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Fault-Related Folding in California's Northern Channel Islands Documented by Rapid-Static GPS Positioning

INSIDE

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science article

Fault-Related Folding in California's Northern Channel Islands Documented by Rapid-Static GPS Positioning

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ABSTRACT

Rapid-static Global Positioning System positioning was used to measure late Quaternary deformation of uplifted coastal terraces on Santa Rosa and San Miguel Islands, which have accumulated regional warping and local faulting over 100+ k.y. Late Quaternary deformation on Santa Rosa is sharply partitioned, with several hundred meters of surface-rupturing left slip, but 15+ m of vertical motion taken up by folding, resulting in anticlinal growth of at least 0.12 m/k.y. Deformation on San Miguel Island to the west is consistent with warping on the north limb of the regional anticlinal structure. Deformation on both islands matches activity to the east, suggesting that the Santa Rosa Island fault represents an en echelon segment of the larger Transverse Ranges Boundary fault system and the Northern Channel Islands antiform. The Northern Channel Islands have been the focus of a debate over differing geometrical models of fault-related folding, and the deformation measurements presented here suggest that uplift of the islands is occurring over a smoothly curved thrust ramp rather than a fault-bend fold. This reinterpretation is important, as current earthquake-hazard assessments on this and other buried reverse faults depend entirely on assumptions unique to the fault-bend fold geometry. We suggest that alternative models should be considered where geologically reasonable, and that surface uplift measurements across fault-related folds can provide a crucial test of subsurface geometry.

INTRODUCTION

Especially since the 1994 Northridge earthquake, buried reverse faults have been the target of intensive research. In southern California and elsewhere, the locations of these structures, their geometry at depth, and rates and histories of slip are based primarily on balanced cross sections utilizing the fault-bend-fold and fault-propagation-fold models (e.g., Shaw et al., 1994). Because so much crucial information is model specific, there have been rumblings of doubt about the widespread application of these models without independent corroboration (e.g., Ramsay, 1992; Stone, 1996). Our work in the Northern Channel Islands has focused largely on using surface deformation measurement to test subsurface models of fault-related folding.

Precise positioning using the Global Positioning System (GPS) has revolutionized investigations of geodynamics and crustal deformation (University NAVSTAR Consortium, 1998). Data collection of ≥24–48 hours per site can yield precisions of a few millimeters in measurements of intersite baseline distances. In contrast, this project used the same geodetic-quality GPS equipment as a high-precision surveying tool, sacrificing roughly an order of magnitude of precision for rapid-acquisition capability and results forthcoming in a single field season. Unlike geodynamic GPS studies, which directly measure tectonic motion over a few years, we measured "fossil" strain accumulated on uplifted coastal terraces over periods of ~10^5 yr.

Setting

The Northern Channel Islands (Fig. 1) form the southern margin of the Santa

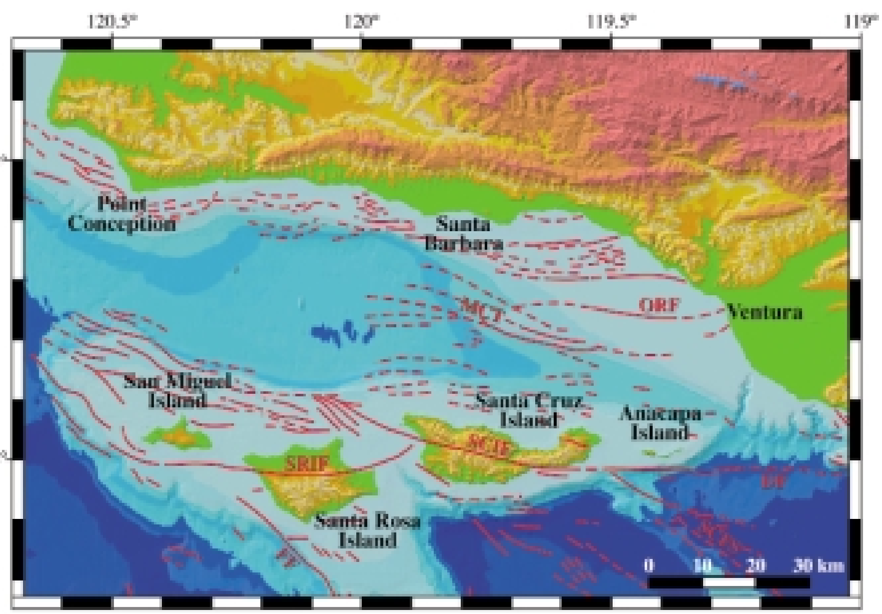


Figure 1. The Northern Channel Islands form the southern margin of the Santa Barbara Channel. Faults are from Jennings (1994). DF—Dume fault; FF—Ferrilo fault; MCT—Mid-Channel trend; ORF—Oak Ridge fault; SCFS—San Clemente fault system; SCIF—Santa Cruz Island fault; SRIF—Santa Rosa Island fault. Digital topography is from U.S. Geological Survey digital elevation models, and bathymetry is from National Oceanic and Atmospheric Administration data, compiled by L. Mertes, Department of Geography, University of California, Santa Barbara.

Barbara Channel and the southernmost range of the western Transverse Ranges. This area is a natural laboratory for examining neotectonic processes that include: (1) complex and partitioned strain; (2) fault-related fold growth; and (3) fault activity that threatens the local area, including Los Angeles. Two active left-lateral faults cut the islands—the Santa Rosa Island fault (Colson, 1996) and the Santa Cruz Island fault (Pinter and Sorlien, 1991). These faults appear to be continuous with similar faults along the northern margin of the Los Angeles Basin, together forming a semicontinuous zone which has been called the Transverse Ranges Boundary fault zone (Pinter et al., 1998). These surface-rupturing faults seem to coexist with low-angle thrust faults at depth (e.g., Shaw and Suppe, 1994; Rivero et al., 2000). Regional thrust structures have been inferred beneath the Santa Monica Mountains (Davis and Namson, 1994; Dolan et al., 1994) and beneath the Northern Channel Islands (the Channel Islands thrust; Shaw and Suppe, 1994). It has been suggested that uplift of the Northern Channel Islands chain is the result of south-vergent slip across a north-dipping ramp in the underlying thrust fault (Shaw and Suppe, 1994; Seeber and Sorlien, 2000). The Northern Channel Islands antiform itself has been interpreted either as a classic fault-bend fold (Shaw and Suppe, 1994) or as the expression of horizontal-axis rotation above a listric-shaped thrust fault (Seeber and Sorlien, 2000). Importantly, each fold model predicts a different magnitude or rate of slip on the causative fault and hence a different earthquake hazard.

Study Area

This research was conducted on San Miguel and Santa Rosa Islands. San Miguel is the westernmost island in the chain. More than 3000 m of Cretaceous to Miocene sedimentary and volcanic rocks are exposed on San Miguel (Weaver and Doerner, 1969). Although traversed by a few faults, no recent slip has been demonstrated on the island. Inland of the sea cliffs that ring San Miguel, the interior has only subdued relief, consisting mainly of uplifted terraces deeply mantled by relict and active sand dunes. On Santa Rosa Island, ~2000 m of Eocene to Miocene sedimentary and volcanic rocks are exposed (Dibblee and Ehrenspeck, 1998). The Tertiary sequence is overlain by diverse late Quaternary deposits, especially dune sand, which reaches thicknesses of ≥50 m (Woolley, 1998). Coastal terraces fringe Santa Rosa and form a broad bench across much of the northern half of the island (Orr, 1960). A uranium-series date of 120 ± 3 k.y., equivalent to oxygen-isotope substage 5e, has been obtained from solitary corals on the second lowest terrace (Thorup, 1994), and this age has been reconfirmed by independent U-Th analysis (J. Lundberg, 2000, pers. comm.).

The most prominent tectonic feature of Santa Rosa Island is the Santa Rosa Island fault. Displacement of Miocene rocks across the Santa Rosa Island fault suggests at least 16 km of left slip on this fault (Weaver, 1969), and more recent motion is indicated by drainages deflected several hundred meters to the left (Colson, 1996). There has been some disagreement about the degree of latest Quaternary activity on the Santa Rosa Island fault. Suggestions of relatively rapid (~1 mm/yr) and recent slip (≥2 ruptures in the past 20 k.y.) and large earthquake hazard (up to M 7.7; Colson, 1996) are difficult to reconcile with other observations, including the eastern sea cliff exposure of the fault, which shows little or no vertical separation across the stage 5e terrace platform (e.g., Sorlien, 1994).

GPS POSITIONING

Several different GPS approaches are available that vary in precision, application, and equipment cost over several orders of magnitude. Since the cessation of military signal degradation in May 2000, handheld GPS receivers yield position accuracies within ±20 m in the horizontal and ±40 m in the vertical. Sources of error include atmospheric effects on the satellite signal, clock errors, and orbital uncertainties. Much of this uncertainty can be reduced using differential positioning, in which two or more receivers are operated simultaneously with one as a stationary base station, yielding meter-level precision with postprocessing. To further increase precision, especially on baselines >5 km, dual-frequency GPS receivers record both the L1 (1227.6 MHz) and L2 (1575.42 MHz) signals in order to remove ionospheric errors.

To achieve the cm-level precision required for most survey applications, GPS carrier-phase data must be used. Receivers that utilize phase data record not only the code from each satellite but also the phase of each incoming signal. In postprocessing GPS phase data, the software must find a unique or fixed-integer solution for the number of carrier-wave cycles for each satellite signal. The resulting level of precision depends largely on the duration of continuous measurements at a site. Rapid-static GPS positioning (Blewitt, 1990) refers to the mode of operation in which one collects the minimum data necessary—as little as ~10 min of measurement—to obtain a fixed-integer carrier-phase solution. For the equipment used here, vertical precision is estimated at 1.0 cm plus one part per million times baseline length (Trimble Navigation, 1998), suggesting that all elevations measured on Santa Rosa and San Miguel were precise to 2.8 cm or better relative to the local base station. Adding this uncertainty to the uncertainty in the local geoid variations, all elevation measurements in the study area should be accurate to better than 5 cm, and all horizontal coordinates accurate to better than 2.5 cm.

Although the rapid-static GPS measurement times were ~150–300 times shorter than for campaign GPS, the positions were only about 5–10 times less precise. This work extended research from the previous 2–3 years on Santa Cruz and Anacapa Islands using ground-based laser surveying. In a single field season, the new GPS-based field work more than doubled the previous data coverage, with precisions equal to or better than the ground-based measurements. The principal advantage of GPS surveying is that it does not require line of sight between measurement points, allowing for much more rapid data acquisition. Another GPS-based alternative is real-time kinematic surveying, which provides real-time differential correction to the roving receiver, although real-time kinematic coverage can be limited in rugged terrain.

On both islands, we used a Trimble 4700 18-channel dual-frequency GPS receiver as the local base station. Two additional dual-frequency receivers (Trimble 4800s) were placed on the terrace points. Although several sites provided as little as 40% sky visibility due to sea cliffs, fixed-integer solutions were obtained at all locations. A total of 139 GPS baselines were measured—102 on Santa Rosa Island and 37 on San Miguel. After the field surveys, base-station data from the two islands were processed using NASA's AutoGIPSY service, producing 3-dimensional base-station coordinates in the 1996 International Terrestrial Reference Frame (ITRF-96). We then processed the baselines between the local base stations and the rover sites using Trimble GPSurvey software.

COASTAL TERRACES

In tectonically active coastal settings, uplifted coastal terraces are valuable markers for assessing the presence, pattern, and rates of late Quaternary deformation. Erosional coastal terraces (Fig. 2) consist of three principal elements: a wave-cut platform, a sea cliff, and an inner edge (or shoreline angle). Coastal terraces form during glacial-interglacial eustatic highstands, and the inner edge marks the highest position of sea level associated with a given highstand. The nature, number, ages, and spacing of terraces on an uplifting coastline depend on the coastal processes active there, the rate of tectonic uplift, and the nature and strength of surface processes that act to erode or otherwise obscure the relict terraces over time (Keller and Pinter, 2001). Terrace inner edges represent vertical datums, with the present-day elevation of a paleo-inner edge, relative to the sea level at which it formed, equal to the magnitude of tectonic uplift since terrace formation. Each uplifted coastal terrace acts as a geomorphic timeline for any active structure that crosses that surface, providing morphological and stratigraphic markers with which to measure the timing and average rates of deformation.

FIELD MEASUREMENTS AND ANALYSIS

In addition to GPS positioning, we mapped the terrace distribution on the two islands. Initial terrace maps were created using 1:40 000 stereo air photographs. The annotated photos were scanned, registered to the U.S. Geological Survey (USGS) digital orthoquadrangles and orthorectified using PCI Orthoengine software. The resulting orthoimage is an undistorted photographic map of the study area, including terrace features, upon which we could automatically overlay our GPS measurements. We mapped three distinct terrace levels on San Miguel Island and five on Santa Rosa (Figs. 3 and 4). The lowest level on both islands, T1, occurs as an irregular notch or narrow bench a few meters above modern sea level, often forming a distinct inset into the terrace above (see Fig. 3). That next level, the 5e-age (~120 ka) T2 terrace, is the most pronounced terrace on both islands, forming a prominent fringing bench around most of Santa Rosa and parts of San Miguel. Above the T2 terrace, the T3 level forms the interior of San Miguel and the broad north flank of Santa Rosa. The great breadth of the T3 terrace on Santa Rosa Island—5 km wide or more in some places—is striking, but careful mapping and GPS measurement reveal that the T3 terrace occurs as two distinct levels with a distinct paleo–sea cliff separating them, largely hidden by the eolian mantle. One additional terrace level was identified still higher on Santa Rosa. The T4 terrace is deeply eroded and is preserved primarily as a series of accordant ridge tops, but the T4 platform is beautifully exposed in outcrop in one location (eastern T4 point on Fig. 4) at 271.7 m elevation. Any other vestiges of T4 have been so severely eroded that no remnants of the platform remain.

Because of the thick eolian cover in the study area, strict criteria were applied in selecting terrace points for GPS measurement. A common misperception about terrace studies is that surface topography can be readily used for quantitative measurements. Where there is sedimentary cover or where erosional stripping is prevalent, careful field investigation is required. We identified terrace wave-cut platforms only in outcrop and only where nearshore marine or beach deposits overlay bedrock across a laterally continuous subhorizontal contact. Typically, the basal deposits on the platform (see Fig. 5) consist of either a fossiliferous sand or imbricate cobbles with abundant molluscan borings. On both islands and on all terrace levels, the primary targets were the inner edges, but where no inner edge was exposed, we measured points on the wave-cut platform as close as possible to the paleo–sea cliff. Because wave-cut platforms have a natural seaward dip, the estimated inner-edge-equivalent elevation (z_{SLA}) for a wave-cut–platform point with a measured elevation of

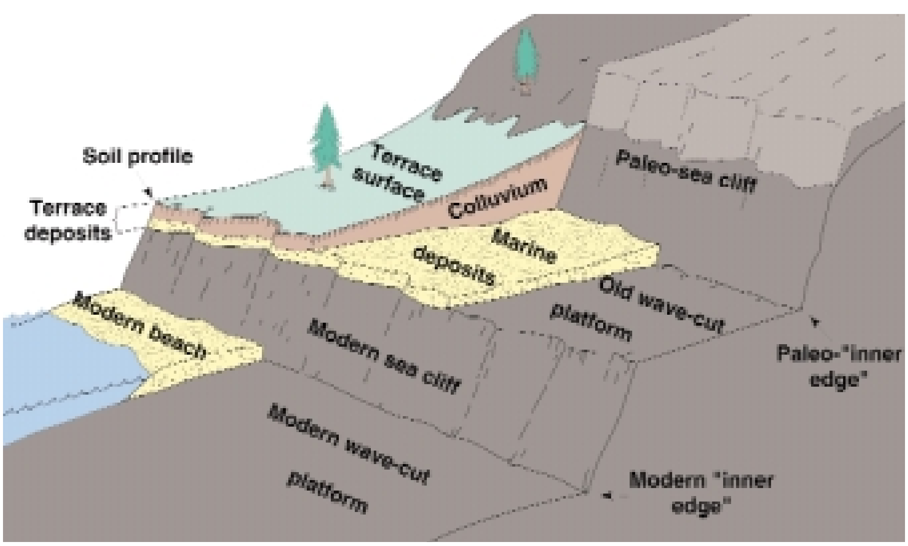


Figure 2. Characteristic morphology of uplifted wave-cut coastal terraces (after Hanson et al., 1990, Guidebook, Friends of the Pleistocene, Pacific Cell, Fall Field Trip).

z_{WCP}, is:

$$z_{SLA} = z_{WCP} + d \tan \alpha \quad (1)$$

where α is the platform slope and d is the orthogonal distance between that point and its associated inner edge. Platform slopes were estimated by measuring trios of terrace points and solving for strike and dip using numerical three-point solutions. The distance d was measured from the terrace orthomaps as the shortest path between each point and the base of its associated paleo–sea cliff. Error ranges were calculated as the sum of the 1 σ standard deviation for platform slope and the GPS measurement uncertainty.

Terrace Profiles

Projecting terrace elevations onto a cross section (Fig. 6), deformation is

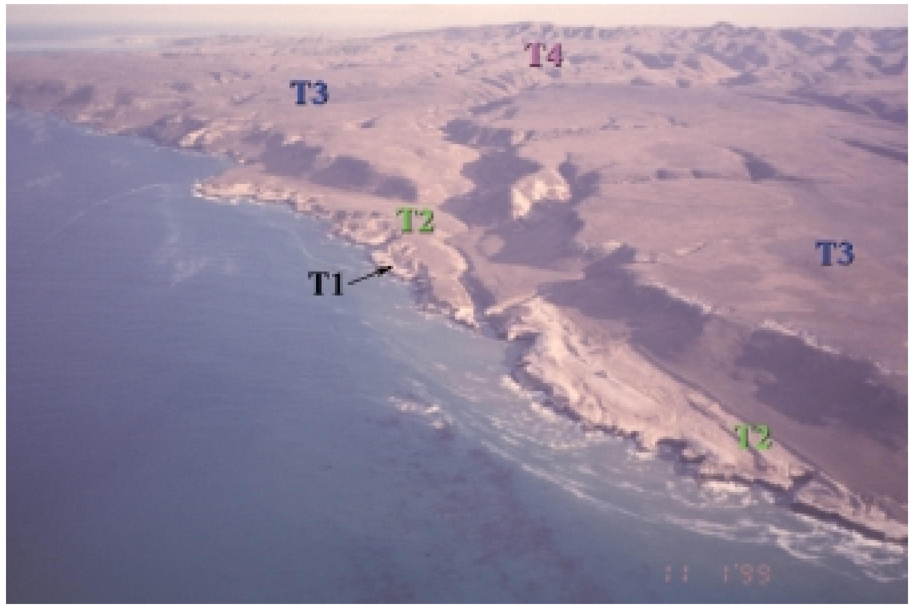
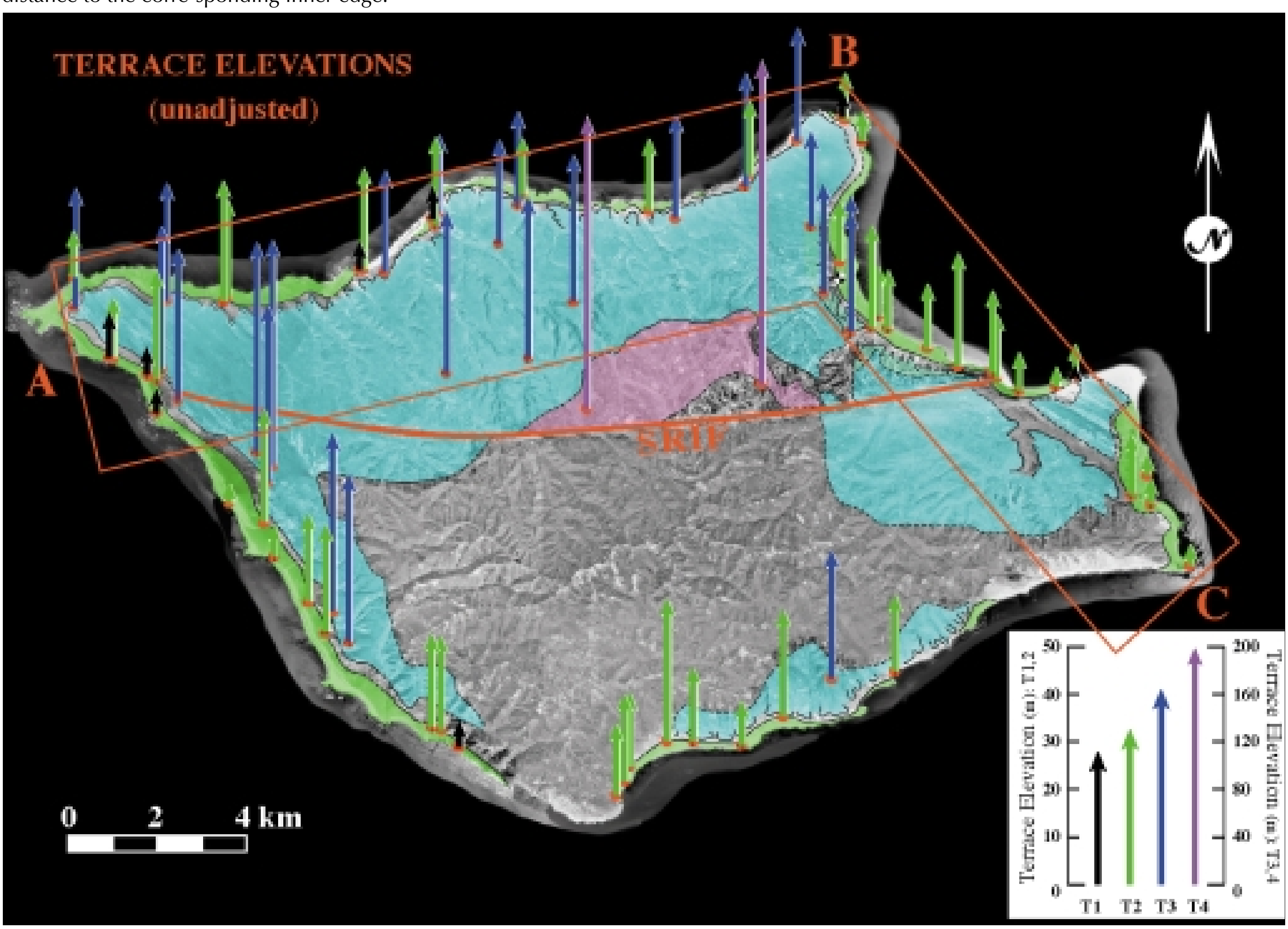


Figure 3. The northwest coast of Santa Rosa Island, looking east. Four terrace levels are shown. Although the surfaces look smooth at this scale, the older terraces are mantled by eolian sand that reaches 50 m in thickness and largely obscures the underlying morphology.

Figure 4 (below). Terrace map and GPS points on Santa Rosa Island. Vectors illustrate elevations of points measured at terrace inner edges and on the wave-cut platforms. Note that the T1 and T2 vectors use a different scale (left) than do the T3 and T4 vectors. Platform elevations shown here are raw elevations, unadjusted for slope and distance to the corre-sponding inner edge.



indicated by variations in the elevation of terrace inner edges. On Santa Rosa Island, the ~125 ka T2 terrace level provided the best tectonic datum, probably because it falls within a critical age window: young enough to be well and widely preserved but old enough to have accumulated tectonic warping that is large relative to the measurement uncertainty. The T2 surface has been anticlinally warped over the Santa Rosa Island fault. The anticline is asymmetrical, with a steep south limb and a gentler north limb. A smooth curve can be fit to the measured T2 points, and scaled versions of this curve also fit the T1 and T3 measurements (Fig. 6). The points on those other terraces alone are too sparse and, on the T3 terrace, the error bars too large to clearly demonstrate the pattern of deformation, but every point measured on Santa Rosa is consistent with the pattern measured on the T2 terrace.

DISCUSSION

Precise measurement of the pattern and rates of late Quaternary deformation across Santa Rosa Island has a number of tectonic implications, both local and regional. Locally, the GPS measurements illustrate that slip on the Santa Rosa Island fault is strongly partitioned, with the strike-slip component of motion manifested at the surface by several-hundred-meter drainage deflections, but the vertical component going blind at shallow depth and absorbed by folding.

A more regional question is how the Santa Rosa Island fault fits into the pattern of deformation along the southern margin

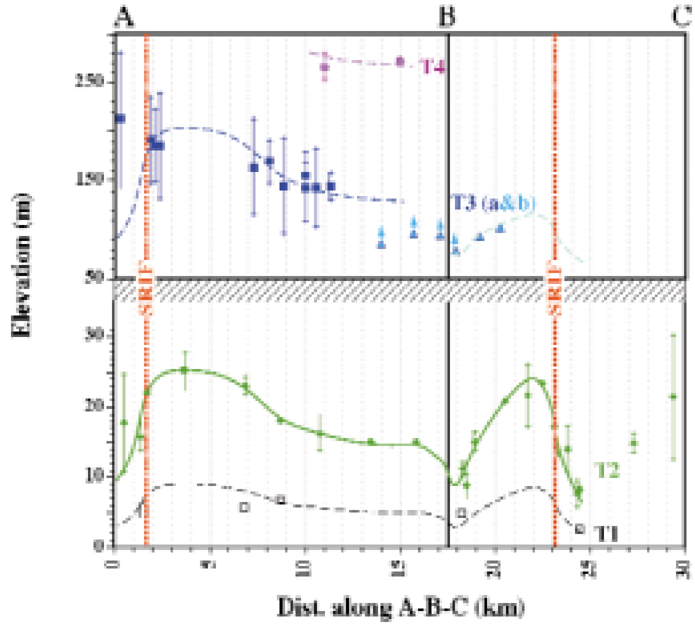


Figure 6. Cross-sectional profile A-B-C on Santa Rosa Island (see Fig. 3) showing corrected terrace elevations. SRIF shows the locations of the Santa Rosa Island fault. Error bars are the sum of the ±1 σ uncertainties in wave-cut platform slope and the GPS measurement errors. Note the change in vertical exaggeration between the lower and upper plots. The green curve was qualitatively fit to the T2 data in order to create the smoothest possible curve that conforms to all points; other curves are scaled versions of the T2 curve. Point spacing is too coarse and error bars too large on the other levels to show deformation details, but the scaled curves show that every measured point is consistent with the pattern measured on T2.

Figure 5. Rapid-static GPS measurement of the wave-cut platform of an uplifted coastal terrace near the inner edge. The receiver sits on the contact between Tertiary bedrock beneath and the late Pleistocene cobble beach above. The beach deposit is overlain by younger eolian and fluvial sediments.

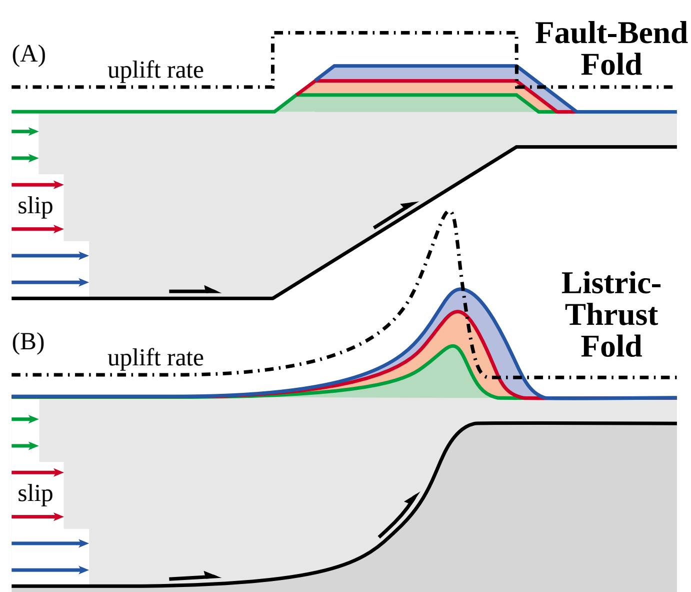


Figure 7. Modeled profiles for three terrace levels (green, red, blue) on (A) a fault-bend fold, and (B) a fold generated above a listric thrust. Uplift rate is proportional to dip on the underlying fault, so that the planar fault ramp uplifts the overlying terraces at a uniform rate, except in narrow zones above the fault kinks. In contrast, a listric thrust ramp results in a smoothly varying uplift-rate profile capable of creating the uplifted coastal terraces measured in the Northern Channel Islands.

of the western Transverse Ranges. The pattern of fault slip and warping on Santa Rosa Island closely matches late Quaternary deformation on Santa Cruz Island to the east. Like the Santa Rosa Island fault, the Santa Cruz Island fault dips steeply to the north, with broad late Quaternary anticlinal uplift north of the fault (Pinter et al., 1998). Both folds are 4–5 km wide, measured perpendicular to the faults, and strongly asymmetrical, with very steep gradients on their south sides. The rates of left slip on the two faults also are similar (0.75 mm/yr on Santa Cruz versus ~1 mm/yr on Santa Rosa), as are the vertical rates of fold-crest uplift (0.1–0.2 mm/yr). These similarities are somewhat surprising because the Santa Rosa Island fault is sharply oblique to the trend of the family of left-oblique faults at the margin of the Transverse Ranges (Fig. 1). We suggest that the Santa Rosa Island fault represents a step-over and the westward extension of the Transverse Ranges Boundary fault zone. Such step-overs in anticlinal axes are documented in a number of locations (e.g., Burbank, 1999), with slip declining along strike on one segment as it picks up on the other. This interpretation is supported by northward tilting of San Miguel Island, confirming that anticlinal deformation follows the trend of the Santa Rosa Island fault westward.

Perhaps the broadest implication of deformation measured on Santa Rosa and San Miguel islands is that, like on Santa Cruz Island to the east (Seeber and Sorlien, 2000), surface uplift rates increase smoothly from north to south up the backlimb of the Northern Channel Islands antiform. This is significant because the fault-bend-fold model that is most widely applied predicts uniform uplift rates above individual fault panels defined by discrete kinks (Fig. 7). The smooth anticlinal warping measured here is inconsistent with a fault-bend-fold model for the Northern Channel Islands. Any fault-bend-fold interpretation can be retroactively fit to varying uplift by inserting as many additional kinks as needed, but we suggest that the listric-thrust model provides a simpler and more robust solution. Furthermore, although folds characterized by discrete kink bands have been unequivocally documented in many locations, smoothly curved thrust ramps are also geologically reasonable in some settings. Listric shaped thrust faults may be reasonable where strain has reoriented over time, and preexisting normal faults have been reactivated as thrusts. The southern California margin experienced widespread and significant extension in the Miocene (Yeats, 1987), and many Miocene extensional faults have been identified (Seeber and Sorlien, 2000). We do not suggest discarding all fault-bend-fold and fault-propagation-fold interpretations, but rather we advocate considering alternative models where they may be geologically reasonable. A broad variety of tools, including measurement of coastal terraces, is available for measuring surface uplift, and this surficial data may provide a vital test for corroborating subsurface fault geometry and verification of fault slip and earthquake hazard assessments that are derived from these models.

ACKNOWLEDGMENTS

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REFERENCES CITED

Blewitt, G., 1990, A new tool for dense monitoring of crustal strain: GPS rapid-static surveying: Eos (Transactions, American Geophysical Union), v. 71, p. 483.

Burbank, D.W., McLean, J.K., Bullen, M., Abdrakhmatov, K.Y., and Miller, M.M., 1999, Partitioning of intermontane basins by thrust-related folding, Tien Shan, Kyrgyzstan: Basin Research, v. 11, p. 75–92.

Colson, K.B., 1996, Neotectonics of the left-lateral Santa Rosa Island fault, western Transverse Ranges, southern California [M.S. thesis]: San Diego, California, San Diego State University, 92 p.

Davis. T.L., and Namson, J., 1994, A balanced cross section of the 1994 Northridge earthquake, southern California: Nature, v. 372, p. 167–169.

Dolan, J.F., Sieh, K., Rockwell, T.K., Yeats, R.S., Shaw, J., Suppe, J., Huftile, G.J., and Gath, E.M., 1994, Prospects for larger or more frequent earthquakes in the Los Angeles metropolitan region: Nature, v. 267, p. 199–205.

Dibblee, T.W. Jr., and Ehrenspeck, H.E., 1998, General geology of Santa Rosa Island, California, *in* Weigand, P.W., ed., Contributions to the geology of the Northern Channel Islands, southern California: Bakersfield, California, Pacific Section, American Association of Petroleum Geologists, MP-45, p. 49–75.

Jennings, C.W., 1994, Fault activity map of California and adjacent areas with locations and ages of recent volcanic eruptions: California Division of Mines and Geology, Geologic Data Map no. 6, scale 1:750 000.

Keller, E.A., and Pinter, N., 2001, Active tectonics: Earthquakes and landscape, 2nd edition: Upper Saddle River, New Jersey, Prentice-Hall, in press.

Orr, P.C., 1960, Late Pleistocene marine terraces on Santa Rosa Island, California: Geological Society of America Bulletin, v. 71, p. 1113–1120.

Pinter, N., and Sorlien, C., 1991, Evidence for latest Pleistocene to Holocene movement on the Santa Cruz Island fault, California: Geology, v. 19, p. 909–912.

Pinter, N., Lueddecke, S.B., Keller, E.A., and Simmons, K., 1998, Late Quaternary slip on the Santa Cruz Island fault, California: Geological Society of America Bulletin, v. 110, p. 711–722.

Ramsay, J.G., 1992, Some geometrical problems of ramp-flat thrust models, *in* McClay, K.R., ed., Thrust Tectonics: London, Chapman & Hall, p. 191–200.

Rivero, C., Shaw, J.H., and Mueller, K., 2000, Oceanside and Thirtymile Bank blind thrusts: Implications for earthquake hazards in coastal southern California: Geology, v. 28, p. 891–894.

Seeber, L., and Sorlien, C.C., 2000, Listric thrusts in the western Transverse Ranges, California: Geological Society of America Bulletin, v. 112, p. 1067–1079.

Shaw, J.H., and Suppe, J., 1994, Active faulting and growth folding in the eastern Santa Barbara Channel, California: Geological Society of America Bulletin, v. 106, p. 607–626.

Shaw, J.H., Hook, S.C., and Suppe, J., 1994, Structural trend analysis by axial surface mapping: American Association of Petroleum Geologists Bulletin, v. 78, p. 700–721.

Sorlien, C.C., 1994, Faulting and uplift of the Northern Channel Islands, California, *in* Halvorson, W.L., and Maender, G.J., eds., The fourth Channel Islands symposium: Update on the status of resources: Santa Barbara, California, Santa Barbara Museum of Natural History, p. 281–296.

Stone, D.S., 1996, Structural trend analysis by axial surface mapping: Discussion: American Association of Petroleum Geologists Bulletin, v. 80, p. 770–779.

Thorup, K., 1994, Deformation of marine terraces on Santa Rosa Island and implications for the activity of the Santa Rosa Island fault [senior thesis]: San Diego, California, San Diego State University, 19 p.

Trimble Navigation, 1998, 4800 Operation Manual: Sunnyvale, California, Trimble Navigation Ltd.

University NAVSTAR Consortium, 1998, UNAVCO brochure, www.unavco.ucar.edu/community/brochure/.

Weaver, D.W., 1969, Geology of the Northern Channel Islands, southern California borderland: Pacific Section, American Association of Petroleum Geologists Special Publication, 200 p.

Weaver, D.W., and Doerner, D.P., 1969, Lower Tertiary stratigraphy, San Miguel and Santa Rosa Islands, *in* Weaver, D.W., ed., Geology of the Northern Channel Islands, southern California borderland: Bakersfield, California, Pacific Section, American Association of Petroleum Geologists Special Publication 200, p. 30–47.

Woolley, J.J., 1998, Aspects of the Quaternary geology of Santa Rosa Island, California, *in* Weigand, P.W., ed., Contributions to the Geology of the Northern Channel Islands, southern California: Bakersfield, California, Pacific Section, American Association of Petroleum Geologists, MP-45, p. 103–110.

Yeats, R.S., 1987, Changing tectonic styles in Cenozoic basins of southern California, *in* Ingersoll, R.V., and Ernst, W.G., eds., Cenozoic basin development of coastal California: Englewood Cliffs, New Jersey, Prentice-Hall, Inc., 496 p.

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AWG and GSA Seek Public Outreach Chair

GSA recently formed several working groups with representatives from its Associated Societies. (See "Dialogue," this page.) The Public Outreach Working Group is made up of representatives from the American Institute of Professional Geologists, the Mineralogical Society of America, the National Ground Water Association, and the Association for Women Geoscientists (AWG).

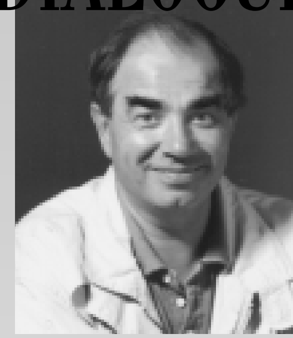
The AWG would like to chair this group and seeks someone with experience in outreach activities (science days, Girl Scout mentoring or leadership, science fair judging, Expanding Your Horizons, other workshops or ventures where the geosciences are brought to young girls and to the public in general). She or he must be an AWG member (but need not be a GSA member) and must attend two meetings per year (the GSA Annual Meeting and one in late winter or early fall in Boulder). AWG will help fund travel to the meetings. The chair also will send a progress report to GSA on substantive issues about one month before each meeting.

AWG looks forward to this opportunity to have a substantive voice in the geoscience community and to take a leadership role in providing geoscience outreach. If you are interested in having an impact on how the geosciences are presented to the public, please contact AWG President Mary Anne Holmes at president@awg.org.

DIALOGUE

Associated Societies Meet at GSA Headquarters

A.J. Naldrett, *Vice-President of GSA*



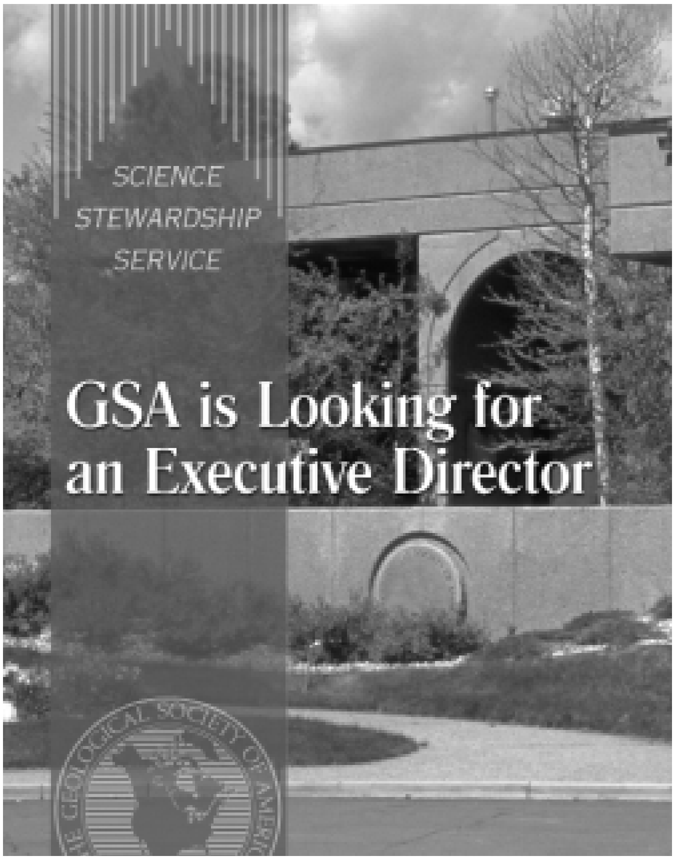
A strong working relationship between GSA and other societies involved in the earth sciences can be highly productive in furthering the goals and missions of all of these groups. In the past, cooperation has involved primarily joint meetings at many levels, including the annual and section meetings and Penrose conferences, and some collaboration on publications, issues of public policy, education, outreach, and professional development. A meeting of representatives of most GSA Associated Societies, headquarters staff, and myself, was convened by GSA President Sharon Mosher in Boulder on February 23. This meeting enabled individual Associated Societies to find out more about each other, to decide on the kind of interrelationships that they would like to have, and also to debate the role that they could play in GSA governance.

The outcome of the day's discussions was a decision to establish a forum of representatives of Associated Societies with the mission to "enhance the common goals and missions of GSA and Associated Societies through communication, collaboration, and cooperation." The forum will meet at the GSA Annual Meeting, as well as convene for a working meeting in late winter or early spring. As GSA vice-president, I will serve as chair of the forum and as liaison to GSA Council. The establishment of this forum is an exciting opportunity for us to collectively work toward common goals and to avoid duplication of efforts.

The meeting started with representatives from each society outlining how their societies function and what their principal interests are with respect to collaboration with GSA and each other. Discussion then focused on the topics of public policy, international representation (globalization), education, public outreach, meetings, and publications. Many interesting ideas were expressed, and it became clear that different societies had very different priorities with respect to each topic. After the discussion of each topic, an "expression of interest" sheet was passed around. This sheet was used to set up five working groups—public outreach, education, publications, global initiatives, and public policy. It was thought that the topic of meetings was adequately covered by the existing structure. Each of the working groups is composed of three to ten societies that will select a coordinator and then communicate by e-mail and phone. The coordinators will present short reports on the work of their groups at the spring meeting of the forum, where it will be discussed as a whole. In the interest of having a manageable number of participants, only those societies expressing a high interest in any topic were included in any one working group. An auxiliary list of societies to be kept informed was also set up for each group.

Associated Societies participating in the forum were the Association of Engineering Geologists, the Society of Economic Geologists, the Geological Society of South Africa, the American Association of Stratigraphic Palynologists, the Society for Sedimentary Geology (SEPM), the Mineralogical Society of America, the Cushman Foundation, the American Institute of Professional Geologists, Sigma Gamma Epsilon, the Council on Undergraduate Research—Geology Division, the Paleontological Society, the National Association of Geoscience Teachers, the National Ground Water Association, the Geoscience Information Society, the Society of Vertebrate Paleontology, the Association of American State Geologists, and the Association for Women Geoscientists, plus an observer from the American Geological Institute. Associated Societies that were not represented will be able to participate in the future and to join any of the working groups in which they have a strong interest.

This agreement to form an Associated Society Forum to cooperate and collaborate on common goals and missions is the first step in developing a strong working relationship among all geoscience societies to further the common interests of earth science in general. Only by working together can geoscience societies meet the challenges ahead in the next decade.



The Geological Society of America (GSA) is seeking an individual to assume the duties of Executive Director as early as Sept. 1, 2001. The selected individual will:

- Work with the Executive Committee and Council of GSA to implement the newly adopted Strategic Plan.
- Work closely with GSA Foundation Board and staff to coordinate and promote the directions and policies of the GSA Council.
- Maintain collaborative relationships with representatives of other national and international geoscience societies and organizations and actively pursue joint ventures that enhance the financial and scholarly status of the Society.
- Lead the GSA Headquarters staff of 65 persons. Articulate the vision and mission of the Society to staff and members through teamwork and collaborative efforts. Society activities include membership services; meetings; publications; education, public policy, and outreach; marketing and strategic communications; financial services; and information technology activities.

The new director will work at the GSA headquarters in Boulder, Colorado, and will hold a position with competitive compensation and benefits.

The deadline for applications or nominations is June 15, 2001.

REQUIREMENTS

- Provide leadership to diverse groups such as committees, Associated Societies, staff, and volunteers through collaborative teamwork.
- Commitment to strong interpersonal communication among and between staff, members, and volunteers. Proven record of motivating staff to develop new sources of revenue and to use technology to improve efficiencies.
- Master's degree in geosciences; Ph.D. preferred. Extensive management experience and achievements in the areas of accrual budgeting, financial planning and investments, and personnel management. Additional preparation in education, marketing, and/or business management encouraged.
- Commitment to geoscience research, public outreach and education programs, and scholarly publishing.
- Familiarity with marketing and public relations.
- Demonstrated familiarity with the geoscience community and GSA programs.

Submit a resume, the names and addresses of three references, and a letter describing your interest in the position to:

Executive Director Search Committee
The Geological Society of America
P.O. Box 9140
Boulder, CO 80301-9140

Book Reviews

Numerical Models in Groundwater Pollution

Karel Kovarik, *Springer-Verlag, Berlin, 2000, $79.95.*

Although this book is clearly written and uses straightforward mathematical notation, it is not an introductory modeling book. Kovarik provides a comprehensive, if rather concise, overview of various modeling methods for groundwater flow and pollutant transport. The focus is on the Finite Element Method and the Boundary Element Method, which are more complex and difficult to implement than the widely used Finite Difference Method. However, the irregularly shaped elements of the Boundary Element Method and Finite Element Method more precisely match the shape of complex, natural domains than does the rectangular grid of the Finite Difference Method. A brief chapter that summarizes and compares the properties of different groundwater flow modeling methods, as well as different methods of modeling pollutant transport, is particularly useful and interesting.

The chapters that develop the numerical methods mostly refer to classic modeling papers from the 1970s and 1980s. The focus is mainly on advective-dispersive transport modeling, and no mention is made of geochemical reactions or reactive transport modeling. Case studies of the application of the Finite Element Method and Boundary Element Method to groundwater flow and remediation problems provide insight into the benefits of these numerical methods. Unfortunately, a reader interested in more detail regarding the interesting example cases in the book is led to references of technical reports written in Czechoslovakian.

Kovarik is a professor at the University of Zilina, Slovakia, who has published numerous articles, mostly in Czechoslovakian, on the transport of pollutants in porous media. This book makes his work accessible to an English-reading audience. In many places, the English grammar is humorously awkward, but this does not prevent technical points from being made.

The enclosed CD contains two software programs: one implements the Boundary Element Method for planar models of steady groundwater flow coupled with the random walk method of modeling pollutant transport; the other utilizes the Finite Element Method to simulate one-dimensional unsaturated flow and pollutant transport. The overly simple test cases included with the programs on CD are useful only for academic demonstrations of the numerical methods developed in the book. It would have been more interesting if at least one of the more complex example simulations from the book had been included on the disk.

Overall, this is an interesting little book, but not the comprehensive treatise that its rather general title would suggest. Its main contribution is the comparison of the advantages of the Boundary Element Method over the more widely used Finite Difference Method.

Diana Holford Bacon
Pacific Northwest National Laboratory
Richland, WA 99352

The History and Dynamics of Global Plate Motions

Edited by Mark A. Richards, Richard G. Gordon, and Rob D. van der Hilst, *American Geophysical Union, 2000, 398 p., $70.00.*

This is a timely book. The authors observe that in the 36 years since plate tectonic theory burst upon our poorly prepared community, the analysis of plate dynamics has been overwhelmingly kinematic. Although early heroes like Forsyth and Uyeda did think about the forces involved, it has only been in the past few years that observational and computational advances have permitted progress toward a full dynamic understanding. Eighteen papers reviewing and advancing various aspects of that understanding are divided into five sections addressing: (1) convection, rheology, and plates; (2) continental dynamics and intraplate deformation; (3) tectonics and dynamics of the Australian region; (4) seismic tomography and mantle flow; and (5) hotspots and plate motions. Several of the papers contain frankly tutorial material that I found to be particularly helpful. Research moves fast in this field, and it should be appreciated that recent publications and talks at meetings by some of the authors represent both change and progress. Nonetheless, I expect to be consulting this book for several years and for that reason regret that there is no index. There are so many good things in the book that I find it hard to select examples. However, because, as I think Tip O'Neal almost said, "All geology is regional geology," I did find that the three papers on Australia and its region together made up a particularly coherent contribution.

A minor point is that I think that the suggestion, on page 26, that the Wilson cycle might operate with a characteristic time scale of 0.5 Ga is misleading. On April 12, 1968, in Philadelphia, Wilson told his American Philosophical Society audience that if you look at a map of the world you can see oceans opening in some places and closing in others. He therefore suggested that, because the ocean basins make up the largest areas of Earth's surface, it would be appropriate to interpret earth history in terms of the life cycles of the opening and the closing of the ocean basins. He did not add that ocean opening and closing have no characteristic length or time scale, but I think that is worth emphasizing because, as Per Bak has told us, those are the hallmarks of self-organized criticality.

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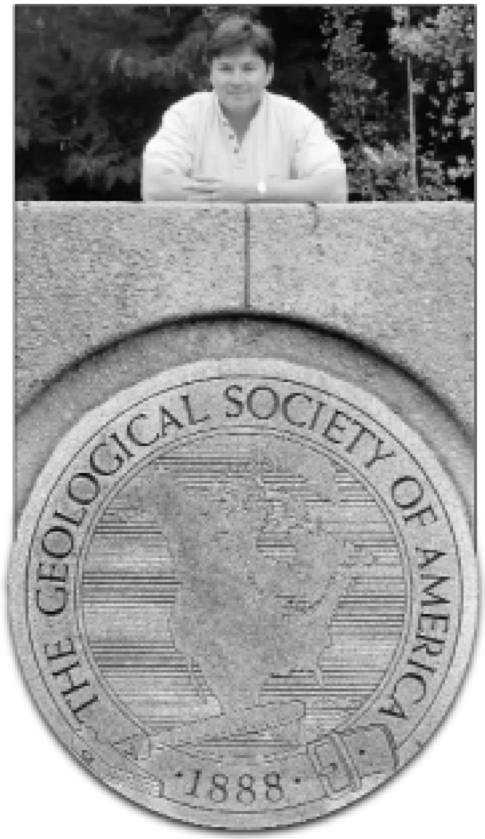
kburke@uh.edu

Sara Foland Resigns as GSA CEO



Sara Foland, GSA chief executive officer since July 1999, resigned on March 9. Foland has made many major contributions to GSA, including starting our new program of global meetings, the first of which, Earth System Processes, held this June in Edinburgh, Scotland, is cosponsored by the Geological Society of London. She has dedicated much time to initializing global strategic partnerships with geological societies of various other countries and to establishing better relationships with other major geoscience societies, including the American Geophysical Union and the American Association of Petroleum Geologists. Foland has also been very active in implementing GSA's Strategic Plan, which was formulated by GSA's strategic planning committee and approved by Council just prior to her arrival at GSA Headquarters.

Foland is perhaps best known, however, for her financial accomplishments. She instituted new budgeting systems and made financial accountability an integral part of all operations at GSA Headquarters. All new initiatives must be thoroughly planned and reviewed for merit and for financial soundness and feasibility, and old programs must be reviewed periodically. Foland has accomplished much of what she wanted to accomplish for GSA and will be moving on to other endeavors. We ask you to join us in wishing her the best of success in the future.

It's Happening, and You Can Still Register!

Earth System Processes—Global Meeting
June 24–28, 2001, Edinburgh, Scotland

Cosponsored by the Geological Society of America and the Geological Society, London

Society presidents Sharon Mosher and Lord Oxburgh of Liverpool and technical co-chairs Ian Dalziel and Ian Fairchild invite you to join them for an exciting interdisciplinary meeting—arranged around the twin themes of Earth System Linkages and Earth System Evolution—in the unique setting of Scotland's capital city.

In addition to daily plenary lectures by distinguished scientists, the following oral and poster sessions are now finalized.

- Tectonosedimentary Process Interaction at Global Ocean Margins
- Causes of Rapid Climate Changes in the Quaternary
- Geological Evolution of the Earth System: Precambrian to Early Paleozoic
- Geological Evolution of the Earth System: Mesozoic and Cenozoic
- Coupled Earth Processes: Deformation, Chemical Reaction, and Heat in Fault- and Fracture-Dominated Flow
- Interactions between the Cryosphere and Biogeochemical Cycles
- Data Assimilation for the Earth System
- Fragile and Hazardous Environments
- Coupling of Fluid Reservoirs within the Earth
- Role of Natural Gas Hydrates in the Evolution of Planetary Bodies and Life
- Earth Resources
- Controls on Phanerozoic Diversifications and Extinctions: Long-Term Interactions between the Physical and Biotic Realms
- Feedbacks and Coupling between Geosphere, Biosphere, Hydrosphere, and Atmosphere
- Archean Earth and Contemporary Life: The Transition from an Anaerobic to an Aerobic Marine Ecosystem
- Global Change in the Late Paleozoic
- Anthropogenic Modifications to the Earth System
- Public Communication of Environmental Issues and Hazards
- Role of Hydrothermal Systems in Biospheric Evolution
- Critical Transitions in Earth History and Their Causes
- Time Scales of Denudation: From Catchment to Continent
- Fluid Seeps and Shallow Migration Phenomena at Continental Margins: Impacts Spanning the Lithosphere, Biosphere, and Hydrosphere
- Role of Tropical Oceans in the Earth System
- Biodegradation of Petroleum—Implications for the Deep Biosphere
- The Snowball Earth Hypothesis: Theory and Observations
- Integrated Approaches to Water Quality Issues
- Timing and Rates in Earth System Processes
- Sedimentary Systems and Microbial Communities: Dynamic Interactions

The full program can be viewed at http://gsa.confex.com/gsa/2001ESP/finalprogram/. This site also posts full information on hotels, accompanying persons' programs, and other details.

Note: We regret that at press time there is still uncertainty concerning some of the field trips due to the severe outbreak of hoof-and-mouth disease in the British Isles. The GSA Web site, www.geosociety.org, will be updated in this regard as soon as the situation is clarified.

GSA supports efforts to increase awareness of the value of geoscience within the greater scientific community, society at large, and among our own members. This column highlights efforts that contribute to the claim that geoscience matters. To submit information about similar efforts contact Senior Director of Programs and Products Dennis Goldman at dgoldman@geosociety.org.

Institute for Earth Science and the Environment (IEE): Evolution of a Vision

Sometimes an idea is born in the right place at the right time. But many times, the right idea is born in the right place, significantly ahead of its time. Such ideas need mindful care, consistent nourishment, and a large dose of dedication to survive their infancy. In 1989, Fred Donath, supported by like-minded colleagues, founded the IEE within GSA. Concisely stated, Donath's vision was that the IEE would "offer a geoscience interface between the private and public sectors and the geological community on matters of the environment." Donath's notion that we must "invest in the wise use of the Earth" was ahead of its time in terms of the sensibilities of the geoscience community in 1989. For six years, Fred Donath volunteered his time, energy, and expertise to the incubation of the IEE. Such dedication epitomizes the concept of professional service.

What's in a Name?

Originally, the IEE acronym stood for Institute for Environmental Education. Donath and his colleagues considered "education" to be a broad mandate and believed that decision makers, the public, and geoscientists themselves needed to be taught that geoscience is relevant to environmental challenges. They were right. Only recently has the concept of relevance become palatable to many sectors of the greater geoscience community. In the last half of the last decade of the past century, however, our community began to see itself as not only relevant, but critical to addressing environmental challenges. As this awareness grew—independently—at varying rates and in variable forms among parts of the geoscience community, GSA's IEE was there. The IEE Annual Environmental Forum became a Sunday afternoon fixture of the annual meeting. Ideas for intern programs, mentor programs, workshops for federal agencies, and media workshops were born.

In 1995, Dan Sarewitz became the first paid director of the IEE. Over the next two years, Sarewitz built a direct connection between the IEE and public policy efforts, working closely with GSA's Geology and Public Policy Committee. Under the IEE aegis, Sarewitz facilitated workshops to help integrate the Biological Resources Division into the U.S. Geological Survey (USGS) and stimulated GSA's leadership to include a goal for integrative science in its developing strategic plan. In 1996, Sarewitz planted the seeds of the IEE's partnership with the Geologic Resources Division of the National Park Service by placing two undergraduate interns in national parks. Building on Donath's groundwork, Sarewitz outlined plans that drew the interest of the IEE's primary benefactors, John and Carol Mann, Roy Shlemon, and Peter Flawn. In 1996 and 1997, each of these benefactors established funds in the GSA Foundation to benefit the IEE.

By the time I came to GSA in 1998, the IEE had an identity that members recognized. *GSA Today* regularly featured the "Environment Matters" column, initiated by Dan Sarewitz. Aided by a generous gift from the Shell Foundation, Barb Mieras had placed eight interns in national parks for that summer. Liz Knapp was handling the public policy interface with the help of the Geology and Public Policy Committee, had Shlemon Mentor programs running at two section meetings, and had launched the first John F. Mann mentor program with enormous help from our friend Bob Stoller.

Also by that time, the term environmental education had come to have generic meaning for the public. "EE" efforts by nonprofit organizations, public schools, corporations, and government from municipalities through federal agencies all centered on teaching ethics and practices of conservation of natural resources. As valuable as this American movement is today, it is not what Donath and his colleagues meant by environmental education. The time had come to change the name of the IEE to reflect its original mandate and its portfolio of programs. With Fred Donath's endorsement, Council voted in 1999 to change the name to the Institute for Earth Science and the Environment.

Today's IEE

Donath's vision of the IEE is no longer ahead of its time. Today, our whole geoscience community recognizes that we have an obligation to bring our science to the public table. Our community knows that we must be part of integrated efforts to address critical questions about global change. We know that we must be involved in addressing global challenges of sustainable energy development, water resources, land use, and agriculture. The IEE's mission is now an expression of a recognition shared by—and uniting—the geoscience community.

Today's IEE is behind GeoCorps America™. GeoCorps, directed by Katie KellerLynn, will place 32 earth scientists in national parks, monuments, and forests this summer. It is designed to be a program of the whole geoscience community, and we hope our associated and allied societies will join us in reaching our goal to place 100 earth scientists on public lands in 2002.

Today's IEE is behind the Roy J. Shlemon Mentor Program in Applied Geology. Since Karlon Blythe began directing the IEE mentor programs, every GSA section meeting now hosts a Shlemon program. Earnings from the Shlemon gift to the IEE ensure that this program will be funded in perpetuity. Gifts to the IEE also support the John F. Mann Mentor Program in Hydrogeology.

Earnings from Peter Flawn's gift to the IEE support the global geoindicators workshop series ("Geoscience Matters," *GSA Today*, February 2001). The IEE backed last fall's successful Colorado-based Earth Science Week efforts. We shipped the beautiful Celebrate Colorado Geology poster and member-recommended reading lists to hundreds of public libraries and school libraries in Colorado and then distributed funds to those libraries to purchase earth science–oriented books. REI provided us with the auditorium in their new Denver flagship store and helped us bring in GSA members to speak to the public on adventure geology (see *GSA Today*, January 2001, p. 24).

The IEE was behind our successful Geology of Coastal Ecosystems conference with the USGS and the National Park Service. It is behind our work to develop the "Geology on Public Lands" short course with the U.S. Department of Agriculture Forest Service, Bureau of Land Management, and National Park Service.

The IEE mission underpins our work with the Geologic Resources Division of the National Park Service to use the geoindicators system in strategic planning and budgeting for resource management. IEE dollars support our joint undertakings with the USGS, which have included six pivotal workshops and/or conferences since 1996. Our support of the American Association of Petroleum Geologists' Division of Environmental Geoscience efforts, including the most recent conference on sustainability ("Geoscience Matters," *GSA Today*, March 2001) is backed by IEE funds.

IEE support allowed the USDA Forest Service to double the size of its "Geology of Ecosystems" field course so that it could be offered to other federal land management agencies. The IEE has helped bring speakers to the Geology and Public Policy Forum every year since 1995, and of course helps support the travel of speakers for the Annual Environmental Forum. The Geology and Public Policy committee's kiosk in the GSA Headquarters exhibit area at the annual meeting has been paid for by the IEE for years. Our work with the National Conference on the Teaching of Evolution is backed by IEE dollars ("Geoscience Matters," *GSA Today*, January 2001). To summarize, the IEE is behind the lion's share of GSA's efforts to promote the value of geoscience in partnership with our allies.

Who is the IEE?

The IEE is many things. It is an idea nurtured over years by Fred Donath. It is the mandate underpinning many of GSA's service programs. The IEE is the spirit of collaboration joining us to similar efforts of our geoscience community. But above all, the IEE is people. It is the late John Mann, whose gift through the GSA Foundation is the financial backbone of the IEE. It is Carol Mann, whose annual gift sustains our efforts. The IEE is Peter Flawn, Roy Shlemon, and the host of donors who believe that geoscience is essential to society.

The IEE is the GSA headquarters staff. It's Karlon Blythe, working with the sections to put on five or six Shlemon programs each spring, and it's Margo Good, turning a lovely photograph of Rabbit Ears Pass into a dynamite poster celebrating Colorado geology. The IEE is Katie KellerLynn and the gang from the National Park Service Geologic Resources Division and the USDA Forest Service screening hundreds of applications to the GeoCorps America™ program, and all of those working with the Bureau of Land Management to hammer out a curriculum for the geology on public lands course. The IEE is Donna Russell in the GSA Foundation, reminding me to always, always recognize and thank our donors, and finding a little money here or there to help us meet our goals. And the IEE is GSA members, taking the time to be a mentor or lending their expertise at a conference, or speaking in a forum. GSA's Institute for Earth Science and the Environment is all of us, and it represents many of our highest aspirations and most significant accomplishments.

Cathleen May

Cathleen May Steps Down as Chief Science Officer

Cathleen May, chief science officer since July 2000, has resigned after nearly three years at GSA Headquarters. May joined the headquarters staff at GSA as the director of the Institute for Environmental Education in June 1998 and also served as director of Science, Education, and Outreach during her tenure at GSA.

May has made numerous contributions to GSA in the areas of public outreach, public policy, and education. She established the GeoCorps America™ program, which puts student interns (and now professional geologists) on public lands. In this program, earth science interns interact with the hundreds of visitors to public lands or work on research projects behind the scenes in National Park Service parks and in U.S. Department of Agriculture Forest Service forests, ensuring that public lands have the scientific resources they need. The number of applicants is 30 times the number of available positions based on the current level of sponsorship. This rapidly expanding program will allow any geoscience organization, other foundations, and additional corporate sponsors to participate by supporting placements in parks, forests and other public lands. In addition, May has been instrumental in building momentum for the Roy J. Shlemon Mentor Program in Applied Geology.

During her time at GSA, May has worked closely with our Associated Societies, the American Geological Institute, the U.S. Geological Survey, and other groups, and she has collaborated on organizing numerous workshops related to the environment and to other areas of public outreach and education. May has indicated that she intends to continue working with the geoscience community to increase society's awareness of geoscience. We ask you to join us in wishing her the best of success in the future.

ANNOUNCEMENTS

MEETINGS CALENDAR

2001 MEETINGS

October 3–6	Society of Vertebrate Paleontology 61st Annual Conference, Bozeman, Montana. Information: Society of Vertebrate Paleontology, 60 Revere Drive, Suite 500, Northbrook, IL 60062, (847) 480-9095, fax 847-480-9282, svp@vertpaleo.org, www.vertpaleo.org.

2002 MEETINGS

April 24–26	15th Argentine Geological Congress, El Calafate, Santa Cruz Province (Southern Patagonia), Argentina. Information: Dr. Miguel Haller, President; Dr. Roberto Page, Secretary, Asociación Geológica Argentina, Maipú 645, 1er Piso, Buenos Aires, Argentina, phone/fax 54-11-4325-3104, haller@cenpat.edu.ar or formicruz@internet.siscotel.com, www. cenpat.edu.ar/xvcga.

Only new or changed information is published in *GSA Today*.
A complete listing is posted in the Calendar section at www.geosociety.org.

Volunteer Geologists Needed for Philmont Scout Ranch

Here's your chance to stay at an old mining camp 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. The program runs from June 17 through August 12. Spouses are welcome, and spouses and/or children may participate in the Philmont Training Center programs. For more information, contact Ed Warner, (720) 904-0560, ewarn@ix.netcom.com.

Fossils of Burgess Shale Explored in Smithsonian Traveling Exhibition

"Burgess Shale: Evolution's Big Bang" from the Smithsonian Institution Traveling Exhibition Service (SITES) uses fossils, lifelike models, scientific illustrations, and interactive displays to highlight events of this evolutionary upsurge. "Burgess Shale" will appear at the Calgary Science Center in Calgary, Alberta, from July 7 through September 30. After its viewing in Calgary, the exhibition will continue on a four-year tour to 15 institutions.

"Burgess Shale: Evolution's Big Bang" was developed by SITES and the Smithsonian's National Museum of Natural History's Department of Paleobiology. GSA member Douglas H. Erwin of the museum is the curator of the exhibition. Information on the Burgess Shale is available at www.nmnh.si.edu/paleo/shale/index.html. Descriptions and itineraries for SITES exhibitions can be found at www.si.edu/sites.

Proposals Invited

The Scientific Committee on the Lithosphere (SCL) invites proposals for new projects to be conducted under the auspices of the International Lithosphere Program (ILP). Since 1990, ILP projects have been operating under the umbrella of four program themes: geoscience of global change; continental dynamics and deep processes; continental lithosphere; and oceanic lithosphere. A small amount of money is available for each project leader for travel and administrative expenses. Further financial support must be sought from funding agencies, but the ILP's experience suggests that its initiation and support offers considerable credibility to grant applications.

For information and guidelines, contact Kaye Shedlock, ILP Secretary-General, U.S. Geological Survey, MS 966, Box 25046, Denver, CO 80225, (303) 273-8571, fax 303-273-8600, shedlock@usgs.gov, or see the ILP home page at www.gfz-potsdam.de/pb4/ilp. Proposals for projects to be initiated in January 2002 are due by October 31, 2001.

The ILP was established in 1980 by the International Council of Scientific Unions at the request of the International Union of Geodesy and Geophysics and the International Union of Geological Sciences.

In Memoriam

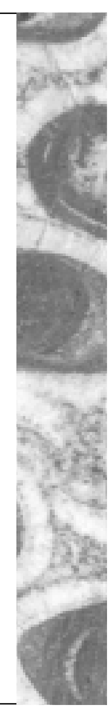
Jack E. Geary
Tehachapi, California
January 2001

Kerry R. Kelts
Minneapolis, Minnesota
February 8, 2001

Glenn C. Prescott Jr.
Augusta, Maine

Louis J. Pribyl
Washington, D.C.
December 13, 2000

Frank W. Wilson
Lawrence, Kansas
February 2, 2001



GSA Foundation Update

Focus on a Foundation Fund

Donna L. Russell, *Director of Operations*

Over the next several months, GSA Foundation Update will focus on the restricted funds held by the Foundation. Each month, we'll bring you up to date on one of the special named funds within the Foundation.

The Young Scientist Award (Donath Medal)

The idea for the Young Scientist Award came from the 1987 meeting of the Path to the Year 2000 Committee. This prestigious award was endowed through the generosity of Dr. and Mrs. Fred A. Donath in 1988, and was announced at the 1988 GSA Annual Meeting in Denver during A.W. Bally's presidential address. Fred Donath's identification with GSA during his career, as well as the medal he received from Rice University in 1962, influenced and motivated this gift. Donath also is a former Foundation Trustee.

The award is given to a young (35 years or younger during the year of the award) scientist for outstanding achievement in contributing to geologic knowledge through original research that marks a major advance in the earth sciences.

The awardees are chosen from nominations presented to the GSA Council by a special committee. The Young Scientist Award consists of a gold medal and a cash prize. The first recipient of this award was Mark Cloos in 1989. The recipient for 2000 is Basil Tikoff. The fund has grown substantially over the years and now supports a $20,000 cash prize.

For further information regarding the Young Scientist Award (Donath Medal), please contact Leah Carter, Program Officer, Grants, Awards, and Medals, at 1-800-472-1988, ext. 137.

Is the Foundation in Your Will?

If you have named the Foundation in your will, please check the space on the coupon below and send it to us. Your name will be added to the Pardee Coterie, which is the Foundation's planned giving roster. All members of the Coterie will be invited to attend a breakfast during GSA's Annual Meeting.

Brunton Sponsorship for Boston Annual Meeting

The Brunton Corporation furnished engraved plaques and transits for 20 GSA awards that were given out at the GSA Annual Meeting in Reno. The recipients of these impressive plaques were very enthusiastic about them.

Jon Cox of Brunton has notified the Foundation that Brunton will again furnish 20 plaques, which will be given out at the Boston meeting in November. On behalf of GSA and the Foundation's Board of Trustees, we extend our sincere appreciation to Brunton and to Jon Cox for their continued generosity.

Digging Up the Past

Most memorable early geologic experience

In 1968, I was SCUBA diving with Michael E. Field, measuring shelf-sediment sedimentary structures off North Carolina, when a blacktip shark decided to accompany us back to the boat.

—Ian G. MacIntyre

GSA Foundation

Enclosed is my contribution in the amount of $____________.

Please credit my contribution to the:

☐ Unrestricted Fund

☐ Other: ________________ Fund

☐ I have named GSA Foundation in my will.

PLEASE PRINT

Name ____

Address ____

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Phone ____

3300 Penrose Place, P.O. Box 9140
Boulder, CO 80301-9140
(303) 447-2020 drussell@geosociety.org

Donors to the Foundation, February 2001

Archaeological Geology Division Award
Vance T. Holliday

Institute for Earth Science and the Environment
Charles C. Rich

John T. Dillon Alaska Scholarship Award
Carl S. Benson

International Division Award
Pembroke J. Hart**

Rip Rapp Archaeological Geology Award
Aureal T. Cross

Research Grants
American Geological Institute**
Susan M. Kidwell
Judith A. Schiebout
Jeffrey A. Sitler

Keith Runcorn Fund
Carl S. Benson

SAGE
Charles C. Rich

Shoemaker Memorial Fund for Crater Studies
Jewish Community Foundation**

Unrestricted
David C. Adams
Charles C. Almy Jr.
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Correction to December 2000 donor list:

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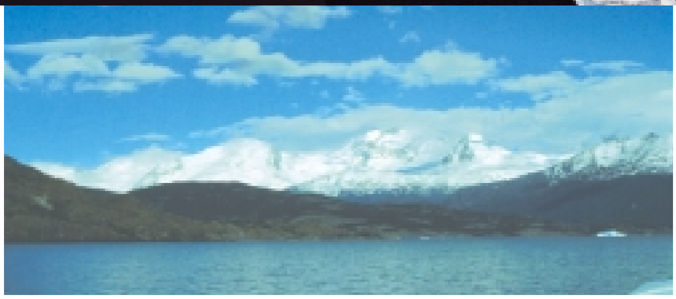
2001 GeoVentures



Lago Argentino. Photo by J. Reynolds.

GeoTrip

New Year's at the End of the World: The Geology of Southern Patagonia, Including Tierra del Fuego
Dec. 26, 2001–Jan. 10, 2002
15 days, 14 nights
Scientific leaders: James Reynolds, Brevard College, Brevard, North Carolina; Dorothy L. Stout, Cypress College, Cypress, California.

Jim Reynolds has spent the past 15 years investigating the uplift history of the Andes. Using magnetostratigraphy, Jim and his colleagues are developing a relatively precise chronostratigraphy across the many tectonic provinces that we will visit. In addition to his work at Magstrat, LLC, and Brevard College, he holds an adjunct position at the University of Pittsburgh.

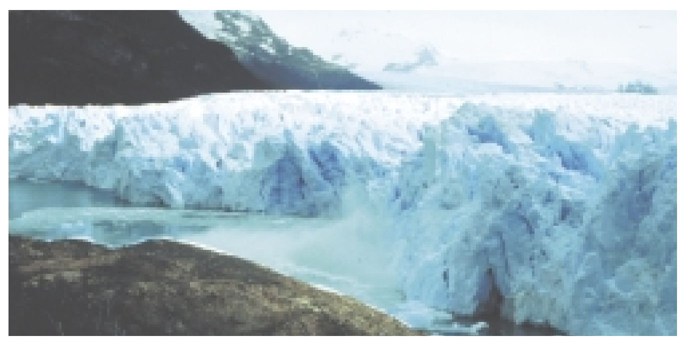
Since 1978, Dottie Stout has been leading geological expeditions around the world, including trips to China, South America, Africa, Europe, Indonesia, Australia, and Russia. Dottie is past president of the National Association of Geology Teachers and is temporarily on leave as a program director at the National Science Foundation.

Description

Our trip will start in Ushuaia, Argentina, the southernmost city in the world, at the base of the Cordillera Darwin on the Beagle Channel along the southern shore of Tierra del Fuego. The austral summer can be pleasant, but is seldom truly warm. We'll look at the glaciers, rocks, and the tectonic setting along the channel before we cross the mountains to the Patagonian steppes that comprise the northern part of the island. After crossing into Chile and taking the ferry across the Straits of Magellan to the South American mainland, we'll head eastward along the straits through the oil and gas fields to the penguin rookery near Punta Dungeness, Argentina. We'll observe the interplay between sea-level changes, glaciations, waves, currents, and extreme tidal ranges that shaped the coastline, while dodging the numerous rheas and guanacos on the plains. From there, we'll go to Río Gallegos and then to Glaciers National Park in the Patagonian Andes. We'll watch icebergs calve off of the Perito Moreno glacier into Lago Argentino, take a daylong boat trip on the lake, and slalom through the icebergs while Andean condors soar overhead. A low pass through the mountains will take us to Torres del Paine National Park in Chile to see the most spectacular mountains in the Andes. After a boat trip up the Ultima Esperanza fjord at Puerto Natales, we'll head to Punta Arenas and our flight home.

Fees and Payment

$4,200 for GSA members, $4,300 for nonmembers. A $300 deposit is due with your reservation and is refundable through Sept. 1, less a $50 processing fee. Total balance is due Sept. 1. Minimum: 20; maximum: 30. Included: Guidebook; airfare from Atlanta to Ushuaia via Buenos Aires; ground transportation; lodging for 13 nights (double occupancy); and meals for 14 days. Not included: Airfare to and from Atlanta, Georgia; and alcoholic beverages.



Perito Moreno glacier. Photo by J. Reynolds.

Register Today!

Send a deposit to hold your reservation; please pay by check or credit card. You will receive further information and a confirmation of your registration within two weeks after your reservation is received.

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GSA Member # ______________________

	Deposit Per Person	No. of Persons	Total Paid Deposit
Patagonia	$300	___	$________

TOTAL DEPOSIT $________

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☐ I've enclosed no deposit, but I'm interested. Please send information.

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Positions Open

RICHARD STOCKTON COLLEGE OF NEW JERSEY

MARINE GEOLOGIST: September 2001. Instructor (ABD); assistant professor (doctorate) preferred with specialization in "hard rock" geology and expertise in some aspect of marine geology and in the use of geographical information systems. We seek a qualified marine geologist to teach and undertake research that involves undergraduate students. The position is a full-time faculty appointment; may be renewable based on continued grant funding. The objective is to combine knowledge of marine geology, mineralogy, and petrology and GIS software to enhance the existing undergraduate programs in geoscience and marine science. Responsibilities will include teaching undergraduate courses in topics such as mineralogy, petrology, and marine geology, a course in the geologic application of GIS, plus courses within the college's General Studies curriculum. The Marine Science program has a marine science field station with some laboratory space and several boats appropriate for back bay studies. Stockton is a state-supported residential liberal arts and sciences college with over 5000 full-time students in rural South Jersey. Salary range: instructor ($31,911–$41,480); assistant professor ($38,789–$42,668) depending upon qualifications, experience, and increases in the appropriately established compensation plan. Screening begins immediately. Send resume, three letters of recommendation, and evidence of completion of the doctorate to Dr. Lynn Stiles, Dean of Natural Sciences and Mathematics, The Richard Stockton College of New Jersey, AA66, P.O Box 195, Pomona, NJ 08240-0195. Stockton is an AA/EOE. Women and minorities are encouraged to apply. R014248

UNIVERSITY OF MIAMI ROSENSTIEL SCHOOL OF MARINE AND ATMOSPHERIC SCIENCE

The Division of Marine Geology and Geophysics is seeking individuals with a Ph.D. and a strong interest in establishing an active research program in the general field of earth remote sensing. These individuals should be able to exploit and contribute to the new Center for Sub-Tropical Advanced Remote Sensing (CSTARS), an X-band ground receiving station for satellite data.

Applications are encouraged in a broad range of disciplines, including environmental sciences, coastal/estuarine processes, and solid earth sciences, and any branch of remote sensing. Two appointments will be made at either the assistant or associate professor level. Successful candidates will have the opportunity to develop interdisciplinary research programs in collaboration with other RSMAS faculty (see Web site for list of research interests: http://www.rsmas.miami.edu/research.html) and should demonstrate the potential to secure extramural research funds. Rank and salary are negotiable. Send CV, names and addresses of five references, and a concise statement of interest to: Chair of Search Committee, Rosenstiel School of Marine and Atmospheric Science, Marine Geology and Geophysics, 4600 Rickenbacker Causeway, Miami, Florida 33149-1098. The search will remain open until a successful candidate is selected. The University of Miami is an Equal Opportunity/Affirmative Action Employer.

VERTEBRATE PALEONTOLOGY POSITION BRIGHAM YOUNG UNIVERSITY

The Department of Geology at Brigham Young University invites applications for a tenure-track position in vertebrate paleontology with an emphasis in dinosaur paleobiology. The successful candidate will be expected to teach courses (undergraduate and graduate) in this field along with Historical Geology and other general geology courses as needed. The successful candidate must have a Ph.D. and will be expected to initiate/maintain a productive research program that includes, but is not restricted to, development of the extensive dinosaur collections currently housed at BYU. The position will be available as early as July 1, 2002. Starting salary and rank will be commensurate with experience.

Applicants should send a letter of application and curriculum vitae including names of three references to Dr. Scott M. Ritter, Faculty Search Committee, Department of Geology-S 389 ESC, Brigham Young University, Provo, UT 84602. Application materials must be received on or before August 1, 2001, 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.

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Translation and Information for Japanese Earth Science. Please visit Earth-J at http://earthj.vis.ne.jp, e-mail: earthj@mf.vis.ne.jp.

Opportunities for Students

Visiting Fellows and Students/Institute for Rock Magnetism. Applications are invited for visiting fellowships (regular and student) lasting for up to 10 days during the period from September 1, 2001, through February 28, 2002. Topics for research are open to any field of study involving fine particle magnetism, but preference will be given to projects relating magnetism to geological or environmental studies, or to fundamental physical studies. A limited number of travel grants of up to $750 are available to cover actual travel costs. No funds are available for per diem expenses. Application forms and information necessary for proposal preparation may be obtained from IRM manager Mike Jackson at the address below, or on the Web at http://www.geo.umn.edu/orgs/irm/irm.html. Short proposals (two pages, single-spaced text plus two forms and necessary figures and tables) are due by June 15, 2001, for consideration by the institute's Review and Advisory Committee. Successful applicants will be notified in early August 2001. Proposals should be sent to: Facilities Manager, Institute for Rock Magnetism, University of Minnesota, 291 Shepherd Laboratories, 100 Union St. SE, Minneapolis, MN 55455-0128, (612) 624-5274; fax: 612-625-7502.

GSA Needs Help

Wanted:

Technical Program Chairs for the 2003 and 2004 GSA Annual Meetings

The search is on for the Technical Program Chair for the 2003 GSA Annual Meeting in Seattle, Washington, and the 2004 meeting in Denver, Colorado. If you are interested in serving as chair, or if you know someone who would be effective in this capacity, visit GSA's Web site at www.geosociety.org /meetings/chairnom.htm or contact the GSA Meetings Department for a nomination form at (303) 447-2020, ext. 190. Nominations are due July 15, 2001.

The Technical Program Chair has the final responsibility for the entire technical program. Review and acceptance of keynote and topical session proposals happens during January and February, and scheduling of all sessions, in conjunction with Joint Technical Program Committee (JTPC) representatives, occurs in July through August. The chair will serve on the Annual Program Committe for three years. This committee meets twice a year, usually in March and again in August.

The Technical Program Chair must be a GSA member with a broad perspective on the geological sciences, and must be efficient, organized, fair-minded, flexible, and committed to organizing a dynamic meeting. Experience in scheduling a technical program (such as membership on the JTCP in the past five years) is helpful but not required.

Hot Topics Chair for the 2002 and 2003 GSA Annual Meetings

The Annual Program Committee is seeking a Hot Topics Chair for the Annual Meetings in 2002 in Denver and 2003 in Seattle. The Hot Topics Chair arranges for spirited debates or controversial, lively discussions during lunchtimes at the annual meeting.

If you or someone you know is interested in the latest issues facing the geosciences, this is a great opportunity to get involved and help shape the Hot Topics schedule for 2002 and 2003. If you are interested in serving, or if you know someone you think would be an effective, energetic Hot Topics chair, visit GSA's Web site at www.geosociety. org/meetings/chairnom.htm or contact the GSA Meetings Department at (303) 447-2020, ext. 190, for a nomination form. Nominations are due July 15, 2001.

Visit GSA's Web site at www.geosociety.org/ meetings/chairnom.htm or contact the GSA Meetings Department at (303) 447-2020, ext. 190, for a nomination form. Nominations are due July 15, 2001.

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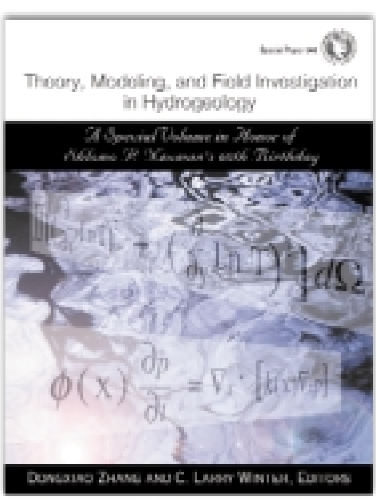

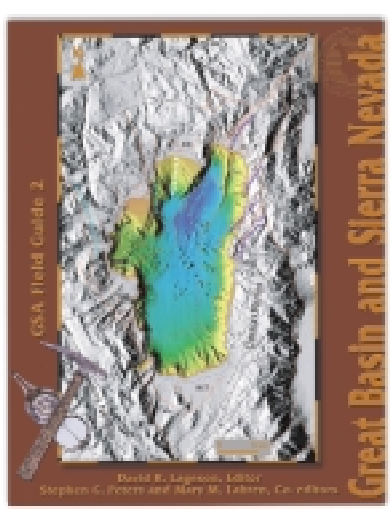

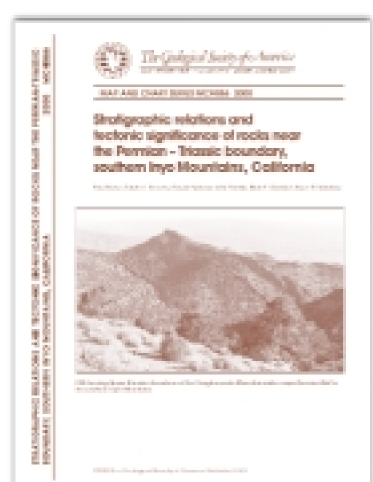

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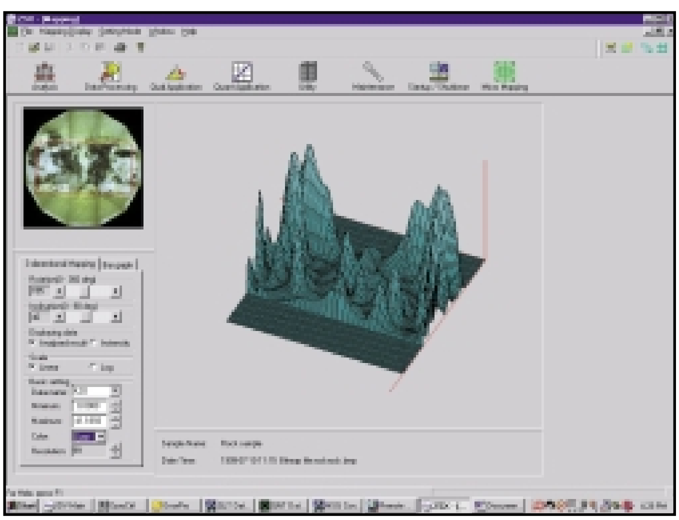

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