ZONE, HENRYS LAKE MOUNTAINS, SW MONTANA AND IDAHO
CALEB O. LUCY, Williams College
Research Advisor: Reinhard A. Wobus

STRUCTURAL ANALYSIS OF PRECAMBRIAN MYLONITE ZONES, HENRYS LAKE MOUNTAIN, SOUTHWEST MONTANA AND IDAHO
ALIANORA WALKER, Smith College
Research Advisor: H. Robert Burger
PETROGENESIS AND DEFORMATION OF PRECAMBRIAN QTZ-DOL MARBLE UNITS IN THE GRAVELLY RANGE AND RAYNOLDS PASS, HENRY'S LAKE MTNS, SW MT AND ID

DANIELLE LERNER, Mount Holyoke College
Research Advisors: Steve Dunn and Michelle Markley

INTRODUCTION

My area of study is in the southernmost Gravelly Range and in the Raynolds Pass area, located in the Henrys Lake Mountains, on the border of Southwest Montana and Idaho. As seen in the geologic map in Figure 1, marble is one of the most extensive units making up the study area. This differentiates the study area from most of the other areas in the Wyoming province. By studying structural data assembled from marble outcrops, the petrography of marble samples, calcite-dolomite geothermometry, as well as carbon and oxygen isotope data for selected marble samples, we may better understand what events took place during the Big Sky orogeny that led to the formation of marble.

DESCRIPTIONS

Marble in the study area generally consist of fine-grained quartz-bearing dolomites, with disseminated calcite in some regions. Marble rich in tremolite + calcite occurs in two localities (locations 4 and 11 in Fig. 1). Quartz layers and banding are very common within the dolomite unit, ranging from 0.5mm to 12.5cm thick. Quartz layers in outcrop are dark grey to purple in color, and appear either waxy or shiny. Dolomite layers range from 0.5mm to almost 1m thick and look either sugary or dull with a smooth surface. Weathered dolomite tends to be a variable light to dark grey, brown, and/or tan. The dolomite unit commonly exhibits folding of siliceous layers (Fig. 2c and 3b).

METHODS

Structural data were collected in the field wherever folds were seen, using a brunton compass to measure...
at Mount Holyoke College, which is equipped with an Edax Genesis X-Ray Detector System. Mineral analyses were done with a dead time of 30-40%, an amp time of 100 micro seconds, count rate between 1000-2000 counts per second, and a counting time of approximately 100-200 live seconds. Stable isotope analyses were obtained on the automated carbonate device at the University of Massachusetts Amherst in the Department of Geosciences.

**RESULTS**

Petrography and SEM analyses establish that mineral assemblages in marble samples vary from outcrop to outcrop, but the majority consist of dolomite and quartz with minor calcite and muscovite or phlogopite. Other less common accessory minerals found in some samples are one or more of the following: tremolite, talc, chlorite, potassium feldspar, pyrite, goethite after pyrite, graphite, hematite, magnetite, pyrrhotite, and sphalerite. Grain sizes in thin sections range from 5 to 250 microns in length.

Calcite-dolomite geothermometry was applied to seven samples taken from five locations throughout the study area that contained both dolomite and...
calcite. The formulation of Anovitz and Essene (1987) was used and the reported results rounded to the nearest 5°C (Figs. 1 and 5). The absolute uncertainty in the temperature calculation is conceivably around 50°C, but the relative uncertainty is likely to be about +/- 25°C. The Mg content of calcite was measured in 0.01 increments and varies from ~0.01 to ~0.08 X(Mg). Figure 5 shows examples of the X-ray spectra collected on the SEM. The calcite in sample DL10-11b has a lower Mg than sample DL10-4d, thus giving an overall lower temperature (Fig. 5). For most samples, the Mg content of multiple calcite grains was averaged to give the final calculated temperature. Station 4 (the furthest east) has the overall hottest temperature at 625°C, while stations 19 and 25 (in the central and western parts of the study area) gave the overall lowest temperatures at about 200°C.

Analyses of tremolite in samples DL10-11b and DL10-4d showed compositions to be essentially end-member tremolite with very little Fe and Al and no measurable Na. Also, chlorite in sample DL10-04c was analyzed and found to be Al-rich with high Mg/Fe, apparently Al-clinochlore variety.

Results of the structural analysis show that layering generally strikes NNE-SSW but shows a full range of dips (Fig. 4a). Fold axes are scattered but generally trend NNE and plunge shallowly to moderately, or they trend SW and plunge moderately.

The stable isotope results show very little variation in δ¹³C‰ values of dolomite samples, from −0.01 to −3.51‰ (Fig. 2). Oxygen isotope values show greater variation with δ¹⁸O values ranging from 14.47 to 22.61‰. The three types of samples analyzed for isotopic data were dol + qtz; dol + qtz + cal; and dol + qtz + cal + tr (Fig. 2).

**DISCUSSION**

The majority of samples taken from throughout the marble units consist of fine-grained dolomite with a variable amount of fine-grained quartz (Fig. 4c). Peak metamorphic temperatures were significantly higher at station 4 (~625°C), located northeast of Henrys Lake, than other areas in this study (Fig. 1b). This location also has abundant tremolite + calcite, which is consistent with higher temperatures relative to dolomite + quartz which are more typical elsewhere in the study area. The only other location with tremolite + calcite, location 11, also gives elevated temperatures of ~490°C, which is higher than other temperature estimates west of Henrys Lake.

Stable isotope data (Fig. 2d) show little variation in δ¹³C‰ values, except for tremolite-bearing samples, which have lower δ¹³C‰ values. The tremolite-forming reaction, 5Dol + 8Qtz + H₂O → Tr + 3Cc + 7CO₂, shows that as tremolite forms, CO₂ is driven off, lowering the δ¹³C‰ value of the rock. CO₂ essentially leaves the rock, taking the heavy carbon with it and leaving behind lighter carbon (Valley, 1986; Bowman et al., 1994). Oxygen isotope compositions show a much wider range than what one would expect for a marine limestone formation. The variation in oxygen isotope compositions, however, cannot be explained by only CO₂ removal. A typical decarbonation trend is shown in figure 2 (Valley, 1986). Although the starting point of the decarbonation trend is arbitrary, many of the δ¹⁸O‰ values are too low for the decarbonation trend to apply by itself. The range in δ¹⁸O‰ values most likely reflects exchange with external H₂O-rich fluid of meteoric or seawater origin. It seems likely that this happened during metamorphism or pre-metamorphic diagenesis. Since δ¹⁸O‰ values of some samples fall within the normal marine carbonate range, marbles are most likely derived from typical marine carbonates.

The deposition age of the dolomite units in this study
CONCLUSION

More work is needed in the study region to establish the details of events that took place during the Big Sky orogeny that affected these marble units. However, we now know that tremolite-bearing samples are relatively rare, and that dolomite-quartz assemblages are common. Metamorphic temperature is higher east of Henrys Lake and lower to the west. Tremolite occurrences are associated with higher temperatures. Carbon isotope values in dolomite marble regions show little to no alteration, but oxygen isotopes suggest some kind of alteration event. The tremolite-forming reaction has caused an alteration in carbon and oxygen isotope values explained by the removal of CO2.

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REFERENCES


Doyle, K., 2011, Petrographic and geothermobarometric analysis of mica schists in the Henrys


