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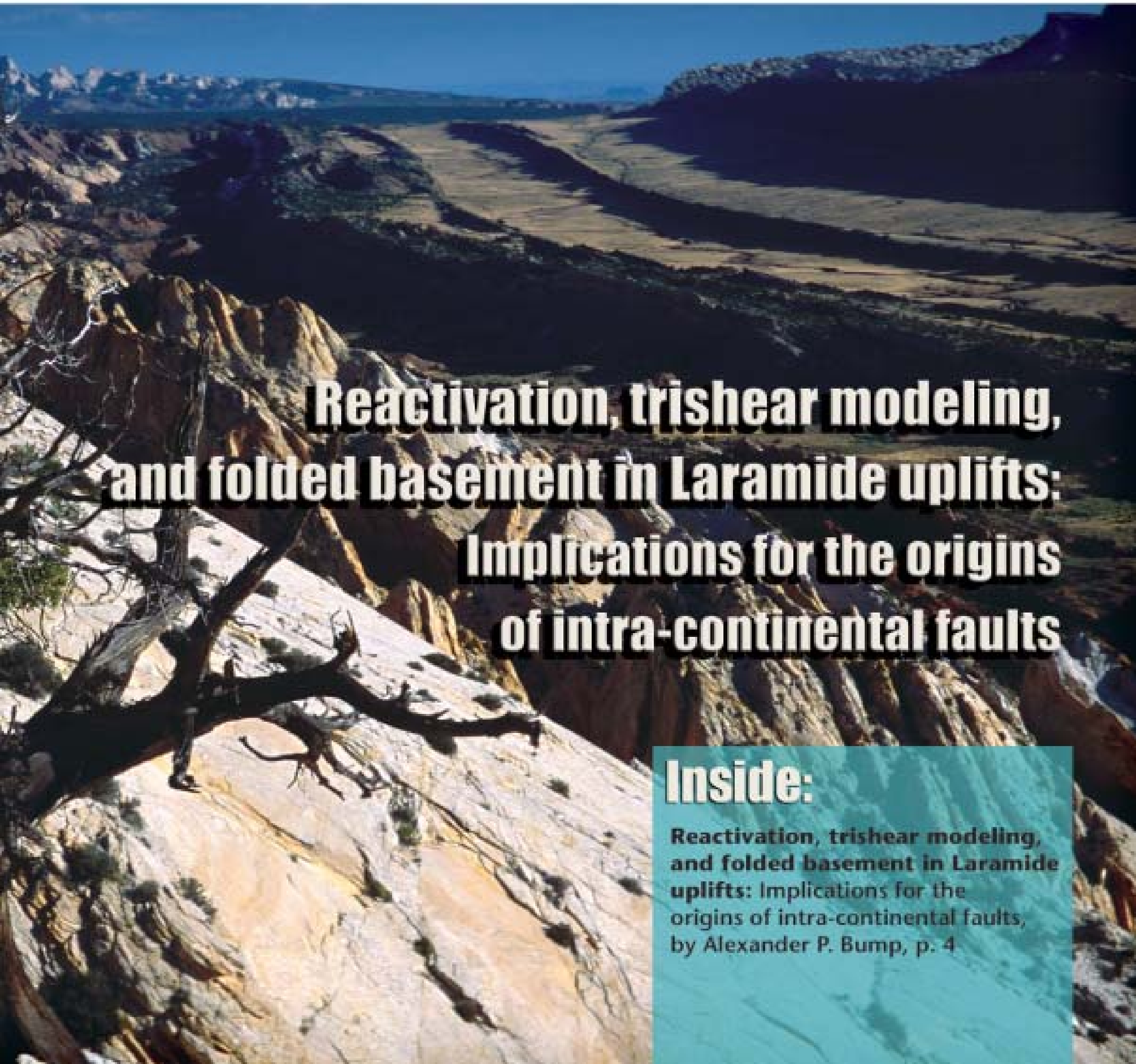

Reactivation, trishear modeling, and folded basement in Laramide uplifts: Implications for the origins of intra-continental faults

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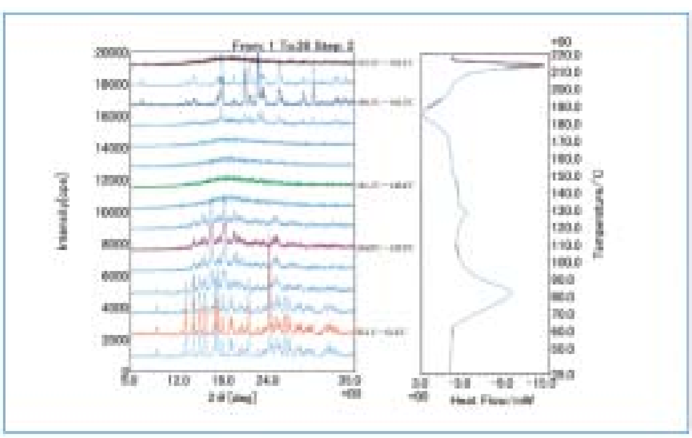

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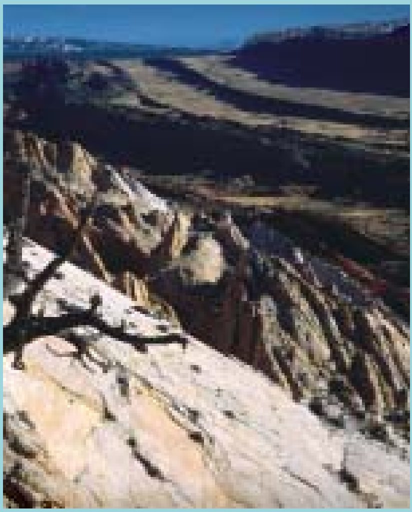
ON THE COVER: View looking north along the steep middle limb of the monoclinal Waterpocket fold, which forms the basis for Capitol Reef National Park. Yellow rocks in the foreground are Jurassic Navajo sandstone. Moving toward the upper right, the first ridge is Jurassic Morrison formation while the second is Cretaceous Dakota sandstone. The upper-rightmost outcrop is flat-lying Cretaceous Mancos shale. The fold is underlain by a reverse fault, the modeled tip of which is located ~200 m beneath the exposures of Dakota sandstone. See "Reactivation, trishear modeling, and folded basement in Laramide uplifts: Implications for the origins of intra-continental faults," by A.P. Bump, p. 4–10.



SCIENCE ARTICLE

Reactivation, trishear modeling, and folded basement in Laramide uplifts: Implications for the origins of intra-continental faults

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ABSTRACT

Laramide uplifts are bounded by reverse faults of enigmatic origin. Two end-member hypotheses have been proposed: (1) they formed during the Laramide orogeny as newly formed contractional features; and (2) they formed as normal faults at some previous time and were reactivated during the Laramide. This paper employs the trishear fault-fold model to test these ideas, based on the premise that, in (1), neoformed faults should propagate from a regional detachment or crustal flaw within the crystalline basement, whereas in (2), reactivated normal faults should begin their Laramide propagation from the base of the Paleozoic cover (i.e., top of basement). Trishear folding takes place entirely ahead of the propagating fault tip, so trishear modeling of fold-fault geometries can be used to evaluate these alternate possibilities. This paper documents 23 uplifts that show a folded basement-cover contact demonstrating that fault propagation began within the basement. Inverse and forward modeling suggest, however, that the faults began propagating only a few kilometers below the basement-cover contact, too shallow for a regional detachment. It is suggested that these faults represent the formation of footwall shortcuts (i.e., lower angle, mechanically easier paths to the surface) to bypass the steep upper sections of reactivated listric faults. This idea unites the two end-member hypotheses, allowing the large-scale map pattern of uplifts to be controlled by reactivated faults at depth while exposing neoformed offshoots of those faults at the surface.

INTRODUCTION

The processes of fault reactivation (Holdsworth et al., 2001) and tectonic inversion (Coward, 1994) of old faults are among the most important issues in continental tectonics. Continental crust, unlike oceanic crust, records the cumulative history of multiple periods of tectonism, and much of continental deformation is focused into large-scale fault networks that are repeatedly reactivated over long time scales. The seismogenic upper crust may be the strongest layer (Jackson, 2002), and hence a stress guide for whole-lithosphere deformation (Axen et al., 1998). To understand a range of seismogenic processes, it is essential to better resolve the interplay between old fault networks and new tectonic stress conditions (Huntoon, 1993; Marshak et al., 2000; Timmons et al., 2001). This paper uses the unique geometries of the Laramide uplifts in the southwestern United States to explore the importance of reactivation versus new fault development in response to Laramide contractional deformation.

The Late Cretaceous–early Tertiary Laramide orogeny has been of particular interest to tectonicists because the horizontal shortening due to plate convergence was expressed within the continental foreland at distances up to twice as far from the plate margin as the more typical and partly contemporaneous Sevier fold-thrust belt (Fig. 1). Style of contractional deformation in the Laramide province is also different from that of the thrust belt, involving a series of fault-bounded, basement-cored uplifts of varying size, orientation, and structural relief. In a few places, such as Rattlesnake Mountain and the Grand Canyon, the uplift-bounding faults are exposed at the surface. In most places, however, they remain blind, either covered by Cenozoic sediments, or expressed at the surface as a monoclinal fault-propagation fold of Paleozoic and Mesozoic strata. Although the geometry and kinematics of some of these faults are relatively well understood, their origin (date of initial rupture) is often difficult to establish. Two end-member hypotheses have been proposed: (1) they formed during the Laramide orogeny (Hamilton, 1988); and (2) they formed at some previous time(s) and were reactivated during the Laramide (Walcott, 1890; Huntoon, 1993; Marshak et al., 2000).

Perhaps the more favored model has been that many, if not most, Laramide faults are reactivated ancient weaknesses, and in a few cases this can be proven directly. For example, Laramide reverse faulting raised Precambrian rift strata along ancient faults in the Uinta Mountains of Utah and the Beltian embayment of Montana. Likewise, Walcott (1890), Huntoon (1993), and Timmons et al. (2001) documented exposures in the Grand Canyon with Precambrian synextensional strata present in the hanging wall of Laramide reverse faults but not in the footwall. Similar evidence for reactivation has also been reported for Laramide faults exposed in the Salt River Canyon in central Arizona (Davis et al., 1981) and exhumed fault blocks in southwestern Montana (Schmidt and Garihan, 1983). Detailed studies of fault zone rocks have also yielded clear evidence of reactivation, showing diachronous deformation at different metamorphic grades (Mitra and Frost, 1981).

These examples are exceptions, however. While many Laramide uplifts offer excellent hanging wall exposure, the footwalls and the uplift-bounding faults are often buried beneath significant thicknesses of syn-orogenic and younger sediments (Tweto, 1979; Love and Christiansen, 1985). Many other Laramide faults never broke the surface and are expressed only as monoclinal fault-propagation folds (Tweto, 1979; Hintze, 1980; Love and Christiansen, 1985). Seismic data often do not have the resolution necessary to document stratigraphic evidence for inversion, and

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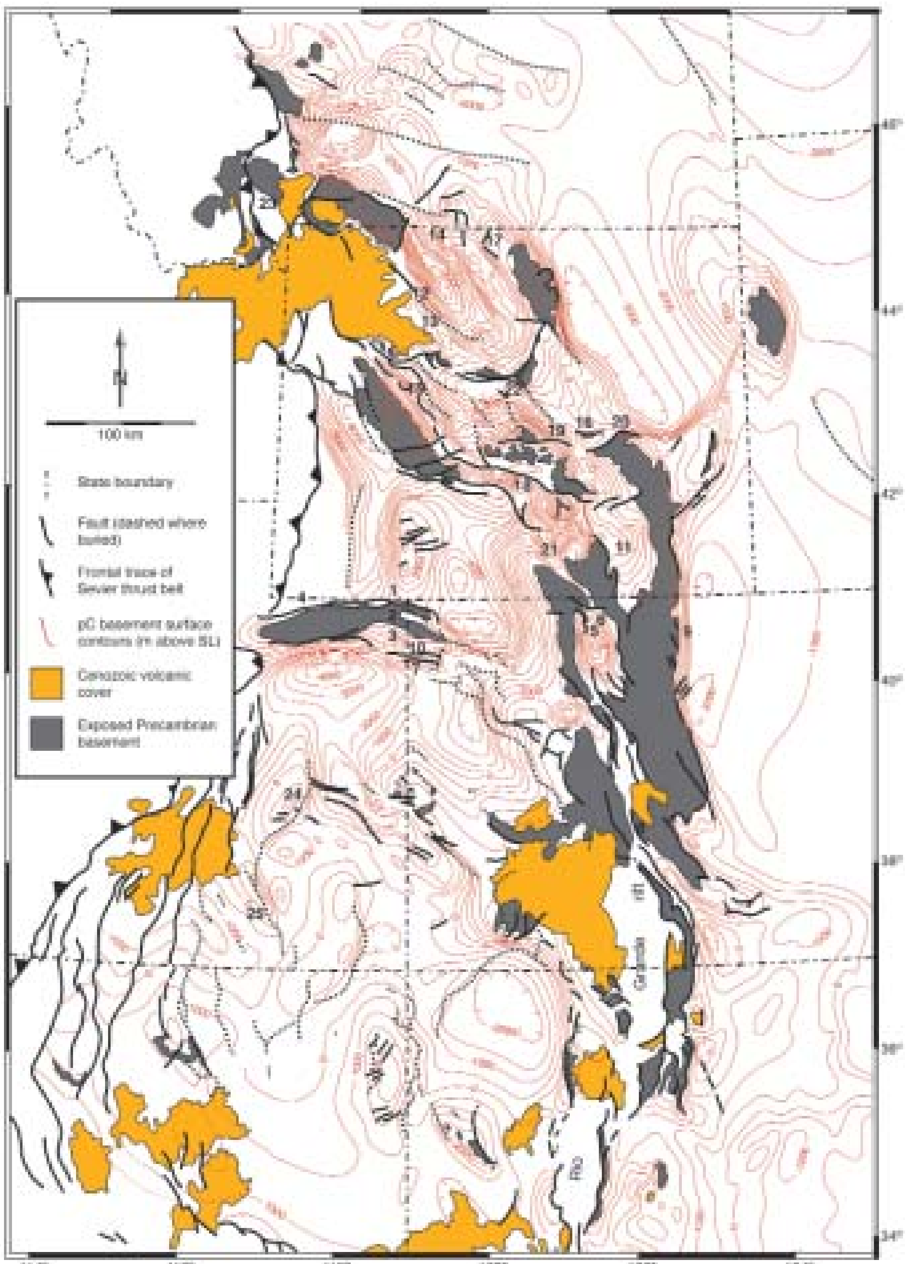

Figure 1. Map of the Laramide orogen (after King, 1969), showing locations of uplifts discussed in the text. Numbers 24 and 25 are the San Rafael Swell and the Circle Cliffs uplifts, respectively. All others are given in Table 1.

boreholes seldom penetrate basement in the footwall, negating the possibility of documenting differences in Precambrian stratigraphy (if present) in the hanging wall and footwall. Thus, for most Laramide faults, the argument for reactivation hinges chiefly on circumstantial evidence. First, Laramide fault strikes show a scatter uncommon in neoformed fault systems such as the extensional faults of the Basin and Range. More specifically, the large-scale map pattern of Laramide faulting is dominated by N-S and NW-SE strikes (Fig. 1) that are similar to those of known Precambrian rifts in the southern Rocky Mountains (Erslev, 1993; Marshak et al., 2000; Timmons et al., 2001). Second, in some cases, Laramide faults parallel nearby Precambrian dikes or shear zones, suggesting that their geometry was governed by associated Precambrian weaknesses (Schmidt and Garihan, 1983). Third, Marshak et al. (2000) pointed out that vergence variations within the Laramide province resemble those of rift provinces, with opposite vergence on either side of the province.

Some authors (Hamilton, 1988; Yin, 1994) have opposed the idea of widespread reactivation, arguing instead that the major uplift-bounding Laramide faults are neoformed features created during the Laramide orogeny. Indeed, most faults show no direct evidence of a pre-Laramide history.

The purpose of this paper is to examine evidence for fault ancestry based on a relatively new criterion: the location of the initial fault tip (Allmendinger and Shaw, 2000; Allmendinger et al., 2003). The initial fault tip location is defined here as the point from which the fault tip began its upward propagation (growth) under Laramide compression. A preexisting fault reactivated in compression could be expected to begin propagating upward from the base of the postorogenic strata (Allmendinger et al., 2003). In the case of the Laramide, that would indicate an initial fault tip depth at the top of the Precambrian, i.e., at the basement-cover contact. Alternatively, a neoformed reverse fault could be expected to do one of two things: either it might propagate upward from a horizontal detachment near the brittle-ductile transition where shear stresses are theoretically highest (Sibson, 1977; Ranalli, 2000), or it might begin with simultaneous up-dip and down-dip propagation from some initial earthquake focus at a flaw or stress concentration in the crust (Allmendinger et al., 2003).

FAULT-PROPAGATION FOLD MODELS

For Laramide faults that began growing in the Late Cretaceous or early Tertiary and are still buried, there is no way to observe the initial tip point directly. However, its location can be inferred through geometric modeling of fold-fault relationships based on structural exposures at the surface and available subsurface information. The key parameter is the propagation to slip (*p/s*) ratio, which describes the distance the fault tip moves (propagates) per unit displacement of the hanging wall. The *p/s* ratio is an inherent feature of all kinematic models of fault-propagation folding, though most treat it only implicitly (Suppe and Medwedeff, 1990; Narr and Suppe, 1994; Mitra and Mount, 1998). The power of the *p/s* ratio lies in its capacity to determine the location of the fault tip prior to fault slip,

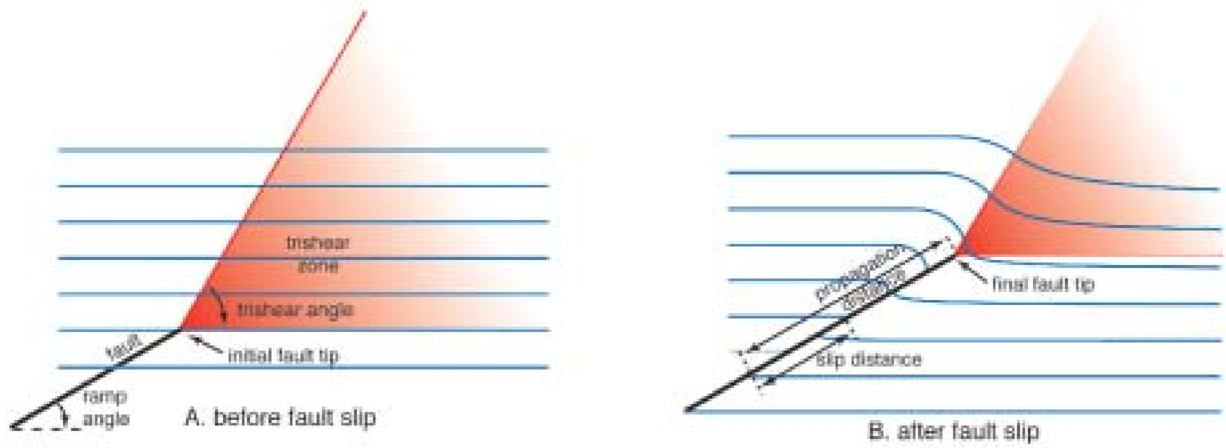

Figure 2. Schematic diagram of the trishear model (Erslev, 1991). Thick black line shows fault plane while red lines define the edges of the active trishear zone. Shading within the trishear zone reflects the intensity of deformation. Horizontal blue lines define stratigraphy. Note that strata below the initial fault tip remain unfolded after slip. Here deformation is distributed evenly across the trishear envelope (center concentration factor = 1).

based only on geometric modeling of the post-slip fold shape (Allmendinger and Shaw, 2000).

To date, the only model to explicitly consider the *p/s* ratio is the trishear model (Erslev, 1991; Hardy and Ford, 1997; Allmendinger, 1998). This model accommodates waning fault slip by folding within a triangular zone, the apex of which is pinned to the fault tip (Fig. 2A). Within this "trishear zone," particle velocities diminish along tie lines perpendicular to the fault, from a maximum in the hanging wall to zero in the footwall. The resulting fold geometry depends on seven variables, including the initial *x* and *y* locations of the fault tip, the fault dip (ramp angle), the total fault slip, the trishear angle, the *p/s* ratio, and the center concentration factor (*ccf*), which determines how folding is distributed within the trishear zone (Fig. 2B; Erslev, 1991; Erslev and Rogers, 1993; Hardy and Ford, 1997; Allmendinger, 1998). Fault dip and the location of the fault tip can often be determined from seismic data, and net slip may be determined from stratigraphic separation across the fault. Of the remaining three variables, *p/s* and *ccf* exert the most important control on fold shape (Allmendinger et al., 2003; E.A. Erslev, 2003, personal commun.). The *p/s* ratio determines how long a given packet of rock remains within the trishear envelope and consequently, how severely that packet is deformed. At low *p/s* values, packets spend a relatively long time within the trishear envelope and may accumulate very high strains. At higher *p/s* values, a given packet passes quickly through the trishear zone and therefore emerges relatively unstrained. Similarly, a high *ccf* will concentrate deformation in the center of the trishear zone, resulting in a local zone of highly strained rock.

For the purposes of this paper, the most important point is that all trishear folding occurs ahead of the initial location of the fault tip. The presence or absence of folding adjacent to the fault at a given horizon can thus be used as a clue to whether the fault began propagation from above or below that horizon. In the present case, it can be used to determine whether a given fault began propagation at or below the basement-cover contact.

LARAMIDE BASEMENT GEOMETRY

In the cases of the largest uplifts, such as the Colorado Front Range, erosion has removed the sedimentary cover and the uppermost basement, rendering it difficult or impossible to establish the geometry of the basement surface near the bounding faults. Outcrop exposures and seismic images of smaller uplifts, however, reveal a range of forms.

In some of these, the basement unconformity is clearly an undeformed, planar surface. Careful surveys of extensive exposures on Rattlesnake Mountain in northwest Wyoming and the Big Thompson anticline on the eastern edge of the Colorado Front Range both indicate that the basement surface is planar, and dike orientations show no sign of rotation at distances greater than 100 m from the fault (Stearns, 1978; Erslev and Rogers, 1993; Narr, 1993). Published seismic surveys reveal a number of other examples (Gries and Dyer, 1985; Stone, 1993a).

In other cases, surface exposures, seismic lines, and well-controlled cross sections clearly show that the basement surface is folded. (Here the term fold is used only to denote a curvature of the basement-cover contact, regardless of whether that curvature is achieved by flexural slip on subhorizontal foliation, distributed faulting, or some other means.) This folding occurs over a half wavelength of 100 m to 5 km (Table 1), where half wavelength is defined as the horizontal distance from flat-lying hanging wall to flat-lying footwall, or fault if the footwall is not imaged. Typical values are 500–1000 m. Within the fold, the basement surface may reach dips of 90° or even 75° overturned. At the other extreme, a few uplifts display basement surfaces that never exceed 10° of dip. Most fall in the range of 30°–60° (Table 1).

It is important to point out that there are several possible mechanisms for folding the basement surface, not all of them requiring an initial fault tip below that surface. First, damage incurred during fault slip might result in local curvature of the basement surface adjacent to the fault. In the cases described above, however, the relatively large horizontal scale of the

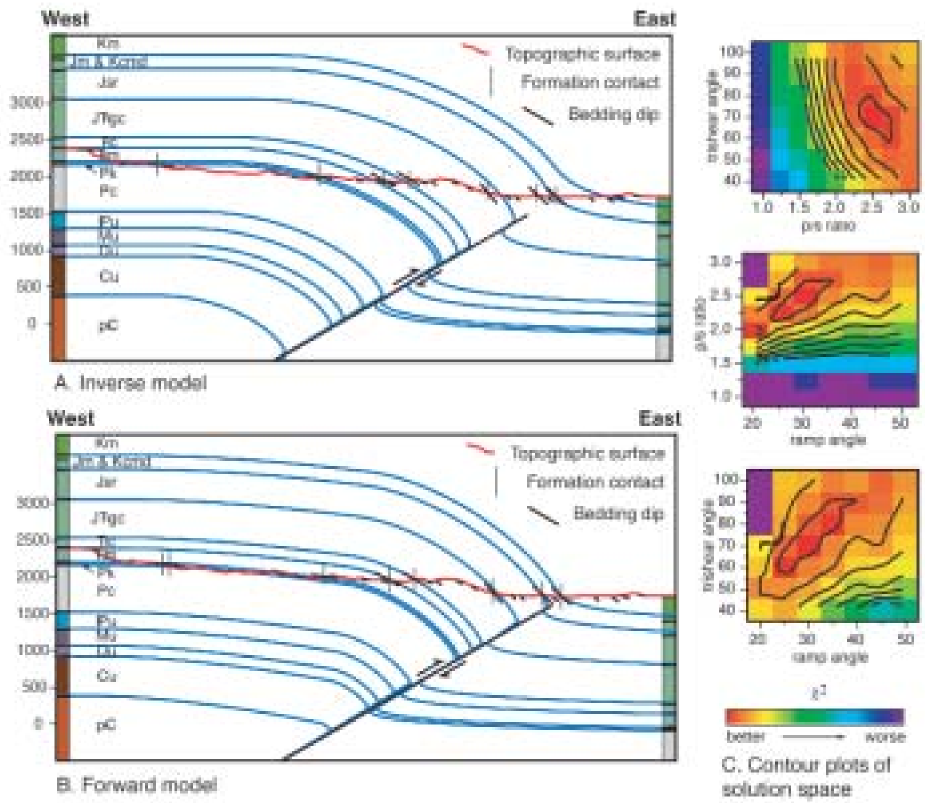

Figure 3. Inverse (A) and forward (B) models of the Waterpocket fold, based on mapping of a surface transect and regional thicknesses of undeformed strata. Elevations are in meters above sea level and cross sections are drawn without vertical exaggeration. Color bar on each side of cross sections shows ages of strata and vertical contact locations based on well logs and projection from the surface. **C:** Contour plots of errors in inverse modeling. Plots show two-dimensional slices through the three-dimensional matrix of error values produced by grid-searching for a best-fit over the specified ranges. Best fit is based on a chi-squared statistical analysis (Allmendinger, 1998). Note that all plots show well-defined regions of best fit.

deformation argues against this. Second, the basement surface may fold as a passive response to bends in the underlying fault (fault bend folding). Nearly all of the examples cited in Table 1 display some fault curvature, so this mechanism may well be responsible for some of the folding described above. However, the fault bends are generally quite small relative to the magnitude of basement folding. Finally, folding of the basement surface could be produced by buckling as a result of a "room problem" set up by horizontal shortening on a concave-upward fault (Coward, 1994). In such cases, however, folding is restricted entirely to the hanging wall, whereas many of the examples cited in Table 1 show folding of the basement surface in both hanging wall and footwall. For these reasons, it seems likely that fault-propagation folding created much of the observed basement curvature, a conclusion also reached by Stone (1993a) based on study of relations between fold shape and net fault slip.

TRISHEAR MODELING

Accepting that folding of the basement surface may reflect Laramide fault propagation from a point below that surface, a key question is how far below that surface did fault propagation begin. An estimate may be obtained from accurate trishear modeling of the structures in question. Current trishear modeling software allows an inverse grid search wherein each trishear model parameter is systematically and independently varied over a user-specified range while the program searches for a best-fit model. Although powerful, these programs are best applied to relatively simple structures and are not capable of handling some of the complexities commonly observed in the field, such as multiple fault strands, fault bends, or oblique slip.

One of the best-fitting models I have produced to date is for the Waterpocket monocline, which forms the steep eastern limb of the Circle Cliffs uplift in southern Utah (Fig. 1). Inverse modeling based on well logs and surficial exposures gives a reasonably good, though imperfect fit to the data (Fig. 3A). The principal problem is that the modeled fold wavelength is `too short, lacking the prolonged, gentle upper-limb dip observed in the field, and shallowing too quickly near the lower hinge. Forward modeling offers the possibility of improving the fit by allowing both spatial and temporal heterogeneity in trishear parameters. In the temporal case, the *p/s* ratio may be varied in accordance with the mechanical stratigraphy through which the fault propagates (Allmendinger, 1998). For the Waterpocket fold, initially rapid propagation (*p/s* = 6.0) through stiff basement rocks followed by slower propagation (*p/s* = 2.1) through less competent sedimentary rocks can produce the observed broad-wavelength fold with long, gently dipping upper and lower limbs and sharply steeper middle limb. Similar results may also be achieved through spatial heterogeneity, that is, by allowing folding to be concentrated toward the middle of the trishear zone, similar to deformation within a ductile shear zone (Erslev, 1991). The best-fit forward model is an excellent match for the data (Fig. 3B) and requires an initial fault tip 2.3 km below the basement-cover contact.

For other uplifts listed in Table 1, inverse modeling is limited by the complexity of observed fault geometries. Taking only those examples where both hanging wall and footwall are imaged and where >90% of the displacement is concentrated on a single fault leaves 15 possibilities for inversion. Of these, one is a seismic time section and is rejected for having too little true depth control. Three more have significantly curved faults and are also rejected. Of the remaining 11, only three have yielded reasonable inverse solutions. The eight failures are probably due to a combination of oblique slip and geometric complexities, including fault bends, problems in pinpointing the current location of the fault tip, and accurately migrating seismic data to show true depth.

Results for the three reasonable inverse models are quite varied. The bounding fault on Casper Mountain appears to have

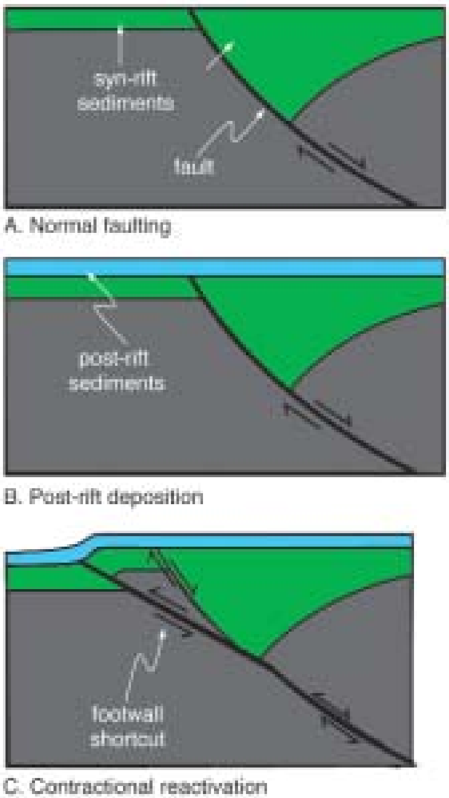

Figure 4. Schematic diagram of the creation of a listric normal fault (top) that is later reactivated in compression (bottom), creating a footwall shortcut. Pre-extensional rocks are shown in dark gray.

nucleated only 400–600 m below the basement surface, while the Island Park fault bounding the Uinta uplift appears to have begun propagation from a point 11 km below the basement surface. This is very close to the 12 km deep forethrust-backthrust junction shown by Stone (1993b) in a cross section of the Uintas. The fault underlying the Willow Creek anticline is in the middle, with an initial tip ~6 km below the basement surface (Fig. 3). Allmendinger's (1998) inversion of the Rangely anticline in Colorado shows an initial fault tip ~4 km below the basement surface, and an initial fault tip depth of 0.6 km below the basement surface for the San Rafael monocline in central Utah has also been found (personal observations; G.H. Davis, 2002, personal commun.).

The question arises as to whether any of these solutions are unique. Contour plots of the inverse modeling results (Fig. 3) suggest that the solution space is small and in controlled experiments with trishear inversions, Allmendinger et al. (2003) have found no local error minima in the inversion space that might be confused with the global minimum (Fig. 3C). That said, experience with the trishear modeling software shows that inverse models can almost always be refined and improved through forward modeling (Allmendinger et al., 2003) and the present models are probably no different. Furthermore, common sense suggests that with seven independently variable parameters, there are probably other solutions that satisfy the data. At present, the models described above are best-fits, but future efforts and continued development of trishear software may lead to further refinements.

DISCUSSION AND CONCLUSIONS

The evidence described above suggests that there is a wide spectrum of fault origins. Some uplifts, such as Rattlesnake Mountain and the Big Thompson anticline, show no evidence for deformation of the basement-cover contact and thus are probably bounded by ancient faults reactivated under Laramide compression. Many others (Table 1) do show deformation of the basement-cover contact. These appear to represent cases in which the bounding faults began propagation from deeper in the crust. Some of these, such as the Island Park fault, are probably entirely neoformed faults that branch off possibly older ones in the mid crust, forming as backthrusts in response to Laramide contraction. These end members are readily understood.

Several other faults, however, appear to have begun propagation from a few kilometers below the basement surface. The origin of these faults is less clear, as there is no obvious reason for a fault to begin propagation there. It is possible that they represent out-of-the-syncline thrusts (Brown, 1993), formed during the creation of larger folds. However, this requires that the folds described here be located in the proximal footwall of a larger fold, which is not true in general. It is also possible that these faults nucleated around point weaknesses within the basement, perhaps flaws or stress concentrators (Eisenstadt and DePaor, 1987; Allmendinger et al., 2003), though there is no clear reason to expect them at this crustal level.

Instead, I propose that they are footwall shortcuts (McClay, 1989; Coward, 1994), created by the compressional inversion of upward-steepening normal faults (Fig. 4). Almost all normal faults show some degree of concave-upward curvature (Coward, 1994). At the topographic surface, failure is often tensile or hybrid tensile-shear and the resulting fault dips are commonly near vertical. Dips decrease toward 60° at 3–4 km depth due to the change in failure mechanism from hybrid to shear fracturing (Walsh and Watterson, 1988). Proffet (1977) and Hamblin (1965) documented Basin and Range faults with dips that decreased at a rate of 0.5°–2° per 100 m of depth at near-surface levels. For crustal-scale faults, dips must decrease further toward 45° at ~10 km depth as the host rock rheology changes from brittle to plastic (Walsh and Watterson, 1988). Histograms showing numbers of seismically active normal faults versus fault dip typically exhibit strong peaks at 45° (Thatcher and Hill, 1991; Collettini and Sibson, 2001). Finally, if the fault is detached at some deeper level, then it must eventually bend toward horizontal. Seismic activity has been documented on normal faults with dips as low as 30° (Collettini and Sibson, 2001).

The structural level of the current basement surface with respect to Precambrian normal faults is uncertain. The Grand and Salt River Canyons expose Precambrian normal faults dipping 60°–85° at the basement-cover contact (Davis et al., 1981; Huntoon, 1993), which suggests a shallow structural level. In the Grand Canyon, the hanging walls are composed of syn-rift sedimentary rocks (Timmons et al., 2001), also consistent with ideas suggesting that the current basement surface may not have been far below the syn-extensional topographic surface. On the other hand, Ar-Ar evidence suggests that >6 km of rock was eroded between widespread extensional faulting at 800 and 1100 Ma and Cambrian deposition (Heizler et al., 2000), which would indicate that current exposures represent deeper levels of the Precambrian normal fault systems (Marshak et al., 2000) that were reactivated in the Laramide. In either case, however, the exposed faults are steep where they intersect the basement unconformity.

Under horizontal compression, it is easiest to reactivate faults dipping 25°–40° (Byerlee, 1978; Ranalli, 2000). At higher dips, it is often easier to create a new, lower-angle fault than to reactivate the old, steep one. Dip catalogs of seismically

TABLE 1. EXAMPLES OF FOLDED BASEMENT-COVER CONTACT

North flank, Uinta Mountains	4	2.3	115	85	cross section[1,2]	Gries, 1983
Anticline in North McCallum field	5	0.6	160	10	seismic line[4]	Lange and Wellborn, 1985
Anticline in Battleship field	6	0.3	165	10	seismic line[4]	Lange and Wellborn, 1985
Rangely anticline	7	0.7	80	75	cross section[1,2]	Mitra and Mount, 1998
Twin Mountain anticline	8	0.1	70	85*	cross section[5]	Schmidt et al., 1993
Big Thompson anticline	9	0.5	75	90	cross section[5,7]	Narr and Suppe, 1994
Willow Creek anticline	10	1.0	100	80	cross section[1]	Narr and Suppe, 1994
Laramie basin	11	0.8	145	21	seismic line[3]	Stone, 1993a
Oregon Basin thrust	12	4.0	130	50	seismic line[3]	Stone, 1993a
Pitchfork anticline	13	0.3	115	35	cross section[1,2]	Stone, 1993a
Elk Basin anticline	14	0.4	100	50	cross section[1,2]	Stone, 1993a
Maverick Springs anticline	15	4.0	60	40	cross section[2,5]	Stone, 1993a
Small anticline on Casper Mountain	16	0.1	105	90	cross section[6]	Narr, 1993
Five Springs thrust, Bighorn Mountains	17	0.7	85	65	cross section[6]	Narr and Suppe, 1994; Wise and Obi, 1992
Rawlins uplift	18	>1.3	70	75*	cross section	Gries, 1983
Granite Mountains	19	2.5	150	34	cross section	Gries, 1983
LaPrele anticline	20	0.6	70	90	cross section[5]	Schmidt et al., 1993
Sheephead Mountain anticline	21	0.1	60	75*	cross section[5]	Chase et al., 1993
Madden anticline	22	5.0	160	10	cross section[1,2]	Ray and Keefer, 1985
London Hills anticline	23	0.5	110	90	cross section[5]	Chase et al., 1993

Note: Asterisk indicates overturned; 1—seismic control; 2—well control; 3—time section; 4—depth section; 5—down-plunge projection; 6—surface control only; 7—gravity control.

active reverse faults typically show a cut off at 60° (Sibson and Xie, 1998; Collettini and Sibson, 2001). Upward-steepening normal faults are thus susceptible to pure reverse-sense reactivation only where they dip less than ~60°, i.e., in their lower extents, at depths >3–4 km beneath the contemporary topographic surface. The upper, steep portion is difficult or impossible to reactivate in pure reverse motion which often leads to the creation of one or more "footwall shortcuts," i.e., splays that branch off the old fault and form new, lower angle routes to the surface, bypassing the steep segment of the original fault (Fig. 4; McClay, 1989; Coward, 1994). These may be unequivocally identified if the abandoned portion of the fault retains normal-sense offset whereas the new splay shows reverse offset. The hanging wall may also include a half graben of older sedimentary rocks and/or an ancient shear zone of steeper dip than the uplift-bounding fault.

In the spirit of Davis (1926) and Wise (1963), this is both a hypothesis to be tested and an attractive idea as it offers a means to unify the end-member interpretations. The scatter in Laramide fault strikes may well reflect tectonic inheritance. Marshak et al. (2000) presented a compelling comparison of the large-scale Laramide fault geometry to that of rift systems exposed in the southern Rockies, and Timmons et al. (2001) documented multiple episodes of Precambrian extensional faulting. At the same time, the fact remains that relatively few Laramide faults show unequivocal evidence of reactivation. This work suggests that ancient faults can be reactivated at depth but form new paths to the surface. The large-scale geometry of the orogen may thus be controlled by ancient structures but the surficially exposed segments of the faults need not be ancient themselves.

In the broader picture, this work suggests that there is an entire spectrum of faults ranging from 100% neoformed to 100% reactivated. Many, perhaps even a majority, of intracontinental faults lie between these end members. Under compressive stress, weak sections of existing faults may localize the initial failure. Bends or other strength heterogeneities in those faults, however, may necessitate the growth of new, more favorably oriented segments if slip continues. Perhaps the resulting fault, such as might typify the Laramide or any other zone of intracratonic shortening, is thus a hybrid of linked ancient and neoformed segments and exhibits characteristics of both.

ACKNOWLEDGMENTS

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UPCOMING DEADLINES

Nominations for the **John C. Frye Environmental Geology Award*** are due March 31, 2003. Nominations for the following national awards are due April 30, 2003: **William T. Pecora Award, National Medal of Science, Vannevar Bush Award,** and **Alan T. Waterman Award.** Details and nomination procedures for these awards are posted at www.geosociety.org. Go to "Grants, Awards & Medals." You may also contact Program Officer, Grants, Awards, and Medals, (303) 357-1037, awards@geosociety.org, P.O. Box 9140, Boulder, CO 80301-9140, or see the October 2002 issue of *GSA Today*.

For details on the following awards, see the January 2003 issue of *GSA Today* or visit www.geosociety.org. Go to "Sections and Divisions."

- **Don J. Easterbrook Distinguished Scientist Award,* Quaternary Geology and Geomorphology Division:** Nominations due by April 1, 2003, to J. Steven Kite, Dept. of Geology & Geography, West Virginia University, 425 White Hall, Morgantown, WV 26506-6300, (304) 293-5603, ext. 4330, jkite@wvu.edu.
- **Farouk El-Baz Award for Desert Research,* Quaternary Geology and Geomorphology Division:** Nominations due by April 1, 2003, to Ellen Wohl, Dept. of Earth Resources, Colorado State University, Fort Collins, CO 80523-1482, (970) 491-5298, ellenw@cnr.colostate.edu.

*Funds supporting these awards are administered by the GSA Foundation.

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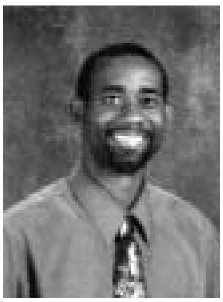
Geoscience Potential in a Middle School Classroom—

Daniel Cabrol, Wheatland Middle School, Lancaster, Pennsylvania

Carol B. de Wet, *on behalf of the GSA Minorities and Women in the Geosciences Committee*



Daniel Cabrol

This is the first of a series of articles from the Minority and Women in Geoscience Committee designed to highlight successful programs and initiatives that promote diversity in the geosciences. The committee hopes that these examples can spawn similar programs around the nation.

Daniel Cabrol exemplifies the science teacher who cares for much more than just good science for its own sake. He sees it as a way to reach kids from all types of backgrounds and abilities. Cabrol has used his scientific knowledge to teach and work with young people from alternative schools and an urban-suburban middle school.

But how did a child growing up in rural Haiti end up inspiring middle school students in Pennsylvania to understand the stratigraphy of the American Grand Canyon? Cabrol's father was an orthopedic surgeon while he was in Haiti, and drove a taxi in New York City when he was in the United States. Daniel Cabrol was born in New York, but soon returned with his family to Haiti. Because he could speak English, he enrolled in the local missionary school where he had access to information about colleges and universities in the United States. His U.S. citizenship enabled him to study at Messiah College in southeastern Pennsylvania. He picked Messiah College because he wanted some cold weather and a small liberal arts school.

After college, he had planned to go into community health and become a physician like his father, but decided that a teaching certificate would get him out into an environment where he could reach many more young people more quickly. He received his teaching certification after a year and a half from Millersville University in Millersville, Pennsylvania, and started substitute teaching and working with school dropouts. Soon he was working at the Buehrle Alternative School to help kids get back into regular classrooms through an eight-week reentry program. He then went to teach at a charter school started by the local Hispanic community. The school emphasizes career placement opportunities for students who are struggling with speaking English as a second language as well as other academic challenges. Cabrol speaks English, Creole, French, and Spanish, and so can communicate with a range of students in a manner that puts them at ease.

The move to teaching middle school science was not as daunting for Cabrol as it might be for many others. He takes the middle-school-age mischief in stride and has quickly earned the respect and admiration of his students. They find him challenging but approachable, and this combination is a winning strategy for getting them to engage with science. Cabrol likes to start off with earth science as a way to demonstrate to students how applicable and visual scientific information can be. He breaks down the lessons into observations and then how we make interpretations from those findings. He pushes the students to ask what, why, and how as they approach a topic. His approach is always hands-on and inquiry-based, which allows students to approach science in a way that values and uses what they already know.

The student body in Cabrol's classes is a mixture of Hispanic, African American, and white children from a wide range of socioeconomic backgrounds. The school draws on urban to suburban neighborhoods. Cabrol's success as a teacher has made him an integral part of the Wheatland Middle School faculty while only in his second year there. He is the kind of earth science teacher the geosciences would like to see more of since he generates such enthusiasm for the field. Hopefully, this will result in a new generation of talented and diverse geoscientists.

The purpose of the Minorities and Women in the Geosciences Committee (www.geosociety.org/aboutus/commtees/c-minority.htm) is to stimulate recruitment and promote positive career development of ethnic minorities and women in the geoscience professions.

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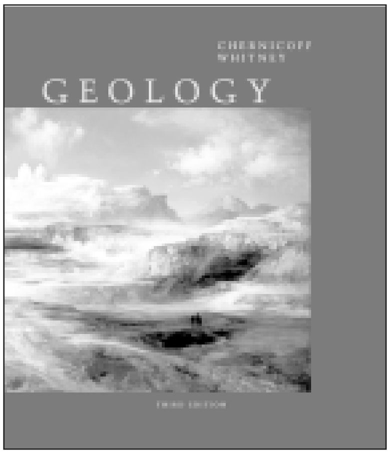

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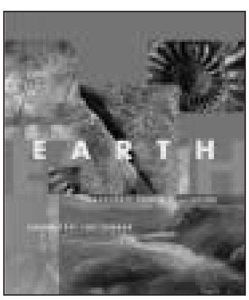

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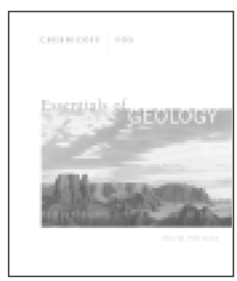

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GSA Announces New GSA BULLETIN Science Co-Editor

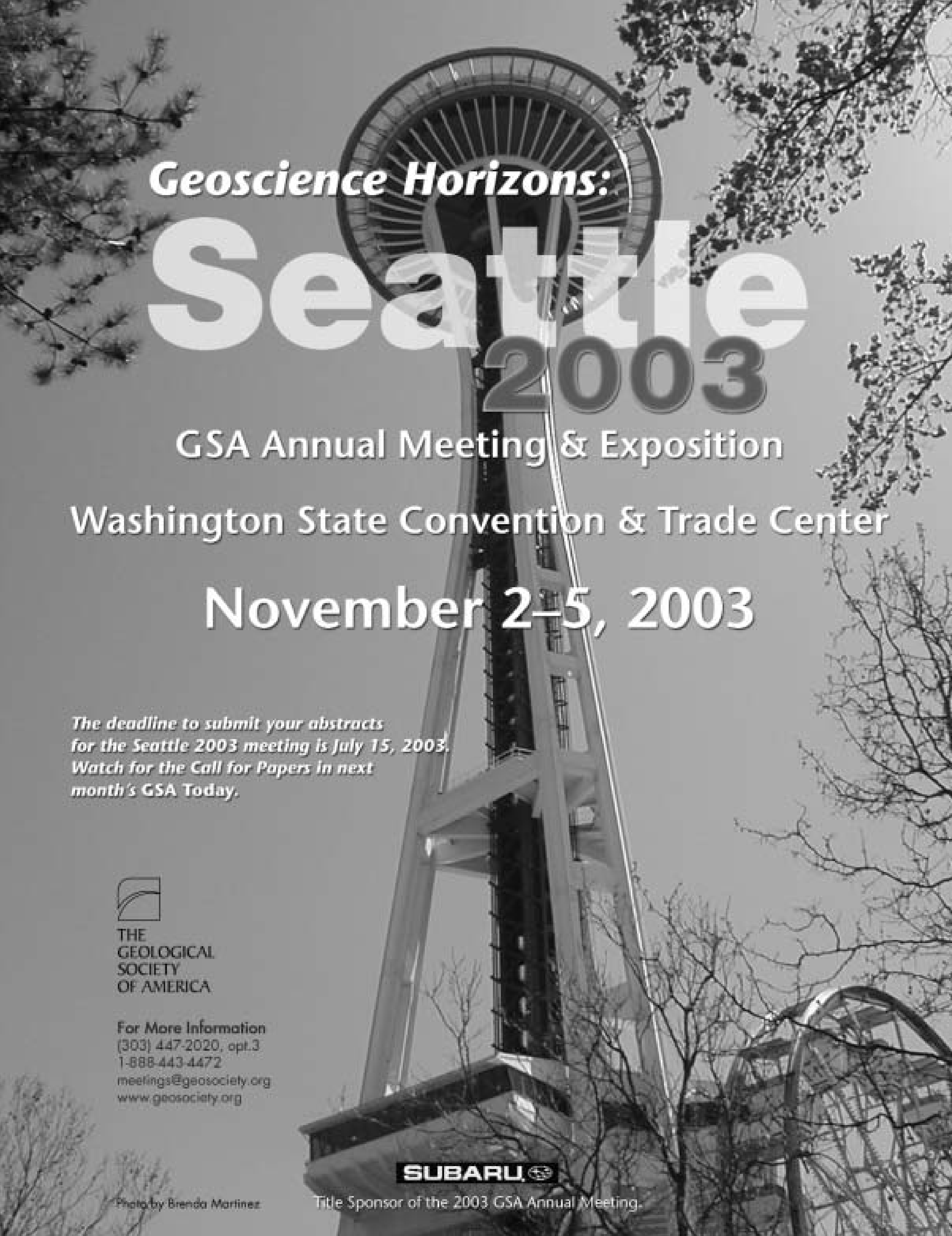
Yildirim Dilek of Miami University joined Peter Copeland (University of Houston) as science co-editor for *GSA Bulletin* in February.

Dilek's expertise is in structural geology and tectonics, and his research projects take him to the western U.S. Cordilleras, the Norwegian Caledonides, and the Alpine-Himalayan orogenic belt to investigate various problems of collisional and extensional tectonics. His strong interest in the evolution of oceanic lithosphere through Earth's history has prompted him to explore ophiolites on several continents and modern oceanic crust near divergent plate boundaries in ocean basins through the Ocean Drilling Program (ODP).

"Participation in ODP projects as a shipboard scientist was an immense learning experience," Dilek says. "The multidisciplinary nature of ODP science utilizes the great synergy among international scientists and their institutions and has helped us make significant advances in marine geology and geophysics and oceanography. I believe that some of the most important questions regarding the formation and evolution of oceanic lithosphere have been addressed by the mutual integration of data, observations, and models derived from systematic studies of ocean basins and on-land investigations of ophiolites through the continuous interactions among the scientific communities. Similarly, deep drilling into the continental crust through multi-national efforts, as presently done in the People's Republic of China, reveals significant new information on crustal processes and the nature of deep biosphere, and it is crucial to disseminate the exciting new results of these interdisciplinary projects to the broader earth sciences community in a timely fashion."

Dilek considers *GSA Bulletin* a premier geoscience journal providing an ideal forum for scientific inquiry and discussion. "*Bulletin* has a unique niche in our science as the top geoscience journal of longer articles, which reflect the current research initiatives, priorities, and developments," he says. "I am looking forward to working with the members of our international scientific community to steer the *Bulletin* to become even more diverse in its scientific and geographic coverage crossing the conventional boundaries of earth sciences by publishing interesting papers that are process-oriented, contemporary, interdisciplinary, and of international interest."

Yildirim Dilek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What is GSA's GeoCorps Program?

Julie Sexton, *Program Officer*

Through the GeoCorps America Program, GSA places all levels of geoscientists—college students, professionals, and retirees—in temporary summer internship positions with the National Park Service, the USDA Forest Service, and other public lands. The projects that participants conduct are in research, resource management, interpretation, and education. For example, participants develop and present interpretive and educational programs for visitors, excavate and prepare fossil specimens, conduct stream surveys and watershed assessments, monitor glacier movement, assess soil compaction and trail conditions, and map and interpret geologic features. Participants receive a stipend and housing (or housing allowance) during their assignment.

The program began in 1997, when GSA partnered with the National Park Service to place two participants in national parks. In 2000, GSA expanded its partnership to include the USDA Forest Service. In that year, GSA placed four participants in positions with the Forest Service and 12 in positions with the Park Service. In 2002, GSA placed 15 participants in positions with the Forest Service and 19 in positions with the Park Service. Since the program's inception in 1997, there have been 135 GeoCorps America participants.

The need for people with geoscience expertise on America's public lands is great. The Park Service and Forest Service have resource management, education, and research projects that require geoscience expertise, but these organizations do not have enough staff to conduct these projects. For example, the Park Service employs approximately 50 geoscientists to help in education, resource management, and research projects in the 387 Park Service units. The Forest Service employs 130 geologists to help manage 192 million acres of public land. With so few geoscientists working for the Park Service and Forest Service, significant education opportunities are lost and needed geoscience projects are not conducted.

The GeoCorps America Program can supply the Park Service and Forest Service with the expertise to carry out these geoscience projects. GSA has a network of geoscience members throughout the United States and strong partnerships with other geoscience organizations. GSA's members represent a broad range of technical and scientific skills from a broad range of geoscience disciplines and experience.

Here's How You Can Help

The program is funded by individual donations, corporate sponsors, and partners. Your contribution is vital in order to:

- increase the number of geoscientists working on public lands;
- raise the public's knowledge and awareness of the value of geoscience resources;
- encourage the participation of minorities and women in geoscience careers;
- enhance resource managers' and policy makers' geoscience knowledge;
- provide hands-on experience for students;
- instill a public service ethic in current and future geoscientists; and
- offer geoscientists opportunities to share their knowledge and learn new skills.

A GeoCorps America Foundation Trustee Committee was recently formed to address the financial needs of the program.

continued on p. 17

continued from p. 16

The committee will raise money for yearly operating expenses, but it will also work to build a GeoCorps endowment. Your contributions can help the GeoCorps America Foundation Trustee Committee in its effort to fund this vital GSA outreach program.

GSA and the GSA Foundation Thank the Partners and Sponsors of the GeoCorps America Program

- GSA Foundation: GeoCorps Fund and John F. Mann Fund
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- USDA Forest Service

Most memorable early geologic experience

Loading dynamite into drill holes of Orphan Boy Mine, Alma, Colorado, 1949, and hearing thuds of successive blasts after descending to safety at a lower level.

—Donald E. Hattin

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and follow the directions.

ROCK STARS

Charles Frederick Hartt—A Pioneer of Brazilian Geology

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Figure 1. Charles Frederick Hartt, a self-portrait. (Department of Earth and Atmospheric Sciences, Cornell University.)

Introduction

With today's mechanical and computer-aided tools, it is easy to forget that 100 years ago geological work was accomplished on foot or from the backs of animals, using only great determination, a hammer, and a compass. Now relatively unknown north of the equator, Charles Frederick Hartt was a celebrity in his day (*The Daily Graphic: New York* devoted a full page to his obituary) and was one of the great explorer-geologists of the 19th century. He is best remembered for his work in Brazil. In 1875, he founded Comissão Geológica do Império do Brasil, the first countrywide geological survey.

Hartt was born in Fredericton, New Brunswick, on August 23, 1840, but grew up and was educated in Wolfville, Nova Scotia. Hartt's interest in geology started at age 10 or 11 when he began working for a professor at Acadia College, where he had his first field experiences. Eventually, Hartt received his B.A. (1860) and M.A. (1863) from Acadia College.

From immigrants in Wolfville, young Hartt discovered languages such as Italian and Gaelic, and a local shoemaker taught him Portuguese. Hartt was a remarkable linguist who could read ten or more languages, and he was fluent in five. He learned several Brazilian native languages and was preparing a dictionary of modern Tupí when he died.

From Student to Professional

His family moved to Saint John, New Brunswick, in the 1860s, and Hartt, then just 24, published a paper about a gold deposit at Corbitt's Mills (Nova Scotia) in which he disagreed with Roderick Murchison's theory of gold formation. Perhaps his most important discovery came at the Fern Ledges near Saint John. In these beds, then considered Devonian in age (actually Carboniferous), Hartt unearthed the oldest insect fossils of the 1860s. Eventually, he came to the attention of Louis Agassiz, famous for his theory of continental glaciation and founder of the Museum of Comparative Zoology (1860), associated with Harvard University.

Agassiz and the Thayer Expedition

In 1865, Hartt was one of two geologists chosen to accompany Agassiz to Brazil on the Thayer Expedition, funded by Nathaniel Thayer, a benefactor and trustee of the museum. On this trip, Agassiz sought evidence of Pleistocene glaciation at sea level in the tropics that would have destroyed all land life and required a Divine recreation, thus refuting Darwin's ideas on the transmutation of species. Hartt was not totally convinced that what he was seeing was truly glacial drift and not just the result of intense weathering. At first he switched from one interpretation to the other until the evidence forced him to break with Agassiz. In the early 1870s, Hartt announced publicly that Agassiz's glacial drift was simply the result of bedrock weathering. This disagreement was really remarkable, for Hartt was challenging not only an important person of the day, but also his mentor and friend.

This first trip to Brazil struck a responsive chord within Hartt, perhaps prompted by learning Portuguese as a child, or his strong desire to succeed, or just the lure of being able to explore the geology of such a large unknown area. Nevertheless, Hartt's attraction to Brazil later proved stronger than his love for his wife and family.

Hartt and Cornell University

After his return from the Thayer Expedition, Hartt established himself as a lecturer in New York City and became acquainted with José Carlos Rodrigues, the founder and editor of *O Novo Mundo*, a local Portuguese newspaper who may have supported Hartt's solo trip back to Brazil in mid-1867 to study the southernmost coral reefs in the Atlantic at the Abrolhos Islands, work Hartt later published in *The American Naturalist*. Hartt's work in Brazil inspired his student, John C. Branner, later the president of Stanford University, to study the eastern shorelines of Brazil. In the resulting monograph, Branner described occurrences of beach-rock, cemented beach sands, along 1000 miles of shoreline. These works of Hartt and Branner still have value in reef studies.

Before their disagreement, Agassiz had recommended Hartt for the position of inaugural professor of geology at the recently founded Cornell University in Ithaca, New York. Hartt accepted the challenge, and with a secure academic position, he married Lucy Lynde in December 1868.

While Hartt was organizing the department, he began raising funds to lead another expedition to Brazil. The results of the Thayer Expedition and his solo journey were published in 1870 as *Geology and Physical Geography of Brazil...*, one of a few such works in English about Brazilian geology. Although it received mixed reviews, it did boost his reputation, and in 1870, Hartt mounted his own Cornell expedition, the first of two Morgan Expeditions, named for Colonel Edwin P. Morgan, the major underwriter. Within a few months of his return from the trip, Hartt and one of the students, Orville A. Derby, were off on a second Morgan

Expedition. In a newspaper article (*New York Daily Tribune*, December 6, 1870) he wrote of the great adventure:

> The river water does not cool much at night, and in the morning I usually found a difference of 15° [F.] between it and the air. It steamed like a hot bath, and felt hot to the body. I found a bath most invigorating soon after sunset, when the air had become cool. A good rubbing, some vigorous exercise, or a cup of coffee warmed one up, and one slept on his sand pillow as comfortably as possible.

On the first of these expeditions, Hartt and his group, headquartered at Pará, explored the geology of the Lower Amazonas, where the local government even provided the Cornell party with a small steamer. But, as he described in an expedition report, travel on land was not so easy:

> The journey [to the high area of Parauaquára] was exceedingly fatiguing, and in the woods we were obliged to use our knives incessantly, but what made our progress most painful, were the high grass and bushes filled with cariá, a long-leafed sword-grass that cuts like a razor. My heavy duck trowsers [sic] were soon cut out at the knees, and my hands and face were cut and bleeding, while the bare feet of my attendants suffered severely.

The brachiopods the group collected from Ereré, both old and new species, proved a match to the Devonian fauna of New York, and Hartt also discovered more evidence to refute Agassiz's glacial drift idea in the Amazon region.

The Geological Commission of Brazil

By 1874, the Hartts had two children, Rollin (1869) and Mary Bronson (1873). That year, Cornell granted Hartt a leave of absence for his fifth and final visit to Brazil, with the goal of conducting the first geological survey of the country. At first, Hartt worked on his own initiative, without any official endorsements, but with the encouragement of, and possible initial funding by, José Carlos Rodrigues. Hartt left his family in Ithaca, but took John C. Branner, his student at Cornell, with him in 1874.

After some political maneuvering, Hartt's Comissão Geológica do Império do Brasil became a reality in early 1875. Funded by the Imperial government, it was the first attempt to survey the geology of the entire country. To ensure a visual record of the commission, Hartt hired Marc Ferrez, a pioneer Brazilian photographer. However, Hartt's objectives for the commission and the outcome the government wanted were quite different. Using the North American model of such surveys, Hartt emphasized geological mapping and basic research, whereas the funding agency, with national economic benefits in mind, expected the "geologic map project" to produce quick results in locating exploitable mineral deposits. For a while the project went well, and Lucy and the children joined him in Rio de Janeiro. Contemporary reports state the commission eventually collected over 500,000 samples and did considerable basic geological research and mapping, but published few reports.

Hartt's Final Days and the Demise of the Comissão

By late 1877, the Imperial government, seeing little immediate economic benefit and few published results, reduced and then, by January 1878, cancelled all funding for the commission. Hartt's family had returned to the United States a few months earlier, but he continued his futile attempt to regain the commission's financial support. In early 1878, Hartt contracted yellow fever. On March 18, 1878, he died, not with his family but in a rooming house in Rio de Janeiro surrounded by the men of his commission. With his death, all hope of restarting the commission died as well. He was first buried in Rio de Janeiro, but in 1883, his wife had his remains brought to Buffalo, New York, for interment in her family plot.

Hartt's Legacy

Though he died before age 38, Hartt made contributions to the geological knowledge of Nova Scotia, successfully challenged the interpretation of two senior and famous geologists, and started the geology department at Cornell University. In Brazil, he was a pioneer in both terrestrial and marine geological study and founded the first nationwide geological survey. Even though Hartt's commission lasted but two years, it set the stage for future endeavors. Hartt introduced many North Americans to Brazil who were later to play important roles in the development of Brazilian geology and its geological institutions. John C. Branner stayed in Brazil for almost ten years, and Orville A. Derby stayed until his death in 1915. Derby started the first state geological survey of the state of São Paulo in 1886 and eventually created another national survey in 1906. Branner prepared a text on Brazilian geology and even tried to find suitable fibers in the forests of Brazil for Thomas Edison's work with the light bulb. The geological collections of the commission became part of the National Museum in Rio de Janeiro. Eventually, the Brazilian government published more of the work, and these publications became the foundation of subsequent geological research in Brazil. Thus, while Hartt is no longer well known in North America, he is the "J.W. Powell" or the "Clarence King" of Brazil in regard to Brazilian geology and geological institutions.

Acknowledgments

The authors are indebted to the following persons and institutions: The Division of Rare and Manuscript Collections, Kroch Library, and the Department of Earth and Atmospheric Sciences, Cornell University, Ithaca, New York; Archives Department, New Brunswick Museum; Provincial Archives of New Brunswick, Fredericton; Manuscripts Department, William R. Perkins Library, Duke University; Biblioteca Nacional, Seçao de Manuscritos; Rio de Janeiro; the J. Paul Getty Museum; and to the known and anonymous reviewers of the manuscript. For references, please contact Brice.

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Figure 2. Pernambucan reef (beachrock). Hartt is sitting at the far right, and photographer (at tripod) is believed to be Marc Ferrez. (Photo no. 86.XA.749.1.16, "Part of the Pernambucan reef looking southward," courtesy of The J. Paul Getty Museum, Los Angeles; Frederick Hartt, chief geologist of survey, and Marc Ferrez, photographer; 1870s; Albumen; 19.2 × 25.2 cm.)

Proterozoic prism arrests suspect terranes: Insights into the ancient Cordilleran margin from seismic reflection data: Comment and Reply

Comment

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Snyder et al. (2002), in their interpretation of Lithoprobe seismic data, suggested that Proterozoic rocks of the northern Canadian Cordillera occurred in "a long-lived, slowly subsiding rift" and consisted of successions similar to the Modern Indus Fan. With this depiction, the authors have mischaracterized a Proterozoic orogen, spanning more than a quarter of earth history, as a clastic prism. Although the authors acknowledged four major sediment pulses, they ignored the largely platformal environment of sedimentation, and intervening events of deformation, metamorphism, uplift, erosion, magmatism, hydrothermal brecciation, and metallogenesis (Eisbacher, 1978; Thorkelson et al., 2001). The inability of the seismic imagery to reveal these complexities calls into question the interpreted thickness and extent of the Proterozoic rocks relative to their crystalline basement.

Proterozoic supracrustal evolution of the northern Cordillera is understood from extensive Precambrian inliers located mainly north of the transect lines. Deposition began with two clastic-carbonate grand cycles prior to 1.71 Ga. By 1.6 Ga these strata had been deformed, metamorphosed, uplifted, and eroded. After mafic magmatism, subsidence, and largely platformal sedimentation at 1.38 Ga, the geological environment resembled that of present-day eastern North America, where subsided parts of the Appalachian orogen are overlain by Atlantic passive margin strata. Subsequent events include: mantle-plume magmatism at 1.27 Ga; uplift and tilting prior to ~1 Ga; platformal sedimentation at ~1 Ga; uplift, folding and thrust faulting prior to 0.78 Ga; mafic magmatism, rifting, glaciations and platform-to-basin sedimentation from 0.78 to 0.6 Ga, and additional uplift and deformation before Cambrian time. Terranes which accreted to ancestral North America in the Mesozoic encountered a mature Proterozoic orogenic belt, not a clastic prism.

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Reply

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Thorkelson et al.'s perceived differences between a Proterozoic orogen and a composite clastic prism are largely perspective and emphasis. The "extensive Precambrian inliers located mainly north of the transect lines" are dominantly supracrustal sedimentary strata with some interlayered volcanics. These supracrustal rocks exceed 20 km thickness with no "basement" yet recognized. Thorkelson et al. (2001, Fig. 8) noted only the Racklan Orogeny affected this area between 1800 and 1300 Ma and attributed it to far-field stresses from convergent margins in SW United States or Australia. Eisbacher (1978) describes two erosional unconformities related to local basins. Plume magmatism and related uplift generally characterize rifting events. Geological history is increasingly recognized as primarily passive subsidence punctuated by widely spaced and relatively short orogeny (Dalziel and Soper, 2001).

We take particular issue with the claim that the seismic images are unable to reveal complexities of deformation, uplift, or erosion in the Proterozoic record. The SNORCLE data provide outstanding images of structural and stratigraphic complexities. For example, along line 2 and ~50 km west of the Tintina fault zone, layering is deformed into a large (~10 km amplitude) syncline that is not manifested in the surface rocks (Figure 2 of Snyder et al., 2002). In some cases, such structures are truncated at the base of the Paleozoic strata and probable equivalents to some of the Proterozoic structures referred to by Thorkelson et al. Indeed, the seismic data reveal such complexities that are not only consistent with the limited outcrop information, but that also extend that information over distances and depths previously not possible.

The terranes which accreted to ancestral western North America did encounter a "mature Proterozoic orogenic belt," but this belt originated largely as supracrustal (dominantly clastic) strata deposited in several major pulses with the layers horizontally shortened around the time of deposition as well as later.

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COMMENTARY

Anonymous Reviews—Are the Pros Worth the Cons?

Alexander McBirney*,*
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One of the practices that is said to have stimulated science in the western world is the open criticism of our work and free debate in the forum of refereed journals. It is this dialectical exchange of views that has ensured the accuracy of our observations and the logic of our conclusions. Today, however, we have a system in which little if any of this exchange appears in the pages of our journals. Instead, it takes place before publication in a review system that is designed to correct errors and clarify our writing before it appears in print. To do this, an editor, who may or may not be conversant with the subject of the paper, selects a set of reviewers whose identity is usually unknown to the author. On this basis, a judgment is reached, and an author may be told that his work is unacceptable or cannot be published unless certain parts are altered in accordance with the views of a secret reviewer.

Similarly, our proposals requesting support for research are evaluated by a group of our peers who are considered qualified to judge the merits of our work. In recent years, this critique has been carried out entirely by anonymous reviewers, the rationale being that anonymity permits reviewers to express their judgment unconstrained by fears of offending a friend or someone who might react vindictively.

Most of us would agree that, on the whole, this system for reviewing journal articles and proposals has worked fairly well. It would probably be ideal if all of us were courteous, rational humans free of emotion and immune to subjective influences. Unfortunately, we are not. Too often, an anonymous review brings out the worst in both its author and its recipient. In the worst cases, anonymity is taken as a license to make demeaning remarks or unfounded accusations that in many instances do not even address the substance of the paper or proposal. We have all received—and some of us have written—rude, patronizing reviews that would be unthinkable if the reviewer were face-to-face with the target of such insults. There are any number of reasons why we do this:

- It offers a chance to settle old scores.
- It is a way of putting down an arrogant “authority” in our field.
- It is an emotional reaction to new ideas the reviewer finds disturbing.
- It reduces the competition for limited research funds.
- It enables us to sidetrack work that may render our own obsolete.

Ironically, reviews are not held to the same standards of objectivity as the papers they address. Statements require no supporting evidence, and twisted logic can pass unchallenged. A good editor or program director will recognize a biased review and discount it, but who can dismiss the judgment of a person who is considered an expert in the field of work in question? The slightest reservation expressed by such an authority can be fatal. When considering the value of peer reviews it is worth remembering that the leading playwrights working in London at the time considered Shakespeare a mediocre hack.

Editors or National Science Foundation panels can, and often do, exercise their own judgment and weed out offensive or unhelpful reviews, but anyone who has been in such a position will acknowledge that it is easy to influence the fate of a paper or proposal simply by making an appropriate choice of reviewers. We may not admit it, but it is common practice to select reviewers that can be counted on to give a desired judgment. To this end, many editors keep at least one person on their team who can be depended on for a negative review, regardless of the merits of the paper.

In a purely philosophical sense, the anonymous review violates one of our most basic democratic principles. A fundamental rule of our justice system holds that one who is being judged has the right to confront his accusers. This right is denied when a verdict is rendered in secret on the basis of testimony from unidentified individuals selected by a process in which one cannot participate. In any court of justice, one has the right to know and challenge the qualifications or objectivity of witnesses. Why should it not be so in science?

To the extent that this situation is becoming unsatisfactory, if not intolerable, it is certainly worth considering alternatives. An increasing number of reviewers have already resolved not to conceal their identity. Even with National Science Foundation reviews that will not bear their name, reviewers insert a comment or reference that serves to identify them. Following this approach forces one to ensure that the review is objective, carefully reasoned, and free of belittling comments. There are times, of course, when one is tempted to go back on this resolve, particularly when a paper or proposal submitted by a good friend fails to meet the standards one would expect, but with a little effort, one can convey a negative opinion in a courteous, constructive manner. By explaining where the work is faulty and suggesting remedies, it is possible to show that the intent is to be helpful.

It may be unrealistic to propose that anonymous reviews be totally abandoned. For one thing, it would certainly make the editors’ task of finding reviewers more difficult. Even if a person does not object in principle to being identified, a signed review demands much more of time and effort and a busy person may be reluctant to evaluate a paper or proposal that may require several hours to review properly. But isn’t that exactly what one has a right to expect? Anyone who has devoted months, if not years, to a piece of work deserves nothing less.

Judging from the views of various friends with whom I have discussed the problem, it seems that most would agree that we need fewer hasty, off-the-wall opinions and more constructive suggestions for improving our work. Perhaps we could set as a minimal requirement that a review must be a courteous, constructive, and objective assessment of the major points the author is striving to make. By adhering to such a simple rule, which, after all, is nothing more than normal civilized conduct, we could save ourselves a good deal of grief and wasted energy.

Meetings Calendar

2003	
June 1–3	7th Annual DOSECC Workshop on Continental Scientific Drilling, Minneapolis, Minnesota, USA. Information: (801) 585-9687, www.dosecc.org/Workshop_2003/workshop_2003.html.
June 22–27	8th International Kimberlite Conference, Victoria, B.C., Canada. Information: www.8ikc.ca.
July 23–30	XVI INQUA Congress, Reno, Nevada, USA. Information: www.inqua2003.dri.edu, Marjory Jones, Congress Secretary, (775) 673-0694.
Sept. 6–11	The Deep Earth: Theory, Experiment and Observation: EuroConference on Multi-Disciplinary Studies of the Mantle and Core, Acquafredda di Maratea (near Naples), Italy. Information: www.esf/org/euresco.
Sept. 21–24	The Society for Organic Petrology (TSOP) 20th Annual Meeting, Washington, D.C., USA. Information: Peter Warwick, U.S. Geological Survey, 956 National Center, Reston, Virginia 20192, USA, (703) 648-6469, fax: 703-648-6419, pwarwick@usgs.gov, www.tsop.org/mtgdc.htm.
Oct. 4–9	Natural Waters and Water Technology: EuroConference on the Roles of Colloids and Particles in Water Technology, Acquafredda di Maratea (near Naples), Italy. Information: www.esf/org/euresco.
Oct. 4–9	Polar Regions and Quaternary Climate: EuroConference on the Comparison of Ice Core Records with Marine Sediments and Climate Models, San Feliu de Guixols, Spain. Information: www.esf/org/euresco.
Oct. 11–16	Achieving Climate Predictability using Paleoclimate Data: EuroConference on North Atlantic Climate Variability, San Feliu de Guixols, Spain. Information: www.esf/org/euresco.
Nov. 5–7	First International Conference on Sustainable Development and Management of the Subsurface, Utrecht, The Netherlands. Information: info@delftcluster.nl, www.delftcluster.nl.

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

About People

GSA member **Donald W. Forsyth** was presented with the 2002 A.G. Huntsman Award by the Royal Society of Canada at a special ceremony on January 15. The annual award, named for pioneer oceanographer and fishery biologist Archibald Gowanlock Huntsman (1883–1972), was established in 1980 by the Canadian marine science community to recognize excellence in research and outstanding contributions to the marine sciences.

BIGGS AWARD

for Excellence in Earth Science Teaching for Beginning Professors

The 11th Annual Biggs Award for Excellence in Earth Science Teaching for Beginning Professors was presented to GSA member **Karen S. Harpp**, Colgate University, during the National Association of Geoscience Teachers–GSA Geoscience Education Division luncheon at the 2002 GSA Annual Meeting in Denver. Pictured with Harpp, center, are GSA Fellow **Bonnie A. Blackwell**, past chair of the Geoscience Education Division, and Harpp's citationist, GSA Fellow **Arthur G. Goldstein**, of the National Science Foundation. For information on this year's award, see page 11.

Geologists Honor One of Their Own With Grant Endowment

The Eastern Section of the American Association of Petroleum Geologists (AAPG), Inc., recently established an endowment within the AAPG Foundation to fund a named grant honoring Richard W. Beardsley. The Beardsley Grant will be bestowed annually to a graduate student to support study and research of petroleum, energy minerals and related environmental geology in eastern North America.

First consideration for receipt of the grant will be given to a deserving graduate geoscience student whose thesis is related to petroleum exploration in the region of the Eastern Section AAPG. If no qualified applicant is available, consideration will be given to a deserving geoscience student enrolled at a college or university (public or private) located within the geographic boundaries of the Eastern Section AAPG region. The grant will be awarded for the first time in the spring of 2003. For more information contact Peter MacKenzie, (614) 781-3271, or pete@cgasinc.com.

Volunteer Geologists Needed for Philmont Scout Ranch

Here's your chance to stay at an old mining camp this summer in the southern Sangre de Cristo Mountains and talk about geology to backpackers. Geology volunteers spend one or two weeks in the backcountry at the famous Philmont Scout Ranch south of Cimarron, New Mexico. Spouses welcome (sorry, no children). Contact Ed Warner at (720) 904-0560, or ewarn@ix.Netcom.com.

Want to be a hero?

Challenger Center for Space Science Education seeks enthusiastic, people-oriented research scientists and engineers to participate in Journey through the Universe, a program that uses themes of human space flight and earth and space sciences to inspire entire communities. To learn more about the program, visit www.challenger.org/journey. For a flavor of programming in a community, visit the Washington, D.C., site at www.challenger.org/dcjourney.

2003 Jahns Distinguished Lecturer Named

Chester F. (Skip) Watts has been named the 2003 Jahns Distinguished Lecturer. The GSA Engineering Geology Division and the Association of Engineering Geologists jointly established the Richard H. Jahns Distinguished Lectureship in 1988 to commemorate Jahns and to promote student awareness of engineering geology through a series of lectures offered at various locations around the country throughout the year. Richard H. Jahns (1915–1983) was an engineering geologist who had a diverse and distinguished career in academia, consulting, and government.

The 2003 Jahns lecture, titled "Geology from the Hill," is based on Watts' 14 months as the GSA–USGS Congressional Science Fellow attached to Senator Joseph Lieberman's personal staff. "It was a remarkable time to be in Washington, D.C., involved in science and engineering in public policy and homeland security," said Watts.

Also available is an alternative lecture titled "Rockslides!" based on case histories from Watts' 20 years of consulting and research in rock slope engineering. Captivating accounts may include the Natural Bridge of Virginia, Yosemite National Park, Harpers Ferry National Historic Park, Virginia's Smart Road, and the military application of tactical rockslides, to mention a few. Abstracts are available on the Engineering Geology Division's GSA Web site (http://rock.geosociety.org/egd/index.html).

A certified professional geologist in the Commonwealth of Virginia, Watts is the Dalton Distinguished Professor of Geology at Radford University, where he has worked since 1984. There, he established the Institute for Engineering Geosciences and has taught undergraduate and graduate courses in engineering geology, hydrogeology, geomorphology, geophysics, soil mechanics, rock mechanics, computer applications in geology, and advanced engineering geology.

Watts is also the author of ROCKPACK III computer software, used internationally for analyzing the safety and stability of mines, quarries, highway cuts, mountain slopes, buildings, and bridge foundations. He serves as a rock slope stability consultant to numerous highway departments, federal agencies, and engineering firms.

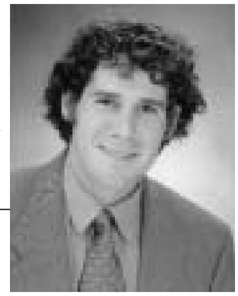
Watts is the recipient of several regional and national teaching awards, including the 1998 Outstanding Professor Award from the State Council for Higher Education in Virginia. He appeared in the television documentary "SLIDE!" on The Learning Channel as well as on National Public Radio, by cell phone, while rock climbing during a rockslide study in Yosemite National Park.

Requests for scheduling the Jahns lecture should be directed to Skip Watts at cwatts@radford.edu.

Congressional Science Fellow:

Report from D.C.

Rafael D. Sagarin, *2002–2003 GSA–U.S. Geological Survey Congressional Science Fellow*



Rafael D. Sagarin,

Washington, D.C., is a long way from the coast of Baja California, where I've done much of my fieldwork. I'm sure any earth scientist who has spent considerable time in the field can appreciate the culture shock. Long drives through wide-open landscapes and rugged back roads have been replaced by packed subway cars and icy sidewalks. Campfires and beer after a day of fieldwork have been replaced by the staid Washington tradition of happy hours filled with gossiping lawyers, lobbyists, and congressional staff members. Dusty T-shirts and boots replaced by suits.

To be fair, I knew what I was getting into. I had always been interested in politics, and having done research on the politically controversial field of climate change made me especially eager to understand how science gets incorporated into policy in Washington. The Congressional Science Fellowship Program, jointly sponsored by GSA and the U.S. Geological Survey, sends scientists from all stages in their careers to Washington, not as lobbyists or activists, but as students of the political process.

Once I got to D.C. in September, I met up with about 100 other fellows sponsored by various societies for a three-week orientation run by the American Association for the Advancement of Science. I was amazed at the diversity of fields represented—geologists, biologists, chemists, psychologists, even veterinarians. For the 30 congressional fellows, our work was just beginning, as we spent the three weeks after orientation walking the halls of Congress passing out resumes to the offices of senators and congressmen and constantly leaving messages for staff members. Eventually, we did get some of our calls returned and everyone found an office in which to spend the year.

I chose to work for Hilda Solis, a freshman Democratic representative from East Los Angeles. I really liked her staff and the idea of helping out a person just getting started in her national political career. While her main issues of concern were not necessarily those that I had worked on as a scientist, I soon learned that issues are much more transient on Capitol Hill than in academic science. The portfolio of scientific projects I've worked on evolved over eight years or more. Yet within a few hours of starting my present position as a science advisor for the congresswoman, I was given a portfolio of issues that includes climate change, fisheries, forest fires, environmental justice, incentives for environmental businesses, Clean Water Act, racism in the census, and anything else I would like to pursue in my free time. Issues come up on Capitol Hill rapidly and opportunities must be seized to deal with them before they pass.

For example, I recently attended the Planning Workshop for Scientists and Stakeholders for the President's Climate Change Science Program (CCSP). More than 1,500 scientists, environmentalists, and government employees attended this meeting, which was billed as an opportunity to be briefed about and comment on the draft of the CCSP. Unfortunately, I was surprised to find that few of the congressional staff members I had come to know were in attendance during the three-day meeting, even though there are several areas where congressional action could greatly improve the scientific plan.

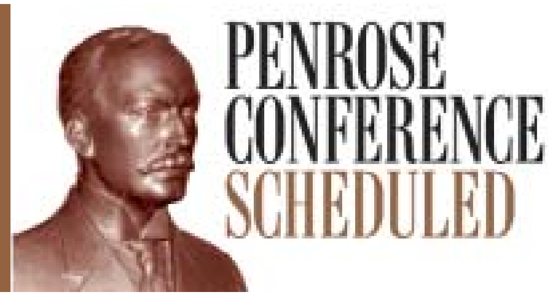
For example, the 2003 budget for the entire program of research on climate change is less than $40 million (less than 2%) greater than the 1996 budget, despite the fact that the CCSP calls for massive new research programs and new organizational structures. Additionally, there is little emphasis on basic monitoring programs to study the effects of climate change on natural systems. Finally, there is a large emphasis on developing future technologies to sequester greenhouse gases, rather than on applying currently available solutions and strategies to mitigate against climate change today.

In all of these issues there are political actions and biases underlying the scientific actions proposed. Yet I believe the lack of congressional involvement in this process is due to the fact that the CCSP has been promoted as a scientific, rather than political, response to climate change, and congressional staff members are reluctant to get involved in what they perceive as a purely scientific issue. As a science fellow, I am trying to bridge this gap on this issue by preparing comments on the draft CCSP and passing them around to various congressional offices. My goal is to find a group of congress members who would be willing to publicly comment on the failings of the draft CCSP and work to improve its budget for the long term.

Fortunately, I have a growing number of allies on Capitol Hill who are willing to take the leap between policy and science. The Washington world retains science fellows at an alarming rate. Almost every day I run into a fellow or a former fellow, some from many years back. They are in practically every branch of government. They are often my best source of information and analysis. And while next year might find me back on the shores of Baja, for now I am really enjoying the opportunity to get a firsthand look at the policy process and I hope to add a small contribution to the growing role of earth scientists in policy making.

This manuscript is submitted for publication by Rafael Sagarin, 2002–2003 GSA–U.S. Geological Survey Congressional Science Fellow, with the understanding that the U.S. government is authorized to reproduce and distribute reprints for governmental use. The one-year fellowship is supported by GSA and by the U.S. Geological Survey, Department of the Interior, under Assistance Award No. 02HQGR0141. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government. Rafael Sagarin can be reached at rafe.sagarin@mail.house.gov.

Plume IV: *Beyond the Plume Hypothesis—Tests of the Plume Paradigm and Alternatives*



August 25–29, 2003, Hveragerdi, Iceland www.mantleplumes.org

Conveners

Gillian R. Foulger, *Visiting Scientist*, Volcano Hazards Team, U.S. Geological Survey, 345 Middlefield Road, MS 910, Menlo Park, CA 94025-3591, USA, (650) 329-4143, fax 650-329-5203, foulger@swave.wr.usgs.gov*

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Don L. Anderson, *California Institute of Technology, Seismological Laboratory 252-21, Pasadena, CA 91125, USA, (626) 395-6901, fax 626-564-0715, dla@gps.caltech.edu*

With the accumulation of ever-superior data from hotspots and volcanic provinces, it is becoming increasingly clear that the hypothesis that attributes them to hot plumes upwelling from great depth fits many observations poorly, and that apparent paradoxes abound. Radically different, alternative models are proliferating, which include propagating cracks and melting anomalies, upper mantle heterogeneity, local convection, recycling of subducted slabs in the upper mantle, and Rayleigh-Taylor instabilities. These ideas represent departures from conventional views in that they assume that hotspot volcanism is closely tied to plate tectonic processes at shallow depth rather than an entirely different convection mode involving deep upwelling. Thus, if substantiated, these ideas may lead to a first-order paradigm shift.

This conference will bring together scientists who wish to be involved in developing fundamentally new models for volcanic provinces, innovative new ideas, and the experiments required to test them. The conference will emphasize petrology, geology, geophysics, geochemistry, modeling of midplate volcanism, and comparisons with plate boundary magmatism.

Topics for presentations and discussion will include:

What is a plume? What is a hotspot? What do scientists today understand by the terms plume and hotspot? Do our terminological limitations suppress the development of alternative concepts?

The big picture. What global factors affect large volcanic regions? Lithospheric architecture? Stress? Fertility? What controls the nature and locations of large volcanic regions? Plate boundaries? Incipient plate boundaries (cracks)? What drives and breaks plates? How deep does recycling of important geochemical tracers occur? Can plumes, as conventionally understood, exist in the presence of plate tectonics and pressure effects?

Kinematics and volcanic tracks. What causes volcanic chains, time progressive and otherwise? What is their relation to geology, seafloor fabric, and stress? Is the concept of a hotspot reference frame useful, sensible, both, or neither?

Heat and temperature. How much do we know about the temperature of the mantle and of volcanic regions? Are "hotspots" hot? If not, where does all the melt come from?

Specific volcanic regions. How well does the plume hypothesis predict the history, spatial distribution, temperature, structure, and volume of melt at specific "melt-spots"? What alternative models are there, and can these do better? What is going on in the Pacific, Atlantic, and Indian Oceans? What is the role of suture zones?

The origin of melt. What do we know about the source, temperatures, and volume of melt at volcanic regions? Are volatiles or eclogite involved? How is melt delivered to the surface? How much of it is there?

Petrology and geochemistry. What is the current state of knowledge of the petrology and geochemistry at volcanic regions? How does it differ from that at spreading plate boundaries and subduction zones? What melting scenarios can be ruled out?

The seismic structure of the mantle. What constraints can geophysical techniques place on plume and non-plume models? Is it possible, fundamentally, to test the plume hypothesis with seismology? What do we expect to see in the shallow mantle and the deep mantle, and what do we see?

Large Igneous Provinces (LIPs). How much melt is there at LIPs and how rapidly are they emplaced? What genesis model fits them best? Are athermal models viable, e.g., focusing, edge-flow, and fertility variations?

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*On leave from the University of Durham, UK.

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VENUE

The conference will be held in the village of Hveragerdi, South Iceland (www.south.is/hveragerdi.html). Iceland is the type example of a ridge-centered hotspot, and a current focus of debate between plume and non-plume models. It is the largest subaerial exposure of spreading plate boundary on Earth, and contains more than 15 spreading segments, two complex transform zones, and 35 active volcanoes. The conference venue is within the extinct Grensdalur volcano and hot-spring field, a component of the Reykjanes-Langjokull–South Iceland ridge–ridge-transform triple junction. Excellent hotel and conference facilities are available. One half-day and one full-day field trip will be conducted during the conference to tour the three branches of this triple junction. The cost of the five-day conference, including room, board, and field trips, is expected to be under $1,300.

APPLY BY MAY 10, 2003

Potential participants should send a letter to one of the conveners, including a brief statement of interests and anticipated contribution to the conference, and an extended abstract if an oral or poster presentation is offered. Discussion will be emphasized at the meeting, so the number of oral presentations will be limited. Preference will be given to contributions that focus on new models, rather than solely criticism of old ones. Attendance will be limited to 60 people. Graduate students are encouraged to apply, and some funds will be available to help offset costs for students and possibly also for delegates in need.

OPTIONAL FIELD TRIP

A four-day post-conference field trip will be offered from August 30 to September 2. The cost of this optional field trip is expected to be around $500 per person.

REGISTRANTS WITH SPECIAL NEEDS

GSA is committed to making Penrose Conferences accessible to all. If you require special arrangements or have special dietary concerns, please contact one of the conveners.

REPORT

The Role of the Earth Sciences in Fostering Global Equity & Stability

Report on Pardee Symposium K4, 2002 GSA Annual Meeting, Denver, Colorado October 28, 2002

Co-Convenors:

W.G. Ernst, G. Heiken, Susan M. Landon, P. Patrick Leahy, and Eldridge Moores

Sponsored by the U.S. National Committee for the Geological Sciences, the U.S. National Committee for Geodesy and Geophysics, and the GSA International Division

Earth scientists can play a unique role in developing understanding and promoting greater international stability. The tragic events of September 11 were a rude wakeup call to Americans and the rest of the world community to their vulnerability to terrorist attacks, as well as to the widespread and deep mistrust of developed nations by people of developing nations. As global citizens, we are interested in doing our part to alleviate to the extent possible the conditions that have promoted this international discord. As earth scientists, we are interested in achievement of a sustainable society at the national, as well as the global level. Many earth scientists maintain close ties with colleagues across the globe. These strong links provide a mechanism for honest exchange of perspectives and at the same time help maintain a global view that is sensitive to regional social constraints. With specialties ranging from resource exploitation and extraction to environmental protection and preservation, the earth sciences community is especially well positioned to develop a balanced enquiry into the issues of resource utilization and international equity. In addition, with expertise in natural hazards, we can provide the means for improving and developing a standard for public safety of the global population. Although earth science information has long been used from a diplomatic perspective, it is now time to use the entire breadth of our profession to realize the opportunities that the earth sciences provide for greater international understanding.

With this perspective in mind, a Pardee symposium was held at the GSA Annual Meeting in an effort to heighten awareness in the earth sciences community of issues of the policy implications of western society's use of resources and their global consequences, as well as quality of life expectations for the global population. Nine speakers addressed various aspects of these issues.

W.G. Ernst led the symposium with his talk addressing the overall issues of global equity, sustained resource consumption through efficient extraction, conservation, and recycling, and through development of cheap, inexhaustible energy. Ernst observed that via modern communications, the global population is aware of how we in the developed world live, and they aspire to our lifestyle. However, if everyone lived as the developed world does by 2050, mineral production would need to be 3–15 times current levels, some 45% of the water cycle would be needed, and energy production would have to be about five times the current level. The use of marginal mineral resources is possible, but the energy needed for extraction increases exponentially as the grade declines. Energy consumption and production are mostly from fossil fuel, and the supply curve is starting to diminish. Coal is plentiful but the environmental costs of its use are prohibitive. Nuclear energy is plentiful, but there is great political and social antagonism, and unresolved geological issues, to its increased use. A plan and societal commitment is necessary if we are to have timely development of alternative energy sources. Sustainable development will occur only with effective conservation, recycling, efficient exploitation of available resources, and timely development of widely available and inexpensive energy. Sustainability will bring with it the crucial question of maintaining the viability of the biosphere.

Osman A. Shinaishin addressed the issue of whether geologists can act as the bridge between ideologies of the Islamic world and the western world. He stated that since the tragic events of September 11, nothing will remain the same, and a new effort is needed. The Islamic nations are all developing nations, and even though they are resource-rich, their human resources have barely been tapped. Science has lagged behind in these nations in the past 150 years, in part because of the increasing influence of conservative ideologies. Islamic nations have a negative psychological but positive economic relationships with the West. There is resentment in providing resources to support a lifestyle that they do not embrace. Western countries have a history of colonialism, a relationship exacerbated hugely by establishment of the state of Israel in 1948—a continuing source of irritation. The role of women is quite variable across the Islamic world—considerable equality in some countries (e.g., Indonesia, Bangladesh), much less so elsewhere. Geologists can help bridge the gap by visiting Islamic countries and working in the field in a collegial way. Geologists generally respect nature and culture; they must speak up about collaborative successes and the development of mutual respect.

Timothy R. Klett summarized the results of the U.S. Geological Survey's World Petroleum Assessment. This is one of a series of periodic impartial, scientifically based assessments used for geopolitical decision

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making. They are geologically based, using all available surface and subsurface geological information to estimate the world's endowment of oil and gas. Assessment results are dynamic and may be further refined based upon a variety of factors such as price, technology, scientific developments, and ultimately environmental values. Distribution of resources is heterogeneous; many resources are not where the demand is. The critical issues in developed countries are ones of sustainability and security of energy supply, whereas economic growth is the dominant issue in developing countries.

Charles G. Groat discussed the role of federal agencies in fostering international collaboration, understanding, and sustainability. Resource issues are the root causes for many international tensions. No major crises are imminent. Resources are available for the foreseeable future, but they are irregularly distributed. Society needs credible assessments. The global mineral assessment, now in progress, will be a seven- to ten-year effort involving many countries around the world, and will include environmental impacts, with the aim of achieving a scenario for sustainable development. Examples of successful international collaboration are the USGS cooperative efforts between the two sides of the Cyprus conflict, collaborative efforts in Afghanistan, and the tri-national geological and geophysical maps of North America. There is a need to bring colleagues from other countries to work in the United States. The U.S. Department of State needs to get geoscientists into U.S. embassies.

Speaking for the GSA Critical Interests Committee, A.R. Palmer addressed the issue of earth resources as "the little engine that could brake sustainability." The recent study by the National Academy of Sciences of sustainability ignored earth resources, including soil, water, energy, essential minerals, and it made only a fuzzy distinction between renewable and nonrenewable resources. Water is being consumed at a high rate; it is essential for energy and mineral production, as well as agriculture. One percent per year of agricultural resources is lost because of salinity problems. Loss of soil on cropland is at a rate of 10–100 times the rate of renewal. Controls are necessary of levels of consumption and population. Earth scientists can contribute by warning of "choke points." Development of a network of databases and monitors is necessary to keep track of global resources and to identify these choke points. Science has a role in identifying conflicts between value systems and national interests. Frugality must be our guiding principle.

George W. Fisher discussed the earth sciences as a fertile ground for an ethic of sustainability. To achieve an ethic of sustainability, we need at least two kinds of knowledge. The first kind, called "propositional truth," is that expressed by simple declarative statements; it is "objective," and it includes most statements of moral philosophy and the equations of physics. The second kind, experiential knowledge, is deeply subjective and personal, but is subject to evaluation, and it often has a moral content. It is commonly expressed indirectly, as in a parable or story with a twist. Both types of knowledge are needed to evolve an ethic of sustainability. Geologists are well suited to convey this fact because much of what we do involves experiential knowledge, and the whole story of Earth is an experiential one. Earth scientists sense the risk to natural systems mostly from their own experience in ecosystems in which they have worked. Sustainability means living in harmony with earth systems. There is significant interdependence, and change is often chaotic.

Eric H. Reitan discussed the role of earth sciences knowledge in equity, stability, and sustainability. The earth sciences need to make objective measurements, communicate their results, and ensure that policy makers put the results to use. Earth scientists cannot depend on others to communicate their knowledge—they need to develop the ability to do it themselves. He stated that three features dominate the typical world vision: (1) naïve and cavalier faith in human ingenuity, (2) equating happiness with material consumption, and (3) a truncated understanding of our moral responsibility, perhaps otherwise known as "lifeboat ethics." There is a link between inequity, environmental degradation, and violence, but a prevalent American view is that global equity is not our concern. Earth scientists must convey what we know about scarcities, moral and physical choke points. Mutual concern for global equity and sustainability can bring together diverse scientists with similar fundamental goals.

Murray Hitzman discussed the issue of sustainable education of mineral production specialists for the global economy. Mineral exploration is moving "offshore" (away from the U.S.). The average age of American scientists involved in mineral production is increasing and the numbers employed are decreasing. Companies moving offshore are bringing in younger professionals at lower salaries. The number of academic scientists and the amount of funding are both decreasing. Most U.S. mining students are foreigners. The mining industry is global, but training is concentrated in the United States, Canada, and Australia, where students obtain better training in English and in environmental ethics.

Eric M. Riggs discussed the issue of equity and stability on Native American reservations, and the impact of geoscience in these areas. Science education on Native American reservations is driven by community needs and goals. U.S. Indian law is amazingly complex; it has been called "inconsistent, indeterminate, and variable." In the Doctrine of Plenary Power, Congress has absolute authority, especially in land and resources cases. Earth scientists have generally been involved in resource extraction, principally uranium, coal, and oil and gas reserves, and they have not traditionally been interested in equity and stability. Thus there has been widespread mistrust of geologists in the Native American community. The situation is changing, but there is still resistance to the geosciences, and there are concerns about data confidentiality, consequences of geological work, and the need for better environmental protection. Recognition of the need for geoscience expertise is increasing, particularly in issues related to water, pollution, and hazards. But geoscience education must not be "colonial"; rather, it must sensitive to tribal control.

In summary, earth scientists can and should play a critical role through their understanding of the science involved in issues of resource recovery and environmental interactions. However, earth scientists are not united in their approach to these problems. Some are focused primarily on resource identification, extraction, and use, whereas others are concerned about the overall future of society, as well as issues of the limits of resource availability, and ethical questions about the inequality of global resource-related wealth and lifestyles.

The heterogeneity of resource availability, and issues of resource depletion remain sources of discord. There is a resonance to O.A. Shinaishin's observation of the resentment felt in the Islamic community towards "western" practices and policies.

The role of earth sciences would be enhanced by better ability of the geoscience community to communicate their perspectives on these issues to themselves, to the general public, and to decision makers.

Ads (or cancellations) must reach the GSA Advertising office one month prior. For 2003, the April and May issues will be combined, deadline is March 3. Contact Advertising Department, (303) 357-1053, 1-800-472-1988, ext. 1053, fax 303-357-1073, acrawford@geosociety.org. Please include address, phone number, and e-mail address with all correspondence.

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Situations Wanted

My Yankee wife wants to go home! British PhD hydrogeologist seeks interesting employment in USA or Canada. Details on www.propubs.com/resume.

Positions Open

PLANT & SOIL SCIENCES: ASSISTANT PROFESSOR PEDOLOGY, PLANT AND SOIL SCIENCES COLLEGE OF AGRICULTURE AND NATURAL RESOURCES UNIVERSITY OF DELAWARE

Appointment: This is a 9 month, tenure-track position with responsibilities divided between research (60%) and teaching (40%). General Duties and Responsibilities: The Department of Plant and Soil Sciences invites applications for a tenure-track faculty position in the area of pedology at the ASSISTANT professor level. The successful applicant will develop a nationally recognized research program supported by extramural funding and participate in teaching at the undergraduate and graduate levels. The candidate will complement existing soils research within the Department of Plant and Soil Sciences by providing expertise in the areas of pedology, mineralogy, and land use management of soil-landscape complexes, particularly as related to environmentally important issues such as water quality of surface and subsurface waters, wetland management, land application of wastes, and remediation of contaminated soils. Expertise in applying geospatial tools to these problems is expected. In addition, the individual will teach an introductory soil science course on an annual basis and a combined undergraduate/graduate course in pedology every other year. The individual is expected to play a leadership role in all undergraduate soil science education areas such as recruitment, advisement, student activities, internships, and career planning. Qualifications: The candidate must have a Ph.D. in soil science or closely related field of geoscience with expertise in pedology (soil genesis, morphology, and classification), soil mineralogy, and land use management. Other desirable areas of expertise include geographic information systems, geomorphology, soil hydrology, and soil conservation. Postdoctoral experience is beneficial but not a requirement. Interest and ability to contribute effectively to collaborative research efforts and to work actively with undergraduate students are essential. Salary: Commensurate with experience and training. The University of Delaware provides an excellent employee benefits package including health and dental insurance, retirement contributions (TIAA/CREF), pre-tax flexible spending accounts, and complete tuition remission for family members. Facilities: Teaching and research facilities are located at the University of Delaware, Newark, DE. The University is a Land-Grant, Sea-Grant, Urban-Grant and Space-Grant institution located midway between Philadelphia and Baltimore. Closing Date for Applications: Review of applications will begin April 1, 2003, and continue until a suitable candidate is identified. Date Position is Available: September 1, 2003. Application Process: Interested persons should submit: (I) letter of application; (II) resume; (III) one-page statement of research and teaching interests; (IV) names, addresses (including e-mail), and telephone numbers of three references; and (V) undergraduate and graduate transcripts. Applications should be sent to: Dr. Jeff Fuhrmann, Professor, Department of Plant and Soil Sciences, 152 Townsend Hall, University of Delaware, Newark, DE, 19717. Contact Information: phone 302-831-1371; fax 302-831-0605; e-mail fuhrmann@udel.edu. The curriculum vitae and letters of reference shall be shared with departmental faculty. The UNIVERSITY OF DELAWARE is an Equal Opportunity Employer which encourages applications from Minority Group Members and Women.

DINOSAUR PALEONTOLOGY AND GEOMICROBIOLOGY MONTANA STATE UNIVERSITY

A position in Dinosaur Paleontology and a position in Geomicrobiology are available at the Assistant or Associate Professor level to support a new Ph.D. program in Earth Sciences at Montana State University. The full position announcement and application requirements for each are on the internet at http://www.montana.edu/msuinfo/jobs/faculty/.

ADAA/EO/AA/VET.PREF

FIELD/MAPPING GEOLOGIST, OREGON DEPARTMENT OF GEOLOGY AND MINERAL INDUSTRIES (DOGAMI)

DOGAMI is recruiting for a field geologist (Natural Resource Specialist 3) to do geologic mapping, develop GIS databases and digital geologic maps and provide geologic advice to the public in its Baker City office in Eastern Oregon. This position is currently funded as a limited duration appointment. Applicants should have an advanced degree in earth science, and at least five years relevant professional experience. A record of published geologic maps and experience with digital mapping and GIS are strongly desired, as are excellent written and verbal communication skills. The successful applicant will immediately be given responsibility for major field mapping and GIS compilation projects. Substantial travel and field work in remote and rugged areas will be required. Salary range is $3115–4346 per month, with a generous benefit package. DOGAMI is an agency of the state of Oregon, and is an equal opportunity employer.

Further information about DOGAMI is available at www.oregongeology.com. Interested applicants should contact Charles Kirby (800 NE Oregon Street #28, Portland, OR 97232, 503 731 4100 x229, charles.kirby@dogami.state.or.us) for an application packet. Completed applications are due in Salem at the state recruitment office by April 1, 2003. For further technical information about the position, email ian.p.madin@state.or.us.

AMEC EARTH & ENVIRONMENTAL, INC. STAFF GEOLOGIST, SAN DIEGO

AMEC Earth & Environmental, Inc. is seeking a staff level geologist to be responsible for preparing workplans, basic cost proposals, conducting field investigations (including oversight of subcontractors), data analysis and report preparation for sites impacted by hazardous materials. May also provide geologic and/or hydrogeologic support

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for water resources related projects. Candidates should have a BS in geology, hydrogeology, or environmental science, 2 to 5 years of experience in the environmental field, including at least 1 year of experience conducting field investigations (i.e., drilling, sampling, monitoring well installation and sampling). Good verbal and written communication skills are necessary. Candidates should be proficient on the computer and have the ability to use standard MS Office software. Basic project management and computer modeling ability is a plus. Position will report to the geosciences group leader. Please send resume to careers.ee.krk@amec.com or fax to (858) 458-0943. EOE/AA.

**VISITING YOUNG SCIENTIST
DARTMOUTH COLLEGE**

A visiting appointment for a young scientist, recent Ph.D., is available at Dartmouth College. The appointment would be for 3 months during 2003–2004 and would include teaching in the department of Physics and Astronomy, Engineering, Earth Science, or Computer Science. Extension of appointment is possible for sponsored research projects. To qualify, candidates must be engaged in research related to space science, planetary science, astrophysics, remote sensing of Earth from space, aerospace technology, or technology dependent on space-based platforms. To apply, send a 1-2 page summary of teaching and research goals, curriculum vitae, and the names of three references to: Visiting Young Scientist, Department of Earth Sciences, Dartmouth College, 6105 Fairchild Hall, Hanover, NH 03755-3571. For more information, e-mail r.birnie@dartmouth.edu. Applications will be reviewed starting March 29, 2002. Position funded by NASA NH Space Grant.

**VISITING INSTRUCTOR
BRIGHAM YOUNG UNIVERSITY
TEMPORARY APPOINTMENT**

The Department of Geology at Brigham Young University (BYU) is seeking to fill a temporary position for a visiting instructor (M.S. or Ph.D.) with excellent teaching skills. The appointment will last for a period of at least one academic year, with the possibility of renewal for a second year. The successful candidate will be expected to teach introductory courses, and perhaps upper-division and graduate courses within his/her area of expertise. The position will be available as early as 1 September 2003. Starting salary and rank will be commensurate with experience.

Applicants should send a letter of application, curriculum vitae, and the names of three references to Dr. Stephen T. Nelson, Faculty Search Committee, Department of Geology, Brigham Young University, Provo, UT, 84602. Application materials must be received on or before 1 April 2003 to be considered.

BYU, an equal opportunity employer, is sponsored by The Church of Jesus Christ of Latter Day Saints and requires observance of Church Standards. Preference is given to members of the sponsoring church.

**DEPARTMENT OF EARTH SCIENCES
UNIVERSITY OF WATERLOO
NEW TENURE TRACK POSITION: 2003**

The University of Waterloo invites outstanding applicants to apply for a tenure track position in the Department of Earth Sciences. There is no restriction on the rank at which this position will be filled. The salary is negotiable. We seek an outstanding candidate with active research in one or more of the following areas: engineering geology, geological engineering, geomechanics, environmental geology, environmental geophysics, hydrogeology, fluid geodynamics, or hydrology. The position is available on May 1, 2003. Evaluation of candidates will begin on February 3, 2003 and evaluations will continue until the position is filled. In order for an application to be complete, a curriculum vitae of the candidate, 2 recent publications and the names of at least three referees are needed.

The Department of Earth Sciences at the University of Waterloo has a well-funded extensive and diverse research program involving 18 full time faculty members, 8 research faculty members, 2 post-doctorate researchers, 2 research associates, 27 research staff and over 100 graduate students. Inter-departmental ties and research are encouraged at the University of Waterloo. Active collaborations and cross-appointments exist with researchers in other departments including Civil Engineering and Chemical Engineering, Biology, Chemistry, Geography and Computer Science. The Departments of Earth Sciences and Civil Engineering operate a cooperative undergraduate program in Geological Engineering. The Departments of Earth Sciences and Civil Engineering possess outstanding laboratory and field equipment and facilities for many types of environmental and applied research. Faculty members have access to many other research facilities on campus. A large new building is currently under construction for occupancy by the Department in mid-2003.

The University of Waterloo encourages applications from all qualified individuals, including women, members of visible minorities, native people and persons with disabilities. All qualified candidates are encouraged to apply; however Canadians and permanent residents will be given priority. This appointment is subject to the availability of funds. Applications should be sent to Dr. John Cherry, Co-chair Search Committee, Department of Earth Sciences, University of Waterloo, Waterloo, Ontario, N2L 3G1 (email: klalbrec@sciborg.uwaterloo.ca).

MARSHALL UNIVERSITY/FACULTY POSITION

The Department of Geology at Marshall University invites applications for a temporary teaching position from August 2003 through May 2004. The position will be filled at the Assistant or Associate Professor level. The successful applicant will be expected to teach upper level courses in Geomorphology (Fall 2003) and Environmental Geology (Spring 2004) as well as an introductory course in General or Physical Geology. A Ph.D. is required and several years teaching experience is preferred. The successful applicant will be expected to integrate a strong field component into the environmental and geomorphology courses.

Applicants should submit a letter of application, curriculum vitae, a statement of teaching and research interests, and the names and contact information (including e-mail addresses) for three references. All application materials should be sent to Dr. Ronald Martino, Chair, Department of Geology, Marshall University, Huntington, WV 25755. Review of applications will begin March 15 and continue until the position is filled.

Marshall University is an EO/AA employer. Women and minorities are encouraged to apply. For additional information about the Department of Geology and Marshall University, please visit the website www.marshall.edu.

Opportunities for Students

Course Offering: Hydrogeology Field Camp at the University of Arkansas, Fayetteville, July 7–August 8, 2003. Field Hydrogeology is a joint effort of the University of Arkansas and the U.S. Geological Survey providing rigorous training in field aspects of physical and chemical hydrogeology. The course is organized in a modular fashion comprising: Module 1—Hydrogeologic Framework and Well Completion, Module 2—Flow Assessment, and Module 3—Water Quality and includes 40-hr HAZMAT training and certification. For information contact: Dr. Phillip D. Hays, 113 Ozark Hall, University of Arkansas, Fayetteville, AR 72701. phone: 501-575-7343, email: pdhays@usgs.gov. Website: www.uark.edu/depts/geology/geology.htm.

Graduate Teaching and Research Assistantships, California State University, Bakersfield. Assistantships available for students wishing to pursue a MS in Geology beginning fall 2003. Appointment carries tuition waiver and $12,500 salary for academic year. Department strengths are in the areas of petroleum geology, structural geology, sedimentary geology, geophysics, hydrogeology and geochemistry. Bakersfield is located in the heart of California's petroleum and agricultural areas and abundant opportunities exist for industry-supported thesis projects. For additional information and application materials contact: Dirk Baron, Graduate Coordinator, Department of Geology, CSU Bakersfield, CA 93311-1099, (661) 664-3044, dbaron@csub.edu or visit the department's web site at http://www.cs.csubak.edu/Geology/.

Research and Teaching Assistantships available for Fall Semester 2003 at Temple University: Research and Teaching Assistantships are available for the fall term (September 2003) in our Masters Program in Geology at Temple University. The 2-year Masters Program offers advanced courses and thesis research opportunities in environmental geology, hydrogeology, geochemistry, environmental geophysics, cyclic stratigraphy, soil science/paleosols, and materials science. Financial support for every student includes stipend, book allowance and full tuition for 2 years. Research Assistantships and/or summer support are currently available for studies in karst hydrology, vertebrate taphonomy and paleopedology, and volcanology monitoring. Graduates of our program have an excellent record of employment and acceptance into doctoral programs. For information and applications please write, call or e-mail Edwin J. Anderson, Department of Geology, Temple University, Philadelphia, PA 19122 (Tel. (215) 204-8249, Fax (215) 204-3496, e-mail andy@astro.temple.edu). Applications will be accepted until these positions are filled. Please visit our web site at http://www.temple.edu/geology for additional information.

Graduate Student Research Grants, The Society for Organic Petrology (TSOP). TSOP invites applications for two graduate student research grants of up to $1000 each. The purpose of the grants is to foster research in organic petrology (which includes coal petrology, kerogen petrology organic geochemistry and related disciplines) by providing support to graduate students who demonstrate the utility and significance of organic petrology in solving the thesis problem.

The Grant Program supports qualified graduate students from around the world who are actively seeking advanced degrees. Preference is given to full-time students in master's (or equivalent) degree programs but applications are also encouraged from Ph.D. candidates and part-time graduate students. Grant are to be applied to expenses directly related to the student's thesis work such as summer fieldwork, laboratory expenses, etc.

Grant application deadline is May 1, 2003. Grants will be awarded in September 2003. Detailed information and an application form on the TSOP web site (http://www.tsop.org/grants.htm) or applications may be obtained from S. J. Russell, Shell UK Exploration & Production, 1 Altens Farm Rd., Nigg, Aberdeen AB12 3FY, United Kingdom; fax: +44(0)1224 88 4184; e-mail: suzanne.j.russell@shell.com.

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