25th Annual Five College Geology Undergraduate Student Symposium

Wednesday April 21, 2004
Red Barn, Hampshire College
4:00pm

25th Annual Five College Geology Undergraduate Student Symposium

Kasey Kathan, Mount Holyoke College

Intrabasin Variability of Volcanic Ash Stratigraphy in a Small Kettle Lake, Lorraine Lake, Anchorage, Alaska

Laura Frye-Levine, Smith College

Graphitic Schists of Syros, Greece

Silvia E. Newell, Smith College

Using Stable Isotopes to Characterize Travel History of Precipitation to a Tropical Montane Cloud Forest in Monteverde, Costa Rica

Caitlin R. Chazen, Smith College

Glacial and Post-Glacial development of the Deerfield River Valley

Marian Kramer, Smith College

Geochemical Variation of Enriched Mid-Ocean Ridge Basalts Erupted From a Dying Rift in Northcentral Iceland

Lauren Seidman, Smith College

Experimental Analysis of the Effect of Anisotropy on Kink Fold Formation, Evolution, and Geometry

Anna M. Dustira, Smith College

Ichnology, Sedimentology, and Interpretation of Holocene Stellate and Cluster Burrows and Enigmatic Trace Fossils, San Salvador Island, Bahamas

Tamee R. Albrecht, University of Massachusetts Amherst

Magnetic Signature of the Pennsylvania Piedmont: Origin and Relationship to Deformation and Metamorphic Events

Kendra Clark, Geosciences, University of Massachusetts Amherst

Brittle to Ductile Transitional Structures in the Lower Paleozoic Octararo Formation Below the Holtwood Dam, Susquehanna River, Pennsylvania

Kathleen H. Staffier, Geosciences, University of Massachusetts Amherst

Timing and P-T Conditions of Deformational and Metamorphic Events in Rocks on the Floor of the Susquehanna River, Holtwood, PA

Nick Venti, Department of Geosciences, University of Massachusetts Amherst

Testing an Indonesian Seaway Closure Ocean Circulation Hypothesis: A Neogene Stable Carbon and Oxygen Isotope Study of Foraminifers at ODP Site 1208, Shatsky Rise in the North Pacific

DASHER, S. R. Dept Geology, Amherst College

Quantitative strain analysis of a penetratively deformed domain within the Kootenay Arc, Metaline Falls Quadrangle, Washington.

GITAHI, Njoki W, Department of Geology, Amherst College Pratt Museum

Geochemistry and Evolution of Eclogites on Syros Island, Greece

Martha M. BUCK, Department of Geology, Amherst College

Beecher's Trilobite Bed in the 21st Century: MicroCT analysis of an Ordovician Lagerstätte

Driscoll, J. M. Department of Geology, Amherst College

Acicular Calcite Texture: Aragonite Pseudomorphs on Syros Island, Greece

Andrew D Schneider, Department of Geology, Amherst College

Structural Analysis of the Martin Bridge Limestone, Wallowa terrane, northeastern Oregon

Intrabasin Variability of Volcanic Ash Stratigraphy in a Small Kettle Lake, Lorraine Lake, Anchorage, Alaskantrabasin variability of tephra deposits, Lorraine Lake, Alaska

Kasey Kathan, Mount Holyoke College

Lorraine Lake is a small (0.53 km^2) shallow (ca. 8 m) kettle located on the Elmendorf Moraine (Pleistocene age), 11 km northwest of Anchorage, Alaska. Situated in a region of low relief (49 m), the basin has a small drainage basin (1.3 km^2), no inflow and remains ice covered for approximately six months of the year. This project was initiated to study the volcanic ash fall record preserved in the Holocene lake sediments from this basin, and to document the occurrence of any intrabasinal variability. It was believed that variations in tephra deposition would be significant throughout the lake basin to due processes such as bioturbation or ash deposition on lake ice and blowing snow and that these variations might be enough to impact the completeness of the volcanic ash fall record in a particular basin location.

Six sediment cores between 3.2 and 5.8 m long were recovered from the north, south, east, and west parts of the lake, which is divided into two (north and south) sub-basins. A total of 21 AMS ^{14}C ages were obtained on terrestrial macrofossils and basal ages from three cores are greater than 14,500 cal yr. BP, confirming that the cores contain the entire postglacial sedimentary record. Eleven tephra deposits, ranging from invisible to several centimeters in thickness, are correlated among the cores based on their relative depths and spacing, color, texture, and thickness, high magnetic susceptibility (MS), low loss-on-ignition, X-ray gray scale value, and abundance of magnetic minerals. Although other less prominent tephra units occur, these 11 clearly defined units are used to compare tephra deposition within the lake. Several physical characteristics were compared to evaluate possible intrabasin variability including stratigraphic thickness, and X-ray density stratigraphy. A numerical classification scheme was developed ranking visual and stratigraphic prominence based on thickness, purity of ash and nature (sharpness and continuity) of stratigraphic contacts.

Despite sedimentation rate variations (ranging from 0.69 to 0.29 mm/yr) the physical characteristics (thickness, MS and purity) of the tephra units display minimal variation, with no consistent pattern of variability, between cores recovered from different parts of the basin or different water depths. The stratigraphic prominence of the tephra layers and their similarity between core sites implies that probable depositional complexities (e.g., wind skimming, waves, lake ice, blowing snow) and post-depositional processes (e.g., bioturbation, bathymetric focusing) have a minimal impact on the deposition and preservation of tephra units in small kettle lake similar to Lorraine Lake.

Graphitic Schists of Syros, Greece

Laura Frye-Levine, Smith College
Sponsor: John Brady

The Cycladic island of Syros, Greece is composed of a sequence of alternating calcareous schists and marbles with scattered metabasaltic belts, all of which have experienced high-pressure metamorphism during the Alpine Orogeny. The rocks show evidence of two metamorphic events. The purpose of this project is to begin an analysis of the metamorphic history and sedimentary protolith (or protoliths) of the graphitic schists that characterize the Northern section of the island.

On the Northern section of the island, massive graphitic schist outcrops are bounded by the eclogite mélange zone to the south, and alternate with the Upper Marble unit. Elsewhere on the island, most graphitic schist samples are calcareous, but exhibit different mineral assemblages from the massive northern units. Twelve thin sections were selected for examination on the basis of location diversity within the northern end as well as on the diversity of metamorphic textures and mineral assemblages.

Assemblages are relatively uniform for samples across the north end of the island. They all include Graphite and Quartz, along with: (Phengite, Albite, Chlorite, Calcite, Pyrite, Titanite), (Garnet, Phengite, Glaucophane, Titanite, Clinozoisite), (Phengite, Garnet, Glaucophane, Chlorite, Graphite, Titanite, Rutile, Tourmaline), or (Calcite, Phengite, Garnet, Glaucophane, Titanite, Chlorite, Clinozoasite, Hematite). The fabric of multiple generations of metamorphic minerals, pseudomorphs, and retrograde reactions results from a complex P-T path. All pseudomorphs show evidence of postdating the main fabric. A pseudomorph of hematite after pyrite seen in one sample indicates a period of high- pressure metamorphism followed by an influx of sulfur bearing fluids (which facilitated pyrite growth) and a subsequent event of oxidizing conditions that replaced pyrite with hematite. This pseudomorph indicates a high-temperature, low-pressure prograde decompression due to tectonic uplift.

Geothermobarometric calculations were preformed based on solid-state reactions occurring independently of fluid partial pressures. Two feasible temperatures were obtained from these calculations, 397.1ºC, and 400.3º C, both from the same sample.

Based on the assemblage similarities of the examined samples, it is likely that the graphitic schists of Syros north of the north-end mélange zone derive from a single sedimentary protolith, with current mineral differences due to varied P/T path conditions. Both the prograde and retrograde metamorphic history for this unit is decidedly complex, with textures varying at different localities. Interesting textures include multiple generations of high-pressure metamorphic minerals of blueschist as well as greenschist facies within the same rock. Blueschist facies minerals present include Glaucophane as well as (pseudomorphs after) what is assumed to be primary Lawsonite. Greenschist faces minerals include Chlorite and Albite. Also of interest are garnets contained within lawsonite pseudomorphs.

Further work should include more thorough analysis of the graphitic schists to the south of the north-end mélange zone for comparison with the Northern unit, as well as detailed chemical zoning analysis and accurate geothermobarometry for a greater number of samples.

Using Stable Isotopes to Characterize Travel History of Precipitation to a Tropical Montane Cloud Forest in Monteverde, Costa Rica

[1]Silvia E. Newell, [1]Amy L. Rhodes, and [2]Andrew J. Guswa

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The purpose of this project is to use stable isotope tracers to improve understanding of water movement through the tropical montane cloud forest in the Rio Guacimal Watershed in Monteverde, Costa Rica. The primary focus was creating for the first time a record of the characteristic isotopic compositions precipitation in Monteverde and using those isotope values to describe the sources of water input to the system. Isotope tracers are useful tools to characterize the length travel history of storms that enter the Monteverde region. With this method, Intertropical Convergence Zone-related precipitation from the Caribbean is easily distinguished from orograohic uplift-related precipitation. During the wet season, the precipitation values are lighter (δ^2H of –96 to –15‰ and $\delta^{18}O$ of –13.2 to –15.0‰) than in the transitional and dry seasons (δ^2H of –16 to +6‰ and $\delta^{18}O$ of –4.3 to –1.9‰), corresponding to the expected value ranges of storms with a longer travel history and a first-stage condensate, respectively. Understanding the precipitation input to the hydrologic budget is critical for assessing the impacts of global climate change on the Monteverde region, as recent studies have shown that overall precipitation is decreasing (Vargas and Trejos 1994) and the elevation of cloud formation is rising (Lawton 2001). Alterations in the cloud and precipitation input to Monteverde could have a devastating impact on the prized Monteverde Cloud Forest Preserve, not only of great ecological importance, but great economic importance, being the major ecotourism draw for the region.

Glacial and Post-Glacial development of the Deerfield River Valley

Caitlin R. Chazen, and Robert M. Newton, Smith College

Why does the Deerfield River flow north before entering the south-flowing Connecticut River? The key to addressing this question lies in examining the features and sediments within a 20 square kilometer area near Historic Deerfield, MA. To investigate this region, 32 core samples were taken with a 3" bucket auger. Twenty-one of these samples were analyzed for bulk weight and grain size. Each of these sample sites were recorded using GIS equipment, creating a detailed surficial map of the Deerfield region used to reconstruct the glacial and post-glacial history of the Deerfield region. This area was inundated by glacial Lake Hitchcock which formed as the last continental ice sheet retreated from the region. As ice retreated from the Connecticut River Valley region the ice front experienced a pause near Old Deerfield. Meltwater streams emerging from the base of the ice built a subaqueous fan at the ice front into Lake Hitchcock. The Deerfield River entered the lake at the ice margin adding sufficient sediment to build a small delta adjacent to the ice. As the lake drained, the subaqueous fan and delta complex prevented the Deerfield River from flowing south, creating a lake in the Old Deerfield basin. The failure of the natural dam near Rocky Hill Connecticut led to rapid drainage of Lake Hitchcock. As the lake drained, the subaqueous fan and delta complex prevented the Deerfield River from flowing south, creating a lake in the old Deerfield basin. The forest-topset contact of this delta indicates a lake level of approximately 66m, suggesting that the southern wall of sediment was the primary control of lake level. In order for this to have occurred there must have been some obstruction in the southern portion of old Deerfield, preventing the water from draining to the south. One explanation is that at the time of Lake Deerfield there was no bedrock spillway that was low enough to facilitate drainage. Curiously, the notch through the Potumkut range (where the current path of the Deerfield River runs) appears to be cut at a lower elevation than that of Lake Deerfield. To account for both the lake level and flow direction, I propose that a tongue of ice was still present in the bars region during the formation of Lake Deerfield. This sequence would then suggest that the failure of the Rocky Hill dam occurred before ice had entirely left the Deerfield region, and that glacial sediments found further north are the result of post-Hitchcock glacial lakes. After the icefront had entirely left the valley, Lake Deerfield drained through the Pocumtuck Range. Unlike the nearly catastrophic drainage of Lake Hitchcock, Lake Deerfield drained gradually as water continually cut down through the bedrock spillway adjoining the Deerfield Valley and Connecticut River Valley. As the lake drained, the Deerfield River cut into deltaic and lake sediments. The multitude of point bars, oxbows, and abandoned river terraces suggests that the migration of the Deerfield River has been complex and multifaceted.

Geochemical Variation of Enriched Mid-Ocean Ridge Basalts Erupted From a Dying Rift in Northcentral Iceland

Marian Kramer, Smith College
Advisor: Mark Brandriss

The purpose of this study is to analyze the petrographic and chemical characteristics of basalts erupted from a dying rift adjacent to a hot spot. Iceland is an ideal location to study mid-ocean ridge dynamics as well the interactions between tectonic rift volcanism and hot spot volcanism due to the anomalous exposure of the Mid-Atlantic Ridge on land and the presence of a hot spot. The hot spot is believed to be a mantle plume, superimposed on the active Mid-Atlantic Ridge. The Mid-Atlantic Ridge in Iceland undergoes rift relocation events due to the interplay between the northwest drift of the rift axis and the hot spot, currently located under the Vatnajokull Ice Cap (Tronnes, 2002). These rift relocation events occur at intervals of 8-12 million years (Hardarson et al., 1997). The rift relocation event that corresponds to abandonment of the major rift in the area of the Skagi peninsula (the rift responsible for most volcanism in the study region) occurred at 7 Ma (Tronnes, 2001). As a result of rift relocation, Iceland contains valuable evidence of the chemical variation of magmas associated with the life of a rift from its inception to its extinction.

Mapping and sampling of the field area revealed three main units based on mineralogical distinctions: B_2 consists of plagioclase ($\pm$ augite and olivine) phyric volcanic flows, $B_{1.5}$ consists of olivine phyric volcanic flows, and B_1 consists of aphanitic volcanic flows. The youngest flow is 7.08 + 0.06 million years old (Ma), very close to the time at which the main rift in the Skagi area went extinct (Tronnes, 2001).

Lavas from the project area are basalts, and show trace element enrichment in a pattern typical of enriched mid-ocean ridge basalts (EMORB) (Sun & McDonough, 1989). Whole-rock geochemical analyses have revealed that $B_{1.5}$ is a relatively primitive magma derived from a different source than B_1 and B_2. Furthermore, Zr/Nb ratios suggest that there was not a significant change in magma sources during the life of the rift, and no apparent influx of depleted North Atlantic NMORB material during the final stages of rift magmatism. These results indicate no apparent trend in changing magma sources during the life of Icelandic rifts.

Experimental Analysis of the Effect of Anisotropy on Kink Fold Formation, Evolution, and Geometry

Lauren Seidman, Smith College

The focus of this investigation is to experimentally stimulate layer anisotropies of varying thickness and stacking geometry in order to research the development of kink folds. A series of experiments were conducted using lateral load pressures of 500 PSI and 1000 PSI to deform stacks of index cards. The resulting kink fold formation, evolution, and geometry were qualitatively and quantitatively analyzed. The thicker, anisotropic layers control the formation, evolution, and geometry of the thinner, surrounding layers. The zone of contact strain around the more competent layers force the layers around them to conform.

Ichnology, Sedimentology, and Interpretation of Holocene Stellate and Cluster Burrows and Enigmatic Trace Fossils, San Salvador Island, Bahamas

Anna M. Dustira, Smith College
Faculty Sponsor: H. Allen Curran

Trace fossils are a common and important component of many of the Quaternary carbonate rocks on San Salvador Island. A surficial Pleistocene/Holocene boundary paleosol horizon at Singer Bar Point contains numerous well-preserved, unidentified structures that resemble trace fossils. The origin of these enigmatic structures could be by plant activity, by animal activity, or something yet unknown. Two plausible but very different explanations are dissolution of the paleosol by roots penetrating downward from the overlying eolianite, or by the activity of snail locomotion.

Holocene eolianites on San Salvador have a distinctive trace fossil assemblage. The two most distinctive burrow types, stellate and cluster, are large in site, distribution, in architecture, and likely represent reproductive activity by their tracemakers. At Hanna Bay abundant, well-preserved trace fossils of both types can be found in the eolianite cliffs. Stellate burrows are believed to have been created by a species of sweat bee (*Halictidae*). The number of individual cells indicates that the bees probably lived together in large numbers, although this does not necessarily indicate that they were entirely social. The large cluster burrows were probably formed by sphecid wasps. Because there are so many individual shafts congregated together in one area, the wasps were most likely at least tolerant of each other, although exact degrees of sociability cannot be determined from nest size alone. Both tracemaker insects are probably still in existence today. Their nests, preserved in these young Holocene eolianites, could potentially provide insight into the social behavior of the modern insects.

Magnetic Signature of the Pennsylvania Piedmont: Origin and Relationship to Deformation and Metamorphic Events

Tamee R. Albrecht, Laurie L. Brown, Donald U. Wise, University of Massachusetts Amherst

The Appalachian Piedmont in southeastern Pennsylvania exhibits a linear, but wavy contour pattern on aeromagnetic maps. Strong positive anomalies occur over some areas of multiply deformed schists of the Octoraro Formation. Aeromagnetic measurements show variation over 1200 nT from the average value of the magnetic field. In the 1x3 km field area, a dramatic range (10^{-4}-10^{-1}) of magnetic susceptibilities was recorded. Irregular patterns of magnetic susceptibility cut across lithologic and structural fabrics, locally with boundaries at decimeter-scale. However, on a regional scale, magnetic susceptibility roughly correlates with the geologic unit; the Tucquan Creek member has high susceptibility, but the Stewart's Run member is low. Rock magnetic studies show low natural remanent magnetism intensities; 90% of cores are under 0.2 A/m, suggesting the anomalies are produced primarily by induced magnetization. In hand sample, magnetite grains are as large as 1 cm in diameter. Thin section analysis reveals two main oxide phases, magnetite and ilmenite. Magnetite occurs as homogeneous, subhedral grains. Because the S_2 fabric bends around the grains, and some have beards of quartz or chlorite, magnetite is a syn-S_2 growth. Susceptibility shows a direct relation to the amount of magnetite in the rock. Ilmenite occurs as laths or "wormy" grains with rutile and/or hematite exsolution. Most ilmenite is flattened and folded with the S_2 fabric as a pre-S_2 phase. The oxide assemblage, and therefore the magnetic susceptibility, varies throughout the area due to the movement of hydrothermal fluids, broadly correlating with, but not restricted to the Tucquan Creek member.

Brittle to Ductile Transitional Structures in the Lower Paleozoic Octararo Formation Below the Holtwood Dam, Susquehanna River, Pennsylvania

Kendra Clark and Donald U. Wise, Geosciences, University of Massachusetts Amherst

Structures spanning the brittle-ductile transition occur in lower garnet-grade metamorphic rocks of the early Paleozoic Octararo Formation in a 3-km^2 exposure on the floor of the Susquehanna River below Holtwood Dam, PA. An early schistosity (S1) is associated with mica development. A second schistosity (S2) is sub-parallel to S1 and forms the dominant N40-60W, 10-30 S foliation. S2 is associated with albite porphyroblast development and the release of excess silica as pervasive quartz stringers. Both these probable Taconian age structures involved almost purely ductile deformation. A spaced cleavage (S3) involving flexing of the micas and minor recrystallization is pervasively developed and locally passes into a well-developed fold set (F3) with several decimeter wavelengths and 1:1wavelength/ amplitude ratios. The N40E, 80S orientation of S3, asymmetry of the folds, and association with the Tucquan antiform suggest NW transport origin during the Alleghanian orogeny. Intensity of development of these structures seems to follow 100-200 m thick packages of S2 schistosity suggesting localization of younger ductile strain by older anisotropy. The best brittle-ductile transition appears in an outcrop of quartz veins on a bluff beneath power pylons on the west side of the river, 1 km below the dam. At higher elevations, N30E, 80 SE en echelon veins are sub-parallel with local S3 foliation and indicate injection under brittle conditions but pass downward into blunted ductile structures and F3 folds superimposed on S2 planes. The veins appear to have acted as a buttress for compression in the last stages of F3 folding. They indicate massive pumping of fluids through spaces developing during S3 time. In addition, completely brittle features overprint all the riverbed exposures. An enigmatic but widespread set of N80W macrojoints exposes surfaces up to 10x150 m below Norman Wood bridge. Average dips are 50S but locally as low as 25^o. A poorly developed conjugate set at N80W, 50S suggests a compressive origin but with no indication of shear movement. Other prominent joint sets and domains evident in aerial photographs are difficult to separate age-wise in outcrop but seem to carry over into areas of low exposure in the adjacent hills. Current work is focused on defining and constraining F3 events within the ductile -brittle transition.

Timing and P-T Conditions of Deformational and Metamorphic Events in Rocks on the Floor of the Susquehanna River, Holtwood, PA

Kathleen H. Staffier, Donald U. Wise, and Michael L. Williams, Geosciences, University of Massachusetts Amherst

Paleozoic rocks of SE PA preserve multiple deformation fabrics and garnet-grade assemblages. However, the timing of the events and their correlation with regional orogenic events is currently uncertain. Garnet grade pelitic schists of the early Paleozoic Octoraro formation are 80-90% exposed in a 3 km^2 exposure below the Holtwood Dam on the lower Susquehanna River in Pennsylvania. The stratigraphy progresses from greenstone volcanics (oldest) under the dam apron through garnet and magnetite bearing schists with abundant quartz layers along foliation, to sulfidic schists below the Norman Wood Bridge to quartz and feldspathic schists beyond the bridge. In the central part of the area garnet grains up to 5 mm in diameter locally form crystal clots up to 5 cm, possibly as a result of hydrothermal alteration of aluminum-rich volcanic clasts associated with the greenstone volcanics. Inclusion trails in large plagioclase porphyroblasts preserve at least three distinct deformational fabrics with only the later two preserved in the matrix. Aligned ilmenite and tourmaline inclusions define an early layering ($S_{1)}$, which is spectacularly crenulated by two later foliations, all within the undeformed albite porphyroblasts. Pervasive quartz stringers, residual from metamorphic reactions, define S_1 in outcrop, and regional relationships suggest correlation of this D1 event with the Taconian (~ 450 Ma) orogeny. The dominant schistosity (S_2), possibly of Taconian age as well, is subparallel to S_1 and trends generally east-west with a northwest vergeance. Superimposed is a widespread, steeply southeast-dipping spaced cleavage (S_3) of probable Alleghanian age (~325-265 Ma) with associated local, well-defined F_3 folds. This deformational event reactivated and rotated S_2 and created space for the deposition of large bull quartz veins by hydrothermal fluids, suggesting cooling of the rocks (exhumation?) from ductile to brittle conditions during deformation. Microprobe analyses are currently underway to constrain the P-T conditions and absolute timing of each deformational event. It is hoped that these superbly exposed rocks can provide a high-resolution P-T-D-t path that can be correlated with other exposures around the region.

Testing an Indonesian Seaway Closure Ocean Circulation Hypothesis: A Neogene Stable Carbon and Oxygen Isotope Study of Foraminifers at ODP Site 1208, Shatsky Rise in the North Pacific

Nick Venti and Mark Leckie, Department of Geosciences, University of Massachusetts Amherst

While the Indonesian Seaway was closing from 15 Ma to 4 Ma, the North Pacific subtropical gyre tightened and its associated currents intensified. The Kuroshio Current is the strong Western Boundary current of the North Pacific subtropical gyre. Today, it flows over Shatsky Rise some 1000 km east of Japan. Foraminifera should record the influence of changing water masses at ODP Site 1208 on Shatsky Rise as North Pacific surface circulation evolved during middle to late Miocene time. I collected planktic and benthic foraminifera from marine sediment cored at Site 1208 and analyzed multiple planktic and benthic species for stable oxygen and carbon isotopes at an approximate sample resolution of 300,000 years from 15 Ma to 4 Ma.

Oxygen isotope data in benthic foraminifera indicate slow cooling and/or increased ice volume throughout the study interval. Oxygen isotope data in planktic species indicate a similar rate of cooling and/or increasing ice volume ~14 Ma to ~6.5 Ma. A shift toward heavy oxygen isotopes in planktic foraminifers indicates cooling in the upper water column from ~6.5 to ~4.5 Ma. Both planktic and benthic species show similar slow rates of increasing light carbon that might indicate a global exhumation of organic carbon. A stable surface to benthic carbon isotope gradient indicates steady productivity from ~14 Ma to ~8 Ma. Productivity shows increased variability after 8 Ma, presumably in response to changing climate and/or ocean circulation. Planktic foraminiferal assemblage data indicate a shift toward cooler waters over ODP Site 1208 during the study interval.

Quantitative strain analysis of a penetratively deformed domain within the Kootenay Arc, Metaline Falls Quadrangle, Washington.

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Deformed trilobites have been used to quantify strain in an outcrop of penetratively deformed limestone and mudstone within the Cambrian Metaline Formation of northeastern Washington. The study site is a quarry outside of Metaline Falls, Washington, in the southern part of the Kootenay Arc, an arcuate belt of metasedimentary rocks in British Columbia and northern Washington deformed during the late Jurassic to Tertiary Laramide and Sevier orogenies.

A best-fit finite strain ellipse for the plane of bedding in the outcrop was calculated using each of two analytical techniques (the Wellman method and the Breddin method). Principal strain axes were determined as $\lambda 1 = 228/30$ and $\lambda 2 = 322/18$, with an aspect ratio of 1.4. These finite strain ellipses were assessed for compatibility with previously calculated finite strain ellipsoids for a nearby outcrop (Stewart, 1996; Whitling, 1999). The principal axes of the finite strain ellipse defined by this study were found to be subparallel to those of ellipses of ellipses of the same orientation within the ellipsoid determined by Stewart (1996); however, the aspect ratio was found to be much lower.

Ultimately, these results may constrain extrapolation from outcrop-scale strain ellipses or ellipsoids to the regional deformation in the Kootenay Arc. Finite strain has been well constrained in the contemporaneous Rocky Mountain fold and thrust belt east of the Kootenay Arc, where shortening was accommodated principally along discrete faults.

GEOCHEMISTRY AND EVOLUTION OF ECLOGITES ON SYROS ISLAND, GREECE.

GITAHI, Njoki W., CHENEY, John T., Department of Geology, Pratt Museum, Amherst MA,

The Cycladic island of Syros is part of a high-pressure blueschist-facies metamorphic belt in the Attic-Cyladic crystalline complex of the Aegean that is regarded as the relic of an extinct subduction zone that resulted from the convergence of the African and Eurasian plates and the complicated interaction of a number of microplates between them (Smith & Woodcock, 1982). Subduction-related burial associated with the Alpine Orogeny is considered the cause of regional low-temperature, high-pressure blueschist metamorphism, which is manifest on Syros as lithologies transitional between epidote blueschist and eclogite facies. Green schist overprinting during the Oligocene to Miocene, thought to be related to processes of exhumation or fluid infiltration, is observed locally on Syros; it is almost complete at the south end but sporadic in the north (Okrusch & Bröcker, 1990; Bröcker & Enders, 1999).

Syros is composed of north to north-east dipping thrust faulted sheets of alternating marbles, schists and metavolcanics overlain and juxtaposed by complex of diverse blocks of diverse blocks of mafic metaigneous enclosed in a matrix of highly altered serpentinite (Dixon & Ridley, 1987; Okrusch & Bröcker, 1990). This study concerns the mineralogic, textural and chemical investigation of eclogites from mafic complexes along the western coast of Syros for the purpose of characterizing variations in bulk composition, determining protolith character, assessing temperature and pressure variation across the island (using a new method omphacite-garnet-phengite geothermobarometry), and further constraining the pressure and temperature evolution of the Attic-Cycladic subduction complex using the high pressure metamorphic assemblages found on Syros.

Syros eclogites are mostly coarse-grained, massive omphacite rich rocks with common assemblage omphacite-garnet-epidote-phengite ± glaucophane, typically with chlorite as a hydrous post-eclogite mineral and varying amount of rutile, zircon, titanite and apatite as an accessory minerals. SEM/EDS chemical composition analyses reveal that garnet is typically only slightly zoned and almandine rich. Omphacite and phengite are generally irregularly zoned with medium to high jadeite content and high silica per formula unit respectively. Major oxide and trace element whole rock geochemical analysis was performed for eleven samples from representative localities. Eclogites have roughly similar bulk compositions with high Fe and Ti content and show high alkalinity and chemical variability. The latter is indicative of significant syn- to post-metamorphic metasomatism, leading to loss of mobile elements in events possibly related to the processes that generated the block-matrix association across the island. Samples are enriched in light rare earth elements with respect to chondrite with positive Eu anomalies and show MORB affinities. They are also strikingly similar to the REE patterns of metagabbros, suggesting that eclogites and metagabbros are both derived from mid-ocean ridge basalt related protoliths.

Using the newly calibrated thermobarometer of Ravna and Terry (2004) for garnet +omphacite+ phengite±rutile±quartz bearing rocks, pressure and temperature conditions of 18.7-23.5±3.2kbar and 500-580º± 65ºC were determined for eclogites from across the island. These conditions are higher than those previously reported for eclogites on Syros of 14-15kbar/450-580ºC by Trotet et al (2001) in earlier studies of Syros metabasites. The elevated pressures and temperatures may imply that eclogites are exotic to the eclogite-blueschist terrain and preserve the conditions of a higher-pressure regime; they did not reequilibrate blueschist metamorphism. They may also suggest that these rocks are merely preserving a different part of the same PT path as other rock types from elsewhere on the island. Alternatively, the discrepancy may reflect analytical differences in the geothermobarometric methods of calibration and application.

Beecher's Trilobite Bed in the 21st Century: MicroCT analysis of an Ordovician Lagerstätte

BUCK, Martha M., and HAGADORN, James W.
Amherst College, Department of Geology

Pyritization of the unmineralized tissues of organisms is extremely rare in the fossil record, yet it offers profound insights into the paleobiology and taphonomy of extinct life. Beecher's Trilobite Bed, a unit of the Ordovician Frankfort Shale of New York State, contains an entire community of extensively pyritized soft-bodied and mineralized organisms. The predominant organism in the deposit, the trilobite *Triarthrus eatoni*, has been studied extensively through careful abrasion of the surrounding shale from the pyritized specimens, and through x-radiography. This study extends these studies through the use of Microfocus computed tomography (microCT), a technology that exploits the compositional contrast between dense minerals such as pyrite and shale, and thus allows three dimensional visualization of pyritized soft-tissues at a level of detail not previously possible in this lagerstätte.

Approximately 130 trilobites were initially scanned using microCT, and models of 106 of these specimens yielded stark enough contrast in X-ray attenuation for quantitative analysis and for 3-Dimensional polygon models to be created.

Constant length to width ratios and minimal size variation suggest that all *T. eatoni* specimens were of the same holaspid life stage thereby allowing for a meaningful taphonomic analysis. The extent or percent of soft-tissue preservation in *T. eatoni* was measured quantitatively as the observed area of pyrite occurring along the dorsal surface, compared to the maximum area for a specimen of a given size. A semi-quantitative scale, Trilobite Preservation Index (TPI) was also developed to characterize trends in the nature and location of pyritization. Percent pyritization and TPI values were then compared to several metrics of preservation style. Comparisons indicated that the presence of preserved soft-tissues is unrelated to total specimen preservation. Additionally, data suggest that larger specimens may exhibit thicker, more thorough pyritization, an observation that partially supports the hypothesis that *Triarthrus* maintained a chemoautotrophic symbiosis with the sulfate-reducing bacteria that ultimately led to their exquisite preservation.

Data obtained through SEM/Electron Back Scatter Diffractometry show framboidal pyrite replacement of soft-tissue, confirming previous hypotheses about bacterially mediated soft-tissue preservation. Additionally, EBSD data show trimodal mineral replacement along *T. eatoni*'s exoskelton, with thin layers of ankerite and barite overlying the pyrite framboids.

ACICULAR CALCITE TEXTURE: ARAGONITE PSEUDOMORPHS ON SYROS ISLAND, GREECE

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In some localities the marbles of Syros exhibit an unusual needle-like morphology with an elongation direction sub-perpendicular to foliation. This acicular calcite texture (ACT) has been interpreted to be calcite after aragonite pseudomorphs (Brady et al., 2003) because of the crystal habit and the blueschist facies metamorphic history of the island. The rocks of Syros experienced metamorphism within the range of 450-500°C and 12-20 kb (Dixon and Ridley, 1987; Brady et al., 2003), which is in the aragonite stability field. There is no aragonite in the marbles of Syros today.

Forty-seven oriented samples were collected in the field from geographically diverse locations. Foliation, trend and plunge were recorded where possible. These samples were then analyzed in the lab with a petrographic microscope and Scanning Electron Microscope/Electron Backscatter Diffractometer (SEM/EBSD). Optically, twelve samples were examined for calcite deformation, including e-twinning morphology, grain boundary morphology, habit and extinction. Ten samples were analyzed with the SEM/EBSD, and orientations of crystallographic axes and deformational slip directions were plotted along with preserved aragonite preferred orientations. Concentrations of orientations on these plots show the CPO in the sample, and plots were divided into types dependant on the extent of their crystallographic preference. Observations from each method of examination were correlated to constrain the sequence of deformational history of the calcite after aragonite.

Deformation before and after aragonite was inferred from observations of morphology relationships. Samples exhibit evidence of deformation in the calcite stability field. Through these deformations calcite maintains a preferred orientation from aragonite.

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Structural Analysis of the Martin Bridge Limestone, Wallowa terrane, northeastern Oregon

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The late Triassic Martin Bridge Limestone is a deformed and metamorphosed limestone in the Wallowa terrane that overlies Permian to Triassic intrusive rocks, volcanic rocks and volcaniclastics. It is overlain by Jurassic sedimentary rocks and intruded by early Cretaceous plutons. The Wallowa terrane was an island arc that was active in the Permo-Triassic before amalgamating with four other terranes during the late Triassic or early Jurassic to form the Blue Mountains "superterrane." This superterrane was subsequently accreted onto the North American craton during the late Jurassic or early Cretaceous (Vallier, 1995).

This project is a structural analysis of the Martin Bridge Limestone at the submicroscopic and microscopic level. This project employed the use of electron backscatter diffraction (EBSD) technology, a method used in conjunction with a scanning electron microscope to determine mineral identification and its respective crystallographic orientation.

EBSD is a very suitable tool for this project – following the deformation related to amalgamtion and accretion the intrusion of the Wallowa batholith during the early Cretaceous resulted in static annealing, thereby overprinting any pre-existing microstructures. Crystallographic orientations collected by EBSD have been plotted in stereographic projections, allowing for the identification of a crystallographic preferred orientation (CPO). In addition to *c* and *a* crystallographic axes, the twinning and slip planes and directions may be plotted. A CPO may be interpreted as preferred deformation according to the respective mechanism. The stereographic projections have been used to identify (1) the dominant deformation mechanism, (2) the conditions of deformation, and (3) the sense of shear. This information corresponds to the deformation that preceded static annealing. Optical observations were also made with the intent to supplement EBSD data and to synthesize a kinemtic history of: (1) the specific Martin Bridge Limestone samples and (2) the Wallowa terrane.