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Architecture and Evolution of an Accretionary Orogen

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Principal Investigator: Johnson, Scott E.
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Architecture and Evolution of an Accretionary Orogen

Project Participants

Senior Personnel

Name: Johnson, Scott
Worked for more than 160 Hours: Yes
Contribution to Project:

Name: Aleinikoff, John
Worked for more than 160 Hours: No
Contribution to Project:
Aleinikoff oversaw the geochronology aspects of the project.

Name: Bedard, Jean
Worked for more than 160 Hours: No
Contribution to Project:
Bedard oversaw the chemical modeling aspect of hte project.

Name: Koons, Peter
Worked for more than 160 Hours: No
Contribution to Project:
Koons oversaw the thermal modeling of low-pressure anatexis.

Name: Dunning, Gregory
Worked for more than 160 Hours: No
Contribution to Project:
Dunning performed the TIMS dating of gabbro from the Boil Mountain Complex.

Name: Fanning, C
Worked for more than 160 Hours: No
Contribution to Project:

Post-doc

Graduate Student

Name: Gerbi, Christopher
Worked for more than 160 Hours: Yes
Contribution to Project:
This project served as the PhD thesis for Gerbi. He managed most aspects of hte project, under teh oversight of Johnson.

Undergraduate Student

Name: Riley, Jon
Worked for more than 160 Hours: Yes
Contribution to Project:
Riley served as field assistant for Gerbi and prepared an undergraduate thesis at Bates College.

Name: Doughty, Alice

Worked for more than 160 Hours: No

Contribution to Project:
Assisted with geochemical sample preparation and interpretation for granitic rocks.

Name: Fiscus, Michelle

Worked for more than 160 Hours: Yes

Contribution to Project:
Field assistant for Gerbi and assisted with geochemical sample preparatio and interpretation of mafic rocks.

Technician, Programmer

Other Participant

Research Experience for Undergraduates

Organizational Partners

Other Collaborators or Contacts

Cees van Staal (GSC) has participated in many discussions about the project. He, Charles Guidotti (UMaine), and Martin Yates (UMaine), along with Johnson (committee chair) and Koons, served on Gerbi's PhD committee.

Activities and Findings

Research and Education Activities:

The major activities in this project centered around ascertaining the role of an exotic crustal block in the Northern Appalachians. The Boundary Mountains terrane, cored by Chain Lakes massif, lies at the junction between peri-Laurentian and peri-Gondwanan rocks and thus serves as an excellent recorder of the processes involved in continental break-up (to form Iapetus) and collision (to form the Appalachians). Our research employed zircon and monazite geochronology, geochemistry and chemical modeling, mapping, structural analysis, and petrography to evaluate (1) the relationship between the rocks of the Boundary Mountains and the surrounding units and (2) the history of the units within the Boundary Mountains, particularly with respect to rifting and accretionary processes recorded in the Appalachians.

The different aspects of the project had an educational as well as research component to them. The primary beneficiary was Chris Gerbi, who was able to be involved in every aspect of the work and who thereby gained knowledge in a broad range of geological techniques, including geochronology and thermal modeling. The collaboration with the U.S.G.S. (Aleinikoff) for U-Pb geochronology allowed Gerbi to travel to Denver and Palo Alto to participate in the work. In a similar vein, though with more limited scope, Jon Riley had his first research experience and produced a senior thesis.

Analytical instrumentation in different labs was critical to the success of this project. Principally, we used the recently-acquired (NSF-funded) electron microprobe at the University of Maine, the thermal ionization mass spectrometer at the Memorial University of Newfoundland, and the U.S.G.S.- Stanford sensitive high-resolution ion microprobe (SHRIMP). On the SHRIMP, we dated seven samples. These geochronological results were badly needed for the database in New England.

Findings:

(1) Geologic history. This project was the first to take a comprehensive look at the involvement of the Boundary Mountains terrane in the growth of the accretionary Appalachian orogen, and as such, a number of the principle findings are substantially different than previous interpretations. The detrial zircon signature of rocks in the Chain Lakes massif û the bulk of the Boundary Mountains terrane û indicates a Laurentian provenance. The detrital data along with the U-Pb ages of volcanic rocks in the massif are consistent with an Early Ordovician depositional age for the protolith of the massif. The lithologic distribution is most consistent with a fore-arc setting. Less than 10 m.a. after deposition, the massif melted in place and little magma migrated from the region. We interpret the age of metamorphic monazite (ca. 469 Ma) as the approximate time of anatexis. That event produced a diatexite, giving the massif its distinctive texture. We dated an arc-related pluton (Skinner granodiorite) that intruded the Boundary Mountains prior to the anatexis, and its age (ca. 473 Ma) is consistent with the terrane being part of a more regional arc system. Later collision and accretion of the Boundary Mountains to Laurentia made little impact on these relatively strong units.
We also showed that there is no ophiolite in the Boundary Mountains, as previously believed. The ultramafic-mafic rocks of the Boil Mountain Complex are chemically and metamorphically distinct from the adjacent pillow lavas of the Jim Pond Formation. We dated the gabbro in the Complex at ca. 477 Ma, an age that overlaps within uncertainty with that of the pillow lavas, suggesting that the two units may have been part of the same arc system, if not part of an ophiolite.

(2) Regional history. Having determined the geologic history of the Boundary Mountains region, we were able to relate the events of the study are to broader Appalachian tectonic patterns. We view the Boundary Mountains terrane as part of a microcontinent system that extended from Newfoundland through Massachusetts, including the Dashwoods block and the Shelburne Falls arc. The microcontinents rifted from Laurentia, served as the nuclei for arcs, then returned to collide with the Laurentian craton. We have been able to show that the Boundary Mountains were indeed part of the Ordovician collider that drove the ôTaconianö orogeny, and that it was a sliver torn from Laurentia.

(3) Controls on low-pressure anatexis. Anatexis of the massif at shallow levels (15 km depth) requires a significant thermal anomaly. The most likely tectonic event responsible for the anatexis is a combination of lithospheric mantle removal and advected heat. Gerbi learned the techniques of thermal modeling and developed a model to demonstrate the tectonic controls on development of low-pressure anatexis. His conclusion is that the only single mechanisms that can produce low-pressure anatexis are pervasive magma flow (resulting in injected migmatites), extreme crustal-scale detachment faulting, and possibly burial of high heat-producing layers. Combinations of other mechanisms, such as removal of lithospheric mantle and pluton-related heat advection, can also warm the crust sufficiently to melt at shallow levels.

(4) Contributions to the discipline. Any comprehensive understanding of the break-up and growth of continents requires an understanding of the history of specific continental margins. Here, we have been able to provide more information about the opening and closing of Iapetus that can be used by those investigating the geodynamics of rifting and accretion.

Training and Development:

The gains in research and teaching skills fall into several categories. (1) For the PIs, this project opened new collaborative avenues, particularly in the area of geochronology. We have continued to develop the relationships as part of other projects. (2) The University of Maine lies near the study area and we are able to incorporate the results of this work into course materials both in courses of the PIs and of others. (3) The students involved have

gained experience by being part of a successful project and by managing the different aspects of the work. (4) The presentations by Gerbi at various meetings have greatly improved his communication skills that he will bring to any classroom.

Outreach Activities:

Besides many informal discussions with people in the University community and beyond, the two main outreach benefits of this project are:

(1) A geologic map to be published by the Maine Geological Survey. These maps are designed for the general public.

(2) Gerbi will lead a field trip as part of the 2006 New England Intercollegiate Geological Conference. These field trips are free and open to the public.

Journal Publications

Gerbi, C., Johnson, S.E., Aleinikoff, J.N., "Origin and orogenic role of the Chain Lakes massif, Maine and Quebec", Canadian Journal of Earth Sciences, p. , vol. , ( ). Submitted

Gerbi, C. Johhson, S.E., Aleinikoff, J.N., Bedard, J.H., Dunning, G.R., Fanning, C.M., "Early Paleozoic development of the Maine-Quebec Boundary mountains region", Canadian Journal of Earth Sciences, p. , vol. , ( ). Submitted

Gerbi, C., Johnson, S.E., Koons, P.O., "Controls on low-pressure anatexis", Journal of Metamorphic Geology, p. , vol. , ( ). Submitted

Gerbi, C.C., Johnson, S.E., Aleinikoff, J.N., "The Chain Lakes massif: Laurentian source and anatectic history", Geological Society of America Abstracts with Program, p. 17-5, vol. 37, (2005). Published

Gerbi, C.C., Johnson, S.E., Koons, P.O., "Kinematic controls on low-pressure anatexis", EOS Transactions of the American Geophysical Union Joint Assembly Supplement, p. T51A-07, vol. 85, (2004). Published

Gerbi, C.C., Johnson, S.E.,, "The Chain Lakes massif, Maine and Quebec: A product of extension?", Geological Society of America Abstracts with Program, p. 29, vol. 35, (2003). Published

Gerbi, C.C., Johnson, S.E., "The Chain Lakes massif, west-central Maine: a persistent problem in Appalachian orogenesis", Geological Society of America Abstracts with Program, p. 77, vol. 34, (2002). Published

Gerbi, C.C., Johnson, S.E., "Kinematics of the Boil Mtn. Complex-Chain Lakes massif contact", Geological Society of America Abstracts with Program, p. 261, vol. 33, (2001). Published

Books or Other One-time Publications

Gerbi, C., "Bedrock geology of the Jim Pond 7.5' Quadrangle, Maine", ( ). Map, Submitted
Bibliography: Maine Geological Survey

Web/Internet Site

URL(s):

http://www.bowdoin.edu/~cgerbi/past/clm/clm.html

Description:

This publicly-accessible site relates the major findings of the project.

Other Specific Products

Contributions

Contributions within Discipline:

Our work has contributed to the field in at least three principle ways.

(1) We have added significantly to the geochronological database for the Northern Appalachians. Interpretations of large-scale tectonic processes from ancient orogens require sufficient chronological control, and that has been notably lacking for the oldest portions of the Appalachians in Maine.

(2) We have provided support for the hypothesis that rifting (and in particular the opening of Iapetus) is not a clean process, but instead may involve several microplate slivers.

(3) We have provided a general critical review of the tectonic processes that can operate to produce low-pressure anatexis. Much previous work had considered the mechanisms that could cause low-pressure metamorphism, but few had quantitatively explored melting at low-pressure.

Contributions to Other Disciplines:

Contributions to Human Resource Development:

Funding from this project supported one PhD student and one undergraduate student, in the process furthering their training as geoscientists.

Contributions to Resources for Research and Education:

The most significant resources generated as part of this project are:

(1) The development of a relationship with the USGS-Stanford SHRIMP lab. The data gathered for this project was critical to its success, and we plan to maintain the established relationship for future work.

(2) Production of a geologic map (to be published by the Maine Geological Survey) to which future researchers will have access.

Contributions Beyond Science and Engineering:

Categories for which nothing is reported:

Organizational Partners

Any Product

Contributions: To Any Other Disciplines

Contributions: To Any Beyond Science and Engineering