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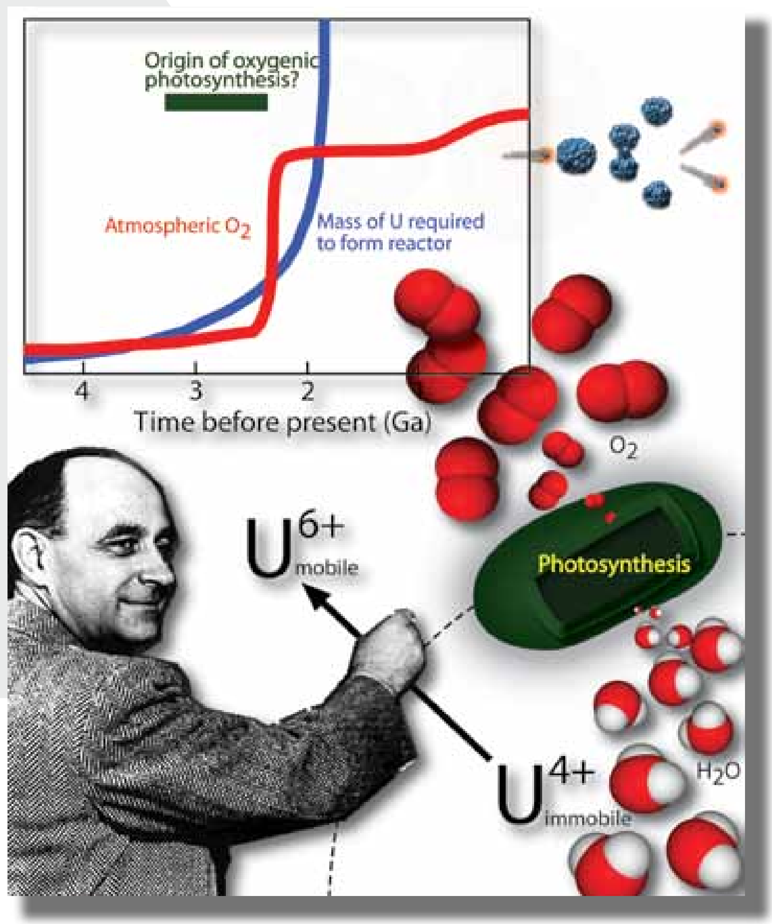

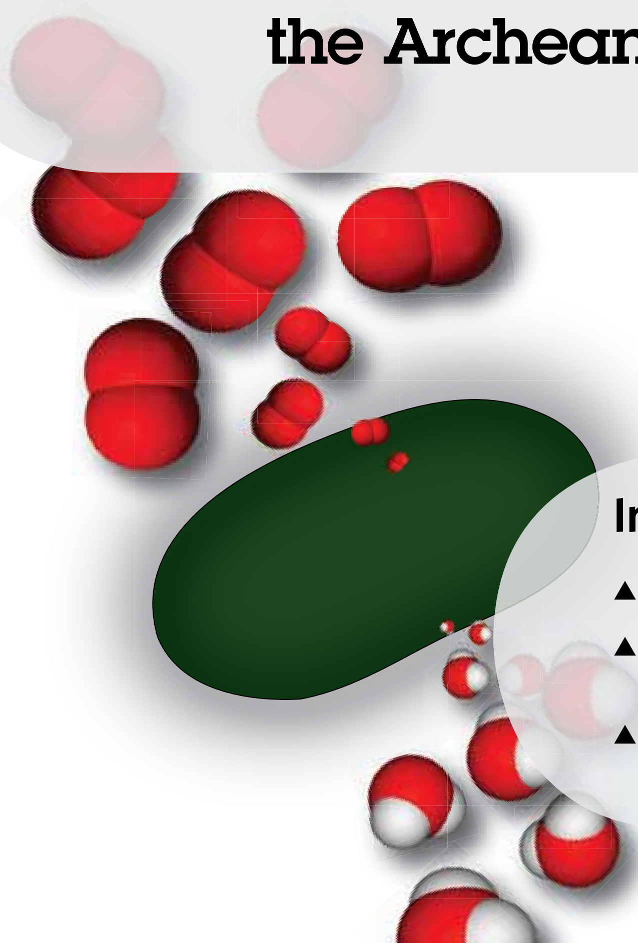

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GSA TODAY

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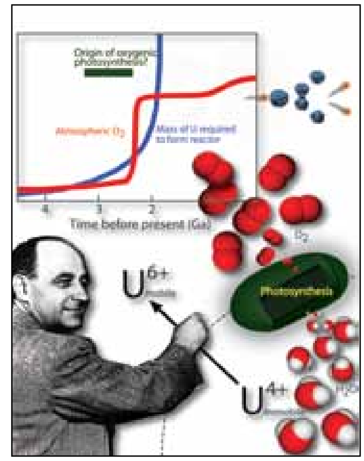
SCIENCE ARTICLE

Cover: Fission before Fermi: Did Archean O_2 production lead to natural reactor formation? See "Did natural reactors form as a consequence of the emergence of oxygenic photosynthesis during the Archean?" by L.A. Coogan and J.T. Cullen, p. 4–10.



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Did natural reactors form as a consequence of the emergence of oxygenic photosynthesis during the Archean?

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ABSTRACT

The advent of oxygenic photosynthesis changed Earth's surface environment in numerous ways, perhaps most notably by making possible the evolution of large and complex life-forms. Current models suggest that organisms that can perform oxygenic photosynthesis first took hold in isolated marine and freshwater basins, producing local oxygen oases. Here we present calculations that suggest that uranium deposits could have formed at the margins of these basins due to the strong local reduction-oxidation gradients. Because of the high abundance of ^{235}U at this time, these uranium deposits could have formed widespread, near-surface, critical natural fission reactors. These natural reactors would have represented point sources of heat, ionizing radiation, and free radicals. Additionally, they would have far-field effects through the production of mobile short- and long-lived radioactive daughter isotopes and toxic byproducts. It is possible that these fission products provided a negative feedback, helping to limit the proliferation of the cyanobacteria in the Archean environment. Secular decreases in the abundance of ^{235}U in turn decreased the probability of such deposits forming critical fission reactors during the early Proterozoic.

OXYGENATION OF EARTH'S ATMOSPHERE

An oxygenated atmosphere is a prerequisite for the evolution of complex life. On Earth, atmospheric oxygen is produced through oxygenic photosynthesis. It is widely, although not unanimously (e.g., Ohmoto et al., 2006), accepted that oxygen levels in Earth's atmosphere were very low throughout the first ~2 Ga of Earth's history (Fig. 1). Evidence from paleosols for soil development under reducing conditions and the occurrence of clastic sediments containing minerals that are highly soluble under oxic conditions, such as pyrite and uraninite, suggest low atmospheric oxygen before ca. 2.3 Ga (e.g., Rye and Holland, 1998). Evidence for low atmospheric oxygen before this time also comes from the occurrence of $\Delta^{33}S$ anomalies in sediments older than ca. 2.4 Ga that are generally believed to originate through photochemical reactions in an essentially O_2-free atmosphere (e.g., Farquhar et al., 2000; Bekker et al., 2004; Domagal-Goldman et al., 2008). Despite this, there is evidence that local oxygenated "oases" existed prior to this time. For example, the Pb-isotopic composition of some >3.7 Ga metasediments suggests that their protoliths had elevated primary U/Th ratios (Rosing and Frei, 2004). This is interpreted as indicating that oxidized, and thus mobile, U was locally reduced and hence accumulated in the sediment. Additionally, local enrichment of Re and Mo, two other redox sensitive elements, in 2.5 Ga sediments suggests local oxygen oases at this time (Anbar et al., 2007).

The suggestion that local oxygen oases existed prior to the widespread oxygenation of the atmosphere is consistent with evidence that oxygenic photosynthesis may have evolved very early in Earth's history (Fig. 1; see also Rasmussen et al., 2008). Fossils resembling cyanobacteria have been documented in ca. 3.5 Ga cherts (Schopf, 1993), and 3.2 Ga organic-rich, but pyrite-poor, sediments are difficult to explain unless oxygenic photosynthesis had evolved by this time (Buick, 2008). Likewise, C-isotope evidence for organisms using RuBisCO-1 (the enzyme that catalyzes CO_2 fixation during oxygenic photosynthesis), alongside other geochemical evidence, suggests that oxygenic photosynthesis had evolved by 2.9 Ga (Nisbet et al., 2007).

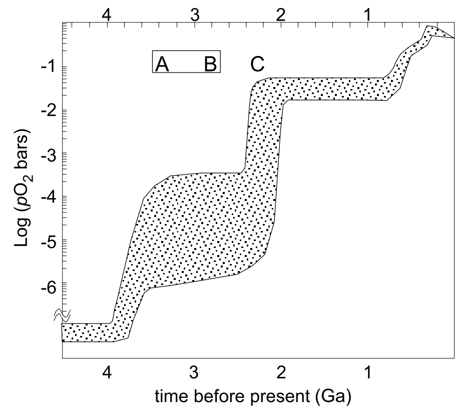

Figure 1. Estimated evolution of atmospheric oxygen content over Earth's history (e.g., Rye and Holland, 1998; Catling and Claire, 2005; Canfield, 2005; Holland, 2006). The likely timing of the evolution of oxygenic photosynthesis, indicated by bar A (Schopf, 1993) to B (Brocks et al., 1999) significantly precedes the large increase in atmospheric oxygen indicated by the end of mass-independent S-isotope fractionation (C; Domagal-Goldman et al., 2008). During this time, local oxygen oases may have existed.

The existence of oxygen oases prior to widespread oxygenation of the atmosphere is consistent with ideas about the evolutionary transition from anoxygenic to oxygenic photosynthesis, which is apparently paradoxical as it requires an already somewhat oxidizing environment. Oxidizing environmental conditions are necessary to select for the biochemical machinery capable of extracting electrons from water and to develop the cellular defenses to cope with acute oxygen toxicity (McKay and Hartman, 1991; Blankenship and Hartman, 1998). A model for the evolution of oxygenic photosynthesis that can address this paradox involves an origin in isolated marine

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basins or terrestrial lakes where H_2O_2, produced photolytically in the Archean atmosphere (Kasting et al., 1985), could act as an oxidant (McKay and Hartman, 1991). H_2O_2 rained out of the atmosphere would have oxidized the common anoxygenic electron donors (Fe^{2+} and H_2S) in the photic zone. Decreasing availability of these electron donors would increase the selection pressure to use H_2O as a reductant. The presence of H_2O_2 in surface waters facilitates the production of more aggressive free radicals like OH· through the Fenton and similar reactions (for example):

$$Fe^{2+} + H_2O_2 \Leftrightarrow Fe^{3+} + OH\cdot + OH^- \qquad (1).$$

The presence of such reactive oxygen species requires that ancient phototrophs adapted biochemical strategies to cope with oxidative stress even before the first molecule of biologically produced O_2 was released into the environment. This model of H_2O_2 induced oxidative stress prior to the emergence of oxygenic photosynthesis provides the selective pressure to extract electrons from water and equips the predecessors of oxygenic photoautotrophs with the cellular machinery to cope with reactive free O_2 (Blankenship and Hartman, 1998). If correct, biological O_2 production first took hold in isolated marine and freshwater environments and must have established oxidizing microenvironments bounded by strong local reduction-oxidation gradients.

DELAYED OXYGENATION OF THE ATMOSPHERE

Evidence for the evolution of oxygenic photosynthesis and the existence of oxygen oases prior to global oxygenation of the atmosphere ca. 2.4 Ga raises the question of what delayed the proliferation of oxygenic photoautotrophs and oxygenation of the atmosphere. Numerous models have been proposed. One class of model suggests that the sinks for photosynthetically produced oxygen decreased ca. 2.4 Ga. This requires that the rate of volcanic and/or metamorphic release of reduced gases, and/or the oxidation state of these gases, changed at this time (Kasting et al., 1993; Kump et al., 2001; Holland, 2002; Kump and Barley, 2007). However, there is little evidence for a change in the oxidation state of Earth's mantle over geological time (Canil, 1997; Li and Lee, 2004), and the evidence for changing rates of volcanism is ambiguous.

A second model suggests that if the Archean atmosphere had been methane-rich, significant H could have been lost into space, leading to irreversible oxidation of Earth's surface (Catling et al., 2001). There is uncertainty over whether the Archean atmosphere was methane-rich (e.g., it is unclear how, under a CH_4-rich atmosphere, local oxidative environments could have existed as is apparently required to provide the selection pressure allowing oxygenic photoautotrophs to evolve). Additionally, hydrogen loss depends on the temperature at the exobase, the height in the atmosphere above which there are the negligible collisions between molecules and escape into space is possible, and it is currently unclear whether this temperature was high enough in the Archean to allow H-escape rates much greater than modern values (Tian et al., 2005).

A further set of models suggests that Earth's atmosphere may have two stable states—oxygen-poor and oxygen-rich. This may be because of nonlinear changes in the lifetime of oxygen in the atmosphere as oxygen and, hence, ozone concentrations increase and provide a shield from ultraviolet radiation (Goldblatt et al., 2006). Alternatively, low O_2 and CO_2 concentrations may be stable in a CH_4-rich atmosphere and vice versa. In this scenario, increased atmospheric O_2 levels under a CH_4-rich atmosphere would have been inhibited by low CO_2 levels limiting photosynthetic O_2 production and because reaction of O_2 with CH_4 would decrease the greenhouse effect, potentially inducing glaciation (Nisbet et al., 2007).

Finally, it has been proposed that links between the oxygen and nitrogen cycles were responsible for the delay between evolution of oxygenic photosynthesis and appearance of an oxygen-rich atmosphere (Falkowski and Godfrey, 2008). In this model, oxygen production by early oxygenic photoautotrophs led to oxidation of oceanic ammonium to nitrate followed by denitrification of the oceans. Because fixed nitrogen is an essential nutrient, a decrease in its availability in the oceans would have acted as a negative feedback on the production of oxygen.

Based on consideration of the geological setting where oxygenic photosynthesis likely emerged, we suggest an additional factor that would have had a negative impact on the local environment of the earliest photoautotrophs. Natural fission reactors may have formed at the margins of local oxygen oases, as illustrated in Figure 2 and explored next.

THE GEOLOGICAL SETTING OF EARLY OXYGEN OASES AND URANIUM MOBILITY

Under an anoxic Hadean and Archean atmosphere, uraninite (UO_2) weathered out of igneous and metamorphic parent rocks was relatively insoluble and was transported to depocenters. Due to its much greater density (~10 gcc^{-1}) than average sedimentary detritus, uraninite will have tended to be hydrodynamically separated from silicate minerals during transport and deposition; this is the proposed origin of many Archean U deposits. Archean placer uraninite deposits can be highly concentrated, locally containing 0.5 wt% uraninite, or they can be of lower grade but extremely widespread, extending many kilometers laterally (Kimberley, 1978; Theis, 1978). Very early in Earth's history (~4.3 Gyr ago) the concentration of ^{235}U may have been high enough for these detrital uraninite deposits to go critical, forming natural fission reactors (Adam, 2007). It is unlikely however that detrital uraninite deposits were sufficiently concentrated for natural reactors to form this way within the mid- or late-Archean, largely due to the secular decrease in the activity of ^{235}U.

Because of the insolubility of uraninite during transport in the Archean, the clastic sediments surrounding the isolated basins in which oxygenic photosynthesis evolved must have contained uraninite either dispersed within the sediments or locally concentrated with other heavy minerals in placer deposits. Photosynthetically produced oxygen would lead to local oxygenation of surface waters. Uraninite becomes highly soluble in the presence of trace oxygen partial pressures (Fig. 3) meaning that uraninite dissolution would occur, thus mobilizing U from the sediments into solution. The rate of uraninite dissolution depends on the pH, bicarbonate, and oxygen concentration of the solution (Ono, 2001). The lifetime ($t_{lifetime}$) of a spherical uraninite grain can be determined from (Lasaga, 1998):

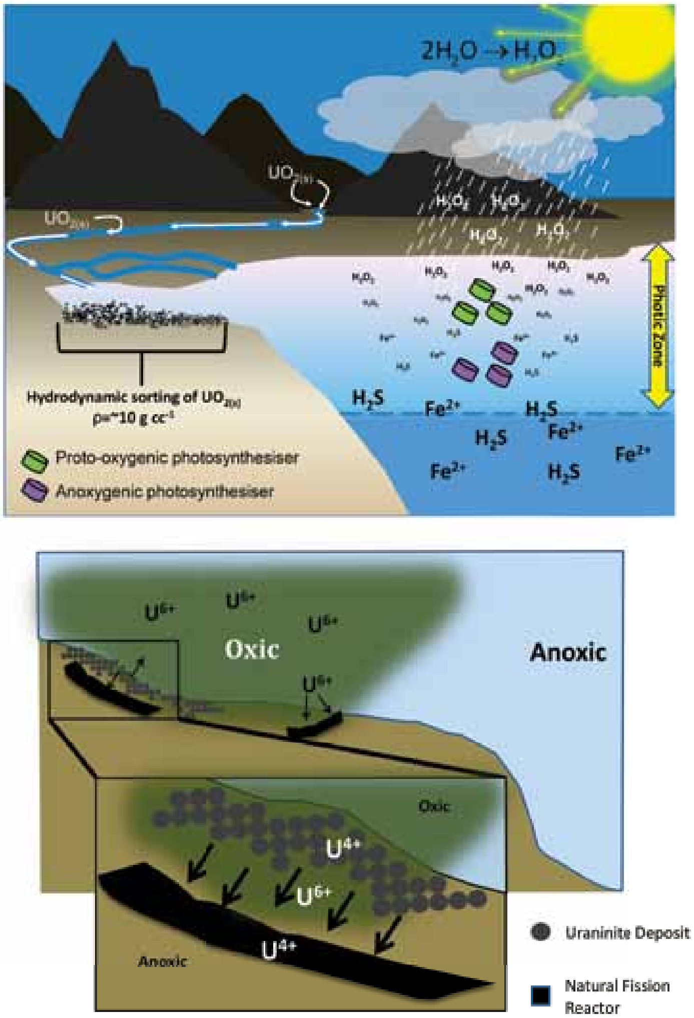

Figure 2. Cartoon showing a possible mechanism by which oxygenic photosynthesis could lead to formation of natural fission reactors. Uraninite weathered out of igneous and metamorphic rocks is transported to isolated basins and deposited in shallow water environments, providing a ready source of U as soon as the waters become oxidizing. Photolytically produced H_2O_2 rains out of the atmosphere and oxidizes the uppermost water column, reducing the concentration of electron donors required by anoxygenic photosynthesizers such as H_2S and Fe^{2+}. This provides the selective pressure required for the emergence of oxygenic photosynthesis due to the abundance of H_2O as an alternative electron donor. Once oxygenic photosynthesis evolves, this produces local enrichment in oxygen in the surface water. This would mobilize uranium into solution (see Figs. 3 and 4), which would be redeposited at the margins of the oxygen oasis. These uranium deposits would have the potential to form natural reactors due to the high concentration of ^{235}U in the Archean.

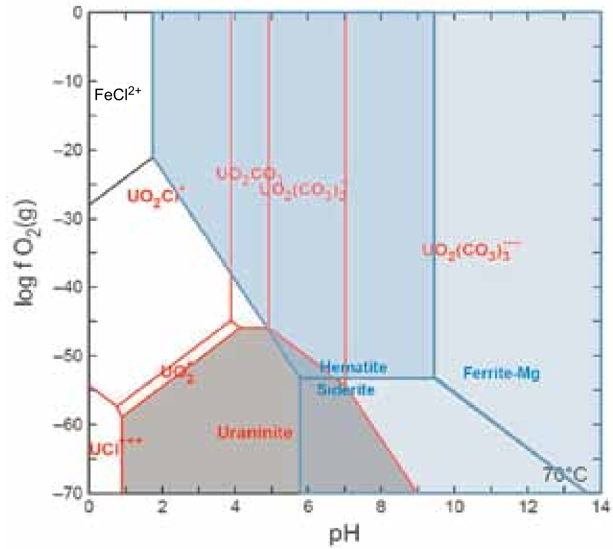

Figure 3. The stability fields of different U-species (red lines), shown as a function of pH and fO_2 calculated assuming T = 70 °C, fCO_2 = 5 atm, and modern seawater concentrations for the major ions. In modeling this phase diagram, uranium activity of 10 nmol/L and Fe activity of 50 μmol/L were used to reflect increased Fe solubility in the anoxic Archean ocean. The stability fields of Fe-species is overlain (separated by blue lines), with the stability fields of the minerals hematite, siderite, and Mg-ferrite shaded in blue. Note the predicted mobility of U with increasing fO_2 while Fe, a potential neutron absorber, remains in the solid phase for pH >5.8.

$$t_{\text{lifetime}} = \frac{r}{V\lambda R} \quad (2),$$

where r = grain radius, λ = surface roughness (assumed = 10), V = molar volume (uraninite = 27 $cm^3 mol^{-1}$), and R is the dissolution rate (mol m^{-2} sec^{-1}) determined experimentally as a function of pH, bicarbonate, and pO_2 (Ono, 2001).

$$R = (10^{-9.2}[H^+]^{0.39} + 10^{-10.2}[HCO_3^-]^{0.43})pO_2^{\,n} \quad (3),$$

where the proton and bicarbonate concentrations are in mol L^{-1} and pO_2 is relative to present atmospheric level (PAL). The order of the reaction with respect to oxygen (n) is uncertain (between 0 and 1), but the experimental study by Ono (2001) suggests an order of n = 0.27. Figure 4 shows that an idealized 200-μm-diameter uraninite grain would completely dissolve in <10 ka at local partial pressures of O_2 ~2% of PAL irrespective of atmospheric CO_2 concentrations (i.e., uraninite dissolution is expected to have been rapid in the surface water of oxygen oases).

Fluid flow out of the oxygen oases would act to trap the mobilized U at the limits of the oxygenated zone due to the insolubility of U^{4+}, potentially generating significant U accumulations. This mechanism of uranium concentration through the reduction of U^{6+} to U^{4+} at redox boundaries is the principal way high-grade Proterozoic and Phanerozoic U deposits formed, demonstrating the efficiency of this process in concentrating U. The dissolution of detrital uraninite, and its subsequent reprecipitation upon reduction, will have purified the uraninite, removing elements that act as potent neutron poisons (e.g., rare earth elements [REEs]) within a natural reactor.

NATURAL REACTORS—GEOLOGICAL INSIGHTS FROM OKLO AND BANGOMBÉ

In the Archean, the abundance of the fissile ^{235}U isotope was much higher than today and thus relatively small uranium deposits could potentially have gone critical (Fig. 5). The potential for U deposits to have formed natural reactors early in Earth's history was recognized by Kuroda back in 1956. Thirty years after Enrico Fermi built a critical fission reactor in a squash court in Chicago, it was discovered that nature had achieved this phenomenon ~2 Ga earlier. This realization came from the observation that uranium deposits at Oklo and Ban-

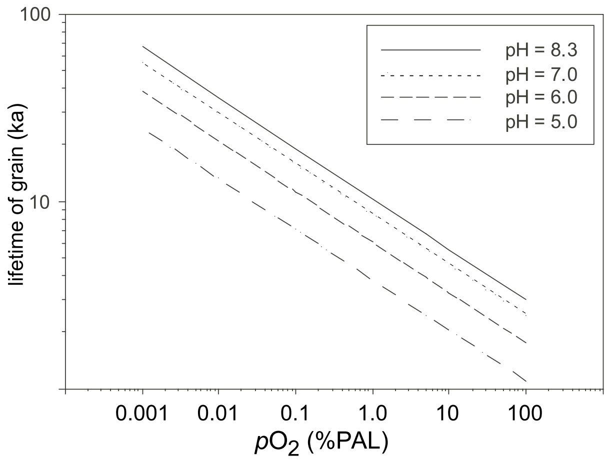

Figure 4. Lifetime of a spherical uraninite grain (200 µm diameter) for different partial pressures of oxygen relative to present atmospheric oxygen (PAL) for various solution pH. Calculated according to Ono (2001) with ALK = 1.3 mM and an oxygen dependence of $n = 0.27$; pCO_2 is 1 times PAL for pH = 8.3 and roughly 2200 times PAL for pH = 5.0.

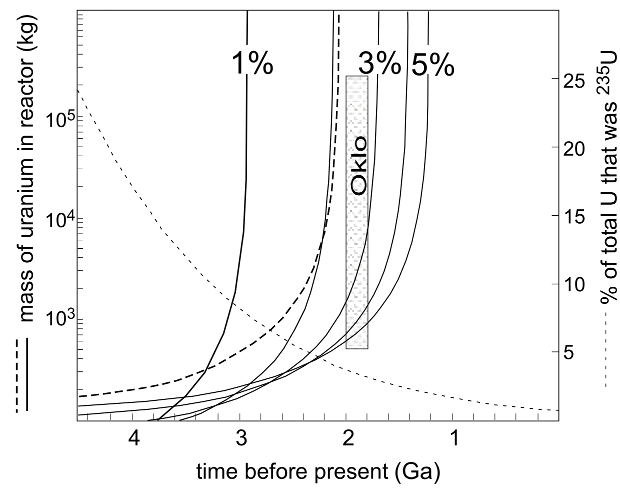

Figure 5. The critical mass of uranium needed to produce a natural fission reactor has changed over Earth's history because the proportion of uranium that is fissile ^{235}U has decreased dramatically. This is shown by the right-hand axis, and exponentially decaying thin dashed line, that illustrate the relative proportion of U that was fissogenic ^{235}U as a function of time. The mass of U required for a natural reactor to go critical is shown as a function of age for different concentrations of uraninite in the reactor core (1–5 modal percentage shown with solid lines) assuming a reactor comprised of quartz, uraninite, and water. The thick dashed line shows the increase in the mass of U required at any given time due to adding 10% ilmenite to the most uraninite-rich reactor core (5%) because the Fe and Ti act as neutron poisons. Although the exact mass of uranium required for a natural fission reactor depends on poorly constrained compositional and geometric factors, it is clear that the mass of uranium required during much of the Archean was very small (<1000 kg, or ~0.1 m^3) and then increased nearly exponentially as the abundance of ^{235}U decreased at some time around the Archean-Proterozoic boundary. Comparison of the calculated mass of uranium required with the mass observed in the Oklo reactors provides some ground-truth to the models. Input parameters for the calculations were $\varepsilon = 1.004$ following Adam (2007) (the exact value plays a secondary role in the calculations); for r, we used the relationship between uranium concentration and resonance escape probability derived by Adam (2007; his Fig. 2); see text for further details.

gombé, separated by ~30 km but both within the Franceville intracratonic basin in Gabon, are depleted in ^{235}U relative to ^{238}U and enriched in numerous isotopes produced by fission reactions (e.g., Gauthier-Lafaye et al., 1996; Hidaka et al., 1999).

These uranium deposits, seventeen of which have been shown to have acted as natural fission reactors, are hosted in relatively unmetamorphosed fluviatile and deltaic sequences of conglomerates and sandstones, some of which were deposited in tidally influenced environments ca. 2150 Ga (Gauthier-Lafeye and Weber, 2003). Some of the conglomerates contain relatively high concentrations of U (and Th) in detrital phases. This suggests that concentrations of heavy minerals, potentially including uraninite, in these units may have been the source of uranium for the natural reactors (Gauthier-Lafeye and Weber, 2003). Uranium was mobilized from these conglomerates by post-deposition oxidized basinal fluids and subsequently reduced, and hence deposited, upon interaction with organic-rich reduced fluids in structurally controlled "traps" (Gauthier-Lafeye and Weber, 2003).

The cores of the natural reactors vary in size: One of the largest and best studied is 12 m × 18 m × 0.2–0.5 m ("reactor 2"); a smaller reactor at Bangombé is 5 m × 1 m × a few centimeters (Gauthier-Lafeye and Weber, 2003). The cores of the reactors currently have high uranium concentrations (20%–60%), but self-sustaining fission is thought to have initiated when the uranium concentration reached ~10%, and subsequent uranium concentration occurred through the dissolution and removal of quartz in hydrothermal fluids driven by the heat from the fission reactions (Gauthier-Lafeye and Weber, 2003).

The lifetime and energy budget of the Oklo reactors have been estimated in a number of ways. Isotopic and modeling studies suggest that the reactors operated for 2×10^4 to 2×10^5 years (Hidaka and Holliger, 1998) and produced ~5×10^{17} J (Gauthier-Lafeye et al., 1996; Petrov et al., 2006). This is equivalent to a steady-state power output of ~100 kW, although it is unlikely heat output was steady. Instead, high energy production likely led to the pore water, which acted as a moderator slowing neutrons, being driven out of the system, thereby shutting down the reactors until they cooled and water could replenish the pores (Meshik et al., 2004). As well as producing energy and fissogenic isotopes, many with short half-lives, radiolysis produced O_2, H_2, and H_2O_2, which are all observed in fluid inclusions within the rocks surrounding the reactor cores (Mathieu et al., 2001; Gauthier-Lafeye and Weber, 2003). The exact reasons the reactors stopped operating are unknown, but it is known that fissogenic light rare earth elements (LREEs), which act as neutron poisons, were retained in uraninite, which must have had a negative effect on fission reactions (Gauthier-Lafaye et al., 1996).

The preservation, and near surface exposure, of any natural reactors is remarkable and suggests that this was not an isolated incident. Archean uranium deposits formed near the surface would have a low preservation potential in the rock record. This is illustrated by the age distribution of epithermal Ag-Au deposits. These have an average formation depth of ~0.5 km and a modal age of only 3 Ma (Wilkinson and Kesler, 2007). Modeling their age distribution suggests that <1% of all mineral deposits formed at this depth over the Phanerozoic are exposed at the surface today (Wilkinson and Kesler, 2007). Considering the smaller portion of Earth's surface covered with Archean and early Proterozoic rocks, and the much greater time since formation for erosion to destroy the deposits, the preservation of the remains of any near-surface natural fission reactor suggests that these might have been relatively common in the late Archean and early Proterozoic.

NATURAL REACTORS—THEORETICAL CONSIDERATIONS

A critical fission reactor requires that the number of fission-inducing neutrons emitted per fission is ≥1. The mass of uranium (^{235}U and ^{238}U combined, ignoring minor isotopes) required for a natural critical fission reactor has changed over Earth's history as the amount of fissile ^{235}U has decreased dramatically (^{235}U has a half-life of ~707 Ma vs. ~4470 Ma for ^{238}U; Fig. 5). The mass of uranium required for criticality can be calculated given estimates of the shape and composition of uranium deposits, but to extrapolate back through geological time, the changing abundances of ^{235}U and ^{238}U due to radioactive decay (to form Pb) must be accounted for. We followed the general approach described by Adam (2007) and the DOE "nuclear physics and reactor theory" handbook (1993), an approach that goes back to Fermi (1947), to determine the mass of uranium required to form a natural reactor. Because neither the composition nor shape of possible deposits are known, we emphasize the relative change in mass of uranium required over time rather than the absolute mass of uranium required at any given time.

Assuming a lens-like uranium deposit, we modeled the reactor as a cylinder. For this geometry, the number of fission-inducing neutrons released per fission (*k*) can be determined from the so-called four-factor equation (numerator in Eq. 4) corrected for leakage of neutrons from the margins of the cylinder (denominator in Eq. 4). The first two factors in the numerator of Equation 4 give the efficiency with which neutrons are thermalized (slowed), and the latter two terms reflect the efficiency of thermal neutron absorption in inducing further fission within the reactor:

$$k = \frac{\varepsilon \rho f \eta}{1 + B^2 M^2} \quad (4)$$

and

$$B^2 = \left(\frac{2.405}{R}\right)^2 + \left(\frac{\pi}{H}\right)^2 \quad (5),$$

where ε = the ratio of the total number of induced fissions to the number of fissions induced by thermal (i.e., slow) neutrons (~1 for an efficient reactor moderator); ρ = the probability of a fast neutron not being absorbed by a ^{238}U nucleus prior to thermalization (i.e., during slowing); *f* = the ratio of the number of thermal neutrons absorbed by uranium to the number of thermal neutrons absorbed within the reactor, which depends on the bulk composition; η = the ratio of the number of fast neutrons produced by fission to the number of thermal neutrons absorbed by uranium; *B* = geometrical term dependent on reactor shape—here a cylinder of height (*H*) and radius (*R*); *M* = neutron migration length. Further details are given in Adam (2007) and DOE (1993).

Figure 5 shows that the mass of U required to produce a natural reactor during much of the Archean was small (<1000 kg, or ~0.1 m^3) and then increased nearly exponentially as the abundance of ^{235}U decreased at some time around the Archean-Proterozoic boundary. The small masses of uranium needed to form a natural fission reaction during the Archean supports the suggestion that they were fairly widespread. The greatest uncertainty in calculating the mass of uranium required to form a natural reactor back through time comes from the lack of constraint on the bulk composition of uranium deposits over geological time (both mineralogy and water content). In computing the curves shown in Figure 5, we assumed a very simple system composed of quartz + water + uraninite ± ilmenite. High concentrations of neutron poisons, such as would be the case for a system containing B- and REE-rich minerals, would require more uranium for a given age. This is illustrated with the example containing 10% ilmenite (both Fe and Ti have neutron absorption cross sections approximately an order of magnitude greater than the other major elements in Earth's crust [Si, Al, Ca, Mg] but still orders of magnitude smaller than poisons such as B).

WERE NATURAL FISSION REACTORS IMPORTANT FOR THE EARTH SYSTEM?

The preceding discussion suggests that natural fission reactors may have been common at the margins of the oxygen oases produced by early oxygenic photoautotrophs. During this time, uraninite occurred as a detrital phase, providing a ready source of U to surface waters as soon as they became oxidized. A key question is whether the natural reactors would have negatively impacted the proliferation of these photoautotrophs, potentially helping to explain the delayed oxygenation of Earth's atmosphere (Fig. 1).

Natural reactors act as point sources of heat, ionizing radiation, short- and long-lived radioactive daughter isotopes, and toxic byproducts. Reactors can thus have near- and far-field negative effects on oxygenic photosynthesizers through desiccation, thermal sterilization, ionizing radiation, and toxicity. Temperature reconstructions of the Archean suggest that early oxygenic photosynthetic organisms were likely living near, or at, their maximum allowable temperature (Lowe and Tice, 2007; Gaucher et al., 2008). Natural reactors in near-surface sediments in shallow water would act to raise local water temperatures. However, given that critical natural reactors were likely moderated principally by water, their power output is limited by the temperature and pressure of near-surface water bodies and would have had typical power outputs in the kilowatt range (Draganic et al., 1983), which is insignificant on the scale of a lake or isolated marine system. Ionizing radiation doses in the krad h^{-1} (~10s Gy h^{-1}) range, significantly higher than natural background levels of ~5×10^{-7} Gy h^{-1}, would be produced in the core of small natural reactors. The co-location of reactors with oxygen oases would increase the rates of radiogenic DNA damage to early oxygenic photoautotrophs through the strong modifying influence of molecular oxygen on free radical production (Karam and Leslie, 1999; Karam et al., 2001). While direct radiation from the core would be rapidly absorbed with distance, part of this energy would generate potent free-radicals in local oxygenated waters. Perhaps the most significant feedback on early oxygenic photoautotrophs would be migration of short- and long-lived fissiogenic radionuclides from reactor cores to the environment. For a reactor operating at 1 kW over 10^5–10^6 years, ~14% of product radionuclides have half-lives greater than a year (Draganic et al., 1983). Among these product atoms are elements that would likely be fixed into local inorganic substrates or ultimately incorporated into organic matter (e.g., ^{90}Sr, ^{137}Cs, ^{135}Cs, and ^{129}I) where they would serve as specific radiation sources for centuries to millions of years. While the absolute dose rates might have been low owing to dilution, the total amount of energy liberated in the aquatic environment would be significant and potentially concentrated in biological targets.

Natural fission reactors would clearly be environmentally detrimental. That said, the abundance of uraninite in sediments surrounding oxygen oases cannot have been high enough for natural fission reactors to provide a globally distributed negative feedback on early oxygenic photosynthesic organisms (i.e., at first sight it seems logical that oxygenic photoautotrophs would simply proliferate distal to the natural reactors). This may have been the case. However, there are two plausible scenarios in which natural reactors might have provided a significant negative feedback on the proliferation of oxygenic photoautotrophs: (1) if oxygenic photoautotrophs could only survive under unusual conditions; or (2) if oxygenic photosynthesis evolved in response to environment changes caused by substantial detrital uraninite accumulations.

If the first oxygenic photoautotrophs evolved in unusual environments, they might have been unable to survive away from these specialized environments and hence unable to migrate away if natural fission reactors formed. For example, the availability of fixed nitrogen in the Archean was intimately tied to the biological reduction of N_2 by the nitrogenase enzyme. Biological N_2-fixation has a high energy requirement (~16 ATPs per N atom), which is met by coupling the process to the oxidation of organic matter to supply chemical energy (Falkowski and Godfrey, 2008). In Archean oxygen oases, an increased supply of organic matter due to the efficiency of oxygenic photosynthesis and the increased energy yield of aerobic respiration likely elevated local rates of nitrogen fixation and relaxed nitrogen limitation of primary production. Increased nutrient availability in the vicinity of natural reactors may have tied early oxygenic photosynthesizers to these environments despite the potential for increased rates of DNA mutagenesis. The second scenario assumes that the oxidizing microenvironments required to provide the selective pressure for oxygenic photoautotrophs to evolve was produced by close proximity to significant detrital accumulations. Radiolysis of water could occur due to non-critical ^{235}U fission in detrital uraninite deposits producing oxidants. If local oxidation of the surface environment in this way provided the selective pressure for the evolution of oxygenic photoautotrophs, then, by necessity, there was abundant uraninite available in these locations and critical fission reactors could readily have formed. In either of these scenarios, it is possible, although not certain, that natural reactors could have provided a (additional) negative feedback to suppress the proliferation of the earliest photoautotrophs and delay the oxidation of Earth's surface.

The formation of natural reactors during the late Archean in response to the formation of local oxygen oases is expected based simply on the high abundance of ^{235}U at this time and the redox sensitivity of U solubility. We conclude by noting that irrespective of whether the formation of these natural reactors had any significant biocidal impacts, the geological, geochemical, and biological impacts of natural reactors during this time period deserve further investigation. Because near-surface natural reactors will generally have been eroded away rapidly after formation, searching for them in the geological record is unlikely to prove fruitful. The hypothesis that natural reactors were common in the Archean can be tested, however, by determining the concentration of stable fissogenic nuclides in Archean sediments (or ^{235}U depletion), although this will require very high precision measurements. The impact of near-surface natural reactors on the Archean biosphere is more difficult to determine. Investigation of the evolution of radiation tolerance in some bacteria (e.g., *Deinococcus radiodurans* and members of the cyanobacteria), for which there is no other obvious terrestrial selective pressure (Sghaier et al., 2007), may prove fruitful.

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THE GEOLOGICAL SOCIETY OF AMERICA®

2010 GSA Medals and Awards

Penrose Medal

The Penrose Medal, established in 1927 by R.A.F. Penrose Jr., recognizes eminent research in pure geology, outstanding original contributions, and/or achievements that mark a major advance in geological science. Penrose's sole objective was to encourage original work in purely scientific geology, which applies to all scientific disciplines represented by GSA. The medal is awarded at the discretion of GSA Council, and nominees may or may not be Society members. Scientific achievements should be the sole consideration, rather than service or contributions to teaching and administration. Mid-career scientists who have already made exceptional contributions should be given full consideration.

Day Medal

The Day Medal was established in 1948 by Arthur L. Day to be awarded annually, or less frequently, at the discretion of GSA Council, to recognize outstanding distinction in the application of physics and chemistry to the solution of geologic problems. Day's intent was to recognize outstanding achievement in contributions to geologic knowledge and inspire further effort rather than to reward a distinguished career. Scientific achievements should be the sole consideration, rather than service or contributions to teaching and administration.

Young Scientist Award (Donath Medal)

The Young Scientist Award was established in 1988 to recognize a scientist 35 years or younger *throughout* the year in which the award is to be presented (for 2010, *only* those candidates born **on or after 1 Jan. 1975** are eligible) for outstanding achievement in contributions to geologic knowledge through original research that marks a major advance in the earth sciences. The award consists of a gold medal (the Donath Medal) and an honorarium.

How to Nominate

To ensure thorough consideration by the respective committees, please follow these nomination instructions carefully; additional information supplied will not enhance the nomination.

1. **Nomination form:** Go to https://rock.geosociety.org/forms/Awardform.asp to submit the form online or to download a hardcopy.
2. **Supporting documents** for the Penrose, Day, and Young Scientist Medals, to be submitted as e-mail attachments or via post:
   - a curriculum vitae;
   - a brief summary (300 words or less) of the scientific contributions to geology that qualify the candidate for the award;
   - a selected bibliography of no more than 20 titles (for the Donath medal only 10 titles are required); and
   - letters from each of five GSA Fellows or members *in addition* to one from the nominator; for the Day Medal only: letters from five scientists with *at least three* from GSA Fellows or members and two from fellows or members of the Mineralogical Society of America, the Geochemical Society, or the American Geophysical Union.

Award Notes

Candidates whose names are submitted by the respective award committees to GSA Council but who do not receive an award will remain under consideration by those committees for three years. It is recommended that an updated nomination letter be sent to GSA for those still under consideration.

Nomination forms and submission instructions are online at **www.geosociety.org/awards/.** Paper submissions will still be accepted; however, we encourage electronic submission. Contact GSA Grants, Awards, and Recognition, P.O. Box 9140, 3300 Penrose Place, Boulder, CO 80301-9140, USA, +1-303-357-1028, awards@geosociety.org, for more information.

The deadline for receipt of all GSA medal, award, and recognition nominations is 1 February 2010.

2010 GSA Medals and Awards

GSA Public Service Award

GSA Council established the GSA Public Service Award in 1998 in honor of Eugene and Carolyn Shoemaker. This annual award recognizes contributions that have materially enhanced the public's understanding of the earth sciences or have significantly served decision makers in the application of scientific and technical information to public affairs and earth science–related public policy. This may be accomplished by individual achievement in

- authorship of education materials of high scientific quality that have enjoyed widespread use and acclaim among educators or the general public;
- acclaimed presentations (books and other publications, mass and electronic media, or public presentations, including lectures) that have expanded public awareness of the earth sciences;
- authorship of technical publications that have significantly advanced scientific concepts or techniques applicable to the resolution of earth-resource or environmental issues of public concern; and/or
- other individual accomplishments that have advanced the earth sciences in the public interest.

This award normally goes to a GSA member, with exceptions approved by Council, and may be presented posthumously to a descendant of the awardee.

How to Nominate

1. **Nomination form:** Go to https://rock.geosociety.org/forms/Awardform.asp to submit the form online or to download a hardcopy.
2. **Supporting documents,** to be submitted as e-mail attachments or via post:
   - a curriculum vitae;
   - a brief letter of nomination (300 words or less);
   - a brief biographical sketch that clearly demonstrates the applicability of the selection criteria; and
   - a selected bibliography of no more than 10 titles.

Nominations due 1 February 2010

The Bromery Award for the Minorities

Randolph W. (Bill) and Cecile T. Bromery established this award to recognize a member of any minority group, but preferably an African American, who has made (1) significant contributions to research in the geological sciences, and/or (2) has been instrumental in opening the field of geoscience to other minorities.

1. **Research contributions:**
   - publications that have had a measurable impact on the geosciences;
   - outstanding original contributions or achievements that mark a major advance in the geosciences; and/or
   - an outstanding lifetime career that demonstrates leadership in geoscience research.
2. **Opening geoscience to other minorities:**
   - demonstrable contributions in teaching or mentoring that have enhanced the professional growth of minority geoscientists;
   - outstanding lifetime career service in a role that has highlighted the contributions of minorities in advancing the geosciences; and/or
   - authorship of educational materials of high scientific quality that have enjoyed widespread use and acclaim among educators or the general public.

How to Nominate

1. **Nomination form:** Go to www.geosociety.org/awards/nominations-Bromery.htm to submit the form online or to download a hardcopy.
2. **Supporting documents,** to be submitted as e-mail attachments or via post:
   - a curriculum vitae;
   - a brief letter of nomination (300 words or less);
   - letters from three scientists with at least two of those from GSA Fellows or members and one from a member of another professional geoscience organization; and
   - (optional) a selected bibliography of no more than 10 titles.

The deadline for receipt of all GSA medal, award, and recognition nominations is 1 February 2010.

2010 GSA Medals and Awards

GSA Distinguished Service Award

GSA Council established the GSA Distinguished Service Award in 1988 to recognize individuals for their exceptional service to the Society. GSA members and employees may be nominated, and any GSA member or employee may submit a nomination. GSA's Executive Committee will select awardees, and GSA Council must ratify all selections. Awards may be made annually, or less frequently, at the discretion of Council.

How to Nominate

1. **Nomination form:** Go to https://rock.geosociety.org/forms/Awardform.asp to submit the form online or to download a hardcopy.
2. **Supporting documents,** to be submitted as e-mail attachments or via post:
   - a curriculum vitae;
   - a brief letter of nomination (300 words or less);
   - a brief biographical sketch that clearly demonstrates the applicability of the selection criteria;
   - (optional) a selected bibliography of no more than 10 titles.

Subaru Outstanding Woman in Science Award

Sponsored by Subaru of America, Inc.

The Subaru Outstanding Woman in Science Award recognizes a woman who has had a major impact on the geosciences based on her Ph.D. research. Women are eligible for this award for the first *three years* following receipt of their Ph.D. The generous support of Subaru of America, Inc., in conjunction with the Doris M. Curtis Fund, makes this award possible.

How to Nominate

1. **Nomination form:** Go to https://rock.geosociety.org/forms/Awardform.asp to submit the form online or to download a hardcopy.
2. **Supporting documents,** to be submitted as e-mail attachments or via post:
   - a curriculum vitae;
   - a letter of nomination that clearly states how the Ph.D. research has impacted the geosciences in a major way;
   - a selected bibliography of no more than 10 titles; and
   - dissertation title and abstract.

GSA Fellowship

Fellowship is an honor bestowed upon the best of our profession at each spring GSA Council meeting. If you are a GSA Fellow, please review the following for updated instructions: GSA Fellows may support only *two* nominees per election cycle and only one as a primary nominator. GSA members who are not Fellows may not be primary nominators, but may be secondary nominators for no more than two nominees per election cycle.

The primary nominator (GSA Fellow) is responsible for collecting the entire nomination packet (including letters of support) and must submit the nomination as one e-mail (with supporting documents as attachments) or as one package via post.

How to Nominate

1. **Nomination form:** Go to www.geosociety.org/members/fellow.htm to submit the form online or to download a hardcopy.
2. **Supporting documents:**
   - a letter of nomination, including a summary of the nominee's significant contributions (up to one page);
   - the nominee's curriculum vitae;
   - a selected bibliography of the nominee's publications (up to four pages) and a paragraph stating the total number of publications (only if pertinent to the selected criteria); and
   - a supporting letter of nomination from each of the secondary nominators.

AGI Medal in Memory of Ian Campbell

The AGI Medal in Memory of Ian Campbell recognizes singular performance in and contribution to the profession of geology. Candidates are measured against the distinguished career of Ian Campbell, whose service to the profession touched virtually every facet of the geosciences. Campbell was a most uncommon man of remarkable accomplishment and widespread influence, and in his career as a geologist, educator, administrator, and public servant, he was noted for his candor and integrity. To submit a nomination, go to www.agiweb.org/direct/awards.html.

The deadline for receipt of all GSA medal, award, and recognition nominations is 1 February 2010.

Call for Nominations

John C. Frye Environmental Geology Award

Nomination deadline: 31 March 2010

In cooperation with the Association of American State Geologists (AASG), GSA makes an annual award for the best paper on environmental geology published either by GSA or by a state geological survey.

Nomination Criteria

Anyone may submit a nomination, using the following criteria: (1) the paper must be from a GSA or state geological survey publication, (2) the paper must have been published during the preceding three full calendar years, and (3) the nomination must include a paragraph stating the pertinence of the paper. Please send your nominations to Grants, Awards, and Recognition, GSA, P.O. Box 9140, Boulder, CO 80301-9140, USA.

Basis for Selection

Nominated papers must establish an environmental problem or need, provide substantive information on the basic geology or geologic process pertinent to the problem, relate the geology to the problem or need, suggest solutions or provide appropriate land use recommendations based on the geology, present the information in a manner that is understandable and directly usable by geologists, and address the environmental need or resolve the problem. It is preferred that the paper be directly applicable to informed laypersons (e.g., planners, engineers). Each nominated paper will be judged on its uniqueness or significance as a model of its type of work or report and its overall worthiness for the award.

2009 Award Recipients

The 2009 award will be presented at the GSA Annual Meeting in Portland to Jonathan L. White and Celia Greenman for *Geological Survey Engineering Geology 14*, "Collapsible Soils in Colorado," published in 2008 by the Colorado Geological Survey.

2010 National Awards

Nomination deadline: 1 February 2010

GSA members are encouraged to nominate colleagues for the following national awards:

The annual **William T. Pecora Award,** sponsored jointly by the NASA and the U.S. Department of the Interior, recognizes outstanding contributions by individuals or groups toward understanding Earth by means of remote sensing. The award recognizes contributions of those in the scientific and technical community as well as those involved in the practical application of remote sensing. Consideration will be given to sustained or single contributions of major importance to the art or science of understanding Earth through observations made from space. Learn more at **http://remotesensing.usgs.gov/pecora.php.**

The **National Medal of Science** is awarded by the president of the United States to individuals "deserving of special recognition by reason of their outstanding contributions to knowledge in the physical, biological, mathematical, engineering, or social and behavioral sciences." The award committee is giving increasing attention to younger U.S. scientists and engineers who may now be reaching a point at which their contributions are worthy of recognition, as well as to outstanding women and minority scientists. Learn more at **www.nsf.gov/od/nms/medal.jsp.**

The **Vannevar Bush Award** is presented periodically to a senior statesperson of science and technology who, through public service in science and technology, has made an outstanding contribution toward the welfare of humankind and to the United States. Nominations should be accompanied by a complete biography and a brief citation summarizing the nominee's scientific or technological contributions to our national welfare in promotion of the progress of science. Learn more at **www.nsf.gov/nsb/awards/bush.jsp.**

The **Alan T. Waterman Award** is presented annually by the National Science Foundation (NSF) and National Science Board to an outstanding young researcher in any field of science or engineering supported by the NSF. Candidates must be U.S. citizens *or* permanent residents and must be *35 years of age or younger* OR *not more than five years beyond receipt of a Ph.D.* by 31 December of the year in which they are nominated. Candidates should have completed sufficient scientific or engineering research to have demonstrated, through personal accomplishments, outstanding capability and exceptional promise for significant future achievement. This award complements the Vannevar Bush Award, which recognizes senior statespersons of science and technology; both awards are designed to encourage individuals to seek the highest levels of achievement in science, engineering, and service to humanity. Learn more at **www.nsf.gov/od/waterman/waterman.jsp.**

The **G.K. Warren Prize** is awarded by the National Academy of Sciences for noteworthy and distinguished accomplishment in fluviatile geology and closely related aspects of the geological sciences. Learn more at **www.nasonline.org/site/PageServer?pagename=AWARDS_warren.**

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JOINT MEETING

45th Annual Meeting of the Northeastern Section, GSA
59th Annual Meeting of the Southeastern Section, GSA
Baltimore, Maryland, USA

13–16 March 2010

Baltimore, Maryland, USA. This false-color Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) composite, acquired 4 Apr. 2000, shows vegetation as red, water as blue, and urban areas as grey. Courtesy NASA/Visible Earth, http://visibleearth.nasa.gov/view_rec.php?id=15611.

Linking North and South: Exploring the Connections between Continent and Sea

LOCATION

Baltimore is an historic major port city located on the upper Chesapeake Bay astride the Fall Zone, which separates the low-lying Coastal Plain province to the east from igneous and metamorphic rocks exposed in the Piedmont to the west. This joint meeting will be held at the Sheraton Baltimore City Center Hotel in downtown Baltimore, a few blocks from the Inner Harbor.

CALLF ORP APERS

Abstract deadline: 8 December 2009
Submit online: www.geosociety.org/meetings/
Submission fee: US$10

Contact Eric Nocerino, +1-303-357-1060, enocerino@geosociety.org, if you cannot submit via the online system.

Symposia

1. **It All Starts in the Field: In Honor of Wallace A. Bothner.** Jo Laird, Univ. of New Hampshire, jl@cisunix.unh.edu; Steven Whitmeyer, James Madison Univ., whitmesj@jmu.edu; Stephen Allard, Winona State Univ., sallard@winona.edu.
2. **The New Bedrock Geologic Map of Vermont: New Answers, New Problems, and New Uses of Bedrock Geologic Data.** Nicholas M. Ratcliffe, USGS, nratclif@usgs.gov; Marjie Gale, Vermont Geological Survey, marjorie.gale@state.vt.us; Peter Thompson, Univ. of New Hampshire, pjt3@cisunix.unh.edu.
3. **Asbestos: Past, Present, and Future.** *Cosponsored by GSA's Geology and Health Division.* Catherine Skinner, Yale Univ., catherine.skinner@yale.edu; Mickey Gunter, Univ. of Idaho, mgunter@uidaho.edu.

ThemeS essions

1. **The Iapetan Rifted Margin and Rift History of Eastern Laurentia.** William A. Thomas, Univ. of Kentucky, geowat@uky.edu; Denis Lavoie, Geological Survey of Canada, delavoie@nrcan.gc.ca.
2. **Laurentian-Gondwanan Interactions in the Paleozoic.** Jim Hibbard, North Carolina State Univ., jim_hibbard@ncsu.edu; Cees van Staal, Geological Survey of Canada, Cees.vanStaal@nrcan-rncan.gc.ca; Sandra Barr, Acadia Univ., sandra.barr@acadiau.ca.
3. **Tectonic Significance of Buried Terranes of the Atlantic and Gulf Coastal Plains.** Wright Horton, USGS, whorton@usgs.gov; Paul Mueller, Univ. of Florida, mueller@geology.ufl.edu.
4. **Strike-Slip and Transpressional Tectonics in the Appalachians and Beyond.** Chuck Trupe, Georgia Southern Univ., chtrupe@georgiasouthern.edu; Kevin Stewart, Univ. of North Carolina, kgstewar@email.unc.edu; David West, Middlebury College, dwest@middlebury.edu.
5. **Vorticity and Strain in Shear Zones.** Ryan Thigpen, Virginia Tech, thigpe05@vt.edu; Walter A. (Bill) Sullivan, Colby College, wasulliv@colby.edu.
6. **Geologic Maps, Geophysical Maps, and Derivatives from Geologic and Geophysical Maps (Poster Session).** Michael W. Higgins, Geologic Mapping Institute, mhiggins@mindspring.com; Ralph F. Crawford, Geologic Mapping Institute, crawford@sprintmail.com.
7. **Landscape Evolution in the Appalachians: Rates, Dates, and Models.** Greg Hancock, College of William & Mary, gshanc@wm.edu; Paul Bierman, Univ. of Vermont, Paul.Bierman@uvm.edu.
8. **Recent Advances in Understanding the Geomorphology and Quaternary History of the Appalachian Region and Adjacent Regions.** Todd Grote, Allegheny College, tgrote@allegheny.edu; J. Steven Kite, West Virginia Univ., jkite@wvu.edu.

9. **Evolution of the Atlantic and Gulf Coasts from Rift Margin to Passive Margin.** Amy Weislogel, Univ. of Alabama, aweislogel@geo.ua.edu; Delores Robinson, Univ. of Alabama, dmr@geo.ua.edu.
10. **The Integration of Marine and Non-Marine Subsurface Sediments to the Interpretation of the Stratigraphic Record of the Atlantic Coastal Plain.** Jesse Thornburg, Temple Univ., jesse.thornburg@temple.edu; Stephen Peterson, Temple Univ., sppete@temple.edu.
11. **Stratigraphy, Correlation, Depositional Environments, and Paleontology of Pliocene to Pleistocene MIS 5 Deposits of the Atlantic Coastal Plain.** Kelvin W. Ramsey, Delaware Geological Survey, kwramsey@udel.edu; John F. Wehmiller, Univ. of Delaware, jwehm@udel.edu.
12. **The Impact of Climate Change on Barrier Island-Backbarrier Systems.** *Cosponsored by Eastern Section, SEPM.* Michael S. Fenster, Randolph-Macon College, mfenster@rmc.edu; Duncan M. Fitzgerald, Boston Univ., dunc@bu.edu.
13. **Measuring and Modeling Coastal Morphodynamics: Beaches and Shelves.** Art Trembanis, Univ. of Delaware, art@udel.edu; Adam Skarke, Univ. of Delaware, askarke@udel.edu.
14. **Coastal and Nearshore Processes Affecting Our National Parks.** Courtney Schupp, National Park Service, courtney_schupp@nps.gov; Mark Borrelli, Provincetown Center for Coastal Studies, mborrelli@coastalstudies.org.
15. **Estuarine Sediment Dynamics.** Cindy Palinkas, Univ. of Maryland Center for Environmental Science, cpalinkas@hpl.umces.edu.
16. **Connecting Continent and Sea: Paleoecologic Studies of the Eastern North American Continental Margin from Coastal Plain to Abyss.** Neil E. Tibert, Univ. of Mary Washington, ntibert@umw.edu; H. Allen Curran, Smith College, acurran@science.smith.edu.
17. **Insights from Microfossils: From Geoarchaeology and Pollution Remediation to Climate and Sea-level Change.** Miriam Katz, Rensselaer Polytechnic Institute, katzm@rpi.edu; Francine McCarthy, Brock Univ., francine@brocku.ca; Ellen Thomas, Yale, ellen.thomas@yale.edu.
18. **Eastern Ichnology: Advances in Paleoenvironmental Applications of Trace Fossils.** *Cosponsored by Eastern Section, SEPM.* Jacob Benner, Tufts Univ., jacob.benner@tufts.edu; Ilya Buynevich, Temple Univ., ibuynevich@whoi.edu.
19. **Geologic and Paleoenvironmental History of the Chesapeake Bay.** Rowan Lockwood, College of William & Mary, rxlock@wm.edu; Thomas Cronin, USGS, tcronin@usgs.gov.
20. **Energy Resources in the Eastern United States and Associated Environmental Effects.** Devin Castendyk, State Univ. of New York, College at Oneonta, castendn@oneonta.edu; Joseph Graney, Binghamton Univ., jgraney@binghamton.edu.
21. **Case Histories in Engineering Geology, Eastern United States.** James T. Kirkland, Professional Consulting Corp., envpcc@aol.com; Page Herbert, paherbert@aol.com.
22. **Selenium as an Essential Micronutrient: Geologic and Geographic Sources and Efficacy.** Michalann HartHill, GHI Inc., mharthill@gmail.com; Mark Cave, British Geological Survey, mrca@wpo.nerc.ac.uk; Fiona Fordyce, British Geological Survey, fmf@bgs.ac.uk.
23. **Mercury in the Environment: From Maine to Florida.** Julia L. Barringer, USGS, jbarring@usgs.gov; Zoltan Szabo, USGS, zszabo@usgs.gov; John Reinfelder, Rutgers Univ., reinfelder@envsci.rutgers.edu.
24. **Hydrogeology of Wetlands and Watershed Processes.** Timothy Callahan, College of Charleston, callahant@cofc.edu; Vijay Vulava, College of Charleston, vulavav@cofc.edu.
25. **Cave and Karst Deposits in the Eastern United States: Archives of Paleoclimates and Paleoenvironments.** Russell W. Graham, Pennsylvania State Univ., rgraham@ems.psu.edu; Blaine Schubert, East Tennessee State Univ., schubert@etsu.edu.
26. **Interaction between Shallow and Deep Karst: Geologic, Hydrologic, Geochemical, and Biologic Indicators.** Dan Doctor, USGS, dhdoctor@usgs.gov; Bruce Lindsey, USGS, blindsey@usgs.gov.
27. **Ancient and Modern Carbonates of Eastern North America.** *Cosponsored by Eastern Section, SEPM.* Bosiljka Glumac, Smith College, bglumac@smith.edu; Sara Pruss, Smith College, spruss@smith.edu.
28. **Faculty and Student Perspectives on Undergraduate Research: Models, Challenges, and Best Practices.** Dori Farthing, SUNY-Geneseo, farthing@geneseo.edu; Peter Sak, Dickinson College, sakp@dickinson.edu; Jeffrey Ryan, Univ. of South Florida, ryan@shell.cas.usf.edu.

FIELD TRIPS

Before the Meeting

1. **Geomorphology, Soils, Landscape Evolution, and Land Use in the Virginia Piedmont and Blue Ridge.** Cullen Sherwood, James Madison Univ., sherwowc@jmu.edu; Scott Eaton, James Madison Univ., eatonls@jmu.edu; Greg Hancock, College of William & Mary, gshanc@wm.edu.
2. **Geology Trails in Delaware Water Gap National Recreation Area, New Jersey-Pennsylvania.** Jack Epstein, USGS, jestein@usgs.gov.
3. **Tectonic Evolution of the Peach Bottom Area, South-Central Pennsylvania.** Rodger T. Faill, Pennsylvania Geological Survey, crfaill@juno.com; Robert C. Smith II, Pennsylvania Geological Survey.
4. **Magmatic Layering and Intrusive Plumbing in the Jurassic Morgantown Sheet, Central Atlantic Magmatic Province.** LeeAnn Srogi, West Chester Univ., lsrogi@wcupa.edu; Loretta Dickson, Lock Haven Univ.; Meagen Pollock, College of Wooster; Ben Edwards, Dickinson College; Tim Lutz, West Chester Univ.

JOINT MEETING *continued on p. 20*

Call for Papers

2010 GSA Section Meetings

13–16 March
Northeastern-Southeastern Joint Meeting, Baltimore, Maryland, USA.
Abstract submission opens
1 Oct.; deadline: 8 Dec. 2009.

11–13 April
North-Central–South-Central Joint Meeting, Branson, Missouri, USA.
Abstract submission opens
1 Nov.; deadline: 19 Jan. 2010.

21–23 April
Rocky Mountain, Rapid City, South Dakota, USA.
Abstract submission opens
1 Nov.; deadline: 26 Jan. 2010.

27–29 May
Cordilleran, Anaheim, California, USA.
Abstract submission opens
1 Dec.; deadline: 9 Mar. 2010.

JOINT MEETING *continued from p. 19*

Aftert heM eeting

5. **A Traverse of Proterozoic to Paleozoic Laurentia, Virginia Blue Ridge and Valley and Ridge.** Lynn Fichter, James Madison Univ., fichtels@jmu.edu; Bill Burton, USGS, bburton@usgs.gov; Steve Whitmeyer, James Madison Univ., whitmesj@jmu.edu; Chuck Bailey, College of William & Mary, cmbail@wm.edu.
6. **A Tale of Two Gaps: Comparisons of Stratigraphy and Structure at Lehigh Gap and Delaware Water Gap.** Jack Epstein, USGS, jestein@usgs.gov.
7. **The Early through Late Pleistocene Record in the Susquehanna River Basin.** Duane Braun, Bloomsburg Univ., drbraun@bloomu.edu.
8. **Coastal Processes and Engineering at Assateague Island.** Sean Cornell, Shippensburg Univ., scornell@ship.edu.
9. **Stratigraphy of Calvert, Choptank, and St. Marys—Chesapeake Bay Area.** L.W. (Buck) Ward, Virginia Museum of Natural History, Lauck.Ward@vmnh.virginia.gov; Dave Powers, USGS.

REGISTRATION

Early registration deadline: 8 February 2010
Cancellation deadline: 16 February 2010

ACCOMMODATIONS

Hotel registration deadline: 20 February 2010

A block of rooms has been reserved at the Sheraton Baltimore City Center Hotel, 101 West Fayette Street, Baltimore, MD 21201, USA. Meeting rates per night, plus tax: US$139 single or double; US$159 triple; US$179 quad. Please call the Sheraton at +1-866-837-5182 and request a reservation under "Geological Society of America."

Accessibility: GSA is committed to ensuring full participation for conference attendees with disabilities at all events at the 2010 meeting. Please indicate special requirements when you register. ■

2009 GSA Annual Meeting
Portland, Oregon, USA

Lunchtime Keynote Lectures

Oregon Convention Center, Room D135/136
12:15–1:15 p.m.

Bring your lunch, relax, and be informed by GSA's new Lunchtime Keynote Lectures.

Lunchtime Keynote Lecture 4:
The dynamic landscapes of volcanoes and vineyards in the Pacific Northwest

Wednesday, 21 Oct. 2009

Cynthia Gardner
Scientist-in-Charge,
Cascades Volcano Observatory

Scott Burns
Portland State University

Cynthia Gardner and Scott Burns will each give a brief talk, and questions are welcome. This final lunchtime keynote lecture ties in nicely with the Annual Meeting theme, and we hope you have time to stop by with your lunch to listen to these two dynamic individuals.

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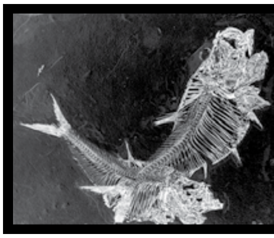
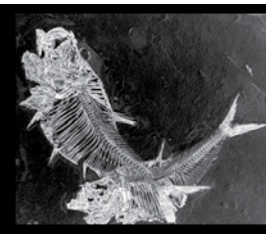


DARWIN DAY



Monday, 19 Oct. 2009

Oregon Convention Center, Portland Ballroom 251/258

This day of activities celebrating the 200th birthday of Charles Darwin is brought to you by The Geological Society of America and The Paleontological Society.

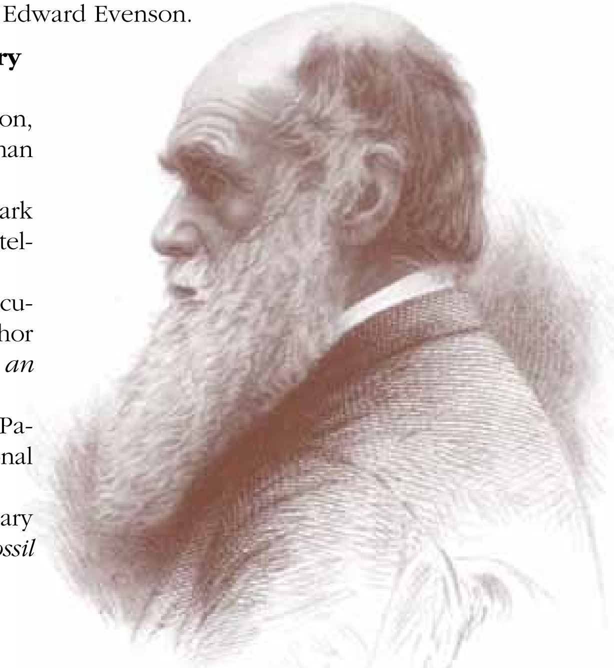
9–11:15 a.m.

Session T92: "In the footsteps of Darwin the geologist: Celebrating Darwin's 200th birthday." Cosponsored by the Darwin Society; convened by Gregory S. Baker, Yildirim Dilek, Patrick A. Burkhart, and Edward Evenson.

11:30 a.m.–1:30 p.m.

Panel Discussion: "Overcoming resistance to the reality of evolutionary change in nature."

- Jeremy Jackson, Director, Center for Marine Biodiversity & Conservation, Scripps Institution of Oceanography, and a leading authority on human impacts on the oceans;
- Judge John E. Jones, well known for his presiding role in the landmark Kitzmiller v. Dover Area School District case bearing on teaching of "intelligent design";
- Randy Olson, marine biologist, independent filmmaker known for his documentary *Flock of Dodos: The Evolution-Intelligent Design Circus*, and author of the forthcoming book *Don't Be Such a Scientist: Talking Substance in an Age of Style*;
- Kevin Padian, Professor of Integrative Biology and Curator, Museum of Paleontology, University of California, Berkeley, and President of the National Center for Science Education; and
- Ray Troll, artist incorporating sound science and focusing on evolutionary themes whose posters and books include *Planet Ocean, Cruisin' the Fossil Freeway,* and *Raptors Fossils, Fins & Fangs.*



1:30–3:45 p.m.

Session T120: "Darwin, geology, and evolution: Impact of Darwinian views on scientific theory-making." Cosponsored by GSA's Geology and Society, Geoscience Education, History of Geology, International, Quaternary Geology and Geomorphology, Sedimentary Geology, and Structural Geology and Tectonics Divisions; the National Association of Geoscience Teachers; and the Paleontological Society. Convened by Yildirim Dilek, Gregory S. Baker, Michael Roberts, and Léo F. Laporte.

4–6 p.m.

Showing of *Flock of Dodos: The Evolution-Intelligent Design Circus* followed by a Q&A with filmmaker Randy Olson.

7:30–10 p.m.

GSA-Subaru of America Inc. Public Forum: L.A. Theater Works: *The Great Tennessee Monkey Trial.* Newmark Theater, Portland Center for the Performing Arts. US$25; tickets can be purchased at registration.

The Great Tennessee Monkey Trial by Peter Goodchild is taken from original sources and trial transcripts. The Scopes Trial, about the right to teach evolution in public schools, reaffirmed the importance of intellectual freedom as codified in the Bill of Rights. The trial, which took place in a small-town Tennessee courtroom in 1925, set the stage for debate over the separation of church and state in a democratic society—a debate that continues to this day.

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International Activities of The Geological Society of America and Results of the International Survey

In May 2009, the Council of the Geological Society of America (GSA) approved the transformation of the International Division into the International Section as of the 2009 GSA Annual Meeting in Portland. With this action, all GSA members who do not live in North America and who do not currently belong to a GSA Section (~1,300 members) will be incorporated into the International Section. Because GSA member benefits include one Section affiliation and additional affiliations are only US$2 each, we encourage you to consider affiliating with more than one Section when renewing your membership for calendar year 2010. International Section dues will support the expansion of the international travel grants program, an international reception at the annual meeting, and other activities to benefit international members.

During the past year, the International Division Management Board has prepared for this transformation by writing new International Section bylaws—a task spearheaded by Ric Terman and Paul Robinson. It also commissioned a survey of international members to seek their input. Reporting the results of the international survey is the primary purpose of this article.

The survey was conceived at the 2008 Annual Meeting in Houston. Survey questions were crafted with input from GSA headquarters staff. In late February, Wesley Hill, GSA's International Secretariat, sent the survey to GSA's international membership and current International Division members via e-mail.

The survey garnered 511 responses—nearly 25% of the international membership—which indicates the interest level is high.

International Membership Survey Results

Demographics

About half of the survey respondents are from Europe and about half have been members for less than five years. Nearly 60% are faculty and about 25% learned about GSA while a student in North America.

About 20% of the North American members (n = 39) of the International Division responded to the survey, and of those, ~40% are academic faculty and 25% are retired. About 60% have been GSA members for more than 21 years, and 70% joined as graduate students. Eighty percent cite the importance of membership in international geoscience organizations as a reason for joining the Division.

Consensus

The overall consensus is that an enhancement of GSA's international operations is desired. A substantial number of GSA's international members expressed their interest in assisting GSA by initiating or helping organize collaborative meetings.

Highlights

International members consider the most important aspect of GSA to be the publication of high-quality journals (80%) and books (50%). About 70% explicitly stated that they are members of GSA to receive its publications, with many noting the price discount that comes with membership. About 60% of the respondents stated that it is important for them to be a member of an international geoscience organization.

Written comments also highlighted that our meetings are "well organized," the science presented is "great," and the "collegiality is good" with "opportunities for networking." Several emphasized they were members of GSA because it is a "non-political geoscience organization."

Other General Findings

- ~40% joined GSA while a graduate student;
- ~70% joined GSA while a resident outside of the USA;
- ~75% rated the visibility of GSA as high to moderate among geoscientists in their country; and
- ~90% said the amount of communication from GSA was "about right" (most said correspondence on a quarterly basis would be desirable).

An open question regarding "other barriers to membership" led to written responses that included "too much competition with other meetings," "too much focus on North America," the "competition with local societies/organizations," "the high cost of publications," and language barriers.

Financial Matters

- Fewer than 5% of respondents received a GSA research grant as a student;
- ~5% have received or hope to receive a GSA travel grant;
- ~40% believed a GSA travel grant would help them receive other funds to attend a GSA meeting to present a paper (most responded that they need outside funds to cover 40% to 80% of the cost);

- ~40% were aware of the reduction in membership dues for low-income countries;
- ~25% said the reduction in membership dues influenced their decision to retain their GSA membership;
- ~30% were aware that GSA had reduced the annual meeting registration fees for people from low-income countries; and
- ~70% cited cost and distance to travel as barriers to attending GSA meetings.

International Participation

About 35% of the respondents said they "are interested" in helping GSA cosponsor scientific meetings or sessions in their region, and about 40% said they "may be interested" in helping. Ninety-three international members volunteered to serve in this capacity by providing their e-mail addresses. About 30% of the international respondents are interested in serving as GSA International Liaisons/Ambassadors; in fact, 97 people volunteered to do so by providing their e-mail addresses.

International Section Career Contribution Award

About 70% of the international respondents said they would view recognition from the International Section with a Career Contribution Award as a distinguished achievement.

Distinguished International Lectureship Program

The International Section and GSA Council are planning to develop a Distinguished Lectureship Program similar to the Birdsall-Dreiss Lectureship organized by the Hydrogeology Division. About 70% of our survey respondents said that they would prefer a lectureship program of international geoscientists touring a sector of the world. About 40% of the respondents said they believe their home institution would provide financial support for a GSA international lecturer. The International Division member respondents were roughly equally divided on this concept.

Summary

The 2009 GSA international member survey indicates that maintenance of high-quality publications is of foremost importance. The survey confirmed that there is significant interest in expanding international member interactions via collaborative meetings held outside of North America. An expanded international travel grants program will increase the participation of international geoscientists at annual meetings. The creation of a GSA-sponsored Distinguished International Lectureship Program is viewed as a worthy endeavor and would receive significant support by organizations that host speakers. Clearly, the desired expansion of international activities will require a steady source of funds.

As a result of the survey, several actions are already under way: (1) an increased effort at fundraising for the international travel grants program; (2) international attendees will be identified with a ribbon on their nametag at the Portland meeting and invited to attend the International Section reception; (3) develop new ways to help GSA members cosponsor topical sessions at international meetings; and (4) two collaborative international meetings (Turkey and Germany) are in advanced planning stages.

The Management Board of the new International Section thanks all survey participants. Please contact Wesley Hill at GSA, whill@geosociety.org, or members of the Management Board with your suggestions and ideas. We will be calling on those who volunteered to help shape the future of GSA's International Section collaborations.

Mark Cloos, *International Secretary, cloos@mail.utexas.edu*
Paul Robinson, *Chair, International Division/Section*

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Social Media:

A Fresh Twist on an Old Idea

One thing we consistently hear from members who attend the GSA Annual Meeting is that it is one of their favorite networking events each year. Today, as new media present new avenues for connecting professionally, GSA continues to lead in building the community that our members and friends have enjoyed for decades and have come to expect.

By all means, attend your alumni reunion, meet colleagues at the welcoming party, catch up with friends over dinner, and discuss a new idea over a poster session and a beer. And this year, you can also plan to join in the online conversations via the world of social media. Even if you haven't participated before, you might discover that folks are on to something!

- **Follow us on Twitter** — We're **@geosociety** & all meeting-related posts will appear under **#GeoPort**.
- The GSA Annual Meeting is also on **Facebook** at **http://www.facebook.com/event.php?eid=67889884209**.

Find out who else is going to be there, get insider hints about Portland, tell everyone about the field trip you're on, and help each other navigate the meeting.

Learn more at **www.geosociety.org/meetings/2009/fusion.htm.**

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GSA Foundation Update

Donna L. Russell, *Director of Operations*

GSA Foundation Activities at the Portland Meeting

The GSA Foundation is a part of the October GSA Annual Meeting in Portland. The Foundation Booth, located in the Headquarters Services area of the Oregon Convention Center, will be the center of many of the Foundation activities.

AT THEF OUNDATIONB OOTH YOU CAN:

- Participate in the Foundation's 10th Silent Auction;
- Learn more about the GSA programs supported by the Foundation;
- Meet the Foundation Trustees;
- Make a donation to your favorite Foundation fund;
- Penrose Circle donors (gifts of $500+) receive a "token of appreciation";
- Bring your gold jewelry and donate it to our "Gold for Gold" program; and
- Meet with the Foundation staff—We hope to see you there!

Most memorable early geologic experience:

My first visit to the Canadian Cordillera in 1952, as a junior field assistant on a GAC field party. This set me on course for a career in geology.

—Raymond A. Price

The GSA Foundation Supports GSA Programs

During fiscal year '09, the Foundation provided support for several GSA programs, including

Earthcache™

GeoCorps™ America Interns

Geology in Government Luncheon

Geology in Industry Program

GSA Public Service Award

GSA's Annual Meeting

Mann Mentor Program

Matching Student Travel Grants for GSA Sections

Minority Scholarships

Outstanding Earth Science Teacher Awards

Research Grants

Shlemon Mentor Program

Student Recruitment

Subaru Distinguished Earth Science Educator

Teacher Advocate Program

Travel Grants (International & Domestic)

Women in Geology Program

Your support of the Foundation's Greatest Needs Fund enables the Foundation to continue to provide the critical support needed for these and other programs—especially vital in today's economy. On behalf of the GSA Foundation's Board of Trustees, I extend sincere appreciation to all donors.

Positions Open

MINERALOGIST/PETROLOGIST
MIDWESTERN STATE UNIVERSITY

Geosciences, Assistant/Associate Professor–tenure track, Fall 2010. Teach introductory courses, Mineralogy/Petrology, and appropriate upper-level courses; develop research program involving undergraduates. Required: Ph.D. in geosciences, broad geosciences background, and strong interpersonal skills. Preference will be given to individuals with research background and resultant publications in refereed journals. MSU is a comprehensive public university serving approx. 6,500 students. Send application letter, curriculum vitae, and names and addresses of 3 references to Dr. P. Stephens, Chair, Dept. of Geosciences, Midwestern State University, 3410 Taft Blvd., Wichita Falls, TX 76308; pamela.stephens@mwsu.edu. Screening starts 1 Oct. Applications accepted until position is filled. This position is designated as security sensitive and requires the finalist to complete a criminal background check. EEO/ADA Compliance Employer.

ASSISTANT PROFESSOR OF GEOSCIENCES
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UNIVERSITY OF NEBRASKA–LINCOLN

Applications are invited for a tenure track position as Assistant Professor in the Dept. of Geosciences at the University of Nebraska–Lincoln. The successful candidate will be expected to conduct a rigorous, externally funded research program in structural geology, tectonics, and/or sedimentary basin analysis, and to participate in teaching and curricular development of core undergraduate and graduate courses. The successful candidate will teach a course on structural geology and contribute to the growing petroleum geosciences-related teaching and research activities in the department, which could include teaching exploration geophysics. There is an opportunity for the candidate to teach part of our summer field camp in the Bighorn Basin. The candidate should demonstrate strong potential for research and teaching and must hold a Ph.D. in a geosciences field at the time of appointment. Women and ethnic minority candidates are strongly encouraged to apply.

The Sedimentary Geology and Paleontology program is one of the three primary components of the Geosciences Department. The department offers B.S. degrees in Geology and Meteorology/Climatology, as well as M.S. and Ph.D. degrees in Geosciences. Find out more about our department at http://geosciences.unl.edu.

To apply, go to http://employment.unl.edu, requisition 090488, and complete the "faculty/administrative form." Applicants must attach a cover letter, curriculum vitae, statements of research and teaching interests, and names of at least 3 references via the above website. We will begin to review applications on 11/15/2009, but the position will remain open until it is filled.

The University of Nebraska has an active National Science Foundation ADVANCE gender equity program and is committed to a pluralistic campus community through affirmative action, equal opportunity, work-life balance, and dual careers. Lincoln is a highly livable city with affordable housing and excellent schools. For further information, contact Dr. Mary Anne Holmes, Search Committee Chair, at mholmes2@unl.edu; +1-402-472-5211; 214 Bessey Hall, Geosciences Department, University of Nebraska, Lincoln, NE 68588-0340.

ASSISTANT PROFESSOR, GEOLOGY DEPT.
UNION COLLEGE, SCHENECTADY, NEW YORK

The Geology Dept. at Union College, www.union.edu/academic_depts/geology, seeks a dynamic teacher and scholar with a research background in marine geology, oceanography or paleoclimatology to fill a tenure track position to begin August 2010. The successful candidate will be expected to teach courses in their field and to contribute to the Environmental Science and Policy Program (http://minerva.union.edu/env/ES_Home.html). Courses could include oceanography, paleoclimatology, sedimentology, and surface processes.

Union College is a highly selective liberal arts college with a strong tradition of science and engineering at the undergraduate level. The Geology Dept., a member of the Keck Consortium, http://keckgeology.org/, is well equipped with analytical instrumentation, and has a strong record of student-faculty research.

Candidates should submit a letter of application, curriculum vitae, statements of teaching and research interests, and the names and contact information (including e-mail) of 3 people who may be contacted to provide letters of recommendation. Screening of applications will begin on 15 Dec. and will continue until the position is filled. Application materials should be sent to D.T. Rodbell, Search Committee Chair, Geology Dept., Union College, Schenectady, NY 12308.

Union College is an equal opportunity employer and is strongly committed to student and workforce diversity.

TENURE-TRACK ASSISTANT PROFESSOR
SEDIMENTARY GEOLOGY, AMHERST COLLEGE

Amherst College invites applications for the position of Assistant Professor of Geology, with specialization in modern or ancient sedimentary environments. This is a tenure-track appointment commencing in the Fall of 2010. A Ph.D. in the geosciences is required at the time of appointment; emphasis in the ancillary fields of paleontology, oceanography, climate change, paleolimnology, surface earth processes, or geomorphology is desired. The position will complement, but not duplicate, existing departmental strengths in hydrogeology and aqueous geochemistry. Teaching responsibilities will include participation in introductory level courses in geology and environmental science, sedimentology as well as a course in the applicant's area of expertise. Mentoring of honors thesis projects is expected, as is participation with faculty from other departments in Amherst College's new Environmental Studies program. Amherst College is a highly competitive liberal arts college that highly values faculty and student engagement in research. Department facilities include an ICP-AES, ICP-MS, SEM/EDS/EBSD, IC and GC. Candidates should submit to https://jobs.amherst.edu one PDF file containing a 1-page cover letter, CV that includes a list of potential course offerings with a brief description of each, statement of research interests, and the names and contact information (mail, e-mail, and phone numbers) of 3 professional references. We will begin considering applications 1 Nov. 2009 and will continue until the position is filled. Amherst has taken a leadership role among highly selective liberal arts colleges and universities in successfully diversifying the racial, socioeconomic, and geographic profile of its student body. The College now aims to enrich the diversity of its faculty, administration, and staff to ensure that full participation and inclusion become desired norms across the culture of the institution. Amherst aspires to become a learning community in which everyone, not just those individuals whom we identify with minority cultures or perspectives, is informed about and responsive to all aspects of diversity.

DEPT. OF GEOGRAPHY AND GEOLOGY
SAM HOUSTON STATE UNIVERSITY
(HUNTSVILLE, TEXAS 77341-2148)

Sam Houston State University seeks to fill the position of **Chair** of the Department of Geography and Geology beginning August 2010. This is a **tenured** position at the rank of **Associate** or **Full Professor** depending on qualifications. The successful candidate must have a relevant record of administrative experience and have demonstrated excellence in teaching, service, and scholarship. A Ph.D. in geography or a related field is required. The candidate will have expertise in **geospatial technology** that complements our existing mix of **GIS, remote sensing, computer cartography and visualization** skills**,** or other relevant geospatial technologies, that will support our new **Master of Applied Geospatial Technology** degree. The Chair will be a forward-looking leader, an advocate for the department, faculty and staff, able to maintain the strong connections between the Geography and Geology programs, and remain engaged in and provide leadership for his/her areas of research and scholarship.

The Department presently has 12 full-time faculty and offers degrees in geography (B.A., B.S.), social science composite–geography emphasis (B.A., B.S.), and geology (B.S.). The Department supports two GIS-related minors (GIS and GSS), maintains modern GIS and remote sensing labs, and possesses a broad range of modern field and laboratory equipment. Sam Houston State University, located about 70 miles north of Houston, is one of Texas' fast growing universities with over 16,000 students and 79 undergraduate, 54 masters, and five doctoral programs.

Letters of interest must be received by 1 Dec. 2009 and will be reviewed until the position is filled. Send the letter, curriculum vitae, statements of teaching, research, and administrative philosophies, 3 sample publications, unofficial graduate transcripts, and the names and contact information (including e-mail) of 3 references to Dr. Donald Albert, Chair of Geography and Geology Chair Search Committee, Dept. of Geography and Geology, Box 2148, Sam Houston State University, Huntsville, TX 77341-2148; voice: +1-936-294-1453; fax +1-936-294-4203; geo_dpa@shsu.edu. SHSU is an EEO/AAP employer

NEW FACULTY POSITIONS
SEDIMENTARY GEOLOGIST/ENERGY GEOCHEMIST
DEPT. OF GEOLOGY & GEOGRAPHY
WEST VIRGINIA UNIVERSITY

The Dept. of Geology and Geography at West Virginia University seeks to appoint two new faculty positions addressing expanded energy research efforts associated with the WVU Advanced Energy Initiative (ruby.geo.wvu.edu/~tcarr/AEI_page.html). Current department research interests include energy geology, carbon sequestration, reservoir characterization, geophysics, remote sensing, GIS, structure/tectonics, petrology, hydrogeology, surficial processes, environmental geology, sedimentology, sequence stratigraphy, paleontology and paleoecology. Successful applicants will contribute to teaching at the undergraduate and graduate levels. Excellent teaching and development of a vigorous externally-funded research program are required. The Department is located in an outstanding newly renovated building. Department resources include 3D visualization systems, an extensive suite of subsurface interpretation software, and five computer teaching labs housing approx. 120 computers. The Department works collaboratively with the National Energy Technology Lab (DOE-NETL), the National Research Center for Coal and Energy (NRCCE), the Department of Petroleum and Natural Gas Engineering, and the West Virginia Geological and Economic Survey, all based in Morgantown.

Applications are invited for two tenure-track positions at the assistant professor level. A Ph.D. is required for both positions:

1. **Sedimentary Geologist.** Specialty in sedimentary geology is open and may include, but is not limited to physical stratigraphy; sedimentary deposits, processes and systems; and basin studies on outcrop and in subsurface, plus we value a willingness to help teach Geology Field Camp. Candidates should apply by sending electronic files as e-mail attachments to sedgeol@mail.wvu.edu, addressed to Sedimentary Geologist Search Committee, Dept. of Geology and Geography, West Virginia University, Morgantown, WV 26506-6300. Questions may be directed to the above e-mail address or to Dr. Tom Kammer at +1-304-293-9663.
2. **Energy Geochemist**. The geochemical specialty is open and may include, but is not limited to geomicrobiology, isotope, organic, and trace element geochemistry. A focus on energy resources is expected. Candidates should apply by sending electronic files as e-mail attachments to geochemist@mail.wvu.edu, addressed to Energy Geochemist Search Committee, Dept. of Geology and Geography, West Virginia University, Morgantown, WV 26506-6300, USA. Questions may be directed to the above e-mail address or to Dr. Tim Carr at +1-304-293-9660.

Submitted electronic files should include (1) letter of application detailing (a) research interests and how these dovetail with the departmental and AEI research activities, and (b) teaching experience and interests; (2) resume/vitae; and (3) names, phone numbers, e-mail and complete mailing addresses of 3 references. Review of applications will begin 1 Nov. 2009 and will continue until the position is filled. The anticipated start date is 16 Aug. 2010. Please see www.geo.wvu.edu, www.wvu.edu, and www.morgantown.com for additional information. West Virginia University is an Equal Opportunity/Affirmative Action employer. Women and minority candidates are encouraged to apply.

TENURE-TRACK ASSISTANT PROFESSOR
SEDIMENTARY GEOLOGY
ILLINOIS STATE UNIVERSITY

The Dept. of Geography-Geology at Illinois State University seeks applications for a tenure-track position at the rank of **Assistant Professor** with expertise in **Sedimentary Geology**. The preferred starting date is August 16, 2010. A Ph.D. in Geology or closely related field is preferred, but ABD candidates who will finish the dissertation before the time of appointment will be considered.

The Department seeks candidates with a strong potential for scholarly research, publication, and teaching in Sedimentary Geology. The successful candidate will be an integrated scholar with a strong commitment to teaching at all levels including coursework in general education, intermediate courses in Sedimentary Geology, and advance courses in his/her area of expertise (e.g. exploration geophysics, basin analysis, etc.). The ability to mentor students in our MS program in Hydrogeology and to participate in the instruction of our summer field geology course is desirable. Research experience with emphasis in Paleozoic cratonic strata or Pleistocene glacial sediments is desirable. The potential for a significant startup package exists.

Illinois State University is a research-intensive university with an annual enrollment of approx. 20,000 students. The university is located in the Bloomington-Normal metropolitan area of central Illinois with a population of approx. 150,000. The Dept. of Geography-Geology offers B.S./B.A. degrees in Geography, a B.S. degree in Geology, and an M.S. degree in Hydrogeology.

Please send applications to Chair, Sedimentary Geology Search Committee, Dept. of Geography-Geology, Illinois State University, Normal, Illinois, 61790-4400, USA. Applications should include a cover letter, curriculum vitae, statements outlining current and future research interests and teaching philosophy, 3 letters of recommendation, and all college and university transcripts. All materials must be received on or before **1 Dec. 2009**. No e-mail applications will be accepted. Inquiries about the application process should be directed to Dr. David Malone, dhmalon@ilstu.edu; +1-309-438-7643. Additional information about the department and the community can be found at www.geo.ilstu.edu. Filling this position is contingent upon budgetary approval.

Illinois State University is an Affirmative Action University encouraging diversity.

TENURE TRACK ASSISTANT PROFESSOR
COASTAL GEOLOGY
GEORGIA SOUTHERN UNIVERSITY

Georgia Southern University's Dept. of Geology & Geography invites applications for a tenure track Assistant Professor of Geology. The full text advertisement is available at http://cost.georgiasouthern.edu/geo/. Screening of applications begins 12 Oct. 2009 and continues until the position is filled. Georgia Southern seeks to recruit individuals who are committed to excellence in teaching, scholarship, and professional service within the University and beyond and who are committed to working in diverse academic and professional communities. Finalists will be required to submit to a background investigation. Georgia is an open records state. Georgia Southern is an AA/EO institution. Individuals who need reasonable accommodations under the ADA to participate in the search process should contact the Associate Provost.

FACULTY FELLOW IN GEOLOGY
STRUCTURE/GEOPHYSICS, COLBY COLLEGE

The Dept. of Geology invites applications for a one-year visiting Faculty Fellow position in structure/tectonics and geophysics/remote sensing, beginning 1 Sept. 2010. The successful applicant will be expected to teach a 200-level structural geology with laboratory and an upper division course of his/her choice for geology majors during the academic year. The upper division course should complement those already offered in the department. The remainder of the teaching assignment will focus on course offerings for potential majors and non-majors. Additionally, the candidate may have the opportunity to direct one or more independent research projects. Colby is a highly selective liberal arts college recognized for excellence in undergraduate education and for close student-faculty interaction. Ph.D. with teaching experience at time of employment preferred; ABDs encouraged to apply. Applicants should submit a letter of application, curriculum vitae, statement of teaching and research interests, and 3 letters of reference to Dr. Robert A. Gastaldo, Chair, Dept. of Geology, 5807 Mayflower Hill Drive, Waterville, ME 04901. Review of applications will begin on 23 Nov. 2009 and will continue until the position is filled. Colby is an Equal Opportunity/Affirmative Action employer, committed to excellence through diversity, and strongly encourages applications and nominations of persons of color, women, and members of other under-represented groups. For more information about Colby College, please visit www.colby.edu.

STAFF POSITION IN MASS SPECTROMETRY
BAYLOR UNIVERSITY

The Department of Geology at Baylor University is pleased to announce a search for a new staff position for hire beginning on or before 1 Jan. 2010 as Instrumentation Specialist in Stable Isotope Mass Spectrometry. The Department currently consists of 15 geoscientists, including geologists, geophysicists and geographers. Please see the department Web site at www.baylor.edu/Geology/ for further information.

INSTRUMENTATION SPECIALIST POSITION. The Dept. of Geology at Baylor University invites applications for a staff position managing the new stable isotope mass spectrometry laboratory at Baylor University, beginning as early as August 2010. A Ph.D. in Geology or Geochemistry is required at the time of appointment. The Department seeks an individual with a strong background in applications of stable isotope mass spectrometry to geological systems, who will manage a new laboratory containing a Thermo-Electron Delta V Advantage isotope ratio mass spectrometer with the following peripherals: Gas Bench II, combustion EA, TCEA, and a dual inlet. The instrumentation specialist is expected to support ongoing research programs that include geology, biology and environmental sciences. The position carries appointment as 90% staff and 10% research scientist, and we especially encourage collaboration with geology faculty and students currently engaged in research focusing on terrestrial paleoclimatology. The successful candidate should also be capable of managing use of the instrument by faculty and students, be able to instruct new users, and conduct routine maintenance and repairs, assisted by a Baylor Sciences Building instrumentation Specialist. Baylor University also supports an annual service contract for the instrument.

Send letter of application, including statement of research interests, curriculum vitae, transcripts, and the names and contact information for 3 references to Dr. Stephen I. Dworkin, Instrumentation Specialist Search Committee Chair, Dept. of Geology, Baylor University, One Bear Place #97354, Waco, TX 76798-7354; +1-254-710-2361; Steve_Dworkin@baylor.edu. The review of applications will begin 1 Oct. 2009 and applications will be accepted until the position is filled. To ensure full consideration, application must be completed by 15 Dec. 2009. Baylor is a Baptist university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Opportunity employer, Baylor encourages minorities, women, veterans and persons with disabilities to apply.

TENURE-TRACK FACULTY POSITION
ORGANIC GEOCHEMISTRY OR
PALEOCLIMATOLOGY
BAYLOR UNIVERSITY

The Dept. of Geology at Baylor University is pleased to announce a search for a new faculty position for hire beginning in August of 2010 in Organic Geochemistry or Paleoclimatology. The Department currently consists of 15 geoscientists, including geologists, geophysicists and geographers . Please see the Department Web site at www.baylor.edu/Geology/ for further information.

ORGANIC GEOCHEMISTRY/PALEOCLIMATOLOGY. The Dept. of Geology at Baylor University invites applications for a tenure-track Assistant or Associate Professor in the general areas of organic geochemistry and/or paleoclimatology, beginning August 2010. A Ph.D. in Geology, Geochemistry or related field is required at the time of appointment. The Geology Dept. seeks an individual with a strong research agenda that possibly includes compound-specific organic geochemistry, paleoclimate modeling, or palynology applied to field and laboratory studies of terrestrial climate records archived within fluvial (river and floodplain), eolian (loess and sand dune), lacustrine (lake), and coastal systems. The individual must be able to communicate and collaborate with a subset of six geology faculty members that are currently engaged in studies in the general area of paleoclimatology, and to carry out a vigorous externally funded research program that involves both undergraduate and graduate students. A strong commitment to excellence in teaching is essential, with both undergraduate and graduate courses that might include organic geochemistry, paleoclimate modeling or palynology, as well as other courses in his/her area of specialization. Research space for terrestrial paleoclimatology is available in the five-year-old, 500,000-square-foot "state-of-the-art" Baylor Sciences Building, and startup funds associated with this position are highly competitive. Construction of a new stable isotope laboratory was completed in the spring of 2009, which currently includes a new 600-square-foot laboratory containing a Thermo-Electron Delta V Advantage isotope ratio mass spectrometer with the following peripherals: Gas Bench II, combustion EA, TCEA, and a dual inlet, supporting ongoing research programs that include geology, biology and environmental sciences. The laboratory will be managed by a dedicated instrumentation specialist.

Send letter of application, including statement of teaching and research interests, curriculum vitae, transcripts, and the names and contact information for 3 references to Dr. Steven G. Driese, Paleoclimatology Search Committee Chair, Dept. of Geology, Baylor University, One Bear Place #97354, Waco, TX 76798-7354, +1-254-710-2361; applications sent by e-mail to Steven_Driese@baylor.edu. The review of applications will begin 1 Dec. 2009 and applications will be accepted until the position is filled. To ensure full consideration, application must be completed by 15 Dec. 2009. Baylor is a Baptist university affiliated with the Baptist General Convention of Texas. As an Affirmative Action/Equal Opportunity employer, Baylor encourages minorities, women, veterans and persons with disabilities to apply.

DEPT. OF GEOLOGY & GEOPHYSICS
TENURE TRACK POSITION
EARTH SYSTEM SCIENTIST–GEOCHEMISTRY
BOSTON COLLEGE

The Dept. of Geology and Geophysics at Boston College seeks to hire an Assistant Professor in the broad area of Earth System Science with a focus in Geochemistry to start in Fall 2010. Areas of expertise might include (but are not limited to) biogeochemistry, organic geochemistry, isotope geochemistry, and paleoclimatology. The successful candidate will be expected to develop a vigorous externally funded research program integrated with excellence in teaching within the earth and environmental geoscience curriculum at both the undergraduate and graduate levels, including teaching a course related to climate change, an introductory geochemistry or environmental geochemistry course, and upper level electives in the area of the successful candidate's expertise. The appointment is expected to be made at the Assistant Professor level, but applications from outstanding candidates at a higher level will also be considered. Information on the department, faculty, and research strengths can be viewed at www.bc.edu/geosciences. Applicants should send a curriculum vita, statements of teaching and research interests, and the names and contact information of at least 3 references as a *single PDF-file* e-mail attachment to geochem_position@bc.edu. Review of applications will begin on 6 Nov. 2009. Department faculty will be available at the GSA and

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(Required by Title 39 U.S.C. 4369)

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a.	Total No. Copies (Net press run)	20,225	21,950
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	(1) Sales through dealers and carriers, street vendors, and counter sales (not mailed)	0	0
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AGU fall meetings to meet with applicants. Boston College is an academic community whose doors are open to all students and employees without regard to race, religion, age, sex, marital or parental status, national origin, veteran status, or handicap.

Opportunities for Students

Graduate Student Fellowships, American Museum of Natural History (AMNH)–Lamont Doherty Earth Observatory (LDEO) (Columbia U). Ph.D. student(s) sought in the fields of high-T and high-P geochemistry, meteoritics and planetary science, mineralogy, mineral deposits, petrology, or volcanology. Non-U.S. citizens are eligible. Students must apply simultaneously to Columbia U.; research is under the direction of a museum curator or senior scientist; work is carried out at AMNH and/or LDEO. Fellows receive a full 12-month stipend and full tuition for 4 years for students in good standing.

Applicants should discuss their interests and background with a potential advisor then send an application due 12/15/09 to Dr. Jim Webster, +1-212-769-5401, jdw@amnh.org.

For applications, see http://rggs.amnh.org/files/uinst10.pdf; http://rggs.amnh.org/pages/academics_and_research/fellowship_and_grant_opportunities; http://research.amnh.org/earthplan, www.ldeo.columbia.edu/; or www.columbia.edu/cu/gsas/.

Two Ph.D. Opportunities, Rensselaer Polytechnic Institute: (1) Eocene Paleoceanography; (2) Triassic C-isotope Stratigraphy and C Modeling. Funding is available for 2 graduate students. One Ph.D. student is sought to utilize benthic foraminiferal stable isotopes to reconstruct the reorganization of deepwater circulation and development of the "icehouse" deep ocean structure, focusing on the mid- to late Eocene (~40 to 33 Ma). A 2nd Ph.D. student is sought to utilize Triassic bulk sediment C-isotopes (organic and inorganic) to establish a stratigraphic correlation tool and to model C cycle changes. Tuition, stipend, field and laboratory expenses, and conference attendance are covered. For more information and application details, see www.rpi.edu/~katzm/ or contact Dr. Mimi Katz, katzm@rpi.edu.

M.S. Opportunities: Epikarst hydrogeologic, geochemical, biological, and geophysical characterization, Dept. of Biology–Aquatic Resources Program, Texas State University–San Marcos. Student(s) sought immediately for cave/karst research project. In-cave work includes hydrologic, geochemical, isotopic, and biologic analysis of drip and ground waters. Surface work includes environmental analyses and shallow geophysics. Project objectives are to characterize the function and properties of the epikarst. Thesis topics for a qualified B.S. will focus on understanding how, when, and where moisture enters and leaves epikarst in the Edwards Aquifer recharge zone, as well as where and for how long it is stored in the epikarst. Students will collaborate with ecohydrology faculty and students working on plant-water interactions at the sites. Study sites are in the recharge and contributing zones for the Edwards Aquifer in central TX. The Edwards Aquifer is one of the most important karstic aquifer systems in the world, providing water for >1.5 million people in San Antonio. Texas State University Dept. of Biology offers M.S. and Ph.D. degrees in Aquatic Resources. Two positions are open. For information and application details, contact Dr. Benjamin Schwartz; bs37@txstate.edu, or visit www.aquaticresources.bio.txstate.edu/.

M.S. Opportunity(s): Hydrogeology, biogeochemistry, nutrient cycling, water quality, non-point source pollution, Dept. of Biology–Aquatic Resources Program, Texas State University–San Marcos. Student(s) sought immediately for 3-yr project at San Marcos Springs in the Edwards Aquifer of TX. Project is a unique opportunity to study gw-sw interactions and nutrient cycling in a complex lake-river system. Objectives are to determine timing and source of NPS contaminants to Spring Lake through monitoring several large spring openings, the lake, and surface watersheds. Depending on the student's research goals, responsibilities may include use and maintenance of diverse instrumentation, as well as collection and analysis of samples for water quality, nutrient, stable isotope, and chemical parameters. SCUBA certification a plus, but not required. Thesis topics for qualified B.S. or M.S. with strong academic background could include topics related to hydrogeology, chemistry, nutrient cycling, and/or aquatic biology. Texas State University Dept. of Biology offers M.S. and Ph.D. degrees in Aquatic Resources. For more information and application details, contact Dr. Benjamin Schwartz, bs37@txstate.edu; or Dr. Weston Nowlin, wn11@txstate.edu; or visit www.aquaticresources.bio.txstate.edu/.

Fellowship Opportunities

POSTDOCTORAL FELLOWSHIPS
AMERICAN MUSEUM OF NATURAL HISTORY

The Dept. of Earth and Planetary Sciences of the American Museum of Natural History invites applications for Research Fellowships in residence for postdoctoral investigators and established scientists to carry out projects in collaboration with department staff. Appointments are for six months to two years. Areas of interest include high-T and high-P geochemistry, meteoritics and planetary science, mineralogy, mineral deposits, petrology, or volcanology.

Please follow the guidelines at http://rggs.amnh.org/files/pdinst10.pdf and discuss potential research projects with research staff before applying by 11/15/09 to Dr. Jim Webster, +1-212-769-5401, jdw@amnh.org.

For further information, see http://research.amnh.org/earthplan or http://rggs.amnh.org/pages/academics_and_research/fellowship_and_grant_opportunities.

AMNH is an equal opportunity employer.

TURNER POSTDOCTORAL FELLOWSHIP
THE UNIVERSITY OF MICHIGAN

The Dept. of Geological Sciences invites applications for the Turner Postdoctoral Fellowship, a highly competitive two-year research fellowship in any field of the geological sciences. This fellowship also provides travel and research funds in addition to salary and benefits. The Department is interested in innovative research with preference for proposals that have a direct connection to the ongoing research of a faculty member. Visit our Web site for more information on faculty and research: www.lsa.umich.edu/geo. A complete application includes a curriculum vitae, a research proposal (3–5 pages) and the names and addresses of at least 3 references. **Applications are due by 31 Dec. 2009** and can be submitted to turnerpdf@umich.edu or Turner Postdoctoral Committee, Department of Geological Sciences, University of Michigan, 1100 North University Avenue, Ann Arbor, MI 48109-1005.

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

The Petroleum Institute
Abu Dhabi, United Arab Emirates

Institution: The Petroleum Institute (PI) in Abu Dhabi, United Arab Emirates was created in 2001 with the goal of establishing itself as a recognized institution in education and research in areas of significance to the oil and gas and the broader energy industries. The PI's sponsors include the Abu Dhabi National Oil Company and four major other international oil companies, namely BP, Shell, Jodco, and Total. The Institute is affiliated with and has collaborative programs in place with the Colorado School of Mines, the University of Maryland at College Park, the University of Minnesota, and Leoben and Linz Universities (Austria). For more information, please refer to the PI website: **www.pi.ac.ae.**

FACULTY POSITIONS
- PETROLEUM GEOSCIENCES

The Petroleum Geosciences Department at the PI is seeking applications for the following positions:

Chaired Professor, Distinguished Professor
Professor, Associate Professor, Assistant Professor
Research Associate

Program faculty will be expected to teach undergraduate and graduate courses, develop an active research program, and to engage in professional and institutional service activities. Opportunities to interact with PI industrial stakeholders and other local industries will be a key feature in the development of a research program.

Interested candidates should submit all materials online:

www.pi.ac.ae/jobs

Review of applications will begin immediately and will continue until successful candidates are selected. Only short-listed applicants will be notified.

Coming to *GSA Today* in November

- **Science article:** Geobiology: Evidence for Early Life on Earth and the Search for Life on Other Planets, by S.L. Cady and N. Noffke
- **First Announcement and Call for Papers:** Joint meeting of GSA's North-Central and South-Central Sections
- **Groundwork article:** Facing the main challenges in carbon capture and sequestration, by R. Snieder and T. Young

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CALL FOR PROPOSALS DENVER 2010

Rock glacier, northern Colorado. Photo by Marli Bryant Miller, University of Oregon. www.marlimillerphoto.com.

Technical Sessions

Proposal deadline: 12 Jan. 2010
Submit proposals to
http://gsa.confex.com/gsa/2010AM/sessionproposals.epl

Field Trips

Proposal deadline: 1 Dec. 2009
Submit field trip ideas to
http://gsa.confex.com/gsa/2010AM/fieldtrip.htm

Short Courses

Proposal deadline: 1 Dec. 2009
Find proposal guidelines at
www.geosociety.org/meetings/2010/scProposals/

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Journal Highlights

New Impact Factors

Thomson Reuters released their 2008 impact factors and, as usual, GSA's journals rank at the top:

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Geological Society of America Bulletin is the #12 ranked multidisciplinary geosciences journal (of 143) with an impact factor of 3.032.

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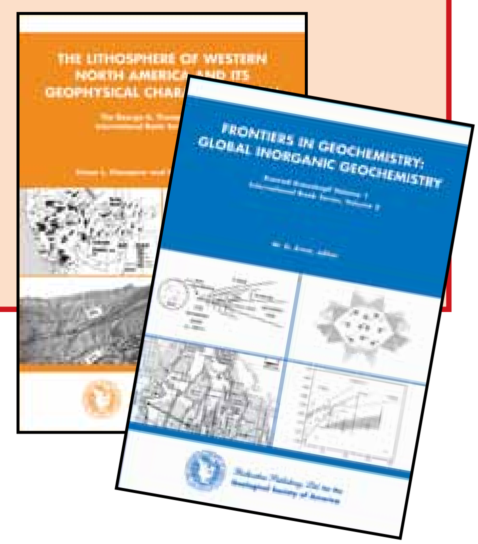

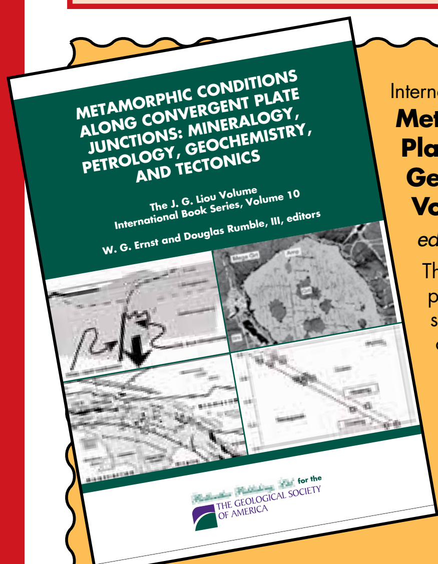

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