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2007-2008 PROJECTS:

Tectonic and Climatic Forcing of the Swiss Alps
John Garver (Union College), Mark Brandon (Yale University), Alison Anders (University of Illinois), Jeff Rahl (Washington and Lee University), Devin McPhillips (Yale University)
Students: William Barnhart, Kat Compton, Rosalba Queirolo, Lindsay Rathnow, Scott Reynhout, Libby Ritz, Jessica Stanley, Michael Werner, Elizabeth Wong

Geologic Controls on Viticulture in the Walla Walla Valley, Washington
Kevin Pogue (Whitman College) and Chris Oze (Bryn Mawr College)
Students: Ruth Indrick, Karl Lang, Season Martin, Anna Mazzariello, John Nowinski, Anna Weber

The Árnes central volcano, Northwestern Iceland
Brennan Jordan (University of South Dakota), Bob Wiebe (Franklin & Marshall College), Paul Olin (Washington State U.)
Students: Michael Bernstein, Elizabeth Drewes, Kamilla Fellah, Daniel Hadley, Caitlyn Perlman, Lynne Stewart

Origin of big garnets in amphibolites during high-grade metamorphism, Adirondacks, NY
Kurt Hollocher (Union College)
Students: Denny Alden, Erica Emerson, Kathryn Stack

Carbonate Depositional Systems of St. Croix, US Virgin Islands
Dennis Hubbard and Karla Parsons-Hubbard (Oberlin College), Karl Wirth (Macalester College)
Students: Monica Arienzo, Ashley Burkett, Alexander Burpee, Sarah Chamlee, Timmons Erickson Andrew Estep, Dana Fisco, Matthew Klinman, Caitlin Tems, Selina Tirtajana

Sedimentary Environments and Paleoecology of Proterozoic and Cambrian "Avalonian" Strata in the United States
Mark McMenamin (Mount Holyoke College) and Jack Beuthin (U of Pittsburgh, Johnstown)
Students: Evan Anderson, Anna Lavarreda, Ken O'Donnell, Walter Persons, Jessica Williams

Development and Analysis of Millennial-Scale Tree Ring Records from Glacier Bay National Park and Preserve, Alaska (Glacier Bay)
Greg Wiles (The College of Wooster)
Students: Erica Erlanger, Alex Trutko, Adam Plourde

The Biogeochemistry and Environmental History of Bioluminescent Bays, Vieques, Puerto Rico
Tim Ku (Wesleyan University) Suzanne O'Connell (Wesleyan University), Anna Martini (Amherst College)
Students: Erin Algeo, Jennifer Bourdeau, Justin Clark, Margaret Selzer, Ulyanna Sorokopoud, Sarah Tracy

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Keck Geology Consortium: Projects 2007-2008
Short Contributions – Alps

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USING (U-TH)/HE THERMOCHRONOLOGY TO CONSTRAIN EXHUMATION IN THE SWISS-ITALIAN ALPS

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INTRODUCTION

(U-Th)/He thermochronology is a technique that can be used to determine the time that a mineral, and inferentially a rock, cooled through a specific closure temperature. Closure temperature (Dodson et al, 1973) of a mineral is the temperature at which retention of daughter products from radioactive decay begins. In this study the U/Th-He closure temperature is approximately 67°C (Farley, 2000) and for zircon is 183°C (Reiners et al., 2004), though there are many factors that can cause this to vary.

Exhumation rates can be calculated if the geothermal gradient from the sample area can be estimated, and the closure temperature correlated to a depth. For this study most samples were taken in vertical transects, covering as much elevation as possible, generally 1 to 3 km, over as small a lateral distance as possible. By minimizing the lateral distance, it can be assumed that the geothermal gradient is approximately the same for all samples, and therefore all samples crossed the closure isotherm at approximately the same depth. The age and elevation of each sample can be plotted, and the slope interpreted as the exhumation rate that is likely related to erosion rate.

In this project thermochronology data are used to study exhumation in the central and southern Swiss and Italian Alps. The European Alps are caused by the collision of the European Plate in the north with the Adriatic Plate (a sub-plate of Africa) in the south. The Adriatic Plate overrides the European Plate, which subducts beneath it. Samples were taken north and south of the Insubric Line, which is a deep basement fault that functions as the back thrust for the orogenic wedge of the Alps, and often is interpreted as the boundary between Europe and Adria. A geologic map with sample localities is shown in Figure 1.

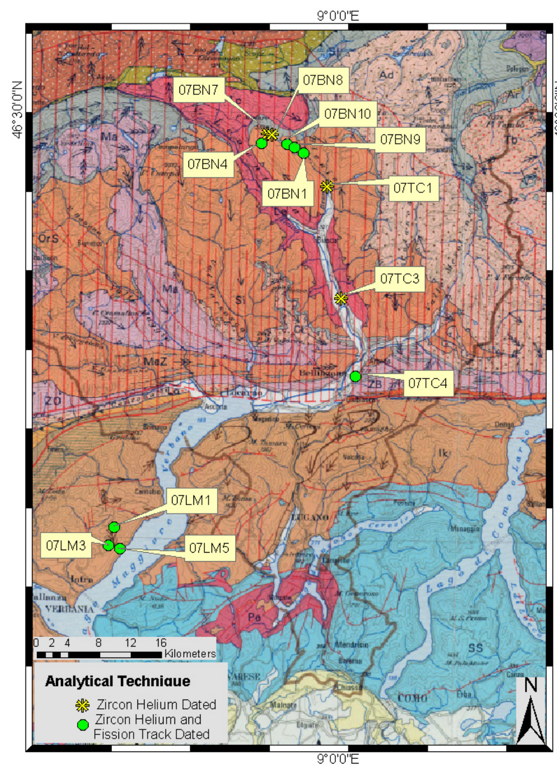

Figure 1: Sample location map. The tectonic map of Switzerland is taken from the Swiss geologic commission (1980)

The samples from north of the Insubric Line were taken from the Lucomagno, Simano, Leventina, and Maggia Nappes within the Pennine Nappes tectonic unit. The Pennine Nappes are the transported, distal part of the European margin, and sediment accumulation within two oceanic basins. The nappes from which the samples were taken are part of the Lepontine Gneiss Region, a region of amphibolite facies metamorphism, considered to be part of the European basement.

The samples from south of the Insubric Line are taken from the Strona-Ceneri Zone of the Southern Alps. This is an amphibolite facies gneiss complex that represents the mid-crustal section of the Adriatic plate.

METHODS AND RESULTS

Thirteen bedrock samples were collected from Ticino and Northern Italy. Ten were taken from the Pennine Nappes, north of the Insubric Line, seven of which were in a vertical transect. Three were taken in a vertical transect from the Southern Alps, south of the Insubric Line. Sample localities can be seen in Figure 1.

All samples were crushed, and zircon and apatite grains were separated and selected for dating using (U-Th)/He method. Unfortunately not all rocks crushed yielded significant zircon, and most rocks did not yield enough inclusion-free apatite to be dated. Two zircon grains from each sample, and apatite grains from a few samples were dated at the Helium Lab at University of Arizona.

NORTH OF INSUBRIC LINE					
Sample	Elevation (m)	Zircon Age (Ma)	2σ (Ma)	Apatite Age (Ma)	2σ (Ma)
07BN1	511	8.41	0.58		
		9.93	0.44		
07BN4	2085	9.97	0.74		
		11.88	0.72		
07BN7	1828	9.88	0.62		
		10.68	0.66		
07BN8	1525	7.15	0.84		
		177.06	7.78		
07BN9	1124	11.27	0.56		
		12.93	0.58		
07BN10	779	8.41	0.54	5.89	8.81
		10.58	0.68	1.84	3.5
07TC1	405	10.57	0.54		
		8.85	0.44		
07TC3	321	11.27	0.56	2.63	6.08
		10.62	0.52	9.38	8.12
07TC4	297	13.43	0.64		
		13.9	0.94		
SOUTH OF INSUBRIC LINE					
Sample	Elevation (m)	Zircon Age (Ma)	2σ (Ma)	Apatite Age (Ma)	2σ (Ma)
07LM1	1412	181.87	8.3		
		160.77	7.22		
07LM3	949	158.36	7.28	23.44	6.56
		171.52	8.08	11.25	13.66
07LM5	480	101.75	4.72		
		144.49	6.42		

Table 1. Helium ages. The only reliable age from apatite was the first age from 07LM3

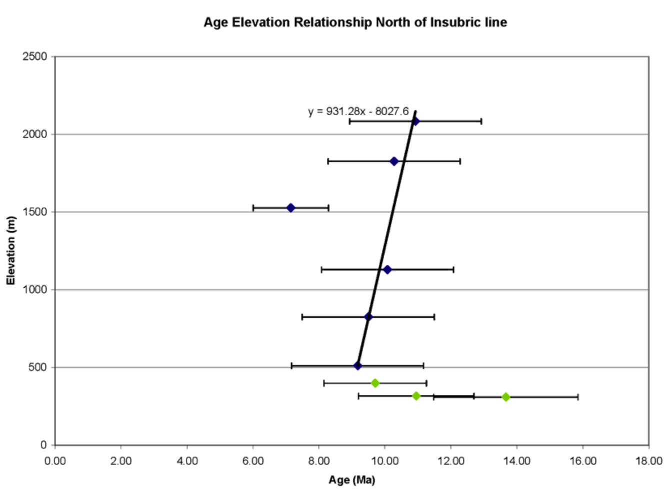

Figure 2. AER from north of the Insubric Line. Error bars are the average inter-grain variance, 16%. The samples in blue are from the vertical transect, while samples in green were taken from down valley toward the Insubric Line. The second aliquots for 07BN8 and 07BN9 were not plotted, and 07BN8 and the 078TC samples were not included in the regression line.

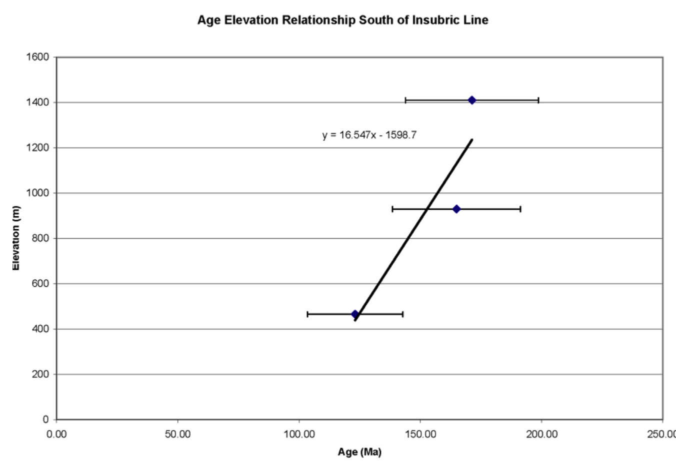

Figure 3. AER for samples south of the Insubric Line. Error bars are the average inter-grain variance, 16%.

The ages for the individual crystals are shown in Table 1. The ages ranged from 7 Ma north of the Insubric Line to 182 Ma south of the Insubric Line. The age-elevation relationship (AER) for the samples north of the Insubric Line is shown in Figure 2, and for those south in Figure 3. The majority of the apatites dated did not yield enough helium to give good results

DISCUSSION

The ages from samples north of the Insubric Line are much younger than the samples south of the Insubric Line. Zircon ages from the north range from 7 to 12 Ma, whereas ages from the south range from 100 to 180 Ma. This pattern indicates differential exhumation across the fault, with much faster rates to the north. When the points from the vertical transects were fit to a regression line, the slope indicates an exhumation rate of about 900 m/Myr in the north, with about 20 m/Myr in the south. This result shows that there is a much faster exhumation in the north, likely indicating more rapid erosion than south of the Insubric Line.

The apatite results are less conclusive because so few samples yielded sufficient quality apatite for analysis, and the best quality apatite often did not have enough helium for precise measurement. A single robust apatite age of 23 Ma comes from south of the Insubric Line. One possible explanation for the lack of helium in many of the samples from north of the Insubric line is that the cooling ages are very young (less than 5 to 10 Ma), which would indicate that the fast exhumation rates have continued into recent times, still with significantly older ages South of the Insubric Line.

Three (U-Th)/He data points from the vertical transect south of the Insubric line results in a distinct slope and a calculated, relatively low exhumation rate of 16m/Myr. (Fig 3).

The helium ages from samples north of the Insubric Line show a clear exhumation trend related to orogenic activity. The points in blue on Figure 2 are the samples taken in a vertical transect, whereas the three points in green are those taken down valley toward the Insubric Line for a constant elevation perspective. As expected, the transect shows older ages at high elevations and younger ages at low elevations. Two samples in the middle of the transect are clear outliers. Sample 07BN8 is exceptionally young. This rock was a calc-arenite belonging to the Bündershifer unit to the north, where as all other samples were gneisses belonging to the basement nappes. The abrasion of the zircon crystals by sedimentary transport showed great variability, some crystals were significantly more rounded than others, and the ages on the two grains dated were 7 Ma and 177 Ma.

The age from 07BN9 is older than expected. There was nothing particularly remarkable about this rock in the field, and if the age from the older aliquot is ignored, the 12.93 Ma age, then the other age, 10.08 Ma, lies on the AER as expected, so it is possible that the age from the second crystal is not correct. The other possible explanation for both of the unexpected ages on 07BN8 and 07BN9 is that there is some unrecognized structure in the field, which is unlikely given the magnitude required.

Samples down valley towards the Insubric Line (in green on Fig. 2) get older as they approach the fault. One can imagine a plane connecting all points of equal age; this surface is termed an isochrone. If the dip between 07BN4 and 07TC3, which have almost the same age, is calculated, the isochrone dips south toward the Insubric Line at an angle of about 5 degrees. This angle is small enough that it the deflection could be caused by the isotherms being warped by topography, or it is possible that the isochrones are being deflected by the Insubric Line.

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