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Collaborative Research: The Tectonothermal Evolution of a Convergent Orogen

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Final Report for Period: 06/2002 - 07/2006

Submitted on: 11/10/2006

Principal Investigator: Johnson, Scott E.

Award ID: 0207717

Organization: University of Maine

Title:

Collaborative Research: The Tectonothermal Evolution of a Convergent Orogen

Project Participants

Senior Personnel

Name: Johnson, Scott

Worked for more than 160 Hours: Yes

Contribution to Project:

Johnson was lead PI on this project and was responsible for overseeing the structural and microstructural investigations. He also played a leading role in the overall tectonic synthesis that has/will come out of the project.

Name: Guidotti, Charles

Worked for more than 160 Hours: Yes

Contribution to Project:

Guidotti was responsible for overseeing the metamorphic and isotopic studies. Guidotti passed away owing to a sudden illness in May of 2005, so did not participate in the one-year, no-cost extension of the project.

Name: Koons, Peter

Worked for more than 160 Hours: Yes

Contribution to Project:

Koons was responsible for overseeing the thermal and mechanical modeling. He also played a leading role in the overall tectonic synthesis that has/will come out of the project.

Post-doc

Name: Upton, Phaedra

Worked for more than 160 Hours: Yes

Contribution to Project:

Upton is a Post-doctoral fellow who was working with Peter Koons on a number of projects.

Although Upton was paid only a small amount of salary from this grant via a supplemental award, she has actively participated in the thermal/mechanical modeling and will be lead author on a summary geodynamic paper currently in preparation.

Graduate Student

Name: Short, Heather

Worked for more than 160 Hours: Yes

Contribution to Project:

Heather Short is a PhD student with Johnson. She is currently living in Canada with her partner who won a faculty position in Anthropology in Quebec. She is writing up her thesis, she maintains full-time student status at UMaine, and I continue to pay her a small salary from this grant.

Name: Groome, Wesley

Worked for more than 160 Hours: Yes

Contribution to Project:

Wesley Groome is a PhD student with Johnson. His salary in his first year was provided by a Departmental TA, but his salary has been paid from this grant since June 2003.

The grant is currently funding most aspects of his research.

Name: Dupee, Matthew

Worked for more than 160 Hours: Yes

Contribution to Project:

Matthew Dupee is a MS student with Johnson. He will graduate in the summer of 2004, and his salary is currently being paid by this grant. His salary was previously provided by a Departmental TA, and the grant is funding most aspects of his research.

Name: Gilbertson, Lea

Worked for more than 160 Hours: Yes

Contribution to Project:

Lea Gilbertson was a PhD student with Guidotti, but she left us in September 2003 to take a teaching job at a small college.

Name: Brown, Lucy

Worked for more than 160 Hours: Yes

Contribution to Project:

Lucy joined our program in September Of 2003 as an MS student. She is working with Peter Koons on numerical models of oblique collision. She will do field work this summer across the Norumbega shear zone, collecting lineation and foliation data that will be compared to model results. Lucy is currently on a TA, but this grant will support her summer salary.

Name: Gerbi, Christopher

Worked for more than 160 Hours: Yes

Contribution to Project:

Chris Gerbi was a PhD student with Johnson who worked on this project in its final year. Gerbi came on board in order to conduct SHRIMP monazite geochronology on metamorphic rocks, and SHRIMP zircon geochronology on intrusive igneous rocks. Chris has expertise in geochronology through his PhD work, and had access to teh SHRIMP lab in Palo Alto, so we invited him to lead this part of the project. Chris will be lead author on a summary geochronology paper to be submitted by the end of 2006.

Undergraduate Student

Name: Washburn, Malissa

Worked for more than 160 Hours: Yes

Contribution to Project:

Malissa is an undergraduate student working with Johnson through an REU supplement to the grant. She is doing a magnificent job, and is presenting a poster on her work at the joint AGU/CGU meeting in Montreal in May 2004.

Name: McCurdy, Kristin

Worked for more than 160 Hours: Yes

Contribution to Project:

Kristin was an undergraduate geology major at Bates College, and Phaedra Upton served as primary advisor for her undergraduate thesis titled: 'Three-Dimensional Thermal Investigations of Acadian Tectonic Models Constrained by Geochronology in Central Maine'. She was not supported by this NSF grant, but the grant did pay for a couple of Ar/Ar ages for her thesis work, and her thesis work was very closely tied to the project. Some of her modeling results will be incorporated in a geodynamic overview paper that Phaedra Upton is currently preparing. Owing to the stronly link between Kristin's thesis work and this grant, we list her as having spent more than 160 hours on the funded research.

Technician, Programmer**Other Participant****Research Experience for Undergraduates****Organizational Partners****Middlebury College**

This Collaborative proposal is formally collaborative with Dave West at Middlebury College.

Other Collaborators or Contacts

Professor Dyk Eusden at Bates College was external committee member for Wes Groome's PhD committee. He worked closely with Wes on aspects of his project owing to his expertise in the rocks of the Presidential Range, New Hampshire.

Activities and Findings

Research and Education Activities:

Heather Short (PhD 2006) evaluated the Devonian-age tectonothermal evolution of the Norumbega shear zone. She also conducted a detailed vorticity analysis using multiple generations of calcite veins. She finished her PhD in May, 2006.

Matt Dupee (MSc 2005) examined the relations between deformation and metamorphism in the aureole of the Mooselookmeguntic pluton in Western Maine. In particular, he evaluated crenulation cleavage development in the aureole, porphyroblast rotation during cleavage development, and the relative timing between the emplacement-related deformation and peak metamorphic mineral growth in the aureole. He received his MSc degree in May, 2005.

Wes Groome (PhD 2006) evaluated the effects of prograde metamorphic mineral growth and partial melting during low-P, high-T metamorphism on crustal rheology, strain partitioning and topographic evolution. He received his PhD degree in May, 2006.

Lucy Brown (MSc 2006) conducted 3D numerical modeling to evaluate the length and time scales of the orogen-parallel thermal anomaly recorded throughout central and southwestern Maine. She received her MSc degree in May, 2006.

Chris Gerbi (PhD, 2005) tackled the timing of metamorphism along our transect using SHRIMP U/Pb geochronology on metamorphic monazite and igneous zircon. He received his PhD in May, 2005.

Malissa Washburn was one of our star undergraduate students who was supported by an REU supplement to this grant. She evaluated the thermal and mechanical aspects of migmatization, and finished a very impressive Honors Thesis in May of 2006 when she received her BSc.

The PIs have been actively involved in helping the students formulate their thesis/project goals. Koons and postdoc Upton established thermal and mechanical frameworks that we have used to address the goals of the project. Johnson and Guidotti spent a lot of time in the field with the students and worked with them in the microstructural and microprobe analyses among other activities.

Findings:

Major findings include:

- 1) Determination of a mean kinematic vorticity number (0.62) for Devonian-age oblique convergence leading to the Norumbega shear zone.
- 2) Characterization of the role of asthenosphere and local plutonic input into the thermal structure preserved in northern New England.
- 3) The first irrefutable published example of porphyroblast kinematics in relation to crenulation cleavage development.
- 4) New geochronological constraints on the ages of metamorphism in the northern New England Appalachians.
- 5) The first published work illustrating that growth of large metamorphic porphyroblasts can lead to measurable strengthening of crustal volumes.

Training and Development:

The students all gained research experience by interacting with the PIs, Upton and professional collaborators. Two of the students (Short and Gerbi) held 1-year NSF K-12 Teaching Fellowships. Short, Gerbi, Dupee and Washburn spent time on our electron microprobe. All students incorporated both analog and 3D numerical modeling into their thesis projects. Short, Gerbi and Groome advised undergraduate field assistants during summer field work. All the graduate students had the opportunity to TA in our department.

Outreach Activities:

In order to provide a sustainable flow of quality outreach material, members of the Geodynamics and Crustal Studies Group at UM have implemented web-based publication of student projects that explore or review fundamental information, concepts and processes in the Earth Sciences. Student response has been very positive, and we are delighted by the process and its positive effect on learning. The following URL shows some of the results to date.

<http://www.geology.um.maine.edu/geodynamics/analogwebsite/>

Our aim with these web-based projects is to develop an education/outreach archive of 'modules'. We know of examples in which our modules have served as a useful resource for earth-science teachers and students at all levels. Our department hosts a yearly workshop for ~50 Maine State teachers, and they have enjoyed exploring Earth processes through our modules, and through hands-on experience in our facilities. We have also received emails from students and teachers at other institutions in the USA and abroad complimenting us on our efforts.

Graduate students associated with this grant contributed several projects to analog site above.

Journal Publications

Matthew Dupee

Scott Johnson

Charles Guidotti, "Relations between deformation and metamorphism in the aureole of the Mooselookmeguntic pluton, western Maine.", Geological Society of America Abstracts with Programs, p. 7-6, vol. 35, (2003). Published,

Heather Short

Scott Johnson, "Strain partitioning is a transpressive orogen, central coastal Maine.", Geological Society of America Abstracts with Programs., p. 18-4, vol. 35, (2003). Published,

Phaedra Upton, Heather Short, Scott Johnson, Peter Koons, David West, Charles Guidotti, "Application of erosional-rheological coupled mechanical models to ancient orogens: an example from the Norumbega shear zone in Maine.", Geological Society of America Abstracts with Programs., p. 12-4, vol. 35, (2003). Published,

Johnson, S.E.

Koons, P.O., "Porphyroblast microstructures and the coupling of deformation and metamorphism.", Eos Trans. AGU, p. V42G-03, vol. 84, (2003). Published,

Johnson, S.E., "Exploring the coupling of deformation and metamorphism.", Geological Society of America Abstracts., p. 89, vol. 34, (2003). Published,

Short, H.A.

Upton, P.

Koons, P.O.

Johnson, S.E., "The exhumation of a high-metamorphic grade terrane within a transpressional orogen: constraints from numerical modeling in central coastal Maine.", Geological Society of America Abstracts, p. 548, vol. 34, (2003). Published,

Dupee, Matt

Johnson, S.E.

Guidotti, C.V., "Porphyroblast-matrix relations across a strain gradient in the aureole of the Mooselookmeguntic Pluton, Western Maine.", Eos Transactions AGU, p. V23B-05, vol. 85(17), (2004). Published,

Groome, W.G.

Johnson, S.E.

Koons, P.O.

Guidotti, C.V.

Eusden, J.D. Jr., "Relations between deformation, metamorphism and magmatism in the Presidential Range, New Hampshire. Range, New Hampshire", Eos Transactions AGU, p. V21A-03, vol. 85(17), (2004). Published,

Short, H.A.

Yates, M.

Johnson, S.E., "Siluro-Carboniferous Transpression In Central-coastal Maine: Constraints from New Chemical Monazite Ages.", *Eos Transactions AGU*, p. V23C-10, vol. 85(17), (2004). Published,

Washburn, M.

Groome, W.G.

Koons, P.O.

Johnson, S.E., "Thermal modeling of melt-fraction gradients in magmatites of the Presidential Range, New Hampshire.", *Eos Transactions AGU*, p. V23B-03, vol. 85(17), (2004). Published,

Koons, P.O.

Upton, P.

Johnson, S.E.

Jessell, M.W., "Model strain and model fabric development in 3D oblique orogens.", *Geological Society of America Annual Meeting Abstracts and Program.*, p. 186-2, vol. 35, 5, (2004). Published,

Johnson, S.E.

Jessell, M.W.

Koons, P.O., "Modeling porphyroblast nucleation and growth, and exploring the consequences for rheological evolution.", *Geological Society of America Annual Meeting Abstracts and Program.*, p. 80-2, vol. 35, 5, (2004). Published,

Groome, W.G.

Johnson, S.E.

Koons, P.O., "Modeling the relations among porphyroblast growth, pseudomorphism and strain localization in turbidite successions.", *Geological Society of America Annual Meeting Abstracts and Program.*, p. 80-3, vol. 35, 5, (2004). Published,

West, D.P.

Gerbi, C.

Johnson, S.E.

Aleinikoff, J.

Berry, H.N., "Strain partitioning and timing of high-grade Acadian metamorphism in south-central Maine.", *Geological Society of America Abstracts with Programs.*, p. 31, vol. 37, 1, (2005). Published,

Washburn, M., Johnson, S.E., Upton, P., and Koons, P.O., "Numerical modeling of fluid pressure gradients in anisotropic rocks undergoing heterogeneous deformation.", *Geological Society of America Northeast Section Meeting Abstracts and Programs*, p. 19-22, vol. 37, 1, (2005). Published,

Washburn, M., Johnson, S.E., Koons, P.O. and Upton, P., "Numerical modeling of deformation-driven fluid pressure gradients in a mechanically heterogeneous medium.", *Geological Association of Canada and Mineralogical association of Canada Joint Meeting, Abstract volume*, p. 204, vol. 30, (2005). Published,

Groome, W.G., Johnson, S.E. and Koons, P.O., "Extracting rheologic information from field data.", *Geological Association of Canada and Mineralogical association of Canada Joint Meeting, Abstract volume*, p. 75, vol. 30, (2005). Published,

Upton, P., Koons, P.O., Johnsons, S.E., "Three dimensional geodynamic modeling of oblique orogenesis: application to New Zealand and the Acadian Orogen of Maine.", *Geological Society of America Abstracts with Programs*, p. 67, vol. 38, 2, (2006). Published,

Washburn, M., Groome, W.G., Koons, P.O., Johnson, S.E., Walker, R.J. and Lux, D.R., "Relationships between migmatites of the Silurian Rangeley Formation and the Wildcat Granite: New Hampshire, USA.", *Geological Society of America Abstracts with Programs*, p. 32, vol. 38, 2, (2006). Published,

Groome, W.G., Koons, P.O. and Johnson, S.E., "Metamorphism, transient mid-crustal rheology and the exhumation of high-grade metamorphic rocks.", *Geological Society of America Abstracts with Programs*, p. 78, vol. 38, 2, (2006). Published,

Brown, Lucy E., Koons, Peter O., Upton, Phaedra, Johnson, Scott E., "Thermal-mechanical implications of a shallow athenosphere in a deforming orogen: constraints from 3-D numerical modeling.", Geological Society of America Abstracts with Programs, p. 68, vol. 38, 2, (2006). Published,

Short, H.A. and Johnson, S.E., "Estimating vorticity from fibrous calcite veins, central Maine, USA.", Journal of Structural Geology, p. 1167, vol. 28, (2006). Published,

Johnson, S.E., Dupee, M.E., Guidotti, C.V., "Porphyroblast rotation during crenulation cleavage development: an unequivocal example from the aureole of the Mooselookmeguntic pluton, Maine, USA.", Journal of Metamorphic Geology, p. 55, vol. 24, (2006). Published,

Groome, W.G., Johnson, S.E. and Koons, P.O., "The effects of porphyroblast growth on the effective viscosity of metapelitic rocks: implications for the strength of the middle crust.", Journal of Metamorphic Geology, p. 389, vol. 24, (2006). Published,

Groome, W.G. and Johnson, S.E., "Constraining the relative strengths of high-grade metamorphic rocks using foliation refraction angles: an example from the Northern New England Appalachians.", Journal of Structural Geology, p. 1261, vol. 28, (2006). Published,

Johnson, S.E., Koons, P.O., Guidotti, C.V., "Emplacement-related strain rates from coupled thermal-mechanical models of static and dynamic pluton aureoles: example from the Maine Appalachians, U.S.A.", Journal of Metamorphic Geology., p. , vol. , (). Submitted,

Groome, W.G., Koons, P.O., and Johnson, S.E., "Coupled deformation, metamorphism and surface evolution: a model for the development of piggyback basins.", Tectonics, p. , vol. , (). Submitted,

Books or Other One-time Publications

Web/Internet Site

Other Specific Products

Contributions

Contributions within Discipline:

- 1) Developed new numerical techniques for evaluating rigid object kinematics in viscous flow.
- 2) Developed new numerical techniques for coupling deformation, conduction and advection.
- 3) Developed new techniques for quantifying the rheological effects of metamorphic mineral growth in metasediments.

Contributions to Other Disciplines:

Contributions to Human Resource Development:

This project supported, partly or entirely, the thesis work of 3 PhD students, 2 MS students and one undergraduate student. A postdoctoral researcher (Upton) was also partly supported.

Contributions to Resources for Research and Education:

In order to contribute to national and international educational and research resources, we have implemented web-based publication of student projects that explore or review fundamental information, concepts and processes in the Earth Sciences. The following URL shows some of the results to date.

<http://www.geology.um.maine.edu/geodynamics/analogwebsite/>

Contributions Beyond Science and Engineering:

Categories for which nothing is reported:

Any Book

Any Web/Internet Site

Any Product

Contributions: To Any Other Disciplines

Contributions: To Any Beyond Science and Engineering