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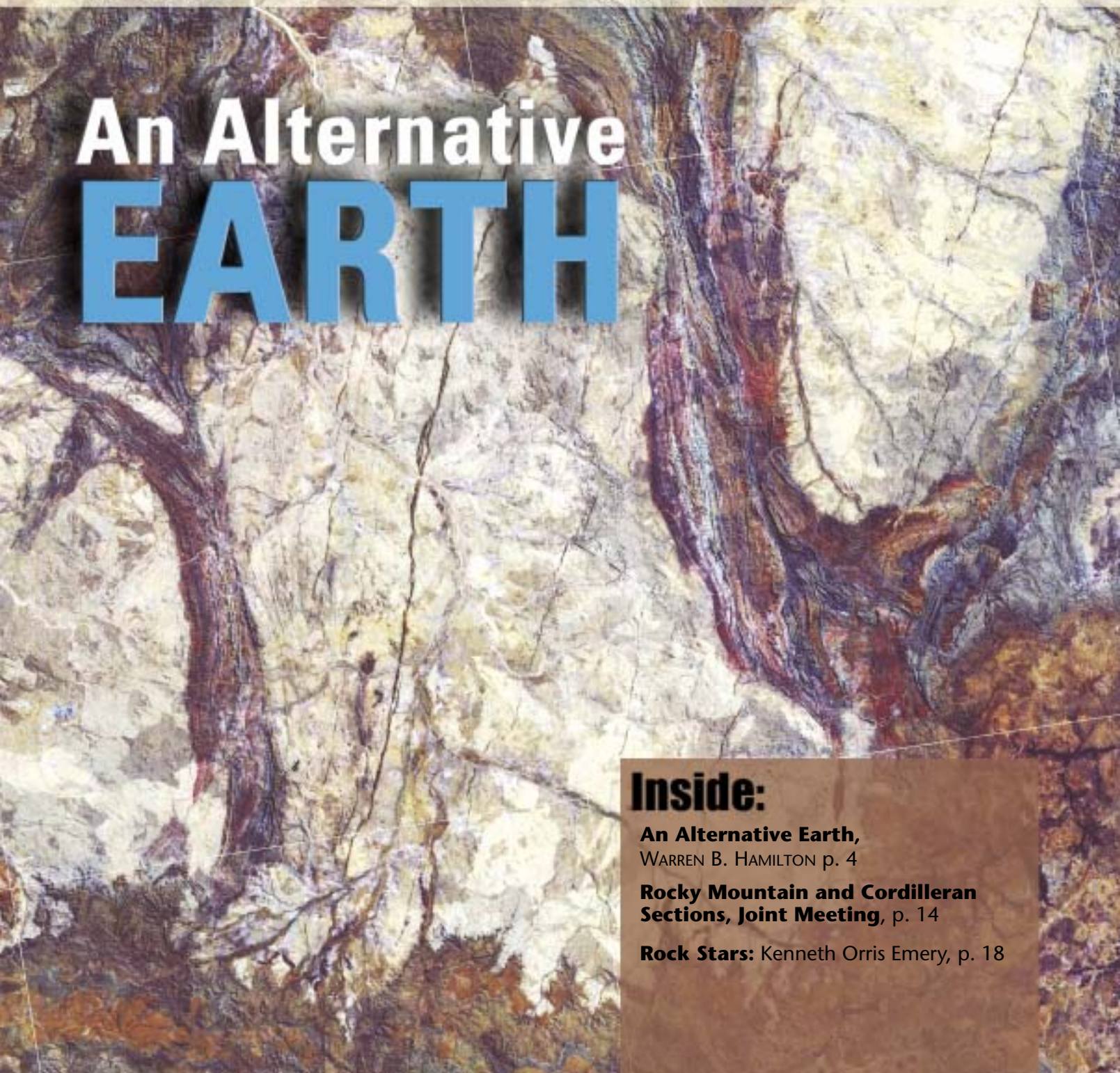

# An Alternative EARTH

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**Cover:** Archean granite-and-greenstone assemblage, central Pilbara craton, NW Australia, in a false-color Landsat satellite image (from Australian Centre for Remote Sensing, Australian Surveying and Land Information Group). Domal granitic batholiths (light; 3.5–2.9 Ga zircons) intrude 3.5–3.2 Ga ultramafic, mafic, and felsic volcanic rocks (multicolor stripes) that are preserved in synclines. Late Archean mafic and felsic volcanic rocks and iron formation, ca. 2.8–2.6 Ga (brown), overlie older units in S (lower part of image). The geology was mapped by Geological Survey of Western Australia geologists. Area is 100 km wide. See "An alternative Earth," by W.B. Hamilton, p. 4–12.

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# An Alternative EARTH

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## ABSTRACT

The standard Earth of geodynamics and geochemistry is rationalized from assumptions that the mantle is compositionally inverted—still-unfractionated lower mantle beneath volatile-depleted upper mantle—and that material circulates easily from bottom to top. Multidisciplinary data better fit a less-volatile and less-radioactive planet wherein depleted lower mantle, fractionated early and irreversibly, is decoupled from upper mantle plus crust that evolve and circulate separately. Early Archean fractionation produced global(?) felsic crust and refractory upper mantle. Later Archean granite-and-greenstone upper crust formed atop this ancient crust, which remained hot and weak; distinct continents and oceans did not exist, and upper mantle was much hotter than now. Plate tectonics began ca. 2.0 Ga when continents could stand above oceans and oceanic lithosphere could cool to subduction-enabling density and thickness. Upper mantle has since become more fertile and new increments of continental crust more mafic as continental crust has been progressively diminished by recycling into cooling mantle. Plate circulation is driven by subduction, which is enabled by density inversion produced by seawater cooling from the top of oceanic lithosphere, is self-organized, and is confined to upper mantle. The matching rates of hinge rollback and of advance of fronts of overriding plates are keys to dynamics. Slabs sinking broadside from retreating hinges drive both subducting and overriding plates and force seafloor spreading in both shrinking and expanding oceans. An Antarctica-fixed framework depicts prediction-confirming "absolute" plate motions that make kinematic sense, whereas hotspot and no-net-rotation frames do not. Plumes from deep mantle, subduction into deep mantle, and bottom-up convective drive do not exist.

## INTRODUCTION

The conventional model (e.g., Turcotte and Schubert, 2002) of Earth's evolution and dynamics postulates that most of the mantle is little fractionated, major differentiation continues, and continental crust has grown progressively throughout geologic time; through-the-mantle convection operates, lithosphere plates are moved by bottom-driven currents, and plumes rise from basal mantle to surface; and plate tectonics operated in early Precambrian time. All of these conjectures likely are false. They descend from speculation by Urey (1951) and other pioneers, reasonable then but not now, that Earth accreted slowly and at low temperature from fertile chondritic and carbonaceous-chondritic materials, heated gradually by radioactive decay and core segregation, and is still fractionating.

The notion of a cold, volatile-rich, young planet has long since been disproved, but its corollary of unfractionated lower mantle survives as the basic assumption from which the standard model is rationalized. This assumption and its derivatives are incompatible with major constraints. This essay summarizes, and continues and diverges from, a long paper (Hamilton, 2002) wherein many topics only noted here were discussed and documented. My sparse citations here are mostly of representative current papers from among hundreds of sources incorporated.

## EVOLVING EARTH

Uniform tectonics should not be assumed over the 4.4 b.y. span recorded by dated Earth minerals. Crust and mantle processes changed greatly as Earth cooled by loss of original heat and by decreasing production of radiogenic heat.

### Accretion and Fractionation

Earth accreted hot, fast, and violently. Distribution of $^{182}$Hf (half-life 9 m.y.) and its daughter $^{182}$W indicates that Earth likely reached two-thirds of its present size within ~10 m.y. of first condensation of solid grains in the solar nebula, ca. 4.567 Ga (Jacobsen, 2003). Orbital considerations require that accretion was dominated by large bolides formed near Earth's distance from the Sun but that much material came from elsewhere sunward of Jupiter; the bulk of atmospheric, hydrospheric, and carbon components may have arrived late, mostly from the outer part of the asteroid belt (e.g., Alexander et al., 2001; Wetherill, 1994). Pre-aggregation material was zoned heliocentrically by evaporation—and condensation beyond "snow lines"—of volatile elements and compounds. This is shown by irregular zonation of asteroids linked to meteorite types by reflectance spectroscopy. Outer asteroids are dominated by ices and organic compounds (no meteorites), medial ones by organic materials and variably hydrated silicates (carbonaceous chondrites), and inner ones by silicates and metal (most meteorites, including chondrites; Alexander et al., 2001; Britt and Lebofsky, 1999). The heliocentric trend obviously continues through Mars and Earth, but to what extent? Modern calculations (e.g., Allègre et al., 2001) of Earth's composition accept volatile fractionation relative to meteorites but assume a relatively low-temperature cutoff and a still-unfractionated lower mantle and may much overestimate Earth's volatile elements.

Accreting Earth was repeatedly partly melted and devolatilized by great impacts, and the likely Moon-forming mega-impact (before 4.45 Ga) would have wholly melted and further devolatilized the protoplanet (Zhang, 2002). Irreversible final fractionation of deep Earth mantle is made likely by intrinsic density, very low thermal expansivity, and very high melting temperature of perovskite, the probable dominant mineral, at lower-mantle pressure (Anderson, 2002a). Barriers, uncrossable by material and hence layering convection, may occur near depths of 2000 km (Badro et al., 2003) and 1000 km (Anderson, 2002a) in the lower mantle and 660 km at its top, but I discuss only

the last of these because upper-mantle circulation likely is closed above it.

A bulk Earth low in K, hence volatile elements, and fractionation of K and the incompatible elements U and Th into upper mantle and crust (and hence layered circulation), are indicated also by thermodynamics. Earth's heat loss, now largely of radiogenic heat, is much overstated in the standard model. The conventional value, ~44 TW, is derived by substituting for measured heat flows on young oceanic crust vastly higher values calculated with the assumptions that heat flow must fit a square-root-of-age function and that oceanic lithosphere has constant conductivity. As conductivity in fact decreases greatly with temperature, actual heat loss is ~31 TW, close to the measured value, and thermodynamic and mineral-physics data require that nearly all radioactivity be above 660 km (Hofmeister and Criss, 2003).

## Evolving Crust and Lithospheric Mantle

Continental crust became more depleted in mobile elements with decreasing age, whereas continental lithospheric mantle, and likely the entire upper mantle, became more enriched in them. These observed trends are opposite to those required by the standard model. Archean crust commonly is more felsic in bulk composition than younger crust and lacks the latter's typical thick underplated norite and mafic granulite (e.g., Durrheim and Mooney, 1994). Both xenoliths (Griffin et al., 2003b) and the inverse correlation of crustal age with mantle contribution to continental heatflow (Artemieva and Mooney, 2001) prove the opposite trend in continental lithospheric mantle, which becomes vastly richer in low-melting compounds with decreasing crustal age. Oceanic upper mantle is less well constrained but resembles Phanerozoic, not Archean, subcontinental lithosphere (Griffin et al., 2003b). Magnesian Archean subcontinental peridotite is lower in density, even though much colder, than asthenosphere and rides buoyantly with cratons.

Upper mantle has cooled during geologic time. Archean lithospheric peridotite has retrograde-metamorphic mineralogy and metasomatism of sampling-kimberlite ages, but texture and bulk composition of some of it fits initial (Paleoarchean?) crystallization from liquidus melt ~400 °C hotter than present near-solidus asthenosphere (Herzberg, 1993). (I use the nonstandardized term Paleoarchean to mean 4.4–3.5 Ga; Mesoarchean, 3.5–3.0 Ga; and Neoarchean, 3.0–2.5 Ga.) Ultramafic lava (komatiite), whose liquidus composition indicates a mantle residuum of olivine + orthopyroxene, is common in Mesoarchean and Neoarchean volcanic sections and requires upper mantle ~200 °C hotter than modern asthenosphere.

If the 660 km discontinuity is uncrossable by material, as I argue subsequently, then the inverse secular compositional trends of crust and upper mantle reflect thorough initial separation followed by progressive mixing back into upper mantle of most early crust and of sediments derived from it, and successively less complete separation of new crust from that increasingly enriched mantle. Volume of continental crust has thus decreased greatly through time. The common contrary claim that crust has grown through time derives mostly from isotopic calculations based on false assumptions of constant compositions of crust and mantle.

**Figure 1.** Paleoarchean heterolithic and polycyclic migmatite (tonalite, granodiorite, pegmatite, and mafic rocks), Acasta Lake, Slave craton, northwest Canada. Nearly concordant ion-microprobe U-Pb ages, by S.A. Bowring, of zircons from this outcrop scatter from 3.96 to 3.5 Ga. Only felsic gneisses are known as basement beneath Archean supracrustal rocks, including ultramafic volcanics.

## Paleoarchean Continental Crust

Archean mafic and ultramafic volcanic rocks are known to overlie only ancient felsic basement. Pre–3.5 Ga rocks in cratons are polycyclic felsic migmatites and gneisses dominated by hydrous (biotite > hornblende) tonalite, trondhjemite, and granodiorite (TTG) and containing abundant small to huge enclaves of ultramafic, mafic, and anorthositic rocks (Fig. 1; Bleeker, 2002). Concordant ion-probe U-Pb age determinations of cores of zircons in these gneisses reach 4.2 Ga (and of clastic zircons in derivative quartzite, 4.4 Ga) in SW Australia, 4.1 Ga in NW Canada, 4.0 Ga in Wyoming, 3.9 Ga in central Canada, Labrador, and SW Greenland, 3.8 Ga in China, 3.7 Ga in NW Australia and South Africa, and 3.6 Ga in West Africa, as reported by various authors. Most zircon ages in these migmatites are, however, much younger, with wide variations between nearby samples, and typically scatter along or close below U-Pb concordia down toward or to the 3.3–2.6 Ga ages of intrusion of granites into supracrustal sequences. The ancient gneisses record a billion years of repeated partial melt or at least of temperatures above that required for formation of new zircon, and remobilized melts must have been hydrous and low-temperature where inherited zircons are preserved (cf. Miller et al., 2003). Isotopes of Pb (Kamber et al., 2003), Hf (Scherer et al., 2001), and Nd in the gneisses accord with separation from mantle of protoliths well before 4 Ga, followed by complex recycling, rather than with prolonged incremental growth from the mantle.

Earth's felsic components may have been mostly fractionated by 4.4 Ga into "continental" crust, most of which has since been returned to upper mantle. Hydrous TTG melt can form at low pressure by fractionation of hydrous basaltic melt, by partial melting of hydrated mafic metamorphic rocks, or by recycling. No Archean mantle or basal crust is exposed but seismic velocities suggest that felsic and intermediate migma-

**Figure 2.** Archean fuchsitic quartzite, Lake Winnipeg, Superior craton, Manitoba, part of thin section deposited on basement gneiss (zircons ca. 3.0 Ga) and overlain by thick pillow basalt (ca. 2.7 Ga). Mapping and dates by J.A. Percival and associates. Coin diameter: 3 cm.

**Figure 3.** Landsat satellite image of Mesoarchean granite-and-greenstone assemblage, central Pilbara craton, NW Australia. Domiform crustal-melt granitic batholiths (light; 3.5–2.9 Ga zircons) rose during and after deposition of 3.5–3.2 Ga ultramafic, mafic, and felsic volcanic rocks and sediments (multicolor stripes) preserved in open to tight and complex synclines. Another greenstone cycle, Neoarchean mafic and felsic volcanic rocks and iron formation, ca. 2.8–2.6 Ga (brown), overlies older units in S and in small syncline in N. Geology mapped by Geological Survey of Western Australia geologists. Area 175 km wide. Image supplied by Australian Centre for Remote Sensing, Australian Surveying and Land Information Group. Colors assigned to spectral bands: blue to visible green, green to near-IR, red to mid-IR.

tites extend to the base of the crust, so major complementary materials are now in the mantle and a dominant origin from metavolcanic rocks is precluded. Direct fractionation, followed by recycling, is inferred. Paleoarchean felsic crust may have been kept hot from below, from within by concentrated radioactivity, and from above by dense greenhouse atmosphere. Crust was too hot and weak to stand high as continents, its tracts moved differentially atop rapidly convecting upper mantle, and it flowed internally.

Regional temporal and isotopic variations in ancient gneisses (Bleeker, 2002; Griffin et al., 2003a) may relate to both impacts and upper-mantle motions. Huge bolides hit the Moon as late as 3.9 Ga, which more likely dates the tail end of main accretion than a late bombardment. Lunar impact history transfers with increased intensity to Earth, where bolides produced great transient excavations into upper mantle, forming giant magma lakes by impact and decompression melting, and redistributed huge tracts of crust. Paleoarchean anorthosites are low-pressure calcic fractionates, now churned into ancient migmatites, and perhaps they and the voluminous ultramafic and mafic enclaves and unidentified hot, dry protoliths for some of the ancient gneisses differentiated in impact lakes.

## Mesoarchean and Neoarchean Tectonics

Volcanic and sedimentary "greenstone belt" assemblages were deposited after ca. 3.5 Ga (possibly 3.8 Ga) in some cratons-to-be and ca. 3.0 Ga in others on TTG basement. Only felsic rocks are known from outcrop or seismology to underlie mafic volcanic rocks, and no supracrustal rocks are proved ensimatic or deep-ocean. Where depositional contacts with basement are preserved, strata commonly begin, not with mafic volcanic rocks, but with thin micaceous quartzite (Fig. 2), derived from basement that was above sea level nearby, and/or with thin chert and banded iron formation (Bleeker, 2002). Above this, lower parts of supracrustal successions are typified by plains of kilometers-thick mafic and subordinate ultramafic submarine lavas, and upper parts by felsic volcanic rocks, often intercalated in mafic rocks, or by repeated cycles of the contrasted types. Basalt associations poorly match modern oceanic basalts in major- and trace-element compositions, and much Archean basalt records voluminous assimilation of felsic basement in more-mafic melt (Green et al., 2000). Early supracrustals are shown to be subregional stratal sheets where concordant ion-probe zircon U/Pb ages are tied to mapped units (e.g., Ayer et al., 2002). Single thick and rapidly erupted ultramafic flow complexes are exposed with strike lengths of hundreds of kilometers and may have reached volumes of 10,000 km$^3$ (Hill et al., 2001).

Diapiric batholiths rose concurrent with deposition, fed felsic volcanics and porphyries, and formed domiform granites

**Figure 4.** Neoarchean conglomerate. Cobbles of leucogranite and pebbles of felsite, eroded from diapiric granite, with downdip stretching due to continuing rise of granite and sinking of greenstone syncline. Vertical surface near Wawa, Superior craton, Ontario.

separated by synclines of contact-metamorphosed and dip-dragged supracrustals (Figs. 3, 4). Little deformation preceded diapirism, and strain and metamorphism are low, distant from batholiths. Greenstone belts are networks of synclines, mostly upright, sunk between, and crowded aside by the batholiths and are not volcanic chains (Bleeker, 2002). Late clastic sediments, eroded mostly from batholiths and silicic volcanoes that rose as islands, blanketed older units (Fig. 4).

Deformation of Archean crust defines a quasi-floating tectonic style. Modest regional syndiapiric shortening and orthogonal extension oriented batholiths, and strike-slip faults disrupted them, in some regions severely, but this deformation did not produce thrust blocks, strongly overturned structures, regional highlands, or major variations in crustal level of exposure—features common only after ca. 2 Ga. Upper-crustal granite-and-greenstone assemblages are sharply decoupled (e.g., Goleby et al., 2002) from undulating TTG gneisses of the middle and lower crust. Where best studied (e.g., Moser et al., 1996), the deep gneisses show pervasive vertical flattening, horizontal extension parallel to granite-and-greenstone elongation, and long-lasting near-magmatic temperatures.

Earth had a hydrosphere continuously after 3.5 Ga, or perhaps 3.8 Ga, but what was its earlier history? Superdense atmosphere and weak young Sun are complicating factors. Transient oceans and a hot early ocean under a greenhouse atmosphere are possibilities. The oldest proved waterlaid rocks, 3.5 Ga, are 0.9 Ga younger than the oldest zircons in basement. Although supracrustal rocks in SW Greenland are widely regarded as partly older than the oldest zircons, 3.7 or 3.8 Ga, in polycyclic migmatites in contact with them, those migmatites might instead be basement remobilized during the later severe plutonism and deformation. The supracrustals may be Neoarchean, as are those in palinspastically contiguous Labrador. An undocumented claim has been made recently for 3.8 Ga high-grade supracrustals in NW Quebec.

Voluminous mafic and ultramafic melts reached the surface only after ancient felsic crust cooled (in part because of condensation of hydrosphere?) below the density of such melts. Early low islands and shallow basins were covered by thickening shallow-water lava plains. Dense supracrustal assemblages insulated and foundered into basement that rose, variably remelted, in diapiric batholiths of regionally uniform areal density and, commonly, terminal-emplacement age (e.g., Collins and Van Kranendonk, 1998; cf. Griffin et al., 2003a; Fig. 3). Inherited zircons are common. Heat conducted from upper mantle, and internal radiogenic heating 3× greater than now, facilitated mobilization. Concentration of radioactivity high in the crust in fractionating batholiths led to cooling and cratonization. These structural and magmatic assemblages have no Phanerozoic analogs.

Plate tectonics did not operate within preserved Archean crust. Supracrustal assemblages display none of the many stratigraphic, structural, and petrologic indicators of rifting, trailing-edge stratal wedges, oceanic separation, subduction, and collision that characterize plate-tectonic interactions of post–2.0 Ga continents. Vague geochemical analogies of Archean igneous rocks with modern rocks are widely cited to support conjecture that diverse plate-tectonic settings are recorded by intercalated supracrustal lithologies and that layer-parallel successions were assembled from sheets, often thinner than 100 m, thrust hundreds of kilometers from unknown directions. I see no credible evidence for such conjecture. Rocks and associations at issue are quite different from proposed analogs—e.g., Archean tonalites and felsites are far more felsic and have steeper rare earth element patterns than the Phanerozoic arc rocks to which they are wrongly likened.

## Proterozoic Tectonics

Changes through Proterozoic time reflect continued mantle cooling. The little preserved very early Proterozoic (ca. 2.5–2.0 Ga) crust contains komatiitic basalts and suggestions of granite-and-greenstone tectonics, which otherwise is restricted to the 3.5–2.5 Ga Archean. The latest Archean and earliest Proterozoic of South Africa and Western Australia include thick supracrustal assemblages of greenstone-belt type, deformed slightly by rejuvenation of diapiric granites in underlying granite-and-greenstone crust (Fig. 3).

Abundant stratigraphic, structural, and petrologic evidence for rifting, rotation, and collision of crustal masses requires initiation of plate tectonics ca. 2.0 Ga. This presumably accompanied cooling of upper mantle through a threshold of thickening and stiffening of oceanic

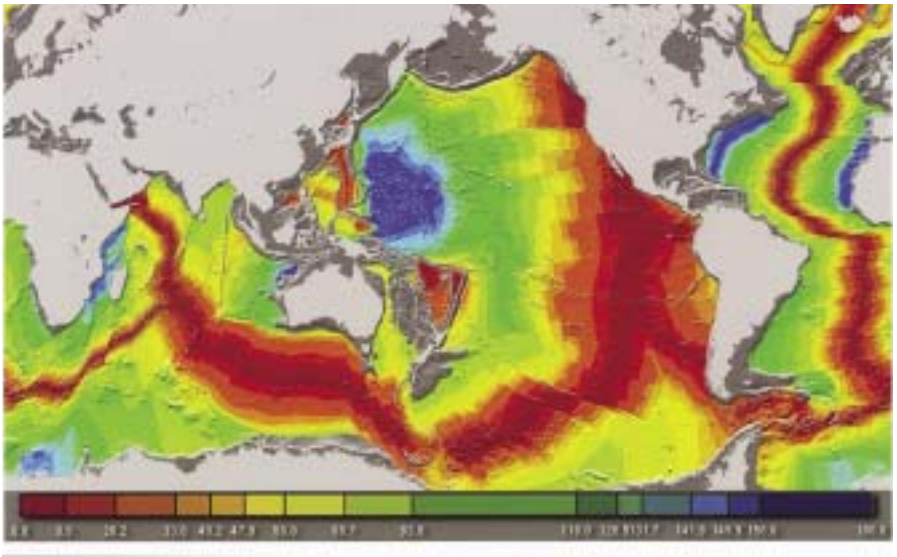

**Figure 5.** Ages of oceanic crust. Pacific Ocean shrinks because subduction hinges roll back into it, yet spreads rapidly because broadside-sinking slabs push upper mantle back under it. Pacific-plate spreading geometry and rates continued smoothly through the 45 Ma age (orange bands) of the Emperor-Hawaii elbow, disproving speculation that those chains formed above fixed plume. Unpublished 2003 compilation provided by R.D. Müller; pre–80 Ma patterns poorly constrained.

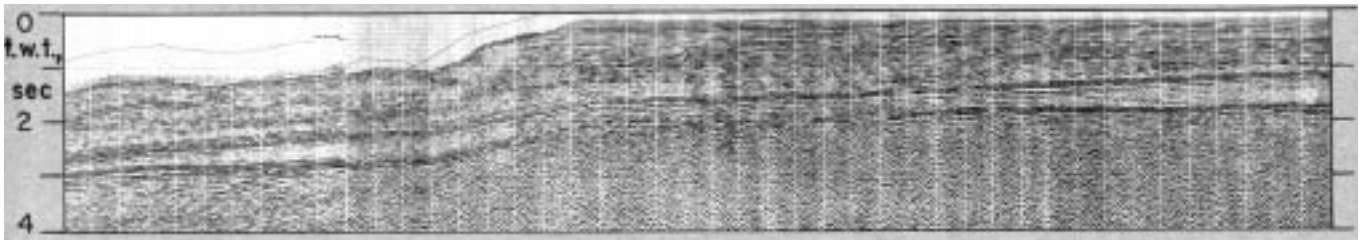


**Figure 6.** Seismic-reflection profile of part of Sumatra fore-arc basin. Section 35 km long; 1:1 for V = 3 km/s, so VE on seafloor 2:1; Sumatra coast ~30 km to right (NE), fore-arc ridge, near Enggano island, 60 km to left (SW); trench, 170 km. Subducting slab is ~40 km beneath SW end of section. Thin front of overriding plate has not been crumpled since deposition of lower Miocene limestone (semi-transparent) at base of section, so velocities of hinge rollback and arc advance have been equal. Profile from White Shield Indonesia.

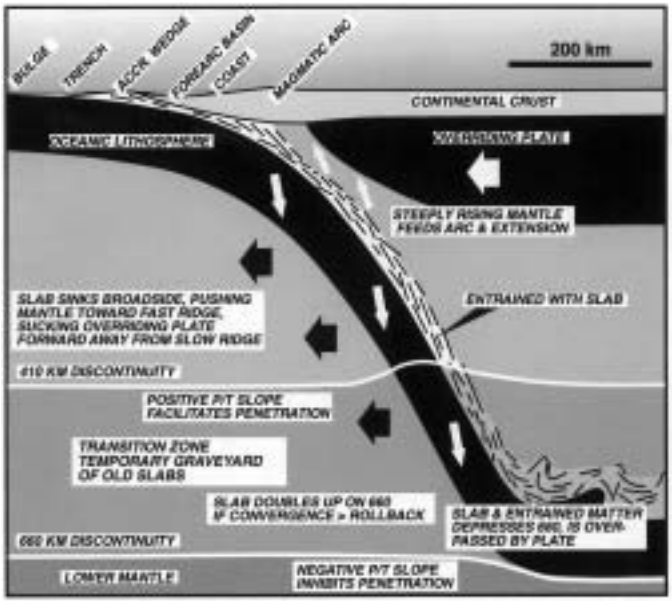


**Figure 7.** Subduction drive of plate tectonics, illustrated for a common type of continent-margin system. Hinge rolls back so slab sinks broadside, pushing sub-plate upper mantle back under shrinking ocean and forcing rapid spreading, and sucking overriding plate forward. Slab plus entrained material is plated down on uncrossable 660 km discontinuity, overridden by continent, and recycled into slowly enlarging ocean offscreen to right. Shallow part scaled to modern Sumatra and Cretaceous California; low-velocity mantle wedge deduced from high-resolution tomography in Japan; kinematic inferences from this paper. Drafted by Dietrich Roeder, Murnau Geodynamics, Inc.

lithosphere, and shallowing of the gabbro-eclogite transformation, which enabled the subduction that drives plate tectonics. Evolving mantle (Griffin et al., 2003b) and orogenic assemblages show that upper mantle has continued to cool since 2.0 Ga. Giant Proterozoic radially injected gabbroic dike swarms require more decoupling between crust and mantle than now operates. High-pressure low-temperature metamorphic rocks are unknown in subduction complexes older than late Proterozoic, and rare in those, but are widespread in late Phanerozoic ones.

## DYNAMICS OF MODERN EARTH

### Plate Kinematics

Earth's outer shell is now broken into plates that variously converge, diverge, and move past one another. About one-sixth of the area of the plates undergoes obvious internal deformation. Present relative motions of internally rigid parts of plates are constrained primarily by seafloor-spreading geometry, which integrates motions over millions of years, and by geodesy, mostly satellite, which defines motions over a decade or so and also quantifies internal deformation. The two data sets mostly are broadly compatible (Kreemer et al., 2003).

What drives plates? Most published models and explanations overlook known plate characteristics and behavior and instead elaborate false assumptions.

#### *Ridge Spreading*

Ridges form where near-solidus asthenosphere wells into gaps between diverging plates of oceanic lithosphere. Oceanic plates commonly are topped by 5 km or so of basaltic, gabbroic, and cumulate rocks erupted at spreading centers and

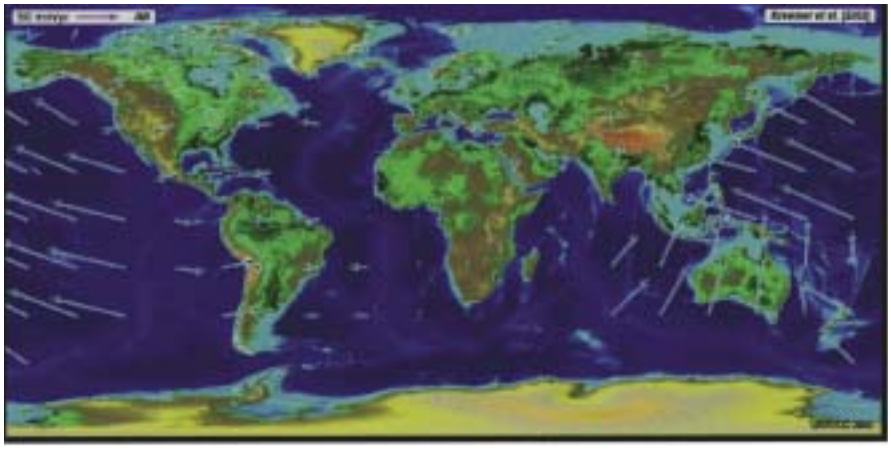

**Figure 8.** Relative-motion vectors of plates in Antarctica-fixed framework. Predictions that subduction, due to top-down cooling, drives plates, that ridges are passive responses to that drive, and that lower mantle does not participate in plate motions are satisfied in this framework when allowance is made for back-arc spreading and plate-internal deformation. Data from geodesy-dominated model by Kreemer et al. (2003). Image provided by L.H. Estey, University NAVSTAR Consortium; see http://jules.unavco.ucar.edu/Voyager/ILP_GSRM.

consist otherwise of lithospheric mantle formed by top-down cooling of asthenosphere. Slow-spreading ridges are almost-amagmatic extensional complexes. Ridges migrate and change shape and length with time (note ridges around Antarctica and Africa: Fig. 5) in response to motions of bounding plates—ridges are not fixed divergences—and thus tap fresh asthenosphere. The fastest-spreading ridge, south-tropical East Pacific Rise, is crossed by detailed geophysical transects. Bathymetry, volcanism, P and S wave tomography, Rayleigh-wave phase velocities, shear-wave splitting, and electrical resistivity all show partial melting in high upper mantle to extend much farther west than east of the spreading axis (Toomey et al., 2002). I see a westward-migrating passive-ridge gap that progressively depressurizes new, fertile upper mantle, from which melt filters upward toward the advancing tent-shaped gap—a stationary ridge would quickly exhaust available melt—whereas Toomey et al. postulated lateral injection from a far-distant plume.

### *Subduction*

The key to plate dynamics is rollback of hinges into subducting plates as oceanic lithosphere, made dense by top-down cooling of asthenosphere, falls away. Hinges have large radii and are under, not in front of, overriding plates (Fig. 7). Ubiquitous cartoons notwithstanding, hinges are not abrupt downturns at steep-sided trenches, which do not exist. Bounding hinges roll back into the Pacific so it shrinks, despite its rapid internal spreading (Fig. 5). Other features requiring rollback include advance of small hinges into large plates, arc-arc collisions, and increasing arc curvatures with time. Rollback shows that slabs sink more steeply than their inclined seismic zones, which define positions, not trajectories. Accretionary wedges are overridden by plate bases inclined gently arcward (Fig. 7). Inner trench slopes in arcs lacking sediment supply for wedges have diverse lithologies, as dredged, consistent with imbrication, and these trenches also lack steep sides.

Fronts of overriding plates migrate with retreating hinges, and shapes of fronts and hinges tend to change together to maintain accordance. Where present, fore-arc basins atop thin leading edges of overriding plates (Figs. 6, 7) and island arcs show that those edges were little shortened or deformed during periods recorded by basin sedimentation, and require velocities of advance of fronts of overriding plates to have equaled those of rollback. The Cretaceous and Paleogene fore-arc basin of California records 100 m.y. of such equality. Plate geometry requires that convergence is faster than rollback in some places (e.g., Nazca-Chile) and equal to it in others (e.g., Antarctica–south Chile and Caribbean-Atlantic).

Where intra-arc or back-arc spreading occurs, as is common, the front of an overriding plate moves faster than the back. Crustal thickening due to arc magmatism and underplating often has been mistaken for shortening. Where intra-arc shortening does occur, it usually is accomplished from the bottom, not the front, of an overriding plate. Plate fronts are crumpled primarily when arcs collide.

Seismicity and high-resolution tomography show that the only directly overlying material with which a slab is in thrust contact is the accretionary wedge and fore arc. Seismicity under arc and back arc is within a slab, not at its top, and chilled mantle directly above a slab is coupled to it. Hot low-seismic-velocity, high-seismic-attenuation material characterizes the medial part of the mantle wedge between slab and overriding lithosphere and rises toward the magmatic arc (Fig. 7). This near-zero-strength zone, not the top of the slab, marks the main pull-apart plate boundary from which slab and coupled material sink. Hot material sucked up into the wedge above a sinking slab feeds the magmatic arc, the position of which is determined kinematically.

Old subducting slabs (lithosphere older than ca. 60 Ma when it began to sink) are shown by earthquakes and by high-amplitude tomographic anomalies to be plated down on the 660 km discontinuity, which they depress by 20 km or so and may not penetrate (e.g., Pankow and Lay, 2002) and are defined at least as far as 1000 km (possibly 3000 km) horizontally from the base of an inclined slab. Slabs downplated on 660 are overpassed by plates; they do not represent (as most modelers have assumed) lateral injection of slabs. Young slabs, or small-basin slabs, sink only to middle upper-mantle levels, into which they are mixed as they are passed over by arcs and plates.

## Upper-Mantle Circulation

### *660 km Discontinuity*

Circulation may be closed above the sharp discontinuity at a depth of 660 ± 20 km, which separates upper from lower mantle and is the most profound seismic break within the mantle. The 660 represents a velocity step and a strong decorrelation of seismic waves, and velocity patterns of all sizes are almost randomly mismatched across it (Gu et al., 2001). The 660 km discontinuity is at the base of the transition zone, wherein seismic velocity increases rapidly downward from the upper-boundary velocity step at 410 ± 15 km. That the 410 represents a density-phase change with a positive P/T slope and the 660 one with a negative slope, is indicated by their weak inverse depth variations as functions of transition-zone velocities, and by mineral physics and experimental petrology (Lebedev et al., 2003). The 410 phase change facilitates sinking of cold material and rising of hot, whereas the 660 change inhibits, and may prohibit, penetration in either direction. Subducted slabs could sink through 660 only after being heated and thereby losing thermal negative buoyancy. Further crossability arguments hang on specific assumptions of P/T slope and of bulk and mineral compositions. If the 660 transformation indeed is uncrossable by material, then circulation above and below is layered, and the boundary must now be compositional as well as a phase change.

That much of the lower mantle is far below its solidus T and thus has very high effective viscosity that precludes rapid circulation is indicated by temperature constraints, experimental petrology, and little-varying $V_p/V_s$. The very low thermal expansivity at lower-mantle pressure requires that factors other than temperature (grain size, anisotropy, mineralogy including mixed-phase gradients, bulk composition) control much variation in velocity (Hofmeister and Criss, 2003).

### *No Deep Subduction?*

Some seismic tomographers depict low-amplitude positive-velocity anomalies, inferred to mark subducted slabs, deep into lower mantle. Penetration would be most expected in East Asian and western Pacific systems that involve the oldest, densest, and thickest subducting slabs (Fig. 5), yet is not seen there with high-resolution tomography (Grand, 2002; Pankow and Lay, 2002). Interpretations of deep subduction elsewhere are shaky.

Tomographic theory requires waves crossing all mantle volumes from many directions—but the extremely irregular distribution of earthquakes and seismographs results in no sampling of vast volumes and of sampling of much else primarily by bundles of minimally crossing waves. Most earthquakes occur near tops of subducting slabs, and high slab velocities not incorporated in models are smeared downward and gain directional bias from slab anisotropy. Purported deep slabs are defined mostly by waves, subparallel to them, from such subduction quakes. Effects of mapping upper-mantle energy into lower mantle are magnified because of contrasted amplitudes of shallow and deep anomalies. Many published models are misleading: colors are saturated for lower-mantle anomalies one-tenth or one-fifth the amplitude of upper-mantle ones, huge unsampled volumes are assigned average values or populated with spherical-harmonic artifacts, illusory continuity is generated by severe smoothing and sharpening, cross sections are placed where subduction interpretations look most plausible. Models account for only a few tenths of traveltime variance, and have not been tested by attempting to squeeze solutions back into upper mantle. Nonsubduction alternatives receive little evaluation. (Zhou et al., 1990, provided an exception.)

The visually most impressive example of purported deep subduction, an anomaly inclined eastward under the Caribbean region through the entire mantle, is depicted by several tomographers (Grand, 2002; most use the same database). It is widely cited as conclusive evidence for rapid whole-mantle convection regardless of other considerations. The anomaly has the problems noted above, and it lacks the along-strike continuity required by its slab interpretation. Sections drawn through the same models, north and south of published sections placed where anomalies plausibly depict subduction, would show disconnected blobs and irregular shapes, despite severe smoothing, in erratic positions and "wrong" and multiple directions. More detailed tomography by a different method requires depression, but not penetration, of the 660 between 5° and 30°S (Collier and Helffrich, 2001).

### *Plumes Do Not Exist*

A huge literature (e.g., Condie, 2001) speculates that narrow plumes of hot, fertile material rise from the base of the mantle to upper mantle and crust. The notion descends from conjecture (rejected earlier) that the mantle is compositionally inverted, and also from speculation that the general SSE, then ESE, age progression in Emperor and Hawaiian seamounts and islands was produced by a stationary plume squirting up through the moving Pacific plate. There, in its only rigorously testable locale, the fixed-plume concept is falsified. That the Pacific plate did not change direction 60°, as required by the conjecture, at ca. 45 Ma (the age of the Emperor-Hawaiian elbow) is proved by paleomagnetism and by continuity of spreading geometry and rates (as defined by spreading angles and transform directions) through that age interval around the entire east and south margins of the plate (Fig. 5). Hawaiian heat flow, tomography, and positive correlation between volume of volcanism and rate of propagation further falsify plume predictions. Plume advocates respond to such refutations by making their conjectures ever more complex, unique to each example, and untestable.

All other geochemical, kinematic, and tectonic plume rationales derive from the misinterpretation that Hawaii stands atop a plume. Circular rationales assign diverse magmatic and tectonic provinces to plumes, but I here discuss only oceanic basalts. Ocean-island basalts (OIB) tend to be more fertile than most mid-ocean ridge basalts (MORB), and this contrast is widely assumed to reflect derivation of OIB from enriched lower-mantle plumes and of MORB from depleted upper mantle. The false logic has been that ridges are fed from upper mantle, islands are not ridges, and therefore islands are not fed from upper mantle. As MORB in fact varies widely and largely overlaps OIB, a narrowly selected subset of high-Mg, low-alkali ridge rocks (N-MORB, often mislabeled "MORB") has then been assumed to be the "normal" product of asthenosphere melting, whereas voluminous interspersed and intercalated, or distant, ridge basalts higher in incompatible elements and lower in compatibles are assigned, with circular reasoning, to plumes, often as lateral injections of thousands of kilometers. Plume proponents have not addressed the OIB composition of large seamounts, which are abundant and mostly randomly distributed (J.H. Natland and E.L. Winterer, 2003, written commun.).

Pro-plume conjectures assume wrongly that magmas are transported from melting sites to surface without modification, thereby preserving elemental and isotopic ratios of sources. Thermodynamics and phase petrology, including cotectic compositions of basalts and presence of underlying cumulates, prove that instead melts are profoundly modified before eruption (O'Hara and Herzberg, 2002). Simplistic geochemical source modeling is further invalidated by the occurrence of incompatible elements in mantle rocks primarily in intergranular films of secondary minerals rather than in major-mineral phases. The contrasts that do exist between many ridge and island basalts and within ridge basalts mostly are required by contrasts in polybaric exothermic crystallization and endothermic assimilation by which melts are forced to evolve while rising through asthenospheric and lithospheric columns differing in thermal gradients and composition.

No plumes extending downward into lower mantle have been detected by credible tomography. Purported-plume displays are flawed in methodology, artifacts, and presentation, most purported hotspots do not overlie abnormally hot upper mantle, most tomographically inferred hot regions are not overlain by purported hotspots, and there is no indication of plumes in upper-mantle geophysics (Anderson, 2000).

Oceanic asthenosphere is everywhere near solidus temperature so local excess

heat is not required for island volcanism. Access of melt to surface, as by propagating rifts, is needed—crackspots, not hotspots. Island alignments, in this view, reflect regional stresses, perpetuation of directions once established, and lithosphere properties. The Emperor and Hawaiian chains avoid huge basalt plateaus, and the elbow between them occurs near a fracture zone across which lithosphere age changes by 10 or 15 m.y.

### *Heterogeneity*

Recycling by subduction of oceanic lithosphere and continental material has made upper mantle increasingly heterogeneous and more fertile. Old slabs and entrained material sink into the transition zone and await lateral and upward recycling, whereas young slabs mix into upper mantle. Temperature, age, and isotopic ratios of sunken slabs vary regionally. Contrasts within and between MORBs and other oceanic basalts presumably partly reflect upper-mantle heterogeneity and also varying degrees of initial melting.

## Driving Mechanism of Plate Tectonics

### *Top-down Subduction Drive*

Cooling from above by seawater produces oceanic lithosphere denser than asthenosphere from which it forms, and this density inversion is righted by gravitationally driven subduction that controls plate motions (cf. Anderson, 2002b). Plate behavior accords with self-organized subduction.

### *Mechanism of Plate Tectonics*

Subduction is the primary drive for plate motions, and its effects are explicable by circulation closed above 660 km (Fig. 7). Slabs and entrained material sink broadside from retreating hinges so mantle beneath slabs is pushed backward, and overriding plates or island arcs are sucked forward. Old slabs sink to 660 km and are overpassed by overriding plates and thus transferred out of the Pacific for recycling into enlarging oceans or back-arc basins. Pacific shrinkage is due to removal of lithosphere, but the volume of upper mantle—everything from 660 km to the base of lithosphere—pushed back under the ocean by slabs is much greater than that of departing lithosphere, so Pacific spreading is much faster than that of passive oceans. The volumes of lithosphere transferred from shrinking oceans, of enlargement of passive oceans, and of advance of overriding plates and arcs are approximately equal. Where convergence is faster than rollback and advance, sunken slabs are doubled up and transfer is accelerated. Overpassed slabs are heated from above as well as from below and so partly insulate continents from lower-mantle heat. Downplated slabs are recycled from the transition zone when new slabs crowd them out, or into spreading oceans, and become magma sources as they rise into basalt-melting P/T fields. Hot material sucked forward by slabs provides heat and substance for back-arc spreading and arc magmatism.

### *No Bottom-Up Drive*

Observed plate features and interactions—including migration and changing shapes and lengths of ridges, rollback and other behavior of hinges, matching of velocities of rollback and advance—are incompatible with popular models wherein plates are colliding rafts dragged from beneath by currents flowing from hot upwellings to cool downwellings. The few bottom-drive models that add awareness that subduction is enabled by top-down cooling (Bercovici, 2003) also cannot explain the observations.

### *Framework and Test*

The subduction-drive mechanism predicts plate motions relative to sluggish lower mantle. Relative plate motions can be transposed to any reference frame, so there should be a frame wherein hinges roll back, directions and rates of plate rotations relate systematically to subduction, and ridges migrate and spread at rates compatible with subduction drive and slab transfer. These predictions are not met in the popular hotspot and no-net-rotation frameworks. The stationary-hotspot frame is tied to Hawaii and is invalidated by disproof of a plume fixed there. The no-net-rotation framework minimizes motions of ridges and randomizes motions of subduction hinges so that many roll forward—impossible with gravity drive. The lack of rational kinematics in these popular frameworks fosters acceptance of mysterious bottom drives.

Subduction-drive predictions are met when plate motions are transposed to the Antarctica-fixed framework (Fig. 8). Antarctica is ringed by spreading ridges (Fig. 5) and should be nearly stationary, as is suggested also by its Cenozoic paleomagnetism. (It moves rapidly in hotspot and no-net-rotation frames.) In fixed-Antarctica frame, all hinges roll back when back-arc spreading and internal deformation of plates are integrated. Ridges migrate to tap fresh asthenosphere. South America is sucked toward its west-bounding subduction systems. North America moves toward subduction boundaries and obliquely retreating Pacific plate. Africa, almost ringed by ridges, is rotating very slowly toward minor subduction systems in the northeast instead of moving rapidly east as in hotspot and no-net-rotation frames. Stable Eurasia, away from its deforming southern and eastern regions, is almost stationary in accord with its lack of subduction boundaries instead of moving rapidly. South and East Asian deformation clearly relates to subduction and rollback, although the continuing northward motion of India is puzzling. Widely varying spreading rates accord with transfer of overpassed oceanic lithosphere from shrinking to enlarging oceans as the basic control, complicated by factors such as the rapid sliding of narrow eastern Pacific plates down their inclined bases toward South and Central American hinges. Lithosphere has a net westward drift, presumably due to Earth-spin influence.

## OVERVIEW

The Earth described here differs profoundly from that accepted as dogma in most textbooks and research papers. Crust and upper mantle have formed a mostly closed system throughout geologic time, and their dramatic temporal changes are responses to cooling. The changing processes define a Punctuated Gradualism and not Uniformitarianism. Major stages in Earth evolution:

(1) 4.567–ca. 4.4 Ga. Hot accretion and major irreversible mantle fractionation. Giant bolides continue to ca. 3.9 Ga.

(2) 4.4–3.5 Ga. Era of nearly global felsic crust, too hot and mobile to stand as continents.

(3) 3.5–2.0 Ga. Granite-and-greenstone era. Permanent hydrosphere. Old crust cooled to density permitting mafic melts to reach surface. Diapiric batholiths mobilized from underlying old crust.
(4) 2.0 Ga–continuing. Plate tectonic era. Distinct continents and oceans. Top-down cooling of oceanic lithosphere enables subduction that drives plates, forces spreading, and mixes continental as well as oceanic crust into upper mantle.


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This award is given to a woman or group of women who have impacted the field of the geosciences in a major way based on their Ph.D. research. For nomination, eligibility, and award details, see the October 2003 issue of *GSA Today*, visit www.geosociety.org, or call (303) 357-1028. Send nominations and supporting material to Grants, Awards, and Medals, GSA, P.O. Box 9140, Boulder, CO 80301-9140.

## John C. Frye Environmental Geology Award

**Nominations Due March 31, 2004**

In cooperation with the Association of American State Geologists, GSA makes an annual award for the best paper on environmental geology published either by GSA or by one of the state geological surveys. For details, see the October 2003 issue of *GSA Today*, visit www.geosociety.org, or call (303) 357-1028. Nominations must be sent to Program Officer, Grants, Awards, and Medals, GSA, P.O. Box 9140, Boulder, CO 80301-9140.

## Congressional Science Fellowship

**Applications Due January 23, 2004**

For application information for the 2004–2005 GSA–U.S. Geological Survey Congressional Science Fellowship, visit www.geosociety.org/science/csf/, or contact Ginger Williams, GSA Headquarters, (303) 357-1040, gwilliams@geosociety.org.

## National Awards

**Nominations Due April 30, 2004**

Candidate nominations are needed for the following national awards: William T. Pecora Award, National Medal of Science, Vannevar Bush Award, and Alan T. Waterman Award. For details, see the October 2003 issue of *GSA Today*. Nominations should be sent to Grants, Awards, and Medals, GSA, P.O. Box 9140, Boulder, CO 80301-9140.

## Preliminary Announcement and Call for Papers

THE GEOLOGICAL SOCIETY OF AMERICA

# JOINT MEETING

**56th Annual Meeting of the Rocky Mountain Section, GSA, and 100th Annual Meeting of the Cordilleran Section, GSA**
**Boise Centre on the Grove, Boise, Idaho**

**May 3–5, 2004**

The 2004 annual meetings of the Rocky Mountain and Cordilleran Sections will be held jointly at the Boise Centre on the Grove, hosted by the Department of Geosciences, Boise State University. Up-to-date information about the meeting can be found at www.geosociety.org/sectdiv/rockymtn/04rmcdmtg.htm or http://earth.boisestate.edu/GSA2004/.

### ENVIRONMENT

Boise, Idaho's capital and largest city, consistently ranks high on lists of the most livable cities in America. The City of Trees is named in part for the lush riparian environment of the Boise River flowing through town. The city's greenbelt provides more than 20 miles of trails along the river, allowing for hiking, biking, and access to fly fishing. The Boise Foothills to the north provide an alternative arena for outdoor activities, and are one reason for Boise's high ranking in mountain biking magazines.

Early May climate in Boise has daytime highs averaging in the upper 60s to low 70s, with nighttime lows averaging in the high 30s to low 40s. In an apparent paradox of terms, sunshine reigns here.

Boise is easily accessible by air, and is serviced by six major carriers and their regional affiliates. The meetings are being held in The Boise Centre on the Grove, located in the heart of downtown within easy walking distance to hotels, restaurants, the greenbelt, and the foothills.

### CALL FOR PAPERS

Papers are invited for a variety of topical sessions (oral and poster), including symposia, theme sessions, and various general technical sessions. Authors interested in volunteering papers for symposia should contact the appropriate convener prior to submitting an abstract. Oral presentations in most technical sessions will be 12 minutes in length, with three minutes for questions. Some sessions may be organized with a longer format (contact session chairs for details). All oral sessions will utilize a single digital projector and PowerPoint software. An overhead projector will also be available in each room. Use of 35mm slides is discouraged and will only be accommodated by special arrangement with the session chair. Poster space will be 4 by 8 feet, and authors will be required to be present at their poster for at least two hours.

### ABSTRACTS

**Abstract Deadline: January 27, 2004**

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

### REGISTRATION

**Preregistration deadline: March 29, 2004**
**Cancellation deadline: April 5, 2004**

GSA Headquarters will handle preregistration. Registration details will be published in the January 2004 issue of *GSA Today* and will be available at www.geosociety.org beginning in the first part of January.

### ACCESSIBILITY

GSA is committed to making its meetings accessible to all people interested in attending. Please indicate special requirements (wheelchair accessibility, etc.) on the registration form. The Boise Centre on the Grove is ADA compliant.

### FIELD TRIPS

For further details on field trips, please contact either the trip leader or the field trip chair, Spencer Wood, (208) 426-3629, swood@boisestate.edu, or visit www.geosociety.org/sectdiv/rockymtn/04rmcdmtg.htm or http://earth.boisestate.edu/GSA2004/. Except as indicated, Premeeting or Postmeeting status of trips has not yet been scheduled.

1. **Upper Paleozoic Continental Margin Tectonics of the Western U.S.: Tectonostratigraphic Framework of Nevada: Elko, Eureka, Ely Areas.** (2 days, overnight in Elko.) James H. Trexler, trexler@mines.unr.edu, (775) 784-1504; Patricia H. Cashman, pcashman@mines.unr.edu, (775) 784-6924, University of Nevada, Reno; Clyde J. Northrup, Boise State University, cjnorth@boisestate.edu, (208) 426-1009; Walter S. Snyder, National Science Foundation, Washington, D.C., wsnyder@nsf.gov, (703) 292-8553.
2. **Payette River—Fires, Floods, Erosion and Sedimentation, and Sawtooth and Stanley Valleys—Quaternary and Glacial Geology, Central Idaho.** (2 days, overnight in Stanley). Grant Meyer, University of New Mexico, gmeyer@unm.edu, (505) 277-5384; Jennifer Pierce, jpierce@unm.edu, University of New Mexico; Tom Black, tblack@fs.fed.us; Charlie Luce, cluce@fs.fed.us, USDA Forest Service Rocky Mountain Research Station; Glenn D. Thackray, thacglen@isu.edu, (208) 282-3560, Idaho State University.
3. **Paleoseismology, Borah Peak Earthquake, Neotectonics, Eastern Idaho.** (2 days, overnight in Arco.) Kathy Haller, haller@usgs.gov, (303) 273-8600; Tony Crone, U.S. Geological Survey.
4. **Rattlesnake Tuff and Eastern Oregon Volcanic Geology.** (2 days, overnight in Burns), Martin J. Streck, streckm@pdx.edu, (503) 725-3379, Portland

State University; Mark Ferns, (541) 523-3133, Oregon Department of Geology and Mineral Industries.

5. **Large Volume Rhyolites of the Snake River Plain Magmatic Province.** (Postmeeting, 2 days.) Mike McCurry, mccumich@isu.edu, (208) 282-3960, Idaho State University; Bill Bonnichsen, Idaho Geological Survey.
6. **Basalt Emergent Volcanoes and Maars, Sinker Butte—Snake River Canyon, Idaho.** (Premeeting, 1 day.) Brittany Brand, BrittanyBrand@mail.boisestate.edu, Boise State University.
7. **Sedimentary Facies of Neogene Lake Idaho: Hydrogeologic Implications for the Western Snake River Plain.** (Premeeting, 1 day.) Spencer Wood, swood@boisestate.edu, (208) 426-3629, Boise State University.
8. **Boise Geothermal Area and Idaho Territorial Penitentiary.** (During meeting.) David Leppert, geoleppert@aol.com, (208) 331-0259, Idaho Museum of Mining and Geology.

## TECHNICAL SESSIONS

In addition to general technical sessions, the program will include a variety of symposia and theme sessions. Detailed description of symposia and theme sessions can be found at: www.geosociety.org/sectdiv/rockymtn/04rmcdmtg.htm or http://earth.boisestate.edu/GSA2004/.

## SYMPOSIA

1. **Geochemical and Geochronological Databases and the Science That Can Be Done with Them.** Allen Glazner, University of North Carolina, afg@unc.edu, (919) 962-0689; Doug Walker, jdwalker@ku.edu, (785) 864-2735.
2. **Large-volume Ryolites of the Western USA: A Tribute to Bill Bonnichsen.** Michael McCurry, Idaho State University, mccumich@isu.edu; Eric Christiansen, Brigham Young University, eric_christiansen@byu.edu.
3. **Building the Global Geologic Time Scale.** Cinzia Cervato; Iowa State University, (515) 294-7583, cinzia@iastate.edu; Bruce Wardlaw; U.S. Geological Survey; (703) 648-5288; bwardlaw@usgs.gov.
4. **The Role of Science in Making Natural Resources Decisions.** David Applegate, American Geological Institute, applegate@agiweb.org, (703) 379-2480; Tammy Dickinson, National Research Council, tdickins@nas.edu, (202) 334-2744.

## THEME SESSIONS

1. **Cordilleran Magmatism from the Forearc to the Hinterland.** Calvin Barnes, cal.barnes@ttu.edu, (806) 742-3106; Aaron Yoshinobu, aaron.yoshinobu@ttu.edu, (806) 742-4025; Keegan Schmidt, klschmidt@lcsc.edu, (208) 792-2283.
2. **Products and Processes of Hydrovolcanism.** Craig White, Boise State University, cwhite@boisestate.edu, (208) 426-3633; Martha Godchaux, mgodchau@MtHolyoke.edu, (208) 882-9062.
3. **Biogeomorphology of River Systems.** Jim McKean, jmckean@fs.fed.us, (208) 373-4383; John M. Buffington, jbuff@uidaho.edu, (208) 364-4082; Charlie Luce, cluce@fs.fed.us, (208) 373-4382.
4. **Recent Advances and Discoveries in Quaternary Geology and Geomorphology from the West Coast to the Front Range.** Joel L. Pederson, Utah State University, (435) 797-7097, bolo@cc.usu.edu; Glenn D. Thackray, Idaho State University, (208) 282-3560, thacglen@isu.edu.
5. **Applications of Geophysics to Hydrogeology.** Warren Barrash, Boise State University, wb@cgiss.boisestate.edu, (208) 426-1229; William Clement, billc@cgiss.boisestate.edu, (208) 426-1419; John Bradford, jbradford@cgiss.boisestate.edu, (208) 426-2898.
6. **Headwater Hydrologic Processes.** Jim McNamara, Boise State University, (208) 426-1354, jmcnamar@boisestate.edu.
7. **A New Look at Old Mountains: Late Paleozoic Intra-plate Tectonics of the Greater Ancestral Rocky Mountains.** Charles F. Kluth, Colorado School of Mines, (303) 904-2939, ckluth@mines.edu; James H. Trexler Jr., University of Nevada, Reno, (775) 784-1504, trexler@mines.unr.edu.
8. **Rates, Magnitudes, and Tectonic Controls of Late Cenozoic Intra-plate Deformation within the Eastern California Shear Zone, Walker Lane, and Central Nevada Seismic Belt, Western U.S. Cordillera.** John S. Oldow, University of Idaho, (208) 885-7327 or (208) 882-6192, oldow@uidaho.edu; Patricia Cashman, University of Nevada, Reno, (775) 784-6924, pcashman@mines.unr.edu.
9. **Eocene Extension of the Northern Rocky Mountains Region.** David A. Foster, University of Florida, dfoster@geology.ufl.edu; Thomas J. Kalakay, Vanderbilt University.
10. **Proterozoic Geology of the Northwest U.S.: Basement and Tectonic Setting of the Belt Basin and Succeeding Windermere Supergroup.** Paul Karl Link, Idaho State University, (208) 282-3846, linkpaul@isu.edu; Reed S. Lewis, Idaho Geological Survey, University of Idaho, (208) 885-7472, reedl@uidaho.edu.
11. **Upper Paleozoic Biostratigraphy of the Western U.S.** Tamra A. Schiappa, Slippery Rock University, (724) 738-2829, tamra.schiappa@sru.edu; Peter E. Isaacson, University of Idaho, (208) 885-7969, isaacson@uidaho.edu.
12. **Using the Local Geological Environment for Communicating and Teaching Earth Sciences.** Karen Viskupic, Boise State University, karenviskupic@boisestate.edu, (617) 216-4965; Charlla Adams, Boise State University, cadams2@boisestate.edu, (208) 426-1720.
13. **Undergraduate Research Poster Session.** *Sponsored by The Council on Undergraduate Research—Geoscience Division.* Kim Hannula, Fort Lewis College, (970) 247-7463, hannula_k@fortlewis.edu; Michelle Stoklosa, Boise State University, (208) 426-3645, mstoklos@boisestate.edu; Charlla Adams, Boise State University, (208) 426-1720, cadams2@boisestate.edu.
14. **State Geological Survey Cooperative Geologic Mapping Projects under STATEMAP and EDMAP.** Kurt L. Othberg, Idaho Geological Survey, University of Idaho, (208) 885-7560, othberg@uidaho.edu; John W. Shervais, Department of Geology, Utah State University, (435) 797-1274, shervais@cc.usu.edu.
15. **New Horizons in Mineral Deposits: Ore Genesis to Mine Closure.** Virginia S. Gillerman, Idaho Geological

Survey, Boise; vgillerm@boisestate.edu, (208) 426-4002; Greg Arehart, University of Nevada, Reno, arehart@unr.edu, (775) 784-6470.

16. **Remote Sensing, GIS, GPS, and Geodesy in Geology and Planetary Geology.** Nancy Glenn, Idaho State University, glennanc@isu.edu, (208) 685-6755; John Chadwick, Idaho State University, chadjohn@isu.edu, (208) 282-2949.

## WORKSHOPS

**Roy J. Shlemon Mentor Program in Applied Geoscience.** *Sponsored by GSA Foundation.* Monday, May 3, and Tuesday, May 4, 11:30 a.m.–1 p.m., luncheon location information available at GSA's registration desk. Karlon Blythe, kblythe@geosociety.org. This interactive and informative program for undergraduate and graduate students, led by professional geoscientists, will cover real-life issues including professional opportunities and challenges that await students after graduation. Plan to attend both free luncheons to hear different presenters each day. Students will receive in their registration packet FREE LUNCH tickets to attend both Shlemon Programs. However, space is limited. First come, first served.

**Other workshops:** Details are not available as of press time; latest information can be found at www.geosociety.org/sectdiv/rockymtn/04rmcdmtg.htm or http://earth.boisestate.edu/GSA2004/.



## SPECIAL EVENTS

**Ice Breaker.** Sun. evening, May 2, Boise Centre on the Grove.
**Annual Banquet and Business Meeting, Rocky Mountain Section.** TBA
**Annual Banquet and Business Meeting, Cordilleran Section.** TBA
**Rocky Mountain Section Board Meeting.** TBA
**Cordilleran Section Board Meeting.** TBA
**Farewell Party.** Wed. evening, May 5, Boise Centre on the Grove.

## SPOUSE AND GUEST ACTIVITIES

The Boise area offers a variety of activities, including shopping, hiking, mountain biking, and whitewater boating. For information on these and other activities, contact: the Boise Metro Chamber of Commerce (www.boisechamber.org) or Boise Convention and Visitor's Bureau (www.boise.org).

## STUDENT TRAVEL

The Rocky Mountain and Cordilleran Sections and the GSA Foundation have made travel grants available for students who are presenting oral or poster papers. Students must be currently enrolled and must be members of the relevant section to apply for support. For more information, contact the appropriate section secretary:
**Rocky Mountain:** Kenneth Kolm, (303) 231-9115, ext. 110, kkolm@bbl-inc.com.
**Cordilleran:** Joan Fryxell, (909) 880-5311, jfryxell@csusb.edu.

## STUDENT AWARDS

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

## EXHIBITS

Exhibit space will be available at $250 per booth for commercial organizations and $100 per booth for nonprofit organizations. For more information or to reserve a booth, contact Dave Wilkins, (208) 426-2390, dwilkins@boisestate.edu.

## ACCOMMODATIONS

A wide variety of hotels are available near the meeting site. Special GSA rates and information about making reservations via the housing bureau (strongly encouraged) will appear in the January 2004 *GSA Today*.

## ADDITIONAL INFORMATION

To obtain the most complete and up-to-date information, visit www.geosociety.org/sectdiv/rockymtn/04rmcdmtg.htm or http://earth.boisestate.edu/GSA2004/.

If you have additional questions or need further clarification, contact a member of the organizing committee: C.J. Northrup, chair, (208) 426-1581, cjnorth@boisestate.edu; Craig White, co-chair, (208) 426-3633, cwhite@boisestate.edu; Dave Wilkins, co-chair, (208) 426-2390, dwilkins@boisestate.edu; Walt Snyder, technical program co-chair, wsnyder@nsf.gov; John Oldow, technical program co-chair, oldow@uidaho.edu; Spencer Wood, field trips chair, swood@boisestate.edu.

**Announcement:**

# Travel Grants to Italy

## 32nd International Geological Congress

## Florence, Italy • August 20–28, 2004

The Geological Society of America is accepting applications for the 32nd International Geological Congress (IGC) Travel Grant Program. The 2004 IGC will be held in Florence, Italy, August 20–28.

This program was established as a final act of the Organizing Committee for the U.S.-hosted 28th IGC held in Washington, D.C., in July 1989. Surplus funds available at the conclusion of the 28th IGC were transferred to the GSA Foundation with the stipulation that income from the fund be used to support the attendance of young geoscientists to future IGCs, until such time as the United States again hosts an IGC. Travel grants will consist of economy airfare to Italy.

To be eligible, an applicant must be a resident or citizen of the United States (including students); must have a birth date after August 31, 1964; and must have an abstract for inclusion in the program of the 32nd IGC.

Application forms are available at www.geosociety.org/grants/index.htm. To receive a paper copy, please email awards@geosociety.org or call (303) 357-1028. Along with the form, applicants must include a copy of the abstract submitted to the 32nd IGC and two letters of support from current or recent supervisors. **Qualifying applications and letters of support must be postmarked no later than February 15, 2004.** Applicants will be notified of the results in April 2004.

# ROCK STARS

## Kenneth Orris Emery (1914–1998): Pioneer Marine Geologist

***Donn S. Gorsline*** *and* ***Kelvin S. Rodolfo,*** *University of Southern California and University of Illinois—Chicago*

An example of Emery's inventiveness. The purpose of this strange contraption is lost to history but may have served as a sediment trap.

### Birth and Formative Years

K.O. Emery was born in Swift Current, Saskatchewan, in 1914. His father, a carpenter and contractor, was there building barracks for World War I soldiers. The family followed construction jobs across the United States to New York, Oklahoma, and Texas, where K.O., as he was universally known, picked up his Texas accent and most of his schooling through early college years. During his senior year in high school, he collected, organized, and identified Cretaceous fossils from outcrops in the Fort Worth area. In high school, he enrolled in ROTC and earned the rank of major at graduation. He chose not to continue this program to an eventual Army commission, but the experience showed his natural talent for leadership.

K.O.'s excellent academic record earned him a one-year scholarship to any college or university in Texas. However, he decided to work to earn additional funds during 1932 and 1933 as manager of the local gas station, using the time between customers to read philosophy books. He attended North Texas Agricultural College, Arlington, in 1933 and studied there for two years. In the summers of 1934 and 1935, he and a college classmate hitchhiked and "rode the rails" to see the World's Fairs at Chicago and San Diego, where they scrounged for work in restaurants to earn living expenses.

Young Emery became interested in engineering and geology and upon the recommendation of a favorite geology professor, transferred to the University of Illinois in 1935. His intent was to combine geology and engineering into a major in mining engineering. Seeking funds for living expenses, he went to the Geology Department where he met Dr. Francis Shepard, who noted Emery's drafting expertise and recruited him to go to the U.S. Coast & Geodetic Survey offices in Washington, D.C., to work on maps of seafloor bathymetry (Curray, 2001). This confirmed K.O.'s interest in marine geology. He continued under Shepard's direction after his undergraduate years, earning an M.S. and Ph.D. Shepard was shifting his work to Scripps Institution of Oceanography, and much of K.O.'s work for his doctorate was also centered at that institution. K.O. received his Ph.D. from Illinois in 1941.

The difficult years spanning the Great Depression and World War II were "sink or swim" times for an entire generation and they greatly affected Emery's development as a person and scientist. There are some interesting parallels between K.O.'s early years and those of Maurice Ewing (Wertenbaker, 2000), another Texan who also experienced the hard times of the Depression era and ultimately achieved international repute as a marine scientist. It is likely that the adaptability, initiative, and confidence to surmount any barrier—characteristics of both of these marine scientists—were a product of those tough times.

### Early Career and Experiences

Emery and his best friend Robert Dietz were Shepard's graduate assistants and followed him to Scripps to become the first generation of "marine geologists" under his tutelage. The pay was poor but they managed to exist student-style in the "community house" on the old Scripps Campus with other graduate students. Shepard assigned them many tasks, one of which was to row him out on repeated trips to the Scripps and La Jolla Submarine Canyons. There, they took depth soundings using a heavy weight attached to a fishing line. K.O. would row, make the sounding, and lift the heavy weight back into the boat, while Shepard located the sounding using horizontal sextant angles between known locations on the beach. Dietz recorded the data. These studies resulted in the first detailed maps of the heads of submarine canyons. The main discovery was a great change in depth over time, showing that active marine processes were taking place.

K.O., like others in that pioneering generation, designed and built most of his own shipboard equipment to sample the seafloor. His earlier work as a mechanic in a gas station may have been a factor in his equipment-design success. His sea experience, begun in a rowboat, now progressed to the *E.W. Scripps*, a 110-foot schooner built for the Scripps Institution with support from the Scripps family. Early cruises off southern California and in the Gulf of California provided data that K.O. and Dietz used for their theses and doctoral dissertations. They worked with bathymetry and structure, seafloor sediments and rock, and phosphorite and marine clays, making discoveries that laid the basic groundwork for future marine geologists. However, geology was not the sole pursuit of these embryonic scientists. Ever the experimenter, K.O. talked Dietz into growing a mustache and

beard and proceeded to measure how long the hairs grew each week during the expedition.

### The War Years

After receiving his Ph.D., Emery took a job with the Illinois Geological Survey locating water supplies for defense industries. At that time, the Navy did not perceive a need for ocean science and the survey job was the only option. A big plus during that time was his marriage to Caroline Alexander in October 1941. Caroline was an ideal partner who dedicated her life to supporting K.O.'s science work. The attack on Pearl Harbor (December 1941) and the entry of the U.S. into war pushed the Navy to recognize needs for oceanographic research and brought Emery back to the sea.

At Shepard's invitation, K.O. joined the University of California Division of War Research (UCDWR), which was formed in World War II to apply ocean science to wartime problems. K.O. made maps that identified different types of substrate on the ocean floor. Combined with the known acoustic reflectances of those substrates, the maps could aid submarines in hiding from enemy destroyers. The maps revealed a patchy distribution of sand, gravel, mud, and rock outcrops over the offshore continental margin; one of his first major scientific contributions was to explain the distribution patterns by describing the processes that formed them.

After the conclusion of World War II, Emery joined with the U.S. Geological Survey in a major study of the Pacific coral islands as a background for the atomic bomb tests at Bikini. The work led to a number of monographs with several co-authors on the characteristics of the atolls and their histories.

### The Rise to International Prominence

While completing the Pacific island study, K.O. joined the geology faculty at the University of Southern California (USC) in 1946. He taught introductory physical geology, a requirement for geology and engineering students. His enthusiastic optimism and interest in everything geologic captured the imagination of all of his students, causing many engineering majors to shift to geology.

Emery continued his relationship with the Office of Naval Research while at USC and organized studies of the Persian Gulf and its shorelines for the U.S. Navy, in preparation for possible amphibious landings to protect American interests in the newly discovered oil fields there. Typically, K.O. did not miss a chance to do some geology along the way, using the continuously-recording echo-sounder aboard the USS *Pocono* to record a continuous depth profile of the Atlantic Ocean floor from Norfolk, Virginia, to the entrance of the Mediterranean.

Following the Persian Gulf expedition, and with the gift to USC of a new oceanographic research ship, the *Velero IV,* courtesy of Captain Allen Hancock, Emery entered a new phase of his career. The ship's design was based on the highly successful tuna boats which were beginning to make extended deep-sea ventures from San Diego.

The acquisition of the *Velero IV* focused K.O.'s interests on the California Borderland, the subsea region for which he had compiled bathymetric charts during his graduate work with Shepard. This major episode in his career was summarized some 15 years later in his book, *The Sea off Southern California,* which examined water, sediments, life, structure, and economic factors of the area. The book is still a primary reference for the region and a model of a complete oceanographic study. It incorporated the theses and dissertations of his graduate students, and revealed what obviously had been the master plan for his tenure at USC.

K.O. did not limit himself to the Borderland and was involved in several projects in other areas of interest. The arrival of a student from Israel, David Neef, provided access to Dr. Y.K. Bentor, the director of the Geological Survey of Israel, and Gen. M. Makleff, the director of the Dead Sea Works. Work on the Dead Sea was initiated, the necessary facilities were bought, built, and installed within a very short period, and the first cruise took place only a month after K.O. arrived in 1959.

### Contributions as a Teacher

K.O.'s graduate students enjoyed close relationships with him, including occasional poker games at his home. He was a Socratic teacher, challenging students to think deeply about the lecture subjects and reading. Undergraduate students had to write term papers to develop this important skill for graduate studies and had to take the hardest classes and strive for the Bachelor of Science degree, not the Bachelor of Arts. Moulded by his strict regimen, many of his students went on to become leaders in the field of marine geology.

### Culmination of His Career

In 1961, K.O. accepted an endowed chair at Woods Hole Oceanographic Institution and leadership of a large comprehensive study of the Atlantic Ocean with U.S. Geological Survey funding and other federal grants. This ten-year study was summarized in a monumental monograph, *The Geology of the Atlantic Ocean*, published in 1984 with Elazar Uchupi as coauthor. This monograph, much like the earlier book on the California Borderland, was a characteristically broad coverage of every aspect of the Atlantic, including economic resources as well as structure, sediments, water, and life of the region.

K.O. was eclectic in his choice of research. Widely varied topics included continental-shelf sediments, estuaries and marshes, beach processes, sand dunes, evaporites, lakes, and streams. K.O.'s other interests included studying the history of oceanography and collecting ocean-themed postage stamps from around the world. He wrote a paper concerning such stamps in 1960. At his death in 1998, he had just completed a manuscript on oceanography as depicted on ancient coins.

At the age of 83, K.O. wrote an autobiography that was recently published in *Marine Geology* (2002). It is a fascinating story of the career of an adventuresome bright young man who rose from inauspicious beginnings to receive the highest honors and acclaim in his profession, including membership in the National Academy of Sciences, most of the prestigious medals and fellowships in geology, and honorary degrees, including one from USC. K.O. died in Falmouth, Massachusetts, in April 1998.

### References Cited


Emery, K.O., 2002, Autobiography: Some early stages of marine geology: Marine Geology, v. 188, p. 251–291.

Curray, J.R., 2001, Francis Parker Shepard: GSA Today, v. 11, no. 12, p. 20–21.

Wertenbaker, W., 2000, William Maurice Ewing: Pioneer Explorer of the Ocean Floor and Architect of Lamont: GSA Today, v. 10, no. 10, p. 28–29.



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

## Call for Proposals for Keynote Symposia and Topical Sessions

# Denver 2004: GEOSCIENCE in a Changing World

Come back to Denver for the 2004 GSA meeting! The Rocky Mountains and High Plains preserve an outstanding record of geological processes from Precambrian through Quaternary times, from mantle dynamics to surficial processes, with everything in between. With its energy resources and water issues, Denver is a particularly appropriate place for a meeting focusing on our changing world. How will our science change in response to changing global conditions and societal needs? To what extent do we need to expand our focus to include other disciplines, other agencies, and new technologies? You can play a role in answering these and many other questions by proposing a topical session or Pardee symposium for the 2004 Denver meeting! The GSA Annual Meeting is what YOU make it.

**Proposal deadline: January 15, 2004**
**Submit proposals at www.geosociety.org**

Have you ever been frustrated to find that none of the topical sessions at a GSA meeting represent your own current area of research and excitement? If so, there is an easy answer: propose a session yourself! The topical sessions and Pardee symposia at GSA meetings are planned entirely by your friends and colleagues. If these sessions do not adequately reflect your own interests, your voice is needed. Please plan to participate in the design of the meeting by submitting a session proposal. The reward is great: you play a direct role in attracting key people to the meeting and in formulating part of the program that will be of direct benefit to you. Yours might even be the session that has everyone talking in the corridors and the bars, or even on the evening news! You may also be well on your way to producing the next GSA Special Paper.

### Program Opportunities

We welcome proposals for Pardee Keynote Symposia and topical sessions. Submit proposals electronically on or before **January 15, 2004,** via the link at www.geosociety.org.

The annual meeting program structure offers opportunities for effective and dynamic program building, allowing a mixture of invited and volunteered papers and different session formats. Joint Technical Program Committee (JTPC) representatives from GSA Divisions play a large role in decisions. Please read the various program options and guidelines at www.geosociety.org carefully before submitting a proposal of one of two types:

**Pardee Keynote Symposia,** made possible by a grant from the Joseph T. Pardee Memorial Fund, are *special events* of broad interest to the geoscience community. Topics appropriate for these symposia are those that are on the leading edge in a scientific discipline or area of public policy; address broad, fundamental problems; are interdisciplinary; or focus on global problems. The primary criterion for selection is excellence, and selection is on a competitive basis. All speakers will be invited; each convener is provided with a budget of $2,000. We strive for a good mix of Pardee Keynote Symposia of interest to GSA and Associated Society members.

**Topical sessions** promote the exchange of timely or state-of-the-art information with respect to a focused topic and allow scheduling of interdisciplinary talks that bear on a specific topic. Organizers (advocates) may invite specific papers to ensure a successful and excellent session and are encouraged to solicit volunteered contributions. A maximum of four invited speakers may be allowed. An advocate may request more invitations if he or she can justify the larger number. However, sessions **must** include volunteered abstracts, which are solicited in *GSA Today* for all approved topical sessions. Advocates may request special formats. All requests are reviewed by the JTPC. All topical sessions must receive a minimum of 12 abstracts to be part of the technical program. Advocates are encouraged to submit their proposals as poster sessions to accommodate the growing technical program.

### Oral and Poster General Sessions

Consisting entirely of volunteered papers, these sessions are an important

### Technical Program Chair

**Jane Selverstone**
(505) 277-6528 • selver@unm.edu

**Denver 2004 Dates and Deadlines**

**Jan. 15** Proposals due by midnight, MST. Electronic submission required.
**April 1** Electronic abstract form posted at www.geosociety.org.
**April** 1st announcement in April *GSA Today*.
**June** 2nd announcement in June *GSA Today*.
**July 13** Abstracts due by midnight, MST.
**Aug. 2** Technical program schedule finalized.

Accepted abstracts with links to speakers and titles will be posted at www.geosociety.org after **Sept. 1.**

**Propose a Session: Who Knows Where It Could Lead?**

When you organize a session, you can help ensure that your area of expertise gets exposure through meeting attendees and the widely cited *Abstracts with Programs* volume. GSA's marketing and communications staff sends out press releases on sessions the media may be interested in, and GSA's publications staff is always looking for that next best-selling Special Paper.

Propose a session. Then watch your efforts come to fruition as abstracts are submitted and your initiative becomes part of science history.

component of the GSA Annual Meeting. The number of abstracts received determines the number of general sessions in each discipline. The goal of the Technical Program Chair and the JTPC representatives is to provide presenters the best possible opportunity for communicating new scientific information rather than to dictate what can or will be presented. To allow for well-attended, dynamic sessions, an effort will be made in scheduling to avoid overlap of poster and oral sessions in the same discipline.

### Hot Topics

The focus of these popular lunchtime forums, held Sunday through Wednesday, is on discussion—with plenty of audience participation. Depending on the subject, a debate format is recommended, and panels are discouraged. Each session must have a moderator. Titles should be catchy and provocative. If you are interested in organizing a session, contact Nancy Carlson, ncarlson@geosociety.org.

### Make Yours the Session Everyone Talks About

Topical session organizers have the ability to ensure a successful, excellent program through topical sessions, with their combination of invited speakers and volunteered papers, and through Pardee Keynote Symposia, which expand the opportunity for high-profile sessions on important developments that have an impact on our science.

We look forward to working with you to make the GSA Annual Meeting dynamic and stimulating for all GSA and Associated Society members and appealing to a wide audience. If you have any questions or concerns regarding the program, please call or e-mail.

## K–16 Education Workshops Call for Proposals

### GSA Annual Meeting—Denver 2004

GSA invites K–12 teachers, teacher trainers, pre-service educators, and post secondary educators to submit proposals for K–16 education workshops at the 2004 GSA Annual Meeting in Denver. For more information and a proposal packet, contact Christine McLelland, (303) 357-1082, educator@geosociety.org.

**Proposals must be postmarked January 15, 2004.**

## Desperately Seeking Short Courses

GSA is soliciting short course proposals for the 2004 GSA Annual Meeting in Denver that include a half-day or one-day field trip.

The GSA Committee on Professional Development invites those interested in proposing a short course to contact GSA headquarters for proposal guidelines. We are particularly interested in receiving course proposals that include a local field trip for the 2004 Denver Annual Meeting or the 2005 Salt Lake City Annual Meeting.

Proposals must be received by January 1, 2004. Selection of courses for 2004 will be made by March 1, 2004. For those planning ahead, we will also consider courses for 2005 at that time.

**For proposal guidelines or** information, contact Edna Collis, Program Officer, GSA Headquarters, 1-800-472-1988, ext. 1034, ecollis@geosociety.org.

# GSA Division and Section Grants 2003

## DIVISION RESEARCH GRANTS

Nine of the 15 GSA divisions offer grants for outstanding student research within the fields of the respective divisions. Recipients of these grants for 2003 are listed below. The GSA Foundation manages the following funds: Archaeological Geology Division, Coal Geology Division, Engineering Geology Division, Hydrogeology Division, Planetary Geology Division, and Quaternary Geology and Geomorphology Division.

No awards were granted this year for the **Archaeological Geology Division's** Claude C. Albritton, Jr., Memorial Student Research Award.

**The Coal Geology Division** presented the annual Antoinette Lierman Medlin Research Awards for 2003. The Field Award went to Ivana Stevanovic-Walls, Department of Earth and Environmental Science, University of Pennsylvania, for her dissertation proposal "Paleoecological Patterns at the Coal-Roof Shale Transition." The Research Award went to Jason Kneedy, Department of Geology, Utah State University, for his thesis proposal "Stratigraphic and Structural Analysis of the Ferron Coals, Utah: Relationships to F. Coalbed Methane Production and Enhanced Methane Production from Carbon Dioxide Injection."

**The Engineering Geology Division** presented the Roy J. Shlemon Scholarship Awards for 2003 to Mimi Diaz, First Place Master's Level, and Cory Zellers, Second Place Master's Level. No Doctorate Level scholarships were awarded.

**The Geophysics Division** presented the Allan V. Cox Student Research Award this year for an outstanding student research proposal submitted to the GSA Research Grants Program. The 2003 Cox Award goes to Nicholas O. Mariita, University of Texas at El Paso, for his project "Heat source location and size at Menengai Geothermal Prospect, Kenya, by use of Gravity and TEM/MT methods." The 2003 Geophysics Division Award was presented to Amanda M.M. Bustin, University of Victoria, for her project "Surface Deformation Due to Convergence along the Queen Charlotte Margin."

Awards for outstanding student research from the **Hydrogeology Division** were presented in 2003 to five students: John Breier, University of Texas at Austin, for "Understanding Groundwater Flow and Distribution to Nueces Bay Estuary using Sediment Resistivity Imaging and Radium Isotope Measurements," Nicole DeNovio, University of Colorado at Boulder, for "Colloid Mobilization and Composition in the Vadose Zone," Kayse Fisher, West Virginia University, for "Morphometric Analysis of Skinholes Using Satellite Imagery in Berkeley and Jefferson Counties, West Virginia," Terence Garner, University of Texas at Austin, for "Characterization of Solute Transport in Fractured Crystalline Rocks," and to Gaisheng Liu, University of Alabama at Tuscaloosa, for "Modeling and Experimental Study of Contaminant Transport in Aquifers Containing Connected High-Conductivity Networks."

**The Planetary Geology Division** presents the Stephen E. Dwornik Best Student Paper Awards annually to students who are U.S. citizens and are pursuing advanced degrees in Planetary Sciences. The awards are presented each year for papers given in March at the Lunar and Planetary Science Conference. The recipient of the 2003 Oral Presentation Award is Brad Thomson, Brown University, for his project "Analogs of Martian Surface Components: Distinguishing Impact Glass from Volcanic Glass." The recipient of the 2003 Best Poster Award is Erin Kraal, University of California at Santa Cruz, for her project "Wave Energy on Mars and Earth: Considering Lacustrine Erosion." The Oral Honorable Mention Poster Awardees went to John Chappelow, University of Alaska, Fairbanks, for his project "Atmospheric Effects and the Record of Small Craters on Mars," and to Catherine Corrigan, Case Western Reserve University, for her project "Evidence for a Second generation of Magnesite in Martian Meteorite ALH84001."

**The Quaternary Geology and Geomorphology Division** awarded the 2003 J. Hoover Mackin Award to Yarrow Axford, University of Colorado at Boulder, for "Toward Understanding Arctic Climate Change: Investigating a New Isotopic Method for Reconstructing Past Temperatures." The Arthur D. Howard Research Grant was awarded to Timothy Sickbert, Illinois State University, for "The Effect of Differential Stream Flow Velocities on Hyporheic Interchange."

**The Sedimentary Geology Division** presented the award for outstanding student research in 2003 to Jennifer N. Flight, Montana State University, for "Sequence Stratigraphic Interpretation of the Hell Creek Formation, Northeastern Montana."

**The Structural Geology and Tectonics Division** presented its 18th annual awards for outstanding student research this year to Christopher Berg, University of Texas at Austin, for "Calculating Strain Rates from Curvature of Inclusion Trails in Garnet Prophyroblasts: An Example from Passo del Sole, Central Swiss Alps," and to Sara Bier, Pennsylvania State University, for "Timing and Kinematics of Deformation of the Kahiltna Assemblage: Evidence for Accretion of the Talkeetna Superterrane."

## SECTION RESEARCH GRANTS

Four of the six GSA regional sections award grants for research to students attending colleges and universities within each section's respective geographical boundaries.

# *GSA Division and Section Grants 2003*

The Cordilleran and Rocky Mountain Sections do not currently offer student research grants. Grants awarded in 2003 by the other sections are listed below.

**The North-Central Section** awarded grants for undergraduate research projects to students who attend a college or university within the North-Central Section geographic area. Research proposals are submitted and evaluated competitively. Recipients for fall 2002 are: Lyshia Goodhue, University of Western Ontario, for "Geomicrobiology of Surficial Geochemical Anomalies"; Stephanie Bear, Muskingum College, for "Petrographic and Geochemical Study on the Mechanism of Lamprophyre Dike Emplacement at Johnson, Vermont"; Jessica Oster, Oberlin College, for "Strontium and Magnesium Variations in a Speleothem from Crevice Cave, Missouri: Potential for Seasonal Scale Paleoclimate Reconstruction"; Jill Leonard, Cornell College, for "Comparison of Modern and Fossil Annual Banding"; Zack Lawrence, University of Missouri—Rolla, for "Shallow Seismic Reflection Study of Deformed Ordovician Strata; Karsting and Collapse vs. Tectonic Activity"; and Stephanie Hocker, University of Wisconsin—Oshkosh, for "Chemistry of Alteration Mineral Phases at the Archean Five-Mile Lake Volcanic-Associated Mineral Prospect in Northeastern Minnesota."

**The South-Central Section** did not award any grants in 2003.

**The Northeastern Section** awarded grants to five students in 2003: Darlene Fisser of Buffalo State, Evan Goldstein of Colgate University, Michael Jahn of Slippery Rock University, Angela Ribeiro of Buffalo State, and Robert Tidmore of Bucknell University.

**The Southeastern Section** awarded undergraduate and graduate research grants in 2003. The undergraduate students are William Craddock of College of William and Mary, Mollie Laird of Western Kentucky University, Christine Meyer of James Madison University, Catherine Shirvell of College of William and Mary, and Isiah Smith of James Madison University. The graduate students are John Allen of University of Georgia, Jennie Cook of University of Tennessee, Michael De Angelis of University of Tennessee, Andrew Kenst of University of Tennessee, Jason Schein of Auburn University, Clifton Whitfield of East Carolina University, Khandaker Zahid of Auburn University, Eleanor Camann of University of North Carolina—Chapel Hill, Patrick Schuneman of University of Tennessee, and Valerie Slater of University of Tennessee.

## Call for Applications:

## Planetary Geology Division's Stephen E. Dwornik Student Paper Award

### The Award

Planetary geologist Stephen E. Dwornik established this award in 1991 to provide encouragement, motivation, and recognition to outstanding future scientists. Two awards are given annually: one for the best oral presentation, the other for the best poster presentation, with each winner receiving a citation and $500. The program is administered through the GSA Planetary Geology Division. The GSA Foundation manages the award fund. For further details, see www.lpi.usra.edu/meetings/lpsc2004.

### Criteria

The Dwornik Student Paper Award applies to papers presented at the annual Lunar and Planetary Science Conference held each March in Houston, Texas. Student applicants must be (1) the senior author of the abstract (the paper may be presented orally or in a poster session); (2) a U.S. citizen; and (3) enrolled in a college or university, at any level of their education, in the field of planetary geosciences. Papers will be judged on the quality of the scientific contributions, including methods and results; clarity of material presented; and methods of delivery, oral or display.

### To Apply

The application form and instructions are found in the Call for Papers for the 33rd Lunar and Planetary Science Conference to be held March 15–19, 2004, at the South Shore Resort and Conference Center, League City, Texas. (Details are posted at www.lpi.usra.edu/meetings/lpsc2004/lpsc2004.1st.html.)

### Deadline

The deadline for electronic submission will be 5 p.m. (U.S. Central Standard Time) Tuesday, January 13, 2004; authors who are unable to submit electronically must send their hard-copy abstracts to the Lunar Planetary Institute by 5 p.m. (U.S. Central Standard Time) Tuesday, January 6, 2004.

# Students:
## Mark your Calendars!

### Shlemon Mentor Programs for 2004

**Students:** If you have career-related questions, plan to attend a Shlemon Mentor Program at a 2004 GSA Section Meeting to chat one-on-one with practicing geoscientists. These volunteers will answer your questions and share insights about how to get a job after graduation. When programs are scheduled for multiple days, each day's program will offer a different set of mentors. These programs are made possible by the Roy J. Shlemon Fund, administered by the GSA Foundation.

**FREE LUNCHES** will be served (to students only) at the following Shlemon Mentor Programs at the spring GSA Section Meetings. Stop by the GSA registration desk to get the location of the luncheon.

**South-Central Section Meeting**

Mon. and Tues., March 15–16
11:30 a.m.–1 p.m.
College Station, Texas

**Northeastern–Southeastern Sections Joint Meeting**

Thurs. and Fri., March 25–26
11:30 a.m.–1 p.m.
Tyson's Corner, Virginia

**North-Central Section Meeting**

Mon. and Tues, April 1–2
11:30 a.m.–1 p.m.
St. Louis, Missouri

**Cordilleran–Rocky Mountain Sections Joint Meeting**

Mon. and Tues., May 3–4
11:30 a.m.–1 p.m.
Boise, Idaho

Students will receive a **FREE LUNCH** ticket along with their registration badge to attend each Shlemon Program. However, space is limited. First come, first served.

# Call for Geological Papers: 2004 GSA Section Meetings

### South-Central Section

March 15–16, 2004

Texas A&M University, College Station, Texas

**Abstract deadline: December 16, 2003**

**Information:** Christopher Mathewson, Texas A&M University, Department of Geology & Geophysics, 3115 TAMU, College Station, TX 77843-3115, (979) 845-2488, mathewson@geo.tamu.edu

### Northeastern–Southeastern Sections Joint Meeting

March 25–27, 2004

Hilton McLean Tyson's Corner, Washington, D.C.

**Abstract deadline: December 16, 2003**

**Information:** George Stephens, George Washington University, Department of Earth & Environmental Sciences, 2029 G St., NW, Washington, D.C. 20052-0001, (202) 994-6189, geoice@gwu.edu; Rick Diecchio, George Mason University, Department of Environmental Science & Policy, MS 572, 4400 University Dr., Fairfax, VA 22030-4444, (703) 993-1208, rdiecchi@gmu.edu

### North-Central Section

April 1–2, 2004

Millennium Hotel, St. Louis, Missouri

**Abstract deadline: January 6, 2004**

**Information:** Joachim O. Dorsch, Saint Louis University, Department of Earth & Atmospheric Science, 3507 Laclede Ave., St. Louis, MO 63103-2010, (314) 977-3124, dorsch@eas.slu.edu

### Rocky Mountain–Cordilleran Sections Joint Meeting

May 3–5, 2004

Boise Centre on the Grove, Boise, Idaho

**Abstract deadline: January 27, 2004**

**Information:** C.J. Northrup, Boise State University, Department of Geosciences, 1910 University Dr., Boise, ID 83725, (208) 426-1009, cjnorth@boisestate.edu

**www.geosociety.org/sectdiv/sections.htm**

# GSA Offers Awards in Geomorphology and Micropaleontology

Two of GSA's most prestigious awards supporting research are made possible by the generosity of the late W. Storrs Cole. Qualified GSA Members and Fellows are urged to apply.

**The Gladys W. Cole Memorial Research Award** provides support for the investigation of the geomorphology of semiarid and arid terrains in the United States and Mexico. GSA Members and Fellows between the ages of 30 and 65 who have published one or more significant papers on geomorphology are eligible for the award. While the funds may not be used for work that is already finished, recipients of previous awards may reapply if they need additional support to complete their work. The 2004 award is for $8,000.

**The W. Storrs Cole Memorial Research Award** supports research in invertebrate micropaleontology. This award carries a stipend of $7,300 in 2004 and will go to a GSA Member or Fellow between the ages of 30 and 65 who has published one or more significant papers on micropaleontology.

For 2004 application forms visit www.geosociety.org/grants/postdoc.htm. For more information, contact Diane Lorenz, Grants, Awards, and Medals, GSA, P.O. Box 9140, Boulder, CO 80301-9140, awards@geosociety.org.

Applications must be mailed and must be postmarked on or before **February 1, 2004.** Applications sent by facsimile or e-mail will not be accepted. The Committee on Research Grants will report its actions to each applicant in April 2004.

**The Gladys W. and W. Storrs Cole Award funds are managed by the GSA Foundation.**



# 2003 Biggs Awardee Named

## *Congratulations to*

**Linda A. Reinen,** Associate Professor of the Department of Geology at Pomona College, who has been named as the 2003 Biggs Award recipient.

The Biggs Award encourages and rewards excellence in teaching among college-level professors of earth science who are in the early stages of their careers. The award is made possible through the support from the Donald and Carolyn Biggs Fund, the GSA Geoscience Education Division, and GSA s Education and Outreach Program.

Earth science instructors and faculty members from any academic institution engaged in undergraduate education who have been teaching full time for 10 years or fewer are eligible. (Part-time teaching is not counted in the 10-years-or-fewer requirement).

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**For more information, contact** awards@geosociety.org or visit:
www.geosociety.org/aboutus/awards/biggs.htm.

**for Excellence in Earth Scicence Teaching**

## *Reminder:* Renew Your GSA MEMBERSHIP FOR 2004!

Renew by November 30 to ensure receipt of the January issue of *GSA Today* and to avoid the dues increase on January 1.

Renew online at www.geosociety.org/members
or with the form you received in the mail, or call
**GSA Sales & Service at (303) 357-1000, option 3.**

# GSA Foundation Update

***Donna L. Russell,*** *Director of Operations*

**We are very pleased to announce the establishment of a new Research Fund within the Foundation. This new fund is under the guidance of the GSA International Division.**

## The Terman Research Award Fund

***Dean Kleinkopf****, Chair, International Division*

The East Asia Geoscience and Environmental Research (EAGER) project has been established as a result of a $100,000 endowment at the GSA Foundation. The fund was created by Maurice J. "Ric" Terman and is accepting contributions, particularly from commercial companies active in East Asia. The project is to be implemented annually per a formal agreement between the International Division of the Geological Society of America and the Coordinating Committee for Geoscience Programs in East and Southeast Asia (CCOP). One-year grants will fund Ph.D. theses or post-doctoral research of East Asian scientists. Scientists will be selected each year from the member country hosting the CCOP Annual Session. Hosting countries currently include Cambodia, China, Indonesia, Japan, Korea, Malaysia, Papua New Guinea, Philippines, Thailand, and Vietnam.

The permanent representatives of CCOP member countries will individually, in sequence, as they host the CCOP Annual Session Meeting, each initiate and chair an EAGER National Committee. Each year, the appropriate National Committee will advertise the EAGER Grants, solicit applications, and select up to five qualified grant applications that will then be forwarded through the CCOP director to the chair of the Advisory Group. The chairman of the Advisory Group comprising representatives of the cooperating countries and organizations and honorary advisors agrees to forward the grant applications to current representatives and advisors. Representatives and advisors will review and rank the applications and return their recommendations to the chairman, who agrees to then prepare a synthesis of the rankings and identify the final grantee(s). The grantee(s) will be formally recognized in October at the CCOP Annual Session, but the International Division, through the GSA Foundation, can distribute monies from the proceeds of the fund (no principal will be used) at earlier dates as necessary.

The chairman of the GSA International Division, working with the GSA officer for research grants, agrees to direct and oversee the GSA Foundation distribution of the necessary monies from the proceeds of the Terman Research Fund to support the grant award. The GSA International Division annually will inform the Terman family of the activities being sponsored by the fund.


*Most memorable early geologic experience*

When Eldridge did field work in Greece in 1973 (the time of the colonels), he had me hide his (contraband) maps in our baby's diaper pail whenever we saw army troops approaching. And that was frequent, because the army was doing maneuvers in his field area.

—Judy Moores



GSA FOUNDATION

3300 Penrose Place, P.O. Box 9140

Boulder, CO 80301-9140 ■ (303) 357-1054

drussell@geosociety.org

Enclosed is my contribution in the amount of $_____.

Please credit my contribution for the:

☐ Terman Fund ☐ Other: _____ Fund

☐ Greatest need

☐ I have named GSA Foundation in my will.

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Name _____

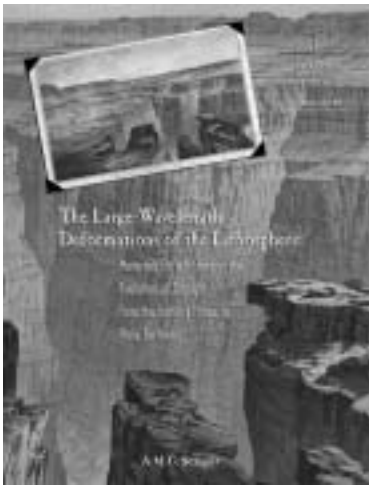
Address _____

City/State/ZIP _____

Phone _____

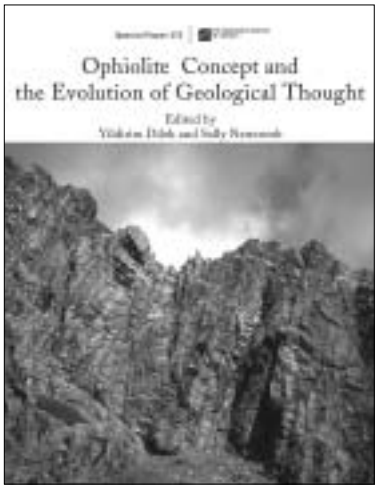
# New at the GSA Bookstore

THE GEOLOGICAL SOCIETY OF AMERICA



**The large-wavelength deformations of the lithosphere: Materials for a history of the evolution of thought from the earliest times to plate tectonics,** by A.M.C. Şengör
MWR196, 333 p. plus index, plates, ISBN 0-8137-1196-7
$100.00, **member price $80.00**

This Memoir takes readers on a fascinating journey that follows the development of ideas concerning large-wavelength lithospheric deformation that forms broad uplifts and basins. The journey begins millennia ago with Middle Eastern and Asian mythology and ends with the plate tectonic revolution in the mid-twentieth century. Readers are treated to a multitude of legends, observations, and theories, along with a host of characters who have explored this subject, from Plato and Aristotle, through de Beaumont and Suess, to Cloos, Wilson, and Burke. In order to tell that story, Şengör has consulted an immense number and variety of sources, many from his own large collection of rare geological and historical texts. Whether you read this volume as a geologist or as a historian, you'll have an enjoyable journey tracing the connections between ancient mythology and modern concepts of large-wavelength deformation.




**Ophiolite concept and the evolution of geological thought,** edited by Yildirim Dilek and Sally Newcomb
SPE373, 470 p. plus index, plate, ISBN 0-8137-2373-6
$90.00, **member price $82.00**

Since their recognition as on-land remnant of fossil oceanic lithosphere, ophiolites have been a major component of the plate tectonics paradigm. Changing hypotheses about the occurrence, origin, and emplacement of ophiolites mimic the broader advancement of the many facets of geology over 200 years. Continuing controversy over ophiolites raises fascinating scientific, historical, and philosophical questions in the evolution of geological thought. The papers in this book examine our current knowledge about ophiolites and their significance in geological studies through time and provide a historical perspective on many fundamental problems and questions that have arisen as ophiolite studies have evolved. Presenting personal views of the authors on major developments in our understanding of ophiolites, papers in the first part of the volume make the critical connections between some of the important discoveries and the flow of events and personal communications among the scientists that led to these discoveries. Other papers present a thorough chronicle of major developments in ophiolite research and provide a probing critique of how these developments aided our understanding of key scientific problems and questions. Major topics include the classification schemes of ophiolites, the validity of ophiolite-ocean crust analogy based on marine geophysical data, definition of the Moho, magma chamber models and their evolution, the significance of the Troodos massif (Cyprus) in the evolving ophiolite concept, geology of supra-subduction zones, the concept of supra-subduction zone origin of ophiolites, petrofabric features of Alpine-type and Pacific-type metamorphic belts and their implications for the exhumation histories of convergent margin plate junctions, discovery of mélanges, and the history of asbestos discovery and use.

The collection in a single volume of divergent perspectives and opposing views on ophiolites and ophiolite studies through time makes this book a vivid account of the scientific process and a unique contribution to the history of science. The book will be of great interest to researchers and students working in the broad fields of petrology and geochemistry, marine geology and geophysics, and tectonics and geodynamics.

## In Press

**Evolution and dynamics of the Australian Plate,** edited by R.R. Hillis and R.D. Müller
SPE372, 430 p. plus index, ISBN 0-8137-2372-8
$90.00, **member price $72.00**

This volume is co-published simultaneously with the Geological Society of Australia as Special Publication No. 22, Evolution and dynamics of the Australian Plate.

## Recently Published Titles

**Geology of a transpressional orogen developed during ridge-trench interaction along the North Pacific margin,** edited by Virginia B. Sisson, Sarah M. Roeske, and Terry L. Pavlis
SPE371, 353 p. plus index, CD-ROM, ISBN 0-8137-2371-X
$90.00, **member price $72.00**

**Extreme depositional environments: Mega end members in geologic time,** edited by Marjorie A. Chan and Allen W. Archer
SPE370, 264 p. plus index, ISBN 0-8137-2370-1
$80.00, **member price $60.00**

**GSA Sales and Service**
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# ANNOUNCEMENTS

## MEETINGS CALENDAR

### 2003

| | |
|---|---|
| December 3–5 | Fennoscandian Exploration and Mining, Rovaniemi, Finland. **Information:** Rovaniemi-Lapland Congresses, Marja-Leena Porsanger, University of Lapland, P.O. Box 122, FIN- 96101 Rovaniemi, Finland, +358 16 341 2799, fax +358 16 317 843, congres@urova.fi, www.lapinliitto.fi/fem2003/index.htm. |

### 2004

| | |
|---|---|
| January 6–9 | 6th SEDRIS Technology Conference (STC 2004), Lake Buena Vista, Florida, USA. **Information:** stc2004@sedris.org, or http://www.sedris.org. |
| February 1–4 | International Society of Explosives Engineers 30th Annual Conference on Explosives and Blasting Technique, New Orleans, Louisiana, USA. **Information:** ISEE, 30325 Bainbridge Road, Cleveland, OH 44139, USA, (440) 349-4400, fax 440-349-3788, www.isee.org. |
| February 22–26 | Symposium on the Application of Geophysics to Environmental and Engineering Problems (SAGEEP 04), 2004, Colorado Springs, Colorado, USA. **Information:** www.sageep.info. |
| March 8–10 | GEO 2004: 6th Middle East Geosciences Conference and Exhibition, Bahrain. **Information:** Gulf Petrolink, P.O. Box 20393, Manama, Bahrain, +973-214-881, fax +973-214-475, geo2004@batelco.com.bh, www.gulfpetrolink.com. |
| March 28–April 1 | 227th American Chemical Society National Meeting, Anaheim, California, USA. **Information:** http://oasys.acs.org/ http://membership.acs.org/g/geoc/, *(Geochemistry-related symposium: "Microbially Mediated Manganese and Iron Oxidation in the Biosphere." Abstract deadlines: online, Nov. 21, 2003; paper, Nov. 14, 2003.)* |
| April 18–21 | AAPG Annual Convention, Dallas, Texas. **Information:** AAPG Convention Dept., P.O. Box 979, Tulsa, OK, 74101-0979, USA, (888) 945-2274 (USA and Canada only) or (918) 560-2679, fax 918-560-2684, convene@aapg.org, www.aapg.org. |
| May 30–June 4 | The Eleventh Pacific Congress on Marine Science and Technology PACON 2004 (20th Anniversary), Honolulu, Hawaii. Information: PACON Secretariat, pacon.hawaii.edu, fax 808-956-2580, www.hawaii.edu/pacon. *(Abstracts deadline: January 30, 2004.)* |
| August 25–28 | EuroScience Open Forum, Stockholm, Sweden. **Information:** info@esof2004.org, www.esof2004.org. |
| September 13–16 | FEM_MODFLOW, International Conference on "Finite-Element Models, MODFLOW, and More 2004: Solving Groundwater Problems," Karlovy Vary (Carlsbad), Czech Republic. **Information:** Conference Secretariat FEM_MODFLOW, Konevova 41, CZ-130 00 Prague 3, Czech Republic, +420-222-580 079 or 581215, fax +420-222-582 282, fem_modflow@itctravel.cz, http://www.natur.cuni.cz/fem_modflow/. |
| October 24–27 | AAPG International Conference & Exhibition, Cancun, Mexico. **Information:** AAPG Convention Dept., P.O. Box 979, Tulsa, OK, 74101-0979, USA, (888) 945-2274 (USA and Canada only) or (918) 560-2679, fax 918-560-2684, convene@aapg.org, www.aapg.org. |

### 2005

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| June 19–21 | AAPG Annual Convention, Calgary, Alberta, Canada. **Information:** AAPG Convention Dept., P.O. Box 979, Tulsa, OK, 74101-0979, USA, (888) 945-2274 (USA and Canada only) or (918) 560-2679, fax 918-560-2684, convene@aapg.org, www.aapg.org. |
| September 4–7 | AAPG International Conference & Exhibition, Paris, France (dates tentative). **Information:** AAPG Convention Dept., P.O. Box 979, Tulsa, OK, 74101-0979, USA, (888) 945-2274 (USA and Canada only) or (918) 560-2679, fax 918-560-2684, convene@aapg.org, www.aapg.org. |
| September 7–11 | 6th International Conference on Geomorphology, Zaragoza, Spain. **Information:** Francisco Gutierrez, Spain, fgutier@unizar.es, and Kenneth Johnson, USA, ksjohnson@ou.edu., http://wzar.unizar.es/actos/SEG/index.html. |

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

## AWG Announces Outstanding Educator, Scholarship Winners

The AWG presented GSA Fellow **Patricia Kelley** with its 2003 Association for Women Geoscientists Foundation Outstanding Educator Award in November at the GSA Annual Meeting in Seattle. Kelley, a paleontologist, is a professor and past chair of the Department of Earth Sciences at the University of North Carolina at Wilmington.

The Association for Women Geologists Chrysalis Scholarship Committee named four winners of the 2003 awards. **Kathleen Moran** and **Linda Garinger** were awarded $1500 each, and GSA members **Geraldine Lopez** and **Nicole Davis** were each awarded $750.

The Chrysalis Scholarship provides financial aid to exemplary women graduate students in the geosciences who have experienced an interruption at some time in their formal education and who are in the final stages of writing their theses.

**More information is posted at www.awg.org.**

# EPA Announces FELLOWSHIPS

The U.S. Environmental Protection Agency will award approximately 50 new fellowships for research in environmentally related fields of study, primarily to encourage the pursuit of advanced degrees and careers in environmentally related fields.

The awards will be made under the Science to Achieve Results program (STAR). The deadline for preliminary applications is November 20, 2003. Awards should be made by July 23, 2004, for the fall 2004 term.

**Information on STAR fellowships** is available at http://es.epa.gov/ncer/fellow.
**Application information** can be found at http://es.epa.gov/ncer/rfa/current/2004_grad_fellow.html.

# IN MEMORIAM

**Alan Bailey**
Lafayette, Louisiana
July 31, 2003

**Roy A. Bailey**
Santa Cruz, California
July 13, 2003

**Charles A. Coffindaffer**
McLean, Virginia
May 26, 2003

**Doak C. Cox**
Honolulu, Hawaii
April 21, 2003

**Franklin W. Daugherty**
Alpine, Texas
August 23, 2003

**Kenneth J. Englund**
Aldie, Virginia
April 6, 2003

**Ted H. Foss**
Friendswood, Texas
September 7, 2003

**Glenn A. Goodfriend**
Washington, D.C.
October 15, 2002

**John W. Hook**
Salem, Oregon
May 17, 2003

**John B. Ivey**
Arvada, Colorado
July 11, 2003

**Robert F. Kaar**
Lafayette, California
February 12, 2003

**William F. Kohland**
Silver Springs, Florida
September 7, 2003

**Konrad B. Krauskopf**
Palo Alto, California
May 4, 2003

**Robert P. Kunkel**
Denver, Colorado
May 11, 2003

**Walter O. Kupsch**
Saskatoon, Saskatchewan
July 6, 2003

**Lloyd Livingstone**
Minnesota City, Minnesota
June 8, 2002

**W. Warren Longley**
Boulder, Colorado
June 24, 2003

**William R. Merrill**
Santa Barbara, California
February 1, 2003

**Grover E. Murray**
Lubbock, Texas
May 22, 2003

**Donald Eugene Owen**
Terre Haute, Indiana
Notified Sept 5, 2003

**William D. Payne**
Englewood, Colorado
December 16, 2002

**Stephen F. Percival Jr.**
Midlothian, Texas
May 22, 2003

**Charles L. Pillmore**
Lakewood, Colorado
August 22, 2003

**Victor K. Prest**
Ottawa, Ontario
September 26, 2003

**Thomas L. Quinn**
Cheyenne, Wyoming
February 2, 2003

**Noel M. Ravneberg**
Williamsburg, Virginia
May 2002

**Salem J. Rice**
Davis, California
August 16, 2003

**Paul R. Seaber**
Las Vegas, Nevada
August 21, 2003

**Herbert R. Shaw**
Menlo Park, California
August 26, 2002

**Robert C. Speed**
Newport Beach, California
September 18, 2003

**Daryl Streiff**
Pagosa Springs, Colorado
August 1, 2003

**James B. Terry**
Largo, Florida
May 27, 2003

**William H. Thornton**
Camas, Washington
December 8, 2002

**Edward B. Towne**
San Francisco, California
October 1, 2002

**Edwin J. Webb**
Amarillo, Texas
December 19, 2002

**Peter W. Weigand**
Northridge, California
September 26, 2003

**Garner Wilde**
Midland, Texas
May 18, 2003

**Albert E. Wood**
Cape May Court House,
New Jersey
November 11, 2002

**Hatten S. Yoder Jr.**
Washington, D.C.
August 2, 2003

**Frederick P. Young Jr.**
Newark, Delaware
April 30, 2003


Photo by Ivo Luchitta

# GeoTrip Rio Colorado: A Geologic Exploration of the Colorado River and Its Grand Canyon—Lee's Ferry to Diamond Creek

**April 22–29, 2004 (8 days, 7 nights)**

**Scientific Leader:** Ivo Lucchitta, U.S. Geological Survey (emeritus), Flagstaff, Arizona.

Even though the stately succession of strata that form the imposing walls of the Grand Canyon will by no means be ignored, the geologic focus of the trip will be more on processes operating within the Canyon, its Quaternary geology and geomorphology, and the interrelation between the activities of the Colorado River and those of humans, including thorny subjects of current interest and unexpected insights into the activities of prehistoric Puebloan farmers.

Non-geologists on the trip will be treated to many talks presented in non-technical language and designed to make them aware of the wonderful stories Earth has to tell.
The purpose of the trip is to learn, travel through some of the most remarkable scenery on Earth, enjoy good companionship, and have fun.

**Fees and Payment:** $2875 for GSA members; $2975 for nonmember spouses; $3125 for nonmembers. A $300 deposit is due with your reservation and is refundable through February 1, less a $50 processing fee. The total balance is due February 1. Minimum: 14. *We are holding 14 spaces. Any additional spaces will be based on availability. If you would like to participate in this trip, we recommend that you register today.*

**Included:** Guidebooks to the river; geologic guide; ground transportation from Las Vegas to and from the river; waterproof bags for clothes; life jacket; camping gear including a two-person tent, sleeping bag and pad, and eating utensils; all river meals; and soft drinks on the river.

**Not included:** Airfare to and from Las Vegas; nights and meals in Las Vegas; alcoholic beverages.

**For more information and to register**, see the October 2003 issue of *GSA Today,* visit www.geosociety.org/geoVentures, or contact Edna Collis, (303) 357-1034, ecollis@geosociety.org.

**Want to find out about all our latest GeoVenture trips?**
Join our E-News GeoVentures list from our Web page,
**www.geosociety.org/geoVentures.**

Ads (or cancellations) must reach the GSA Advertising office one month prior. 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.

| Per Line for | Per line each addt'l month | |
|---|---|---|
| Classification | 1st month | (same ad) |
| Situations Wanted | $2.25 | $1.90 |
| Positions Open | $7.00 | $6.00 |
| Consultants | $7.00 | $6.00 |
| Services & Supplies | $7.00 | $6.00 |
| Opportunities for Students | | |
| first 25 lines | $0.00 | $2.85 |
| additional lines | $1.85 | $2.85 |
| Web Only Ads | $7.00 | $6.00 |
| live link: add $25 | | |

Agencies and organizations may submit purchase order or payment with copy. Individuals must send prepayment with copy. To estimate cost, count 54 characters per line, including all punctuation and blank spaces. Actual cost may differ if you use capitals, centered copy, or special characters.

# Positions Open

**HYDROGEOLOGY, UNIVERSITY OF PITTSBURGH**

The Department of Geology and Planetary Science at the University of Pittsburgh invites applications for a tenure-track position in hydrogeology to begin in the Fall Term 2004–2005, pending budgetary approval. The appointment is at the Assistant Professor level. We are particularly interested in an individual who combines field and laboratory studies with hydrologic modeling to build an interdisciplinary research program focused on hydrologic systems and water resources. Preference will be given to candidates whose expertise will complement ongoing research in the department (see www.geology.pitt.edu), including Quaternary geology and global change, volcanology, low temperature geochemistry and isotope geology, remote sensing, geophysics, regional tectonics, and studies of planetary surfaces. A Ph.D. is required at the time of appointment. The successful candidate will be expected to develop a vigorous, externally funded research program, including supervision of M.S. and Ph.D. students and undergraduate research projects. Teaching duties will include undergraduate and graduate courses in their areas of expertise. Applicants should submit a resume (including current and past grant support), statement of research and teaching interests, copies of relevant publications, and the names and addresses of at least four references to Hydrogeology Search Committee, Department of Geology and Planetary Science, 200 SRCC, University of Pittsburgh, Pittsburgh, PA, 15260, USA. Applications should be submitted before January 2, 2004. For additional information, see our web site: http://www.geology.pitt.edu. The University of Pittsburgh is an Affirmative Action, Equal Opportunity Employer. Women and members of minority groups under-represented in academia are specially encouraged to apply.

**U.S. GEOLOGICAL SURVEY MENDENHALL POSTDOCTORAL RESEARCH FELLOWSHIP PROGRAM**

The U.S. Geological Survey (USGS) invites applications for the Mendenhall Postdoctoral Research Fellowship Program for Fiscal Year 2005. The Mendenhall Program provides opportunities to conduct research in association with selected members of the USGS professional staff. Through this Program the USGS will acquire current expertise in science to assist in implementation of the science strategy of its programs. Fiscal Year 2005 begins in October 2004.

Opportunities for research are available in a wide range of topics. The postdoctoral fellowships are 2-year appointments. The closing date for applications is January 16, 2004. Appointments will start October 2004 or later, depending on availability of funds. A description of the program, research opportunities, and the application process are available at http://geology.usgs.gov/postdoc. The U.S. Geological Survey is an equal opportunity employer.

**QUANTITATIVE LANDSCAPE EVOLUTION OR NEOTECTONICS UNIVERSITY OF KANSAS**

The Department of Geology at the University of Kansas seeks applications for a 9-month, tenure-track faculty position in the field of quantitative landscape evolution or neotectonics. We seek an outstanding colleague whose research addresses fundamental problems of rates of surface processes. Individuals with expertise in cosmogenic nuclide dating, satellite-based geodesy, or numerical modeling of surface or neotectonic processes are particularly encouraged to apply. The successful candidate will be expected to establish an externally funded research program, direct graduate students, and participate in teaching graduate and undergraduate students, including courses in quantitative landscape evolution, neotectonics, or geodesy. Refer to www.geo.ku.edu and links for additional information about the department and the University of Kansas. Appointment will begin August 18, 2004, with a later starting date possible.

Applicants must have a completed Ph.D. degree by the starting date. A letter of application, a complete resume, graduate-school transcripts, and names and contact information of at least three persons, who can be contacted for letters of reference, should be sent to Doug Walker, Department of Geology, 1475 Jayhawk Blvd., 120 Lindley Hall, University of Kansas, Lawrence, KS 66045-7613 (tel. 785-864-2735, fax 785-864-5276, e-mail: jdwalker@ku.edu). Review of complete application will begin on January 15, 2004, and will continue until the position has been filled. EO/AA employer. The University is committed to increasing the ethnic and gender diversity of its faculty, and we strongly encourage women and minority candidates to apply. This position is contingent on budgetary approval.

**ASSISTANT RESEARCH GEOLOGIST IDAHO GEOLOGICAL SURVEY**

The position at the University of Idaho requires research and public service. The research emphasis is geologic mapping of Idaho. Please see www.idahogeology.org for details about the position and the Survey. Strong preference will be given to candidates with demonstrated ability and experience in geologic mapping and related topical research in a variety of geologic settings.

Please send a letter of application, curriculum vitae, statements of research interests and philosophy of geological service to the public, and contact information for three or more referees to: Kurt Othberg, Idaho Geological Survey, University of Idaho, Moscow, ID 83844-3014;or via email to igs@uidaho.edu. The Idaho Geological Survey and the University of Idaho are equal opportunity/affirmative action employers.

**POSTDOCTORAL SCHOLAR IN EARTH AND PLANETARY SCIENCES JOHNS HOPKINS UNIVERSITY**

Johns Hopkins University invites applications for the newly created Morton K. and Jane Blaustein Postdoctoral Scholar in the Earth and Planetary Sciences.

We seek an outstanding individual with a recent Ph.D. from any area of the Earth and Planetary Sciences. The successful candidate will be free to pursue his/her independent research interests, but projects that complement our existing research programs will be given special consideration. Information on our department and its research activity can be found at http://www.jhu.edu/~eps/.

The nominal start date for this position is July 2004, with completion of the Ph.D. required by the beginning of the appointment. The duration of the appointment is one year, with the option for a second year. The position carries a competitive salary and fringe benefits, includes an annual stipend for travel and research expenses, and eligibility to participate in Johns Hopkins University health plans.

To apply, please send in paper format your curriculum vita (with your email address), names and emails of three or more references, and a brief research plan to: Peter Olson, Chair, Morton K. Blaustein, Department of Earth and Planetary Sciences, 3400 North Charles Street, Johns Hopkins University, Baltimore MD 21218 USA, (email olson@jhu.edu) by December 1, 2003.

Johns Hopkins University is an Equal Opportunity/Affirmative Action employer. Women and minorities are especially encouraged to apply.

**TENURE TRACK FACULTY POSITION IN CHEMICAL OR PHYSICAL SURFICIAL PROCESSES BOISE STATE UNIVERSITY**

The Department of Geosciences at Boise State University invites applications for a tenure-track faculty position in biogeochemistry, aqueous geochemistry, water quality or surficial processes as applied to surface and/or near-surface hydrology. Desirable areas of research focus include, but are not limited to: nutrient cycling in watersheds, water/rock interactions, fluvial or hillslope geomorphology, and sediment transport processes. We especially encourage applicants with combined strengths in field experiments, laboratory/analytical skills, and modeling. The successful applicant will develop a nationally-recognized research program supported by extramural funding and will complement our existing research and educational strengths in hydrology, hydrogeology, and surficial processes. Interest in and ability to contribute effectively to collaborative research efforts, participate in developing analytical facilities, provide research opportunities for undergraduate and graduate students, and deliver courses for undergraduate and graduate geoscience programs are essential. A Ph.D. in a related Earth Science or Engineering discipline is required at the time of appointment.

Boise State University, with an enrollment exceeding 18,000 students, is located in a metropolitan area (population over 400,000). Boise is the state capitol and business, financial, and cultural center of Idaho. Numerous state and federal agencies are located in the city and the Geosciences Department benefits from collaborative activities with several of these agencies. The area is recognized as one of America's best places to live and has emerged as one of the nation's major growth regions in technology-related industry. The moderate climate and a wide variety of wild and scenic areas contribute to an outstanding quality of life with a wide variety of recreational opportunities. Additional information about the Department of Geosciences and the university can be found through our web site: http://earth.boisestate.edu/.

Boise State University is an EOE/AA institution and is strongly committed to achieving excellence through cultural diversity. The University actively encourages applications from women, persons of color, and members of other underrepresented groups. Veteran's preference may be applicable. Applicants should send a Curriculum Vita, Statement of Research and Teaching Interests, and contact information for a minimum of three referees to: Search Committee, Department of Geosciences, Boise State University, Boise, ID 83725. Review of applicants will begin on 11/17/2003, and will continue until a qualified applicant pool is established. Email correspondence (questions or submission of application materials) can be sent to jmcnamar@boisestate.edu.

**GEOLOGIST IV**

Geologist IV conducts original active geological deformation research using InSAR; provides direction to employees according to established policies and management guidance; analyzes SAR images and incoming raw data received from satellites; prepares complex mathematical analyses and formulas; and develops SAR, ScanSAR, and InSAR processing software to conduct research. Applicants must have BS in Computer Science or Engineering with five years of experience in the job offered or as a Computer Systems Technologist. Applicant must have experience with remotely sensed imagery analysis and application processing, SAR processing algorithm development and applications, and software development, valuation, implementation and integration. Salary: $57k. Reference job order SD1235241. Direct all inquiries to the Sioux Falls One-Stop Career Center, 811 E. 10th Street, Sioux Falls, SD 57103-16500; tel. 605-367-5300, fax 605-367-5308.

**ANALYTICAL GEOCHEMISTRY GEORGIA STATE UNIVERSITY**

The Department of Geology at Georgia State University invites applications for an anticipated tenure track position, at the rank of Assistant Professor or beginning Associate Professor, in Analytical Geochemistry, beginning August 15, 2004.

The successful candidate will take over operation and management of the department's NSF-funded Regional Laser Ablation ICPMS laboratory (http://www.gsu.edu/~geoamg/Page_3.html) and is expected to develop a productive externally funded research program emphasizing data generated in the ICPMS laboratory. He/She will also be expected to develop collaborative research projects involving use of the ICPMS lab and which will generate funding sufficient to maintain the lab and a portion of the ICPMS technician's salary.

The LA-ICPMS facility at Georgia State is built around a high resolution sector field ICPMS (Element2 with high speed magnet option by Finnigan MAT) and a 213 nm Nd:YAG laser by New Wave-Merchantek. Accessories include an auxiliary helium sample introduction and an autosampler. The lab consists of two rooms, one to house the instrument and accessories and the other to serve as the wet analytical lab. Both rooms are kept at positive air pressure and have HEPA-filtered air systems. The analytical lab has HF- and Perchloric-rated hoods, an 18.2 M-ohm-cm water system, parr bombs, and other laboratory materials for rock digestion and cation/anion exchange columns.

The successful candidate will supervise M.S. and/or Ph.D. student research, and will teach courses in his/her specialty in geosciences, both undergraduate and graduate, and introductory geology courses. We expect the candidate to have a strong background in geology and geochemistry and to be an excellent instructor. A Ph.D. is required. Post-doctoral experience, preferably with an ICPMS component, and in-hand funding are desirable.

Georgia State's Geology Department (www.gsu.edu/geology) has eight tenured and tenure-track faculty, one lecturer, approximately 38 undergraduate majors, and 24 resident graduate students, including 5 Ph.D. Geochemistry students. Georgia State is a research university with approximately 28,000 students and is located in downtown Atlanta. Our location offers collaborative

opportunities with other units of the University System of Georgia, including Georgia Tech, University of Georgia, and Skidaway Institute of Oceanography, as well as private educational institutions, government agencies, and private companies.

To ensure full consideration, please send your curriculum vitae (resume), statement of teaching and research interests, and the names and contact information of four references to: Dr. Timothy E. La Tour, Departmental Chair and Chair of the Search Committee, Department of Geology, Georgia State University, Atlanta, GA 30303. Initial consideration of applications will begin on December 15, 2003. We also anticipate conducting preliminary interviews at the fall, 2003 GSA and AGU meetings. GSU, a unit of the University System of Georgia, is an equal opportunity employer. Applications from underrepresented groups are particularly welcomed.

**PENNSYLVANIA STATE UNIVERSITY**
**FACULTY POSITIONS IN GEOSCIENCES**
**HYDROGEOLOGY, GEOPHYSICS, PETROLOGY**

The Department of Geosciences at Penn State University expects to hire three tenure-track Assistant Professors over the next three years in the areas of hydrogeology (broadly defined), geophysics (lithospheric deformation in particular, including active tectonics and satellite geodesy), and petrology (igneous and metamorphic processes, high-temperature geochemistry). We invite applications in any of these fields for the first position with a possible starting date of July 1, 2004. Outstanding candidates who creatively apply theoretical, observational, and/or experimental approaches are encouraged to apply. This broad search is designed to complement and advance research and education taking place in the Department and University as well as target new opportunities.

Applicants should demonstrate a distinguished record of scholarship and potential for developing a vigorous research program at Penn State, and they are expected to contribute to core teaching. Review of applications will begin December 1, 2003, and will continue until a suitable candidate is found. Applications should include a complete vita, a statement outlining teaching and research interests, and names and addresses of four or more references. Send application materials to: Search-Committee Chair, Department of Geosciences, 503 Deike Building, The Pennsylvania State University, University Park, PA 16802.

Penn State is committed to affirmative action, equal opportunity and the diversity of its workforce. Women and members of underrepresented groups are encouraged to apply. For more information on the Department of Geosciences go to http://www.geosc.psu.edu.

**PENNSYLVANIA STATE UNIVERSITY**
**ASSISTANT PROFESSOR IN ASTROBIOLOGY**

The Department of Geosciences at Penn State University invites applications for a tenure track faculty position (Assistant Professor level) in Astrobiology. The position is co-funded by the College of Earth and Mineral Sciences and the Huck Institutes for Life Sciences. The candidate's academic home will be in the Department of Geosciences.

The successful candidate will join the Penn State Astrobiology Research Center (PSARC), one of the founding members of the NASA Astrobiology Institute (NAI), and pursue research that will complement/advance the research carried out by the PSARC members. Current PSARC research foci are: geochemical and paleontological record of the early Earth's biosphere, photochemical reactions of sulfur and iron in the early Earth, genomic record of the Earth's early biosphere, laboratory microbial simulations, modern analogues of Precambrian microbial ecosystems, and planetary habitability and life detection.

Applicants should demonstrate the potential for developing a significant research program and high quality teaching. A Ph.D. is required at the time of appointment. We will begin consideration of candidates on December 1, 2003, and will continue until suitable candidates are identified. Applications should include a complete resume, examples of published work, a statement outlining research and teaching interests and the names and addresses of at least four individuals who could provide references. Send application materials to: Chair, Astrobiology Search, Department of Geosciences, 503 Deike Bldg., The Pennsylvania State University, University Park, PA 16802

Penn State is committed to affirmative action, equal opportunity, and the diversity of its workforce. For more information on the Department of Geosciences and PSARC go to http://www.geosc.psu.edu and http://psarc.geosc.psu.edu.

**PENNSYLVANIA STATE UNIVERSITY**
**GEOSCIENCE EDUCATION**

The Department of Geosciences at Penn State University invites applicants for a fixed-term faculty position in Geoscience Education. This position is part of an established program to improve instruction in courses for majors and non-majors. The Department enrolls 120 undergraduate majors and a comparable number of graduate students, and it offers a diverse suite of General Education courses to over 3500 students annually.

Expectations: We seek a dynamic individual to work with faculty members in developing an integrated core course sequence for undergraduate majors in our Geosciences BS and BA programs. Experience in curriculum design is desirable. The position will involve extensive interaction with faculty members and students to build consensus on desired learning outcomes in our programs, focusing on higher-order learning skills as well as specific content.

Terms: The initial term of the position is 1–3 years, with renewal possible to a maximum of 5 years. Teaching and co-teaching within the core curriculum will be negotiated on an individual basis, depending on the interests and areas of expertise of the candidate. The successful applicant will have the opportunity to build and maintain his/her research program through pursuit of external funds.

Qualifications: Qualifications include a Ph.D. at the time of appointment and a record of effective classroom teaching. Preference will be given to applicants with advanced degrees in the Geosciences, but we will consider applications with appropriate experience in both education and in related science disciplines. We invite applications from senior faculty members who wish to hold this position while on sabbatical leave from their home institution, as well as junior faculty members who are at the initial stages of their careers.

Review of applications will begin December 1, 2003, and will continue until a suitable candidate is found. Applications should include a complete vita that includes research interests, a teaching portfolio, a statement discussing previous experience in curriculum design and thoughts about curriculum revision in the geosciences, and names and addresses of three or more references. Send application materials to: GeoEducation Search Committee Chair, Department of Geosciences, 503 Deike Building, The Pennsylvania State University, University Park, PA 16802.

Penn State is committed to affirmative action, equal opportunity and the diversity of its workforce. Women and members of underrepresented groups are encouraged to apply.

**TENURE-TRACK FACULTY POSITION**
**HYDROGEOLOGY AND WATER RESOURCES**
**UNIVERSITY OF WISCONSIN—EAU CLAIRE**
**BEGINNING AUGUST 23, 2004**

Instructional responsibilities will include water resources, physical hydrogeology, chemical hydrogeology, computer modeling in hydrogeology, and introductory geology courses as needed by the department. Applicant must also involve students in high-quality collaborative research projects. A Ph.D. in geology or a closely related discipline is required at the time of appointment. The department has modern facilities in hydrogeology, geophysics, geochemistry, and sedimentology.

To apply, please send a letter of application, curriculum vita, copies of college transcripts, and arrange to have three letters of recommendation sent to the department. Reply to Dr. Robert Hooper, Chair, Department of Geology, University of Wisconsin—Eau Claire, Eau Claire, WI, 54702-4004. To be considered for priority screening all application materials must be received by January 15, 2004; however, screening may continue until position is filled.

For a complete position description, call 715/836-3732 or visit http://www.uwec.edu/geology. UW-Eau Claire is an AA/EEO employer and encourages applications from women and minorities.

**UNIVERSITY OF NORTH CAROLINA AT CHAPEL HILL**
**SEDIMENTARY GEOLOGY AND**
**EARTH SYSTEM HISTORY POSITION**

The Department of Geological Sciences at the University of North Carolina at Chapel Hill invites applications for a tenure-track faculty position at the assistant professor level to begin July 1, 2004.

We seek applicants with a broad range of research interests in earth system history, including one or more of the following areas. (1) Marine geobiology, including paleoecology, paleobiogeography, and paleoceanography, with an emphasis on the relationships between geology, plate tectonics, climate, and biological evolution; (2) Quantitative studies of past climates, including abrupt climate change, utilizing marine, terrestrial, and/or ice core data; (3) Evolution of sedimentary basins, including stratigraphic, biostratigraphic, geochronologic, and paleoenvironmental investigations, and the relationship between climate and sediment supply. This position will complement existing strengths at UNC-CH in paleobiology, climate modeling, continental margin geology, and tectonics. The successful candidate will be expected to interface with existing departmental research programs and advance undergraduate and educational programs through developing cross-disciplinary ties with other units on campus.

The department houses several laboratories including a scanning electron microscope, thermal ionization mass spectrometer, and DCP, and has access to an ICP-MS and electron microprobe at Duke University. The Department of Marine Science houses a GC-C-IR mass spectrometer. UNC-CH and Duke jointly operate the R/V *Cape Hatteras*, a part of the UNOLS oceanographic research fleet. The university offers access to several in-house supercomputing facilities.

Applicants must hold a Ph.D. at the time of appointment. Postdoctoral and teaching experience is highly desirable. The candidate will be expected to develop a vigorous, externally funded research program, and to demonstrate excellence in both undergraduate and graduate teaching.

Applicants must submit a letter of application, names, addresses, and email and phone numbers of four references, statements of teaching and research interests, and their vitae to Prof. J. A. Rial, Chair, Search Committee for Earth System History, Department of Geological Sciences, CB# 3315, University of North Carolina, Chapel Hill, NC 27599-3315. Review of applications will begin on December 15, 2003, and will continue until the position is filled. Informal meetings with UNC-CH faculty at GSA or AGU meetings can be arranged. More information about the department can be found at http://www.geosci.unc.edu. UNC-CH is an Equal Opportunity/Affirmative Action employer. Women and minorities are encouraged to apply.

**MANAGER, GEOLOGIC MAPPING PROGRAM**
**NEW MEXICO BUREAU OF GEOLOGY**

New Mexico Institute of Mining and Technology (New Mexico Tech) invites applications for a manager of the geologic mapping program with the New Mexico Bureau of Geology and Mineral Resources (NMBGMR). The Bureau, a research and service division of New Mexico Tech, functions as the state geological survey with a staff of approximately 40 earth science professionals and a support staff of 25. Applicants must meet a minimum educational requirement of a Ph.D. in geology (although candidates with an M.S. in geology with truly exceptional work experience could be considered), and a demonstrated record of innovative and original field-based geologic research, including a minimum of five years experience in field geologic mapping and the production of geologic maps. Experience in program management and personnel management, especially of field-based programs that involve geologic mapping, is required. Experience in managing multi-faceted projects with complex budgets is desirable. The successful applicant will manage, maintain, and nurture a successful statewide geologic mapping program with an annual budget of $630,000. Salary range is $46,238.40–$58,011.20, depending on experience. Application deadline is November 20, 2003, but will remain open until the position is filled. instructions. Applicants should send a resume, transcripts, and the names, email addresses and phone numbers of three employment references to: New Mexico Institute of Mining and Technology, 801 Leroy Pl., Human Resources Wells Hall Box 125C , Socorro, NM 87801. For information about New Mexico Tech, visit our web page http://www.nmt.edu/. E-mail applications NOT accepted. AAEOE.

**TRINITY UNIVERSITY**
**ASSISTANT PROFESSOR OF GEOSCIENCES**

The Department of Geosciences at Trinity University, a member of the Keck Geology Consortium, invites applications for a tenure-track position at the rank of Assistant Professor beginning in August 2004. Candidates must be dedicated to excellence in undergraduate teaching and to an active research program that includes the involvement of undergraduates. Teaching responsibilities will include upper and lower division courses in the major and introductory Geoscience courses in the University's Common Curriculum. Participation in the development of field and interdisciplinary courses is expected. Applicants should have a specialization that includes a significant component of field work and that complements the existing faculty specializations in igneous petrology, structural geology, invertebrate paleontology, geomorphology/Quaternary geology, and geophysics. Applications must include a letter of application, curriculum vitae, undergraduate and graduate transcripts, a detailed description of teaching philosophy and research plans, and 3 letters of recommendation; sent to Dr. Glenn Kroeger, Department of Geosciences, Trinity University, One Trinity Place, San Antonio, Texas 78212-7200 (email: gkroeger@trinity.edu). Further information about the department and search can be found at http://www.trinity.edu/departments/geosciences/. Review of completed applications will begin December 1, 2003. Women and minority candidates are

strongly encouraged to apply. Trinity University is an Equal Opportunity Employer.

**POSTDOCTORAL POSITION IN IGNEOUS PETROLOGY AND INFORMATION TECHNOLOGY VIRGINIA TECH**

A Geoinformatics based GeoscienceNetwork (GEON) Postdoctoral Associate position is available at Virginia Polytechnic Institute and State University. GEON is a NSF-funded, multi-institutional effort to create the cyberinfrastructure for the geosciences (http://www.geongrid.org/). The successful candidate will be responsible for implementing web accessible schemas to facilitate integration of databases for field based geochemical, isotopic, mineralogic information on igneous rocks. The individual must possess quantitative research interests in igneous petrology, as well as a strong background in computer science. Ability to work with information technology researchers to develop ontologically driven software for integration of petrologic databases is important

Anticipated start date is February 2004; initial appointment is for two years, with the possibility of an additional one-year renewal. Starting annual salary is $35,000 plus benefits. Position requires a Ph.D. with demonstrated ability in numerical modeling and use of petrologic tools. Experience in GIS protocol required.

Review of materials will begin January 5, 2004, and will continue until the position is filled. To apply send cover letter, CV, no more than three reprints, and the names of three referees to: Dr. A. Krishna Sinha, Department of Geosciences, Virginia Tech, Blacksburg, VA. 24061; e-mail: pitlab@vt.edu.

Virginia Tech has a strong commitment to the principle of diversity and, in that spirit, seeks a broad spectrum of candidates including women, minorities, and people with disabilities.

**POSTDOCTORAL RESEARCH ASSOCIATE IN THERMOCHRONOLOGY/TECTONICS UNIVERSITY OF KANSAS**

The Isotope Geochemistry Laboratory in the Department of Geology at the University of Kansas invites applications for a postdoctoral research associate with experience in noble gas thermochronology and geochronology. The appointment will begin on February 1, 2004, with a later starting date possible. We seek an individual with expertise in noble gas thermochronology and geochronology. Duties include maintaining the noble gas laboratory and working with students, faculty and outside users. Possibilities exist for project related fieldwork. Outstanding candidates may apply for principal investigator status with the University of Kansas.

A Ph.D. degree in geology or closely related field is required by the time of appointment. A letter of application, a complete resume, graduate-school transcripts, and names and contact information of at least three persons, who can be contacted for letters of reference, should be sent to Daniel Stockli, Department of Geology, 120 Lindley Hall, University of Kansas, Lawrence, KS 66045-2124 (tel. 785-864-4995, fax 785-864-5276, e-mail: stockli@ku.edu). Review of complete application will begin on November 15, 2003, and will continue until the position has been filled. EO/AA employer. The University is committed to increasing the ethnic and gender diversity of its faculty and staff, and we strongly encourage women and minority candidates to apply. This position is contingent on budgetary approval.

**STRUCTURAL/SEDIMENTARY GEOLOGIST UNIVERSITY OF SOUTH FLORIDA**

The University of South Florida (USF) Department of Geology (www.cas.usf.edu/geology) seeks an innovative, multidisciplinary, field-oriented geoscientist with expertise in basin evolution, carbonate platform development, or tectonics for a tenure-earning Assistant Professor position. It is scheduled to start in Aug., 2004, pending available funding. Applicants combining any of the above disciplines with use of remote sensing, geologic mapping, petrography, or numerical dating as well as those with a commitment to educational and research excellence are especially encouraged to apply. A Ph.D. is required at the time of employment to be appointed at the level of Assistant Professor.

To apply, send a letter of interest, curriculum vitae, statements of teaching and research goals, and arrange for three letters of reference to be sent to: Dr. Peter J. Harries, Search Committee Chair, Department of Geology, University of South Florida, 4202 E. Fowler Ave., SCA 528, Tampa, FL 33620-5201. Applications will be accepted through December 1, 2003. For additional information contact Peter Harries (813-974-4974, harries@chuma.cas.usf.edu).

USF is an AA/EEO institution. Women and minorities are strongly encouraged to apply. Those persons requiring reasonable accommodation under the ADA should contact the Search Chair. According to Florida law, applications and meetings regarding them are open to the public.

**SENIOR ASSOCIATE WATER/WASTEWATER UTILITIES GROUP**

Environmental Science Associates (ESA), a leader in the environmental consulting industry for over 33 years, seeks mid to senior-level professionals to join our Water/Wastewater Utilities Group. Our team is working on some of the most challenging and stimulating water resources projects in the West, including: water transfers, aquifer storage and recovery/conjunctive use, recycled water master plans, indirect potable reuse, storm water management, wetland creation and state of the art treatment facilities. Position requirements include: BA/BS Degree and experience with water resource planning and impact assessment; CEQA/NEPA and related resource permitting and excellent written and oral communication skills. Positions available in our San Francisco, Sacramento and Los Angeles offices. ESA offers a great salary and benefits package, including an Employee Stock Ownership Plan (ESOP) and a 401(k) match. Please send resumes/references to: ESA, 225 Bush Street, Suite 1700, San Francisco, CA 94104 Attn: HR or e-mail hr@esassoc.com. EOE/AA.

**REMOTE SENSING EARTH SYSTEM SCIENTIST LEHIGH UNIVERSITY**

The Department of Earth and Environmental Sciences has an opening at the assistant-professor level for a scientist with experience in innovative application of remote sensing to earth and environmental systems. We are particularly interested in individuals who have worked across traditional disciplinary boundaries, and who have expertise in one or more of the areas of active tectonics, geodesy, geomorphology, global change, and natural hazards.

We expect the successful candidate to develop a vigorous externally funded research program, teach a course in remote sensing, contribute to our GIS curriculum, and mentor Ph.D., M.S., and undergraduate students in internships and research.

This position is the one of several new hires in Earth and Environmental Sciences, engineering, and the social sciences expected to participate in a university wide, multidisciplinary, initiative focusing on the environment.

To receive full consideration, applicants should submit by December 15 a letter of application, curriculum vitae, statement of research and teaching interests, up to 3 reprints, and the names of three referees to Anne Meltzer, Chair, Department of Earth and Environmental Sciences, 31 Williams Drive, Lehigh University, Bethlehem, PA 18015.

For further information about the EES Department, visit http://www.ees.lehigh.edu/.

Lehigh University is committed to recruiting and retaining women and minorities.

**UNIVERSITY OF HAWAII INSTITUTE FOR ASTRONOMY ASTROBIOLOGY POSTDOCTORAL FELLOWS**

The Institute for Astronomy (IfA) invites applications for postdoctoral fellows with a strong interest in astrobiology to collaborate with the University of Hawaii's NASA Astrobiology Institute lead team members. The UH lead team will maintain an innovative multi-disciplinary research environment linking biological, microbiological, chemical, geological and astronomical sciences to investigate the origin, history, distribution and role of water as it relates to life in the universe. The core of this program will center around interactions with an interdisciplinary group of postdoctoral fellows. Areas of primary research collaboration will be (1) formation and measurement of astrobiologically important molecules such as sugars, aminoacids, carboxylic acids, carbon homologoues, hopanes, steranes, and head to head isoprenoids, as well as interpretation of the redox environment as it pertains to life in water-rich extraterrestrial ice analog samples, (2) star formation (IR spectroscopy of sources in and behind dark clouds; sub-mm interferometry of disks), (3) studies of small solar system primitive bodies (including both IR spectra, and isotopic studies), (4) modeling the incorporation of water into preplanetary grains; (5) mineralogy, petrology and isotope (D/H) chemistry of aqueously altered carbonaceous chondrites; (6) incorporation of water into planetary bodies, its cycling between surface and interior and its subsequent loss to space; (7) aqueous alteration on Mars; (8) evolution and diversity of microorganisms, especially those living in extreme and unusual Earth environments; (9) experimental and field investigation of indigenous microbiota and energetics of potential metabolic pathways in ocean crust and mantle rocks as analogs for early Earth habitats; (10) the ecology and biogeochemistry of extreme aqueous environments on the Earth, including subglacial lakes, high-altitude lakes and fumaroles as analogs to habitats elsewhere in the solar system; (11) the development of astrobiological instruments; and (12) models of theoretical ocean-bearing extrasolar planets and their remote characterization (13) the development of collaborative multidisciplinary computing techniques.

Minimum qualifications include a Ph.D. and the expertise appropriate for the specific research focus selected by the applicant. This could include (but is not limited to):

- Expertise in infrared astronomical spectroscopy and research experience in star formation, circumstellar disks, or small solar system bodies
- Experience with astronomical sub-millimeter spectroscopy & interferometry
- Background in experimental physical chemistry (reaction dynamics, photo-chemistry, charged and neutral particle sources and high vacuum technology)
- Experience with solar nebula models
- Familiarity with basic analyses of seawater based fluids, microbial molecular genetic techniques, and thermodynamic modeling of fluid-rock solution systems;
- Strong research programming skills (Java/C++/other) with an interest in collaborative computing and/or artificial intelligence.
- Experience with scanning and transmission electron microscopy, electron and ion microprobes; experience in geo/cosmochemistry or physicochemistry.
- Experience in marine microbial ecology and biogeochemistry
- Molecular Biology and microbiology techniques
- Modeling of upper atmospheric chemistry and physics
- Analysis of remote sensing of terrestrial surface and atmosphere
- Experience in the design and construction of instrumentation

Additional desirable qualifications:

- Education and public outreach is an integral part of the Astrobiology program and experience with or interest in E/PO will be considered positively in an application.

The successful candidates will have access to unequaled astronomical observing facilities at the Mauna Kea and Haleakala observatories, an Ultra-High Vacuum Surface scattering machine, a 5 spectrometer electron microprobe and scanning electron microscope, a prototype Cryobot, fully-equipped molecular biology and microbiology laboratories, the R/V *Kilo Moana* oceanographic research ship, and the University of Hawaii Undersea Research Laboratory. In addition, successful candidates will be in close proximity to a variety of unique aquatic habitats (open ocean, high-altitude lakes, fumaroles). Appointments will be up to 3 years assuming satisfactory progress. Fellows will receive a stipend of $4,333 per mo, a relocation allowance

OHIO UNIVERSITY

**Sturgeon Visiting Professorship**
**Department of Geological Sciences**

We invite applications for the Sturgeon Visiting Professorship in Geological Sciences for the 2004-2005 academic year. We particularly encourage scientists in fields allied with current departmental strengths. The visiting professor funds provide stipend and research money for a visitor to conduct research at Ohio, and can be used to extend a normal sabbatical leave. The appointee would be expected to give department/university colloquia and/or teach a course in the visitor's area of speciality.

Information on the Department of Geological Sciences can be found at http://www.ohio.edu/geology. Please send curriculum vitae and 1-2 page summary of teaching and research goals to: Chair, Sturgeon Visiting Professor Committee, Department of Geological Sciences, Clippinger Laboratories 316, Athens, OH 45701-2979. Applications will be accepted until January 31, 2004. Ohio University is an equal opportunity affirmative action employer.

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and small research budget. Fellows may apply for a subsequent 2 year position as senior fellows.

Applicants are expected to propose a program of research in consultation with the lead team members. Please address application materials including a complete application form (http://www.ifa.hawaii.edu/uhnai/application.html), which includes a CV, publication list, a research proposal describing connections to at least 2 lead team members (http://www.ifa.hawaii.edu/UHNAI/application.html) and a list of at least three professional references to Dr. Rolf Kudritzki, Director, Institute for Astronomy, 2680 Woodlawn Drive, Honolulu, HI 96822. Request that the letters of recommendation are sent directly to this same address. Further details may be obtained from Dr. Rolf Kudritzki at 808-956-8566 or email kud@ifa.hawaii.edu. Questions about the UH Astrobiology lead team's program may be directed to Dr. K.J. Meech email meech@ifa.hawaii.edu. Applications will be reviewed beginning Dec. 15, 2003, but the positions will remain open until filled. The University of Hawaii is an EEO/AA employer and encourages applications from women and minorities.

**HYDROLOGY FACULTY POSITION**
**UNIVERSITY OF VIRGINIA**

The Department of Environmental Sciences at the University of Virginia invites applications for a faculty position in the hydrological sciences. We expect to hire at the Assistant Professor level, but exceptional candidates at a higher level will be considered. The Department is an interdisciplinary community of process-oriented scientists representing hydrology, ecology, geosciences and the atmospheric sciences. The Department offers B.A., B.S., M.S. and Ph.D. degrees.

The Department seeks candidates with clear interest and potential for advancing our understanding of the controls and dynamics of hydrological processes at the landscape scale, preferably with a focus on field and laboratory observation and experimentation. We encourage applications from diverse areas of the hydrological sciences (including, but not limited to, ground water-surface water interactions, land surface water dynamics inferred through remote sensing, and land-cover controls on hydrology of large basins). Regardless of specialization, the ideal candidate will be a process-based scientist with an interest and capacity for interdisciplinary research.

The successful candidate will be expected to develop outstanding programs in research and teaching at both the undergraduate and graduate levels. Applicants must show demonstrated excellence in their research and a strong commitment to quality teaching. Candidates should have a Ph.D. in the hydrological sciences or closely related discipline.

Send statements of research and teaching interests, curriculum vitae, and the names and addresses of three referees to: Bruce P. Hayden, Department of Environmental Sciences, University of Virginia, 291 McCormick Road, PO Box 400123, Charlottesville, VA 22904-4123.

Preference will be given to applications received by 19 December 2003. We especially encourage applications from under-represented groups. For additional information, see the department web site at www.evsc.virginia.edu.

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

**ARCHAEOLOGY, DEPARTMENT OF ANTHROPOLOGY**
**WASHINGTON STATE UNIVERSITY**

Pending budgetary approval, Department of Anthropology, Washington State University, seeks a scientist to fill an archaeology position with a geoarchaeological focus for a tenure-track assistant professor position beginning August 16, 2004. Ph.D. in Anthropology or closely related field completed by May 2004, a specialty in geoarchaeology with a demonstrated record of excellence in teaching and active program in research; training and experience adequate to enable successful teaching and to serve on graduate student committees. WSU is an EEO/AA educator and employer. Protected group members encouraged to apply. Send letter of interest, names of 3–5 references (with current phone numbers and email addresses), and curriculum vitae by November 14 to: Robert E. Ackerman, Chair, Geoarchaeology Search, Department of Anthropology, P.O. Box 644910, WSU, Pullman, WA 99164-4910. (ackermanr@wsu.edu).

**CHAIRPERSON, DEPARTMENT OF GEOLOGY**
**APPALACHIAN STATE UNIVERSITY**

Applications are invited for the position of Chair of the Department of Geology, Appalachian State University. The successful candidate will be charged with guiding the continuing development of a geology department consisting of eight faculty who are strongly committed to excellence in teaching, research and service.

Applicants must have a doctorate degree in geology, a demonstrated commitment to undergraduate education, a record of publication and funded research, excellent leadership capabilities and interpersonal skills, and a background appropriate for the rank of Associate professor or Professor. Field of specialization within geology is open, but will ideally complement the Department's existing strengths. The salary will be commensurate with rank and experience, with duties to begin July 1, 2004.

Appalachian State University, with an enrollment of 13,000 undergraduates, is a comprehensive university and a member of The University of North Carolina System. The Department offers four undergraduate degrees in Geology. The University is located in the heart of the Blue Ridge Mountains, a region that provides excellent opportunities for research and instruction in classic field settings.

Applications must include (1) a cover letter summarizing qualifications, teaching and research interests, administrative philosophy, and reason for seeking the position; (2) a current curriculum vitae; (3) the names and addresses (including e-mail) and telephone numbers of at least three references; and (4) copies of transcripts (official copies required at time of employment). Send completed package to: Geology Chair Search Committee, Office of the Dean, College of Arts and Sciences, Appalachian State University, Boone, NC 28608, USA. Inquiries can be directed to Dr. Loren Raymond, Chair of Search Committee, (828) 262-3049.

Review of completed applications will begin on January 5th, 2004, and will continue until the position is filled. Appalachian State University is an Equal Employment Opportunity/Affirmative Action employer.

**TENURE TRACK FACULTY POSITION**
**MIAMI UNIVERSITY**
**SOLID EARTH GEOPHYSICIST**

The Department of Geology at Miami University invites applications for a tenure-track faculty position at the Assistant Professor level, beginning August 2004. Applicants must have a Ph.D. degree at the time of appointment. The successful applicant will be expected to teach effectively at the undergraduate and graduate levels, supervise student research at the undergraduate, M.S. and Ph.D. levels, and initiate and maintain a vigorous, externally funded research program.

We are seeking an outstanding candidate who is undertaking significant field and/or laboratory based research in solid earth geophysics or geodynamics. The particular research emphasis should complement current program strengths indicated below.

The successful applicant will join an active department that consists of ten faculty members, four research/technical staff members, forty undergraduate majors and twenty four graduate students. The department maintains active research programs in geomicrobiology, geomorphology, hydrogeology, igneous petrology, isotope geochemistry, low-temperature geochemistry, mineralogy, sedimentology and stratigraphy, structural geology, tectonics, volcanology, and Quaternary geology. Included among departmental instrumentation are: DC plasma spectrometer, multi-collector thermal ionization mass spectrometer, HPLC ion chromatograph, atomic force/scanning tunneling microscope, single-crystal and powder x-ray diffractometers, single-crystal x-ray cameras, electrophoretic mobility analyzer, and cathode lumniscope. The department also owns a truck-mounted hollow-stem auger drilling rig. Please visit www.muohio.edu/geology/ for additional information.

Miami University, with 16,000 students, is located in a small-town setting within a one-hour drive of Cincinnati and Dayton. Interested candidates should submit a packet containing a letter of application, curriculum vitae, statement of teaching and research objectives and accomplishments, transcripts, and arrange three letters of reference to be sent to: Geophysicist Search Committee, Department of Geology, Miami University, 114 Shideler Hall, Oxford, OH 45056 (fax: 513-529-1542). Applications will be accepted until December 19, 2003 or until the position is filled.

We encourage applications from women, members of ethnic minorities, and individuals with disabilities. Miami University offers equal opportunity in employment and education.

**MINERALOGY, GEORGE MASON UNIVERSITY**

The Department of Environmental Science and Policy invites applications for a tenure-track Assistant Professor position in Mineralogy for fall 2004. We seek a dynamic person with expertise in mineralogy and geochemistry. Successful candidate will be expected to pursue an active externally-funded research program, aspire to teaching excellence, and engage in interdisciplinary collaboration. Teaching duties would be primarily at the undergraduate level and will include mineralogy (hand-sample and optical), and other potential courses including geochemistry, soils, hydrogeology, and/or environmental geology. A Ph.D. is required.

The Department offers undergraduate degrees in Geology/Earth Science and MS/Ph.D. in Environmental Science and Policy. Our faculty includes ecologists, biologists, geologists, oceanographers, and policy specialists. Additional information about the Department and University may be found at mason.gmu.edu/~espp and www.gmu.edu, respectively.

Candidates should submit CV, letter of intent including statements of research and teaching interests, examples of published work, teaching evaluations (if available), and contact information (with e-mail addresses) of three references to Rick Diecchio, Search Committee Chair, Dept. of Environmental Science and Policy, Mail Stop 5F2, George Mason University, Fairfax, VA 22030-4444. Application deadline is 12 December 2003. George Mason University is an Affirmative Action/Equal Opportunity Employer. We strongly encourage women and minority candidates to apply.

**INTEGRATED SCIENCE EDUCATION**
**GRAND VALLEY STATE UNIVERSITY**

Integrated Science Education (Assistant/Associate, tenure track). Doctoral degree is required in one of the following: Astronomy, Geology, Physics, or Science Education. Academic appointment will be in the science department which best matches the candidate's academic background. Strong science background, expertise in science education (K–12), and demonstrated success in teaching and scholarly activity in science instruction for pre-service teachers are required. Excellent communication skills are essential. A complete application consists of an application letter; curriculum vitae; unofficial transcripts; statement of teaching philosophy; description of research interests, goals, and expectations; and three letters of reference. Review of candidate files will begin November 17, 2003, with applications accepted until the position is filled. Submit application materials to: Steve Mattox, Chair, Integrated Science Education Search Committee, Department of Geology, Grand Valley State University, 1 Campus Drive, Allendale, MI 49401-9403. Inquiries may be addressed to: mattoxs@gvsu.edu. Phone (616) 331-3734. Fax: (616) 331-3740. Website: www.gvsu.edu.

**STRUCTURE/NEOTECTONICS**
**CALIFORNIA STATE UNIVERSITY AT BAKERSFIELD**

The Department of Physics and Geology at California State University at Bakersfield (CSUB) announces a tenure track position in structure/neotectonics beginning in the 2004–05 school year. The successful candidate would demonstrate a strong commitment to sharing in department responsibilities toward the education of K–12 teachers-in-training as well as general education, major and graduate courses.

The small, high-quality geology department at CSUB is very active in peer-reviewed research involving both undergraduates and M.S.-level graduate students. The department is well equipped with aqueous chemistry and hydrology labs including field hydrology equipment, an automated XRD, an ICP-MS with laser ablation system, an SEM-EDX, a research petrography lab, and a wide variety of field geophysics equipment including gravimeter, refraction seismograph, electrical resistivity system, magnetometers, sedigraph, rock crushing equipment and a ground conductivity meter. The California Well Sample Repository on campus houses the largest public collection of oil and water well cores and cuttings in California. The Geotechnology Training Center is also located within the department. It includes six SGI Octane workstations, 12 PCs, and extensive software including Landmark, Geographix, Seismic Microtechnology's Kingdom Suite, Petra, and ArcGIS.

The San Joaquin Valley is located in an active tectonic environment and is one of the world's great centers of both the agricultural and petroleum industries. Thus, local research opportunities are readily available and connections are easily made with local industry and government agencies.

California State University at Bakersfield is a regional comprehensive university, which prides itself in a liberal arts approach to undergraduate education and small, high-quality graduate programs. It has an enrollment of approximately 7,000 students and resides in a rapidly growing community of over 400,000 people in the southern San Joaquin Valley of central California. The campus is conveniently located near popular beach, mountain, and desert attractions and is a two-hour drive from Los Angeles.

Review of applications will begin after ***November 21, 2003.*** Candidates should submit a letter of application, a current curriculum vitae, and names of at least three references to: Chair of the Geology Search Committee, Department of Physics and Geology, California State University, 9001 Stockdale Highway, Bakersfield, CA 93311-1099 USA, Web site: http://www.cs.csubak.edu/Geology/

CSUB fosters and appreciates ethnic and cultural diversity among its faculty and students, and is committed to increasing the diversity of its faculty to reflect the diver-

## Department of Geosciences
## PRINCETON UNIVERSITY

The Department of Geosciences at Princeton University is seeking applications for two tenure-track faculty appointments. We anticipate hiring at the assistant professor level. The search will concentrate in the following areas, but we also encourage outstanding applicants from other areas of the earth sciences.

**Earth history** – including examination of paleoclimates and paleoenvironments through the rock record, and the origin and evolution of the earth.

**Surficial and tectonic processes** – including crustal deformation and active tectonics, geomorphology, structural geology, the interface between petrology and tectonophysics, and links to climate and geochemistry.

**Solid earth geology, geochemistry, and geophysics** – including the dynamics and evolution of the mantle and/or lithosphere, deformation of the crust and lithosphere, the physics of earthquakes, seismology, mantle petrology, rock mechanics, and mineral physics.

The Department seeks individuals with a demonstrated record of excellence who will interact with and complement existing research programs in the department (http://geoweb.princeton.edu). Applicants should send a curriculum vitae, including a publication list, a statement of research and teaching interests, and contact information for three references to Chair, Search Committee, Department of Geosciences, Guyot Hall, Princeton University, Princeton, NJ 08544. The starting dates for the two positions are flexible, ranging up to September 2005. Evaluation of applications will begin immediately and continue until both positions are filled. Princeton University is an Affirmative Action Equal Opportunity Employer; women and members of minority groups are encouraged to apply. For general information about applying to Princeton and how to self-identify, please link to http://web.princeton.edu/sites/dof/ApplicantsInfo.htm.

sity of the campus community. Applications from women, ethnic minorities, veterans, and individuals with disabilities are welcome.

**DEPARTMENT OF EARTH & OCEAN SCIENCES**
**UNIVERSITY OF BRITISH COLUMBIA**
**ASSISTANT PROFESSOR**

**Applied Sedimentology and/or Stratigraphy**

The Department of Earth and Ocean Sciences at the University of British Columbia invites applications for a tenure-track faculty position in the area of sedimentology and/or stratigraphy. We seek a scientist whose research enhances and extends our existing strengths, particularly in areas that are process oriented and/or applied, including but not limited to, exploration and exploitation of fossil fuels, environmental studies and economic geology. This appointment is at the Assistant Professor level although applications from exceptionally well-qualified, more senior scientists will be considered, particularly if they address under-representation of designated equity groups such as women, visible minorities, disabled persons or aboriginal peoples. Candidates from all relevant fields of Science and Engineering are encouraged to apply. The position will be available as early as July 1, 2004. A Ph.D. is required by the commencement date. Teaching at the undergraduate and graduate levels is expected.

The University of British Columbia hires on the basis of merit and is committed to employment equity. All qualified persons are encouraged to apply; however, Canadians and Permanent Residents of Canada will be given priority. For more information about the Department and this position, visit our web site at http://www.eos.ubc.ca.

Applicants should send their curriculum vitae, a statement of research and teaching interests, and the names and complete contact information of three referees to Dr. Paul L. Smith, Head, Department of Earth and Ocean Sciences, the University of British Columbia, 6339 Stores Road, Vancouver, British Columbia V6T 1Z4. E-mail: psmith@eos.ubc.ca; Fax: 604-822-9014. Applications will be considered until January 9, 2004.

**THE CALIFORNIA INSTITUTE OF TECHNOLOGY**
**GEOLOGICAL AND PLANETARY SCIENCES**
**O.K. EARL AND TEXACO**
**POSTDOCTORAL FELLOWSHIPS**

The California Institute of Technology announces two fellowships in Geological and Planetary Sciences. The O.K. Earl and Texaco Postdoctoral Fellowships are awards funded by endowments from Orrin K. Earl, Jr. and the Texaco Philanthropic Foundation. Each fellowship carries an annual stipend of $44,000 plus a research expense fund of $2,000 per year and one-way travel costs to Pasadena. The duration of each appointment is normally two years, contingent upon good progress in the first year, beginning with the 2004–05 Fall term. Fellows are eligible to participate in Caltech's health and dental program.

These fellowships have been established to sup-

port the research of scientists typically within two years after receipt of the Ph.D. The intent of the program is to identify and support innovative and creative work in the earth and planetary sciences, with particular emphasis on interdisciplinary work. Applicants with training in physics, chemistry, biology, or computer sciences are urged to apply. The Caltech family is currently active in geobiology, geochemistry, geology, geophysics, petrology, seismology, environmental science and engineering, and atmospheric and planetary sciences. It is expected that each fellowship recipient will be hosted by a division professor (designated by the Chairman) who will provide both financial support and intellectual guidance.

Applications may be obtained through the Division website at www.gps.caltech.edu or by contacting Alexandra Katsas by email at: katsas@gps.caltech.edu. Completed applications with references are due by Friday, December 19, 2003.

Fellowship candidates will automatically be considered for other available postdoctoral positions at Caltech in their fields of interest.

Caltech is an Affirmative Action/Equal Opportunity Employer. Women, minorities, veterans, and disabled persons are encouraged to apply.

### UNIVERSITY OF WEST FLORIDA
### ASSISTANT PROFESSORS
### HYDROGEOLOGY & GEOLOGY

The Department of Environmental Studies, University of West Florida, invites applications for two tenure-track assistant professor positions beginning August 2004.

**Position 1.** Hydrogeology. We seek candidates with expertise in applied groundwater hydrology or water/land surface interactions. Interest in environmental issues is highly desirable, and candidates will be expected to teach both lower-division as well as upper-division classes in geology and hydrology.

**Position 2.** Geology, specialization open. We seek candidates whose expertise would mesh well in an environmental science program. Specialization in coastal geology, oceanography, geohazards, or environmental geochemistry preferred. Distance learning experience highly desirable.

Applicants are expected to develop an active research program and should be committed to peer-reviewed publication. Applicants must have an appreciation for undergraduate education. A Ph.D. in geology or related discipline is required at the time of appointment. Salary is commensurate with qualifications and experience.

The Department of Environmental Studies offers a bachelor of science degree, and a Certificate in Geographic Information Science. Over 120 majors specialize in tracks in natural science, environmental policy, and geography. A Master's program is planned effective Fall 2004. The department is housed in a renovated building with new research and teaching facilities. The department maintains the university-wide GeoData Center, which has extensive GIS capabilities. Personnel include 7 full-time faculty, several adjunct faculty, and a GIS Coordinator. For more information on the department see http://uwf.edu/environmental/.

Candidates are requested to submit a statement of research and teaching interests and experience, a curriculum vitae, transcripts, and three letters of reference. Review of applications will begin November 15, 2003, and will continue until the position is filled.

For Position 1, apply: Dr. Johan Liebens, Department of Environmental Studies, University of West Florida, 11000 University Parkway, Pensacola, FL 32514, phone 850-474-2065, fax 850-857-6036, or email liebens@uwf.edu.

For Position 2, apply: Dr. Klaus Meyer-Arendt Department of Environmental Studies, University of West Florida, 11000 University Parkway, Pensacola, FL 32514, phone 850-474-2792, fax 850-857-6036, or email kjma@uwf.edu.

The University of West Florida is an Equal Opportunity/Access/Affirmative Action Employer. Minorities and women are encouraged to apply.

### DEPARTMENT OF GEOLOGICAL SCIENCES
### COLLEGE OF NATURAL SCIENCE AND MATHEMATICS
### CALIFORNIA STATE UNIVERSITY, FULLERTON
### Hydrogeochemist/Hydrologist, Tenure Track

The Department of Geological Sciences invites applications for a tenure-track position starting August 2004. The Department has 11 full-time faculty with expertise in physical hydrogeology, geomorphology, paleoclimatology, seismology, engineering geology, tectonics and petrology. We have about 50 undergraduate majors and 25 MS students. The nearby geological provinces provide abundant opportunities for field-based research, which the department emphasizes in its curriculum. The Department operates summer hydrogeology field camps at Mammoth Lakes and Orange County, CA. See http://geology.fullerton.edu/ for additional information.

**Position**

Teaching responsibilities may include, but not be limited to, undergraduate and graduate courses in hydrogeochemistry, contaminant fate and transport, hydrogeology, aqueous geochemistry, field hydrogeology/hydrology, and physical geology. Research activities must result in publications in refereed journals. Supervision of both undergraduate and graduate student research projects is required.

**Qualifications**

The successful applicant will have the following credentials and capabilities:

A Ph.D. in Geology or a related discipline at the time of appointment.

A primary interest in achieving excellence in teaching.

A vigorous, field-based research program in hydrogeochemistry that would involve undergraduate and graduate students.

An ability to interact with faculty in physical hydrology, geomorphology, paleoclimatology and stable isotope geochemistry would be considered favorably.

**Rank and Salary**

This position will be filled at the rank of Assistant Professor; salary is competitive and commensurate with experience and qualifications. An excellent comprehensive benefits package is available.

**Appointment Date**

August 19, 2004

**Application Procedure**

To apply, please send (1) a detailed curriculum vita, (2) a letter of application that explains how you meet the qualifications outlined above, (3) a statement about teaching that includes a discussion of relevant course work and/or experience in preparation for teaching, a list of courses you would feel comfortable teaching, and a statement of your teaching philosophy, (4) a statement of your future research plans and goals, and (5) letters of recommendation from at least three references familiar with your teaching and research potential. Referees should send their letters to: Dr Diane Clemens-Knott, Search Committee Chairwoman, Department of Geological Sciences, California State University, PO Box 6850 Fullerton, California 92834-6850.

**Application Deadline**

Applications will be accepted until the position is filled. To assure full consideration, submit applications by November 19, 2003.

Cal State Fullerton is an Equal Opportunity/Title IX/503/504/VEVRA/ADA Employer.

### IGNEOUS/METAMORPHIC PETROLOGY
### CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

The Department of Geological Sciences invites applications for a tenure-track faculty appointment at the assistant professor level. Requirements are a Ph.D., an established record of published research in the area of igneous or metamorphic petrology, a demonstrated record of teaching ability, and strong field skills. Preference will be given to applicants with experience in obtaining research funding, and who have research interests that complement and enhance existing departmental strengths. Teaching assignments will include mineralogy, igneous and metamorphic petrology, a senior and/or graduate course in the hire's specialty, and, on a rotational basis, physical science for prospective K–5 teachers and appropriate general-education courses.

To apply send as e-mail attachments a curriculum vitae; statements of teaching and research interests; and names and addresses of at least three referees to **j.d.yule@csun.edu.** Include "Ig/Met Petrology Application" in the subject line. Ancillary materials, such as copies of recent publications, may be mailed to: Dr. Doug Yule, Department of Geological Sciences, California State University, 18111 Nordhoff Street, Northridge, CA 91330-8266. Review of applications will begin January 5, 2004 and continue until the position is filled.

For additional information see: www.csun.edu/geology. The University is an EO/AA educator and employer. Candidates will be expected to provide effective instruction to students of diverse backgrounds in a multicultural setting. Position is subject to final approval of budget.

### ANTICIPATED FACULTY POSITION IN
### "SOFT ROCK" GEOLOGY
### JUNIATA COLLEGE, HUNTINGDON, PA

The Department of Geology at Juniata College—a private, liberal arts college in Central PA, highly regarded for academic excellence—invites applications for an anticipated one-year sabbatical replacement for 2004/05. Teaching duties will include Historical Geology, Stratigraphy/Sedimentology, Oceanography and associated labs. The successful candidate will have strong field skills and a willingness to utilize excellent local exposures for fieldtrips during lab periods. Ph.D. preferred, although ABD considered. A commitment to excellence in undergraduate education is a must.

The Department consists of three full time faculty and one emeritus. A large proportion of our ~30 majors go on to graduate schools. The Department has excellent field and laboratory instrumentation/equipment which is available for student course work as well as faculty and student research. To learn more about the Department, visit http://departments.juniata.edu/geology/ .

Send letter of application, curriculum vitae, statement of teaching philosophy, and three letters of recommendation by December 1, 2003, to Gail Leiby Ulrich, Director of Human Resources, Juniata College, 1700 Moore Street, Box BB, Huntingdon, PA 16652. AA/EOE.

### HOFSTRA UNIVERSITY
### ASSISTANT PROFESSOR
### SEDIMENTOLOGY/FIELD GEOLOGY

The Department of Geology, Hofstra University, invites applications for a tenure track position at the assistant professor level beginning September, 2004. We seek a candidate with a background in sedimentology and field geology who is strongly committed to excellence in undergraduate teaching and research. The successful candidate will have a nine contact hour per semester teaching load and will be expected to teach one introductory level and one advanced undergraduate course per semester. The ideal candidate will teach physical geology and should be prepared to offer advanced laboratory courses in sedimentology and field methods, as well as one additional advanced course in a topic of interest to the candidate. We are looking for a dynamic individual who combines excellence in teaching with breadth and versatility in professional productivity, and who shares our commitment to close student-faculty interaction, including a vigorous program of field trips and student involvement in faculty research and professional activities.

Hofstra University is located in suburban Long Island, New York, about 25 miles from Manhattan. The University occupies a beautiful 240 acre campus that is also a registered arboretum and enrolls over 13,000 undergraduate and graduate students. The Geology Department consists of four full time and seven adjunct faculty and offers undergraduate degrees in Geology and Environmental Resources.

Applicants should have their Ph.D. completed by September 2004. Send a letter of introduction discussing your teaching and research interests, a curriculum vitae, and three supporting letters to: Dr. Dennis Radcliffe, Chair – Department of Geology, 114 Hofstra University, Hempstead, NY 11549-1140. We will begin reviewing applications on November 15, 2003.

Hofstra University is an equal opportunity employer and is dedicated to ethnic and cultural diversity among the faculty and student body.

### ASSISTANT PROFESSOR IN
### TERRESTRIAL PALEOECOLOGY
### UNIVERSITY OF IOWA

The Department of Geoscience at the University of Iowa invites applications for a full-time tenure-track Assistant Professorship in terrestrial paleoecology. The appointment will begin in August 2004. We seek an outstanding researcher and teacher who uses modern quantitative and analytical techniques to reconstruct and interpret the Earth's nonmarine ecosystems and natural history. Desirable qualifications include a research emphasis that complements existing faculty research and teaching, including but not limited to expertise in community paleoecology, the evolution of terrestrial ecosystems, or the use of biotic information for understanding regional or global change. In addition to developing an active, externally-funded program of research, the successful candidate will be expected to teach three courses per academic year, which includes participating in a rotation team for a general education course in Environmental Sciences. Applicants must have a Ph.D. in hand by August 2004. Women and minorities are especially encouraged to apply. Applicants should send a complete resume (including a bibliography and statement of teaching and research interests) and have at least three letters of recommendation sent to: Search Committee Chair (Terrestrial Paleoecology), Department of Geoscience, University of Iowa, Iowa City, IA 52242-1379 (geology@uiowa.edu, Phone: 319/335-1818; Fax: 319/335-1821). Screening of candidates begins December 1, 2003, and will continue until the position is filled. The University of Iowa is an affirmative action–equal opportunity employer.

### QUATERNARY PROCESSES POSITION AT THE
### UNIVERSITY OF CINCINNATI

The Department of Geology at the University of Cincinnati invites applications for a tenure-track faculty position at the assistant professor level in the area of Quaternary Processes with an emphasis on glacial processes beginning in Spring 2003. This hire is intended especially to enhance research and graduate student training in the surface process group, which currently has strengths in

Quaternary stratigraphy, slope processes, earth surface and geochemical processes. The Department of Geology seeks to maintain and strengthen its traditional research approach to problems of global interest from field-based observation and laboratory analysis.

Areas of expertise for this position might include: geochronology, fluvial and lacustrine sedimentation in the glacial environment, entrainment, transport, or deposition of glacial debris, glacial erosion, glaciology and global climate change.

The successful applicant will be expected to supervise graduate research, participate in graduate and undergraduate teaching, and establish an externally funded research program. Candidates must demonstrate active research activity as exemplified by peer-reviewed publication and grants and show potential for interacting with existing programs in the Department (e.g. sedimentology, ground water hydrology) and in related disciplines (e.g. Geography, Biology, Engineering, Environmental Studies).

Interested candidates should send current vita, statement of research and teaching interests and three letters of recommendation to address below. Review of applications will begin on 10 October 2003. The successful candidate must have a Ph.D. degree at the time of appointment. The Department of Geology especially encourages the application of qualified women and minorities. The University of Cincinnati is an affirmative action/equal opportunity institution.

For more information please contact: Chair, Quaternary Processes Search, Committee, Department of Geology, 500 Geology/ Physics Building, University of Cincinnati, Cincinnati, OH 45221, 513-556-3732.

**MARSHALL UNIVERSITY/FACULTY POSITION**

The Department of Geology at Marshall University invites applications for a tenure track teaching position beginning August 17, 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, Environmental Geology, Engineering Geology, and Soils as well as service courses in General Geology, Earth Materials Lab. 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 upper level courses and develop a vigorous, externally supported research program that involves undergraduates.

Candidates should submit a letter of application, curriculum vitae, undergraduate and graduate transcripts, 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 on January 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

**Structural geology Assistantship at the University of Kentucky.** It is anticipated an MS or Ph.D. degree assistantship in the field of structural geology/organic petrology will be available for spring or fall of 2004. The appointment involves a flexible combination of Research and Teaching Assistantships. The Research Assistantship stipend will be $15,000/year for 2 years, plus health insurance and tuition, and can be supplemented by an additional $3,000/year for students with the requisite academic qualifications. The project involves a combination of field and laboratory work, using frictional heating of coals on faults in the southern Appalachians, as a paleo-stress indicator on ancient seismic faults. This project is topical and is a newly emerging field in structural geology. The candidate will be encouraged to collaborate with the Center of Applied Energy Research at the Univ. of KY. Candidates may take courses in a wide range of graduate disciplines, including structural geology, seismology, and organic petrology. For further information contact Kieran O'Hara at geokoh@uky.edu, or see our web page at http://www.uky.edu/AS/Geology/.

**Graduate Assistantships in Tropical Paleoclimatology at the University of Nevada, Las Vegas.** The Department of Geoscience at UNLV is seeking qualified Ph.D. and M.S. level students to participate in tropical paleoclimate research. Available projects utilize U-series dating, stable isotopes, and luminescence banding of stalagmites from tropical caves in southern Central America to reconstruct late Quaternary variability in the Central American Monsoon and the El Niño/Southern Oscillation. Travel to field sites and collaborating institutions is likely. Proficiency in Spanish and caving experience are considered beneficial. Teaching and Research Assistantships for qualified students may be available as early as January 2004. Application deadlines for 2004 Spring and Fall semesters are November 15, 2003, and March 15, 2004 respectively. For further information please contact Matthew Lachniet (matthew.lachniet@ccmail.unlv.edu); (702) 895-4388. For application materials contact: Graduate Coordinator, University of Nevada, Las Vegas, Dept. of Geoscience, 4505 Maryland Parkway, Las Vegas, NV 89154-4010 or see our website http://geoscience.unlv.edu.

**Graduate Research Fellowship in Clay Mineralogy.** The Department of Geological Sciences at Indiana University has an opening for the Grassmann Fellowship in Clay Mineralogy for fall 2004. This competitive Fellowship is open to Doctoral-level candidates in the general area of clay mineralogy and carries a tuition waiver plus an award of $24,000 for 12 months, renewable on a yearly basis for up to 3 years. The Fellowship also includes a budget for research and travel expenses. The successful candidate for this fellowship will conduct research of their own choosing in the broad area of clay mineralogy. The Geology Department has outstanding facilities for fundamental and applied studies of clay minerals, including new X-ray diffraction, thermoanalytical, and scanning electron microscope laboratories and excellent applied clay mineralogy, stable isotope, and biogeochemical facilities. Information on the Department can be found at www.indiana.edu/~geosci/. Applicants should have a good background in mineral sciences and/or geochemistry and familiarity with X-ray diffraction. Proficiency in writing and speaking English is required. Preference will be given to students with a strong quantitative background. Interested students should contact Dr. David L. Bish, Haydn Murray Chair of Applied Clay Mineralogy,

Department of Geological Sciences, Indiana University, 1001 E. 10th St., Bloomington, IN 47405 USA; phone: 812-855-2039; email: bish@indiana.edu.

**Research/Teaching Assistantships. Graduate Program of Hydrologic Sciences.** University of Nevada, Reno. Applications are encouraged for graduate teaching/research assistantships beginning July 1, 2004. Positions carry an annual stipend of a minimum of $15,000 including tuition and fees. Students interested in the area of ground water, surface water and aqueous geochemistry are encouraged to apply. Additionally, numerous funded assistantship are available in contaminant transport, watershed hydrology and numerical simulation, as well as scholarships and doctoral fellowships offered through UNR and the Desert Research Institute. Completed application packages are due January 10, 2004, and should be mailed to : Graduate Program of Hydrologic Sciences, Mail Stop 175, LMR 267, Reno, NV 89557-0180. Information on assistantships and fellowships in the Hydrologic Sciences Graduate Program can be found at www.hydro.unr.edu or by calling 775-784-6250.

**Ph.D. Student Assistantships. Oregon State and Portland State Universities** are offering ten Ph.D. research assistantships to explore all aspects of the Earth's subsurface microbial biosphere. Tuition and stipend are provided by the NSF IGERT program and the two universities. Students will work in interdisciplinary teams of engineers, oceanographers, microbiologists, microbial ecologists, geologists, soil scientists, and chemists to solve environmental problems, to understand global chemical cycles, and to determine the impact of subsurface microorganisms on surface ecosystems. More information can be found at: http://oregonstate.edu/dept/igert, or Martin R. Fisk, College of Oceanic and Atmospheric Sciences, Oregon State University, mfisk@coas.oregonstate.edu Students from all scientific backgrounds are encouraged to apply to departments represented by IGERT faculty at either institution. U.S. citizens or permanent residents can be supported by IGERT funds however students of all nations can participate in the program. Review of applications starts 1/15/04. Oregon State and Portland State Universities are committed to equality in education.



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## GEOSCIENCE DIRECTORY

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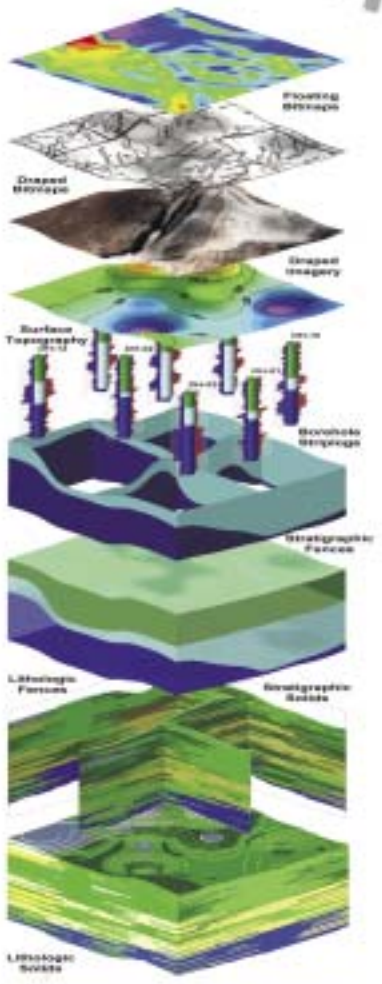

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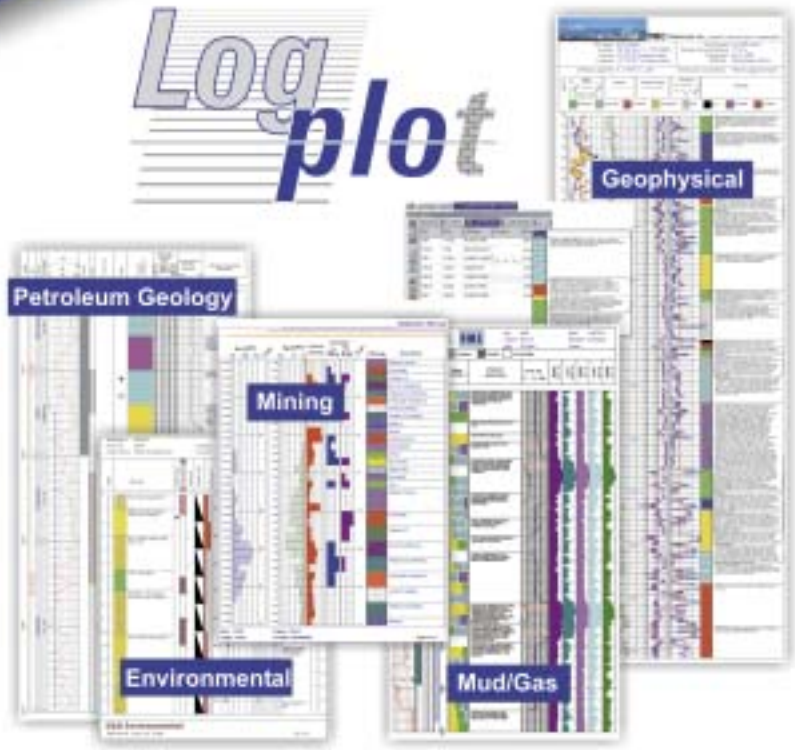


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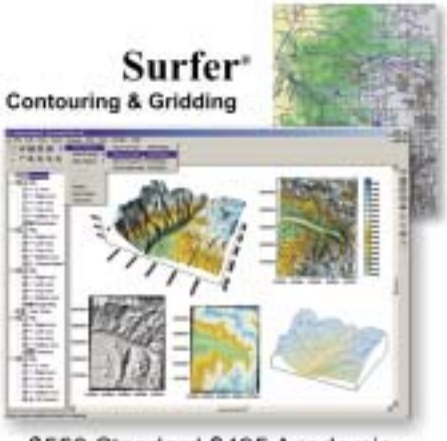

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