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Stream Piracy Revisited: A Groundwater-Sapping Solution

INSIDE

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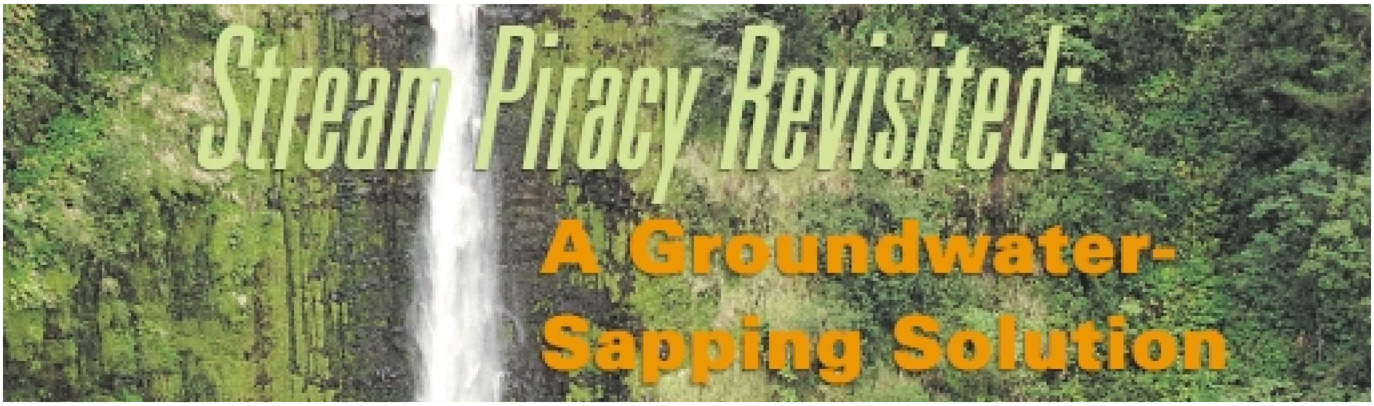
science article

On the cover: Akaka Falls, Hawaii. The bellowing form of the plunge pool is the result of groundwater-sapping processing as well as vapor effects from the plunging water, enhancing biological activity. See "Stream Piracy Revisited: A Groundwater-Sapping Solution," by Darryll T. Pederson, p. 4–10.



Darryll T. Pederson, *Department of Geosciences, University of Nebraska, Lincoln, NE 68588-0340, USA*

ABSTRACT

Stream piracy describes a water-diversion event during which water from one stream is captured by another stream with a lower base level. Its past occurrence is recognized by unusual patterns of drainage, changes in accumulating sediment, and cyclic patterns of sediment deposition. Stream piracy has been reported on all time and size scales, but its mechanisms are controversial. Some researchers conclude that stream piracy is a rare event and happens only on small scales; this is based on a recognition that surface-water energy decreases near divides and the belief that groundwater-sapping processes decrease in effectiveness near divides and are not effective in rock and cohesive sediment. In contrast, numerous studies show that groundwater-sapping is effective in rock and cohesive sediment, focused by the intersection of the extending channel with the water table, and effective in hillslope processes. Further, destruction of evidence by surface water is the reason for the general lack of recognition of groundwater-sapping effects. I argue that the persistence of groundwater-flow systems, coupled with the evolving geometry as a pirating stream approaches a divide, can sustain breaching by groundwater-sapping processes. The principal determinant of the maintenance of energy is the position of the groundwater divide as compared to the topographic divide where streams in adjacent drainage basins are at different elevations. Wetter climatic periods can add energy to the system as increased recharge causes groundwater levels to rise, accelerating stream piracy.

INTRODUCTION

The term stream piracy brings to mind an action of forcible taking, leaving the helpless and plundered river poorer for the experience—a takeoff on stories of the pirates of old. In an ironic sense, two schools of thought are claiming villain status. Lane (1899) thought the term too violent and sudden, and he used "stream capture" to describe a groundwater-sapping–driven event, which he envisioned to be less dramatic and to be the common mechanism for stream piracy. Crosby (1937) took issue with Lane (1899 and later papers) and argued that surface water is the principal agent of stream piracy in most settings. This set up a debate on the relative roles of surface-water erosion and groundwater-sapping erosion that persists today. This paper contends that groundwater-flow patterns and groundwater-sapping processes are important in most cases of stream piracy, and the final act of piracy can be rapid because of the developing geometry. There is a predictable imprint of groundwater flow, and groundwater sapping is effective at all scales and in all geologic material.

The issue of stream piracy is more than an academic discussion because it is an important geologic process—past and present. Sediment-deposition patterns and mineralogy can be drastically altered with the event of stream piracy. Stream piracy can change migration patterns for aquatic animals and can change rates of erosion in upland areas. Stream chemistry can be changed as a consequence of stream piracy. In some geologic settings, such as in a delta, stream piracy is a cyclic event. The final act of stream piracy is likely a rapid event that should be reflected as such in the geologic record. Understanding the mechanisms for stream piracy can lead to better understanding of the geologic record.

Recognition that stream piracy has occurred in the past is commonly based on observations such as barbed tributaries, dry valleys, beheaded streams, and elbows of capture. A marked change of composition of accumulating sediment in deltas, sedimentary basins, terraces, and/or biotic distributions also may signify upstream piracy (Bishop, 1995; Pissart et al., 1997; Mather et al., 2000; Johnsson, 1999). Recognition that piracy is happening now is based on observed higher erosion rates for streams with steeper gradients on one side of a drainage divide relative to the other, with the steeper gradient stream capturing the headwaters of the lower gradient stream (Bates, 1961; Vogt, 1991; Ries et al., 1998). As variants, development of karst aquifers can lead to underground capture of rivers over time, such as the recognition of loss of upper Danube flows (Hötzl, 1996), and cyclic development of lobes on the Holocene Mississippi River delta is modulated by stream capture (Roberts, 1997).

While the identity of the villain (mechanism) remains controversial, there are common elements in stream piracy regardless of the erosion process. To have energy to do the work of erosion and transport, the pirating stream needs to be at a lower elevation or have a steeper gradient. In addition, the geologic material near where the capture takes place must be susceptible to disaggregation by mechanical or chemical processes or to solution, or must already be disaggregated. The process of erosion at the channel head coupled with the geologic setting and energy in the system determines the rate and direction of channel extension. There must be a mechanism for transport of eroded sediment from the channel head. Bishop (1995) argued that in most settings, there is minimal energy for stream piracy and therefore little piracy. This paper will show that the evolving groundwater-flow system as a pirating stream approaches the divide can provide the threshold energy for breaching.

GROUNDWATER AND STREAM PIRACY

The phenomenon of groundwater "sapping" has been identified with a number of terms. Higgins (1984) expanded the term "seepage erosion" to encompass the more complex erosion of consolidated rock. He included intensified chemical weathering; leaching and dissolution within the seepage zone; and enhanced physical weathering by granular disintegration or flaking owing to wetting-drying, salt-crystal wedging, root wedging, rainbeat, congelifraction, and needle-ice wedging. Howard (1988a) further expanded the overall concept proposing "Groundwater sapping, as distinct from piping, is a generic term for weathering and erosion of soils and rock by emerging groundwater, at least partially involving intergranular flow (as opposed to the channelized throughflow involved in piping)" (p. 3). Groundwater sapping is used in this context in this paper.

The study of groundwater-sapping processes and their extension to stream piracy is complicated by the presence of surface water, which in many cases destroys evidence of groundwater sapping. For example, I have observed freezing groundwater in a vertical riverbank near Cook, Nebraska, that led to the dislodging of frozen bank material in meter-sized blocks during January 1999. Spring freeze-thaw cycles fragmented the blocks into transportable sediment that was carried away by a June flood. A July visitor would recognize significant bank erosion since the previous summer visit, but, because all evidence for groundwater sapping was destroyed, would attribute this to the June flood.

Figure 1. Erosion by needle ice growth in a road bank, Boone, North Carolina, USA. Groundwater extrusion represented by ice columns several cm long.

Lawler (1993) reported a similar result from needle-ice growth on the River Ilston, South Wales, United Kingdom. Prosser et al. (2000) found that needle-ice growth in winter and desiccation of clays in the summer control erosion on Ripple Creek Canal, Tasmania. Surface-water flows were unable to erode firm, cohesive clay banks that had not been preconditioned by groundwater sapping. I have found that needle-ice growth is responsible for road-bank erosion (Fig. 1) and erosion of lakeshore banks (Fig. 2).

Groundwater Sapping Examined

The effect of positive pore-water pressure in promoting erosion and increasing instabilities of slopes is well known. An expansion of the concept is needed to relate it to stream piracy. In computer modeling and laboratory studies (Howard, 1988b), headcuts spontaneously formed in response to groundwater seepage, and they migrated up gradient because of their intersection with the groundwater table where positive pore pressures occur, promoting erosion. With continued

Figure 2. Erosion by groundwater sapping (one week of freeze-thaw cycles) on shoreline bank of Lake Ashtabula, North Dakota, USA. With melting of lake ice, wave action removed the talus.

headward development, groundwater flow was focused in the few uppermost headcuts that interfered minimally with each other. These continued to erode headward, intercepting the groundwater flow that would have gone to the now-inactive headcuts. As groundwater-discharge energy in the form of positive pore pressures is rapidly focused in the few remaining headcuts, a consequent acceleration of headward erosion takes place, and a roughly parallel drainage network is developed. Dunne (1998) described a similar positive feedback in hollow formation. On a smaller groundwater-flow scale, Collison's (1996) simulations showed that even small soil cracks (enhancing recharge) just upstream from gully heads resulted in positive pore pressures at the base of the headcut. Collison (1996) also found that most eroded material transported by surface water originates in the gully itself rather than upslope, so the controlling factor for gully expansion should be headcut and wall instability. Flume experiments (Kochel et al., 1988; Baker et al., 1990) that modeled headcut migration under hydrogeologic conditions found in the Colorado Plateau yielded long valleys, short tributaries, and amphitheater heads, comparing well with the field description of Laity and Malin (1985).

The ability of a river to erode, transport, and deposit sediment is in part determined by interaction with the groundwater system. As an example, positive pore-water pressures in areas where groundwater discharges into a stream can increase the erodibility of the stream bed. Changes of erodibility and transport competency with groundwater influx and outflux in beach and stream settings can favor sediment accumulation or enhance erosion (Harrison and Clayton, 1970; Howard, 1988b; Butt and Russell, 2000).

Several case examples show the nature of the interaction of the groundwater-flow system and headcut migration in field settings of possible incipient stream piracy. Higgins (1984) observed that when the water table slopes at an angle less than that of the beach face, gully heads incise deeper as they advance updip. There is a threshold in gully depth where small slumps and block slides, due to deep entrenchment, negate further advancement. Where the water table parallels the beach face, gullies advance updip without increasing incision. By extension, to divide areas, if the water-table slope is less than the surface slope, increasing entrenchment would be favored where groundwater sapping is the dominant erosion process at the headcut. The development of a drainage network in the Finisterre Mountains in New Guinea (Hovius et al., 1998) may be similar to Higgins' beach example. Initial gorge incision is expanded by large-scale landsliding controlled by groundwater seeping, with the resulting debris being incised by fluvial erosion. Montgomery and Dietrich (1988) reported that channel initiation on steep slopes in the Coos Bay region of Oregon and in the southern Sierra Nevada is associated with landsliding that is probably caused by seepage erosion. In most settings, the actual sapping rates should be a function of groundwater-flow rates. Gabbard et al. (1998) found in laboratory studies that introduction of groundwater inflow caused accelerated headward erosion with erosion rates increasing by 60 times. The importance of groundwater-sapping erosion in geologic processes should not be overlooked (Higgins, 1984; Dunne, 1980; Schumm, 1980; Roloff et al., 1981; Netto et al., 1988). Dunne (1990) rated water as second only to gravity in producing slope instabilities.

In broader terms, because of the great variety of groundwater-sapping processes and the nearly universal presence of groundwater, it is likely that most hillslope erosion and channel extension patterns carry the imprint (pattern) of groundwater-flow systems.

The Imprint of Groundwater Flow

In broader terms, because of the great variety of groundwater-sapping processes and the nearly universal presence of groundwater, it is likely that most hillslope erosion and channel extension patterns carry the imprint (pattern) of groundwater-flow systems. Freeze (1987) modeled the resulting water table between parallel rivers with given conditions of recharge and aquifer characteristics and coupled the output to slope-stability calculations to show effects of recharge from various precipitation events. His results showed that hydrogeologic factors coupled with climatic variation and short-term precipitation events exerted considerable control on the slope of the surface topography between the rivers in terms of stability of slopes and channel banks as controlled by pore pressures. His results suggest that the surface topography can be a reflection of the groundwater table as opposed to the popular concept of the water table being a subdued reflection of the surface topography. This suggestion is supported by the consequences of hillslope processes and the nature of channel extension in divide areas.

More specifically, groundwater sapping can be recognized by distinctive patterns of erosion occurring as a consequence of the geologic setting and regional and local groundwater-flow systems. Fyodorova and Sasowsky (1999) described the dissolution of quartz cement by groundwater leading to increased porosity and reduction of the mechanical strength of a sandstone. This weakening has led to additional groundwater-sapping processes becoming active with development of caves along preexisting fractures and joints within the sandstone bedrock. They suggest that dissolution of silica is transport controlled so the process is most active where fractures have been enlarged and groundwater has not adjusted chemically. (The bigger fractures with greater flow continue to grow.) Norris and Back (1990) described a similar evolution where mixing of groundwater and seawater leads to dissolution of carbonate rock along the Yucatan. It should be noted that groundwater is nearly as effective and rapid in erosion of siliceous rocks as of limestone rocks in terms of chemical weathering and removal of dissolved substances (Young and Saunders, 1986). Johnsson (1999) identified two sets (based on orientation and elevation) of horizontal cave passages associated with different historical elevations of the water table and directions of groundwater flow in the karst of Swago Creek in West Virginia. In each case, the fracture pattern of the rock and the direction of the groundwater gradient were contributing factors to the pattern of groundwater sapping. Nash (1996) found that the headward development of valleys in the Hackness Hills in North Yorkshire, England, was in part controlled by groundwater-sapping processes operating in an updip direction.

If groundwater-sapping location is a function of groundwater-flow systems and headcut interception, then groundwater-flow models should suggest patterns of development of stream drainages. In fact, drainage patterns based on groundwater-flow models using field hydrogeologic parameters and recharge rates show close agreement with actual field settings. Streams of a given order (in the sandy Pleistocene area of the Netherlands) can be explained as outcrops of groundwater-flow systems of a corresponding order reflecting the drainage density necessary to effectively drain the aquifer system (DeVries, 1976, 1994). DeVries (1995) expanded his work to include a model of contracting and expanding stream networks with groundwater-level change, as related to seasonal rainfall characteristics. Troch et al. (1995) applied DeVries's (1976) model to the Zwalmbeek catchment in Belgium. Coupled with the observation that in many humid lowland areas, overland flow is rare and so most flow is underground, they submitted that the existing drainage network developed through sapping erosion at the zone of groundwater exfiltration. In a setting comparable to that described by DeVries, the drainage network in the Sand Hills of Nebraska consists of roughly parallel rivers with no tributaries. The drainage-network density corresponds to the thickness of the underlying aquifer; it is less dense where the aquifer is thicker and was likely developed by headward erosion caused by groundwater sapping (Pederson, 1995).

The Groundwater-Sapping Model of Stream Piracy

The principal fact favoring stream piracy by groundwater sapping is that the groundwater divide does not correspond to the surface-water divide when there is a difference in elevation of streams in the adjacent drainages (Fig. 3). Because of this, the groundwater-flow system does not lose its energy with gully extension like the surface-water system does with its decreasing catchment size. Three selected stages of channel extension across a divide are shown in Figure 3.

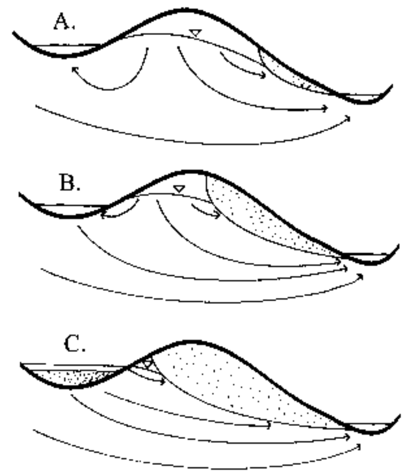


Figure 3. Cross-section sequence (A–C) of pirating channel extension and eventual divide breaching by groundwater sapping. Arrows show paths of groundwater flow and inverted triangle shows position of water table. Sedimentation in pirated stream shown by higher density of dots. Erosion in pirating channel shown by lower density of dots.

In stage A, a tributary of the pirating stream is extending itself by headward erosion toward the divide. Groundwater flow is focused, much like flow to a pumping well. The energy driving the groundwater-flow system is reflected by the difference between the elevation of the groundwater divide and the elevation of the water-table outcrop at the headcut. The energy of the surface-water system would be the difference between the topographic divide and the base of the headcut. Note, no mass considerations or energy conversions that occur along the flow paths are included, so this is not a measurement of the actual energy available at the headcut for erosion. The elevation and location of the groundwater divide represents a dynamic equilibrium that will change with climatic changes and changing geometries such as channel extension.

Continued headward erosion of the extending channel results in a migration of the groundwater divide toward the soon-to-be-pirated stream. More of the regional recharge to the groundwater-flow system is now moving toward the extending channel in stage B (Fig. 3) with a likely increase in groundwater-sapping potential. At some point in time, the soon-to-be-pirated stream will start losing flow to the groundwater system, which will further increase the groundwater-sapping potential. At this point, the potential exists for the initiation of sediment accumulation in the pirated channel. In contrast, the energy for headcut erosion by surface water is decreasing because of the decreasing catchment size.

In stage C (Fig. 3), the pirated stream is losing considerable flow to the groundwater system and the potential for sediment accumulation is high. Breaching of the topographic divide was possible because the groundwater-flow system is able to maintain its energy and, in fact, may experience an increase in energy gradient as the pirated stream is approached by the extending channel of the pirating stream. An additional increase in energy in the groundwater-flow system will occur with the accumulation of sediment in the pirated stream. A positive-feedback situation develops in which losses of water from the pirated stream augment the groundwater-sapping process, leading to further sediment accumulation and other outcomes.

While the basic process shown in the model is the same in heterogeneous and anisotropic settings, the actual flow paths followed by groundwater in these settings may modify the geometric pattern shown in Figure 3. Also, developing fracture flow or development of karst (limestone or rock with soluble cement) may cause stream piracy to occur well before there is an apparent surface expression. It is only a matter of time before the subsurface flow paths would be expressed at the surface.

It is very difficult to identify areas of incipient stream piracy on a large scale because the process is slow compared to the human time scale, and the quantification of channel extension rates is complicated by the nonlinearity of the erosion system. It is also very difficult to determine past rates of stream piracy because the evidence has usually been destroyed. Having said that, the proposed model of stream piracy by groundwater sapping should work on all time and size scales as the mechanics should operate at all scales.

SURFACE WATER AND STREAM PIRACY

The basics of a "surface water view" of stream capture (the other potential villain) were described by Crosby (1937) and are still found in many textbooks. Erosion is "gnawing back at the headwaters of every stream" (p. 469) with the rate of erosion dependent on the formations present, slope of the land, climatic conditions, and protecting vegetation. Weathering breaks rocks into fragments, which are transported by hillslope processes—including sheetwash, landslides, and soil creep—to stream channels where they are transported. Rates of erosion are controlled by water velocity, abrasion tools, and the underlying formation. Crosby acknowledged the "apparently impotent little brook" (p. 471) in the headwaters, but credits weathering between floods for wearing away these rocks and the floods themselves for removing sediment.

There are many complicating factors in determining the mechanisms and rates for channel extension. Weissel and Seidl (1997) found that while bedrock lithology and upstream drainage area had minimal impact on knickpoint retreat, bedrock jointing profoundly affected the hillslope processes that control knickpoint migration rates. Whipple et al. (2000) determined that the efficacy of fluvial erosion processes (plucking, abrasion, cavitation, and solution) was a strong function of substrate lithology and that joint spacing, fractures, and bedding planes exert the most direct control. Montgomery and Dietrich (1989) identified thresholds of upslope catchment area needed to erode a channel head. As a channel head approaches a divide, the catchment area will decrease, reducing runoff. Gomez and Mullen (1992) recorded more than 90% of network growth in the first 10% of their experiment's duration. An exponential curve for gully extension was suggested by Rutherford et al. (1997). A broader interpretation is that intrinsic and/or extrinsic factors may provide a threshold for initiation, and the physical effect of channel extension "exhausts" these factors.

Figure 4. Rainbow Falls, near Hilo, Hawaii, USA. There is a clear undercutting of the falls' face well beyond the zone of plunge. The presence of adjacent springs and water flowing from the cavelike feature suggests a complex system of knickpoint advancement in this setting.

STREAM PIRACY: GROUNDWATER AND SURFACE WATER AS COOPERATORS

Water, the common element of surface water and groundwater, is obviously the major initiator and accelerator in erosion and the key element in stream piracy. The hardest rock can be broken down by freeze-thaw cycles, and a cohesive sediment can be fragmented by wet-dry cycles. Fractures in an "impermeable" rock leave them vulnerable to erosion and enlargement by water. Water supports living organisms that condition rock and sediment for erosion, and it can dissolve interstitial cement and the rock itself. Where there is water movement, there is an increasing probability of a chemical disequilibrium between the rock and the interstitial water. Positive pore-water pressure undermines slopes, triggers landslides, and contributes to debris flows. As water erodes, it usually creates a preferred flow path, further accelerating the erosion process. Groundwater-sapping processes are equally effective in the presence of surface water, but they are often not recognized because either the evidence is destroyed by surface water or they are lumped under hillslope processes. Because of the inertia of the system, groundwater sapping is more continuous and persistent over time as compared to surface water.

Groundwater energy is little affected by topographic divides as compared to surface-water energies. Surface-water energy usually decreases near divides because of shrinking catchment areas and sometimes decreased surface gradients. With breaching of the divide, considerable erosion would be required to develop a catchment area for surface runoff to feed the pirating stream on the pirated stream side of the drainage basin. This is unlikely because nearly all sediment comes from the extending channels. If there is insufficient flow in the channel, accumulating sediment in the headcut can slow the erosion process, so availability of sediment transport may control the rate of extension. This fact is an argument for the occurrence of stream piracy being most likely during wetter climatic periods. Finally, extension of a channel is often very rapid at first, implying that a threshold has been crossed. This also suggests that the final act of stream piracy should occur as the consequence of an event rather than as the continuation of an average.

The only connection between the

pirated and incipient pirating stream is through the groundwater-flow system (Fig. 3). The incipient pirating stream can gain flow (sapping energy) from the pirated stream. The pirating stream can cause the accumulation of sediment in the incipient pirated stream. This concept should apply in the building and breaching of river levees, delta formation, alluvial fans, and hillslope processes.

Most stream piracy is likely the result of a succession of channel extensions in response to climatic events. One must recognize that the current climatic conditions may not be the same as when stream piracy occurred. Just as short-term precipitation events accelerate groundwater-sapping erosion and surface-water erosion, longer climatic events can add or remove energy from the pirating equation, including base-level changes. Higgins (1984) proposed that the pectinate (comb-like) drainage networks of the High Plains were formed chiefly by groundwater sapping when the water tables were higher during wetter climates of the past. Alley (2000) highlighted the relative stability of the climate over the past 10 000 yr as compared to the much larger instabilities of the past 100 000 yr, so our historical perceptions may be inappropriate in interpreting stream piracy. The rates of surface processes and denudation (Young and Saunders, 1986) are such that many stream-piracy events likely occur over time scales greater than the current period of climate stability, especially in lithified and cohesive material. However, of all natural variables controlling surface water and groundwater flow in general, only climate can change significantly over time periods shorter than geologic time. An exception to the previous statement may occur with disruptions of drainages during earthquakes, volcanic activity, and subglacial drainage events. On an even shorter time scale, several years of unusually high precipitation can significantly increase the erosive power of groundwater and surface water.

SUMMARY

Groundwater exists in nearly all geologic environments in a dynamic system with persistent flow from recharge areas to discharge areas where groundwater-sapping processes are focused. Groundwater sapping is highly effective in eroding sediment and rock. The presence of perennial surface water is strong evidence for groundwater intersecting the surface and for effective groundwater sapping. Groundwater sapping is effective in the absence of surface water. Unfortunately, the evidence for groundwater sapping is usually destroyed by surface water.

Headward extension of channels results in a distortion of the groundwater-flow system. The head of the channel represents a low potential energy point for groundwater flow, much like a pumping well. With concentration of flow, groundwater-sapping processes are concentrated at the headcut, resulting in further channel extension and/or incision that in turn leads to increasing incision of the groundwater-flow system. There is the potential for the development of thresholds that, on being exceeded, can lead to rapid channel extension. An analogous event would be the failure of the Teton Dam.

Groundwater sapping should be suspected at locations where the surface morphology suggests incision into the groundwater table and concentration of groundwater flow. A greater potential for groundwater sapping is found at the outside of meander bends, at the point where streams become live, where riverbanks feel spongy, where talus slopes form during freeze-thaw cycles, and in deeply entrenched channels. Groundwater sapping may be found in areas where banks and slopes are wet or undercut or have zones of vegetation growth, surface evaporitic deposits, desiccation cracks, water flow from fractures, and evidence of soil flow. If the setting appears too dry, try visualizing a long-duration thunderstorm and a much higher groundwater table.

If there is a difference in elevation of streams in adjacent drainage basins, the topographic divide does not correspond to the groundwater divide (Fig. 3). As a result, the groundwater-flow system maintains its energy as the headcut approaches and crosses the topographic divide, because its energy comes from the groundwater divide. In contrast, the energy of surface water at the headcut decreases as the divide is approached because of reduced catchment area and possibly reduced surface gradients.

Only the groundwater-flow system has the potential for pre-piracy "communication" between the pirating and pirated stream (Fig. 3). The pirated stream can provide flow and potential energy to the groundwater system. This can further enhance groundwater sapping at the headcut of the extending pirating stream. As the pirating stream advances, the changing groundwater-flow paths (Fig. 3) can cause a loss of flow in the pirated stream, resulting in sediment accumulation in the bed as stream competency decreases. This can in turn lead to an increasing energy gradient in the groundwater-flow system.

A heterogeneous and anisotropic geologic environment would modify the actual groundwater-flow paths, but the overall results would be similar to the homogeneous and isotropic model shown (Fig. 3). Karst development would occur along fractures and higher permeability zones, reflecting the imprint of the groundwater-flow system from recharge to discharge areas. Fractures zones would enlarge and grow in a similar manner.

Because groundwater sapping is a basic geologic process, and energy gradients can exist at all scales, the stream-piracy model presented in this paper should be applicable at all time and size scales. Stream piracy is a possibility on the smallest streams and the largest intermountain drainage basins. Where diversion has occurred, groundwater sapping should be suspected.

This model suggests that higher energy gradients would be expected during wetter climatic periods, and as a consequence, channel extension should be more rapid during these periods. The increased rate of channel extension under wetter climatic conditions is intuitive in part, but by extension, it also means that the actual stream diversion is most likely during wetter climatic periods.

Lane (1899) promoted the role of groundwater sapping in stream piracy. Unfortunately, the visibility of surface water and the lack of understanding of groundwater-flow and groundwater-sapping processes have led to a long advocacy of surface water as the pirating villain. Waterfalls (e.g., Fig. 4; cover photo) on the Island of Hawaii demonstrate that factors other than surface water alone must be at work in knickpoint migration. There is considerable evidence for groundwater sapping in these two localities using criteria discussed in this paper.

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REFERENCES CITED

Alley, R., 2000, The two-mile time machine: Ice cores, abrupt climate change, and our future: Princeton, New Jersey, Princeton University Press, 229 p.

Baker, V., Kochel, R., Laity, J., and Howard, A., 1990, Spring sapping and valley network development, *in* Higgins, C.G., and Coates, D.R., eds., Groundwater geomorphology: The role of subsurface water in earth-surface processes and landforms: Boulder, Colorado, Geological Society of America Special Paper 252, p. 235–265.

Bates, R., 1961, Drainage development, southern Sacramento Mountains, New Mexico: The Ohio Journal of Science, v. 61, no. 2, p. 113–134.

Bishop, P., 1995, Drainage rearrangement by river capture, beheading, and diversion: Progress in Physical Geography, v. 19, p. 449–473.

Butt, T., and Russell, P., 2000, Hydrodynamics and cross-shore sediment transport in the swash zone of natural beaches: A review: Journal of Coastal Research, v. 16, p. 255–268.

Collison, A., 1996, Unsaturated strength and preferential flow as controls on gully head development, *in* Anderson, M., and Brooks, S., eds., Advances in Hillslope Processes: New York, John Wiley & Sons, p. 753–769.

Crosby, I., 1937, Methods of stream piracy: Journal of Geology, v. 45, p. 465–486.

DeVries, J., 1976, The groundwater outcrop-erosion model: Evolution of the stream network in the Netherlands: Journal of Hydrology, v. 29, no. 1-2, p. 43–50.

DeVries, J., 1994, Dynamics of the interface between stream and groundwater systems in lowland areas, with reference to stream net evolution: Journal of Hydrology, v. 155, no. 1-2, p. 39–56.

DeVries, J., 1995, Seasonal expansion and contraction of stream networks in shallow groundwater systems: Journal of Hydrology, v. 170, no. 1-4, p. 15–26.

Dunne, T., 1980, Formation and controls of channel networks: Progress in Physical Geography, v. 4, p. 211–239.

Dunne, T., 1990, Relation of subsurface water to downslope movement and failure, *in* Higgins, C.G., and Coates, D.R., eds., Groundwater geomorphology: The role of subsurface water in earth-surface processes and landforms: Boulder, Colorado, Geological Society of America Special Paper 252, p. 51–76.

Dunne, T., 1998, Critical data requirements for prediction of erosion and sedimentation in mountain drainage basins: Journal of the American Water Resources Association, v. 34, p. 795–808.

Freeze, R.A., 1987, Modeling interrelationships between climate, hydrology, and hydrogeology and the development of slopes, *in* Anderson, M.G., and Richards, K.S., eds., Slope stability: New York, John Wiley & Sons, p. 381–403.

Fyodorova, A., and Sasowsky, I., 1999, Silica dissolution and the development of sandstone caves: Geological Society of America Abstracts with Programs, v. 31, no. 7, p. A51.

Gabbard, D., Huang, C., Norton, L., and Steinhardt, G., 1998, Landscape position, surface hydraulic gradients, and erosion processes: Earth Surface Processes and Landforms, v. 23, p. 83–93.

Gomez, B., and Mullen, V., 1992, An experimental study of a sapped drainage network: Earth Surface Processes and Landforms, v. 17, p. 465–476.

Harrison, S., and Clayton, L., 1970, Effects of groundwater seepage on fluvial processes: Geological Society of America Bulletin, v. 81, p. 1217–1226.

Higgins, C., 1984, Piping and sapping: Development of landforms by groundwater outflow, *in* LaFleur, R.G., ed., Groundwater as a geomorphic agent: The Binghamton Symposia in Geomorphology, International Series 13: Boston, Massachusetts, Allen & Unwin, p. 18–58.

Hötzl, H., 1996, Origin of the Danube-Aach systems: Environmental Geology, v. 27, p. 87–96.

Hovius, N., Stark, C., Tutton, M., and Abbot, L., 1998, Landslide-driven drainage network evolution in a pre-steady-state mountain belt: Finisterre Mountains, Papua, New Guinea: Geology, v. 26, p. 1071–1074.

Howard, A., 1988a, Groundwater sapping on Mars and Earth, *in* Howard, A., et al., eds., Sapping features of the Colorado Plateau: A comparative planetary geology field guide: Washington, D.C., National Aeronautics and Space Administration, p. 1–5.

Howard, A., 1988b, Groundwater sapping experiments and modeling, *in* Howard, A., et al., eds., Sapping features of the Colorado Plateau: A comparative planetary geology field guide: Washington, D.C., National Aeronautics and Space Administration, p. 71–83.

Johnsson, M., 1999, Speleogenesis, stream capture, and geomorphic development as recorded in cave sediments: Preliminary observations from the Swago Creek area, West Virginia: Geological Society of America Abstracts with Programs, v. 31, no. 7, p. A155.

Kochel, R., Simmons, D., and Piper, J., 1988, Groundwater sapping experiments in weakly consolidated layered sediments: A qualitative summary, *in* Howard, A., et al., eds., Sapping features of the Colorado Plateau: A comparative planetary geology field guide: Washington, D.C., National Aeronautics and Space Administration, p. 84–93.

Laity, J., and Malin, A., 1985, Sapping processes and the development of theater-headed valley networks on the Colorado Plateau: Geological Society of America Bulletin, v. 96, p. 203–217.

Lane, A., 1899, A note on a method of stream capture: Geological Society of America Bulletin, v. 10, p. 12–14.

Lawler, D., 1993, Needle ice processes and sediment mobilization on riverbanks: The River Ilston, West Glamorgan, United Kingdom: Journal of Hydrology, v. 150, no. 1, p. 81–114.

Mather, A., Harvey, A., and Stokes, M., 2000, Quantifying long-term changes of alluvial fan systems: Geological Society of America Bulletin, v. 112, p. 1825–1833.

Montgomery, D., and Dietrich, W., 1988, Where do channels begin?: Nature, v. 336, p. 232–234.

Montgomery, D., and Dietrich, W., 1989, Source areas, drainage density, and channel initiation: Water Resources Research, v. 25, p. 1907–1918.

Nash, D., 1996, Groundwater sapping and valley development in the Hackness Hills, North Yorkshire, England: Earth Surface Processes and Landforms, v. 21, p. 781–795.

Netto, A., Fernandes, N., and de-Deus, C., 1988, Gullying in the southeastern Brazilian Plateau, Bananal, SP: International Association of Hydrological Sciences Publication 174, p. 35–42.

Norris, R., and Back, W., 1990, Erosion of sea cliffs by groundwater, *in* Higgins, C.G., and Coates, D.R., eds., Groundwater geomorphology: The role of subsurface water in earth-surface processes and landforms: Boulder, Colorado, Geological Society of America Special Paper 252, p. 283–290.

Pederson, D.T., 1995, Pattern of stream development in the Nebraska Sand Hills and controlling processes [abs.]: EOS (Transactions, American Geophysical Union), v. 76, p. 267.

Pissart, A., Krook, L., and Harmand, D., 1997, The capture of the Aisne and heavy minerals in the alluvium of the Meuse in the Ardennes: Comptes Rendus de l'Academie des Sciences, Serie II, Sciences de la Terre et des Planetes, v. 325, p. 411–417.

Prosser, I., Hughes, A., and Rutherford, I., 2000, Bank erosion of an incised upland channel by subaerial processes: Tasmania, Australia: Earth Surface Processes and Landforms, v. 25, p. 1085–1101.

Ries, J., Merritts, D., Harbor, D., Gardner, T., Erickson, P., and Carlson, M., 1998, Increased rates of fluvial bedrock incision in the Central Appalachian Mountains, Virginia: Geological Society of America Abstracts with Programs, v. 30, no. 7, p. A140.

Roberts, H., 1997, Dynamic changes of the Holocene Mississippi River delta plain: The delta cycle: Journal of Coastal Research, v. 13, p. 605–627.

Roloff, G., Bradford, J., and Scrivner, C., 1981, Gully development in the deep loess hills of central Missouri: Soil Science of America Journal, v. 45, p. 119–123.

Rutherford, I., Prosser, I., and Davis, J., 1997, Simple approaches to predicting rates and extent of gully development, *in* Wang, S.S.Y., et al., eds., Proceedings of the Conference on Management of Landscapes Disturbed by Channel Incision, p. 1125–1130.

Schumm, S., 1980, Some applications of the concept of geomorphic thresholds, *in* Coates, D.R., et al., eds., Thresholds in Geomorphology: London, George Allen & Unwin, p. 473–485.

Troch, P., DeTroch, F., Mancini, M., and Wood, E., 1995, Stream network morphology and storm response in humid catchments: Hydrological Processes, v. 9, p. 575–587.

Vogt, P., 1991, Estuarine stream piracy: Calvert County, U.S. Atlantic Coastal Plain: Geology, v. 19, p. 754–757.

Weissel, J., and Seidl, M., 1997, Influence of rock strength properties on escarpment retreat across passive continental margins: Geological Society of America Bulletin, v. 25, p. 631–634.

Whipple, K., Hancock, G., and Anderson, R., 2000, River incision into bedrock: Mechanics and relative efficacy of plucking, abrasion and cavitation: Geological Society of America Bulletin, v. 112, p. 490–503.

Young, A., and Saunders, I., 1986, Rates of surface processes and denudation, *in* Abrahams, A.D., ed., Hillslope processes: The Binghamton Symposia in Geomorphology, International Series 16: Boston, Massachusetts, Allen & Unwin, p. 3–27.

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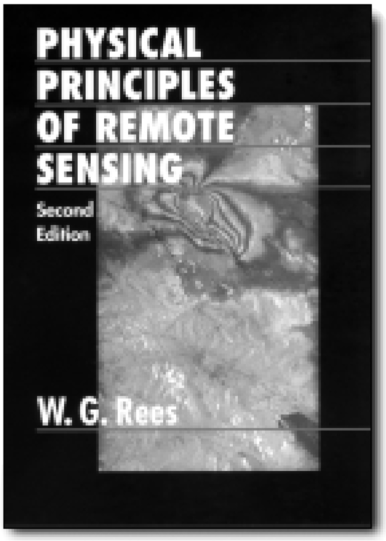

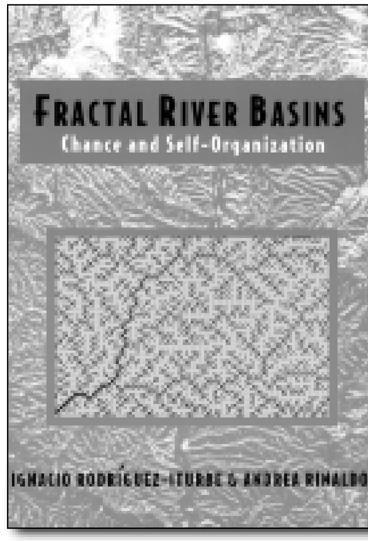

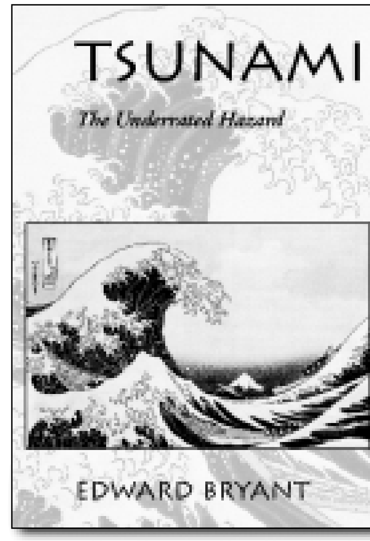

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DIALOGUE

Measuring Success Scientifically:

Earth System Processes Meeting in Edinburgh is a Hit

Sharon Mosher, *GSA President*

"This is one of the best meetings for science I have been to in years!"

"This meeting was really good for science."

Comments like these are music to a program organizer's ears. This meeting was a risky venture for GSA. Co-convened with the Geological Society of London, the meeting focused on an interdisciplinary look at earth systems, and it was GSA's first global meeting. Based on the comments of participants and the quality of the sessions, this meeting was extremely successful scientifically. Quite frankly, it has been years since I have attended a meeting that had such scientific enthusiasm.

The sessions were clearly interdisciplinary and designed so that the linkages among biological, chemical, physical, and geological processes were emphasized. I, along with many attendees, purposely went to sessions where we knew little, just to learn. I know my appreciation of Earth's system and how much we know about how it works has been broadened tremendously. People from different disciplines and from all over the world attended the meeting. It wasn't unusual for someone to preface a question or comment by saying, "I'm a biologist, and…."

Each day started with a plenary address. These speakers set the stage for most of the subsequent sessions with stimulating talks ranging from the geological consequence of evolution to the connection between Earth's deep interior and the evolution of its surface. A few concurrent oral sessions with plenty of discussion followed, and lively poster sessions at the end of each day provided great opportunities for further discussion and mixing. As one person commented, it took a little over a day to learn how to attend this meeting because the structure was so different. But the juxtaposition of topics and expertise was conducive to integrating discoveries of different branches of science.

Sessions had interweaving themes—some concentrated on the complex biological and biochemical processes associated with microorganisms around ridge-related hydrothermal vents and terrestrial hot springs. Such topics spun into sessions exploring the role of the fluid's mineral chemistry on life, the effect of changes in mantle chemistry with time, the physical processes of mineralization around such vents, the origin of life, the effect of life and other factors on early atmosphere evolution, and the possibilities for extraterrestrial life.

Poster session, Earth System Processes.

Another major theme was the carbon cycle, its evolution through time, the effects of trees and other plants, and the anthropogenic effects today. Climate change from "snowball Earth" to modern day, causes and effects of extinctions, and other scientific controversies abounded. The overwhelming theme, however, was the incredible interplay between various processes and the feedback effects within all earth systems.

Media coverage was excellent, highlighting everything from topics that caught the public's imagination to technical articles on fundamental advances in our understanding of various earth processes.

By Thursday, the question being asked of me was whether GSA will do this again. I hope so. I can't wait to see the scientific progress that is made in the next few years. This expanding and important field of earth system science is one that GSA should promote and foster. In addition to advancing the integration of science related to earth processes, this meeting served as a valuable educational experience for all and provided new perspectives on exploration of Earth. I wish all of you could have been there; it was a great experience.

From Loch Ness to Biomedical Research:
Communicating the Science from "Earth System Processes"

Ann Cairns, *GSA Director of Communications*

Media coverage of the Earth System Processes meeting, held June 24–28 in Edinburgh, Scotland, was the most extensive ever associated with a GSA meeting. It was also perhaps the most effective in reaching different audiences with a wide range of topics.

Contrary to conventional wisdom, in media relations we work with more than "dinos and disasters." Guided by GSA's Strategic Plan, and especially by GSA's vision of a broad, unifying scientific society, we look for leading-edge science with a particular eye for integrative science. We also look for topics that appeal to the science-reading public, public policy makers, and other scientists.

Working with Ted Nield, my counterpart at the Geological Society of London, the technical program chairs, numerous session chairs and presenters, and GSA staff writer Kara LeBeau, two comprehensive media advisories and 14 press releases on individual papers were generated.

A Broad Spectrum of Coverage

One subject that received considerable attention was a mathematical model estimating the effect of human-driven deforestation on the Amazon rainforest. According to Bud Alcock of Penn State—Abington, without immediate intervention the rainforest could pass "the point of no return" in 10–15 yr and essentially disappear within 40–50 yr. That's considerably different from the widely held view that the forest is still 75–100 yr away from total deterioration.

Bruce Runnegar, Center for Astrobiology, University of California, Los Angeles, and his colleagues modeled 250 m.y. of solar system dynamics, looking at how gravitational resonance can cause chaos among planets and asteroids. Their suggestion that possible changes in planetary orbits 65 Ma could have destabilized the asteroid belt and sent one plummeting to Earth, causing the K-T boundary event, was widely reported.

Among the many other subjects reported were links between volcanic eruptions and mass extinctions, subglacial volcanoes and the search for water on Mars, Earth's greenhouse gases in the Archean, a possible explanation for how one earthquake can trigger another on a different fault line, and the evolution of trees and their impact on Earth's lithosphere, hydrosphere, atmosphere, and biosphere.

One of the greatest media successes was coverage of a paper by microbial ecologist Anna-Louise Reysenbach of Portland State titled "Gourmet Geochemical 'Primordial Soups' at Hydrothermal Vents Support Novel Thermophilic Chemolithotrophs: Implications for the Evolution of Life on Early Earth." She made the point that determining what life exists in hot springs today is essential in defining what early life on a hot planet was like. This story made its way onto a Web site for biomedical researchers, among other places.

The Loch Ness Media Frenzy

I haven't encountered a GSA member yet—or anyone else, for that matter—who didn't hear about Italian geologist Luigi Piccardi's suggestion of a possible relationship between Nessie sightings and the Great Glen fault.

This fun and engaging topic reached a wide, general audience, but it was more than "infotainment." In his front-page article in the *Boston Globe*, Gareth Cook briefly explained tectonics, fault lines, and seismic activity, and gave examples of geology's relationship to other legends and myths. He followed up with an online chat session.

Perhaps the most amusing example of the story's impact is an incident that took place the afternoon of Luigi's poster presentation. He'd been giving nonstop interviews for two days, so I volunteered to hold down the fort in the Newsroom while Ted took Luigi out for a break before the 4 p.m. poster session.

As Ted tells it, "He and I approached the bar of a nearby drinking den in mid-afternoon. The barman stopped polishing his glass. After a quick glance to a paper lying nearby he said, 'Hey pal, are you the feller who thinks Nessie's all sump'n tae dae wi' earthquakes?' And so instead of resting, Luigi gamely explained it all again to the interested drinkers of Edinburgh, using the excellent graphics in the *Daily Mail* to show them how earthquakes might cause monsters."

Why This Is a Good Thing

In last month's "Dialogue," GSA president Sharon Mosher pointed out that "like most large,well-established scientific societies of our stature," GSA needs to "educate the public, the media, public policy makers, educators, and students about the geosciences." She emphasized that this in no way diminishes GSA's emphasis on science; it simply expands the audience. Earth System Processes, with its wide-ranging scientific content, gave us a wonderful opportunity to do just that.

GSA-GSL Meeting Is the Talk of the Wire

Here are some of the media outlets that reported on the GSA–Geological Society of London Earth System Processes meeting, held June 24–28 in Edinburgh, Scotland.

ABC.com
ABC News (London)
Associated Press
BioMedNet
BBC News Online
BBC Radio Leeds
BBC Radio 4
BBC Radio 5
BBC World News Service
Boston Globe
Capital Press News Agency
Cosmiverse
Daily Telegraph
Deutschlandfunk
Diario El Correro (Bilbao, Spain)
Discovery.com
Estado (Sao Paolo, Brazil)
Folha de Sao Paolo
Honolulu Star-Bulletin
Laboratory Network.com
La Nazione (Firenze, Italia)
London Evening Standard
Nature News Service
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Space.com
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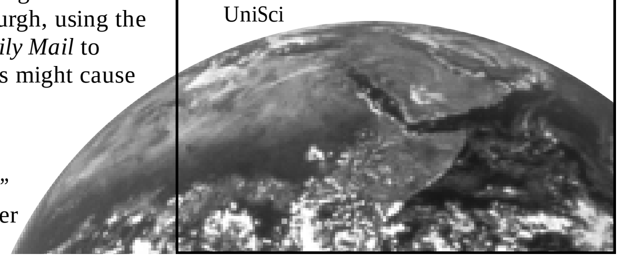
The Times (London)
The Guardian (London)
The Scotsman (Edinburgh)
Time
UniSci



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Boston 2001: A Geo-Odyssey Pardee Keynote Symposia

Invited Papers

This series of keynote symposia, established in 1998, is supported by the Joseph T. Pardee Memorial Fund.

Take a look at this year's lineup of Pardee Symposia. We think you'll agree there's something for everyone. From the micro-world of geobiology and the ultra-small devices used in nanogeology to the sweeping issues of global policies on water and world health and the mind-expanding theories about our planet's seafloor and crust, topics for these Pardee Symposia continue the tradition of presenting leading-edge science.

Monday, Nov. 5

8 a.m.–noon—The Emerging Discipline of Medical Geology (K5)

Institute for Earth Science and the Environment; Armed Forces Institute of Pathology; International Union of Geological Sciences; U.S. Geological Survey; COGENENVIRONMENT; IGCP #454; Swedish Geological Survey; Institute for Metal Biology. Dennis Goldman, Geological Society of America, Boulder, Colo.; José A. Centeno, Armed Forces Institute of Pathology, Washington, D.C.; Peter T. Bobrowsky, International Union of Geological Sciences, Victoria, B.C.; H. Catherine W. Skinner, Yale University, New Haven, Conn.

The emerging discipline of medical geology assesses the effects of static and dynamic earth science factors—natural and anthropogenic—on ecological and human health. Health issues related to earth science factors will likely affect each of us within our lifetime. More geoscientists need to become aware of the field and involved in research. This symposium will bring together geoscientists and medical professionals to increase the awareness of these impacts and the need/potential for research.

1:30–5:30 p.m.—Ophiolites as Problem and Solution in the Evolution of Geological Thinking (K4)

GSA History of Geology Division; GSA Structural Geology and Tectonics Division; International Geology Division; Society of Economic Geologists; History of Earth Sciences Society. Sally Newcomb, retired, Silver Spring, Md.; Yildirim Dilek, Miami University, Oxford, Ohio.

Ophiolites are an important and controversial topic in geology, strongly linked to many earth processes of the seafloor, crust, and mantle. Studies of ophiolites have both reflected and advanced the methods and theories of geology for more than 200 years. This symposium will provide a forum to discuss the history and development of ideas, principles, and theories established in the geological sciences as a result of the investigations of ophiolites and ophiolitic rocks through time.

Tuesday, Nov. 6

8 a.m.–noon—Melt in the Crust and Upper Mantle: How Much, Where, for How Long, and What Significance for Geodynamics? (K2)

GSA Structural Geology and Tectonics Division; Geochemical Society; Mineralogical Society of America. Tracy Rushmer, University of Vermont, Burlington, Vt.; Michael Brown, University of Maryland, College Park, Md.; George Bergantz, University of Washington, Seattle, Wash.; Greg Hirth, Woods Hole Oceanographic Institution, Woods Hole, Mass.

This symposium brings together innovative scientists with backgrounds in petrology, geochemistry, rock properties, and tectonics to consider melt-related processes in the lithosphere. Speakers will address these processes at a variety of length scales, involving established and new techniques to give new insights into the role of melt during orogenesis.

1:30–5:30 p.m.—The Future of Biogeochemistry: A Symposium in Honor of Harold C. Helgeson (K6)

Geochemical Society. Dimitri A. Sverjensky, Johns Hopkins University, Baltimore, Md.; Jan Amend and Everett L. Shock, Washington University, St. Louis, Mo.; Eric H. Oelkers, University of Paul Sabatier, Toulouse, France.

We wish to honor and celebrate Hal Helgeson's achievements in theoretical geochemistry, and particularly his current goals and projects bearing on the origin of petroleum, the biogeochemistry of proteins, and enzymes at high temperatures with this symposium. We hope to draw as many researchers as possible to the exciting research possibilities in areas that cross the boundaries of the geochemical and geological sciences.

Wednesday, Nov. 7

8 a.m.–noon—Water's Many Forms in the Solar System: Implications for Geology, Exploration, and Life (K8)

GSA Planetary Geology Division. Susan E.H. Sakimoto, University of Maryland, Baltimore County, Goddard Earth Science and Technology Center, Greenbelt, Md.; Tracy K.P. Gregg, The University at Buffalo, State University of New York, Buffalo, N.Y.

Our recent discoveries of the role of water in the solar system and our expanding understanding of environmental ranges conducive to life on Earth promise to drive planetary exploration and research in the coming decades. This session explores our current understanding of solar system water, recent solar system discoveries revolutionizing our understanding of the role of water, their implications for environments amenable to life, and our capabilities and motivations for continued exploration.

1:30–5:30 p.m—The Watershed Within: Scientific and Moral Reflections on Water in the 21st Century (K7)

Critical Issues Subcommittee of Geology and Public Policy; GSA Quaternary Geology and Geomorphology Division; Institute for Earth Science and the Environment. George W. Fisher, Johns Hopkins University, Baltimore, Md.

Water use and allocation are critical global policy issues. One-third of the world lives in areas subject to water stress. Discussions of water use must consider availability, human equity, and the needs of both ecosystems and future generations. They require both a scientific understanding of water resources and a moral sense of how stakeholders value water and understand equity. This symposium will explore both the scientific and moral dimensions of global water issues.

Thursday, Nov. 8

8 a.m.–noon—Geobiology: Applications to Sedimentary Geology (K1)

Nora Noffke and Andrew H. Knoll, Harvard University, Cambridge, Mass.

Microorganisms influence sedimentary processes, and the geobiological signatures they impart provide potentially useful tools in reconstructions of paleoclimate and paleoenvironment. This session explores microbial processes in recent sediments and the distribution of geobiological signatures in time and space.

1:30–5:30 p.m.—Nanogeology: The Application of Nanotechnology in Earth Sciences (K3)

Jaakko K. Putkonen, University of Washington, Seattle, Wash.

Emerging nanotechnology allows manufacturing of miniature devices that compute, move, sense their environment, and repair themselves. Potential applications for nanogeology include: ultra-small sensors and devices, including transducers for force, pressure, and chemical compounds; and molecular gears, motors, and actuators. Now is the time to plan for applications and shape the future with groundbreaking innovations.

Join us Monday through Thursday for two Pardee sessions each day.

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Reminder: GSA's Employment Interview Service to be in Boston

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Cole Awards for Postdoctoral Research

Dorothy Sack of Ohio University was awarded the 2001 Gladys W. Cole Memorial Research Award in the amount of $11,500 to support her project, "The Middle Transgressive Phase of Lake Bonneville—A Comprehensive Basinwide Analysis." This award is restricted to support research for the investigation of the geomorphology of semiarid and arid terrains in the United States and Mexico.

The W. Storrs Cole Memorial Research Award, which is restricted to support research in invertebrate micropaleontology, was not awarded in 2001 due to the lack of qualified applications.

Eligibility for both Cole awards is restricted to GSA Members and Fellows between 30 and 65 years of age. The deadline for 2002 awards is February 1, 2002. Watch for more information in *GSA Today* later this year.

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GSA Foundation Update

Donna L. Russell
Director of Operations

Ken Ciriacks Joins the Board of Trustees

Kenneth W. Ciriacks

The GSA Foundation is pleased to announce that Kenneth W. Ciriacks has joined the Board of Trustees.

Ciriacks retired from Amoco Corporation in 1994, where he served as vice-president of technology in the Chicago office. His career with Amoco spanned 32 years, and he held a mix of research and managerial positions both in the United States and in international offices. During his years as an exploration manager, he was in charge of the exploration operations in Egypt, in the African–Middle Eastern region, and in Houston, Texas.

Born in West Bend, Wisconsin, Ciriacks received his bachelor's degree in geology in 1958 from the University of Wisconsin and his Ph.D. in geology in 1962 from Columbia University.

Since retiring, he has continued to be active in professional societies such as the American Geological Institute. He has served on the alumni board for the University of Wisconsin—Madison's Department of Geology and Geophysics, and he received a Distinguished Alumni Award from the department in 1999.

Currently a GSA Fellow, Ciriacks joined the Society in 1962. He served as chairman of the Rocky Mountain Section portion of the Second Century Fund Campaign and is a current member of the Foundation's Development Committee.

Ciriacks and his wife, Linda, have four children. Their hobbies include traveling, hiking, skiing, and activities with the University of Wisconsin—Madison.

Foundation President Lee Suttner commented, "We are delighted to have Ken join the Board. He was one of the most effective fund-raisers for the Second Century Campaign. His record of volunteer service for the geosciences community is exemplary. The wisdom and insight he will bring to the Board, based on his long and distinguished career in industry, will be invaluable."

We are very glad to have Ken on board.

Focus on a Foundation Fund: The John C. Frye Environmental Award

John C. Frye served as executive director of GSA from 1974 to 1982. Before coming to GSA, the majority of Frye's career was spent with state surveys in Kansas and Illinois.

Frye received a Ph.D. from the University of Iowa and worked with the Ground Water Division of the U.S. Geological Survey until 1942. He then joined the Kansas State Geological Survey, where he spent the next 12 years, the last nine as director. He was appointed chief of the Illinois State Geological Survey in 1954, a position he held for the next 20 years. Upon retirement from the survey in 1974, he began a second career as executive director of GSA. He died shortly after his retirement from GSA.

During Frye's tenure at the Illinois Survey, the term environmental geology had its origin. Environmental geology provided a means of focusing public and professional interest on the application of geology to society. He was one of the early proponents of this sector of geology, and the award, supported by the income from this fund, is appropriately entitled the John C. Frye Environmental Geology Award.

The Association of American State Geologists and GSA select an awardee annually for a paper on environmental geology published by a state survey or printed in a GSA publication.

Established in 1983 with contributions from family and friends, the net assets as of May 2001 were $54,263.

Most memorable early geologic experience

At the age 18, a freshman at Mesa Junior College, I helped excavate a brontosaurus in eastern Utah that is now displayed at the Field Museum.

—Leonard W. Heiny

Enclosed is my contribution in the amount of $____________.

Please credit my contribution to the:

- ☐ Unrestricted Fund
- ☐ Other: _________________ Fund

☐ I have named GSA Foundation in my will.

GSA Foundation

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drussell@geosociety.org

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A John F. Mann Mentor Program in Applied Hydrogeology

Environmental Consulting: What to Expect and How to Succeed

***Michael B. Portnoy,** P.G., President and CEO of Portnoy Environmental, Inc., Houston, Texas*

This past spring, Michelle Olive, an independent consultant in Houston, and I presented a Mann Mentor Program in Applied Hydrogeology. Andreas Lüttge, an associate professor of earth science at Rice University, hosted the program, held on the Rice campus. The workshop included discussions about qualifications that prospective employers require; job hunting; activities performed by geologists in the environmental field; working for industry vs. consulting vs. regulatory agencies; the business aspects of consulting (administration, marketing, and "billability" expectations); and career advancement.

Students from Rice University, Texas A&M University, and the University of Texas at Austin attended the workshop and luncheon. It concluded with a field trip to a natural gas compressor station located near Houston. Olive and I discussed issues that could potentially impact such a facility, including those related to air quality, solid waste, mercury, storm water, spills, and general issues related to groundwater, as well as state-specific requirements (e.g., the Texas Risk Reduction program).

Attendees enthusiastically praised the fun and informative presentation. One student remarked that she had come to the workshop to find out more about the environmental field because she wants to work as an environmental geochemist. She commended both the workshop's content and the personalized counseling offered that enabled her to interact with those in the profession and "hear an insider's account of what it's like in the real world."

If programs of this type inspire you to volunteer to serve as a Mann mentor, please contact program officer Karlon Blythe at kblythe@geosociety.org for more information.

GSA Foundation Fund Backs Program

The John F. Mann Mentor Program in Applied Hydrogeology, supported by the John F. Mann Fund for Applied Hydrogeology, provides opportunities for geoscientists to share their professional and personal experiences in applied hydrogeology with undergraduate and graduate students and faculty. Designed to bridge the gap between academic studies and the application of hydrogeology in the service of society, the program's goals are to:

- inform students about, and generate enthusiasm for, the exciting and challenging career opportunities in applied hydrogeology;
- foster relationships between the professional community and local colleges and universities in order to increase student exposure to applied geosciences via course work and/or through research projects; and
- provide guidance for students to help them prepare for careers in applied hydrogeology and create opportunities for students to network with professionals.

For information on contributing to the John F. Mann Fund for Applied Hydrogeology, please contact the GSA Foundation, gsaf@geosociety.org, or (303) 447-2020.

Part 1

The Evolution of GSA:

Our Story so Far

GSA's Strategic Plan, proposed by an 11-member task force convened by Eldridge Moores during his presidency in 1995–1996 and adopted by Council in 1998, set goals and objectives for the organization, defining GSA's mission and vision for the first time.

The plan guides decisions and puts GSA's mission and vision into action. Its goals and objectives assure the quality and value of GSA's service to its members, to the geosciences, and to society. They address both existing programs and embarking on new activities.

Following are examples of projects that stemmed from the plan.

Earth System Processes Meeting

Co-convened with the Geological Society of London (GSL), Earth System Processes in Edinburgh, Scotland, proved a great success. Coverage of the meeting by scientific publications and mainstream media alike was extensive, and meeting-goers were enthusiastic about the science presented. (See "Dialogue," p. 12, and "From Loch Ness to Biomedical Research," p. 13.)

The meeting advanced more than one of GSA's goals. It came about through a cooperative effort with GSL, was supported in part by the NASA Astrobiology Institute, focused on integrative science, and injected vitality into GSA's meetings program.

"The prestige of GSA went up considerably as a result of this meeting," noted Dave Stephenson, GSA's acting executive director and a member of the Strategic Plan task force. "All in all, it was a great start for GSA's global initiative."

GeoCorps America™

Launched in 2000, GeoCorps America™ brought GSA's internship programs into a stronger, larger system to increase the presence of geoscientists on public lands and raise awareness of the geosciences among land managers and the public. This year, the program sent 32 interns to national parks, monuments, and forests. (Read more about GeoCorps America in the December 2000 and August 2001 issues of *GSA Today*, available at www.geosociety.org/pubs/gsatoday/gsatoday.htm.)

Field Forums

Started in 2000, Field Forums are designed after Penrose Conferences but take place in the field. They are characterized by frank, open discussions that are more likely to emerge in informal field settings, and proposals that capture new discoveries or controversial topics are welcomed. To date, three forums have been held with a total of 98 participants. (A new forum is announced on p. 43.)

Subaru Distinguished Earth Science Educator

The Subaru Distinguished Earth Science Educator is selected by GSA and supported by Subaru of America, Inc. This master educator works to strengthen the role of geoscience in education. The first educator, Diana Stordeur, arrived at GSA in the fall of 2000 and spent the year launching the program and creating resources for teachers on the Web. (Go to Education at www.geosociety.org.)

GSA Mission

The mission of GSA is to advance the geosciences, to enhance the professional growth of its members, and to promote the geosciences in the service of humankind.

GSA Vision

GSA will be a broad unifying scientific society

- fostering the human quest for understanding Earth, planets and life;
- catalyzing new scientific ways of thinking about natural systems; and
- applying geoscience knowledge and insight to human needs, aspirations, and stewardship of Earth.

Goals and Objectives

Details of the objectives listed are posted at www.geosociety.org. Go to About Us, then to Goals and Objectives.

Goal 1: To advance the discovery, development, dissemination, and stewardship of geoscience knowledge. Objectives: to maintain the quality and increase the vitality of meetings and conferences; to maintain the quality and increase the vitality of publications; to identify and implement new and more effective ways to communicate science; and to promote innovative research.

Goal 2: To catalyze cooperative interactions among earth, life, planetary, and social scientists who investigate natural systems over varying scales of time and space. Objectives: to build a focus on integrative science into the infrastructure and culture of GSA; to generate cooperative interactions with other organizations; to promote GSA membership participation in integrated research; and to publish and disseminate the results of integrative natural systems investigations.

Goal 3: To promote geoscience in the service of society. Objectives: to actively foster dialogue with the public and decision-makers on relevant geoscience issues; to encourage and support member participation in education and societal outreach; and to strengthen the role of geoscience in formal and informal science education.

Goal 4: To attract and sustain a dynamic and viable membership. Objectives: to increase and ensure the value of GSA to its members; to increase and retain the membership base of the Society; and to increase the cultural, disciplinary, professional, and international diversity of the membership.

Goal 5: To maintain GSA and GSA Foundation as financially viable entities. Objectives: to exercise due diligence in management and expenditure of Society assets; to maintain an active development program ensuring supplemental financial support for GSA programs and activities; and to exercise due diligence in management and expenditure of Foundation assets.

Goal 6: To optimize GSA's governance and organizational structure in fulfillment of GSA's mission. Objectives: to assess and enhance the effectiveness of GSA governance, committees, and headquarters organization; to evaluate and strengthen relations among GSA Divisions, Sections, Associated Societies, and Council; and to promote internationalization of the Society.

Next month:
Part II—Who Are Our Members?

Preliminary Announcement and Call for Papers

NORTHEASTERN SECTION, GSA

37th Annual Meeting • Springfield, Massachusetts • March 25–27, 2002

REGISTRATION

Preregistration deadline: February 15, 2002
Cancellation deadline: February 22, 2002

GSA Headquarters will handle preregistration. Registration details will be in the December 2001 issue of *GSA Today* and at www.geosociety.org. You'll be able to preregister online at www.geosociety.org beginning in the first part of December.

CALL FOR PAPERS

Papers are invited from students and professionals for presentation in oral and poster general sessions and for presentations that may fit into the symposia and theme sessions listed below. Additional general discipline sessions will be scheduled on the basis of submitted abstracts. Oral technical sessions and symposia provide 15 minutes for presentation and five minutes for questions and discussion. All slides must fit a standard 35-mm carousel tray. Two projectors will be provided in each of the technical sessions. Speakers are encouraged to bring their own loaded trays to the meeting. Poster sessions will allow at least three hours of display time.

ABSTRACTS

Abstracts deadline: December 18, 2001

Abstracts for all sessions must be submitted online at the GSA Web site, www.geosociety.org. If you have questions, contact technical program committee chairs, Mark Leckie, mleckie@geo.umass.edu, and Michele Cooke, cooke@geo.umass.edu.

Only one volunteered paper may be presented by an individual; however, a person may be a co-author on other papers. Also, those invited for symposia may present additional papers.

SYMPOSIA

Symposia will include invited papers and selected volunteered papers. Prospective authors are encouraged to contact individual conveners directly. Address requests for general information regarding symposia to Mark Leckie, mleckie@geo.umass.edu, or Michele Cooke, cooke@geo.umass.edu.

1. **Paleozoic Tectonics of the Northern Appalachian Mountains: New Insights and Persistent Problems: First Annual NETectonics Symposium.** Michael L. Williams, mlw@geo.umass.edu, and Scott E. Johnson, johnsons@maine.edu.
2. **Geochemistry of Sedimentary Systems.** Bosiljka Glumac, bglumac@science.smith.edu, and Stephen Burns, sburns@geo.umass.edu. *Cosponsored with SEPM (Society for Sedimentary Geology).*
3. **New Perspectives on the Grenville Orogeny in the United States and Canada: A Symposium in Honor of Jim McLelland.** Art Goldstein, agoldstein@mail.colgate.edu, Bruce Selleck, bselleck@mail.colgate.edu, and William Peck, wpeck@mail.colgate.edu.
4. **Tectonostratigraphy of Ophiolites.** Lirim Hoxha, Geological Research Institute, Albania, lirimhoxha@yahoo.com.
5. **Fracture Hydrogeology in New England: Can it be Deciphered? Challenges, Approaches, and Needs.** Gary Robbins, gary.robbins@uconn.edu.

THEME SESSIONS

Theme sessions will include only volunteered papers. Prospective authors are encouraged to contact individual conveners directly. Address requests for general information regarding theme sessions to Mark Leckie, mleckie@geo.umass.edu, or Michele Cooke, cooke@geo.umass.edu.

1. **Holocene Climate and Lakes.** Mark Abbott, mabbott@geo.umass.edu, and Andrea Lini, alini@zoo.uvm.edu.
2. **New Advances in Sedimentary Processes and Accumulation Forms: From the Shelf to the Estuaries.** Duncan Fitzgerald, dunc@bu.edu.
3. **Rift Basins of the Northeast**. John Hubert, jhubert@geo.umass.edu. *Cosponsored with SEPM (Society for Sedimentary Geology).*
4. **Microbeam Analysis in Geologic Studies: New Techniques and Recent Applications.** Michael J. Jercinovic, mjj@geo.umass.edu, and Michael L. Williams, mlw@geo.umass.edu.
5. **Fractures, Lineaments, and Implications for Fluid Flow.** Michele Cooke, cooke@geo.umass.edu, Bob Jacobi, rdjacobi@acsu.buffalo.edu, Ken Hardcastle, Hardcastle@eggi.com, and Steve Mabee, sbmabee@geo.umass.edu.
6. **Watershed and Wetland Hydrology of the Adirondacks**. Christopher P. Cirmo, cirmoc@cortland.edu, and Edwin Romanowicz, romanoea@plattsburgh.edu.
7. **Environmental Isotopes as Tracers in Water Resources Investigations.** Doug Burns, daburns@usgs.gov, and Bob Newton, rnewton@science.smith.edu.
8. **Assessment of Anthropogenic Impact on Ground- and Surface-Water Quality.** Anna Veeger, veeger@uri.edu, Tom Boving, University of Rhode Island, and Lois K. Ongley, loisongley@earthlink.net.
9. **K–16 Education: Earth and Environmental Science.** Richard Little, Greenfield Community College, RDLITTLE2000@cs.com, and Mark McMenamin, mmcmenam@mhc.mtholyoke.edu.

POSTER SESSION

Undergraduate Research in the Geological Sciences.

SHORT COURSES

For more information on short courses, contact the short course organizer, Chris Condit, ccondit@geo.umass.edu.

1. **Microprobe Monazite Geochronology; Methods, Applications, and Challenges for the Future.** Sun., March 24. Michael L. Williams, mlw@geo.umass.edu, and Michael J. Jercinovic, mjj@geo.umass.edu, University of Massachusetts.
2. **The Construction of Dynamic Digital Maps and Virtual Field Trips.** Sun., March 24. Chris Condit, ccondit@geo.umass.edu, University of Massachusetts.

3. **Geophysical Methods of Prospecting.** Sun., March 24. Frank Revetta, revettfa@potsdam.edu, State University of New York, Potsdam.
4. **Using CARIS: GIS Software with Focus on Producing Geologic Digital Maps.** Sat. and Sun., March 23 and 24 (tentative). Maria L. Crawford, mcrawfor@brynmawr.edu, Bryn Mawr College, and Walter van de Poll, University of New Brunswick.

FIELD TRIPS

Trips planned at this time are listed below and are contingent on the weather. For more information on field trips, contact either of the field trip committee chairs, Michael Williams, mlw@geo.umass.edu, and John Hubert, jhubert@geo.umass.edu.

1. **Mesozoic Deerfield Basin, Massachusetts.** Sun., March 24. John F. Hubert, jhubert@geo.umass.edu; Peter T. Panish; and James A. Dutcher, University of Massachusetts. *Cosponsored by SEPM (Society for Sedimentary Geology).*
2. **Dynamic Events and Processes in the Devonian Catskill Front, Eastern New York**. Sun., March 24. Chuck Ver Straeten, cverstra@mail.nysed.gov, New York State Museum. *Cosponsored by SEPM (Society for Sedimentary Geology).*
3. **A Tectonic-Stratigraphic Examination of the New England Caledonides in West-Central Massachusetts.** Sun., March 24. Peter Robinson, Peter.Robinson@ngu.no, University of Massachusetts and Geological Survey of Norway.

STUDENT TRAVEL AND RESEARCH GRANTS

The Northeastern Section is giving travel grants to students who are presenting papers at the Springfield meeting. The awards are open to both graduate and undergraduate students. To apply, please contact Stephen Pollock, Secretary-Treasurer, GSA Northeastern Section, pollock@usm.maine.edu.

The Northeastern Section also announces the availability of undergraduate research grants. Students in the Northeastern Section who are juniors in the 2001–2002 academic year are eligible to apply for a research grant. For an application, e-mail Stephen Pollock, pollock@usm.maine.edu. The deadline for completed applications is January 25, 2002.

EXHIBITS

Exhibits will be located in the Sheraton Convention Center in Springfield, Mass. Snacks and refreshments will be available for exhibitor visitors. For information on exhibit rates and space reservations, contact Sheila Seaman, Department of Geosciences, University of Massachusetts, Amherst, MA 01003-9297, sjs@geo.umass.edu.

DETAILED INFORMATION

For further information, see www.geosociety.org, contact General Chair Sheila Seaman, Department of Geosciences, University of Massachusetts, Amherst, MA 01003-9297, sjs@geo.umass.edu, or contact one of the technical program chairs, also at the University of Massachusetts: Mark Leckie, mleckie@geo.umass.edu, or Michele Cooke, cooke@geo.umass.edu.

2002 GSA Section Meetings

CALL FOR PAPERS

NORTHEASTERN SECTION

See page 22 for Call for Papers

SOUTHEASTERN AND NORTH-CENTRAL SECTIONS

April 3–5, 2002, Hyatt Regency Hotel and Lexington Civic Center, Lexington, KY.
Information: John D. Kiefer, kiefer@kgs.mm.uky.edu, or James C. Cobb, cobb@kgs.mm.uky.edu, Kentucky Geological Survey.

Abstract deadline: December 19, 2001

SOUTH-CENTRAL SECTION

April 11–12, 2002, Sul Ross State University Center, Alpine, TX.
Information: Kevin Urbanczyk, Sul Ross State University, kevinu@sulross.edu.

Abstract deadline: December 27, 2001

ROCKY MOUNTAIN SECTION

May 7–8, 2002, Southern Utah University Campus, Cedar City, UT.
Information: Robert Eves, Southern Utah University, eves@suu.edu.

Abstract deadline: February 4, 2002

CORDILLERAN SECTION

May 13–15, 2002, Oregon State University, Corvallis, OR.
Information: Robert S. Yeats, yeatsr@geo.orst.edu.

Abstract deadline: February 7, 2002

NORTHEASTERN SECTION

Kenneth N. Weaver Student Grant Program

Student Travel Grants for Boston 2001

The GSA Northeastern Section's student travel grants program is available for graduate and undergraduate students.

To be considered for a travel grant:

- The student must be a student associate or member of GSA.
- The student must be enrolled at an institution in the Northeastern Section.
- The student must be presenting at the Boston meeting, November 5–8, 2001.
- The grant must be used for travel expenses to the Boston meeting.
- APPLICATIONS MUST BE RECEIVED BY 5:00 P.M., SEPTEMBER 28, 2001.
- Awardees will be notified by October 5, 2001.

Please visit www.geosociety.org to download the application form.

For further information, please contact:

Stephen G. Pollock, Secretary, NEGSA, Department of Geosciences, University of Southern Maine, Gorham, ME 04038-1091
(207) 780-5353, TTY (207) 780-5646, Fax 207-228-8361
pollock@usm.maine.edu

ROCK STARS

J. Tuzo Wilson

***Derek York**, Physics Department, University of Toronto*

Tuzo Wilson lived for ideas, and those he created were weird and wonderful. Many were wrong, but some were marvelously right. And, until his death in 1993, he never stopped creating ideas.

The Early Years

He was the first child, born on October 24, 1908, in Ottawa, to the former Henrietta Tuzo and John Armistead Wilson. His mother's name, Tuzo, came from her father's distant Angevin Huguenot ancestors, who landed in Virginia in the seventeenth century. Henrietta was a remarkable and adventurous woman who loved mountaineering. Mount Tuzo in western Canada was named after her because she and Christian Bohre were the first to scale its peak. She had met her future husband, John Wilson, while attending the camp of the Alpine Club of Canada near Banff in Alberta. John, a Scottish engineer, was to play an important role in the development of civil aviation in Canada. Thus, a love of the outdoor life and world travel was instilled in their son, John Tuzo Wilson.

When Tuzo was 17, he had the good fortune to become field assistant to the famous Everest mountaineer Noell Odell who, recalled Tuzo, "showed me the wonders of field geology." Tuzo enrolled in physics at the University of Toronto, but he soon switched to a double major in physics and geology, and in 1930, he considered himself to be Canada's first-ever graduate in geophysics.

A scholarship then took Tuzo to Cambridge University, ostensibly for graduate work in geophysics. However, he quickly found that the university had no clearly organized department, and, after being baffled by Harold Jeffreys' high-powered mathematical lectures, he decided to take an assortment of lectures in geology and physics that appealed to him, and he completed a second B.A. degree.

This was followed by a stint at the Geological Survey of Canada (GSC), where Tuzo worked on Sudbury rocks with the GSC's director, W.H. Collins. Collins, presumably responding to Tuzo's tremendous drive and ability, recommended that he take a Ph.D. in geology at a leading university in the United States. Tuzo was accepted at Harvard and MIT but chose to enroll at Princeton because "it offered the most money, and because Professor R.M. Field said that he hoped to start teaching geophysics there." At Princeton, Tuzo met future giants Harry Hess, Maurice Ewing (visiting from Lehigh), and George Woollard, but Field "failed to bring anyone to Princeton to teach us geophysics." So the young Canadian completed his Ph.D. at Princeton by carrying out geological mapping in the Beartooth Mountains under the nominal supervision of Professor Taylor Thom. During this thesis work, he made the first recorded climb of Mount Hague, shining as his mother had in the mountains.

With the outbreak of World War II, Tuzo left the job he'd had at the GSC since graduating from Princeton and joined the Canadian Army as an engineer. He spent four years overseas before returning to Canada as a colonel and director of operational research. In this capacity, he organized Exercise Musk Ox, which he described in 1982 as "the first and still the most extensive motorized expedition ever to cross the Canadian Arctic."

Following his demobilization, Tuzo was appointed professor of geophysics at the University of Toronto in 1946. In the next 14 years, he built a considerable reputation, clarifying the structures of the Canadian Shield with the help of the newly flowering field of geochronology. Here, he applied ideas initially derived locally, perhaps, to Earth at large. He pointed out that the age divisions he could see in the Canadian Shield were probably features of all the major shields of Earth. He wrote about continental growth, and not merely for the North American continent. He adopted Jeffreys' theory of mountain building on a contracting Earth and rejected the idea of continental drift. By the late 1950s, Tuzo was famous but also controversial—something of a maverick and a promoter of ideas, some said, that made them uncomfortable. Not only that, the contraction hypothesis he promoted so strongly was turning out to be inadequate.

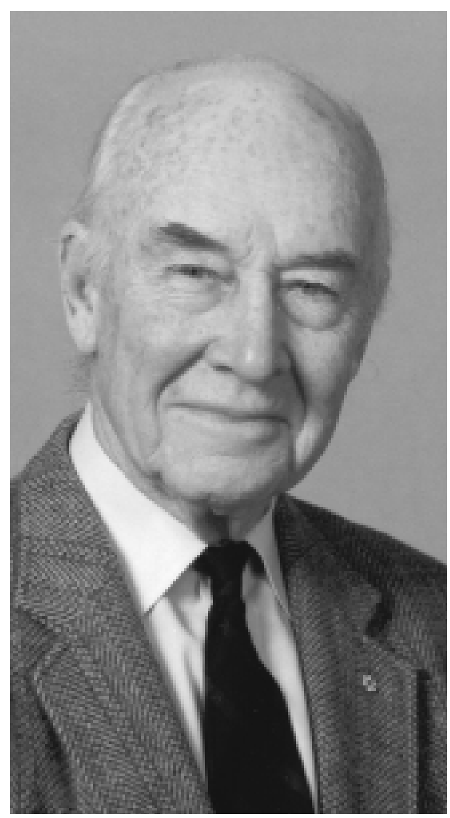
The Climactic Years

It was at the University of Toronto that Tuzo reacted brilliantly by admitting to himself that he was wrong about a contracting Earth and by wondering if Dietz, Hess, Irving, and others might be right about continental drift. And remarkably quickly, at an age (about 50) when very few scientists have come up with great ideas, Tuzo recognized that Earth was a highly mobile place. Years of global, large-scale thinking had prepared him to take geology forward in a dramatic fashion.

Tuzo's mind had a fascinating way of solving problems. Unlike most physicists, who find their solutions via mathematics, Tuzo solved problems almost entirely with visual images and then presented the solutions in extremely clear prose. He had a remarkable ability to look into the heart of extreme complexity and see simplicity itself. The nearest mind that I can think of to compare with Tuzo's was that of Michael Faraday who, instead of integrating differential equations to calculate the electric field, imagined a charged particle to be an octopus with tentacle-like lines of force reaching out into the space around it.

To solve the problem of the origin of the Hawaiian Islands, for example, Tuzo imagined someone lying on his back on the bottom of a shallow stream, blowing bubbles to the surface through a straw. The bursting bubbles were the Hawaiian Islands, and they lay in a line because they were swept along the surface by the moving stream. Thirty years later, leading geophysical theorists use supercomputers to solve horrendous equations that Tuzo "solved" in the visualizing region of his brain.

Tuzo's great paper describing this, "A Possible Origin of the Hawaiian Islands,"



J. Tuzo Wilson in his 80s.
Photo courtesy of Delroy Curling.

was rejected by the leading American geophysical journal in 1963 on the grounds that it was completely at variance with the latest seismic studies of the region. Undeterred, he sent it to the Canadian Journal of Physics, where it was immediately published because, I suspect, the editors didn't know what else to do with anything so devoid of mathematics.

His second great, yet simple, idea was that of transform faults. Again, Tuzo's approach was visual and non-numerical. And yet it was devastatingly definitive in what it predicted. It did not give us an equation, such as $E=mc^2$, or say that the magnetic field near a wire is proportional to the current flowing through it. Tuzo's transform fault concept said to earth scientists that they were living in a looking-glass world. For earthquakes occurring underwater and in the middles of oceans, he predicted that the rocks everybody believed had moved right to left during the earthquake had moved left to right, and vice versa. This was a wonderful geometric test for the existence of continental drift and plate tectonics. If the rocks moved as Tuzo said, continental drift was a racing certainty. If they didn't, Earth was a far more static place. Wilson capped his transform fault paper (1965) with a stunning synthesis of what we now know as plate tectonics.

In 1967, Lynn Sykes of the Lamont Geological Observatory examined the motion of rocks in 10 earthquakes on two mid-ocean ridges and found Tuzo's predictions were correct in every case. His announcement of this went a long way in convincing people that continental drift had not only occurred in the past 200 m.y., but was going on under our feet today, at the rate at which our toenails are growing.

Interestingly, in his very last paper, which appears not to have been published, he merges his beautiful Hawaiian plume idea with geophysical exploration. He gave the preprint to me in late 1992, just before I was to leave Toronto for six months. In his irrepressible style, Tuzo entitled it, "On Migrating Mountains and a Revolution in Earth Sciences."

Among many other ideas, he pointed out in the paper an association between bonanza gold deposits in the United States and rising plumes, which he claimed underlay the continent. The manuscript I have is incomplete, but in the very sentence where it halts is contained the quintessence of Tuzo Wilson: the word "ideas." Said he, "These great faults may or may not have plumes associated with them, but the *ideas* gained in Nevada suggest that even without plumes, large faults may provide channels bringing ores from far greater depths of origin than has been previously considered." He had stamped December 4, 1992, on the manuscript, and in his familiar script had written "Thanks, Derek! Tuzo. Nearly done now!" Four months later, I received in Capetown a message that on April 15, 1993, he had died of a heart attack.

Extraordinarily powerful—mentally and physically—to the end, Tuzo had in later years been happy and successful as principal of Erindale College at the University of Toronto, where he and his wife, Isabel, entertained thousands of students and visitors. After stepping down from this position, he was, at 65, appointed director-general of the internationally renowned Ontario Science Centre, a position in which he reveled, with his magnetic personality and gift for popularization.

Further Reading

Garland, G.D., 1995, John Tuzo Wilson: Biographical memoirs of Fellows of the Royal Society, v. 41, p. 535–552.

Wilson, J. T., 1982, Early days in university physics: Annual Review of Earth and Planetary Sciences, v. 10, p. 1–14.

Wilson, J.T., 1963, A possible origin of the Hawaiian Islands: Canadian Journal of Physics, v. 41, p. 863–870.

Wilson, J.T., 1965, A new class of faults and their bearing on continental drift: Nature, v. 207, p. 343–347.

Wilson, J.T., 1966, Did the Atlantic close and then re-open?: Nature, v. 211, p. 676–681.

"Rock Stars" is produced by the GSA History of Geology Division. Editorial Committee: Michelle Aldrich, Robert Dott, Robert Ginsburg, Gerald Middleton (editor of this profile).

J. Tuzo Wilson in his early 60s, sailing his Chinese junk on Georgian Bay. Photo courtesy of Susan Wilson.

J. Tuzo Wilson in preparation for the International Geophysical Year in 1957, examining a gravimeter with Jack Jacobs and Ron Farquhar. Photo by MacLeod-Gilbert A. Milne & Co.

GSA Names 2001 Research Grant Recipients

The GSA Committee on Research Grants met in Boulder, Colorado, on April 20, 2001, and awarded $421,460 to 224 graduate students. Committee members for 2001 are James G. Schmitt (chair), Dennis R. Kolata, Daniel K. Holm, Rodney V. Metcalf, John F. Bratton, Ward E. Sanford, Marith Cady Reheis, Barbara E. John, John A. Breyer, Bruce E. Broster, Janet S. Herman, Aiyun Zhang, Wanda J. Taylor, Claudia C. Johnson, Carol M. Tang, and Anne Raymond.

In 2001, the evaluation committee was doubled from eight to 16 members because of the number of applications received in 2000. While only eight committee members traveled to the meeting in Boulder, each was paired with another member and the teams reviewed applications together. Another change for 2001 was the requirement that grant applicants be GSA members. The response was consistent with that of previous years, even with this new requirement. As in previous years, the committee was pleased with the high quality of the research proposals submitted to the GSA Research Grants Program.

Student Awards

GSA received 583 student proposals, and 224 (39%) were awarded grants. Of these recipients, 133 were doctoral candidates and 91 were master's degree candidates. Proposal requests totaled $1,432,367 with an average of $2,457 per proposal. The average award was $1,882.

Seventeen alternate candidates were selected by the committee in the event that any grantees return all or part of their funds due to a change in their research project or receipt of funds from another source.

The committee's total budget was $421,460. The National Science Foundation's portion of the budget was $130,000, and the GSA Foundation's portion was $121,360, which included $43,000 from the Research Fund, $55,385 from the GEOSTAR and Unrestricted Funds, $3,900 from the Lipman Research Fund, and $2,600 from the Hydrogeology Division. The budget also included $132,550 from the Penrose Endowment and the Pardee Memorial, and $7,550 from the Harold T. Stearns Award Fund, the Geophysics Division, the Sedimentary Geology Division, and the Structural Geology and Tectonics Division.

Recipients of student research grants awarded by GSA Divisions and Sections will be announced in the October issue of *GSA Today*.

Outstanding Mention

The committee especially recognized the following 23 students for submitting proposals of exceptionally high merit in conception and presentation.

Eric Leland Bilderback, Western Washington University, for "Chronology, Paleoclimatic Significance, and Erosive Behavior of Small Cirque Paleoglaciers, Enchantments Lakes Basin, Washington."

Jason P. Briner, University of Colorado, for "Ice Limits or Subglacial Processes—Towards Solving a Long-Standing Controversy using Cosmogenic Nuclides."

Monica Carroll, Virginia Polytechnic Institute and State University, for "Analyzing the Environmental Record Contained in Freshwater Mussels: Applying Paleontology to Conservation Biology."

Jason A. Crosswhite, University of Oregon, for "Seismic and Gravity Analyses in the Vicinity of the Cheyenne Belt: Seeking the Origin for a Long-Lived Root."

Sarah B. Das, Pennsylvania State University, for "Towards Improved Paleoclimate Reconstructions from Ice Cores: Analyses of Stable Oxygen and Hydrogen Isotope Ratios of Snow and Firn Samples from West Antarctic Automatic Weather Station Sites."

Katrina E. Gobetz, University of Kansas, for "Evolution and Ecology of Extinct, Horned Rodents."

Julie C. Kickham, Utah State University, for "Temporal and Kinematic Evolution of Intrabasinal Extensional Folds in Grasshopper Basin, Southwest Montana."

Terri Lacourse, Simon Fraser University, for "Late Quaternary Paleoecology of the Queen Charlotte Islands, Vancouver Island, and the Adjacent Continental Shelf, British Columbia, and its Archaeological Implications."

Janna Melissa Levin, University of Virginia, for "The Mobilization and Transport of Colloids and Contaminants."

Dave Lewis, University of Alberta, for "Field Studies in Support of Mass Balance Modeling for High Arctic Glaciers and Ice Caps."

Ted Lewis, University of Massachusetts, Amherst, for "Spatial and Temporal Changes in Processes of Sediment Delivery and Distribution at Lake Tuborg, Ellesmere Island."

Joanne M. Livingston, University of Calgary, for "Reconstructing the Late Holocene (Last 5000 Yr) Ice-Jam Flood History of the Upper Yukon River."

Carrie Morrill, University of Arizona, for "Lake Level Fluctuations of Ahung Co, Tibet, and Implications for Century-Scale Variability of the Asian Monsoon."

Stephen A. Nathan, University of Massachusetts, for "Ontong Java Plateau: A Key to the Development of the Western Pacific Warm Pool During the Late Miocene."

Philip M. Novack-Gottshall, Duke University, for "Ecological Structure and Evolution of Middle Paleozoic (Silurian-Devonian), Offshore, Soft Substrate Assemblages."

Daniel Obrist, University of Nevada, Reno, for "Influence of Fire and Subsequent Cheatgrass Invasion on the Spatial and Temporal Distribution of Soil Water in the Rooting Zone of a Sagebrush Ecosystem."

Jeff Pigati, University of Arizona, Tucson, for "Evaluation of ^{14}C Inventory of Small, Living Land Snails from Southern Nevada."

Geoffrey S. Pignotta, University of Southern California, for "Testing Emplacement Models and Magma Chamber Evolution in the Jackass Lakes Pluton, Central Sierra Nevada."

Veronica Stouffer, University of Georgia, for "Pluton Emplacement Processes and

Syn-Plutonic Wall-Rock Deformation in the Bloody Run Hills, Northern Nevada."

Kenton Trubee, The University of Akron, for "Ostracodes as Paleoenvironmental Proxy Indicators: Characterizing the Variability of Nonmarine Ostracode Faunas on San Salvador Island, Bahamas."

Nathaniel Warner, Miami University, for "Groundwater Contamination in Nepal: A Regional Comparison and Assessment of Controlling Site Characteristics."

Christopher M. Wurster, Syracuse University, for "Can Stable Carbon Isotope Values from Bat Guano Be Used in the Examination of Precipitation and Vegetation Changes in Arid Mexico?"

Christopher K. Zahm, Colorado School of Mines, for "Predicting Deformation from 3-Dimensional Geometry of Ductile Lithofacies, Thermopolis Anticline, Wyoming."

Student Recipients of Special Awards in 2001

The **Gretchen Louise Blechschmidt Award Fund** was established for women in the geological sciences who have an interest in achieving a Ph.D. in the fields of biostratigraphy and/or paleoceanography, sequence stratigraphy analysis, particularly in conjunction with research in deep-sea sedimentology, and a career in academic research. The 2001 recipient is Terri Lacourse, Simon Fraser University, for "Late Quaternary Paleoecology of the Queen Charlotte Islands, Vancouver Island, and the Adjacent Continental Shelf, British Columbia, and its Archaeological Implications."

The **John T. Dillon Alaska Research Award** honors the memory of Dillon, who was particularly noted for his radiometric age-dating work in the Brooks Range, Alaska. Two areas that serve as guidelines for selection of the awardee are field-based studies dealing with the structural and tectonic development of Alaska, and studies which include some aspect of geochronology (either paleontologic or radiometric) to provide new age control for significant rock units in Alaska. The recipient is David Frederick Sunderlin, University of Chicago, for "Permian Tectonics and Paleobotany of the Farewell Terrane in Denali National Park, Alaska."

The **Robert K. Fahnestock Award** honors the memory of Fahnestock, a former member of the Research Grants Committee, who died as an indirect result of service on the committee. The grant is awarded for the best proposal in sediment transport or related aspects of fluvial geomorphology, Fahnestock's field. The 2001 recipient is Martin W. Doyle, Purdue University, for "Mechanisms, Rates, and Magnitudes of Channel Adjustment Following Catastrophic Disturbances."

The **Lipman Research Fund**, established in 1993 and supported by gifts from the Howard and Jean Lipman Foundation, promotes and supports student research grants in volcanology and petrology. The president of the Lipman Foundation, Peter W. Lipman, was the recipient of a GSA research grant in 1965. This year, the committee presented the award to two candidates: Darin Snyder, Miami University, for "Magma Chamber Processes and Time Scales: An Isotopic Investigation of the Agua de Pao Volcano, Sao Miguel, Azores," and Jose Luis Arce, Universidad Nacional Autónoma de México, for "Eruptive Dynamics and Possible Triggering Mechanisms During the Last Major Plinian Eruption at Nevada de Toluca Volcano, Central Mexico."

The **Bruce L. "Biff" Reed Scholarship Fund** was established to provide research grants to graduate students pursuing studies primarily in the tectonic and magmatic evolution of Alaska, but it also can fund other geologic research. The 2001 recipient is Andrew R. Greene, Western Washington University, for "Evolution of the Mid-Crustal Level of an Intraoceanic Island Arc: Talkeetna Island Arc, South Central Alaska."

Family members of Alexander Sisson established the **Alexander Sisson Research Award** in his memory to promote and support research for students pursuing studies in Alaska and the Caribbean. The recipient of the award this year is Carolyn E. Garrison-Laney, Virginia Polytechnic Institute and State University, for "Diatom Evidence for Earthquake-Induced Relative Sea-Level Change, Copper River Delta, Southeastern Alaska."

Harold T. Stearns established the **Harold T. Stearns Fellowship Award** in 1973 for student research on aspects of the geology of the Pacific Islands and the circum-pacific region. This year, the committee presented the award to two candidates: Amy M. Gaffney, University of Washington, for "A Geochemical Investigation of the Role of Recycled Oceanic Crust in Hawaiian Magmatism," and Stephen A. Nathan, University of Massachusetts, for "Ontong Java Plateau: A Key to the Development of the Western Pacific Warm Pool During the Late Miocene."

The **John Montagne Fund** was established in 2000 to support one recipient's research in the field of Quaternary geology and/or geomorphology. The 2001 recipient is Jason P. Briner, University of Colorado, for "Ice Limits or Subglacial Processes—Towards Solving a Long-Standing Controversy using Cosmogenic Nuclides."

Other Applicants Recommended for Funding

Markus Albertz
Matthew Allen
Helge Alsleben
Lisa Amati
Matthew Anders
Michael Apfelbaum
Irene Arango
Charles Ardoin
James Ashby
Rich Barclay
German Bayona
Aiguo Bian
Sarah Boon
Jeremy Boyce
Matthew Brueseke
Robert Buchwaldt
Jason Burt
Eric Cannon
Eric Carson
Alexandre Castrounis
Joyia Chakungal
Alice Chang
Krista Chomicki
Cory Clechenko
Mary Cooke
Howard Cyre
Kevin Davis
Maya Del Margo
Weiquan Dong
Daniel Douglass
Amy Draut
Scott Dufrane
Mirela Dumitrescu
Gita Dunhill
Michael Dunn
Tina Edwards
Joe Elkins
William Elliott
Julie Esdale
Thomas Fenstemaker

Research Grant Recipients *continued on p. 28*

Research Grant Recipients *continued from p. 27*

Colin Ferguson
Manuel Filgueira-Rivera
Richard Fink
Mara Finkelstein
Barbara Fletcher
Mike Formolo
Michael Fortwengler
Karen Frey
Benjamin Fruchey
Joel Gagnon
William Garcia
Stephanie Gaswirth
Christopher Gerbi
Jean-Philippe Gobeil
Allen Gontz
David Goodwin
Mark Goodwin
Karen Gran
James Grant
Robert Graves
Seth Haines
Jenney Hall
Brian Hampton
François Hardy
Melanie Hartman
Trent Hayden
Wayne Henderson
Rebecca Heumann
Nancy Hilbun
Emma Hill
Tessa Hill
Emily Himmelstoss
Heidi Hoffower
Kimberly Hoke
John Hora
Jennifer Horwath
Christopher Houck
Brenda Hunda
Tran Huynh
Adrienne Johnson
Benjamin Johnson
Priyanka Johri
Patricia Jones
James Kaste
Young-Woo Kil
Kelly Knudson
John Kollmeier
Andrew Kozlowski
Joseph Krieg
Sanghoon Kwon
Daniel Lao Davila
Thomas Lapen
Joanna Latham
Jerome-Etienne Lesemann
Amy Lesen
Mark Lesh
Elizabeth Leslie
Viktoras Liogys
James MacDonald
Daniel Mackie
Risa Madoff
Jacqueline Mann
Jonathan Marcot
Aaron Martin
James McCaughey
Jennifer McClung
Michelle McGee
Alistair McGowan
Lindsay McHenry
Patrick McLaughlin
Karen Michelsen
Alexei Milkov
Drew Mirante
Brandi Molitor
Kelley Moore
Kyle Murray
Roshni Narayan
Seth Newsome
Chris Okubo
Cornel Olariu
Gordon Osinski
Eungyu Park
Jonathan Payne
Janna Peevler
Elizabeth Pendleton
Rebecca Perlroth
Gary Petro
Michael Petronis
Julie Pett-Ridge
Jennifer Pierce
Pratigya Polissar
Michael Potter
Steven Quane
Mark Quigley
Jeffrey Rahl
David Ray
Scott Rayburg
Joanna Redwine
Sergio Restrepo
Brook Riley
Bethany Rinard
Mark Rits
Michelle Roberts
Elizabeth Robertson
Alexander Robinson
David Rodland
Joseph Rogers
Chrysten Root
Michael Rygel
Derek Ryter
Morgan Salisbury
Rajeev Sasidharan Nair
Katherine Scharer
Jeffrey Schroeder
Patrick Schuneman
Suanna Selby
Jocelyn Sessa
Timothy Shanahan
Mingjuan Shi
Todd Shipman
Renee-Luce Simard
Christopher Simpson
Jacqueline Smith
Krister Smith
Kurt Steffen
Matthew Strine
Caroline Stromberg
Christy Suh
Mark Sweeney
Neil Tabor
Jing Tao
Andrew Taylor
Tatia Taylor
Kathryn Thomas
Douglas Tinkham
Eric Tohver
Alexandru Tomescu
Livio Tornabene
Amanda Tyson
Dorothy Vesper
Brigitte Vlaswinkel
Marilyn Vogel
Kristi Wallace
Steve Wathen
Cynthia Werner
Karah Wertz
Gina Wesley
Paul White
Mary Kate Wimberly
Timothy Wineland
Thomas Wynn
Grant Yip
Aubrey Zerkle
Susan Zimmerman

ENVISION YOURSELF IN A GSA DIVISION PART 1

Archaeological Geology, Coal Geology, Engineering Geology, Geobiology and Geomicrobiology, Geophysics, Geoscience Education, History of Geology, Hydrogeology, International, Planetary Geology, Quaternary Geology and Geomorphology, Sedimentary Geology, and Structural Geology and Tectonics—the 13 GSA Divisions provide a forum for communication among scientists with linked interests by:

- *sponsoring symposia, field trips, short courses, teacher workshops, and other events at GSA Annual Meetings and in other venues;*
- *supporting student research and participation in professional meetings;*
- *recognizing scientific achievement and service in their various disciplines; and*
- *communicating through newsletters and Web sites that share information and provide a forum for discussion of interests and issues.*

When you join a GSA Division, you enter a community of scientists and educators who represent a wide range of experience and thought, and who share many of your professional and scientific interests, concerns, and priorities. Through sponsorship of meeting events and their facilitation of dialogue among members, GSA Divisions are helping to shape policy and practice within GSA and beyond.

Consider becoming a member of a GSA Division. This issue features six of the Divisions, and a future issue will feature the remaining seven, including the new Geobiology and Geomicrobiology Division. For more information, please visit the Division Web sites through www.geosociety.org/sectdiv/divisions.htm or at the individual sites in the following descriptions.

Archaeological Geology Division

Paul Goldberg, *Chair*
paulberg@bu.edu

The Archaeological Geology Division fosters research along the suture between archaeology and geology. Geological approaches from a wide spectrum of specialties (e.g., sedimentology, geomorphology, geophysics, geochemistry) are fair game in order to solve problems of interest to either or both communities.

The Division membership is geographically and topically diverse, as a recent poll of our membership, with about 10% of members responding, indicated.

- Most members are faculty or students, although about a quarter of the respondents are independent consultants.
- Most people work in North America, although many carry out projects in Europe, Central America, South America, West Asia, and Africa.
- The majority of members are occupied with late Pleistocene and Holocene time, but late Tertiary and early and middle Pleistocene time slices are also well represented. In North America, Paleo-Indian and Archaic periods are studied most often, although later periods are prominent as well. In the Old World, Paleolithic through Historic (e.g., Iron Age) periods are about equally represented.
- Most of the research appears to involve the study of landscapes and paleoenvironmental conditions, including geomorphology, stratigraphy, soils, and site formation. Less widespread, but still prominent, are the applications of geophysics (e.g., exploration, archaeomagnetism, magnetic susceptibility) and chronometric dating. The analysis of materials (e.g., metals and ceramics) by microscopy and chemical analyses constitutes a distinct, although less numerous, group of research specialties.

Statistics aside, archaeological geology is just plain exciting. Working out the geological context and paleoenvironments of early hominids in the Georgian Republic, as C. Reid Ferring is doing, is both challenging and exhilarating. The same is true of my own research into the use of fire at Zhoukoudian Cave, China, the home of Peking Man. In the United States, researchers such as Vance Holliday, Art Bettis, and Rolfe Mandel are using a broad array of techniques to assess Quaternary landscapes and environments. The list is endless, but the Division members' activities illustrate the point that there are no technical or geographic limits on the ways in which geology can be applied to the study of archaeological sites.

Our Division's increasing membership reflects a clear rise in interest in archaeological geology. We enthusiastically invite *you* to become our newest member.

Coal Geology Division

Thomas D. Demchuk*, Secretary*
thomas.d.demchuk@usa.conoco.com

The members of the Coal Geology Division are a diverse group, specializing in fields such as petrology, sedimentology and stratigraphy, structural geology, hydrogeology, geochemistry, paleontology, and environmental geology. The Division traces its origins to 1945, when it was created as a special subcommittee of the Society of Economic Geologists. In 1948, the group sponsored its first formal meeting at the New York GSA Annual Meeting, and in 1955, it became a formal division of GSA. The Coal Geology Division has been an integral part of GSA's program ever since.

Over the past few years, the Coal Geology Division has concentrated much of its attention on coalbed methane exploration, mining and extraction, resource evaluation, and the advancement of clean coal utilization. The year 2001 may mark a significant change for the Division as we debate a change in name. In order to recognize the Division's recent scientific emphases, a change to Energy Geology Division has been proposed. The new name continues to recognize the importance of coal to the energy needs of our countries but also welcomes GSA members who are employed in other sectors of the energy industry. With the addition of new members and their diverse research interests, the Division would grow not only in size but in breadth, and it would eventually include a wide range of geological topics linked by the central theme of energy. This change must be approved by a majority of the Division's membership, and early polls indicate that the membership is evenly split on the issue.

Another significant change within the Division is in the expanded scope of the

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Antoinette Lierman Medlin Scholarship. The scholarship provides support to undergraduate and graduate students involved in coal science research. Two scholarships are available: One supports laboratory study and the other supports field research. The scholarship will be expanded to support students attending Coal Geology Division–sponsored field trips and short courses held at GSA Annual Meetings. In addition, the Division will continue to present the Gilbert H. Cady Award to members who have made outstanding contributions to coal science during their careers.

Finally, the Division's Web site has a new home, www.isgs.uiuc.edu/coalsec/GSA, where you can check out the past, present, and future activities of our exciting Division. Please visit us there; we invite you to join us as a member of the Coal Geology Division.

Planetary Geology Division

Eric B. Grosfils, *Secretary-Treasurer*
egrosfils@pomona.edu

Geology is more than just earth science to the members of GSA's Planetary Geology Division. The Division's goals are: to stimulate communication, facilitate learning, and promote student research across the full range of planetary-geology topics; to recognize outstanding contributions to the field; and to advise and assist the members of GSA in matters pertaining to planetary geology. A series of yearly activities helps meet these goals. These activities include:

- the Stephen T. Dwornik awards, given annually to the best student presentations—both oral and poster—given by U.S. citizens at the Lunar and Planetary Science Conference;
- the G.K. Gilbert Award, given annually to an individual who has made exceptional contributions to the solution of fundamental problems in planetary geology;
- providing support for student research related to craters, cratering, and related phenomena through the Eugene M. Shoemaker Impact Cratering Award;
- awarding the Best Student Paper in Planetary Sciences annually in recognition of an outstanding paper published in English by a student first author in a peer-reviewed scientific journal (a joint award with the Meteoritical Society);
- workshops at GSA Annual Meetings for K–12 educators, bringing current planetary topics to those who can best energize the youngest generation of planetary explorers;
- theme sessions and symposia on planetary topics, including the upcoming Pardee Keynote Symposium, "Water's Many Forms in the Solar System: Implications for Geology, Exploration, and Life," at the 2001 GSA Annual Meeting;
- promoting field trips to sites of interest to Planetary Geology Division members, often in association with the GSA Annual Meeting; and
- distribution of recent, relevant planetary educational materials, as well as other planetary goodies, at the Division booth in the Exhibit Hall of the GSA Annual Meeting.

For more information, please see the Division's Web site. We encourage and invite you to become a member of the far-reaching Planetary Geology Division.

Quaternary Geology and Geomorphology Division

R. Craig Kochel, *Chair*
kochel@bucknell.edu

The Quaternary Geology and Geomorphology Division is GSA's second largest division. Remarkable in its rich diversity and new directions of research, the Division encompasses a spectrum of scientists who specialize in the study of Earth's surface processes and the Quaternary record. Interdisciplinary studies, within geology and beyond, are the norm in this field in such research areas as: paleoclimate; the physics of sediment, ice, and water movement; glacial deposits and erosion; rivers and hillslopes; geologic hazards; hydrology; and tectonics, weathering, and even processes and landforms on the surfaces of other planets. Quaternary scientists are also uniquely suited to make enormous contributions toward the success of charting the future environmental quality of Earth and to help influence policies concerning landscape use, design, engineering, and water-related issues of sustainability.

Much of our exciting work is highlighted at the GSA Annual Meeting in special theme and technical sessions, as well as at our annual Division awards ceremony and reception—and you are invited.

The Division's award program promotes research and recognizes excellence in Quaternary geology and geomorphology. Through our generous endowment, we offer significant awards for research, writing, and career achievement each year and honor students with awards to help further their graduate school aspirations. Two awards assist our students: the J. Hoover Mackin Research Grant for Ph.D. research and the Arthur D. Howard Grant for M.S. research. The Distinguished Career Award recognizes demonstrated excellence and contributions to Quaternary geology and geomorphology.

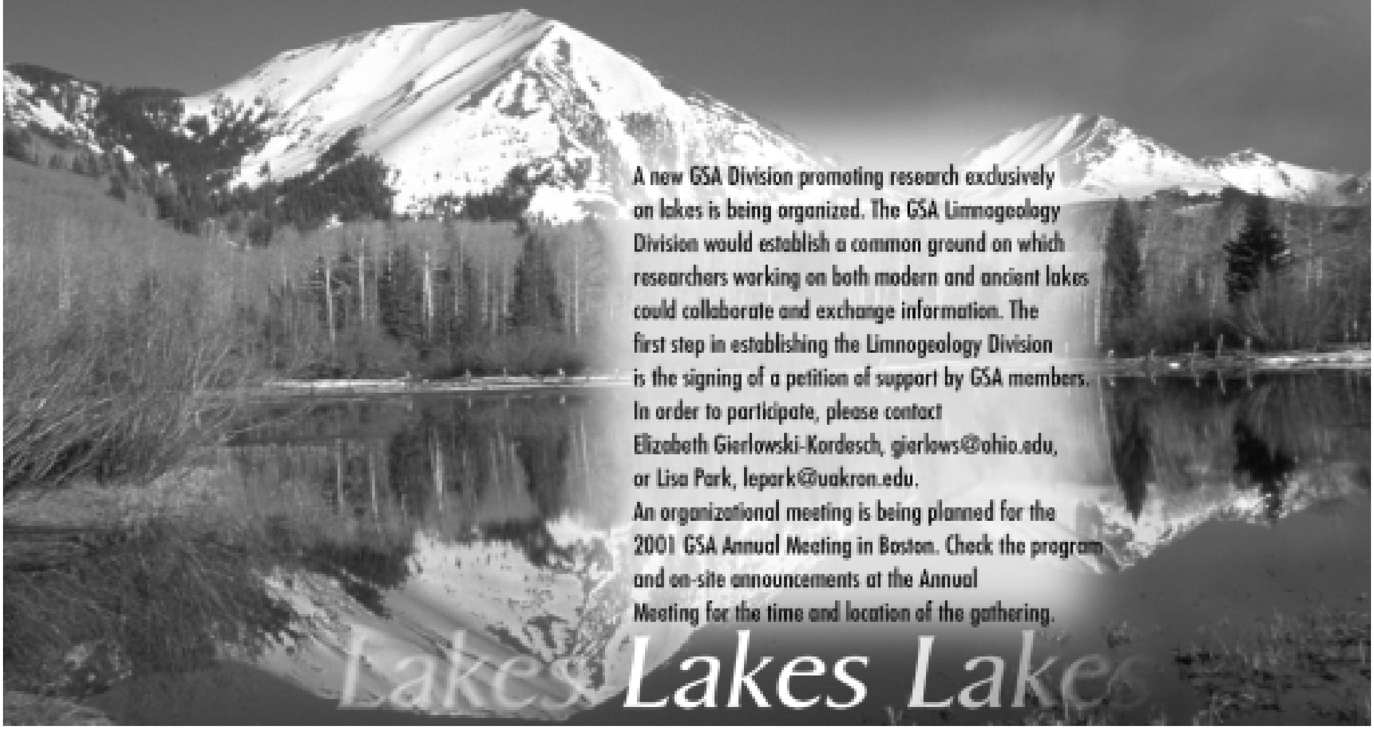
The Quaternary Geology and Geomorphology Division also selects recipients for two GSA awards: The Kirk Bryan Award recognizes a recently published paper of distinction that advances the science of geomorphology, and the Gladys W. Cole Memorial Research Award, which supports research on semiarid and arid terrains. Our newest awards are the Farouk El-Baz Award for Desert Research and the Don J. Easterbrook Distinguished Scientist Award. The El-Baz Award, now in its third year, recognizes outstanding research contributions in the study of desert regions. The Easterbrook Award honors an unusually excellent body of published research in Quaternary geology and geomorphology and includes an opportunity for the winner to apply for a grant to further their work. Watch for special, highlighted addresses from each of the Division's winners at the GSA Annual Meeting.

You are cordially invited to join the excitement as a member of the Quaternary Geology and Geomorphology Division. We are always eager for new members, and we extend a special invitation to students. Learn more about the Division at www.geog.ukans.edu/Quatgeo/.

Sedimentary Geology Division

Raymond V. Ingersoll, *Chair*
ringer@ess.ucla.edu

Our members' enthusiastic participation and creativity are responsible for the vitality and energy of the Sedimentary Geology Division, the fourth largest of GSA's 13 divisions. The Sedimentary



Geology Division exists to bring together the diverse group of GSA members who are interested in the broad field of sedimentary geology. It does this by sponsoring events at the GSA Annual Meeting as well as by building a sense of community through a gathering at the meeting, a newsletter, and a Web site. Students enter this community through the workshop subsidies, field trips, and an annual Student Research Award offered by the Division.

The Division instituted the Laurence L. Sloss Award for Sedimentary Geology in 1999. Our first three awardees, Bill Dickinson, George Klein, and Bob Dott, represent years of scientific achievement and service to GSA. The 2001 Sloss Award and the Student Research Award will be presented at the Division Business Meeting and Awards Ceremony at the GSA Annual Meeting in Boston.

The most important development for the Division last year and continuing this year is the merging of interests and activities of the Division with GSA's Associated Society, SEPM (Society for Sedimentary Geology). The Division and SEPM have agreed to invite each other's officers to attend their governing board meetings and to encourage cooperation wherever possible. The most obvious modes of cooperation are to cosponsor sessions, short courses, and field trips at meetings, and to encourage members (especially students) to join both societies. A large percentage of Division members are already SEPM members, so working together is a win-win situation.

Sedimentary geology has always been an integral part of GSA. As the field changes and grows, the Sedimentary Geology Division will strive to support the efforts of all its members, especially students. We invite you to visit us on our Web site and to become a member of our exciting Division.

Structural Geology and Tectonics Division

Peter Vrolijk, *Secretary-Treasurer*
peter.j.vrolijk@exxon.sprint.com

The Structural Geology and Tectonics Division is the largest of GSA's 13 topical Divisions. Its members are students and professionals in industry, government, consulting, academia, and K–12 teaching. The Division's purpose is to provide an environment where scientists with interests in structural geology and tectonics can find discussions, news, and information related to their fields. To further this goal, the Division sponsors professional activities that foster interest in structural geology and tectonics; works to improve communication among researchers, teachers, and students within the discipline; and takes action to support the interests and concerns of its members. The Division is strengthening its links with our European colleagues by contributing to the International Association of Structural Geologists and by cosponsoring meetings with the Tectonic Specialist Group in the United Kingdom.

At the GSA Annual Meeting, in addition to holding business and award meetings and a reception, we sponsor theme sessions, symposia, field trips, and short courses on subjects of interest to Division members. The Division supports students through subsidies for attending Division-sponsored field trips and short courses. Twice a year, the Division publishes a newsletter that includes information on members, awards, and upcoming meetings and activities, as well as updates on opportunities for research sponsorship through the National Science Foundation. The Division's Web site, www.geology.uiuc.edu/SGTDiv/, also outlines Division activities and announces upcoming meetings.

Every year, several awards are given to recognize individuals who have made notable contributions to the field. The Division gives the Career Contribution Award to a distinguished geologist who has had a major impact in structural geology and/or tectonics over many years. We also offer a Best Paper Award to highlight recent contributions in print and two student research awards to recognize exciting research in progress by graduate students.

The Division strives to provide an arena in which its members can raise issues, both technical and political, discuss solutions, and take action if appropriate. At www.geology.uiuc.edu/SGTDiv/SGTwhitepaper98.html, you can read a copy of a 1998 policy paper sponsored by the Division to counteract decreasing federal funding for the discipline. More recently, the Division has promoted discussion about the consolidation of technical publishers and its impact on the high cost of technical journals. This discussion continues as solutions, some of which may involve Division action, are sought. We cordially invite *you* to become a member of our dynamic Division.

THE PENROSE CONFERENCE

Penrose Conference Report

THE IAPETUS OCEAN

Conveners

Ian W. D. Dalziel, *University of Texas Institute for Geophysics, Austin, Texas, USA*

Ricardo Astini, *Estratigrafía y Geologia Historic, Universidad Naciónál de Córdoba, Córdoba, Argentina*

Douglas J. Fettes, *British Geological Survey, Edinburgh, Scotland*

Anthony L. Harris, *Dept. of Earth Sciences, University of Liverpool, Liverpool, U.K.*

September 16–21, 2000
Edinburgh, Scotland

In the earliest application of plate tectonics to the pre-Pangea Earth, J. Tuzo Wilson proposed in 1966 that a "proto-Atlantic" ocean opened between the present eastern margin of Laurentia and the present western margins of Baltica and northern Africa. Posing the question "Did the Atlantic Ocean open, close, and reopen?" he proposed that the Paleozoic Appalachian and Caledonian mountain chains formed when this ocean closed, in much the same way as the Himalayas resulted from the India-Asia collision in the Cenozoic (Wilson, 1966). This process of ocean opening and closing has become known as the Wilson Cycle. Harland and Gayer (1972) proposed that the name Iapetus Ocean be used rather than proto-Atlantic because the early Paleozoic ocean is distinct from the present Atlantic Ocean although is in part bordered by the same continental masses. Iapetus was the mythological father of Atlantis. Because Laurentia, Baltica, and the Gondwana supercontinent (the latter newly amalgamated in the latest Precambrian–Early Cambrian) constituted a large proportion of the cratonic entities of early Paleozoic time, the Iapetus Ocean plays a dominant role in understanding paleogeography and the global paleoenvironment of the critical Precambrian-Cambrian transition in Earth history as well as the early Paleozoic times.

Wilson (1966) specifically proposed that the proto-Atlantic or Iapetus Ocean opened within a supercontinent and closed to juxtapose the proto–Appalachian-Caledonian margin of Laurentia with Baltica and present-day northern Africa as the late Paleozoic–earliest Mesozoic Pangea supercontinent. Thus, from the late 1960s to the 1990s, all paleogeographic maps for latest Precambrian to earliest Paleozoic times show these margins directly opposed. This requires a wide (~5000 km) Iapetus Ocean between Laurentia and northwest Africa in Ordovician times when the area of the present Sahara Desert was undergoing glaciation in high southern latitudes. Over the past decade, however, attempts to reconstruct the late Precambrian supercontinent Rodinia (from the interior of which Laurentia appears to have "broken-out" with the development of ~14000 km of rifted margins [Bond et al., 1984]), have resulted in suggestions that the present Pacific and Atlantic margins of Laurentia were respectively juxtaposed with the Pacific margin of East Antarctica–Australia and the Pacific margin of the Amazonia and Rio del la Plata cratons of South America. This has led to an alternative, paleogeologically acceptable paleogeography for the Iapetus Ocean: namely, that it was a narrow ocean between the Laurentian and the proto-Andean margin of South America until Silurian times (for review, see Dalziel, 1997). The strongest evidence for some form of tectonic interaction between Laurentia and the proto-Andean margin of Gondwana in early Paleozoic times is the presence of the Precordilleran terrane in northern Argentina. This is now widely accepted as a Laurentian fragment, most likely derived from the area of the southern Appalachians-Ouachita embayment (for review, see Dalziel et al., 1996).

These new ideas significantly widened the list of possible Iapetus-facing cratonic margins in the early Paleozoic, and it was therefore proposed to convene a Penrose Conference to re-examine the birth, life, and death of this ancient ocean basin in the Wilson Cycle type. Scotland was part of Laurentia until the opening of the present North Atlantic in early Cenozoic times separated it from North America. It was located at the tip of a major Laurentian promontory between the proto-Appalachian and proto-Caledonian margins and hence in a paleogeographically critical position at the time of Iapetus' opening. Therefore, Edinburgh, Scotland's capital city, was chosen as the venue for the meeting, held at the new Dynamic Earth exhibition and conference facility directly below Salisbury Crags, which are formed of a Carboniferous teschenite sill. It was the contact relations of the Salisbury Crag sill that James Hutton used to demonstrate the intrusive nature of basaltic magma. The 64 participants traveled to Edinburgh from 10 countries, including not only the traditional borderlands of Iapetus such as Europe and America, but also Argentina, Mexico, and Australia. The meeting at Dynamic Earth was preceded by a field trip across the Scottish promontory, from the outcrops in northwest Scotland of the Hebridean shield, a fragment of Laurentia left behind in northwest Europe when the North Atlantic Ocean Basin opened in early Cenozoic times, and through the Neoproterozoic-Cambrian Moine and Dalradian successions (possible rift-related sequences on the Laurentian margin). John Mendum, British Geological Survey, Edinburgh, led the field trip.

In the first session of the conference, Ian Dalziel, University of Texas at Austin, welcomed participants, outlined the scientific background to the conference, and introduced Brian Harland, Cambridge University. Harland, as "father of Iapetus," presented the topic of the meeting from the perspective of his unique knowledge of the critical Svalbard Archipelago in the far north Atlantic Ocean Basin.

The second session was on the cratonic setting of the Iapetus Ocean basin. It was moderated by Rob van der Voo, University of Michigan, and introduced by Dalziel, who pointed out the difference between the traditional Wilsonian view of the paleogeographic setting of Iapetus opening and the alternative view as set out above. It appeared that most participants were ready to accept the non-Wilsonian views that the Grenvillian margin of Laurentia was opposed to the Andean margin of South America prior to the opening of Iapetus. However, Staci Loewy, University of Texas at Austin, presented new geochronologic and stable isotopic data that strongly refute the suggestion of Dalziel

(1997) that the Arequipa Massif of southern Peru is a displaced fragment of Laurentia left behind by the opening of Iapetus in much the same way as Scotland was separated from North America by the much later opening of the North Atlantic. While the concepts of a late Precambrian supercontinent of Rodinia (ca. 1 000–800 Ma), or Rodinia plus Panotia (ca. 550 Ma) are still attractive, their exact configuration is likely to remain the subject of debate for some time.

The next session was devoted to discussions about the rift-to-drift transition of the Iapetus Ocean. It was moderated by Ricardo Astini, Universidad Nacionál de Córdoba, and introduced by van der Voo. Here, a real enigma became apparent in that the sheetlike shelf-carbonate sequence preserved all along the Appalachian margin of Laurentia was initiated in the late Early Cambrian and is thereby inferred to date the beginning of drift, whereas paleomagnetic results for the Early Cambrian seem to indicate that drift was well under way and had started in the latest Vendian at ca. 550 Ma. While the ages and locations of the paleomagnetic data are not always precise, they indicate that the separation between South American (as part of Gondwana) and North American seems to have been quite advanced by late Early Cambrian time.

The rift-drift session was rather complex and lengthy, covering various aspects of the Laurentian margin from present north to south and then moving around western Gondwana and Baltica counterclockwise. The extensive passive-margin–sedimentary sequences that developed along eastern Laurentia have no clear counterpart in any other present day continental mass. It seems quite clear that two superimposed effects were involved in the stratigraphic development of most of the platform sections along eastern Laurentia, including the Scottish promontory and the Argentine Precordillera, now attached to different continental masses. Even today, this is the only clear—indeed defining—side of Iapetus. The suggested Gondwanan as well as the Baltic conjugate margins have unfortunately been obscured during their more recent histories. Some of these margins have been disrupted from originally rifted terranes and are now situated on the Laurentian side as Gondwanan suspect terranes in North America, or as terranes of uncertain provenance but exotic to Laurentia. Neoproterozoic extension and associated east-facing rifting is thought to have controlled the deposition of the Torridonian, Moine, and at least the earliest stages of the deposition of the Neoproterozoic–Early Cambrian Dalradian Supergroup in Scotland. Extension has also been suggested as having given rise to mafic and acid magmatism and pre-Caledonian (ca. 750 Ma) orogenesis in the Moine Supergroup, while extensional syndepositional faults are thought to have been the precursor of ductile thrusts in the Dalradian.

A broad subsidence signature like that previously recognized by Bond et al. (1984), slightly modified to cope with the present-day time-scale refinements, clearly shows that slightly diachronous thermotectonic subsidence was driving accommodation along the eastern Laurentian platforms from north to south. Time variations in rift-related magmatism and synrift facies development seem to reflect some irregularities on the margin, which may be related to the nature and asymmetries of the rifting process in different segments. As it is known for the Atlantic opening, rifting of an ocean does not need to be synchronous. However, it has been suggested that the Iapetus opened in a very short time span in a rather simplistic way. Apparently, a major eustatic event associated with the triggering of carbonate deposition along the Laurentian margin is the main reason for arguing in favor of the passive-margin development. Recent work in the southern Appalachians suggests, however, that carbonate sedimentation obscures the real stage of development of a margin by strongly reflecting the direct climatic influence. While Laurentia moved into low latitudes soon after breakup, triggering carbonate sedimentation, the conjugate margins were out of the carbonate depositional environment. Thus, the effect of any real variations along the Laurentian passive margin, as suggested by different timing of magmatism and variable thickness of synrift facies, may have been obscured. It is quite clear that a major feedback between plate tectonics, climate changes, and biogeochemical evolution have existed and have probably resulted in the striking similarities observed all along the Laurentian margin. However, very little is known from suggested conjugate margin(s) in any reconstruction.

Recent work in the southern Appalachians suggests, however, that carbonate sedimentation obscures the real stage of development of a margin by strongly reflecting the direct climatic influence.

Late Brasiliano amalgamation of southern South America (ca. 540 Ma) precludes the possibility that this continent had been completely amalgamated before the suggested breakup of the Vendian (Pannotia) supercontinent. Moreover, unequivocal paleomagnetic constraints on the different masses involved in South America are not available and the timing of rift-drift transition for South American margins cannot be determined because of the scarcity of proven passive margin successions. In this context, the Puncoviscana Formation from northwest Argentina is a critical unit because it is possibly a rift-related clastic wedge. However, strong deformation, metamorphism, and poor age constraints inhibit confident inferences as to its subsidence and tectonic significance.

Unfortunately, drifting paths are very difficult to prove from paleomagnetism and paleoclimatological viewpoints, unless evidently crossing paleolatitudes. This was the case for most of the Iapetus traffic jam of terranes. A very promising approach was, however, outlined by Chris Barnes, University of Victoria, based on the conodont record.

Stig Bergström, Ohio State University, moderated the session on Iapetus' paleoenvironment and biota. In his introductory presentation, Bergström reviewed pitfalls and possibilities in using fossils for paleogeographic reconstructions. The short larval stages of many shallow-water benthic marine organisms such as brachiopods, corals, trilobites, ostracods, and bryozoans preclude normal distribution across water bodies of oceanic dimensions. Hence, faunal distribution patterns can be used for broad estimates of the changing width of such oceans and provide constraints on the longitudinal positions of plates, which are not available from paleomagnetism. Bergström also discussed the changing early Paleozoic biogeography in the Iapetus region and its relation to the evolution of Iapetus and various paleoenvironments and oceanic circulation patterns, and he reviewed the significance of exciting new Nd and ^{13}C studies on the interpretation of the missing of water masses. Using paleoecologic, biogeographic, and geochemical indications, mainly from conodonts, Barnes gave a multifaceted review of Ordovician and early Silurian paleoenvironments along the eastern margin of Laurentia. In the final presentation of the session, Astini discussed the Cambrian and Ordovician depositional environments in the Argentine Precordillera and noted similarities to—and differences from—those in the southern United States, presumably the original home of the Precordilleran Terrane. The session was wrapped up by Barnes, who stressed the necessity of integrating all geologic and geophysical data—including those from paleoenvironments and biota—to reach reliable results in our attempts to clarify the evolution of Iapetus.

The arc-terrane collision session was the longest of the conference, and was as diverse as it was lengthy. Moderated by Robert Hatcher, University of Tennessee, discussion ranged from early (Penobscot-Grampian) arcs in the Caledonides and Appalachians to the generation of Oaxacia along the eastern Laurentian margin and to the arc accreted to Gondwana during the Middle-to-Late Ordovician Ocloyic orogeny in Argentina. The topic was introduced by Nicholas Ratcliff, U.S. Geological Survey, Paul Ryan, University of Ireland, Galway, and Augusto Rapalini, Universidad de Buenos Aires.

During the discussion, it became evident that a major event related to arc generation occurred throughout the Appalachians and Caledonides at 470–505 Ma. Geochemical evidence presented by Peter Clift and Amy Draut, both from Woods Hole Oceanographic Institution, suggested that the Laurentian crust was clearly involved after 485 Ma. Other evidence suggests that arc development was still going on at 460 Ma throughout the orogen. Several participants suggested that the earliest subduction zone related to arc generation and accretion along the Laurentian margin was east dipping in the Appalachians and the British and Irish Caledonides. John Dewey, University of Oxford and University of California at Davis, and Cees Van Staal, Geological Survey of Canada, suggested that, following arc accretion, the subduction zone flipped and became west dipping in the Late Ordovician–Early Silurian. In this scenario, the accretion of Avalonia to Laurentia (including the British Isles) and the closing of Iapetus occurred at this time. Avalonia(-Carolina) formed by arc development close to Gondwana at 730–660 Ma and again diachronously from 590 to 540 Ma.

The Cambrian-Ordovician arc accretion model that involves east-dipping subduction off Laurentia had to involve the closing of a small ocean along this boundary throughout the Appalachians and British Caledonides if the closing of Iapetus involved accretion of Avalon and Carolina to Laurentia. It may be that the events that occurred outboard of the margin are more complex and diachronous than previously thought and that the elements caught up in the orogen between Avalon and Laurentia are the products of local geometric and kinematic variations along the orogen. Dalziel argued that the near synchroneity of arc collision times from the British Isles to the Famatinian arc in Gondwana would be more likely in a narrow Iapetus Ocean basin.

Evidence for the collision of an island arc with the Laurentian margin in the Llanvirn gave rise to probably short-lived orogenesis in Connemara in the west of Ireland. This was probably coeval with Grampian contractional orogenesis (480–465 Ma) affecting the Dalradian and at least some of the Moine rocks in Scotland, where, however, the youngest rocks known to have been involved are topmost Lower Cambrian. Possibly the arc impinged during the initial stages of closure, having originally developed on the continental crust that now underlies the Scottish Midland Valley. Sensitive high-resolution ion microprobe (SHRIMP) ages on deformed granites in the central Highlands of Scotland of 590 Ma are now interpreted as implying that they were entirely pretectonic, rather than syntectonic, as formerly believed. Ages of 596 Ma from volcanics within the Dalradian suggest very slow deposition of the 4–5 km of the Southern Highland Group Dalradian sediments that intervene between these volcanics and the fossiliferous Early Cambrian strata. Martin Smith, British Geological Survey, Edinburgh, demonstrated the existence of a major discontinuity in the central Highlands, where the British Geological Survey has mapped overlapping units within the Grampian and Appin Group strata, with younger rocks coming to rest on high-grade metasediments. The latter have yielded ages of ca. 750 Ma, possibly equivalent to the Moine, the main outcrop of which lies in the northern Highlands of Scotland where the Late Archean–lower Proterozoic Lewisian gneisses form its basement. The thrust-related deformation in the northern Highlands that overprinted the structures and fabrics formed during the earlier ?extensional Neoproterozoic and Grampian deformation and metamorphism is probably Scandian. Thrusting was directed towards the west-northwest and the early thrust planes were subsequently folded as younger, lower thrusts locked and shortening continued in their hanging wall. The posttectonic Newer granites of the Scottish Highlands (425–390 Ma) mark the death of Iapetus on the Scottish promontory of Laurentia; they are commonly associated with renewed extension in the area and some may have directly fed Late Silurian–Early Devonian extrusives.

The final session of the conference involved, appropriately, the "final closure" of Iapetus. The discussion was moderated by Jack Soper, University of Sheffield, and introduced by Dewey. Critical evidence on the timing of orogenic death appears to come from northeast Greenland, where Jane Gilotti, University of Iowa, has determined that eclogites range from 440 to 400 Ma, though younger eclogites may have been modified by Carboniferous events. Eclogites in Norway are dated at 410–400 Ma and contain garnet, kyanite, amphibole, and coesite. They lie below an extensional surface on which Devonian rocks rest. The implications are that 40–60 km of strata were tectonically excised.

In conclusion, there can be no doubt that 35 years after J. Tuzo Wilson introduced the concept of an early Paleozoic proto-Atlantic ocean basin that we now refer to as Iapetus, and despite enormous advances in knowledge within individual continents, its global significance is still surrounded by uncertainty. Early in the conference, a participant from Scandinavia was overheard asking one from Argentina just why he was attending a meeting on a distinctly North American topic. By the end of the meeting, all participants were embracing the need to consider evidence from North Greenland and northern Scandinavia to the Ouachita embayment and the southern cone of South America. Apart from the need for a broad, indeed, global geographic view, the need for an interdisciplinary approach was also apparent. Understanding Iapetus in early Paleozoic time remains a critical step in understanding the evolution of the entire Earth system, from Archean times to the present.

Acknowledgments

Support for participation in the conference was provided by the Tectonics Program of the National Science Foundation and by IGCP 440, a project aimed at reconstructing the late Precambrian supercontinent, Rodinia. Funds and support for logistics and communications were provided by the Institute for Geophysics, University of Texas at Austin, and by the British Geological Survey, Edinburgh. The British Geological Survey also organized the field trip.

The conveners would particularly like to thank Lois Elms of Western Experience, Longmont, Colorado, who arranged the meeting with her customary attention to detail. This acknowledgment is especially appropriate, as this was Elms' final

conference prior to retirement after 30 years of involvement with GSA's Penrose Conference program. Special thanks are also due to the moderators of the various sessions.

The participants were saddened to learn, early in the conference, of the passing of Brian Sturt of the Norwegian Geological Survey, who had registered as a participant and contributor. Sturt had devoted his career to furthering the understanding of the margins of Iapetus in the Scottish promontory of Laurentia and in Baltica.

Just at press time, the conveners learned of the sudden and untimely death of Chris Powell, who played a major role in the Penrose Conference, not least with his insights regarding the global setting of the Iapetus Ocean in time and space. His passing will be a notable loss to the international community in its efforts to unravel the major paleogeographic problems identified at the conference.

Participants

Torgeir B. Andersen
Ricardo A. Astini
Christopher R. Barnes
German A. Bayona
Stig M. Bergström
Robert Bourrouilh
Caroline Elaine Burt
Peter A. Cawood
David Chew
Peter Clift
Dan Condon
John Dewey
Ian Dalziel
Amy Draut
Douglas Fettes
Michael Flowerdew
Jane A. Gilotti
Brian Harland
Anthony Harris
Robert D. Hatcher Jr.
David Healy
J. Christopher Hepburn
James (Jim) Hibbard
A.K. (Tony) Higgins
D.H.W. Hutton
Feiko Kalsbeek
Duncan Keppie
Graham Leslie
Staci Loewy
Conall Mac Niocaill
Maria Mange
Roberto Martino
Joseph Meert
John Mendum
Phil McCausland
Sam Mukasa
Brendan Murphy
Richard Damian Nance
Grahame Oliver
Stephen Parry
Christopher McA. Powell
Siobhan Power
Tony Prave
Victor A. Ramos
Augusto Rapalini
Nicholas Rast
Nick Ratcliffe
Paul Ryan
Fred Schwab
James Sears
Martin Smith
Paul Smith
N.J. Soper
W.E. Stephens
Philip Stone
Craig Storey
Keene Swett
P.W.G. (Geoff) Tanner
Stephen Temperley
William A. Thomas
Trond Torsvik
Rob Van der Voo
Cees van Staal
John W.F. Waldron

References Cited

Bond, G.C., Nickeson, P.A., and Kominz, M.A., 1984, Breakup of a supercontinent between 625 Ma and 555 Ma: New evidence and implications for continental histories: Earth and Planetary Science Letters, v. 70, p. 325–345.

Dalziel, I.W.D., 1997, Neoproterozoic-Paleozoic geography and tectonics: Review, hypothesis, environmental speculation: Geological Society of America Bulletin, v. 108, p. 16–42.

Dalziel, I.W.D., Dalla Salda, L.H., Cingolani, C., and Palmer, A.R., 1996, Penrose Conference Report, The Argentine Precordillera: A Laurentian Terrane?: GSA Today, v. 6, no. 2, p. 16–18.

Harland, W.B., and Gayer, R.A., 1972, The Arctic Caledonides and earlier oceans: Geological Magazine, v. 109, p. 289–314.

Wilson, J.T., 1966, Did the Atlantic close and then re-open?: Nature, v. 211, p. 676–681.

Birdsall-Dreiss Distinguished Lecturer for 2002 Announced

Graham Fogg of the University of California, Davis (UCD), has been selected as the 2002 Birdsall-Dreiss Distinguished Lecturer, sponsored by the GSA Hydrogeology Division. At the request of interested institutions, he will present one of three lectures for audiences interested in the broad geologic aspects of groundwater resources.

Fogg received a B.S. in hydrology from the University of New Hampshire, an M.S. in hydrology and water resources from the University of Arizona, and a Ph.D. in geology from The University of Texas at Austin, where he also worked for the Bureau of Economic Geology from 1978 to 1989. In 1989, he moved to UCD, where he is a professor in the Hydrology Program, the Department of Land, Air, and Water Resources, and the Department of Geology. He served as chair of the Hydrologic Sciences Graduate Group from 1993 to 1998 and chair of the Hydrology Program from 1998 to 2001. His research interests include transport processes in heterogeneous systems, geologic and stochastic characterization of aquifer heterogeneity, regional hydrogeology, and heat transport in groundwater. His research and teaching over the past 25-plus years have addressed problems of groundwater contamination, groundwater resource sustainability, high-level nuclear waste isolation, coal mining, and petroleum reservoir characterization and recovery.

To request a visit to your institution, contact Graham Fogg, Department of Land, Air, and Water Resources, University of California, Davis, CA 95616-8628, (530) 752-6810, gefogg@ucdavis.edu. The Hydrogeology Division is particularly interested in including liberal arts colleges in the itinerary. The Division will pay transportation expenses, and the host institution will provide local accommodations.

Talk Topics

Plume Behavior in Heterogeneous Geologic Systems: Natural Attenuation, Remediation, and the Role of Diffusion

The subsurface is inherently heterogeneous and 3-dimensional, and it is commonly composed not only of aquifer materials but also of large fractions of intermingled aquitard materials (e.g., silt and clay beds). Molecular diffusion, rather than advection, can be the dominant physical transport process in the aquitards. Investigators commonly interpret field data on groundwater contaminant concentrations with the help of conceptual models that are not 3-dimensional, that are less heterogeneous than the actual system, and that lack representation of diffusion into aquitards. Recent research shows how reliance on such models can lead to mischaracterization of the plume and of remediation success, natural attenuation, and scale-dependent dispersion.

Development of improved geostatistical methods (TProGS) for modeling hydrostratigraphy and of a fast, random-walk particle method (RWHET) for accurate simulation of advection-, dispersion-, and diffusion-dominated processes provide the necessary tools for modeling transport processes in typically heterogeneous media, exemplified by alluvial fan systems of Livermore Valley, eastern San Joaquin Valley, and the South Tahoe basin, California. All of these geostatistical simulations, which are based on field borehole data and geologic concepts, generate heterogeneous representations of aquifers that are extensively connected networks of channel deposits, except where interrupted by paleosol sequence boundaries (Kings River fan, San Joaquin Valley) or other unconformities. In 2-dimensional sections, the aquifers typically appear to be disconnected lenses. Three-dimensional transport simulations consistently produce simulated plumes that have important characteristics lacking in conventional models but consistent with field observations: (1) rapid plume migration along preferred pathways, in both lateral and vertical directions, and (2) substantial retention of solute mass in aquitard materials near the source for decades or centuries, even when the source is an instantaneous pulse. Apparent longitudinal dispersivity (α_L) of simulated plumes grows spatially and temporally in accordance with generic data on α_L, suggesting that scale-dependent dispersion can be more an artifact of diffusion processes than an indicator of multiscale heterogeneity. The preferential flow down sinuous pathways produces plumes that would easily be missed by conventional monitoring with well networks. Animation of plume evolution with and without the heterogeneity and with wells pumping demonstrates the dominant role of the heterogeneity and groundwater production in plume evolution. Mass accounting among facies demonstrates that most of the mass being sequestered is in the aquitards. Sensitivity analysis shows that relatively small changes in the diffusion coefficient can change the distribution of mass significantly, although the overall plume behavior remains essentially unchanged. Remediation experiments show that the slow release of contaminants by diffusion and advection from low-permeability materials may lead to exceedingly long times (decades to centuries) for pump-and-treat cleanup. Results also show that even if advanced remediation technologies could succeed in removing contamination from the aquifers (alluvial channels), back-diffusion and advection out of the aquitards could cause concentrations in the aquifers to increase again to levels of concern for decades into the future.

Groundwater Vulnerability and the Meaning of Groundwater Age Dates

Regional-scale analyses of flow and transport in two groundwater basins demonstrate hydrogeologic approaches for characterizing the vulnerability of groundwater to contamination and lead to important implications for the meaning of groundwater age dates and the sustainability of groundwater quality. The approach combines detailed models of 3-dimesional hydrostratigraphy with a backward-time solution of the advection-dispersion equation (ADE). Results for the Salinas Valley, California, show that, owing to heterogeneities represented through geostatistical modeling, the simulated regional spatial patterns of nitrate occurrence agree closely with field data from wells. The transport simulations suggest time lags of >30 yr for breakthrough at well screens 55 m below the water table, implying that nitrate groundwater contamination, which was first detected in the 1970s, originated from land-use practices of the 1940s. The random-walk solution of the backward-time ADE also produces estimates of the age distributions of groundwater pumped by individual wells (i.e., ages of individual water "particles" reaching the well screen). The simulated groundwater ages typically range from decades to >100 yr within individual water "samples," suggesting that if nitrate-loading rates do not decline appreciably, historical breakthroughs of contaminants at wells merely represent the beginning of a gradual deterioration in groundwater quality.

A more detailed analysis of both hydrostratigraphy and transport in the eastern San Joaquin Valley, California, leads to refinements in the vulnerability-mapping approach and further investigation of age distributions in water samples. A new approach to modeling alluvial fan heterogeneity uses geostatistical simulation in a sequence stratigraphic framework in which paleosols form sequence boundaries and semiconfining beds. This model of multiscale heterogeneity produces detailed maps of vulnerability that more accurately reflect the geology, including nonstationary heterogeneity. Simulated CFC-11 and CFC-12 age dates agree closely with field-measured CFC-11 and CFC-12 ages. However, the distributions of water age reaching the well screens in the model at any instant in time are both broad (many decades) and skewed, except at shallow (<10 m) wells. Significant dispersion due to heterogeneity causes mixing of relatively old water (>40 yr) with young water in most wells, even when the well screen is short (<1 m). Consequently, the true average groundwater age differs significantly from the CFC age. These results suggest that groundwater age-date measurements *alone* are inadequate for estimating vulnerability to contamination in systems with typical alluvial heterogeneity.

A Geologic Approach to Simulation of Subsurface Hydrology

The unknown heterogeneity of the subsurface remains a major obstacle to reliable simulation of subsurface flow and transport processes. Characterization of spatial patterns in properties with typically sparse data requires knowledge of the geologic processes that created the patterns. A geostatistical approach based on transition probability theory provides a means for quantitative modeling of 3-dimensional hydrostratigraphy through the use of commonly available field data as well as geologic fundamentals and knowledge of the depositional processes. By modeling interfacies-transition probabilities with Markov chains, an intuitive method for building 3-dimensional models from basic geologic principles is developed, extending qualitative geologic characterization into the quantitative realm necessary for flow and transport simulation. This geologic/geostatistical technique, implemented with the software TProGS, uses the hard data together with interpretive input on proportions, average lengths, and juxtapositioning of geologic facies to create multiple realizations of heterogeneity. The resulting characterizations honor fundamental probability laws while preserving observed or inferred facies proportions, continuity, asymmetries (e.g., fining-upward sequences), and facies relations (e.g., levee adjacent to channel facies). Lateral facies relations, which are typically undersampled, can be modeled based on the observed vertical patterns in facies through the use of Walther's Law. Furthermore, the approach can incorporate nonstationarities such as spatially varying dip angles, or more severe nonstationarity, such as unconformities and transitions between different depositional environments. Example applications in alluvial fan and fluvial environments depict the resulting hydrostratigraphic models and demonstrate the significance of highly resolved heterogeneity in the simulation of flow and transport, while providing a fair degree of field validation with hydraulic and groundwater age-date data.

Hello, USGS? **ESPN Calling**

Dave Ozman, public affairs specialist for the U.S. Geological Survey (USGS) in Denver got a call in July from ESPN. The folks at the sports network wondered if the National Hot Rod Association's (NHRA) cars make much of a seismic impact as they blast down the quarter-mile track.

To find out, two USGS seismologists, John Lahr and Mark Meremonte, attended the Mopar Parts Mile-High Nationals July 21–22 at the Bandimere Speedway outside of Denver.

"We buried one weak motion seismometer near the track ~600–700 ft from the start, set one weak motion seismometer on the surface under the ESPN broadcast booth, and, initially surface mounted but later buried, one broadband seismometer under the broadcast booth at about the 900–1000-ft mark on the 0.25 mile (1320 ft) track," said Meremonte.

The surface-mounted seismometers reacted strongly to the pressure air wave as the top fuel cars zoomed by. Apparently, the seismometer was tilted by the air wave. Burying the seismometer reduced this effect.

Although the recordings definitely show that there is coupling between the cars hurtling down the track and Earth, it was difficult to decide how much of the ground vibration resulted from direct contact between the wheels of the cars and the track and how much was due to air waves striking the ground and also causing surface structures to vibrate and sway.

"Using data from our only calibrated instrument (the broadband seismometer), we calculated a ground-motion amplitude of ~20 µm from the top fuel cars," said Meremonte. "However, much of this may have been caused by the site-structure interaction above the seismometer and not directly by the coupling of the cars to Earth. Since we were in the booth, we can attest to the fact that the booth was shaking."

Top fuel dragsters produced the largest amplitudes, funny cars produced similar amplitudes, pro stock produced little, and pro stock motorcycles were pipsqueaks. Top fuel and funny car vehicles reached speeds close to 300 mph, more than 100 mph faster than the other categories. Thus, the speed of the car is significant in generating ground motions above background noise.

The response? "People who saw us doing this seemed to be very receptive and interested in our observations," said Meremonte.

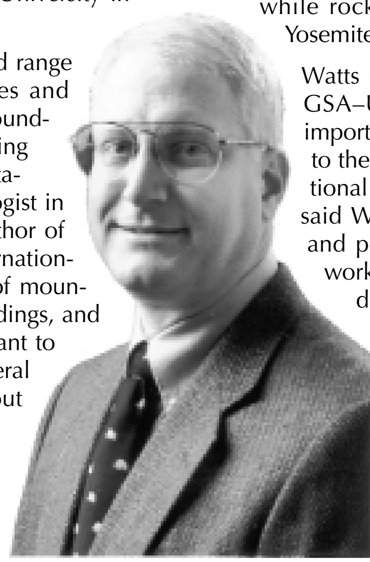
Have a story about bringing the geosciences to the public in a unique way? Send your story to jhammann@geosociety.org.

Congressional Science Fellow Begins Term This Month

Chester F. "Skip" Watts has been selected as the 2001–2002 GSA–U.S. Geological Survey Congressional (USGS) Science Fellow. Watts is the Dalton Distinguished Professor of Geology at Radford University in Virginia, where he also serves as director of the Institute for Engineering Geosciences. His teaching has focused in recent years on engineering geology, advanced engineering geology, soil mechanics, and rock mechanics. He also enjoys teaching environmental geology, hydrogeology, computer applications in geology, geomorphology, and general geology. Watts received his bachelor's degree in geology from Virginia Tech in 1974, his master's degree in physical science from Radford University in 1977, and a doctorate in engineering geology from Purdue University in 1983.

Watts' research interests focus on the broad range of interaction between geologic processes and human activity. His studies range from groundwater resource and contamination to flooding and dam safety to landslides and ground stability. Watts is a certified professional geologist in the Commonwealth of Virginia and the author of ROCKPACK computer software, used internationally for analyzing the safety and stability of mountain slopes, mines, quarries, highways, buildings, and bridge foundations. He serves as a consultant to numerous state highway departments, federal agencies, and engineering firms throughout North America.

The Virginia Office of the Attorney General, the USGS, the U.S. Forest Service, and the Army Corps of Engineers are among those to have enlisted Watts' assistance. His projects have included Federal Emergency Management Administration studies in Hot Springs, Arkansas, evaluations of dam spillway stability adjacent to the San Andreas fault, rock fall and visitor safety at Natural Bridge National Historic Landmark in Virginia, wildfire rehabilitation in the Cascade Mountains of Washington, and rock-slide studies in Yosemite National Park in California.



Chester F. "Skip" Watts

Watts has received several regional and national teaching awards, including the 1998 State Council for Higher Education in Virginia's Outstanding Professor Award. He recently appeared in a television documentary called "Earth's Fury!" on TLC (The Learning Channel) and on National Public Radio while rock climbing during rock-slide investigations in Yosemite National Park.

Watts feels very honored to serve as the 2001–2002 GSA–USGS Congressional Science Fellow. "Many important geologic and environmental issues are rising to the political forefront. It is both exciting and educational to become a part of the public policy process," said Watts. He hopes to become involved in science and policy issues related to the environment, public works, and natural hazards and will continue the tradition of writing perspective articles for upcoming issues of *GSA Today*.

For information on the Congressional Science fellowship, visit the Professional Development section at www.geosociety.org.

Call for Applications!

Opportunities to serve as a Congressional Science Fellow are rare, and the experience is unique. If you are interested in working with national leaders to help shape science and technology policy on Capitol Hill, this position may be a good fit for you.

The Congressional Science Fellow will be selected from top competitors early in 2002. Candidates must be **GSA Members** who possess either a Ph.D. in the earth sciences or a related field, or a master's degree in the earth sciences (or a related field) plus at least five years of professional experience.

If you have this professional background, are experienced in applying scientific knowledge to societal challenges, and want to help shape the future of the geoscience profession, put your expertise, experience, and passion for science to work where it counts! The fellowship is open to U.S. citizens or permanent residents of the U.S. **The deadline to apply is February 1, 2002.**

For application information, check the Web site at www.geosociety.org/science/csf/index.htm, or contact Karlon Blythe, Program Officer, GSA Headquarters, (303) 447-2020, kblythe@geosociety.org.

Apply for GSA's

GSA–U.S. Geological Survey

Congressional Science Fellowship

2002–2003

Figures:

Have We Confused You Yet?

Last month, *GSA Today* published figure guidelines for *Geology* and *GSA Bulletin*. We also told you about the new online manuscript submission system for the journals. Careful readers probably noticed we asked for one type of figure file for online submission and another in the guidelines for publication.

Here's the deal: For submission and review, publication-quality figures are not required. Lower resolution PDF or JPEG files will suffice, as long as the files open properly and are readable.

However, if your paper is accepted for publication, you'll be asked to deliver the final version of your figures in specific formats that ensure high-quality and accurate publication. So, although publication-quality figures are not required at the submission stage, creating your figures with publication in mind is a good idea. That's where the guidelines come in.

Figures continue to be a concern for most scientific journals because standards and software used vary widely. Read the author information for other journals—the instructions and caveats all have a way of sounding similar, because most journals experience the same sorts of figure challenges. Here at GSA, we have only to go downstairs to production and say, "Canvas 5.0!" and our designers tremble uncontrollably.

As always, if you have questions, please contact the journal managing editors. *GSA Bulletin*—Larry Bowlds, lbowlds@geosociety.org; *Geology*—Anika Burkard, aburkard@geosociety.org.

Online Peer Review Brings Convenience, Maintains Security

With the launch of GSA's online manuscript submission and peer-review system in August, *Geology* and *GSA Bulletin* join many other scientific journals in becoming all-electronic—submitted, edited, reviewed, and published in electronic formats. (See "GSA Journals Take the Plunge…" *GSA Today*, v. 11, no. 8, p. 16.)

As most of you can confirm, however, electronic ≠ easy. Who among us can say that upgrades are always up to snuff or conversions consistently more convenient? And many of us still prefer to read articles on paper, whether in a bound, delivered copy or printed out from a file.

But the move to electronic publishing has many benefits that make the growing pains and missteps worth it. Searching online archives, the ability to link directly to references as you read, shorter publication time with instant distribution worldwide, and interactive features on the horizon all make journals even more useful to researchers.

Online submission also has many benefits. Take peer review, for instance. Potential reviewers of *Geology* and *Bulletin* papers are everywhere—from Bloomington and Woods Hole to Bahrain and Wollongong. Shipping stacks of manuscript pages has been expensive, time consuming, and unreliable. The move to sending papers via PDF files helped, but was only a partial fix. With AllenTrack, the new online system, files are at your fingertips.

A Potentially Paperless System

Last month, we outlined how you will go about submitting a paper online. Here's what happens next.

Each journal has two science editors. *Geology* editors David Fastovsky and Ben van der Pluijm assign reviewers to papers. *Bulletin* editors Peter Copeland and Allen Glazner assign papers to associate editors, who choose reviewers.

With the new system, editors, associate editors, and reviewers are notified in turn that a paper awaits them on the AllenTrack server. When they log on to their accounts, they receive messages regarding the papers assigned to them. Reviewers in Brazil or China won't wait weeks to receive a paper sent surface mail and won't have to put up with the bother and cost of sending a paper manuscript back.

If a reviewer is going to be out of town, he or she can put that information in the system so that editors know not to assign papers during that time. Reviewers may still decline to review a paper if, for example, they have a conflict of interest or other reasons.

Reviewers return their reviews electronically, and only the paper's assigned editors can gain access to these reviews.

We suspect that all desks look the same: stacked with paper. One pile has your "read when I have time" stuff, another has expense reports and human resources paperwork, another has committee minutes to review, and yet another has your own notes to write up for your own manuscript. We like to think you'll enjoy NOT having a stack of manuscripts to review on your desk.

The Editors Are In

GSA journal science editors and GSA staff members will be available at the Annual Meeting in Boston to answer your questions and demonstrate the online manuscript submission system. Look for the Editor's Corner by the GSA Bookstore in the Exhibit Hall, Hynes Convention Center.

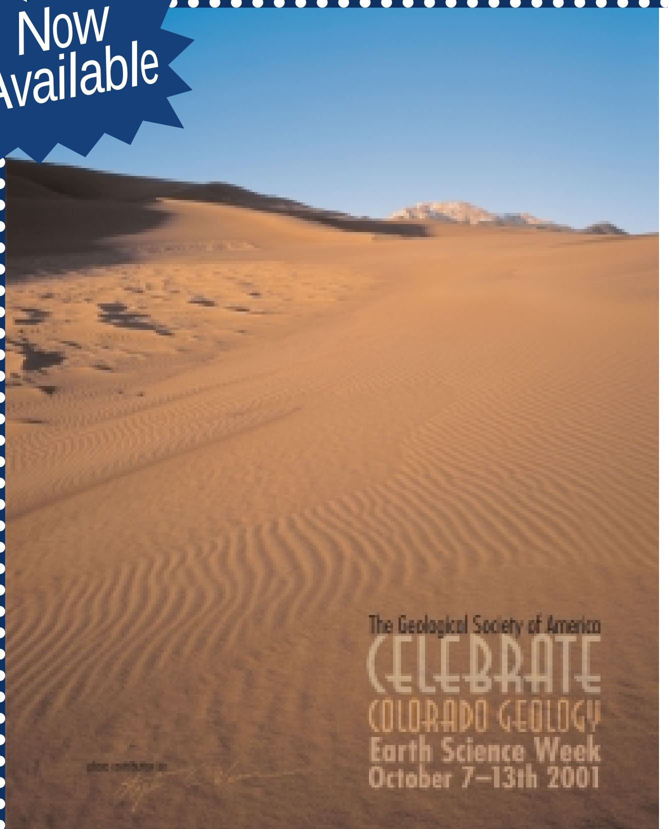
EARTH SCIENCE WEEK Evolves

Earth Science Week, October 7–13, is an annual grassroots effort sponsored by the American Geological Institute (AGI) and its member societies, including GSA. The aim is to increase public understanding of the earth sciences. As geoscientists develop earth-science outreach programs in their local schools and communities, the collective impact of their efforts continues to grow. During Earth Science Week 2000, scores of celebrations—including field trips, demonstrations, lecture series, film series, exhibits, school visits, and open houses—took place in all 50 states, Australia, Canada, and at least 20 other countries. Eighteen AGI member societies and more than 100 state geological surveys, regional societies, academic geoscience departments, museums, libraries, and federal agencies hosted these events and activities. In addition, 30 state governors, the mayors of several cities, and former President Clinton issued proclamations and messages in support of Earth Science Week.

This year, for the first time, Earth Science Week has a general theme, "evolution in earth history." AGI has provided the poster inserted in this issue of *GSA Today* in hopes that you'll use it to help students and adults gain a better understanding of one of the fundamental underlying concepts of modern science: evolution. The dramatic timeline and engaging activity on the poster illustrates how much Earth has changed through time.

AGI's Earth Science Week information kit for 2001 includes a variety of posters, bookmarks, and other materials that illustrate this concept. The kit contains a new 32-page *Ideas and Activities* booklet that emphasizes evolution in earth history through an array of activities about rocks, fossils, and geologic time, as well as information on the upcoming PBS series, "Evolution," which is to be aired in late September. Single copies of the Earth Science Week information kit are available at no charge from AGI. You may request a kit on the Earth Science Week Web site, www.earthsciweek.org, by phone, (703) 379-2480, by fax, 703-379-7563, or by mail to Earth Science Week, American Geological Institute, 4220 King Street, Alexandria, VA 22302.

Now Available



The GSA Earth Science Week 2001 poster features the Great Sand Dunes of south-central Colorado. Photo by Stephen Weaver.

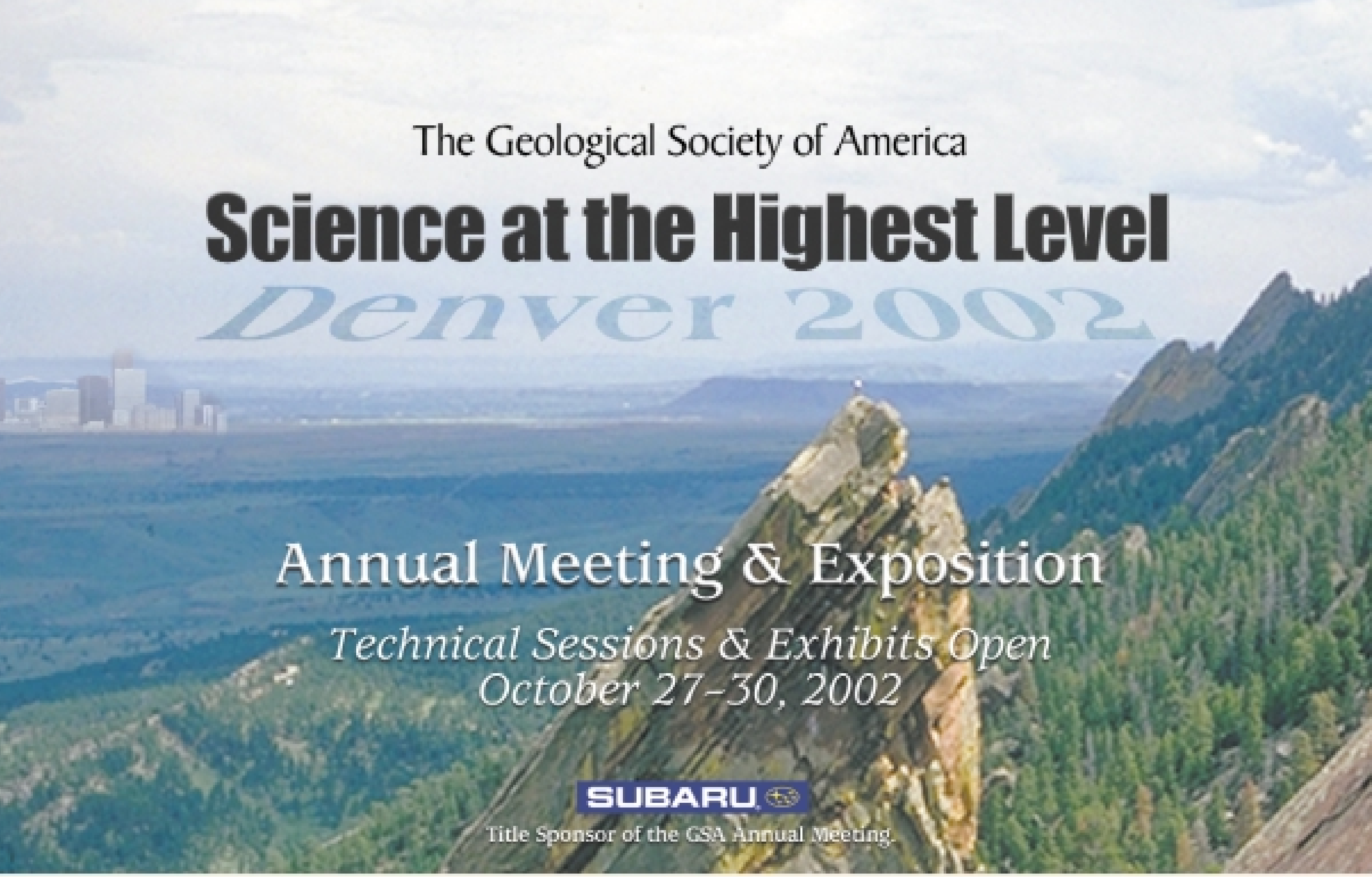
GSA EARTH SCIENCE WEEK 2001 POSTER

In celebration of Earth Science Week (October 7–13), GSA has created a poster highlighting Colorado geology. GSA is sending the poster and a list of member-recommended books that feature earth sciences to some of our neighbors here at headquarters—public libraries and public school libraries in Colorado. Librarians will be encouraged to use the materials in Earth Science Week displays.

Colorado librarians also will have a first-come-first-served opportunity to receive up to $50 in reimbursement from GSA for the purchase of general geology books or books that present the earth sciences as an integral part of story lines.

Copies of the poster are free to Colorado educators and may be purchased by GSA members for $8. To order, contact Member Services, member@geosociety.org, (303) 447-2020, or 1-888-443-4472. Members are also encouraged to submit titles for the book list to member@geosociety.org.

Colorado photographer, geologist, and GSA member Stephen Weaver has been photographing the North American landscape for more than 25 years. Growing up in Pennsylvania, Weaver first experienced the landscapes of the American west as an undergraduate geology student attending Yellowstone-Bighorn Research Association field camp in Red Lodge, Montana. Since then, he has worked to capture on film fine examples of geologic features and intimate and grand landscapes throughout western North America. To capture the highest detail possible in his landscape images, Weaver usually uses a large-format, 4 × 5 view camera with fine-grained transparency film. In 1995, he established Earth Systems Imaging, a small part-time business to market his images. (Visit www.earthsystemsimaging.com.) Weaver lives in Colorado Springs and is technical director of geology at The Colorado College.



Colorado Convention Center

TECHNICAL PROGRAM CHAIR

John W. Geissman
University of New Mexico
Department of Earth and Planetary Sciences
203 Northrop Hall
Albuquerque, NM 87131-1116
(505) 277-3433
Fax: 505-277-8843
jgeiss@unm.edu

CALL FOR PARDEE SYMPOSIA
AND TOPICAL SESSION PROPOSALS

Due January 17, 2002

Proposal forms will be online beginning Nov. 1, 2001. Go to the Meetings section at www.geosociety.org.

CALL FOR FIELD TRIP PROPOSALS

Due October 1, 2001

Contact the Field Trip Chair with your proposals for half-day, single-day, and multi-day field trips beginning or ending near Denver and dealing with all aspects of the geosciences.

Field Trip Chair

Eric A. Erslev
Department of Earth Resources
Colorado State University
Fort Collins, CO 80523
(970) 491-5661
Fax: 970-491-6307
erslev@cnr.Colorado.edu

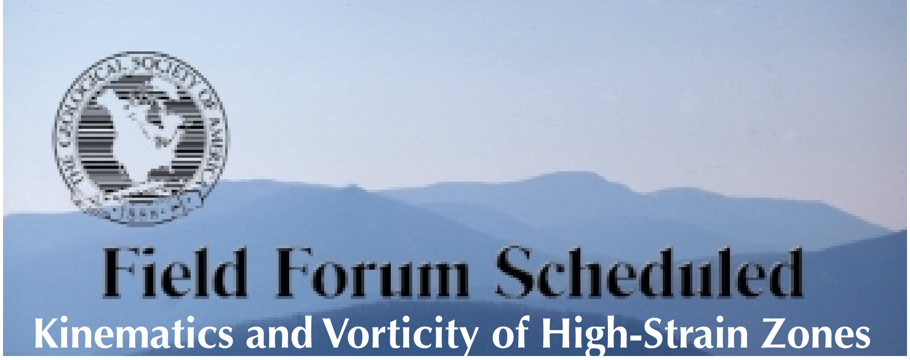
CALL FOR SHORT COURSE PROPOSALS

Due December 3, 2001

The GSA Committee on Professional Development invites those interested in proposing a short course to contact GSA Headquarters. Courses may be conducted in conjunction with all GSA Annual Meetings and Section Meetings. Selection of courses for the 2002 Denver Annual Meeting will be made by March 1, 2002. We also are interested in receiving proposals for the 2003 Seattle Annual Meeting and will consider those proposals at the same time.

For proposal guidelines or information, contact Edna Collis, Program Officer, GSA Headquarters, 1-800-472-1988, ecollis@geosociety.org.

For More Information
(303) 447-2020 ◎ 1-800-472-1988
meetings @geosociety.org ◎ www.geosociety.org



Field Forum Scheduled

Kinematics and Vorticity of High-Strain Zones

April 16–21, 2002 • Virginia Blue Ridge and Piedmont

Conveners: Christopher M. Bailey, College of William & Mary; Andy R. Bobarychick, University of North Carolina, Charlotte; Dazhi Jiang, University of Maryland

Web site: www.wm.edu/CAS/GEOLOGY/faculty/bailey/GSA/fieldforum/

Location: Blue Ridge and Piedmont provinces, north-central Virginia, approximately 120 km southwest of Washington, D.C. Lodging at the Graves Mountain Lodge, Madison County.

Purpose

High-strain zones are common features in orogenic belts and have long generated debates as to their movement history and tectonic significance. A number of notable advances have recently been made toward quantitatively understanding the nature of flow during deformation, but very few studies have applied these methods to naturally deformed rocks. This field forum will examine a number of high-strain zones in the Blue Ridge and Piedmont provinces of the Virginia Appalachians and discuss what information can be gained into the kinematic history of these rocks. It will provide geologists the opportunity to discuss contemporary research in the context of what *can* and *cannot* be learned about deformation history from naturally deformed rocks.

Significance

The structural geology community first appreciated the significance of high-strain zones in the 1970s. Early models considered volume constant, simple shear strain in parallel-sided zones. Kinematic indicators such as asymmetric tails on porphyroclasts and shear bands were widely used in the 1980s to better understand the movement history of high-strain zones. However, field geologists have long recognized that not all high-strain zones experienced simple shear deformation nor do they have easily resolvable kinematics. Recent advances in the study of high-strain zones include: (1) the ability to quantify the bulk strain geometry and vorticity of deformation using rock structures; (2) the understanding that significant displacement may occur at high angles to elongation lineations in transpressive zones; and (3) the recognition that flow in high-strain zones may have a triclinic symmetry rather than a simple monoclinic symmetry. In spite of this progress, there seems to be a growing gap between geologists who are modeling deformation and geologists attempting to understand the history and significance of high-strain zones. We hope to attract a diverse group of geologists and strive for lively interchange while examining a well-exposed suite of highly deformed rocks. Specific questions we plan to address at this field forum include:

(1) Can structures in natural high-strain zones be used to meaningfully characterize the finite vorticity and progressive vorticity changes during deformation?

(2) How does the recognition of triclinic symmetries in high-strain zones influence kinematic and tectonic interpretations?

(3) How many estimates of strain and vorticity are needed to characterize the bulk flow of a high-strain zone?

(4) Is the deformation path (strain geometry and vorticity) influenced by the specific tectonic environment (e.g., contraction, extension, or transpression) in which material is deformed?

High-strain zones in the Virginia Blue Ridge significantly deviate from the classic simple shear zone model. These zones record general shear deformation with strong flattening strains and formed under greenschist facies conditions during Paleozoic contractional deformation. In Madison County, Virginia, an intense storm in June 1995 caused extensive slope failure and erosion. Large debris-flow scars created by this storm commonly expose hundreds of square meters of well-exposed bedrock.

Transpressional high-strain zones with oblique strike-slip displacements are exposed in the Virginia Piedmont. Many Piedmont high-strain zones have been interpreted to be major Appalachian terrane boundaries with complex histories. Some of the Piedmont zones are associated with syntectonic plutons and characterized by L-tectonites with orogen-parallel lineations.

Itinerary:

Tues., April 16—Participants should fly into Charlottesville, Virginia (served by Delta, United, and USAirways), by 5 p.m. Van transportation will be provided to Graves Mountain Lodge in Madison County, Virginia (50 km north of Charlottesville). Orientation and introductory presentations will follow dinner.

Wed., April 17—Examination of Mesoproterozoic basement rocks and high-strain zones exposed in the Blue Ridge anticlinorium in Madison County. Discussion of the relationship between foliation, high-strain zone boundaries, and strain in zones that have experienced a progressive general shear deformation path.

Thurs., April 18—Examination of Blue Ridge high-strain zones in Madison County including an ~100-m-thick zone of heterogeneously deformed mylonitic rock that records top-to-the-northwest reverse displacement, intense flattening strains, and a nonsteady vorticity path.

Fri., April 19—Piedmont exposures, including the Hylas high-strain zone, folded and boudinaged pegmatitic veins in mylonitic gneiss, the Central Piedmont and Spotsylvania high-strain zone, and L-tectonites.

Sat., April 20—Morning: phyllonitic rocks in the Mountain Run fault zone, the tectonic boundary separating the Blue Ridge and Piedmont. Afternoon: Rockfish Valley fault zone in the Blue Ridge south of Charlottesville. Evening: summary presentation, discussion, and wrap up.

Sun., April 21: Travel to the Charlottesville airport for flights in the morning.

Registration Limit: 35 participants

Cost: $625 ($300 for students), including guidebooks, handouts, meals, lodging (double occupancy), refreshments, and transportation to and from the Charlottesville airport.

Registration Applications and Information: Geologists with an interest in high-strain zones are encouraged to apply. We hope to attact a diverse group of field geologists, modelers, and experimentalists. Contact Christopher (Chuck) M. Bailey, Department of Geology, College of William & Mary, Box 8795, Williamsburg, VA 23187, (757) 221-2445, fax 757-221-2093, cmbail@wm.edu.

GSA is committed to making Field Forums accessible to all. If you require special arrangements or have special dietary concerns, please contact Christopher (Chuck) Bailey.

CLASSIFIED Advertising

Ads (or cancellations) must reach the GSA Advertising office one month prior. Contact Advertising Department, (303) 447-2020, 1-800-472-1988, fax 303-447-1133, or e-mail acrawford@geosociety.org. Please include complete address, phone number, and e-mail address with all correspondence.

Positions Open

EARTH SURFACE PROCESSES
UNIVERSITY OF MICHIGAN

The Department of Geological Sciences is seeking applicants for a tenure-track faculty position. This reopened search will now consider applicants at the assistant, associate, or full professor level. We seek a geoscientist with research interests in any aspect of earth surface or near-surface processes. Areas of expertise may include, but are not limited to: quantitative geomorphology, neotectonics, soil processes, hydrogeology, geological hazards, remote sensing, or glacial geology. We expect the applicant to develop a vigorous, externally funded research program and to show a commitment to teaching at both the graduate and undergraduate levels. These expectations include involvement in our Environmental Geology degree program and in new interdisciplinary initiatives at the University of Michigan. A Ph.D. is required. Interested persons should send a curriculum vitae, names of at least four persons from whom the department may request letters of recommendation, and brief statements of research and teaching interests to: Prof. L. Ruff, Search Comm. Chair, Dept. of Geological Sciences, University of Michigan, Ann Arbor, MI 48109-1063, ruff@umich.edu. To ensure a careful evaluation, applications should be received by Oct. 1, 2001. The University of Michigan is an affirmative action, equal opportunity employer. Additional information about the department can be found at our Web site, www.geo.lsa.umich.edu/.

AMHERST COLLEGE
ASSISTANT PROFESSOR

The Department of Geology at Amherst College solicits applications for a tenure-track position at the level of assistant professor to begin in the fall of 2002. We seek a sedimentologist whose interests and expertise may also include stratigraphy, paleontology, paleoclimatology, marine geology, and/or oceanography.

The successful candidate will teach sedimentology and an additional upper-level course or courses that will strengthen our undergraduate major and complement the present departmental offerings in tectonics, structural geology, hydrogeology, aqueous geochemistry, petrology, and geophysics. All geology faculty teach at the introductory level as well. Preference will be given to candidates with a demonstrated interest in continued development and teaching of our introductory course in surficial earth systems and the environment. Geology faculty also supervise undergraduate research projects annually.

Candidates must have an ongoing program of research. Amherst College provides competitive start-up funds in support of research. A Ph.D. is required and postdoctoral experience is desirable. Submit a résumé, a brief statement of your research interests, transcripts, and three letters of recommendation to: Professor Tekla A. Harms, Chair of the Search Committee, Department of Geology, Amherst College, Amherst MA 01002-5000 (taharms@amherst.edu). Review of applications will begin on November 20, 2001, but applications will be accepted until a pool of qualified candidates is identified. Amherst College is an equal opportunity/affirmative action employer. Women, minorities, and persons with disabilities are particularly encouraged to apply.

GEOLOGICAL REMOTE SENSING
OR STRUCTURAL GEOLOGY/TECTONICS
SOUTHERN ILLINOIS UNIVERSITY CARBONDALE

The Department of Geology at Southern Illinois University Carbondale invites applications for a tenure-track position in geological remote sensing or structural geology/tectonics at the assistant professor level, starting either Jan. 1, 2002, or Aug. 16, 2002. Please visit our Web site http://www.science.siu.edu/geology/position.html for more information. SIUC is an AA/EOE.

BAYLOR UNIVERSITY
STRUCTURAL GEOLOGY

The Department of Geology at Baylor University invites applications to fill a vacancy in structural geology, rank and salary negotiable. A Ph.D. in geology or a related discipline is required at the time of appointment. Responsibilities will include introductory and advanced instruction in structural geology, supervision of graduate research, and the development of an active research program. The successful candidate will be expected to support the graduate program in petroleum geology, regardless of their area of specialty. Applications for this tenure-track position will be reviewed beginning immediately, and will be accepted until the position is filled. To ensure full consideration, your application must be completed by November 30, 2001.

Applicants should submit a letter of application addressing qualifications and experience, a curriculum vitae, description of teaching and research interests, transcripts of academic work, and the names of three professional references to: Dr. Stacy Atchley, Department of Geology, P.O. Box 97354, Baylor University, Waco, Texas 76798-7354. Phone: (254) 710-2361. E-mail: stacy_atchley@baylor.edu. Fax: 254-710-2673. The Baylor Geology Web site is www.Baylor.edu/~Geology.

Baylor is a Baptist university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Opportunity employer, Baylor encourages minorities, women, veterans, and persons with disabilities to apply.

LIMNOGEOLOGIST
UNIVERSITY OF MINNESOTA—TWIN CITIES

The Department of Geology and Geophysics at the Winchell School of Earth Sciences, University of Minnesota—Twin Cities, invites applications for a tenure-track assistant professor, tenure-track/tenured associate professor or tenured full professor position from outstanding researchers with a proven track record to help focus the department's interdisciplinary efforts in paleolimnology and global environmental change. We seek a candidate who is rigorously trained in current earth science research techniques utilizing lake sediment archives to reconstruct global climatic and environmental changes. The successful applicant is expected to participate fully in the department's undergraduate and graduate course offerings. The choice of courses is flexible and will take into consideration the applicant's as well as existing faculty's specialties. The successful applicant will greatly benefit from the Limnological Research Center, which includes "LacCore," an NSF-funded national repository of lake sediment cores, a multi-disciplinary analytical core laboratory modeled after integrated ocean sediment research facilities, and operating core systems for small and large coring expeditions. Existing faculty in geology and geophysics and affiliated units provide excellent opportunities for cooperative research in related disciplines such as sedimentology, paleontology, geochemistry, and sediment magnetism. Interested applicants are invited to visit our Web site (http://www.geo.umn.edu/). At the Twin Cities campus, the Winchell School of Earth Sciences also includes the Institute for Rock Magnetism and the Minnesota Geological Survey. The College of Biological Sciences includes the Department of Ecology and Behavioral Biology and other departments with strong research programs linked to geologic studies. The Graduate School administers the Large Lakes Observatory on the Duluth campus, which is actively involved in chemical, physical, and biological studies of lake systems.

Applicants are expected to have a PhD at the time of appointment. To apply send a curriculum vitae, statements of teaching and research interests, and names, addresses, telephone numbers and e-mail addresses of five references to Chair, Limnogeologist Search Committee, University of Minnesota, Department of Geology and Geophysics, 310 Pillsbury Dr. S.E., Minneapolis, MN 55455. Review of files will begin on October 1, 2001. Applications will be accepted until the position is filled. The start date is expected to be fall 2002. Questions may be addressed by e-mail to Professor W.E. Seyfried, Head of Winchell School of Earth Sciences, at wes@umn.edu.

The University of Minnesota is an equal opportunity educator and employer.

BIOGEOCHEMISTRY
UNIVERSITY OF MASSACHUSETTS, AMHERST

The Department of Geosciences seeks applications for a full-time tenure-track position in biogeochemistry, to begin September 2002. The appointment will likely be at the assistant professor level, but exceptionally strong candidates above that level are encouraged to apply; a completed Ph.D. is required.

The area of specialization is open and could include, for example, application of organic or isotope chemistry to paleoceanography, sediment biogeochemistry, or geomicrobiology. Candidates with backgrounds in biogeochemical cycling of the elements in modern or ancient environments are particularly encouraged to apply. We expect the appointee to have an excellent grasp of analytical techniques and to establish a state-of-the-art laboratory in his or her field in our newly renovated Biogeochemistry Laboratory. Preference will be given to candidates whose expertise would lead to productive interactions with existing groups in the department (see the department's Web site at http://www.geo.umass.edu). The successful candidate will be expected to develop a vigorous, externally funded research program and to demonstrate excellence in both teaching and research. Teaching responsibilities include a course in earth history (every other year) and graduate and undergraduate courses/seminars in his/her research area.

The department offers a broad-based program in geology and earth systems at the undergraduate, M.S., and Ph.D. levels. In addition, the university has strong programs in microbiology and paleobiology, with the Graduate Program in Organismic and Evolutionary Biology housed with Geosciences in the same building. We would also encourage the successful candidate to foster strong synergies with relevant faculty within other departments on campus. Outside of UMass, the Pioneer Valley has a diverse and active community of earth scientists with geology programs at each of four nearby colleges (Smith, Hampshire, Amherst, and Mount Holyoke colleges).

Review of applicants will begin November 1; the position will remain open until a successful candidate is identified.

Applicants should send a letter of interest outlining research and teaching plans, a curriculum vitae, and the names/addresses/fax numbers/and e-mail addresses of at least three referees to: Search Committee Chair, Department of Geosciences, Morrill Science Building, 611 North Pleasant Street, University of Massachusetts, Amherst, MA 01003-9297.

The University of Massachusetts is an Equal-Opportunity Affirmative-Action Employer; women and members of minority groups are encouraged to apply.

GEOMORPHOLOGY/SURFICIAL PROCESSES
FURMAN UNIVERSITY

The Department of Earth and Environmental Sciences at Furman University invites applications for a tenure-track position at the assistant professor level for the fall 2002.

The required qualifications are a Ph.D. in geology or physical geography, the ability to develop a strong undergraduate research program, and some teaching experience. Experience using current ESRI software and an interest in applying GIS to geological, environmental, and ecological research is desired. Teaching duties would include earth systems, geomorphology, and an advanced course in area of expertise. The successful candidate would be expected to excel in teaching and to develop a strong research program involving talented undergraduates. The department currently consists of four faculty with specializations in watershed hydrology, biogeochemistry, structure and tectonics, mineralogy and petrology, and sedimentation. Furman University is a private liberal arts university with a strong emphasis on undergraduate research and teaching. Furman's location in the Piedmont region of South Carolina at the base of the Blue Ridge escarpment provides many opportunities for field tripping and research in fluvial processes, neotectonics, and landscape evolution, including human impact on the landscape.

Applicants should send a vita including experience, publications, statement of teaching philosophy and research interests, and names of three references. Applicants should discuss how their research could be applied in the undergraduate setting.

Applications and requests for more information should be sent to Kenneth A. Sargent, Dept. of Earth and Environmental Sciences, Furman University, Greenville, SC 29613 or e-mailed to ken.sargent@furman.edu. Furman University is an equal opportunity, affirmative action employer.

TENURE-TRACK POSITION IN GEOPHYSICS
INDIANA UNIVERSITY–PURDUE UNIVERSITY
AT INDIANAPOLIS (IUPUI)

The Geology Department at IUPUI invites applications for a tenure-track, assistant professorship in geophysics. We seek an individual who will develop an externally funded research program and is committed to high quality undergraduate and graduate teaching. A research specialty in geophysics as applied to environmental issues is preferred, and applicants should demonstrate potential for collaboration with faculty in geochemistry, hydrology, and/or sedimentology. Preference will be given to individuals with ability to teach introductory geology and structural geology as well as geophysics.

IUPUI is Indiana's third largest university, with about 28,000 students. The Geology Department is composed of 10 full-time and nine adjunct faculty, with about 60 undergraduate and 15 graduate majors. The department is closely affiliated with the Center for Earth and Environmental Science, which provides opportunities for multidisciplinary collaboration in research and education. Further information about the department and the university is available at www.geology.iupui.edu.

A Ph.D. in geology or a related field is required at initial appointment, beginning in August 2002. Interested candidates should send a curriculum vitae, statements of research and teaching interests, and the names of three referees by November 15, 2001, to Dr. Andrew Barth, Search and Screen Committee, Department of Geology, Indiana University–Purdue University, 723 W. Michigan Street, Indianapolis, IN 46202-5132.

IUPUI is an equal opportunity, affirmative-action employer.

FACULTY POSITION
CALIFORNIA STATE UNIVERSITY, HAYWARD

The Department of Geological Sciences at California State University, Hayward, seeks a dynamic faculty member in applied geophysics. Expertise in sedimentology and stratigraphy is highly desirable, as is field experience using GPR, seismic and other geophysical techniques. A tenure-track position at the assistant professor level will be offered beginning September 2002, conditional upon availability of funds. The individual hired will be expected to have talents in undergraduate and graduate teaching for a diverse student population, and become part of the research program in geology or environmental science. The department offers B.A., B.S., and M.S. degrees in geology and plays a major role in the university's environmental science and teacher credential programs. The university and its San Francisco Bay setting offer a rich combination of cultural amenities, renowned geology and nearly limitless research opportunities. Applicants who will possess the Ph.D. by September 2002 should mail a letter of application; curriculum vitae; graduate transcripts; copies of peer-reviewed publications; statement of teaching interests; and three letters of recommendation to: Search Coordinator, Department of Geological Sciences, California State University, Hayward, 25800 Carlos Bee Boulevard, Hayward, CA, 94542-3088. Refer to position #02-03 GEOL-GEOPHYS/SEDIMENT-TT. Review of applications will begin December 15 and continue until a suitable candidate is found. California State University is an Equal Opportunity Employer, and is committed to principles of diversity in employment and education.

ENVIRONMENTAL GEOLOGY

The Department of Geology and Geography at DePauw University invites applications for a tenure-track position in Environmental Geology to begin in August 2002. Rank and salary commensurate with credentials and experience. A Ph.D. is required, although persons with ABD will be considered. We are seeking a person who is broadly trained in the geosciences with expertise in hydrogeology and/or geochemistry. The successful applicant will teach a variety of courses for undergraduate students, including Physical Geology, Physical Geography, Applied Hydrogeology, and Geochemistry, will develop research projects for undergraduate students, and will possess excellent field and/or computational skills. DePauw has an exceptional program for supporting its faculty, including startup funding and pre-tenure leaves for new faculty, and funding for professional and curriculum development activities (see http://www.depauw.edu/admin/acadaffairs/facdev.htm). Candidates should submit a letter of application, curriculum vitae, three letters of recommendation, transcripts, a statement of teaching interests and philosophy, professional development plans, and a statement of research interests to Dr. Frederick M. Soster, Chair, Department of Geology and Geography, DePauw University, Greencastle, IN 46135. Closing date for applications is November 15, 2001. DePauw University is an Equal Opportunity Affirmative Action Employer; women and minorities are strongly encouraged to apply. For more information about the department, visit http://www.depauw.edu/acad/geology.

PALEONTOLOGY/BIOGEOSCIENCE

The Department of Geological Sciences of the University of Oregon invites applications for an entry-level, tenure-track position to begin in fall 2002. We seek a researcher with interests in fundamental problems of paleontology and biogeosciences, including the origin and evolution of life, evolutionary radiations, mass extinctions, and relationships among organisms, geochemical cycles and environmental change. Our interests are broad and range from microbial biogeology to vertebrate paleontology.

The successful applicant will be expected to develop an academically oriented, externally funded, research program, and to contribute to the teaching of undergraduate paleontology and advanced courses in his/her research specialty. Completion of the Ph.D. is required.

Applicants should send a curriculum vitae, statement of teaching and research interests, and contact information for at least three referees to **Biogeoscience Search Committee, Department of Geological Sciences, 1272 University of Oregon, Eugene, OR 97403-1272.** We will begin reviewing applications November 1, 2001, and will continue until the position is filled.

The University of Oregon is an equal opportunity/affirmative action institution committed to cultural diversity and compliance with the Americans with Disabilities Act.

HYDROGEOLOGY

The Department of Geosciences of the University of Massachusetts at Amherst intends to make a tenure-track faculty appointment in the field of **hydrogeology**. The University of Massachusetts at Amherst is a Research 1 University awarding both masters and Ph.D. degrees in geosciences. Further details can be found at our Web page http://www.geo.umass.edu/. The ideal candidate will be a geologist with research interests that apply the principles of groundwater systems to the development of water resources or understanding subsurface transport. Research in all areas of hydrogeology are of interest, including for example, groundwater contaminant transport, vadose zone hydrology, flow through fractured systems, deterministic or stochastic models of fluid flow systems, hydroclimatology, geophysical characterization techniques, and chemical hydrogeology. The department has a long history of field-based research combined with experimental and modeling studies, and we wish to continue this focus. Developing an externally funded research program involving issues of national relevance is expected. This hydro-program will contribute to supporting the goals of our dynamic graduate program.

The department values good teaching, and the major instructional responsibilities will involve introductory hydrogeology on an annual basis along with appropriate upper-level courses in more specialized topics. The successful candidate will also be expected to share in teaching a large-enrollment general-education course on a rotating basis.

The expected appointment will be at the assistant-professor level but outstanding senior candidates will be considered; a completed Ph.D. is required. Please send application materials, including curriculum vitae, names of 3 references (with e-mail addresses and fax numbers) and a letter discussing your plans for teaching and research by October 30, 2001. Review of applications will start November 1st until a short list is finalized. Please send materials to: Hydrogeology Search Committee, Department of Geosciences, University of Massachusetts, 611 North Pleasant Street, University of Massachusetts, Amherst, MA 01003-9297.

The University of Massachusetts is an Equal-Opportunity Affirmative-Action Employer. The position is contingent upon university funding.

ASSISTANT/ASSOCIATE PROFESSOR OF GEOLOGY

Probationary, tenure-track. Salary is competitive and commensurate with training and experience. Date of appointment is January 10, 2002. **RESPONSIBILITES:** Teach undergraduate and graduate courses such as Planetary Geology, Planetary Science, Geophysics, General (Physical) Geology, Mineralogy, Petrology, and Structural Geology. Actively engage in interdisciplinary teaching efforts and/or honors program courses. Advise undergraduate and graduate students (including thesis) enrolled in Space Studies, Geology, Environmental and Earth Sciences.

Direct and manage the Bemidji State University space Grant Program of the Minnesota Space Grant Consortium (requires some travel). Up to 25% release time is available for Space Grant administration and research. **QUALIFICATIONS:** Ph.D. or ABD in planetary geology/geophysics with an emphasis on surface-forming processes. Demonstrated teaching effectiveness in the geosciences and space sciences. An association with NASA programs in solar system exploration is extremely useful. Work experience and a record of publications in planetary studies may be substituted for extensive teaching experience. All applicants must be able to lawfully accept employment in the United States at the time of an offer of employment. **APPLICATION INFORMATION:** Send letter of application, statement on teaching philosophy, resume, graduate and undergraduate transcripts (official transcripts required at the time of appointment) and three (3) or more letters of recommendation. APPLY TO: Dr. Ranae Womack, Dean,

KING FAHD UNIVERSITY OF PETROLEUM & MINERALS DHAHRAN, SAUDI ARABIA

College of Sciences
Earth Sciences Department

The Department of Earth Sciences at King Fahd University of Petroleum & Minerals, Dhahran, Saudi Arabia invites applications for a faculty position at a professor rank in the field of Environmental and Engineering Geology. This position requires someone who is experienced in all aspects of environmental investigations and assessments. Areas of particular interest are interaction of humans with the geologic environment, waste and pollution management, assessing geological hazards and risks, toxic substance control and land use management. Additional requirements are a Ph.D. degree in Environmental Geology / Engineering Geology and at least ten years of industry experience. The successful candidate must be innovative and have the vision and ability to apply advanced scientific and computer techniques to environmental and geological engineering problems. Teaching at the undergraduate and graduate levels and maintaining a strong research program will be expected of the successful candidates.

Salary/Benefits: Two year renewable contract. Competitive salaries based on qualifications and experience. Free furnished air-conditioned on-campus housing unit with free essential utilities and maintenance. The appointment includes the following benefits according to the University's policy: air ticket to Dammam on appointment; annual repatriation air tickets for up to four persons; assistance with local tuition fees for school-age dependent children; local transportation allowance; two months paid summer leave; end-of-service gratuity. KFUPM campus has a range of facilities including a medical and dental clinic, an extensive library, computing, research and teaching laboratory facilities and a recreation center.

To apply: Mail, fax or e-mail cover letter and detailed resume to:

Dean, Faculty & Personnel Affairs
KFUPM, DEPT. ES-2103
Dhahran, 31261, Saudi Arabia
Fax: 966-3-860-2429 E-Mail: faculty@kfupm.edu.sa or
es.chairman@kfupm.edu.sa

Please visit our website address: http://www.kfupm.edu.sa

College of Social and Natural Sciences, Bemidji State University #27, 1500 Birchmont Drive NE, Bemidji, MN 56601-2699. Postmarked deadline is October 1, 2001, and continue until the position is filled.

Bemidji State University is an Equal Opportunity, Affirmative Action Employer.

BIOGEOCHEMIST/GEOBIOLOGIST
UNIVERSITY OF CALIFORNIA, RIVERSIDE

The Department of Earth Sciences invites applications for a faculty position at assistant professor, associate professor, or full professor rank in the geobiochemistry of sedimentary rocks. We seek an individual to expand our core research program in the paleoecology of ancient environments, which includes faculty research in field- and specimen-based paleobiology, paleoenvironmental analysis, stratigraphy, sedimentology, biogeography, and paleoclimatology. The individual should have research interests that link global ecological and paleoenvironmental change through the study of the biochemical/geochemical record. Specialties may include the evolution of, or changes in, the biosphere, developmental systems, biomarkers, isotopes, or geochemical proxies of oceanographic processes. Teaching responsibilities will include undergraduate and graduate courses in the area of specialty. The applicant must hold a Ph.D. and have a strong commitment to excellence in both research and teaching.

Information about Earth Sciences at UCR is available on the Web at http://cnas.ucr.edu/~earth/es.html. Applications, including a vita, statement of research and teaching interests, and full contact information of three referees should be sent to: Dr. Mary Droser, Chair—Biochemist/Geobiologist Search, Department of Earth Sciences, University of California, Riverside, CA 92521. E-mail contact: mary.droser@ucr.edu. Review of applications will begin November 15, 2001, and will continue until the position is filled. The University of California is an Affirmative Action/Equal Opportunity employer.

CARLETON COLLEGE DEPARTMENT OF GEOLOGY
PETROLOGY AND DYNAMICS,
CRUST AND UPPER MANTLE

The Geology Department at Carleton College invites applications for a tenure-track position (Ph.D. completed or substantially completed) at the assistant professor level. We seek an individual with broad strengths in the processes and evolution of the crust and upper mantle, using the tools of petrology, geochronology, structural geology, and possibly geophysics. The ideal applicant will have demonstrated outstanding teaching skills with an emphasis on field- and laboratory-oriented, hands-on learning. In addition, we seek someone who will be actively engaged in a strong research program that can include undergraduate students in an integral way. All Carleton geology majors complete a senior thesis; we expect our new colleague to help students design and carry out these projects, many of which represent a half a year's worth of research and writing.

The successful candidate is expected to teach three or four courses and associated labs each year, including introductory courses, core courses for majors, and advanced courses. Core course responsibilities for petrology, structural geology, tectonics, and mineralogy will be shared with existing staff. Carleton's geology department averages between 16 and 30 majors in each graduating class; it is a vibrant place that emphasizes cooperation, discussion, field work, inquiry-based learning, creativity, and intellectual depth in a supportive atmosphere. Carleton's geology department has a strong, successful tradition of teaching geology as one of the liberal arts and we are looking for someone to help carry on that tradition.

The position begins in late August 2002. Interested individuals should submit a letter discussing their qualifications, statements of teaching and research interests (the latter addressing how undergraduate students will be incorporated), plus a curriculum vitae with the names and addresses of at least three references (we will solicit letters for applicants passing the initial selection) to Shelby J. Boardman, Acting Chair, Department of Geology, Carleton College, One North College Street, Northfield, MN 55057. Applications will be considered until an appointment has been made, but to ensure full consideration, applications should be received by October 15, 2001. Carleton College is an equal opportunity/affirmative action employer. Women and minorities are encouraged to apply.

POSTDOCTORAL RESEARCHER
(MICROPALEONTOLOGY)
DEPARTMENT OF GEOLOGY AND GEOPHYSICS

The Department of Geology and Geophysics, Louisiana State University, anticipates an opening for a postdoctoral researcher to work on a project entitled, "Foraminiferal Communities of Bathyal and Abyssal Hydrocarbon Seeps, Northern Gulf of Mexico." The project is expected to be for a two-year period supported by a grant from the Minerals Management Service, U.S. Department of the Interior, and to begin in October 2001.

Responsibilities: foraminiferal taxonomy, scanning electron microscopy, generation and analysis of numerical data, report writing, and preparation of manuscripts for publication. Required qualifications: Ph.D. in a geological or biological science. Salary will be competitive. Application deadline is September 17, 2001, or until candidate is selected. Send an application, curriculum vitae, and the names and addresses of three referees (preferably by e-mail) to: Professor Barun K. Sen Gupta, Department of Geology and Geophysics, Louisiana State University, Ref: Log #0137, Baton Rouge, LA 70803; phone: (225) 578-5984; fax: 225-578-2302; e-mail: barun@geol.lsu.edu. For further information, please write to the same address. LSU IS AN EQUAL OPPORTUNITY/EQUAL ACCESS EMPLOYER.

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TRANSLATION & INFORMATION FOR JAPANESE EARTH SCIENCE. Please visit Earth-J at http://earthj.vis.ne.jp, Email: earthj@mf.vis.ne.jp.

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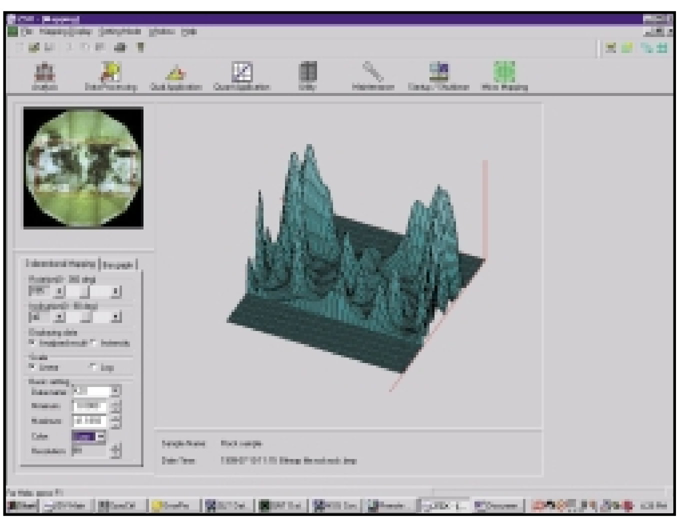

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