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Tectonic inheritance at a continental margin

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Cover: Map showing the record of tectonic inheritance through two complete Wilson cycles in eastern North America. See the 2005 GSA Presidential Address, "Tectonic inheritance at a continental margin," by William A. Thomas, p. 4–11.

SCIENCE ARTICLE

Tectonic inheritance at a continental margin

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INTRODUCTION

Forty years ago, the eastern margin of North America inspired Tuzo Wilson (1966) to ask, "Did the Atlantic close and then re-open?" The Wilson cycle of closing and opening of ocean basins incorporates the cyclic assembly and breakup of supercontinents. Alternate processes of extension and compression of continental margins suggest an important potential for tectonic inheritance and overprinting.

Now, we recognize a succession of two complete Wilson cycles in eastern North America: closing of an ocean and assembly of the Rodinia supercontinent, breakup of Rodinia and opening of the Iapetus Ocean, closing of Iapetus and assembly of the Pangaea supercontinent, and breakup of Pangaea and opening of the Atlantic Ocean (Fig. 1). Precambrian rocks of cratonic North America indicate less well-defined, earlier cycles. Tectonic inheritance at a range of scales has been recognized in the successive continental margins preserved within the crust of present eastern North America, posing several fundamental questions. Does each episode of supercontinent assembly and breakup adapt to the tectonic framework of a preexisting continental margin and, in turn, leave a mold for the next episode? Is tectonic inheritance through successive Wilson cycles a first-order constraint on the processes through which continental crust is accumulated and continental fabrics evolve? Does tectonic inheritance in the shallow crustal structures reflect a pervasive fabric of the deeper lithosphere?

ASSEMBLY OF RODINIA (THE GRENVILLE OROGEN)

Metamorphic and igneous rocks of the Grenville province, ranging in age from ca. 1350 to 1000 Ma, record closing of an ocean and assembly of the Rodinia supercontinent (e.g., Hoffman, 1991). The long span of ages suggests multiple events during which multiple elements were swept up and sutured successively to cratonic proto-Laurentia (e.g., McLelland et al., 1996; Mosher, 1998).

The Grenville front, at the leading edge of the province, is mapped through generally broad curves along the outcrop in Canada and southward with decreasing resolution in the subsurface, using drill and geophysical data, approximately to central Tennessee; subsurface data define a separate segment in Texas (Figs. 1 and 2). No data presently are available to locate the Grenville front precisely beneath a thick sedimentary cover in the Mississippi Embayment of the Mesozoic-Cenozoic Gulf Coastal Plain; however, the trace must accommodate a substantial dextral bend between the mapped Grenville (Llano) front in Texas and the approximately located trace in the subsurface in central Tennessee (Fig. 2).

The pre-Rodinia (pre-Grenville) continental margin is unknown; however, the dextral bend of the Grenville front beneath the Gulf Coastal Plain suggests possible inheritance from a dextral offset in the older continental margin. Northwest-striking dikes (ca. 1350 Ma) in Oklahoma (Denison, 1982) parallel the trend of the dextral bend of the Grenville front and suggest the possible orientation of the offset of the older rifted continental margin (Fig. 2). Few other hints are available to suggest the trace of the pre-Rodinia rifted margin of cratonic proto-Laurentia. The Grenville front truncates internal tectonic fabrics within, and boundaries between, several older provinces, from the Archean Superior province to the 1500–1300-Ma

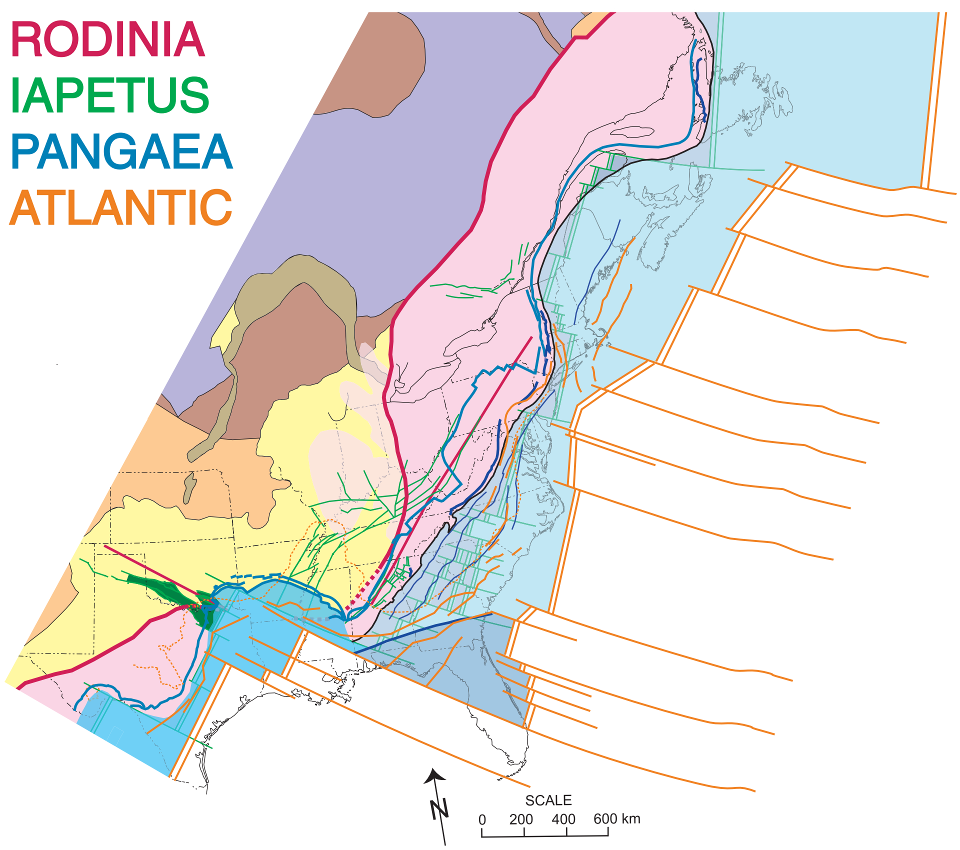

Figure 1. Map showing the record of tectonic inheritance through two complete Wilson cycles in eastern North America (compiled from Figs. 2–5). Assembly of Rodinia, opening of the Iapetus Ocean, assembly of Pangaea, and opening of the Atlantic Ocean are color-coded on this map and in Figures 2–5.

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Granite-Rhyolite province (Fig. 2), which have distinct ages and tectonic origins. Fabrics from older cycles of tectonic accretion may hold clues to the trace of the pre-Rodinia margin, perhaps extending tectonic inheritance during cyclic assembly and breakup of supercontinents back in time to the Archean cratons.

Sedimentary deposits in the Grenville foreland in Ohio and Kentucky (Fig. 2) are interpreted to record filling of an intracratonic rift system (Drahovzal et al., 1992) or, alternatively, a synorogenic foreland basin (Santos et al., 2002), possibly a broken foreland. Further resolution of the structure of the Grenville foreland may help to constrain the shape of the pre-Rodinia rifted margin by analogy with younger foreland basins that have distinct tectonic inheritance from the preceding rifted margin.

The range of ages and compositions of Grenville rocks, variations in Pb isotopic ratios, and tectonic fabrics indicate intra-Grenville sutures, consistent with multiple accreted terranes and conjugate continental margins within the assembly of Rodinia (e.g., McLelland et al., 1996; Hatcher et al., 2004). One possible intra-Grenville suture, the New York–Alabama magnetic lineament (King and Zietz, 1978), has a nearly straight trace that may reflect either accretion along a straight segment of the pre-Grenville rifted margin of proto-Laurentia, accretion at a margin already smoothed by accreted terranes, or orogen-parallel slip cutting across the shape of the margin. A Grenville age and Pb isotopic ratios link the basement rocks of the Argentine Precordillera terrane to Laurentia (Kay et al., 1996), indicating that rifting during breakup of Rodinia cut across intra-Grenville sutures.

BREAKUP OF RODINIA AND OPENING OF THE IAPETUS OCEAN

Synrift sedimentary and igneous rocks, a post-rift unconformity, and early post-rift sedimentary strata document the breakup of Rodinia, the opening of the Iapetus Ocean, and the isolation of Laurentia by Cambrian time (ca. 530 Ma). A range of ages (e.g., Aleinikoff et al., 1995; Hogan and Gilbert, 1998; Thomas et al., 2000; Cawood and Nemchin, 2001; Owens and Tucker, 2003) spans early extension (760–650 Ma), pervasive rifting (620–545 Ma) along most of the Laurentian margin, and late-stage rifting (540–530 Ma) of microcontinents. Later sedimentary burial and deformation have obscured the trace of the Iapetan rifted margin, segments of which are dispersed in the Appalachian allochthon and Ouachita footwall. Data from outcrop geology, deep wells, and geophysical surveys provide for palinspastic reconstruction of the rift (e.g., Thomas, 1977, 1991; Cawood et al., 2001).

The palinspastically restored Iapetan rifted margin follows an orthogonally zigzag trace defined by northeast-striking rift segments offset by northwest-striking transform faults (Figs. 1 and 3). Intersections of rift segments and transform faults frame promontories (convex oceanward) and embayments[1] (concave oceanward) of the rifted continental margin. The trace of the Iapetan Alabama-Oklahoma transform corresponds to the probable location of the large-scale dextral bend in the Grenville front, suggesting tectonic inheritance from the shape of the Grenville orogen, as well as from the possible dextral offset in the pre-Rodinia rifted margin of proto-Laurentia and the northwest-striking 1350-Ma dike fabric (Fig. 3). Excepting the Alabama-Oklahoma transform, no tectonic inheritance from Grenville margins, sutures, or other fabrics has been recognized in the Iapetan rift system.

The trace of the Iapetan rifted margin is almost entirely within rocks of the Grenville province, leaving a belt of Grenville rocks along the eastern margin of Laurentia (Fig. 3). Along the Iapetan Alabama-Oklahoma transform, however, granite boulders in Ordovician slope deposits have ages (Bowring, 1984) that correspond to the Granite-Rhyolite province, suggesting that the rift and transform in the corner of the Ouachita embayment cut across the Grenville front (Fig. 2). The Iapetan rift evidently cut across intra-Grenville sutures, for example, leaving some isotopically distinct, possibly "non-Laurentian Grenville" rocks of the Blue Ridge attached to "Laurentian Grenville" rocks (Loewy et al., 2002; Hatcher et al., 2004) and transferring the Laurentian Argentine Precordillera terrane to Gondwana (Thomas and Astini, 1996). Further resolution of traces of intra-Grenville sutures and terranes will define additional piercing points for reconstruction of conjugate margins within the assembly of Rodinia.

Contrasts in crustal structure and tectonic history distinguish transform, upper-plate-rift, and lower-plate-rift segments along the Iapetan rifted margin of Laurentia, consistent with a low-angle-detachment simple-shear mechanism (Thomas, 1993, Figure 2 therein). Narrow (~25 km) zones of transitional crust characterize transform faults, which function as vertical fracture zones to offset the rift and to bound domains of opposite dip of the detachment (e.g., Lister et al., 1986). A wide zone (>200 km) of extended transitional crust with rotated basement graben blocks and thick (>10 km) synrift sediment on a lower-plate rifted margin contrasts with a more narrow zone of transitional crust, general lack of preserved synrift sediment, and a post-rift residual thermal uplift on an upper-plate margin (e.g., Thomas, 1993; Thomas and Astini, 1999). Despite the important contrasts in crustal structure, no clear association with fabrics of Grenville and older rocks indicates tectonic inheritance of the internal style of the Iapetan rift; however, these structures did set the stage for pervasive inheritance during the assembly of Pangaea.

Rift-parallel graben systems (Mississippi Valley, Birmingham, and Rome; Fig. 3) indicate Early to early Late Cambrian, late synrift extension inboard from the rifted margin (Thomas, 1991). A dextral offset from the Mississippi Valley graben to the Rome trough, including the transverse Rough Creek graben, suggests a transform offset of the intracratonic graben systems (Thomas, 1993). Any possible relationship between the intracratonic rift-parallel graben systems and older fabrics is obscure and presently unrecognized; however, like the structures of the rifted margin, these faults provide a mold for tectonic inheritance by later structures. The Southern Oklahoma fault system parallels the Alabama-Oklahoma transform and extends into the Laurentian craton from the Ouachita embayment in the rifted margin (Fig. 3). Bimodal igneous rocks (539–530 Ma) along the Southern Oklahoma fault system (Gilbert and Denison *in* Van Schmus et al., 1993) suggest a leaky transform, which, like

[1]Originally termed "reentrant" (Thomas, 1977) but changed to "embayment" (Thomas, 1983) to avoid confusion with the term "recess," which denotes a cratonward concave bend in a thrust belt.

the Alabama-Oklahoma transform, parallels the dextral bend in the Grenville front, the strike of the 1350-Ma dikes, and the possible dextral offset in the pre-Rodinia continental margin, clearly indicating tectonic inheritance.

ASSEMBLY OF PANGAEA (THE APPALACHIAN-OUACHITA OROGEN)

The Appalachian-Ouachita orogenic belt records the successive, diachronous Taconic (Ordovician-Silurian), Acadian (Devonian-Mississippian), and Alleghanian (Mississippian-Permian) orogenies (Drake et al., 1989; Osberg et al., 1989; Hatcher et al., 1989), culminating in closure of Iapetus and assembly of the Pangaea supercontinent in Permian time. The well-mapped trace of the orogen from Newfoundland to Alabama exhibits sweeping curves of salients (convex cratonward in the direction of tectonic transport) and more angular recesses (concave cratonward) (Fig. 4). Westward from Alabama in the subsurface beneath the Gulf Coastal Plain, deep drill and seismic reflection data, as well as outcrops in the Ouachita Mountains and in the Marathon region of west Texas, document curves of similar magnitude (Thomas et al., 1989).

Appalachian-Ouachita salients are located at embayments of the Iapetan margin, and recesses are on promontories (Rankin, 1976; Thomas, 1976, 1977). The leading part of the thrust belt wrapped around the shape of promontories and embayments of the older rifted margin (Fig. 4), indicating a grand scale of tectonic inheritance. Other specific manifestations of tectonic inheritance are expressed at a range of scales.

Each of the three comprehensive orogenic episodes encompasses substantial along-strike diachroneity, which reflects a systematic relationship to the shape of the Iapetan rifted margin. From the St. Lawrence promontory to the Alabama promontory, a stratigraphically upward transition from shelf carbonates to black shale records Taconic tectonic loading, foreland subsidence, and synorogenic sedimentation (Drake et al., 1989). The times of initial Taconic tectonic loading and foreland subsidence vary systematically in relation to the shape of the Iapetan rifted margin: first, on the St. Lawrence promontory in Newfoundland; next, on the Alabama promontory followed by migration

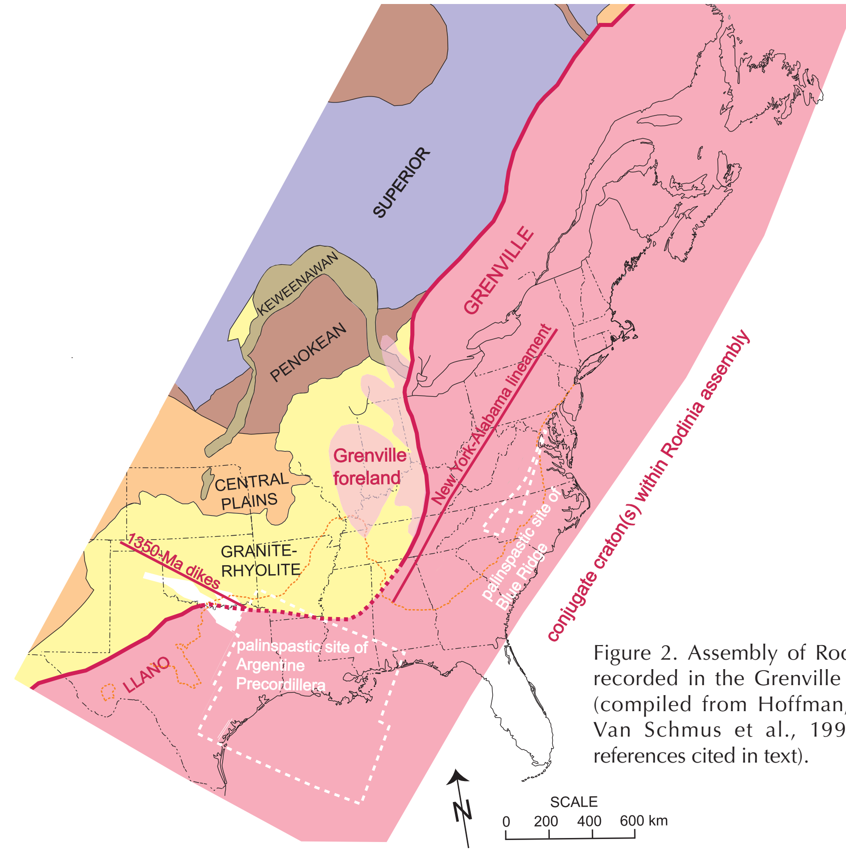

Figure 2. Assembly of Rodinia as recorded in the Grenville orogen (compiled from Hoffman, 1989; Van Schmus et al., 1993; and references cited in text).

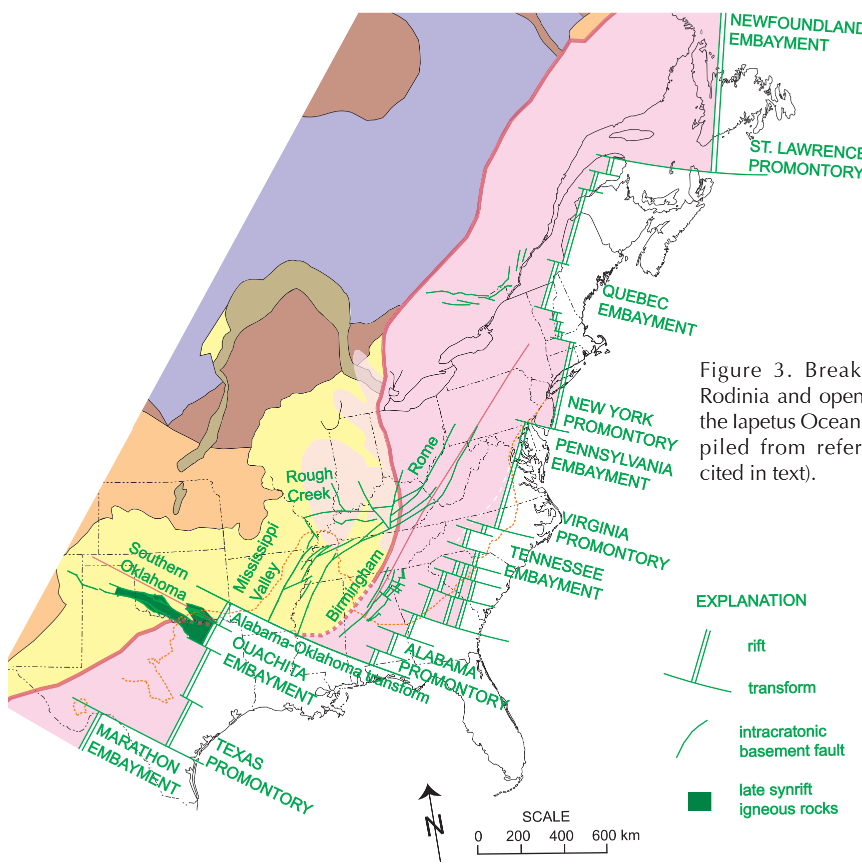

Figure 3. Breakup of Rodinia and opening of the Iapetus Ocean (compiled from references cited in text).

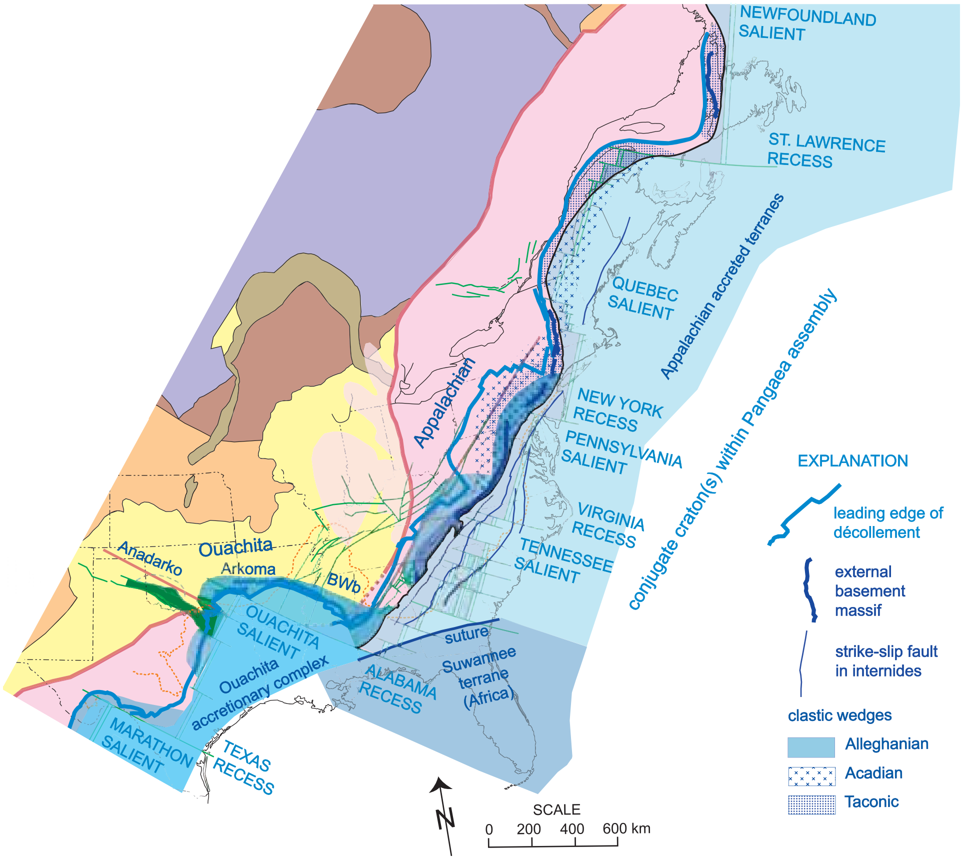

Figure 4. Assembly of Pangaea as recorded in the Appalachian-Ouachita orogen (compiled from references cited in text). Patterns for synorogenic clastic wedges show areas where thickness is >50% of the maximum (in present allochthonous position not palinspastically restored); dashed line shows deeper part of the intracratonic Anadarko basin. BWb—Black Warrior basin.

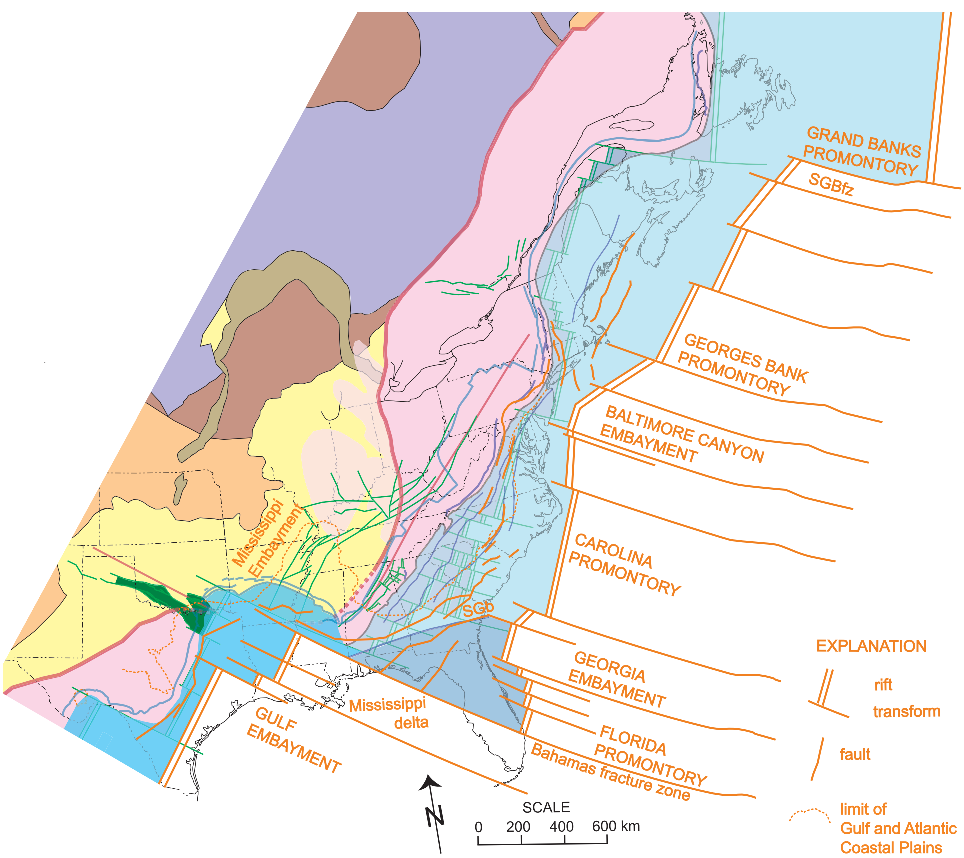

Figure 5. Breakup of Pangaea and opening of the Atlantic Ocean (compiled from Klitgord and Schouten, 1986; and references cited in text). SGBfz—Southern Grand Banks fracture zone (transform); SGb—South Georgia basin.

into the Tennessee embayment; then, on the New York promontory followed by migration into the Pennsylvania embayment; and finally, in the Quebec embayment (Bradley, 1989, Figures 1 and 7 therein). Taconic terrane accretion must have modified the shape of the margin; however, initial Acadian foreland subsidence migrated progressively southward from the St. Lawrence promontory to the Virginia promontory (Ettensohn, 1985, Figures 1 and 2 therein). Along the Appalachian orogen, late Paleozoic Alleghanian foreland subsidence overprinted the Taconic and Acadian forelands; however, along the Ouachita margin westward from the corner of the Alabama promontory, a passive margin persisted until Mississippian time (Thomas, 1989). Ouachita tectonic loading of the Laurentian margin began in middle Mississippian time in the Black Warrior foreland basin along the southeastern part of the Alabama-Oklahoma transform on the Alabama promontory and migrated northwestward along the transform to the Arkoma foreland basin in the Ouachita embayment in Early Pennsylvanian time (Fig. 4) (Houseknecht, 1986; Thomas, 1989), continuing the pattern of adaptation of the shape of the orogen to that of the Iapetan rifted margin.

Regardless of the diachroneity of foreland subsidence and synorogenic sedimentation along the orogen, maximum subsidence, as indicated by maximum thickness of synorogenic sediment along the Taconic, Acadian, and Alleghanian forelands, is centered consistently in embayments of the Iapetan rifted margin (Fig. 4) (Thomas, 1977, Figures 5–10 therein). Although the differences in the magnitude of subsidence could reflect along-strike variations in the magnitude of the tectonic loads, the systematic relationship of differentially greater foreland subsidence in the embayments than on the promontories suggests a systematic spatial variation in the strength of the lithosphere in relation to the shape of the older rifted margin. Brittle structures in the shallow crust define the shape of the rifted continental margin; however, the distribution of magnitudes of foreland subsidence suggests tectonic inheritance at a lithospheric scale.

In addition to thrust-belt curvature convex toward the craton, where thrust-belt salients bend around embayments of the rifted margin, the thrust belt propagated to a greater width and farther cratonward in salients than in recesses (Fig. 4). The geometry of the salients adapted to the greater thickness of sedimentary cover and to greater depth to crystalline basement rocks beneath foreland basins in the embayments. Along the Appalachian orogen, the thin-skinned décollement in salients is within the Paleozoic sedimentary cover succession above Precambrian crystalline basement rocks. On some promontories along the arms of thrust-belt recesses, the Appalachian allochthon incorporates crystalline basement rocks in external basement massifs (Fig. 4), indicating that the décollement cuts down from the thick sedimentary cover in embayments along strike into basement rocks beneath a thinner sedimentary cover on promontories. Unconformable overstep of Silurian conglomerate onto basement rocks on the southern part of the New York promontory (Drake et al., 1989) indicates that the Taconic foreland, like the later Alleghanian foreland, incorporated an external basement massif on the promontory.

Synorogenic brittle reactivation of Iapetan synrift intracratonic faults inboard from the rifted margin is evident from the proximal to the distal foreland, indicating compressive stress from Appalachian-Ouachita orogenesis (e.g., Kolata and Nelson, 1991). The thin-skinned thrust belt includes both frontal and lateral ramps that rise above basement extensional faults and transverse faults, respectively (e.g., Thomas and Bayona, 2005). Reactivated faults and a south-plunging arch overprinted the Iapetan Mississippi Valley graben (Thomas, 1991). Reactivation of the Southern Oklahoma fault system generated the Arbuckle-Wichita-Amarillo basement uplifts (Perry, 1989); the associated Anadarko basin along the fault system is among the deepest known cratonic basins.

In the Appalachian metamorphic internides, which include accreted terranes and internal basement massifs, orogen-parallel strike-slip faults (Gates et al., 1988) show no systematic adaptation to the shape of the older Iapetan rifted margin (Fig. 4), suggesting oblique collision, transpression, and orogen-parallel tectonic transport. The effects of tectonic inheritance evidently diminish outboard from the older rifted margin, probably because accretion of successive terranes modified the shape of the margin.

The latest episodes of Alleghanian foreland thrusting appear nonsystematically diachronous along the orogen. Although not precisely dated, the last of a succession of Alleghanian events around the Alabama promontory was continent-continent collision with African continental crust, now marked by a suture beneath the Gulf Coastal Plain (Fig. 4). The suture is oblique to the Iapetan rifted margin, diverging eastward from the corner of the Alabama promontory. Continent-continent collision drove previously accreted terranes onto the continental shelf of the Alabama promontory, accounting for a diachronous succession of Ouachita and Appalachian thrusting (Thomas, 2004). The shape of the Iapetan margin, and not the shape of the collider, evidently controlled the orientation of Appalachian-Ouachita foreland structures.

Appalachian-Ouachita structures, from the scale of salients and recesses to foreland basins to individual thrust ramps and basement faults, have a clear pattern of tectonic inheritance from the trace and structures of the Iapetan rifted margin of eastern Laurentia. Most of the inherited structures are in the brittle, shallow crust; however, localization of maximum synorogenic flexural subsidence of the foreland in embayments of the Iapetan margin along transform faults (at oceanward concave intersections of transform faults with rift segments) suggests tectonic inheritance at a lithospheric scale. The assembly of Pangaea also set the mold for subsequent structures that formed during supercontinent breakup.

BREAKUP OF PANGAEA AND OPENING OF THE ATLANTIC OCEAN

Triassic grabens adjacent to the Atlantic Coastal Plain document inboard extension associated with the breakup of Pangaea, the opening of the modern Atlantic Ocean, and the isolation of the North American continent. Unlike the records of earlier Wilson cycles, this latest event is recorded in the modern continental shelf and ocean floor, including transform faults that extend from the Mid-Atlantic Ridge to offsets in the shelf margin (Fig. 5). In addition to the exposed Triassic faults, subsurface data document other Triassic faults beneath a post-rift unconformity at the base of the Mesozoic-Cenozoic passive-margin successions in the Atlantic and Gulf Coastal Plains (Fig. 5). The Triassic faults are analogous to the intracratonic faults associated with Iapetan rifting.

The trace of the rifted continental margin includes promontories and embayments analogous to those of the Iapetan margin. The Bahamas fracture zone (transform fault) offsets the continental margin from the Florida promontory into the Gulf embayment; along the Gulf margin, a northwest-trending alignment of Triassic faults parallels the transform (Fig. 5). The traces of the Bahamas transform and the Triassic faults are aligned with the trace of the Iapetan Alabama-Oklahoma transform in a clear expression of large-scale tectonic inheritance (Thomas, 1988).

The width of transitional crust differs on opposite sides of the Gulf of Mexico, suggesting a lower-plate structure on the Texas-Louisiana margin (Buffler and Thomas, 1994). The attenuated lower-plate crustal structure overprints the Ouachita accretionary complex (Keller et al., 1989), suggesting the possibility that distinctive crustal properties may be inherited by the geometry of continental rifting. Deep subsidence of the lower plate along the Bahamas transform within the Gulf embayment accommodated the very thick accumulation of sediment in the Mississippi River delta, inheriting the location of the Iapetan Ouachita embayment and the Pangaean Ouachita thrust-belt salient.

The Bahamas transform reoccupied the position of the older Alabama-Oklahoma transform; however, the Atlantic rifted margin of North America crosses Pangaean sutures and does not follow older Iapetan rift segments (Fig. 5). The Bahamas transform and the Triassic faults cross the Pangaean Suwannee suture; however, the fault boundaries of the Triassic South Georgia basin approximately parallel the Suwannee suture. Northward from the Bahamas transform, the Atlantic rifted margin follows neither the Iapetan rifted margin nor Pangaean sutures; instead, it is outboard of the Iapetan rift, leaving accreted African crust of the Suwannee terrane attached to North America, forming the Florida promontory.

The Southern Grand Banks fracture zone (transform) along the southern margin of the Grand Banks of Newfoundland (Keen and Haworth, 1985) is aligned with the trace of the Iapetan transform at the southern margin of the St. Lawrence promontory (Fig. 5). The trace of the Atlantic rifted margin east of the Grand Banks promontory roughly parallels the trace of the Iapetan rifted margin, but it is far outboard of the Iapetan rift, leaving accreted terranes attached to the North American margin, a pattern that persists southward to the Florida promontory.

Tectonic inheritance on a large scale is reflected in the coincidence in location of large transform offsets of the rifted continental margins. The extraordinary subsidence and sediment accumulation in the Mississippi River delta along the Bahamas fracture zone (transform) within the Gulf embayment is comparable to other examples of differentially greater subsidence along transforms. Inboard from the Bahamas transform margin, subsidence of the Mississippi Embayment, a south-plunging syncline in the Gulf Coastal Plain, overprints the Pangean (late Paleozoic) south-plunging arch and the Iapetan intracratonic Mississippi Valley graben, documenting successive inheritance at a pervasive zone of weak crust. The same zone of weak crust hosts the modern New Madrid seismic zone. On a smaller scale, Atlantic-opening extensional faults reactivated accretionary compressional fabrics of the Pangaean assembly (e.g., Bobyarchick and Glover, 1979).

CONCLUSIONS

Transform faults and aligned compressional structures show repeated tectonic inheritance through successive Wilson cycles of supercontinent assembly and breakup (Fig. 1). In contrast, rift segments of continental margins accumulate accreted terranes, because subsequent rifts break across terrane boundaries, fragmenting the supercontinent assembly. Brittle extensional structures and upper-crustal orogenic structures reflect processes in the shallow crust, as do the many examples of smaller scale tectonic inheritance and reactivation of individual faults. Two relationships, however, suggest inheritance at a lithospheric scale: successive reoccupation of traces of transform faults at the continental margin and differential crustal subsidence along transform faults at rift offsets in continental embayments. A pervasive fabric may vertically partition the lithosphere, both controlling the locations of transforms during successive events of supercontinent breakup and reducing the elastic strength of the lithosphere along transforms, thereby accounting for locations of greatest differential subsidence.

Kinematics of plate boundaries require that transform faults are small circles around the pole of rotation, are parallel to the direction of plate motion, and are essentially vertical, consistent with extent down through the lithosphere. In contrast, rift segments are brittle upper-crustal structures above low-angle detachments that flatten downward within the crust, consistent with inheritance at the scale of individual faults in shallow (brittle) crust.

Recognition of tectonic inheritance has implications for a range of applications beyond the fundamental questions of crustal structure and evolution of continental crust and lithosphere. Differential subsidence at zones of lithospheric weakness, primarily along transform systems, localizes the potential for petroleum provinces in exceptionally thick sedimentary accumulations. Mineralizing brines may be selectively driven from the thicker sedimentary thrust loads in thrust-belt salients at rift-margin embayments, including into the distal foreland. On a smaller scale, frontal thrust ramps over older basement faults, thin-skinned transverse zones over basement transverse faults, and reactivation of basement faults in the foreland provide predictable controls on fracture sets that affect fluid flow in both petroleum and groundwater systems. Repeated inheritance of zones of crustal weakness suggests a focus for modern seismicity.

Studies of tectonic inheritance generally rely on data from the shallow crust, limiting evaluations to a crustal scale. The pervasiveness of zones of crustal weakness associated with transform faults, however, requires a lithospheric scale of investigation. Recent studies of seismic anisotropy define lithosphere-penetrating zones of distributed shear along transform systems (e.g., Baldock and Stern, 2005). The probable significance of transform inheritance and lithospheric properties suggests a fruitful line of investigation, because transform faults appear to be the dominant controls on tectonic inheritance at large scales along continental margins during supercontinent breakup and assembly, as well as on locations of differential subsidence and exceptionally thick sediment accumulations. Resolution of the lithospheric structure of transform faults in the context of tectonic inheritance offers an exciting new perspective and understanding of the evolution of continental crust and lithosphere.

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Prepared from the Presidential Address delivered at the 2005 GSA Annual Meeting & Exposition in Salt Lake City, Utah, on 15 October 2005. ✤

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2005 MEETING STATISTICS

Total attendance:	5891
Abstracts submitted:	3350
Number of technical sessions (including oral and poster sessions):	257
Number of short courses and field trips:	26
Number of exhibiting companies:	225
Number of schools in the Graduate School Information Forum:	67
Employment Service	
Number of interviews scheduled:	312
Number of applicants:	164
Number of employers using the service: (74% academic, 20% applied geology, 6% government)	33
Number of new members signed up:	101

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4 Apr. 2006:	**Farouk El-Baz Award for Desert Research.**** Quaternary Geology and Geomorphology Division. Send nominations to Jack F. Shroder, Jr., Dept. of Geography and Geology, University of Nebraska, Omaha, NE 68182-0199, USA, jshroder@mail.unomaha.edu.

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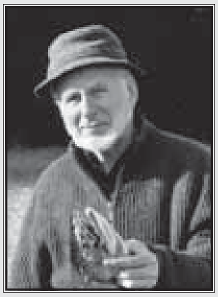

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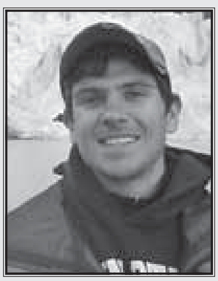

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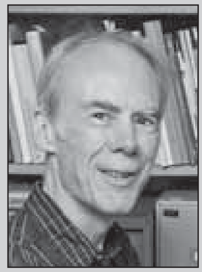

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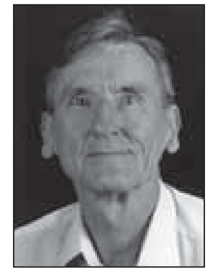

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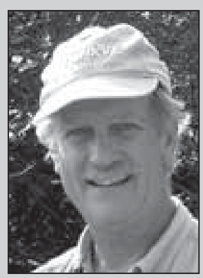

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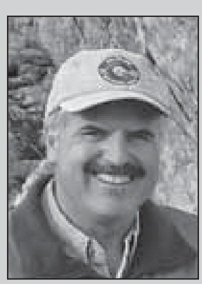

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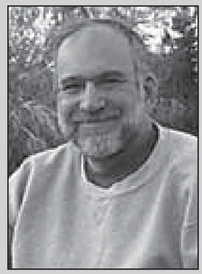

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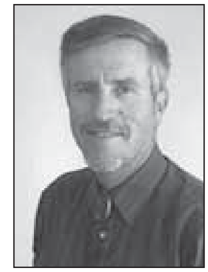
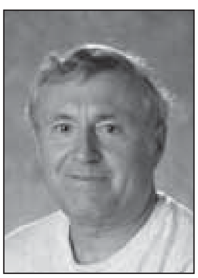
Syracuse University
Hans Olaf Pfannkuch, Citationist



Fred M. Phillips

KIRK BRYAN AWARD

Presented to Fred M. Phillips,
New Mexico Tech
Edward Evenson, Citationist



Lionel Wilson

G.K. GILBERT AWARD

Presented to Lionel Wilson
Lancaster University, UK
James W. Head III, Citationist

John C. Gosse

KIRK BRYAN AWARD

Presented to John C. Gosse,
Dalhousie University
Edward Evenson, Citationist

Teresa E. Jordan

LAURENCE L. SLOSS AWARD

Presented to Teresa E. Jordan
Cornell University
Peter B. Flemings, Citationist

The full text of all 2005 citations and responses is online at:

www.geosociety.org/aboutus/awards

For a paper copy of any or all of the citations and responses, please contact:

Grants, Awards, and Recognition
GSA
P.O. Box 9140
Boulder, CO 80301-9140, USA
awards@geosociety.org
+1.303.357.1028

Jan Tullis

STRUCTURAL GEOLOGY & TECTONICS CAREER CONTRIBUTION AWARD

Presented to Jan Tullis
Brown University
Jane Selverstone, Citationist

THE GEOLOGICAL SOCIETY OF AMERICA

ROCKY MOUNTAIN

58th Annual Meeting
Rocky Mountain Section, GSA
Western State College of Colorado, Gunnison, Colorado

17–19 May 2006

www.geosociety.org/sectdiv/rockymtn/06rmmtg.htm

The 58th Annual Meeting of the Rocky Mountain Section will be hosted by the Geology Program of the Department of Natural and Environmental Sciences, Western State College of Colorado. The meeting will take place on the Western State College campus in Gunnison.

ENVIRONMENT

Western State College of Colorado is a small liberal arts college located in Gunnison, Colorado (population 6,000), on the west side of the divide in southwestern Colorado. Gunnison lies in a pristine Rocky Mountain valley 200 miles southwest of Denver, and at an elevation of 7700 feet, it offers significant year-round outdoor recreational opportunities. Although surrounded by high mountains, up to 14,000 feet in elevation, the town is located in a semiarid basin and is typically cool but sunny in May. The resort town of Crested Butte is 30 miles to the north. Gunnison lies on the eastern margin of the Paleozoic Ancestral Uncompahgre highland and the western tectonic margin of the Laramide Rocky Mountains. Local features of geological interest include the Slumgullion earthflow, the San Juan volcanic field, and the Powderhorn carbonatite complex to the south, West Elk volcano and Black Canyon of the Gunnison to the west, and the Laramide Elk Mountain thrust zone to the northeast. Less than one mile south of town is an extensive Folsom archaeological site. Within a two-hour drive are the northern reaches of the Rio Grande rift and Great Sand Dunes National Park.

CALL FOR PAPERS

Papers are invited for theme and general sessions. Technical session presentations will generally be 12 min in length with 3 min for questions. Some sessions may use a longer format. Only digital media presentations will be allowed (sorry, no slides). Since a centralized computer system will be used, speakers will not be allowed to use their own laptops.

Poster space will be 4' × 8'. A limited number of tables will also be available upon request. Poster authors are required to be present for at least one hour at the end of the day.

ABSTRACTS

Abstracts Deadline: 21 February 2006

Abstracts for all sessions should be submitted online at www.geosociety.org. If you cannot submit your abstract electronically, contact Nancy Carlson, +1-303-357-1061, ncarlson@geosociety.org.

REGISTRATION

Early Registration Deadline: 17 April 2006
Cancellation Deadline: 24 April 2006

GSA Headquarters will handle meeting registration. Please register online at www.geosociety.org.

On-site registration will be available in the Student Union at Western State College:

Tues., 16 May	3–8 p.m.
Wed., 17 May	7:30 a.m.–4 p.m.
Thurs., 18 May	7:30 a.m.–4 p.m.
Fri., 19 May	7:30 a.m.–10 a.m.

Registration Fees

	Early		On-site	
	Full mtg.	One day	Full mtg.	One day
Professional Member	US$125	US$85	US$135	US$95
Professional Member (70 & older)	US$95	US$55	US$105	US$65
Professional Nonmember	US$135	US$95	US$145	US$105
Student or Associate Member	US$75	US$65	US$80	US$70
Student Nonmember	US$85	US$75	US$90	US$80
K–12 Professional	US$40	US$30	US$45	US$35
Guest or Spouse	US$25	US$15	US$30	US$20
Field trip or workshop only	US$25	US$25	US$25	US$25

ACCESSIBILITY

GSA is committed to making its meetings accessible to all people interested in attending. Indicate special requirements (wheelchair accessibility, etc.) on the registration form. Western State College of Colorado is ADA compliant.

FIELD TRIPS

Unless otherwise stated, all field trips will depart from and return to the north entrance of the Student Union at Western State College. The field trip coordinator is Jim Coogan, Western State College, jcoogan@western.edu, but for detailed information on individual field trips, please contact the field trip leaders.

PREMEETING

1. **Black Canyon of the Gunnison: From Proterozoic Assembly to Quaternary Canyon Incision.** (2 days) Mon.–Tues., 15–16 May. Karl Karlstrom, University of New Mexico, +1-505-277-4346, kek1@unm.edu. This field trip offers an overview of the geology of the Black Canyon of the Gunnison, with emphasis on new work on Proterozoic tectonics (Micah Jessup and Karl Karlstrom) plus early stages of work on Quaternary canyon incision (Karl Karlstrom and Eric Kirby). Max.: 30. Cost: US$90, includes lunches, transportation, and guidebook. Trip will start from and return to Western State College Student Union each day.
2. **Eruptive and Non-Eruptive Calderas, Northeastern San Juan Mountains (Where did the ignimbrites come from?).** (2 days) Mon.–Tues., 15–16 May. Peter Lipman, U.S. Geological Survey, +1-650-329-5295, plipman@usgs.gov; William McIntosh, New Mexico Bureau of Geology

& Mineral Resources, mcintosh@nmt.edu. The northeastern San Juan Mountains, the least studied portion of this well-known volcanic region, are the site of several newly identified and/or reinterpreted ignimbrite caldera systems. On Day 1, we will traverse the previously unrecognized North Pass caldera, source of the 32 Ma Saguache Creek Tuff, a regionally distinctive crystal-poor alkalic rhyolite that bridges an apparent gap in the southwestward migration from older explosive volcanism in central Colorado to the culminating locus of Tertiary volcanism in the central San Juan region. Day 2 will focus on features of the Cochetopa Park caldera, presenting evidence that no large explosive eruptions vented from this morphologically beautifully preserved caldera; rather, Cochetopa Park subsided passively as the >500 km^3 Nelson Mountain Tuff vented at 26.8 Ma from an "underfit" caldera 30 km to the SW. New Ar-Ar single-crystal age determinations are critical to these reinterpretations. Leave Comfort Inn of Alamosa, Colorado, 8 a.m., 15 May; overnight in Gunnison; return to Gunnison ~6 p.m., 16 May. Max.: 20. Cost: US$105 for 1 night lodging (double occupancy in Gunnison 15 May), or US$135 for 2 nights lodging (double occupancy in Alamosa 14 May and Gunnison 15 May). Cost includes lunches, transportation, and guidebook.

3. **Depositional Environments of the Cretaceous Dakota Sandstone, Gunnison Basin.** (1 day) Tues., 16 May. Bruce Bartleson, Western State College of Colorado, +1-970-943-2138, bbartleson@western.edu. Trip participants will examine the stratigraphy and depositional systems of the Dakota Sandstone in the Gunnison area. These rocks have previously received little attention; the area has become of interest to petroleum geologists because the Dakota and other sedimentary units here afford a last look at their characteristics before they are buried in the San Juan Sag to the south, a potential petroleum province. Locally, the Dakota Sandstone consists of a lower, low-sinuosity, coarse-grained fluvial system, overlain abruptly by a nearshore fine-grained marine sequence that then grades transitionally upward into the offshore marine shales of the lower Mancos Formation. The nearshore marine sequence shows great variability in detail in depositional systems over the areal extent of the region. The trip will focus on these different depositional systems. Leave Western State College Union at 8:30 a.m., May 16; return at 5 p.m. Max.: 22. Cost: professionals, US$40; students, US$30; includes lunch and transportation.

Concurrent

4. **Multiple Folsom Sites in an Intermontane Setting, Tenderfoot Mountain, Gunnison, Colorado.** (Half-day, afternoon) Thurs., 18 May. Mark Stiger, Western State College of Colorado, +1-970-943-2073, mstiger@western.edu; Erik Bjornstad, +1-970-943-2543, ebjornstad@western.edu. Western State College archaeologists will guide van tours to the Folsom-age Mountaineer site and the Early Archaic Tenderfoot site two miles from town. The Mountaineer site, on top of 900-ft-high W Mountain, has yielded evidence of multiple Folsom occupations, including a Folsom structure. Leaves Western State College Union at 1 p.m. and returns by 5:30 p.m.

Postmeeting

5. **Pleistocene Glacial History of the Taylor River Basin, Gunnison County, Colorado.** (1 day) Sat., 20 May. Keith Brugger, University of Minnesota–Morris, +1-320-589-6310, bruggeka@morris.unm.edu; Barry S. Goldstein, University of Puget Sound, +1-253-879-3822, goldstein@ups.edu. The drainage basin of the Taylor River was extensively glaciated during the Pleistocene. Glacial systems existed as individual cirque and valley glaciers and larger glacier complexes consisting of large valley glaciers whose accumulation areas coalesced with upland ice fields centered on interfluves. During this trip, we will visit several field localities to facilitate discussions regarding the mapping of ice extent during the Last Glacial Maximum, glacier reconstructions and their paleoclimatic significance, recent cosmogenic exposure ages obtained from moraine boulders, and several remaining "unsolved" problems within the study area. Cost: professionals, US$40; students, US$30.
6. **Laramide-Age, Left-Lateral Strike-Slip Faulting along the Bull Canyon Fault Zone of the Northern Uncompahgre Plateau, Western Colorado: Colorado River Raft Trip from Loma, Colorado, to Westwater, Utah.** (2 days) Sat.–Sun., 20–21 May. Michele Nelson; James Hodge; Richard Livaccari, Mesa State College, +1-970-248-1081, rlivacca@mesastate.edu. This trip involves rafting through mainly flat water stretches of the Colorado River with a brief stretch of relatively tame class I to II rapids along the Black Rocks area. Hiking and moderate climbing can also be expected. A prominent Laramide-age strike-slip structure, called the Bull Canyon fault, has been mapped in the northern Uncompahgre Plateau. The Bull Canyon fault is a complex, subvertical, oblique-slip fault with a predominance of left-lateral strike-slip and lesser amounts of reverse dip-slip. This field trip will focus on field assessment of the kinematic nature of the Bull Canyon fault. Spectacular outcrops will be visited. Trip begins and ends in Grand Junction, Colorado. Primitive camping Sat. night, 20 May, in a remote canyon along the Colorado River. Min.: 8; max.: 13. Cost: professionals, US$200; students, US$50 (max. of 6). Trip includes map, raft guides and equipment, two lunches, one dinner, one breakfast, and van transportation.
7. **Laramide Structural Inheritance of Ancestral Rockies Folds and Faults near Almont, Colorado.** (1 day) Sat., 20 May. James C. Coogan, Western State College of Colorado, +1-970-943-3425, jcoogan@western.edu. Participants of this field trip will visit key exposures of two fault zones and an angular unconformity that document reactivation of Ancestral Rockies structural trends during Laramide folding and faulting in the area between the Taylor River and Cement Creek canyons northeast of Almont, Colorado. Field stops include the Roaring Judy fault zone, the Cement Creek fault zone, and the Jurassic angular unconformity that defines the regional erosion surface after Ancestral Rockies uplift. The Roaring Judy fault formed the northeastern boundary between the Ancestral Uncompahgre uplift and the Central Colorado trough in Pennsylvanian through Permian time. The fault zone was reactivated by Laramide high-angle reverse faults. The Cement Creek fault is a Laramide high-angle reverse fault that reactivated

the hinge zone of an Ancestral Rockies–age anticline. The angular unconformity at the base of the Jurassic Junction Creek Sandstone truncates Ancestral Rockies structures and is folded and faulted along Laramide reverse fault zones. Observations from field stops are integrated into a palinspastic reconstruction of the northeast margin of the Uncompahgre uplift at the time of unconformity development. Leave Western State College Union at 8:30 a.m.; return at 5 p.m. Max.: 22. Cost: professionals, US$40; students, US$30; includes lunch, transportation, and map.

THEME SESSIONS

1. **Structural, Stratigraphic, and Igneous Evolution of the Rio Grande Rift System.** Scott Baldridge, Los Alamos National Laboratory, +1-505-667-4338, sbaldridge@lanl.gov; John Fletcher, Western State College of Colorado, +1-970-943-2367, jfletcher@western.edu.
2. **Tertiary Laramide Evolution of the Rocky Mountains.** Jim Coogan, Western State College of Colorado, +1-970-943-3425, jcoogan@western.edu; Dave Lageson, Montana State University, +1-406-994-6913, lageson@montana.edu.
3. **Evolution of Pennsylvanian-Permian Ancestral Rocky Mountains—Structure, Stratigraphy, and Tectonics.** Chuck Kluth, Colorado School of Mines, +1-303-904-2939, ckluth@mines.edu; Ron Blakey, Northern Arizona University, +1-928-523-2740, Ronald.Blakey@nau.edu.
4. **Council on Undergraduate Research (Posters).** Bill Dinklage, Utah Valley State College, +1-801-863-7607, dinklawi@uvsc.edu.
5. **Geoarchaeology of the Southern Rocky Mountain Region.** Mark Stiger, Western State College of Colorado, +1-970-943-2073, mstiger@western.edu; Casey Dukeman, Western State College of Colorado, +1-970-943-2180, cdukeman@western.edu.
6. **Volcanism of the Southern Rocky Mountain Region.** Allen Stork, Western State College, +1-970-943-3044, astork@western.edu.
7. **Geoscience Lecture and Lab—What Works for You? Tried and True or Innovative and Different!** C. Frederick Lohrengel II, Southern Utah University, +1-435-865-8051, lohrengel@suu.edu; Robert L. Eves, +1-435-586-1934, eves@suu.edu; Mark R. Colberg, +1-435-865-8331, colberg@suu.edu.
8. **Collaborative Efforts to Link Science to Natural Resource Management in the West.** Christine Turner, U.S. Geological Survey, cturner@usgs.gov.
9. **Unraveling Ancient Continental Ecosystems.** Fred (Pete) Peterson, U.S. Geological Survey, +1-303-236-1546, fpeterson@usgs.gov; Ron Blakey, Northern Arizona University, +1-928-523-2740, ronald.blakey@nau.edu.
10. **Advances in Petroleum Geology in the Rocky Mountain Region.** Rex Cole, Mesa State College, +1-970-248-1599, rcole@mesastate.edu; Jim Coogan, Western State College of Colorado, +1-970-943-3425, jcoogan@western.edu.
11. **Springs of the Intermountain West.** Laura Crossey, University of New Mexico, +1-505-277-5349, lcrossey@unm.edu; Abe Springer, Northern Arizona University; Dennis Newell, University of New Mexico.
12. **Cenozoic Paleoclimate of the Southern Rocky Mountains.** Emmett Evanoff, University of Northern Colorado, emmettevanoff@earthlink.net.

STUDENT ACTIVITIES

Roy J. Shlemon Mentor Program in Applied Geoscience. *Sponsored by GSA Foundation.* Wed.–Thurs., 17–18 May, 11:30 a.m.–1 p.m. Lunch provided; location information will be available at the meeting registration desk. Karlon Blythe, kblythe@geosociety.org. This is a chance for students to discuss career opportunities and challenges with professional geoscientists from multiple disciplines. Plan to attend both free luncheons to hear different presenters each day. Students will receive FREE LUNCH tickets in their registration packet to attend the Shlemon Programs. However, space is limited: first come, first served.

The John Mann Mentors in Applied Hydrogeology Program. *Sponsored by GSA Foundation.* Wed., 17 May, 5–6:30 p.m. Location information will be available at the meeting registration desk. Karlon Blythe, kblythe@geosociety.org. This event starts right after tech sessions end. It presents opportunities for students and recent graduates with interest in applied hydrogeology or hydrology as a career to chat over a meal with professionals practicing in these fields of interest. Students will receive a FREE pizza supper ticket in their registration packet to attend the Mann Program. However, space is limited: first come, first served.

SHORT COURSES

1. **Springs Inventory and Classification.** Tues., 16 May, 8 a.m.–5 p.m., half-day in classroom, half-day field trip. Abe Springer, Northern Arizona University–Flagstaff, Arizona, Ph.D., Ohio State University; Larry Stevens, Stevens Ecological Consulting, Flagstaff, Arizona, Ph.D., Northern Arizona University. Limit: 25. Fee: US$175; includes course manual, field trip, and boxed lunch. CEU: 0.8.

   This course introduces the theory and technique of inventorying spring ecosystems and how to classify springs with this inventory of information. The first half of the course is a classroom introduction to the theory and the second half is a field demonstration of the materials and techniques. Although inventory and classification of spring ecosystems has been of great interest to land and resource managers, there has been increased interest in using springs ecosystems for teaching laboratories. Springs are "windows" to aquifers that are much easier to access for teaching purposes than boreholes or wells. Springs are wonderful natural laboratories for teaching many basic concepts of hydrogeology.
2. **Measurement of Indoor Radon in Geologically Diverse Terrains.** Mon.–Tues., 15–16 May, 8 a.m.–5 p.m. Douglas Mose, George Mason University, Fairfax, Virginia, Ph.D., University of Kansas; George Mushrush, George Mason University, Fairfax, Virginia, Ph.D., Georgetown University. Limit: 40. Fee: US$360, includes course manual and lunch. CEU: 1.6.

   This course provides hands-on training to understand, anticipate, and measure geologically dependent indoor radon and waterborne radon. The course is designed for teachers and researchers. An optional exam earns a Radon Measurement Specialist Certificate (National Radon Safety Board, info@nrsb.org) for employment as a home inspector in the real estate market. A general knowledge of soil and hydrology is required. *Optional Exam: Earn a Radon Measurement Specialist Certificate. Contact course instructors to arrange exam (Fee: US$150).*

SPECIAL EVENTS

Ice Breaker. Wed., 16 May, 5 p.m., Aspinall-Wilson Center, Western State College Foundation.

Annual Banquet and Business Meeting. TBA.

Rocky Mountain Section Board Meeting. TBA.

STUDENT TRAVEL

The GSA Rocky Mountain Section and GSA Foundation have made travel grants available for students who are presenting oral or poster papers. Students must be currently enrolled and must be GSA Rocky Mountain Section members. Contact Kenneth Kolm, +1-303-231-9115, kkolm@bbl-inc.com.

STUDENT AWARDS

Awards will be given for best student oral (undergraduate or graduate) and poster (undergraduate only) presentations. To be eligible, students must be lead authors and presenters and should clearly identify their abstracts as student work.

EXHIBITS

A limited amount of exhibit space will be available at US$250 per booth for commercial organizations and US$100 per booth for nonprofits. Contact Robert Fillmore, +1-970-943-2650, rfillmore@western.edu.

ACCOMMODATIONS

The Rocky Mountain Section has arranged special rates at the following hotels. These hotels are within easy walking distance of the Western State campus. Please contact the hotels directly for reservations, and be sure to mention that you need the GSA Rocky Mountain Meeting rate. Because Gunnison is a popular tourist destination, it is recommended that you make your reservation early.

Quality Inn: 400 E. Tomichi Ave., +1-970-641-1237. Single/double: US$55.

Super 8: 411 E. Tomichi Ave., +1-970-641-3068. Single/double: US$50.

Gunnison Inn: 412 E. Tomichi Ave., +1-970-641-0700. Single: US$45; double: US$65.

A complete list of Gunnison hotels can be found at www.gunnisonchamber.com/availability/location.cfm.

For students or those on a budget, a limited number of on-campus apartments may be available. Check the GSA Web site, www.geosociety.org/sectdiv/rockymtn/06rmmtg.htm, for more information.

ADDITIONAL INFORMATION

For additional information, please contact one of the committee members: Robert Fillmore, general chair, +1-970-943-2650, rfillmore@western.edu; Allen Stork, vice chair and technical sessions chair, +1-970-943-3044, astork@western.edu; Jim Coogan, field trip chair, +1-970-943-3425, jcoogan@western.edu.

Call for Geological Papers

2006 GSA Section Meetings

SOUTH-CENTRAL SECTION

6–7 March 2006
University of Oklahoma, Norman, Oklahoma
Early Registration Deadline: 31 January 2006
Information: Neil Suneson, Oklahoma Geological Survey, University of Oklahoma, 100 E Boyd St., Rm N131, Norman, OK 73019-0628, +1-405-325-3031, nsuneson@ou.edu

NORTHEASTERN SECTION

20–22 March 2006
Radisson Penn Harris Hotel and Convention Center
Camp Hill/Harrisburg, Pennsylvania
Early Registration Deadline: 7 February 2006
Information: Noel Potter, Dickinson College, Dept. of Geology, Carlisle, PA 17013-2896, +1-717-245-1340, pottern@dickinson.edu

SOUTHEASTERN SECTION

23–24 March 2006
Marriott Hotel, Knoxville, Tennessee
Early Registration Deadline: 20 February 2006
Information: Claudia Mora, University of Tennessee, Dept. of Earth and Planetary Sciences, 1412 Circle Drive, Knoxville, TN 37996-1410, +1-865-974-5499, cmora@utk.edu

NORTH-CENTRAL SECTION

20–21 April 2006
Student Center, University of Akron, Akron, Ohio
Early Registration Deadline: 20 March 2006
Information: John Szabo, Dept. of Geology, University of Akron, Akron, OH 44325-4101, +1-330-972-8039, jpszabo@uakron.edu

CORDILLERAN SECTION

(Joint Meeting with PSAAPG and SPE-A)
8–10 May 2006
University of Alaska, Anchorage, Alaska
Abstract Deadline: 7 February 2006
See the January 2006 issue of *GSA Today* for more information.

ROCKY MOUNTAIN SECTION

17–19 May 2006
Western State College, Gunnison, Colorado
Abstract Deadline: 21 February 2006
Information: Rob Fillmore, Western State College, Dept. of Natural and Environmental Sciences, Gunnison, CO 81231-0001, +1-970-943-2650, rfillmore@western.edu

Call for Nominations:

Fifteenth Annual Biggs Award

for Excellence in Earth Science Teaching for Beginning Professors

The Biggs Award was established by GSA to reward and encourage teaching excellence in beginning professors of earth science at the college level.

Eligibility

Earth science instructors and faculty from all academic institutions engaged in undergraduate education who have been teaching full-time for 10 years or fewer. (Part-time teaching is not counted in the 10 years.)

Award Amount

An award of $750 is made possible as a result of support from the Donald and Carolyn Biggs Fund (maintained by the GSA Foundation), the GSA Geoscience Education Division, and GSA's Education and Outreach Programs. In addition, this award includes up to $500 in travel funds to attend the award presentation at the GSA annual meeting.

Deadline and Nomination Information

Nomination forms for the 2006 Biggs Earth Science Teaching Award are posted at www.geosociety.org/aboutus/awards/biggs.htm. Or, contact Diane Lorenz-Olsen, +1.303.357.1028, awards@geosociety.org. Nominations must be received by **9 June 2006.**

Mail nomination packets to:

Diane Lorenz-Olsen
Program Officer, Grants, Awards, and Recognition
Geological Society of America
3300 Penrose Place, P.O. Box 9140
Boulder, CO 80301-9140, USA

2005 BIGGS AWARD

Joel L. Pederson of Utah State University receives the 2005 Biggs Award from Beth Wright, presented at the National Association of Geoscience Teachers/GSA Geoscience Education Division Luncheon and Awards Reception in Salt Lake City, October 2005.

GEOPAST

GSA GEOLOGISTS STILL MAKE WAVES
GSA Bulletin, September 1923

J Harlen Bretz: *Glacial drainage on the Columbia Plateau*

Since 1888, GSA Members and their *GSA Bulletin* articles have impacted world thought, and they continue to make news today, influencing not just students and scientists, but the media as well. A fairly recent example of this far-reaching influence is a 2005 PBS episode of Nova, "Mystery of the Megaflood" (see www.pbs.org/wgbh/nova/megaflood/), which illustrates the work and conclusions of geology greats J Harlen Bretz and Joseph T. Pardee. The broadcast focuses on what had been a controversial issue in geology: "For decades Washington's strange Channeled Scabland stumped experts as to its origin—until a pair of geologists named Bretz and Pardee came along and solved the riddle" (pbs.org, 2005).

"'Mystery of the Megaflood' features a dogged geologist sticking to his bold theory for decades despite virtual professional banishment" (pbs.org, 2005). That dogged geologist was J Harlen Bretz; his paper "Glacial drainage on the Columbia Plateau" was published in the September 1923 issue of *GSA Bulletin* (v. 34, p. 573–608).

In the paper's introduction, Bretz writes, "This article endeavors to show that glacial-born streams, under proper conditions, are erosive agents of great vigor over large tracts far from the front of melting ice" (p. 573). Pages later, he states, "Probably the entire highland area north of the plateau was buried beneath the Cordilleran ice-sheet during the Pleistocene glaciations. At least three times the Cordilleran ice forced a crossing of the Columbia Valley and advanced onto the Plateau" (p. 580). Bretz implies that pre-Wisconsin glacial flooding must account for the extent of the "Scablands" on the Columbia basalt plateau, noting "the existence of granite boulders scattered over the basalt plateau of Washington far beyond the limits reached by the Wisconsin ice" (p. 580).

Following expansive descriptions of the channels, coulees, and scabland tracts in the area, Bretz summarizes the "megaflood" we have now come to accept: "Thus a brief episode in the latter half of the Pleistocene … introduced conditions under which the scablands … have been denuded of overlying sedimentary deposits by running water" (p. 607–608).

Joseph T. Pardee's paper, "Unusual currents in Glacial Lake Missoula, Montana," which is believed to have helped vindicate Bretz' conclusion of megaflooding, was published in *GSA Bulletin* in November 1942 (v. 53, p. 1569–1600).

REFERENCE CITED

PBS.org, 2005, "Mystery of the Megaflood" TV program description, http://www.pbs.org/wgbh/nova/megaflood/about.html (Accessed 3 Oct. 2005).

STUDENTS—Mark Your Calendars!

Plan now to attend a Shlemon Mentor Program in Applied Geoscience and/or a Mann Mentor Program in Applied Hydrogeology at your 2006 Section Meeting to chat one-on-one with practicing geoscientists. These volunteers will answer your questions and share insights on how to get a job after graduation. When programs are scheduled for multiple days, each day's program will offer a different set of mentors.

FREE lunches will be served (students only) at the **Shlemon Mentor Programs**. Students will receive a free lunch ticket with their registration badge to attend each Shlemon Program. However, space is limited: first come, first served.

FREE pizza suppers will be served (students only) at the **Mann Mentor Programs**. Students will receive a free pizza supper ticket with their registration badge to attend the Mann Program. The Mann Program is geared toward careers in hydrogeology or hydrology. Whether you've already decided to head down the hydro career path or whether you just would like to know more about these career options, this meeting is for you! However, space is limited: first come, first served.

Mentor Programs for 2006 Section Meetings

For program locations, ask at the Section Meeting registration desk.

SOUTH-CENTRAL SECTION MEETING
University of Oklahoma, Norman, Oklahoma
Shlemon Mentor Program Luncheon:
Mon., 6 March, 11:30 a.m.–1 p.m.
Mann Mentors in Applied Hydrogeology Program:
Mon., 6 March, 5–6:30 p.m.

NORTH-CENTRAL SECTION MEETING
Student Center, University of Akron, Akron, Ohio
Shlemon Mentor Program Luncheons:
Thurs.–Fri., 20–21 April, 11:30 a.m.–1 p.m.
Mann Mentors in Applied Hydrogeology Program:
Thurs., 20 April, 5–6:30 p.m.

NORTHEASTERN SECTION MEETING
Radisson Penn Harris Hotel and Convention Center
Camp Hill/Harrisburg, Pennsylvania
Shlemon Mentor Program Luncheons:
Mon.–Tues., 20–21 March, 11:30 a.m.–1 p.m.
Mann Mentors in Applied Hydrogeology Program:
Mon., 20 March, 5–6:30 p.m.

CORDILLERAN SECTION MEETING
University of Alaska, Anchorage, Alaska
Shlemon Mentor Program Luncheons:
Mon.–Tues., 8–9 May, 11:30 a.m.–1 p.m.
Mann Mentors in Applied Hydrogeology Program:
Tues., 9 May, 5–6:30 p.m.

SOUTHEASTERN SECTION MEETING
Marriott Hotel, Knoxville, Tennessee
Shlemon Mentor Program Luncheons:
Thurs.–Fri., 23–24 March, 11:30 a.m.–1 p.m.
Mann Mentors in Applied Hydrogeology Program:
Thurs., 23 March, 5–6:30 p.m.

ROCKY MOUNTAIN SECTION MEETING
Western State College, Gunnison, Colorado
Shlemon Mentor Program Luncheons:
Wed.–Thurs., 17–18 May, 11:30 a.m.–1 p.m.
Mann Mentors in Applied Hydrogeology Program:
Wed., 17 May, 5–6:30 p.m.

ROCK STARS

Reginald Aldworth Daly, from the Harvard archives.

Reginald Aldworth Daly (1871–1957): Eclectic Theoretician of the Earth

James H. Natland, *Rosenstiel School of Marine and Atmospheric Science, University of Miami, Miami, Florida 33149, USA*

Reginald Aldworth Daly was an authority in igneous petrology, structural geology, physiography, geophysics, and marine geology who wrote cogent syntheses that considered Earth from several vantages. In his earliest book, he presented what he called an "eclectic theory" of volcanic action and magmatic differentiation, and thus I describe him as an "eclectic theoretician of the Earth."

The son of a tea merchant and a minister's daughter, Daly was born on a farm near Napanee, southeastern Ontario, the youngest of four sons and five daughters. Late in his career, he recalled the simple life of a small town, the high standards of conduct expected by his parents, and an early introduction to the importance of hard work and wide reading. He was educated in public schools and attended Victoria College in Ontario (B.A., 1891; S.B., 1892; instructor in mathematics, 1892). There, inspired by Professor A.P. Coleman's description of granite ("This is made of crystals."), he decided on a career in geology. Encouraged by interviews with Nathaniel Southgate Shaler and Josiah D. Whitney, Daly commenced graduate studies at Harvard under John E. Wolff, obtaining his Ph.D. in 1896.

Daly seemed always to absorb the better part of the knowledge of his mentors and associates. Of the Harvard faculty, Wolff's interests in ore mineralogy, petrography, and economic geology had the greatest influence on Daly at this time. Daly also was teaching assistant under Shaler and William Morris Davis, the latter attuning Daly to an understanding of physiography and planation surfaces. At the same time, Daly formed important lifelong friendships with two contemporaries, crystallographer Charles Palache and the future Hawaiian volcanologist, T.A. Jaggar. His closest friend, however, was Lionel Marks, soon to be a mechanical engineer in the physics department at Harvard, who introduced Daly to his future wife. These young men shared a community of mutually reinforcing interests that led them all to positions of leadership in their fields.

In 1893, Daly began his dissertation study of the geology and petrology of Ascutney Mountain, Vermont. The project culminated in the publication of a landmark paper (1903) that outlined his developing theory of the geological and petrological consequences of large-scale magmatic stoping and assimilation of roof rocks. The paper combined careful mapping, detailed petrographic descriptions, sophisticated treatment of chemical analyses of rocks, and analysis of the process of intrusion in light of contrasting densities of rocks and magma. The stoping hypothesis evidently came to Daly in a flash, while dropping off to sleep. Daly later wrote, "The solution then found still seems the best in sight, but its chief result has been the realization that geology must be based on geophysics."

Upon completing his degree, he obtained a superb postdoctoral overseas fellowship in Europe (1896–1897), where he became an expert at thin section analysis under the petrographers Harry Rosenbusch (1836–1914) and Alfred Lacroix (1863–1948), toured many famous field localities, and attended the 7th International Geological Congress in Russia (1897). Looking at photographs taken at this time, Francis Birch (1958) described the young Daly as "physically impressive, sartorially elegant, [and] conspicuous among the somewhat worn-down gathering of international geologists."

In 1903, Daly married Louise Porter Haskell, who was from a distinguished Southern family, a graduate of Radcliffe College, and the owner and headmistress of a girls' school in Boston where she taught history and literature. Two of his books are dedicated to her as "inspiring fellow worker," another as "comrade and wise counselor in the search for the meaning of things." In a letter, she in turn described him as "a genius who remembers his mineral stage as few others ever have, & so feels earth-secrets as few others do." After their marriage, she was his companion on journeys, field assistant, amanuensis, typist, manuscript critic, and editor. The Dalys had one child, a son named for his father and called Aldworth, who died of a fever from tubercular meningitis at the age of two.

In 1901, Daly left Harvard, where he had been teaching physiography and oceanography. Despite the Ascutney work and the amenities of his position, he had not, as he later wrote, "made much progress in the development of original thought." He joined the Canadian International Boundary Survey and undertook a monumental exploration of the Canadian–U.S. boundary from the Pacific coast through the wide belt of the Cascades and Rocky Mountains into the Great Plains. The survey was along the 49th parallel, the border between the United

States and Canada. Working with but one field assistant during five field seasons, Daly mapped a strip 5 to 10 miles wide and 400 miles long through some of the most rugged country in North America. He then was able to present his fully developed theory in five chapters of his final report (1910, reprinted as Memoir 38 of the Geological Survey of Canada in 1912) and his first book, *Igneous Rocks and Their Origin* (1914). In 1907, he returned to academic life, first taking a position at Massachusetts Institute of Technology, and then succeeding William Morris Davis as Sturgis-Hooper Professor at Harvard in 1912.

The maturity of Daly's thought and the scope of his scholarship are evident in the treatment of many topics in *Igneous Rocks and Their Origin.* Using Rosenbusch's petrographic classification of igneous rocks, he divided 2631 chemical analyses to give average analyses of 116 petrographic types. He presented not only distributions of rock types of different composition, but described and classified the many forms of extrusive and intrusive rocks and the links between intrusive and extrusive bodies of igneous rock. The central problem of petrology at that time was to understand the diversity of igneous rocks. To Daly, crystallization differentiation by itself was insufficient, and he instead argued that magmatic stoping and assimilation contribute fundamentally to diversity. He also saw that beneath all igneous action, injection of basaltic magma into the crust was the essential precursor. Basalt is present in all associations, in all provinces, and at all times in Earth's history. It is "the bringer of heat."

Drawing from geophysical conceptions of shells of the Earth, Daly proposed the existence of a universal basaltic substratum beneath the crust that he argued was vitreous (a strongly viscous liquid; glass at high pressure) in its physical properties. Basalt was thus "primary" (a direct melt of the vitreous substratum). Gravitational accumulation of olivine then leads to formation of olivine gabbros seen as cumulates in so many intrusive bodies and the complementary olivine-free basalt so commonly found along the perimeter of the North Atlantic and in flood-basalt provinces. Ever since, discussion of basaltic petrogenesis has had to deal with concepts of primary magma and the question of the potential uniformity of composition of its mantle sources.

Daly's outer two shells of the Earth are a discontinuous layer of sediments and, beneath that, a silicic or *acid* crystalline layer, together comprising the upper part of the continental crust. He supposed that the acid shell is discontinuous beneath the oceans and viewed the continental crust as reworked by sediment melting, or *syntexis*, operating at and near basaltic intrusions. In this way, the crust becomes more strongly differentiated toward granite than its average protolith, which Daly considered to be sedimentary material derived from ancestral basaltic and andesitic terranes. His theory *required* that the field relations be considered along with any theoretical or experimental inferences about the behavior of magmatic fluids. From his study of rock distributions, Daly was able to declare (1914, p. 52), "The igneous rocks of the globe chiefly belong to two types, granite and basalt … one of these dominant types is intrusive, and the other is extrusive. To declare the meaning of this fact is to go a long way toward outlining petrogenesis as a whole."

Louise Porter Haskell, Daly's "inspiring fellow worker," Christmas 1901, a year before her engagement to Daly, from a family portrait.

Daly's subsequent career added layers of expertise to his core concepts in petrology and field geology. In 1909, before completion of his Boundary Survey report, he traveled to Hawaii with T.A. Jaggar, accompanied also by Louise (this was shortly after their son's death). There, the two scientists examined Kilauea volcano. The trip led directly to the establishment of the modern Hawaii Volcano Observatory, which Jaggar headed for nearly three decades. Daly's first publication on Hawaiian volcanism was in 1911. His observations of island subsidence and reef distribution convinced him that fluctuations in sea level were critical to the formation of the lagoons of barrier reefs and atolls. He published this as "The Glacial Control Theory of Modern Reefs," also in 1911. After the First World War, he traveled extensively to study other volcanic islands (Ascension, St. Helena, American Samoa), ore bodies in Sweden, and (with Charles Palache) the Bushveld intrusion in South Africa.

His interests came to include uplifted beach rock, the bearing of coral reefs on Pleistocene fluctuations in sea level, submarine canyons, isostasy and glacial rebound, and the great questions of continental geology, including continental drift. He sparred with experimental petrologist N.L. Bowen in attributing the origin of alkaline magmas to the effects of limestone assimilation by basaltic magma rather than crystallization differentiation (Daly, 1918). He endorsed continental drift in *Our Mobile Earth* (1926) and offered a mechanism for it: very low-angle continental landslides or detachments slipping over a medium of extremely low strength, his own vitreous basaltic substratum, and compressing sediments in geosynclines. The idea is not far removed from today's view of the geodynamics of accretionary prisms at subduction zones. In 1927, he favorably reviewed the evidence for drift summarized by Alexander du Toit in *The Geology of South Africa*, which put him in a small minority of North American geoscientists who favored drift.

In 1930, together with physicist Percy Bridgman and other Harvard colleagues, Daly initiated an interdepartmental committee on geophysics, hiring Francis Birch, who held a Harvard degree in physics, to undertake experimental study of the properties of rocks at high pressure. An early graduate student in this program was Norman A. Haskell (not related to Louise), whose work on post-glacial Scandinavian uplift,

continued on p. 26

continued from p. 25

suggested by Daly, led to the first estimates of the viscosity of the upper mantle.

In 1933, Daly published a second edition of his 1914 book, this time calling it *Igneous Rocks and the Depths of the Earth*. In contrast to Bowen's advocacy that crystallization differentiation led to granites, Daly continued to stress the importance of syntexis in the formation of continental crust, of superheat driving that syntexis, and of transport of alkalis in magmatic volatiles. Daly also added a full chapter on the physical properties of igneous rocks, which incorporated results of laboratory measurements made in collaboration with Percy Bridgman.

In retirement, Daly presciently argued that the origin of the Moon involved collision of Earth with another planetoid (1946) and that the Vredevort structure in South Africa was produced by giant impact (1947). Daly became a U.S. citizen in 1920, was elected to the National Academy of Sciences in 1925, and received both the Penrose Medal of the Geological Society of America (1935) and the Bowie medal of the American Geophysical Union (1946). He published actively until 1952, and in 1957 he wrote a biographical memoir of his Harvard friend and colleague, mineralogist Charles Palache.

Daly was a gifted lecturer who made good use of his and others' drawings, diagrams, and photographs in both talks and published works. The title page of *Our Mobile Earth*, in which he endorsed continental drift, is wryly inscribed, following Galileo, "E pur si muove!" Daly's forte was clearly in selecting among disparate observations and lines of reasoning and then reinforcing or extending hypotheses into new and more powerful syntheses. He tried to view geological processes from as many angles as possible. Almost all of us today are specialists, but to read Daly is to be reminded that ours is a multidisciplinary enterprise, and that understanding Earth requires mastery of many arts.

Daly died in 1957 at the age of 86; Louise, his wife, predeceased him in 1947. Reginald, Louise, and Aldworth Daly are buried in the Haskell family plot at Elmwood Cemetery in Columbia, South Carolina.

ACKNOWLEDGMENTS

I've drawn on biographical information in Berkey (1936), Billings (1958), Birch (1960), Oreskes (1999), and Young (1998). I thank Angela Clark of the Rosenstiel School Library and the staff of the South Caroliniana Library at the University of South Carolina for assistance in gathering materials for this contribution. Warren Hamilton, Jerry Winterer, Paul Hoffman, Gerry Middleton, Robert Dott, and Bob Ginsburg provided helpful comments on the manuscript.

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"Rock Stars" is produced by the GSA History of Geology Division, Editorial Committee: Kennard Bork, Robert Dott, Robert Ginsburg, Gerard Middleton, Peter von Bitter, and E.L. (Jerry) Winterer.

Reviews in Engineering Geology Volume XVI • Humans as Geologic Agents • Reviews in Engineering Geology Volume XVI • Humans as Geologic Agents

GSA National Leadership Initiative: GSA in Washington, D.C.

To enhance its ability to represent and serve the geoscience community, GSA is considering establishing an office in Washington, D.C. This office would provide a mechanism to strengthen and expand the society's national leadership role by (1) providing timely information to policy makers on national issues of relevance to the geosciences, (2) allowing more effective participation in national coalitions, (3) facilitating work with the GSA community on geoscience initiatives, (4) encouraging federal funding agencies to support the geosciences and GSA's community, and (5) helping to foster collaborations with and among mission agencies and organizations, industry, and academia.

The earth sciences, and the GSA community in particular, are not sufficiently represented or visible in Washington. With an ongoing presence in Washington and as the representative of the earth sciences community, GSA's voice would carry greater weight in Congress, with the Office of Management and Budget, the Office of Science and Technology Policy, and with other federal agencies. Working in conjunction with AGI, AGU, and others, GSA in D.C. would significantly increase the capacity for representation of the geoscience community and provide enhanced visibility and access to the federal establishment.

The Washington office would be more than a government affairs office. Its staff would work with the GSA community as a liaison and communications center and provide timely identification of important issues and projects. The office would help to ensure that geoscience is an integral part of broader science initiatives in key funding agencies. The Washington office would work with the community on emerging initiatives and serve as a touch point for these initiatives. GSA's physical presence in D.C. would ensure a better flow of information to the society membership about geo-issues and place the Society membership in a better position to respond promptly to these issues. This would enable GSA to become a more proactive advocate for members' needs and concerns.

A more complete discussion of the National Leadership Initiative can be found on the GSA Web site at www.geosociety.org/science/govpolicy.htm. The GSA Executive Committee and the Geology and Public Policy Committee request community comment on the concept of a Washington, D.C., office. Additionally, opinions of the GSA membership will be sought in a general membership survey to be conducted in early 2006. Please send comments to:

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Future GSA Annual Meetings

2006	Philadelphia (October 22–25)
2007	Denver (October 28–31)
2008*	TBD
2009	Portland, Ore. (October 18–21)
2010	Denver (October 31–November 3)
2011	Minneapolis (October 9–12)

* Joint meeting with American Society of Agronomy, Crop Science Society of America, and Soil Science Society of America.

COMMENTARY

International Union of Geological Sciences: What is it and what is the role of the United States?

Farouk El-Baz, *Boston University, Center for Remote Sensing, 725 Commonwealth Ave., Boston, Massachusetts 02215-1401, farouk@crsa.bu.edu*

During August 2004, Florence, Italy, was host to the 32nd International Geological Congress (IGC), an eight-day meeting that attracted 8,000 geologists from most of the world's nations. The surroundings of Florence offered many distractions to the geologists attending the IGC, including unique geology, a pleasant environment, and many tourist attractions. Despite these distractions, the remarkably organized technical sessions were well attended and many new friendships (and potential collaborations) were made. Some 650 U.S. geologists attended the IGC, which was sponsored by the International Union of Geological Sciences (IUGS). Behind the scenes, meetings required much work and some diplomacy by representatives from the 117 nations in attendance.

Such international fora are, in some respects, the geosciences equivalent to the United Nations. Therefore, it is appropriate to ask: How is the United States represented in the IUGS?

The U.S. National Academy of Sciences (NAS) represents the United States to the IUGS, which is an umbrella organization that includes national representatives and 34 affiliated organizations (including GSA, the American Geophysical Union, and the American Association of Professional Geologists). The U.S. National Committee for the International Union of Geological Sciences (USNC/IUGS) serves as a liaison between U.S. geoscience organizations and the IUGS and seeks their input for IUGS programs, actions, and activities. The USNC also coordinates U.S. participation in furthering the goals and work of the IUGS.

The USNC represents the NAS in the IUGS International Geoscience Program, which was developed jointly by IUGS and the United Nations Educational, Scientific and Cultural Organization to facilitate the collaboration of multinational research teams involved in research topics of global interest. The committee also serves the NAS in an advisory capacity, consulting with U.S. Government agencies concerning the needs and opportunities of international geological science.

The USNC includes members from academia, research institutions, government agencies, and private industry. USNC members provide information to the U.S. geoscience community about IUGS activities and sponsor symposia at scientific association meetings on topics of international interest, such as biodiversity, sustainability, and megacities.

A major thrust of the IUGS is the Year of Planet Earth, which is a multidisciplinary, international project that involves the expertise available from the different entities of IUGS and its 37 affiliated organizations. The plan for the Year of Planet Earth has been submitted to the United Nations for its adoption and will likely be declared by that body. The purpose of the Year of Planet Earth is "…intended to be a vigorous international program, the principal goal of which is to demonstrate the enormous potential of the Earth sciences to lay the foundations of a safer, healthier and wealthier society. This goal leads naturally to the Year's subtitle: Earth sciences for society."

The Year of Planet Earth will likely occur in 2007–2008. Much of the activity will be dedicated to outreach programs that demonstrate the importance of the geosciences to society. Collaborative research programs will most likely follow the approach used by the International Geoscience Program.

The Year of Planet Earth is only one of many issues that the USNC addresses. Another example of international cooperation is the establishment of better communications between U.S. scientists and geoscience organizations in the Middle East, the Islamic world, Asia, and South America. Symposia at national and international meetings that have been organized by the USNC have included such topics as sustainability, social equity and the geosciences, and the role of the earth sciences in national security.

The United States' representation in the IUGS is paramount for facilitating international connections in our profession, and there is no question that the United States benefits greatly from official participation in international scientific conferences such as the IGC. As one Russian colleague stated, the IGC is "geology without borders." This is particularly important at a time when U.S. foreign policy is not universally supported. Science and technology are areas in which the United States is still held in esteem. Thus, strong participation in international scientific gatherings similar to the IGC should be encouraged for a better understanding of our country among the rest of the world's scientists.

For more information about the USNC and its membership please visit http://www7.nationalacademies.org/usnc-iugs/.

FUND ESTABLISHED TO HELP SUSAN LANDON

Matt Silverman and Robbie Gries

Susan Landon

Susan Landon, a GSA Fellow and GSA Foundation Trustee, suffered a traumatic brain injury while skiing on 22 February 2005. Comatose for several weeks and with little memory of the months after the accident, Susan has struggled to regain her health, both mental and physical. She is wheelchair-bound and dependent on nursing help to turn in bed, eat, and exercise. While she is regaining her memory, it is still erratic. Susan will continue to need physical, occupational, and speech therapy for at least a year, possibly for many years. The prognosis that Susan will eventually be able to walk and resume an active life seems good, but her recovery has been slow and will continue to be slow.

Susan is currently at Learning Services, a rehabilitation facility in Lakewood, Colorado. She could be there for six months or more depending upon the rate of her recovery. Susan will continue to require special care and therapy even when she goes home or to another temporary home, until she can manage well and safely on her own.

It now seems likely that she will have expenses over the next five years of US$500,000, not covered by insurance. Many of her friends have asked how they can assist financially.

A *tax-deductible gift* to help Susan can be made through the National Transplant Assistance Fund (NTAF), a nonprofit organization dedicated to helping people who have experienced catastrophic injuries. Ninety-six percent of each check would go to pay Susan's medical and related expenses, either directly or as a reimbursement.

Checks may be made payable to NTAF Midwest/West Brain Injury Fund, with IN HONOR OF SUSAN LANDON noted in the memo section of the check. The donation address is NTAF, 3475 West Chester Pike, Suite 230, Newtown Square, PA 19073, USA. For more information, please go to www.catastrophicfund.org or call the NTAF at +1-800-642-8399.

Most memorable early geologic experience:

In the summer of 1949, in the Brooks Range, Northern Alaska, I was helping Art Bowsher measure a section of limestone, thought to be Carboniferous. The first day, Art pointed uphill and said, "See that shale break up there—we'll find Mississippian crinoids!" And we did! (It was the first proof of this age.)

—John T. Dutro

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ANNOUNCEMENTS...

MEETINGS CALENDAR

2006

3–5 May	2nd Shlemon Specialty Conference in Engineering Geology: Mass Wasting in Disturbed Watersheds, Durango, Colorado, USA. **Information:** www.haneberg.com/watersheds.
7–13 May	42nd Forum on the Geology of Industrial Materials, Asheville, North Carolina, USA. **Information:** www.geology.enr.state.nc.us/NCIndustrialMineralsForum/index.htm.
8–12 May	52nd Annual Meeting of the Institute on Lake Superior Geology, Sault Ste. Marie, Ontario. **Information:** e-mail ls2006@mhtc.net or go to www.lakesuperiorgeology.org.
29 May–2 June	Geology of the area between North and South America with focus on the origin of the Caribbean plate: An International Research Conference, Sigüenza, Spain. **Information:** www.geolsoc.org.uk/template.cfm?name=Caribbean_Plate.
18–21 June	International Conference on Continental Dynamics and Environmental Change of the Tibetan Plateau, Xining, Qinghai Province, People's Republic of China. **Information:** www.geosociety.org/meetings/06Tibet/06Tibet-Circular1.pdf.

2007

27–30 March	EarthScope 2007 National Meeting, Monterey, California. **Information:** EarthScope, 1200 New York Ave. NW, Suite 700, Washington, DC 20005, USA, +1-202-682-0633, earthscope-info@earthscope.org.
3–8 June	First North American Landslide Conference—Landslides and Society: Integrated Science, Engineering, Management, and Mitigation, Vail, Colorado, USA. **Information:** www.mines.edu/academic/geology/landslidevail2007.
18–22 June	Alluvial Fans 2007, Banff, Alberta, Canada. **Information:** http://husky1.smu.ca/~pgiles/AF2007/AlluvialFans2007.htm.

Visit www.geosociety.org/calendar/for a complete list of upcoming geoscience meetings.

FIELD FORUM REPORT

Rethinking the Assembly and Evolution of Plutons: Field Tests and Perspectives

7–13 October 2005

Sierra Nevada and White-Inyo Mountains, California

Conveners:

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Richard D. Law, *Department of Geosciences, Virginia Tech., Blacksburg, Virginia 24061, USA, rdlaw@vt.edu*

On 7–13 October 2005, 40 geologists gathered to examine field evidence concerning the assembly of plutons and to discuss the idea that plutons may be incrementally constructed over millions of years. Participants included specialists in plutonic, volcanic, and structural geology; perhaps the most significant benefit of the meeting was the interaction among these groups.

The forum comprised five field days, an evening poster session, and a wrap-up session. The first two days were spent in Yosemite National Park, examining the 103 Ma Yosemite Valley intrusive suite and the 95–85 Ma Tuolumne Intrusive Suite. Day 1 focused on the role of mafic magmatism in the evolution of the suites, contact relations between the two suites, and reasons for the marked differences between them.

Day 2 centered on the contact of the Tuolumne Intrusive Suite and the anatomy of the Half Dome Granodiorite, which U-Pb zircon data indicate grew over 3–4 m.y. One focus was wall-rock inclusions in the outermost Tuolumne Intrusive Suite: do they reflect stoping or in situ isolation by dike intrusion? Related questions included the significance of gradational contacts between units that yield distinct U-Pb zircon ages, and the origin of modal layering. We examined km-scale lithologic cycles in Half Dome that may reflect incremental assembly, as well as K-feldspar crystal-size distributions passing from the equigranular Half Dome to its porphyritic phase to the megacrystic Cathedral Peak, and considered implications for timing and mechanisms of phenocryst growth.

The next two days were spent in the eastern Sierra Nevada. On Day 3, we examined the Treasure Lakes mass of the Lamarck Granodiorite, a steeply tabular pluton emplaced into a ductile shear zone late during its movement history. Discussion focused on the role of the shear zone during intrusion, the presence of melt in the granite during deformation, and, again, the origin of tabular wall-rock inclusions.

Day 4 began with views from Owens Valley of intrusive relationships exposed high in the Sierras: (1) the Split Mountain wall-rock screen forms the roof of the leucogranite of Red Mountain Creek and the floor of the Tinemaha Granodiorite, and (2) the Goodale intrusive complex comprises a large layered mafic complex overlain by and commingled with gran-

ite. Discussion centered on pluton floors and on formation of mafic sheeted complexes as floors of magma chambers versus injection of sills. We then examined mafic-felsic interactions in the Jurassic Tinemaha pluton and features of the Independence dike swarm, including amalgamation of dikes and in situ isolation of xenoliths between dikes as a model for growth of larger intrusions.

Day 5 was spent examining isolated Jurassic plutons in the White-Inyo Mountains. Two plutons were compared: the composite EJB pluton, which is enveloped by a foliated ductile aureole into which wall-rock strata bend downward to parallel the intrusive contact; and the Sage Hen Flat pluton, which intruded similar wall rocks only a few million years after the EJB pluton, yet is abruptly discordant and lacks a ductile aureole.

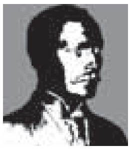
Morning break-out sessions on Day 6 considered eight topics suggested by participants. (1) Regional tectonics in the development of plutons. (2) What can petrology reveal about pluton assembly? (3) Temporal variation of power input to a magmatic system. (4) Application of U-Pb zircon geochronometry to pluton growth. (5) Methods that might be used to distinguish intrusive increments. (6) How is space made for plutons? (7) Why are granitic plutons so homogenous? (8) How to bridge disciplinary divides to achieve integrated understanding of magmatic systems.

In a final plenary session, break-out session leaders summarized the results of each session, followed by general discussion. The discussion cannot be adequately summarized in this brief report, but significant points include: (1) major unsolved problems remain concerning the chronological development of magmatic systems, regarding both the growth of individual plutons and the degree to which they are composite, and why entire arc plutonic systems seem to grow in discrete pulses; (2) recent studies have examined in unprecedented detail the U-Pb zircon systematics of a handful of plutons, but larger and more detailed data sets are needed to resolve temporal and spatial scales of pluton assembly; (3) new methods for analysis and interpretation of mineral zoning may be useful in dissecting temporal and spatial scales of pluton assembly; and (4) variations of the melt fraction in magmatic systems, in both time and space and in both modern and ancient systems, must be better understood.

Achieving the goals defined in the wrap-up discussion will depend on effective collaboration among geologists, geochemists, and geophysicists interested in both the plutonic and volcanic components of magmatic systems.

PARTICIPANTS

Catherine Annen, Carlos Arevalo, Charlie Bacon, Andy Barth, George Bergantz, Alan Boudreau, Bill Collins, Fidel Costa-Rodriguez, Sandy Cruden, John Dilles, Mike Dungan, John Eichelberger, Nicole Fohey, Mike Garcia, Brad Hacker, Mitch Hathaway, Wes Hildreth, Andrew Kylander-Clark, Peter Lipman, Lily Lowery, Craig Lundstrom, Kevin Mahan, Jo Malcolm, Ken McCaffrey, Elizabeth Miller, Calvin Miller, Bob Miller, Geoff Pignotta, Kent Ratajeski, Matt Rioux, Tom Sisson, Art Sylvester, Basil Tikoff, B.J. Walker, Bob Wiebe



PENROSE CONFERENCE REPORT

Lessons in Tectonics, Climate, and Eustasy from the Stratigraphic Record in Arc Collision Zones

Conveners:

Peter D. Clift, *Schools of Geosciences, Meston Building, University of Aberdeen, Aberdeen AB24 3UE, UK, p.clift@abdn.ac.uk;*

Amy E. Draut, *University of California at Santa Cruz and U.S. Geological Survey, 400 Natural Bridges Drive, Santa Cruz, California 95060, USA, adraut@usgs.gov*

Active plate margins are of great research significance to the earth science community because they are the primary locations for the formation and destruction of the continental crust, and because they also appear to be important controls on the long-term evolution of global climate. Moreover, they are of great societal importance because of their potential for hydrocarbon exploration in the deep basins formed in these settings, as well as for the dangers associated with the earthquakes and tsunamis that characterize these regions. Although subduction margins are often active for long periods of geologic time, they are rarely steady-state in their tectonic evolution. These regions are strongly affected by episodic collisions between the subduction trench and topography on the subducting plate.

On 10–14 October 2005, 45 geoscientists from 10 countries met for a GSA Penrose Conference in Price, Utah, USA, to discuss how the sedimentary record in such areas can be used to reconstruct arc collisions in the past and to assess their effects on the tectonic, erosional, and climatic development of active plate margins. The conference included oral and poster presentations of recent research on arc collisional settings and a scientific planning phase to identify future topics for focused research.

A number of areas in which full understanding of arc collisional tectonic and sedimentary processes is lacking were identified. Some of the most pressing research goals in the modern oceans are being addressed by proposed Integrated Ocean Drilling Program (IODP) operations in Costa Rica, the Nankai Trough, the Okinawa Trough, the Izu-Bonin forearc, and the Yakutat-Alaska Collision Zone. Nonetheless, other goals remain unresolved, requiring new research efforts if we are to fully understand the role that arc collisions play in such first-order processes as the formation of the continental crust, control of global climate, and societally relevant issues such as seismogenesis and tsunamis. A combination of offshore and onshore work in modern settings, together with informed exploitation of ancient examples from the geologic record, hold the best chances for major progress in the next five to ten years.

Although simple climate-tectonic models have been developed over the past few years, the detailed role that evolving climate plays in collisional tectonism remains obscure. There is general consensus that precipitation can govern orogenic structure at least to some extent, but the connection between orogenic-trench tectonics and sediment flux is less well defined. The formation of the Western Pacific Warm Pool appears to have been triggered by an arc collision, yet its presence affects the local climate and oceanography, most notably the Asian monsoon, and as such it may in turn affect the subduction and collisional tectonics of the western Pacific, including Taiwan. Defining in detail how such linkages work, here or in other settings, was highlighted as target for future research.

This topic is connected to another identified goal of understanding how increased sediment flux to the trench can influence subduction tectonism, either causing more or less tectonic erosion of the overriding plate and at the same time enhancing or reducing seismic coupling across the plate boundary. This is important because it is such coupling that can result in catastrophic earthquakes and their associated tsunamis. The sedimentary record at arc collisions has yet to be fully exploited to help understand these events (such as the 2004 Indian Ocean Tsunami) and to help plan responses to future events. Techniques have been developed to look at storm deposits in coastal settings, yet in only a few locations have they been applied to active margins. Use of the deep-sea record to understand seismogenesis is in its infancy, but this could potentially provide a readily dated, more complete history of seismicity than is available onshore.

Similarly, it is still conjecture whether arc collisions can change oceanic circulation patterns beyond the cutting of oceanic gateways. Collision of the Yakutat Terrane with North America must have increased orographic precipitation following uplift and thus driven increased run-off into the Bering Sea. The freshening of these waters reduced their ability to sink and in turn drive thermohaline circulation in the North Pacific. The cessation of deep-water flow from the Bering Sea into the North Pacific seems to have resulted in a significant reorganization of circulation and upwelling patterns over the region. Demonstrating that enhanced fluvial run-off from collisional orogens has changed oceanic circulation patterns should be a goal for describing a new type of climate-tectonic coupling.

If some of these higher goals are to be addressed, then it is crucial to better understand the processes that generate forearc sedimentary records in the first place, so that the evolution of arc collisions can be reconstructed in ancient examples. We rely on this record to date collisions and to trace rates of subduction erosion and/or accretion, yet the transport of material to forearcs is not well understood because of the complicated tectonic morphology often seen in these areas. The conference attendees agreed on the need to determine to what extent the stratigraphy is formed by steady-state processes and how much through catastrophic events, such as collapse of volcanic centers or tsunami generation. As part of this effort, we also need to identify ways to make better long-distance correlations in volcaniclastic forearc deposits, which are often hard to trace far across or along strike. Tephra and mass-wasting deposits from major explosive eruptions seem to offer the best chance of making such correlations, though determining how to make possible correlations convincing is not yet clear. Detailed radiometric dating would seem the most promising avenue to pursue, given recent analytical advances in inductively coupled plasma–mass spectrometry technology. Along with dating, we need to develop additional, more detailed methods to quantify tectonic and erosional processes in the source regions from the sedimentary record. Improved, less ambiguous provenance methods are required to date collisions and quantify the response to these events. Single-grain isotopic methods are needed as supplements to, but not replacements for, detailed classic petrographic studies. While methods based on rare mineral groups can be informative, they can be hard to apply in some settings, such as in drill cores, where sample size is an issue. As well as being of great academic interest, the development of new techniques for studying provenance and exhumation would be of use to petroleum exploration in forearc regions.

Such analytical methods will, however, not result in better understanding until the best locations in the forearc for the study of arc evolution can be identified. This is because trenchward basins are usually too tectonically disrupted by the collision itself to form continuous records and are often separated from the source volcanoes by forearc topography, instead being filled by reworking of older arc sediments. Conversely, those parts of the forearc closest to the arc are subject to episodic slumping and mass wasting, preventing formation of continuous sequences. Further surveying and drilling of modern forearcs are needed if the optimal location of continuous forearc records is to be better defined for the general case.

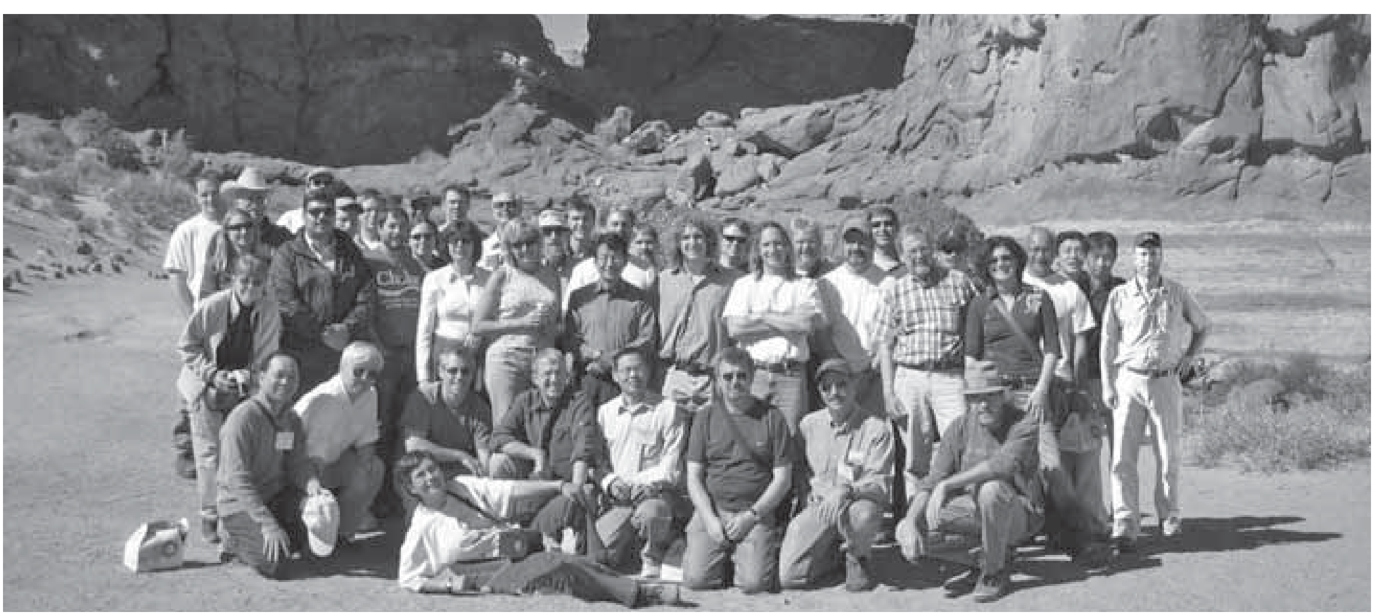
Conference attendees also recognized the need to better define rates of mass gain and loss in forearc regions. Although some progress has been made in quantifying rates of trench retreat or growth, it has become apparent that in many settings the simple assumption of steady-state forearc geometry cannot be made. This is especially true given the increased sediment flux to trenches since the Pliocene that favors subduction accretion compared to the conditions that prevailed over longer periods of geologic time. The conclusion appears to be that mass loss cannot be reliably estimated based on one forearc drill site, but requires transects, including onshore basins where those exist. Identifying ways to reconstruct subaerial uplift as well as submarine subsidence would be a crucial part of this challenge. Resolution of this issue is fundamental to geochemical and geophysical models for planetary-scale crustal recycling because uncertainties in the present mass recycling budget are very high and make accurate predictions of crustal production rates impossible.

Continuous sedimentary records are required to shed light on a number of issues related to arc–passive-margin collisions. Can the sedimentary record be used to identify and quantify lower crustal delamination of the colliding arc crust during collision? Such delamination is predicted by geophysical modeling but has yet to be convincingly identified in modern arc settings. Similarly, can the sedimentary record be used to quantify and date the nature of post-collisional extension and collapse? In the classic example of Taiwan, debate continues as to whether Okinawa Trough represents a basin formed by trench forces that is coincidentally propagating into the arc collision or whether Okinawa Trough is a product of that collision. If it is the latter, are there other examples of similar processes in modern and ancient records? Determining whether Okinawa Trough is truly a new type of marginal basin would be a first-order accomplishment for active-margin tectonics.

CONFERENCE PARTICIPANTS

Juergen Adam, Jonathan Aitchison, Joaquina Alvarez-Marron, Heinrich Bahlburg, Adam Boozer*, Dwight Bradley, Dennis Brown, Cathy Busby, Andrew Carter, Elena Centeno, Peter Clift, Steve Dorobek, Amy Draut, Hesham El-Sobky*, Clive Gerring, Sean Gulick, Robert Hall, Brian Hampton*, Tom Hilde, Gary Hoffmann*, Greg Hoke*, Chi-yue Huang, Bruce Idleman, John Jaeger, Jay Kalbas*, Gaku Kimura, Peter LaFemina*, Jonathan Lewis, Andrew Lin, David MacDonald, Maria Mange, Andrew Meigs, Tom Moore, Ian Moxon, Yujiro Ogawa, Koichi Okusawa, Ken Ridgway, David Scholl, Eli Silver, Helen Smyth*, Jeff Trop, Paola Vannucchi, Roland Von Huene, Francis Wu

*student attendee



ESP2: A BLOCKBUSTER

Lee Kump, Chris Beaumont, and Don Canfield

As Hollywood knows, the success of a sequel is difficult to predict. As we embarked on the planning of the second Earth System Processes (ESP2) meeting, we had to wonder if it would meet the high expectations of those who attended the first ESP in Edinburgh in 2001. By all accounts, however, ESP2, which was held 8–11 August 2005 in Calgary, Alberta, Canada, was an unqualified success.

The meeting was small—about 300 registrants—which created a sense of familiarity, identity, and community, impossible in a larger meeting. Students represented a large fraction of this community, aided substantially by travel awards cosponsored by the U.S. National Aeronautics and Space Administration's (NASA) Astrobiology Institute and the Canadian Institute for Advanced Research.

PLENARY ADDRESSES

The community gathered early each day for the plenary address, an event that for many was the highlight of the meeting.

- On Monday, **Stefan Bengston** (Swedish Museum of Natural History) regaled us with his insights on the evolution of animals and their propensity to form shells and skeletons suitable for framing.
- The next day, local star **Shawn Marshall** (University of Calgary) presented an analysis of the self-destructive nature of ice sheets. Using numerical models, Marshall demonstrated that when ice sheets grow large they trigger instabilities that ultimately can lead to their collapse.
- **Dianne Newman** (Caltech), a leader in the emerging field of geobiology, presented a tour-de-force survey of her research on microbial biofilms on the following day. In a remarkable bait and switch, Newman lured us in with a discussion of microbial processes in Archean environments, then deftly switched gears, showing how her work on natural biofilms is informing the search for a cure for cystic fibrosis.
- On the final day of the meeting, **Fred Mackenzie** (University of Hawaii) raised our awareness of the truly colossal effect humans have had on global biogeochemical cycles. No longer seeming so mighty, the Mississippi and other rivers of the world are now forced to carry twice their natural load of dissolved nitrogen. As if that weren't bad enough, Mackenzie also showed that we have actually reversed the natural flow of sulfur from ocean to land as a result of the transfer of fossil fuel burning derived SO_2, which dissolves in rain and falls on the ocean.

THEMATIC SESSIONS

Dozens of thematic sessions explored exciting, interdisciplinary topics in earth system evolution, modern earth system processes, and the future of Earth on human and astronomical time scales. A session chaired by Djordje Grujic (Dalhousie University) explored the strength of couplings among climate, erosion, and tectonics and the time and length scales over which such couplings operate. In the Phanerozoic oxygen session, John Vanden Brooks showed that oxygen levels up to 27% lead to faster development and growth rates in *Alligator mississippiensi* eggs, but beyond this, the negative effects of high oxygen begin to come into play. Parabolas are everywhere in nature. The Proterozoic biosphere session chaired by Y. Shen (University of Montreal) wrestled with a number of controversial issues, including the timing of the rise of animals, cyanobacteria, and the establishment of an oxygen-rich atmosphere. One of the more compelling presentations by Allison Olcott (University of Southern California) and colleagues showed a strong organic geochemical evidence for a complex and productive microbial ecosystem during the Neoproterozoic low-latitude glaciation.

Anoxia was pervasive at the meeting, thanks to the organizational efforts of Tim Lyons (University of California at Riverside) and his colleagues Brad Sageman (Northwestern) and Ariel Anbar (Arizona State). Energetic, oxygen-depleting exchanges between advocates of competing hypotheses characterized the two-day session, involving invocations of flood basalt volcanism, massive methane release from dolerite intrusion of Gondwanan coals, voluminous discharge of hydrothermal basinal brines into the ocean, and toxic hydrogen sulfide releases to the surface ocean and atmosphere. One thing everyone could agree upon was the irrefutable relationship between the extent of marine anoxia across geologic time and the appearance, expansion, and extinction of life on Earth. According to Lynn Soreghan (University of Oklahoma), consensus was the theme of the geosystems & Chronos session "Probing Earth's Deep-Time Climate and Linked Systems." All agreed that the multiproxy approach is making real sense of earth system evolution over a variety of time scales.

WORKSHOPS

For most participants, the evenings were spent socializing with colleagues. However, two special evening events proved quite popular with the workaholics. A group of educators, led by Kristen St. John (James Madison University), presented a two-day workshop on how to incorporate earth system science into secondary and university education. The second evening activity was a community forum on the justification for and mechanisms of funding continental drilling for deep-time paleoclimatology. Representatives from NASA and the National Science Foundation discussed successful models for collaboration and have since met again to take these ideas the next step toward the realization of a multiagency initiative.

ESP3

By Thursday afternoon, when participants should have been looking forward to returning home to their families and accumulated workload, they instead were buzzing with curiosity about ESP3. The good news is that there almost certainly will be another ESP meeting. But there will be changes. We want to do a better job of promoting transdisciplinary interactions, both among geoscientists of various ilk and with our colleagues in the allied disciplines of life sciences, oceanography, climatology, and soils. We want to schedule ESP3 at a time that is convenient to the greatest number of participants. We want to identify and promote the latest discoveries, the most significant developments, and the most exciting new approaches, so that ESP will continue to be a major force in the ontogeny of earth system science. We are looking to you for guidance in this planning process and welcome your suggestions. *Please send any correspondence regarding ESP3 to Deborah Nelson at GSA, dnelson@geosociety.org.*

GeoVentures™ 2006

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GeoHostel™ 2006

From the Peak to the Park:
The Geology of Pikes Peak Country, Colorado
17–22 June 2006

The Nature Place Conference Center
Florissant, Colorado
(5 days, 6 nights)

Scientific Co-Leaders:

Reinhard A. (Bud) Wobus is professor of geosciences at Williams College. Bud received his Ph.D. from Stanford in 1966 and has been studying the Proterozoic basement and Tertiary volcanic rocks of the southern Rocky Mountains for more than 40 years, 16 of them as a WAE (part-time) member of the U.S. Geological Survey. He has published dozens of geologic maps and reports on the Pikes Peak region, where he has led three GSA Annual Meeting field trips and directed more than 20 week-long field seminars for college and museum groups.

Herb Meyer is the paleontologist for Florissant Fossil Beds National Monument, an adjunct curator for the University of Colorado, and a research associate for the Denver Museum of Nature & Science. He is the author of *The Fossils of Florissant* and a co-author of *Geologic Guidebook to the Goldbelt Byway, Colorado*. He received his doctorate in paleontology from the University of California at Berkeley; research interests are in Tertiary paleobotany, climate change, and paleoelevation. He has been the leader for three GSA field trips in this area.

Steve Veatch conducts educational earth science programs throughout the Pikes Peak region. He is an adjunct professor of earth science at Emporia State University, where he received his M.S. in physical science with an emphasis in earth science. His primary research interests are in geomorphology and Quaternary geology. He has led many field trips in the area and is president of the Friends of the Florissant Fossil Beds.

Description

The southern Front Range, from Pikes Peak west to South Park and from the Cañon City embayment north to Florissant, is a geological classroom of extraordinary variety. As accessible as it is scenic, the region climbs from ~5000 ft in the Arkansas Valley to over 14,000 ft at the Pikes Peak summit. Geological features ranging from Early Proterozoic basement to Pleistocene glacial deposits lie within its bounds. During day-long field trips and evening lectures, we will explore three generations of Precambrian granite plutons and their metamorphic wall rocks and mineral deposits, Paleozoic and Mesozoic stratigraphy and paleontology (including the dinosaur localities in Garden Park), Laramide structures, and the Eocene Thirtynine Mile Volcanic Field and its most significant "product"—the Florissant lake beds, with one of the world's richest collections of plant and insect fossils. At the Cripple Creek diatreme, we'll spend a day visiting underground and surface (heap-leach) gold mining operations. Our base for the week will be The Nature Place Conference Center near Florissant, within the 6000-acre Colorado Outdoor Education Center property. Participants will reside in studio apartments, each with moss-rock fireplace, loft, kitchenette, and deck. Meals are served family-style in the central lodge, with a broad deck overlooking Pikes Peak.

Accessibility

GSA is committed to making its activities accessible to all people interested in attending. Please contact Wesley Massey, wmassey@geosociety.org, if you have any special requirements. The Nature Place Conference Center is ADA compliant.

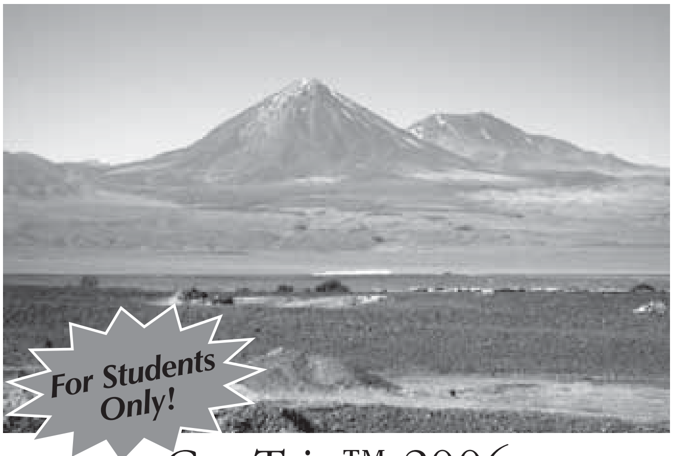
Fees and Payment

GSA Members, US$1305 (double occupancy); spouses, US$1355; nonmembers, US$1405 (double occupancy); the single occupancy fee is an additional US$240. A US$200 deposit is due with your reservation and is refundable through 15 April, less a US$20 processing fee. The balance is due 15 April 2006. Min.: 20; max.: 30. **Included:** Program and materials, lodging for six nights, all meals, field trip transportation, use of conference facilities and sportsplex, welcoming and farewell events, and shuttle transportation to and from the Colorado Springs

2006 GeoVentures™

For complete details on GeoVentures™ or for full itineraries go to www.geosociety.org/geoventures/ or e-mail geoventures@geosociety.org. Participants must be 18 or older and in good health. Any physical condition requiring special attention, diet, or treatment must be reported in writing when reservations are made. We'll do our best to accommodate special needs, including dietary requirements and physical disabilities. Deposits and payments are refundable less a processing fee, up to the cutoff date. Termination by an individual during a trip in progress for any reason will not result in a refund, and no refund will be made for unused parts of trips. For details on accommodations and occupancies, see trip descriptions.

airport (about a 1-hour drive). **Not included:** Transportation exclusive of field trips and airport shuttle, alcoholic beverages, and other expenses not specifically included.



GeoTrip™ 2006

Desert Trails of the Atacama

3–11 June 2006

Copiapó-Antofagasta, San Petro de Atacama, Chile

(6 days, 7 nights)

Scientific Co-Leaders:

Nicholas Pinter, Southern Illinois University–Carbondale (SIUC). Pinter is a professor in the geology department and environmental resources & policy program at SIUC. He researches earth surface processes and natural hazards, including hydrology (of which there is little in the Atacama region) and active tectonics (of which there is lots). Pinter received his Ph.D. from the University of California at Santa Barbara in 1992, and he currently has research projects in the United States, South America, and Europe.

Scott Ishman, Southern Illinois University–Carbondale (SIUC). Ishman is an associate professor in the department of geology and environmental resources & policy program at SIUC. His research is in foraminiferal micropaleontology and focuses on Cenozoic paleoenvironmental reconstruction. Ishman received his Ph.D. from The Ohio State University in 1990, and he has active research projects in the United States, South America, and Antarctica.

Hans Wilke is a professor in the department of geological sciences at Universidad Catòlica del Norte in Antofagasta, Chile. His research areas are regional geology, stratigraphy, and paleontology. Wilke received his Ph.D. from Technical University of Berlin, Germany, in 1987, and his research includes a number of projects across northern Chile.

Description

The Atacama region of northern Chile includes some of the most rugged topography and spectacular geology in the world. This trip is designed to present some of this spectacular terrain to a small group of graduate and undergraduate students who have a background in geology or other areas of the earth sciences. Transportation for the group will be in 4WD vehicles, and the itinerary includes several remote field stops accessible only by off-road vehicles. Field stops focus on active faulting, Neogene marine sedimentology and paleontology, environments of deposition, sequence stratigraphy, coastal and eolian geomorphology, volcanology, hydrothermal systems, and mining and mineral resources. The Atacama Desert is the driest location on Earth, resulting in unique characteristics and remarkable preservation of both landforms and geologic features.

Accessibility

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Fees and Payment

GSA Members, US$1995; nonmembers, US$2095. A US$300 deposit is due with your reservation and is refundable through 1 March, less a US$50 processing fee. The balance is due 1 Mar. 2006. Min.: 10; max.: 18 (students only). **Included:** Field guide and curricula, field trip transportation, lodging for seven nights (double occupancy), meals (4 June through lunch on 10 June), bottled water, and entrance fees. **Not included:** Transportation to Copiapó with return from Calama, Chile, optional activities, alcoholic beverages, personal travel insurance, and other expenses not specifically included.

GeoTrip™ 2006

Henry Darcy's Legacy in Dijon and Paris: Public Fountains and the Railroad

5–11 June 2006

Paris and Dijon, France

(7 days, 6 nights)

Scientific Leader:

Patricia Bobeck is a geologist and the translator of Henry Darcy's *Public Fountains of the City of Dijon*. She studied in France and Switzerland while completing an undergraduate degree in French and later received a master's degree in linguistics from the University of Michigan. She taught languages in South America and Hawaii before entering the University of Texas, where she received her master's degree in geology. She works for the state of Texas in groundwater remediation. In addition, she is certified by the American Translators Association as a French-to-English translator. In 2004, the American Foundation for Translation and Interpretation awarded her the inaugural S. Edmund Berger Prize for Excellence in Scientific and Technical Translation for the translation of the Darcy book.

Description

Henry Darcy founded the science of hydrogeology when he published "Darcy's Law" in an appendix of his 1856 book *Les Fontaines publiques de la ville de Dijon*. Our trip will begin in Paris, where the group will see the location of Darcy's workshop in which he conducted his pipe-flow experiments. We will also visit the Musée des Egouts (Sewer Museum) for a first-hand look at the "tout-à-l'égout," the combined sanitary and storm sewer system that was being built during Darcy's tenure in Paris as superintendent of municipal services. After a day in Paris, we will take the TGV (Train de Grande Vitesse [high speed train]) to Dijon. In Dijon, we will visit Place Darcy, where the aqueduct empties into the first of two reservoirs Darcy constructed. We will walk the extent of Darcy's cast-iron pipe water supply system throughout the old city of Dijon and see the Montsouris Reservoir, the end of Darcy's distribution system. Traveling outside of Dijon, we will visit the Rosoir spring that still supplies Dijon's water. We will also travel to Blaisy Haut, the mountaintop above the Blaisy Tunnel, which was Darcy's worksite while he supervised construction of the tunnel. While touring Burgundy, we will stop at the Chateau de Bourbilly, a thirteenth century castle owned by Darcy's descendants that is open for visitors in the summer. In Beaune, we will enjoy the Burgundy tradition of wine tasting!

Accessibility

GSA is committed to making its activities accessible to all people interested in attending. Please contact Wesley Massey, wmassey@geosociety.org, if you have any special requirements.

Fees and Payment

GSA Members, US$2400 (est.); nonmembers, US$2500 (est.). A US$300 deposit is due with your reservation and is refundable through 1 April, less a US$50 processing fee. The balance is due 1 April 2006. Min.: 20; max.: 30. **Included:** *The Public Fountains of the City of Dijon*, lodging for six nights (double occupancy), local sightseeing transportation, train tickets between Paris and Dijon, all breakfasts and dinners, and a one-day central zone metro pass in Paris. **Not included:** Transportation to and from Paris, optional activities, alcoholic beverages, personal travel insurance, and other expenses not specifically included.

For exact fees for this trip and up-to-date information, please check the GeoVentures™ Web page, wwwgeosociety.org/geoventures.

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GSA Member #

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FRANCE	US$300	____	US$________
	TOTAL DEPOSIT		US$________

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QUEEN'S UNIVERSITY AT KINGSTON
ONTARIO, CANADA**

The Department of Geological Sciences and Geological Engineering of Queen's University, one of Canada's premier earth science departments, invites applications for its William E. White Postdoctoral Scholarship, created from a fund endowed by the estate of William E. White. The award will be made for one year and may be renewed for a second year. The annual stipend is $43,000.

The William E. White Postdoctoral Scholarship will be awarded to an outstanding scientist who has completed the Ph.D. degree, normally within the two-year periods preceding the time of the appointment. The area of research is open, but the scholar's research must be complementary to that being pursued in the Department of Geological Sciences and Geological Engineering. The research program to be undertaken and the level of support of research costs and moving expenses will be negotiated with a faculty member at the time the award is made. Potential applicants may obtain an outline of current research interests on the Departmental Web site, www.geol.queensu.ca, and are strongly encouraged to initiate contact with a potential faculty supervisor in advance of applying. Fit with the research interests of the Department and the research excellence of the candidate will be the primary considerations in the selection process.

The Department invites applications from all qualified individuals. Queen's University is committed to employment equity and diversity in the workplace and welcomes applications from women, visible minorities, aboriginal people, persons with disabilities, and persons of any sexual orientation or gender identity. All qualified candidates are encouraged to apply; however, Canadian citizens and Permanent Residents will be given priority.

Applicants should send a curriculum vitae, a statement of research interests, and samples of research writing to the following address. Applicants must arrange for at least three confidential letters of reference to be sent to the same address. Review of complete applications will begin on 31 March 2006.

Professor R.W. Dalrymple, Department Head, Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, Ontario, Canada, K7L 3N6, Fax: 613-533-6592, zarichny@geol.queensu.ca.

**POSTDOCTORAL RESEARCH POSITION
LOW TEMPERATURE GEOCHEMISTRY
ENHANCED OIL RECOVERY INSTITUTE
DEPARTMENT OF GEOLOGY & GEOPHYSICS
UNIVERSITY OF WYOMING**

The Enhanced Oil Recovery Institute/Department of Geology & Geophysics at the University of Wyoming is looking for a postdoctoral researcher to conduct modeling and experimental studies related to sequestration of CO_2 by injection into petroleum reservoirs. This research is a part of the Big Sky Carbon Sequestration Partnership (www.bigskyco2.org) investigations into the geologic sequestration of CO_2 into reactive host rock. The successful candidate will investigate the geochemistry of CO_2/oil field brine/rock systems.

Appointment will be initially for 1 year, starting as soon as possible. Prerequisites include a completed Ph.D. and experience using appropriate geochemical codes. Applications should include graduate transcripts, letter of interest that demonstrates experience in field area, and the names and contact information of three referees; these should be sent to the Enhanced Oil Recovery Institute, University of Wyoming, 1000 E University Avenue, Dept. 4068, Laramie, WY 82071, or may be submitted on line to julieh@uwyo.edu.

Contact M. Boyles, 307-766-2773, jmboyles@uwyo.edu, or J. Drever, 307-766-6434; drever@uwyo.edu, for further information. Review of completed applications will begin on 15 Feb. 2006. Later applications may be considered until the position is filled.

For more information: University of Wyoming, www.uwyo.edu; Enhanced Oil Recovery Institute, http://eori.gg.uwyo.edu; Department of Geology & Geophysics, http://home.gg.uwyo.edu.

The University of Wyoming is an equal opportunity/affirmative action employer.

**ASSISTANT PROFESSOR, SCIENCE
MERCER UNIVERSITY, MACON, GEORGIA**

Mercer University's College of Continuing and Professional Studies would like to invite applications for a full-time faculty position in Science in the Department of Mathematics and Science. The position is a three-year renewable, non-tenure track appointment at the rank of Assistant Professor beginning 1 August 2006. Primary duties will include teaching a seven course load each academic year and academic advising. Candidates should have a doctorate in one of the physical sciences or in a related interdisciplinary field, such as environmental science, from an accredited university/college. Some experience with teaching undergraduate adult learners is also desirable. The department seeks applicants who can contribute in the ongoing design and implementation of a minor program in forensic science/criminology. Interested applicants must apply online at www.mercerjobs.com. Review of the applications will begin immediately and will continue until the position is filled. AA/EOE/ADA.

**ASSISTANT PROFESSOR
SUNY POTSDAM**

SUNY Potsdam invites applications for a tenure track Assistant Professor position in the Department of Geology to begin in the fall of 2006.

Responsibilities include teaching undergraduate sedimentology and stratigraphy, an introductory course of the successful candidate's choice and design, and participation in our interdisciplinary science program to train elementary school teachers. Knowledge of GIS is an asset. Scholarly research, with student participation, is expected. We emphasize undergraduate research and fieldwork with all majors. Courses taught will complement existing courses in paleontology, igneous and metamorphic petrology, structural geology, geophysics, mineralogy, and geochemistry. Potsdam is located in the Grenville terrain of the Adirondack Mountains and St. Lawrence River Valley of Northern New York. Field areas abound, and all faculty actively engage students in their research. The Geology Department, consisting of five full time faculty, currently has about 40 majors. Additional information on the college and the department may be obtained from the college's Web site: www.potsdam.edu or by e-mail at amatilm@potsdam.edu or badgerrl@potsdam.edu. Facilities to support teaching and research include an SEM, AA, XRD, an eight station seismic network, electrical resistivity, Strataview R24 for seismic reflection and refraction, a Worden Prospector Gravity Meter, a proton precession magnetometer and minimate seismograph. Applicants must have a Ph.D. by 15 August 2006.

Applications should provide evidence of teaching ability. Base salary: $41,500. Review of applications will begin 2 February 2006 and continue until the position is filled. Please send curriculum vita, cover letter, statement of teaching and research interests, and phone numbers/e-mail addresses of at least three references to: Sedimentology Search Committee, Department of Geology, SUNY Potsdam, Potsdam, NY 13676. Electronically submitted applications will not be accepted. SUNY Potsdam is an equal opportunity employer committed to excellence through diversity.

**TENURE TRACK ASSISTANT/ASSOCIATE PROFESSOR, PLANETARY GEOLOGICAL PROCESSES
DEPARTMENT OF GEOLOGICAL SCIENCES
BROWN UNIVERSITY**

The Department of Geological Sciences (www.geo.brown.edu/), Brown University, invites applications for a tenure-track faculty appointment in Planetary Geological Processes. Candidates should complement our current planetary science strengths in planetary evolution, volcanism, impact cratering, and remote sensing as well as departmental focus areas of Earth system history, tectonophysics, and Earth and planetary materials and processes. Possible areas of interest include remote compositional analyses, physical and chemical weathering of surfaces, environmental response to impact processes, and modeling of planetary processes. One particular emphasis could be the application of broad quantitative skills to analysis of remotely sensed data, particularly using spectroscopic analysis. Candidates may find additional opportunities for collaboration with the Marine Biological Laboratory through the Brown-Marine Biological Laboratory Joint Graduate Program (www.brown.edu/research/MBL/index.html). The successful candidate will maintain an active, externally-funded research program and enjoy a commitment to teaching at both undergraduate and graduate levels. Appointment is expected at the Assistant Professor level, although exceptional circumstances could warrant appointment as untenured Associate Professor. A Ph.D. degree or equivalent is required, and postdoctoral experience is considered important.

Applicants should forward a curriculum vita, descriptions of research and teaching interests, and a list of at least three potential referees. These materials may be submitted either by mail to James W. Head, III, Chair, Search Committee, Department of Geological Sciences, Box 1846, Brown University, Providence, RI 02912-1846, or e-mail, planetarysearch@brown.edu. Inquiries and other communications may be directed to the same addresses.

Applications received by 1 March 2006 will receive full consideration, but the search will remain open until the position is closed or filled. The start date for this position is 1 July 2006.

Brown University is an equal opportunity/affirmative action employer. We welcome applications from minority or female candidates.

COLBY COLLEGE: VISITING ASSISTANT PROFESSOR OR INSTRUCTOR IN GEOLOGY

The Department of Geology invites applications for a one-year, full-time, non-tenure-track, Visiting Assistant Professor or Instructor in structure/tectonics and geophysics/remote sensing, starting 1 September 2006. A Ph.D. with teaching experience at time of employment is preferred; ABDs are encouraged to apply. The successful applicant will be expected to teach five undergraduate courses including a 200-level structural geology with laboratory during the fall term and an upper-division laboratory course of his/her choice for geology majors in the spring term. The upper-division course should complement those already offered in the department. The remainder of the teaching assignment will focus on non-major offerings. Additionally, the candidate may have the opportunity to direct one or more independent research projects. Colby is a highly selective liberal arts college recognized for excellence in undergraduate education and for close student-faculty interaction. Applicants should submit a letter of application, curriculum vitae, statements of teaching and research interests, and three (3) letters of reference to Dr. Robert A. Gastaldo, Chair, Department of Geology, 5807 Mayflower Hill Drive, Waterville, ME 04901. Review of applicants will begin on 17 February 2006 and will continue until the position is filled. Colby College is an Equal Opportunity/Affirmative Action employer. Applications and nominations of women and minorities who would enrich the diversity of the campus community are strongly encouraged. For more information about the College, please visit the Colby Web site: www.colby.edu.

DEPARTMENT OF EARTH SCIENCES FACULTY POSITIONS SEISMOLOGY AND ASTROBIOLOGY

The Department of Earth Sciences at the University of California, Riverside, invites applications for two faculty positions available 1 July 2006:

Position 1: Astrobiology at Assistant Professor, Associate Professor, or Full Professor level. We seek an individual to integrate astrobiological research with the current faculty programs in geochemical, paleoenvironmental, and organic evolution. We are particularly interested in candidates that use the organic geochemical record of early Earth to decipher the effects of planetary processes on life and evolution with a particular emphasis on geochemical cycles as they relate to the habitability of planetary environments, but we welcome a broad range of interests. Specialties may include the evolution of, or changes in, the early Earth's biosphere, developmental systems, biomarkers, or isotopic approaches.

Position 2: Seismology at Assistant Professor level. We seek a candidate who uses seismological data to investigate the physics of earthquake processes. The successful candidate will be expected to develop a research program complimentary to our strengths in theoretical/numerical modeling of earthquakes and earthquake processes, experimental and theoretical investigations of rheological properties as they pertain to shallow and deep earthquakes, and electromagnetic field research on faults and crustal structure. Our current faculty in these areas is James Dieterich, Harry Green, David Oglesby, Stephen Park, and Guanshui Xu. We are a core member in the Southern California Earthquake Center and active in the Institute of Geophysics and Planetary Physics (IGPP).

Successful candidates must hold a Ph.D. and have a strong commitment to excellence in both research and teaching. Teaching responsibilities for both positions will include undergraduate and graduate courses in the area of specialty. Information about Earth Sciences at UCR is available on the Web at www.earthscience.ucr.edu/.

Applications, including a vita, statement of research and teaching interests, and full contact information of three referees should be sent to: Dr. Martin Kennedy, Chair, Astrobiology Search Committee, or Dr. Harry Green, Chair, Geophysics Search Committee, Department of Earth Sciences, University of California, Riverside, CA 92521. E-mail contact: Martin.Kennedy@ucr.edu (astrobiology) or Harry.Green@ucr.edu (seismology). Review of applications will begin 15 February 2006 and will continue until the position is filled. Salary will be commensurate with education and experience.

The University of California is an Affirmative Action/Equal Opportunity employer.

Central Connecticut State University

ASSISTANT PROFESSOR STRATIGRAPHY/SEDIMENTOLOGY/ HYDROGEOLOGY [#C06-065]

Central Connecticut State University's Physics & Earth Sciences Department invites applications for Assistant Professor beginning August 2006. We are seeking a candidate with experience in the broad areas of Stratigraphy/ Sedimentology and Hydrogeology. Primary teaching responsibilities will be introductory courses in geology and advanced undergraduate courses depending upon their field of specialty. Our department stresses a balance of classroom, field and laboratory experiences for our majors, and we seek a colleague who will contribute to all of these components of our undergraduate curriculum. In addition, the individual will direct undergraduate research projects and conduct an active research program. The successful candidate will also participate in the design, development, and growth of the geology program at CCSU.

Requirements: Teaching experience and a Ph.D. in the above area at the time of appointment; demonstrated ability to work with a diverse student body required.

Send curriculum vita, statements of undergraduate teaching philosophy and research interests, along with three letters of reference to: Dr. Ali Antar, Physics & Earth Sciences Dept., CCSU, 1615 Stanley Street, New Britain, CT 06050.

Application deadline is January 23, 2006.

CCSU aggressively pursues a program of equal employment and education opportunity and affirmative action. Members of all underrepresented groups, women, veterans, and persons with disabilities are invited and encouraged to apply.

MATHEMATICAL STATISTICIAN: GS-1529-14 PERMANENT FULL TIME (ONE POSITION) ANNOUNCEMENT NUMBER: ER-2006-0028 LOCATED IN RESTON, VIRGINIA ANNOUNCEMENT DATES: 2 JAN 2006–28 FEB. 2006

The U.S. Geological Survey invites applications for the following position. This position is in the Eastern Energy Resources Team, Geologic Discipline, located in Reston, VA. The Team has responsibility for planning and conducting research relating to the oil, gas, and coal resources of the United States and for the application of the results of these investigations to the exploration, development, and assessment of the resources. Applicants must apply online on the Online Automated Recruitment Service (OARS): www.usgs.gov/ohr/oars.

The Energy Resources Team has oil and gas, and coal resource volume and quality assessment responsibilities as well as research responsibilities relating to effects of fossil fuel combustion and carbon sequestration. The incumbent will serve as a member of a multidisciplinary team (geologist, geochemists, geophysicists, and economists.) to design assessment methods and participate in the preparation of assessments. In addition, the incumbent will be responsible for design, analysis, interpretation of laboratory experiments, and in the sampling design of field data collection programs in support of ongoing team research activities.

PHYSICAL GEOLOGY/PHYSICAL GEOGRAPHY VISITING ASSISTANT PROFESSOR DENISON UNIVERSITY

The Dept of Geosciences at Denison University invites applications for a one-year position to begin in the Fall of 2006. We seek a teacher/scholar to teach Physical Geology or Physical Geography and a course in the applicant's area of expertise and to enhance the diversity of our existing program. We are most interested in applicants with expertise in the broadly defined area of Surficial Processes, but all applicants will be considered. This temporary position is separate from the sabbatical replacement position we advertised in September 2005 and is the result of a new tenure track position in Surficial Processes/Physical Geography that will begin in Fall 2007.

We seek a colleague who is committed to teaching excellence in the liberal arts tradition, is field-oriented, has broad interests beyond their specialty, and will provide a balance of classroom, field and laboratory experiences for our majors. We will consider ABD candidates, but we prefer candidates with a Ph.D. at the time of appointment. Denison is a highly selective liberal arts college strongly committed to, and supportive of, excellence in teaching and active faculty research that involves undergraduate students.

Please submit a letter of application and a discussion of your approach to teaching and research in a liberal arts setting, along with a vitae, copies or originals of academic transcripts, and three letters of recommendation to: David Hawkins, Department of Geosciences, Denison University, Granville OH 43023; 740-587-5788; hawkins@denison.edu. Application materials should arrive by 17 Feb. 2006, although the search will remain open until the position is filled. Denison University is an Affirmative Action, Equal Opportunity Employer. In a continuing effort to diversify our Campus Community, we strongly encourage women and people of color to apply.

Opportunities for Students

Three Applied Geohydrology Summer Research Assistantships, Kansas Geological Survey, University of Kansas. These are 12-week summer positions open to students at any university. The individual will participate in a variety of field activities in support of KGS research programs. The themes of the activities in the summer of 2006 will be stream-aquifer interactions, groundwater consumption by phreatophytes, and new direct-push technologies. Start approx. 15 May 2006. Salary $6,000 for 12 week appointment. Required:

Relevant coursework in earth sciences or engineering; interest in hydrogeology; ability and willingness to participate in moderate physical activity in mid-summer temperatures in Kansas; and clear communication skills. First consideration given to application material received by 1 March 2006. For complete description go to www.kgs.ku.edu/general/jobs.html; to apply, go to jobs.ku.edu (search by research assistant title); or contact Annette Delaney, 785-864-2152, hr@kgs.ku.edu. For further technical information, contact Jim Butler, jbutler@kgs.ku.edu. EO/AA Employer. Paid for by KU.

Graduate Assistantships and Fellowships, University of Kentucky. The Dept. of Earth and Environmental Sciences at the University of Kentucky has assistantships and fellowships available for the 2006–2007 academic year for M.S. and Ph.D. students. All awards include tuition and health insurance. The department has 11 regular faculty and 15 adjunct or cross-appointed faculty, including staff at the Kentucky Geological Survey and the Center for Applied Energy Research. Research specializations include tectonics, sedimentary and coal geology, geophysics, geochemistry, hydrogeology, and igneous and metamorphic petrology. Facilities include UK's Environmental Research and Teaching Laboratory, the Kentucky Seismic and Strong-Motion Network, electron microprobe and X-ray diffraction laboratories, and extensive library holdings. UK is located in Lexington, a vibrant community of 260,000. The surrounding area offers a wealth of outdoor and cultural opportunities. For more information, visit www.uky.edu/AS/Geology or contact Dr. Alan Fryar, Director of Graduate Studies, 859-257-4392 or alan.fryar@uky.edu.

Ph.D. Students Wanted. Program in Infrastructure and Environmental Systems. University of North Carolina–Charlotte. The interdisciplinary program in Infrastructure and Environmental Systems at UNC Charlotte is accepting applications for Ph.D. students. Full funding, including tuition waivers and health care coverage, is available as early as January 2006. Areas of student research include: biogeochemistry, applied climatology, coastal processes, contaminant transport, engineering geology, environmental geology, fluvial processes, geochemistry, geotechnical engineering, GPS, surface and groundwater hydrology, landfill design, tropical meteorology, mineralogy, petrology, Quaternary geology, remote sensing, sedimentology, stratigraphy, site remediation, slope stability, soil geomorphology, structural geology, surficial processes, vadose zone processes, watershed analysis and numerical weather prediction. Students have access to extensive field and analytical equipment and facilities including IC, ICPMS, XRD, XRF, GPR, grain size analysis and GIS laboratories. We are located in the beautiful Piedmont of North Carolina close to pristine beaches and the Blue Ridge Mountains. Application deadline: 15 February 2006 for the 2006–2007 academic year. Applications for January 2006 admission are encouraged. For more information contact jadiemer@uncc.edu or visit www.ce.uncc.edu/INES/.

Graduate Fellowships at Indiana University. The Department of Geological Sciences at Indiana University (Bloomington) solicits applicants for at least five graduate fellowships in the following areas: Geobiology/Stratigraphy, Geophysics, Geomorphology, Petroleum Geology, and Clay Mineralogy. The fellowships offer up to $18,000 per year plus tuition waiver. The duration of the fellowship varies but Ph.D. and M.Sc. students are guaranteed 4 and 2 years of support within the Department, respectively. Applicants for the 2006–2007 academic year should contact: Dr. Mark Person, Director of Graduate Studies, Indiana University, Department of Geological Sciences, maperson@indiana.edu, 812-855-4404.

Research and Teaching Assistantships available for Fall 2006 at Temple University: Research and Teaching Assistantships are available for the Fall term (September 2006) in our Masters Program in Geology at Temple University. The 2-year Masters Program offers advanced courses and thesis research opportunities in **environmental geology, hydrogeology, geochemistry, environmental geophysics, soil science/paleosols, stratigraphy/sedimentology, and materials science**. Financial support for every student includes stipend and full tuition for 2 years. Graduates of our program have an excellent record of employment in consulting and education professions and acceptance into doctoral programs. For information and applications please write, call or e-mail Dr. George Myer, Department of Geology, Temple University, Philadelphia, PA 19122, 215-204-7173, Fax 215-204-3496, e-mail: gmyer@temple.edu. Applications will be accepted until these positions are filled. Please visit our Web site at www.temple.edu/geology for additional information. Be sure to fill out the graduate information survey at www.temple.edu/geology/gradsurvey.html for more information about particular aspects of our program.

Graduate Research Opportunities: The Dept. of Geosciences at Texas Tech University solicits applicants for its M.S. and Ph.D. programs. The department has research opportunities across all Geoscience disciplines. We particularly encourage applications from students wishing to pursue research projects in environmental/low temperature geochemistry, structural geology/tectonics, remote sensing and GIS, and geophysics. Assistantships are available on a competitive basis, beginning Fall 2006. For more information, please see the departmental Web site at www.gesc.ttu.edu or contact the geology graduate advisor, Dr. Moira Ridley, moira.ridley@ttu.edu.

Research and Teaching Assistantships. The geology department at California State University–Bakersfield has several research and teaching assistantships available for students wishing to pursue a MS in Geology beginning fall 2006. Appointments include health benefits and a salary of ~$16,500 per year. Department strengths are in the areas of sedimentary geology, petroleum geology, geophysics, hydrogeology, geochemistry, structural geology, and environmental geology. Bakersfield is located in the heart of California's petroleum and agricultural areas, and abundant opportunities exist for other industry-supported thesis projects. Review of applications will begin 1 April 2006 and continue until all positions are filled. For additional information and application materials, contact Dirk Baron, Graduate Coordinator, Department of Geology, California State University, 9001 Stockdale Hwy., Bakersfield, CA 93311-1099, dbaron@csub.edu, or visit the department's Web site at www.cs.csubak.edu/Geology/.

ISES

Announcement:

A Summer School in Integrated Solid Earth Sciences (ISES)

Topic: Rheology of Earth Materials

Sponsored by a grant from the National Science Foundation

Application Deadline: April 1, 2006
Decision date: April 15, 2006
Location: The Colorado College, Colorado Springs, CO
Dates of summer school: Aug. 5 (pm) to Aug. 12 (pm), 2006

A 7-day workshop for advanced graduate students addressing different aspects of the rheology of Earth Materials. A panel of experts will present rapid advances in this topic from many different avenues of geological research (listed on website). The short course will also involve lectures, activities, and fieldtrips. More information is posted on the web site.

Topics to be addressed: Deformation mechanisms / Field rheology/ Analog modelling / LPO and EBSD / Brittle rheology / Petrological approaches / Numerical modelling / ELLE modeling / Petrology/Embrittlement / Mantle rheology

Web site & On-line application:
http://acad.coloradocollege.edu/dept/gy/ises/ISESSummerSchool.php

Applications will start being accepted on January 15, 2006

For more information, please contact
Basil Tikoff (basil@geology.wisc.edu)
or Christine Siddoway (CSiddoway@ColoradoCollege.edu).

University of Massachusetts Boston

Assistant Professor

The Department of Environmental, Earth and Ocean Sciences (EEOS) (http://www.eeos.umb.edu/) invites applicants for a tenure-track Assistant Professor position (beginning 1 Sept 2006) in Fluvial Geomorphology or Hydrogeology (ground or surface water). Competency in GIS is preferred. Applicants must have interests in understanding and managing the effects of natural and human perturbations on linked watershed-coastal or coastal-marine ecosystems, and must have a fundamental commitment to join an multidisciplinary faculty that emphasizes linkages between the social and natural sciences. Preference will be given to candidates with strong quantitative skills, with a sincere commitment to interdisciplinary research who are willing to both initiate and participate in team-based research projects, and whose research complements research by other EEOS faculty. Applicants must have a well-conceived research and teaching program, capable of supporting graduate research through external funding. Teaching responsibilities include supervising graduate and undergraduate students and teaching both undergraduate and graduate courses related to their discipline.

Qualifications: Ph.D.in a related area, with post-doctoral experience preferred. Send a cover letter that includes statements of interests and goals in research and teaching, c.v., and three letters of reference to: **EEOS Search, Dean's Office, College of Science and Mathematics, Search 615c, University of Massachusetts Boston, 100 Morrissey Blvd., Boston, MA 02125-3393.** Application review will begin on January 15 and continue until position is filled.

UMass Boston is an Affirmative Action, Equal Opportunity Title IX employer.

University of Massachusetts Boston
UMASS
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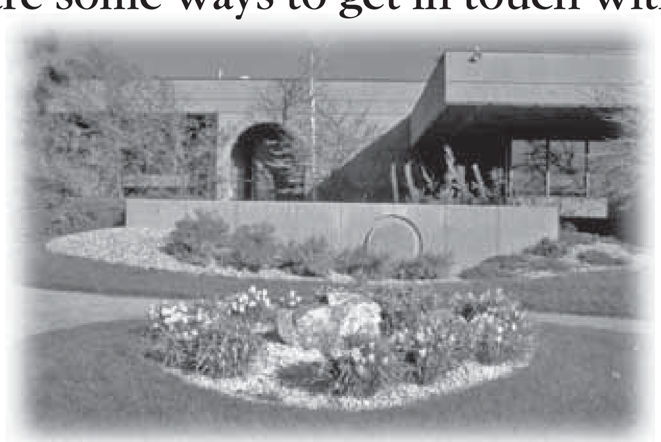

- **Web site:** www. geosociety.org
- **e-mail:** gsaservice@geosociety.org
- **call:** +1-303-357-1000 opt. 3 *or* +1-888-443-4472
- **fax:** +1-303-357-1071
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