KECK GEOLOGY CONSORTIUM

21ST KECK RESEARCH SYMPOSIUM IN GEOLOGY SHORT CONTRIBUTIONS

April 2008

Dr Andrew P. de Wet, Editor
Keck Director
Franklin & Marshall College

Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lancaster Pa, 17603

Dr Amy Rhodes,
Symposium Organizer
Smith College

Keck Geology Consortium Member Institutions:
Amherst College Beloit College Carleton College Colgate University The College of Wooster The Colorado College Franklin and Marshall College Macalester College Mt. Holyoke College Oberlin College Pomona College Smith College Trinity University Union College Washington and Lee University Wesleyan University Whitman College Williams College

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

Funding provided by:
Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)

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

Funding provided by: Keck Geology Consortium Member Institutions and NSF (NSF-REU: 0648782)

Keck Geology Consortium
Franklin & Marshall College
PO Box 3003, Lancaster Pa, 17603
Keckgeology.org

FINE CLASTICS OF THE BOSTON BAY GROUP: NEW DATA AND INTERPRETATIONS CONCERNING DEPOSITIONAL PROCESSES AND ENVIRONMENTS

MARK A. S. McMENAMIN: Mount Holyoke College
JOHN D. BEUTHIN: University of Pittsburgh, Johnstown

ABSTRACT

In light of the perception that "mudstone science is poised for a paradigm shift" (Macquaker and Bohacs 2007), we analyzed the fine clastics of the Boston Bay Group with the goal of better understanding their depositional environments and depositional processes, particularly as these relate to the remains of the problematic Proterozoic marine organism *Aspidella.* Our results indicate that these rocks record a variety of depositional processes and water depths, and that in particular ripple accreted muds, generated by floc-ripple clay transport, were important in the deposition of these strata. They also support the biogenicity of *Aspidella* and help to further characterize the habitat of this enigmatic Ediacaran.

INTRODUCTION

Avalonian strata of the eastern United States have a unique historical importance for the study of geology. These sequences, which span the Neoproterozoic-Cambrian boundary, have yielded both the first trilobite described from the United States (McMenamin, 2004), important Ediacaran fossils (Weaver et al., 2006) and among the best lower Paleozoic paleontological evidence for plate tectonics. Correlative strata to the north (Newfoundland) bear the stratotype section for the Proterozoic-Cambrian boundary, and thus assume a particular stratigraphic importance. Controversy exists, however, concerning the depositional environments of these rocks (McMenamin, 1998). We address these issues from the standpoint of depositional processes, as described below.

The study of mudrocks has been hindered by the fact that "they do not reward casual inspection and are [thus] poorly understood relative to other rock types" (Macquaker and Bohacs, 2007:1734). Recent results (Schieber et al., 2007) indicate that all laminated mudrocks thought to have been deposited in quiet water deep basinal settings are in serious need of re-evalution.

Flume studies show that advective traction current transport of mud, as floccule pellets, is far more important for understanding mudrock sedimentary processes than anyone has hitherto suspected. Ripple-accreted muds, recognizable in hand sample and outcrop once one knows what to look for, indicate that throughout geologic time advective tractions currents have eroded, transported and deposited substantial volumes of fine grained sediment. Floccule ripples generated in flume experiments have crests only 2-20 mm in amplitude, with crest spacings on the order of 30-40 cm (Schieber et al., 2007). With such possibility for traction transport, mudrock sequences are therefore potentially far less complete than has often been assumed under the model of basinal, quiet water deposition (Schieber et al., 2007).

HEWITT'S COVE SECTION

Attempts to understand the depositional environments of the fine clastics of the Cambridge Argillite (Boston Basin, USA, Atlantica terrane) have been marked by controversy (Bailey and Bland, 2001) over whether or not the formation contains lonestones that are best interpreted as dropstones derived from the Late Proterozoic glaciation. This debate goes in tandem with discussions about the till versus debris flow origin for the coarser clastics of the underlying Roxbury Formation and in particular its Squantum "tillite" member.

A granitoid lonestone from Locality F at the Hewitt's Cove site in Hingham, MA, occurs with argillite roll-up clasts and planar laminated clasts that were apparently deposited in a series of similar events. The planar laminated clast appears as if it had traveled a short distance, presumably downslope, as a mudball.

The granitoid lonestone is angular (in accord with a dropstone interpretation) and appears to be a granite in terms of its petrology. It has large microcline crystals with splotchy interiors that look as if they have been partly reconfigured during late stage magma cooling. Well preserved albite is present (approximately An5 by the Michel-Levy and perpendicular to X methods on albite twinning). Quartz crystals were subjected to some pressure, as indicated by mildly wavy extinction. This granite petrology seems to be most similar to presumed granite-derived conglomerate (Newport Formation) clasts recovered at King's Beach, Rhode Island, although in the latter case, the microcline is in a much better state of preservation and the associated albite has a composition of An9.

The identity of this granite lonestone in formational terms seems to be similar to the igneous rock unit that was providing clasts for the Newport Formation conglomerate. Several sources nearby can be ruled out as sources for the clast. The Dedham Granite (source of Plymouth Rock) can be ruled out because its alkali feldspar is a pink perthite, and its sodic feldspar is a highly altered saussurite rimmed by an inclusion-free zone of sodium-rich plagioclase. Also, the clast apparently lacks the blood-red sphene characteristic for the Dedham. The Cape Ann and Quincy Granites can be ruled out because, although they are gray granites like this clast, they only have a single feldspar.

Hence, the clast seems to best fit with the plutonic suite of the Fall River Batholith, and in particular the Fall River Granite, a medium-grained, light gray granite with only minor dark minerals (Skehan, 2001). This and other light-colored granites in southern Avalonia have ages in the vicinity of 600 million years (Skehan, 2001). A Fall River, southern Avalonian provenance for this clast seems likely.

Evidence therefore seems to be accumulating for glacial ice as a sedimentary agent in the Boston Basin Group. Some such explanation is needed to explain the strange association of very coarse-grained and very fine-grained facies in the Boston Basin Group, a juxtaposition that has posed a challenging sedimentological puzzle. The iceberg dumping, dropping, and grounding structures described by Thomas and Connell (1984) may be of assistance with this conundrum. Isolated lenses of diamictite encountered in the Boston Basin Group may best be interpreted in terms of possible ice grounding and ice dumping structures. If some of these structures can be interpreted as evidence for ice grounding, then they would be evidence for a very shallow water environment for the deposition of major parts of the Boston Basin Group. Thomas and Connell (1984) note that the "appearance of an isolated trough of diamictite within otherwise fine-grained lacustrine sediment, in the form of the downfold structure occurring beneath it, and the nature of the associated faults, are all commensurate with the grounding and subsequent in situ decay of a large, debris-rich iceberg." Thus, the lenticular diamictite beds that are interstratified with the laminite facies are perhaps not in fact channel deposits as has been previously envisioned by Bailey and Bland (2001), Smith and Socci (1990) and Socci and Smith (1990).

Another factor in interpreting the Boston Basin Group depositional environments involves recognition of the correct depositional conditions in the fine clastics of the Cambridge Argillite (CA). These laminated fine clastics have been interpreted as turbidites (Bailey and Bland, 2000), implying that these strata were deposited in a lower fan, basin plain depositional environment, following a depositional model that is most frequently applied (and perhaps most appropriate for) Mesozoic and Cenozoic sediments (Mattern, 2005). However, there are myriad laminae in the CA that do not support the hypothesis of density current deposition, but rather are better interpreted as the result of deposition by traction currents, suggesting either tidal or wave influence. The primary signature of turbidity current deposition is either graded bedding or a structureless bed (A unit) with a scour or load casted base. Isolated ripple sets lacking an associated graded bed below are most parsimoniously interpreted as traction/fluid-flow deposits, as there is no "A unit" to go with the "C unit." A few intervals within the CA fine clastics are best interpreted as low density (Stow) turbidites as suggested by Bailey and Bland (2000); many others probably result from suspension settling derived from turbid, presumably glacial sediment plumes (Ó Cofaigh and Dowdeswell, 2001).

ASPIDELLA'S DEPOSITIONAL ENVIRONMENT

Although *Aspidella* seems to serve as a catch-all taxon for oval holdfast impressions and similar fossils from the Ediacaran biota, it seems reasonable to assign the Cambridge Argillite specimens to this genus. The size and internal structures of the specimens strongly support a multicellular-biogenic interpretation. The absence of pyrite blebs in direct association with the fossils further supports a fossil rather than pseudofossil interpretation (Seiders et al., 1975).

The *Aspidella* specimens at Hewitts' cove are associated with laminated rock that suggests basinward deposition in comparison to other facies at the site. The CA strata at Hewitt's cove bearing sedimentological features indicative of both shallower water deposition and glacial influence do not host fossils. We propose here a model in which the fine clastics of the CA can be divided into two groups.

The first group is unfossiliferous and was deposited nearshore under conditions of rapid influx of glacial derived sediment and occasional dropstones, plus evidence for till dump and grounding structures. Water depth was shallow and possibly influenced by seasonal or year-round shore ice accumulations (Ó Cofaigh and Dowdeswell, 2001).

The second group consists of fossiliferous laminites that were somewhat distal to the first group, deposited below wave base. Dropstones are not seen in this facies, but nevertheless the depositional processes of second group laminites are genetically related to the processes of the first group, in the following fashion. Turbid glacial plumes, possibly generated under shelf ice, flowed into the Boston Basin and deposited laminae both above and below storm wave base.

More distal deposits of facies number two were deposited in open water conditions, below wave base, and out of the dropstone zone in an area where sediment influx and turbidity was limited. The *Aspidellas* occupied a habitat between the nearshore deposition of facies one and the center of the basin, in other words, we hypothesize here that they lived in a relatively narrow zone between storm wave base and the base of the photic zone. Storm wave base may have been relatively shallow, if as seems likely, the Boston Basin represented a relatively restricted embayment. *Aspidella* may have preferred this hypothesized habitat because of more moderate sedimentation rates and, possibly, clearer water and/or greater food availability at a site distal from the influx of relatively sterile, glacial derived sediments.

Judging from field relationships and inferring from the implications of Walther's Law, CA facies one and two were not greatly distant from one another, but rather constituted a transitional series from inshore laminites influenced by grounded ice to offshore laminites formed primarily by suspension sedimentation resulting from periodic turbid glacial plumes.

REFERENCES

Bailey, R.H., and Bland, B.H., 2000, Ediacaran fossils from the Neoproterozoic Boston Bay Group, Boston area, Massachusetts: Geological Society of America Abstracts with Programs, v. 32, p. A11.

Bailey, R.H., and Bland, B.H., 2001, Recent developments in the study of the Boston Bay Group in Guidebook for Geological Field Trips in New England, 2001 Annual Meeting of the Geological Society of America: Boston, Massachusetts, Geological Society of America, p. U-1 - U-23.

Mattern, F. 2005. Ancient sand-rich submarine fans: depositional systems, models, identification, and analysis: Earth-Science Reviews, v. 70, p. 167-202.

McMenamin, M. A. S., 1998, The Garden of Ediacara: Discovering the First Complex Life. Columbia University Press, New York, 295 p.

McMenamin, M. A. S., 2004, Ediacaran and Cambrian fossils and strata of the Hewitt's Cove locality, Weymouth Back River, and East Point, Nahant region, Boston Basin, in Hanson, L. S., ed., Guidebook to field trips from Boston, MA to Saco Bay, ME, New England Intercollegiate Geological Conference 96th Annual Meeting, Oct 8-10, 2004, Dept. of Geological Sciences, Salem State College, p. 211-218.

Ó Cofaigh, C., and Dowdeswell, J. A., 2001, Laminated sediments in glacimarine environments: Diagnostic criteria for their interpretation: Quaternary Science Reviews, v. 20, p. 1411-1436.

Schieber, J., Southard, J., and Thaisen, K., 2007, Accretion of mudstone beds from migrating floccule ripples: Science, v. 318, p. 1760-1764.

Seiders, V. M., Mixon, R. B., Stern, T. W., Newelt, M. F. and Thomas, C. B., 1975, Age of plutonism and tectonism and a new minimum age limit on the Glenarm Series in the Northeast Virginia Piedmont near Occoquan: American Journal of Science, v. 275, p. 481-511.

Skehan, J. W. 2001, Roadside Geology of Massachusetts, Mountain Press Publishing, Missoula, Montana.

Socci, A. D., and Smith, G. W., 1990, Stratigraphic implications of facies within the Boston Basin: Geological Society of America Special Paper 245, p. 55-74.

Smith, G. W. and Socci, A. D., 1990, Late Precambrian Sedimentary Geology of the Boston Basin: Geological Society of America Special Paper 245, p. 75-84.

Macquaker, J. H. S., and Bohacs, K. M., 2007, On the accumulation of mud: Science, v. 318, p. 1734-1735.

Thomas, G. S. P., and Connell, R. J., 1984, Iceberg drop, dump, and grounding structures from Pleistocene glacio-lacustrine sediments, Scotland: Journal of Sedimentary Petrology, v. 55, p. 243-249.

Weaver, P. G., McMenamin, M. A. S., and Tacker, R. C., 2006, Paleoenvironmental and paleobiogeographic implications of a new Ediacaran body fossil from the Neoproterozoic Carolina Terrane, Stanly County, North Carolina: Precambrian Research, v. 150, p. 123-135.