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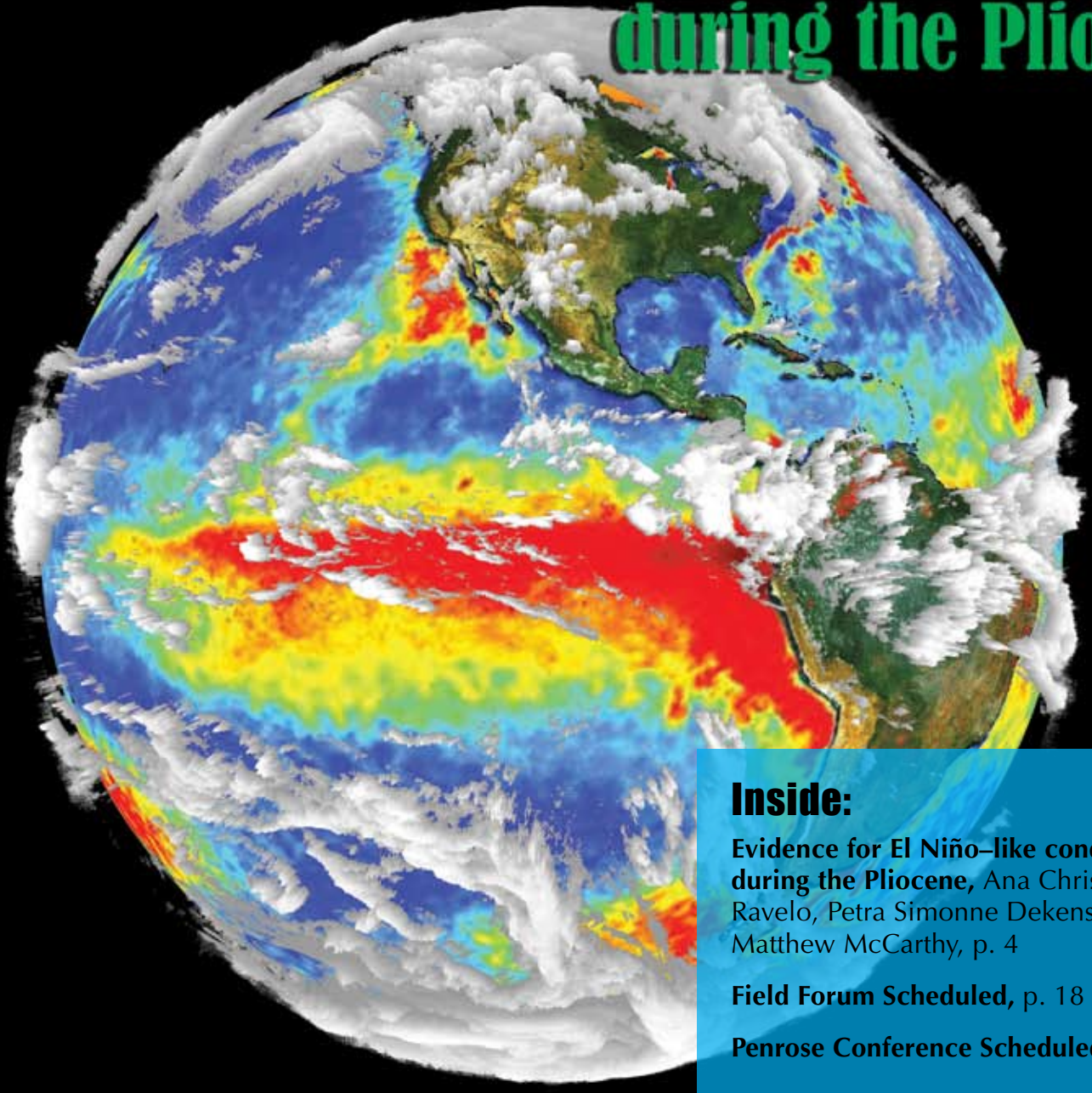
Evidence for El Niño–like conditions during the Pliocene



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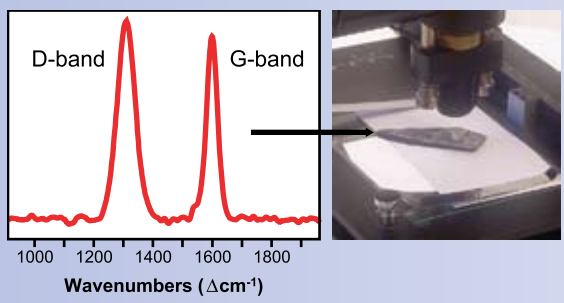

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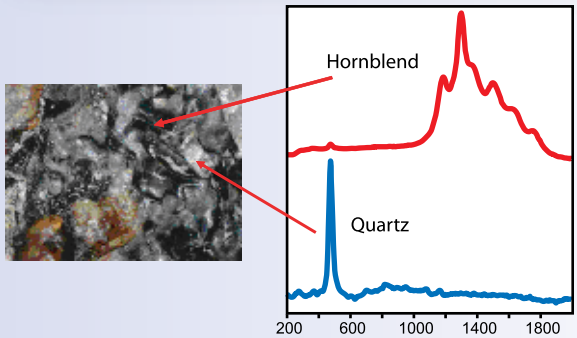

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GSA TODAY

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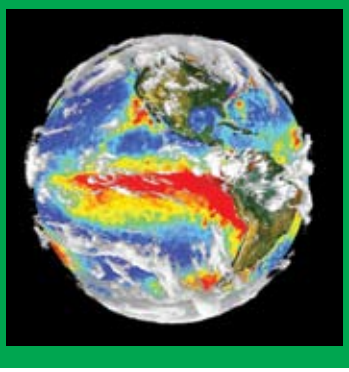

SCIENCE ARTICLE

Errata: The table of contents in the January issue of *GSA Today* read "Council Adopts New Mission Statement." This should have read "Council Adopts Two New Position Statements" to correspond with the article on page 10. *GSA Today* regrets the error.

Evidence for El Niño–like conditions during the Pliocene

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ABSTRACT

The modern tropical Pacific Ocean is characterized by strong east-west asymmetry in sea surface temperature and subsurface thermocline depth coupled to easterly trade winds and zonal atmospheric, or Walker, circulation. Walker circulation and the "normal" east-west asymmetry of sea surface temperature and thermocline depth break down temporarily during El Niño events. Since these temporary deviations from the "normal" tropical climate state are known to have global impacts, it is important to consider whether permanent shifts in the mean tropical Pacific climate state are an integral part of global climate change on longer time scales. To understand the link between tropical conditions and global warmth, we focus our study on the early Pliocene, the most recent period in Earth's history of sustained global warmth relative to today. A data synthesis of tropical paleoceanographic data, including a new alkenone unsaturation index ($U^{k'}_{37}$)–based sea surface temperature record from the eastern equatorial Pacific, indicates that, in the early Pliocene, the east-west asymmetry in sea surface temperature and thermocline depth was reduced compared to today and the tropical Pacific was in a permanent El Niño–like state. Thus, the "normal" mean state of the modern tropical Pacific is not a persistent feature of Earth's climate over long time scales.

INTRODUCTION

Studies of the El Niño Southern Oscillation (ENSO) phenomenon indicate that, through atmospheric teleconnections, small changes in the pattern of tropical Pacific sea surface temperature (SST) have a global impact on interannual time scales (Alexander et al., 2002). Although the mechanisms responsible for the ENSO do not directly apply to studies of climate changes on longer time scales, ENSO events provide a clear example of how changes in the distribution of SST across the Pacific Ocean can have far-field climate effects such as higher than average rainfall in the southwestern United States and higher than average temperature in temperate regions of North America. The potential global effect of small, long-term changes in the tropical SST pattern is substantiated by modeling studies (Yin and Battisti, 2001; Barreiro et al., 2005). However, while the impact of changes in the mean SST pattern of the tropical Pacific on global climate is recognized, the circumstances under which they could occur are difficult to predict. For example, in simulations of future climate change forced with enhanced greenhouse gases, climate models do not give consistent results in the tropical Pacific: some predict no long-term changes; some predict El Niño–like mean conditions; still others predict La Niña–like mean conditions (Cane, 2005; Collins, 2005). Because the instrumental record is too short to examine multidecadal and longer-term climate changes, paleoceanographic studies are needed to establish whether modern mean tropical SST patterns across tropical basins are stable over long time periods. These data-based studies can then be used to test and improve theoretical and computer models of long-term climate change, including those that are used to predict future climate change.

While much can be learned from studying the extreme globally cool climate of the Last Glacial Maximum (LGM), it is also important to focus on past periods of global warmth prior to the ice ages of the past few million years. Paleoceanographic studies generally indicate that the mean SST of the Pacific tropical ocean was stable within a few degrees over millions of years, yet these studies rarely include enough data to characterize the east-west SST difference across the Pacific. For example, the Pliocene warm period (ca. 4.5–3.0 Ma) (Fig. 1) has been the focus of much interest among paleoclimatologists because of the need to understand climate processes in past times of global warmth. Landmark studies, such as those by the Pliocene Research, Interpretation, and Synoptic Mapping (PRISM) group, including compilations of oceanic and terrestrial data (Dowsett et al., 1996, 2005; Thompson and Fleming, 1996) and modeling studies (Haywood et al., 2000; Sloan et al., 1996), indicate that the Pliocene was significantly warmer than today, especially in extratropical regions. However, the PRISM reconstructions include very little data from the tropical Pacific Ocean and therefore do not provide insight into changes in tropical SST patterns. Crowley (1996) pointed out the urgent need for more tropical data in order to further constrain the mechanisms that explain global climate conditions in the Pliocene, and in the last decade, several studies were conducted that focus on the tropical Pacific utilizing Pliocene-age material obtained by the Ocean Drilling Program.

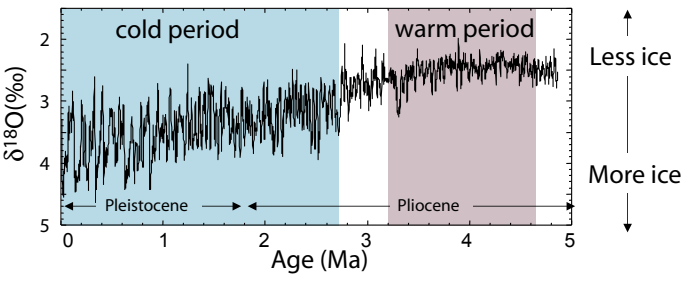

Figure 1. Benthic foraminifera $\delta^{18}O$ record of high-latitude climate (primarily ice volume) from Ocean Drilling Program (ODP) Site 677 (Shackleton et al., 1990) and ODP Site 1085 (Andreasen, 2001). The end of the Pliocene warm period and the onset of Northern Hemisphere glaciation occurred ca. 3.0 Ma.

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The purpose of our study is to present a comprehensive view of tropical Pacific conditions during the Pliocene warm period that takes into account the most recent results in order to assess the importance of tropical conditions in determining Pliocene warmth. Overall, recent results indicate that in the Pliocene warm period the pattern of SST across the Pacific was quite different and resembled a permanent El Niño–like mean state (Wara et al., 2005). Because of the need for multiproxy studies, we have generated a new SST record, based on alkenone-paleothermometry, to confirm the Mg/Ca-based estimates of warmer than modern SSTs in the eastern equatorial Pacific. In addition, a compilation of paleoceanographic reconstructions of the subsurface (~100 m below sea level) shows that the permanent El Niño–like state was coupled to a deeper or warmer thermocline in the east equatorial Pacific, indicating that thermocline conditions may play an important role in determining the long-term mean state of the tropical Pacific.

EAST-WEST ASYMMETRY OF THE MODERN TROPICAL PACIFIC OCEAN

During "normal" conditions in the modern tropical Pacific Ocean, easterly trade winds drive the flow of equatorial currents from the east to the west, resulting in a thick, warm, mixed layer in the western equatorial Pacific underlain by a deep (~200–400 m) thermocline, the steep thermal gradient between the warm, mixed layer above and the cooler water below (Fig. 2). In the eastern equatorial Pacific, the thermocline is relatively shallow (~50 m). The easterly trade winds drive divergent upwelling along the equator, causing SST to be relatively cool only in the eastern equatorial Pacific where the thermocline is shallow; in the western equatorial Pacific, SSTs remain warm because cool subsurface waters within and beneath the thermocline are deep. Thus, as a result of the easterly trade winds and a shallow thermocline in the east relative to the west, there is a strong east-west SST difference across the equatorial Pacific (~5 °C during normal conditions). Sinking air and dry conditions over the eastern equatorial Pacific due to cooler SST and rising air and relatively high precipitation rates over the western equatorial Pacific due to warmer SST result in a sea level pressure (SLP) gradient that enhances the easterly trade winds, which further augments the east-west SST contrast, SLP and precipitation gradients, winds, and so on. The atmospheric circulation cell, comprised of easterly trade winds, rising air in the western equatorial Pacific, westerly flow

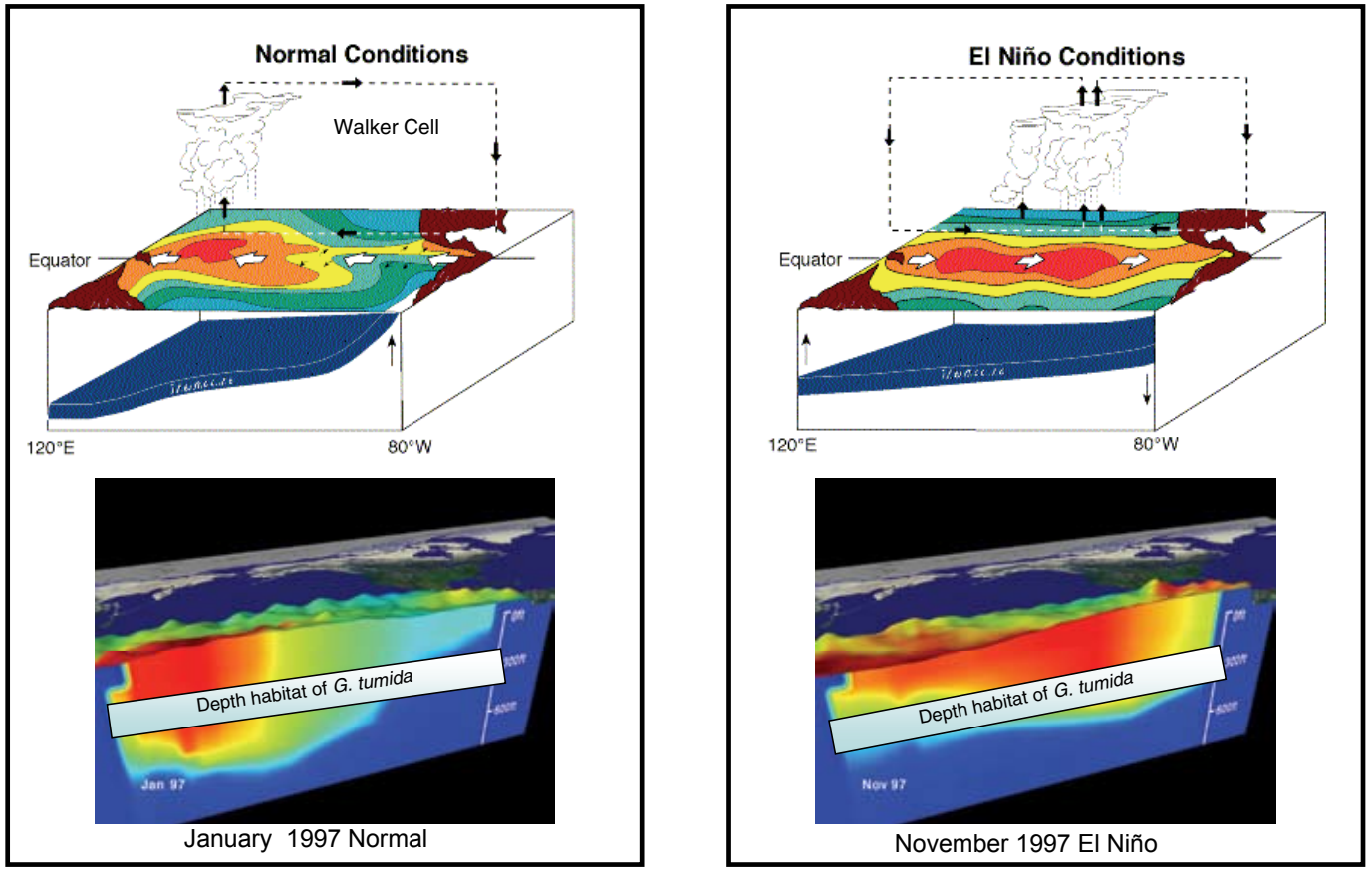

Figure 2. Comparison of normal and El Niño conditions in the modern ocean (adapted from the National Oceanic and Atmospheric Administration [2005] El Niño Web site, www.pmel.noaa.gov/tao/elnino). Schematic of normal conditions includes strong Walker circulation or convective loop and strong east-west temperature gradient and thermocline tilt (upper left); schematic of El Niño conditions includes weakened Walker circulation, temperature gradient, and thermocline tilt (upper right). Lower left: equatorial Pacific cross sections of temperature prior to El Niño (January 1997), when subsurface temperature gradient is relatively large; lower right: during an El Niño (November 1997), when subsurface temperature gradient is relatively small. Sea surface height is represented by bumps. Temperature range is from 30 °C (red) to 8 °C (blue). The thermocline is approximately at the 20 °C isotherm (the border between dark blue and cyan). The depth habitat of *G. tumida*, the species used to monitor subsurface temperature, is indicated.

aloft, and sinking air over the high SLP region in the eastern equatorial Pacific, is called Walker circulation (Fig. 2). Air-sea feedbacks maintain a strong Walker circulation and the asymmetric pattern of conditions across the equatorial Pacific, which is the stable mean state of the tropical Pacific today.

An El Niño event, which occurs every few years, includes the temporary breakdown of Walker circulation accompanied by a more symmetrical pattern of SST, SLP, and thermocline depth across the Pacific (Fig. 2). In addition, rainfall patterns change with relatively dry conditions (drought) in the western equatorial Pacific and high rates of precipitation in the eastern equatorial Pacific. ENSO events are considered to be extreme swings, or interannual variability, superimposed on the stable mean zonally asymmetric state described above. Much less is known about decadal and longer time scale oscillations and trends. Although tropical climate signals may also have decadal variability (Liu and Huang, 2000; Philander and Fedorov, 2003a), the instrumental record is too short to allow differentiation between decadal variability and long-term shifts. Thus, it is not clear whether changes in the mean state are related to the global warming of the last century.

Both decadal-scale variability and longer-term changes in the mean tropical climate could be related to changes in the subsurface thermocline, which could influence SST in upwelling regions. For example, when the thermocline is relatively deep, the SST in the eastern equatorial Pacific would be relatively warm, and vice versa. Factors that might influence the thermocline over long time scales are the latitudinal temperature gradient (Boccaletti et al., 2004), the latitudinal salinity gradient (Fedorov et al., 2004), and mid-latitude winds in the region where water is subducted into the thermocline (Liu and Yang, 2003; Sun et al., 2004). Displacement of the thermocline over long time scales could cause changes in SST in upwelling regions, such as the eastern equatorial Pacific, thereby altering the mean tropical Pacific climate state. Whether or not this could happen in the future is unknown; there may or may not be feedbacks that, regardless of the forcing or perturbation, keep Walker circulation strong and stable on average and prevent tropical conditions from deviating from its current asymmetric pattern. Geologic studies of past warm periods that monitor changes in the west-east asymmetry of SST and thermocline depth, and by inference the strength of Walker circulation, can be used to assess the long-term stability of tropical Pacific climate and the factors that might be responsible for long-term changes in mean conditions if they occurred.

EVIDENCE FOR REDUCED EAST-WEST ASYMMETRY DURING THE PLIOCENE

Foraminifera Assemblages

Sediment cores recovered during Ocean Drilling Program (ODP) Leg 130 in the western equatorial Pacific and Leg 138 in the eastern equatorial Pacific have been used to characterize open ocean conditions across the Pacific in a number of different studies published over the past ten years or so. The first study (Chaisson, 1995) to focus on development of east-west gradients across the Pacific during the Pliocene and Pleistocene utilized planktonic foraminifera assemblages in the western equatorial Pacific (ODP site 806) and eastern equatorial Pacific (ODP site 847) (Fig. 3). In the tropics, planktonic foraminifera mainly grow in the upper 100–150 m of the water column and are depth stratified. Census counts of an assemblage can be used to determine changes in surface and subsurface conditions. In the modern ocean, there is a strong asymmetry in the planktonic foraminifera assemblages across the Pacific, with species that thrive in the mixed layer dominating the western equatorial Pacific, where the mixed layer is thick and occupies the entire photic zone (upper 100–150 m). In the eastern equatorial Pacific, where cool nutrient-rich water upwells into the photic zone and stimulates biological productivity, the assemblages are more diverse and include mixed-layer species as well as those indicative of higher levels of productivity (Andreasen and Ravelo, 1997).

Chaisson (1995) showed that planktonic foraminifera assemblages in the western equatorial Pacific were more similar to those in the eastern equatorial Pacific during the early Pliocene relative to today, indicating that the east-west asymmetry of upper ocean conditions in the early Pliocene was reduced compared to today. The abundances of foraminifera species indicative of productivity increased throughout the Pacific just after 4.0 Ma, but the strong east-west difference in assemblages found today developed after ca. 3.0 Ma and intensified at the beginning of the Pleistocene epoch (ca. 1.6 Ma). These results indicate that in the Pliocene warm period, there were weak easterly trade winds on the equator (much like during an El Niño) and that modern-like east-west asymmetry in SST and thermocline depth must have developed as global climate cooled (Chaisson, 1995). Because many of the species Chaisson (1995) used are now extinct, he had to make a number of assumptions about paleoecology and depth habitat and his results are not quantitative. To better quantify changes in

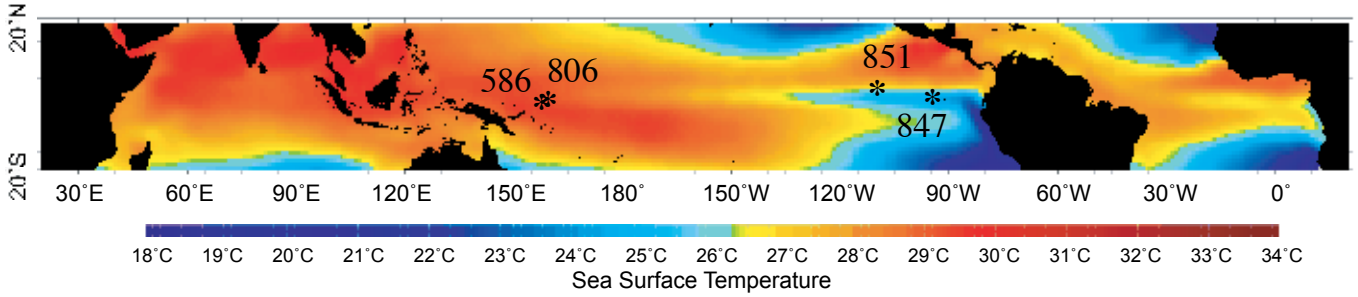

Figure 3. Sea surface temperature (SST) map (October climatology) of the tropical Pacific (Reynolds and Smith, 1994). Change in the strong SST gradient across the equatorial Pacific is monitored in this paper by using Deep Sea Drilling Project Site 586 (0.50°S, 159°E, 2507 m), Ocean Drilling Program (ODP) Site 806 (0°N, 159°E, 2520 m), ODP Site 847 (0°N, 95° W, 3373 m), and ODP Site 851 (3°N, 111°W, 3761 m).

the east-west surface and subsurface temperature differences across the tropical Pacific through the Pliocene, the application of geochemical measurements is required.

Geochemical Sea Surface Temperature Estimates

Geochemical measurements of planktonic foraminifera shells can be used to constrain changes in surface ocean conditions across the tropical Pacific. One of the most common tracers of climate change is oxygen isotope measurement ($\delta^{18}O$) of foraminifera shells. Because $H_2{}^{16}O$ evaporates more readily than $H_2{}^{18}O$, the $\delta^{18}O$ values of water vapor, cloud droplets, precipitation, and continental ice are low compared to that of seawater. Thus, the $\delta^{18}O$ of seawater is influenced by changes in local salinity, which reflects hydrological processes (evaporation minus precipitation) and changes in ice volume. The offset between the $\delta^{18}O$ composition of foraminiferal calcite ($CaCO_3$) and the $\delta^{18}O$ of seawater in which they calcify is temperature dependent. Thus, foraminiferal $\delta^{18}O$ values reflect multiple environmental parameters. Since the exact history of ice volume over the past 5 m.y. is not well known, it is most useful to look at differences between $\delta^{18}O$ records, which are not influenced by the shared variance related to ice volume fluctuations. The difference between two $\delta^{18}O$ records therefore reflects local changes (in salinity and temperature) at one location relative to another.

$\delta^{18}O$ measurements of *G. sacculifer* (without the sac-like final chamber), a species that calcifies in the surface mixed layer, from ODP sites 851 and 847 in the eastern equatorial Pacific and ODP site 806 and Deep Sea Drilling Project (DSDP) site 586 in the western equatorial Pacific, indicate that the east-west differences in local conditions (salinity and temperature) were smallest in the early Pliocene and increased ca. 1.7 Ma (Fig. 4A). The scatter of data around the smoothed curve mainly reflects glacial to interglacial changes, but there is a clear increase in the long-term average $\delta^{18}O$ difference between the eastern equatorial Pacific and the western equatorial Pacific. If this data were interpreted solely as reflecting changes in surface temperature, they would indicate the absence of an east-west SST difference across the Pacific and therefore an absence of Walker circulation in the early Pliocene. After ca. 1.7 Ma, the $\delta^{18}O$ data indicate that the SST difference increased to ~5 °C, much like the modern ocean. However, changes in precipitation or evaporation could also have occurred, thereby influencing the $\delta^{18}O$ records at either or both sites. As such, it is important to apply additional proxies that more directly reflect past ocean temperature.

Two recent studies (Rickaby and Halloran, 2005; Wara et al., 2005) include analyses of magnesium to calcium ratios (Mg/Ca) measured in planktonic foraminifera shells at two sites, ODP site 806 in the western equatorial Pacific and ODP site 847 in the eastern equatorial Pacific. The incorporation of Mg relative to Ca into foraminiferal calcite shells varies exponentially with calcification temperature (Anand et al., 2003; Dekens et al., 2002; Nürnberg et al., 1996). Records of Mg/Ca measured on shells of *G. sacculifer* (without the sac-like final chamber) from the western equatorial Pacific and the eastern equatorial Pacific can be used to quantitatively reconstruct the east-west SST difference by applying a Mg/Ca-temperature calibration (Dekens et al., 2002) (Fig. 4B and 4C). The results indicate

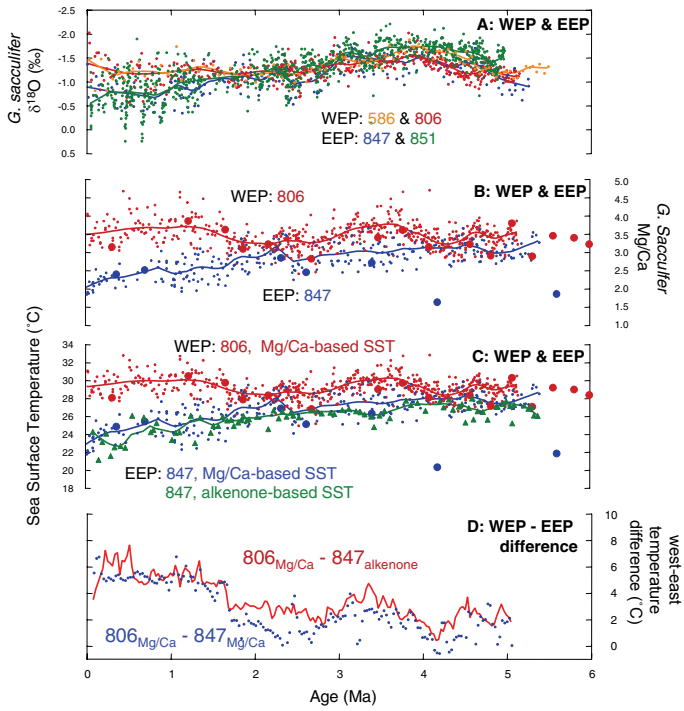

Figure 4. (A) Planktonic (*G. sacculifer* without sac-like final chamber) foraminifera $\delta^{18}O$ records from two western equatorial Pacific (WEP) locations: Deep Sea Drilling Project site 586 (orange) (Whitman and Berger, 1992) and Ocean Drilling Project (ODP) site 806 (red) (Chaisson and Ravelo, 2000; Wara et al., 2005) and two eastern equatorial Pacific (EEP) locations: ODP site 847 (blue) (Chaisson and Ravelo, 2000; Wara et al., 2005) and ODP site 851 (Cannariato and Ravelo, 1997). (B) Planktonic (*G. sacculifer* without sac-like final chamber) foraminifera Mg/Ca records from the western equatorial Pacific location, ODP site 806 (red), and eastern equatorial Pacific location, ODP site 847 (blue). Small dots and smoothed line are data from Wara et al. (2005); large dots are data from Rickaby and Halloran (2005). (C) Sea surface temperature (SST) (°C) estimates for the western equatorial Pacific site 806 (red) and eastern equatorial Pacific site 847 (blue) based on Mg/Ca records (shown in B) using Dekens et al. (2002) calibration and for the eastern equatorial Pacific site 847 (green) based on $U^{k'}_{37}$ measurements (this study). (D) The west minus east SST difference record calculated by subtracting the site 847 Mg/Ca-based SST record from the site 806 Mg/Ca-based SST record (blue) (adapted from Wara et al., 2005) and by subtracting the site 847 alkenone-based SST record from the site 806 Mg/Ca-based SST record (red).

that the eastern equatorial Pacific was ~2.5 °C warmer and the western equatorial Pacific was ~2 °C cooler in the warm Pliocene compared to today. The east-west SST difference was only ~1.5 °C in the warm Pliocene and increased to ~5 °C after ca. 1.7 Ma (Wara et al., 2005) (Fig. 4D). Concordance of the Mg/Ca measurements of *G. sacculifer* with that of *G. ruber* (Medina-Elizalde and Lea, 2005) at the western equatorial Pacific site indicate that results are not dependent on the choice of surface-dwelling planktonic foraminiferal species. A few outlier data points in the eastern equatorial Pacific (ODP site 847) from the Rickaby and Halloran (2005) study are offset from the data from the same site and time period generated by Wara et al. (2005). These outliers cannot be explained by systematic differences between the two laboratories since all other data from the two studies agree. Both groups used the same procedure to clean foraminifera shells, and the Wara et

al. group participated in an international lab comparison and calibration (Rosenthal, 2004) and found that their data were close to the median of all labs. In sum, of several hundred Mg/Ca measurements used to characterize the east-west SST difference across the tropical Pacific, there are only a few outliers, and only one in the Pliocene. Thus, we conclude that there is strong evidence, based on Mg/Ca data, for a reduced east-west SST difference indicative of weak zonal asymmetry and Walker circulation during the warm Pliocene compared to today.

Another proxy that has been used extensively in paleoceanographic studies is the alkenone unsaturation index ($U^{k'}_{37}$), which has a strong correlation with ocean temperatures in the modern ocean and has been extensively calibrated (Herbert, 2001). The $U^{k'}_{37}$ index utilizes long-chain (C_{37}) ketones synthesized by certain species of phytoplankton (coccolithophorid algae) and found in the organic fraction of the sediment. It is thus an indicator of past SST that is completely independent from the Mg/Ca proxy, which is measured on calcite shells. Our new analyses of $U^{k'}_{37}$ in sediments from the eastern equatorial Pacific (ODP site 847) (following the protocol described in Herbert et al., 1998) indicate that the eastern equatorial Pacific was warmer in the early Pliocene compared to today, corroborating SST reconstructions based on Mg/Ca data from the same site (Fig. 4C). The absolute temperatures of the $U^{k'}_{37}$ and Mg/Ca based temperature records at the eastern equatorial Pacific site depend on the calibrations used. In our study, we use commonly accepted calibrations for these environments and species: Dekens et al. (2002) for converting Mg/Ca to SST and Müller et al. (1998) for converting $U^{k'}_{37}$ to SST. Our chosen calibrations result in reasonable absolute temperatures when applied to Holocene sediments from these locations. Most notably, the magnitude of the cooling with time, which is not dependent on the chosen calibration, is similar, with both proxies predicting that the eastern equatorial Pacific was on average ~4 °C warmer in the warm Pliocene (from ca. 5 to 2.5 Ma) compared to the Pleistocene (from 1.6 to 0 Ma) and ~2.5 °C warmer compared to today. The $U^{k'}_{37}$-based SST reconstruction is further evidence that the single early Pliocene Mg/Ca data point at ca. 4.2 Ma (Fig. 4B and 4C) generated by Rickaby and Halloran (2005) does not represent the average SST conditions in the eastern equatorial Pacific during that time.

In the warm Pliocene, it was cooler in the western equatorial Pacific while it was warmer in the eastern equatorial Pacific, so that the average tropical Pacific temperature may have been a bit warmer. The few existing planktonic foraminifera assemblage–based SST estimates from the tropical Pacific (Dowsett et al., 2005) indicate that tropical temperatures were not warmer than today, but these estimates do not resolve spatial patterns across the Pacific and do not include data from the eastern equatorial Pacific. Overall, while more data are needed to quantify the average tropical Pacific temperature, there is clear evidence that east-west asymmetry in SST, and by inference Walker circulation, was reduced during the Pliocene warm period compared to today.

Geochemical Thermocline Depth Estimates

As described, analyses of Mg/Ca in *G. sacculifer* (without the sac-like final chamber) and of $U^{k'}_{37}$ in the organic fraction of the sediments support Chaisson's (1995) idea that the modern east-west asymmetry of the tropical Pacific developed through the Pliocene and into the Pleistocene. Chaisson (1995) further argued that changes in foraminiferal abundances reflect changes in subsurface conditions and the depth of the thermocline, and that the modern tilt of the thermocline, from shallow in the east to deep in the west, developed through the Pliocene and Pleistocene. Establishing linkages between the evolution of the thermocline and changes in SST are critical for understanding the processes and conditions responsible for El Niño–like conditions in the warm Pliocene.

Geochemical evidence for changes in thermocline conditions through the Pliocene and Pleistocene consists of $\delta^{18}O$ (and limited Mg/Ca) measurements of shells of species of planktonic foraminifera that live and calcify in the subsurface. In the western equatorial Pacific, a compilation of $\delta^{18}O$ data from a number of studies (Billups et al., 1999; Chaisson and

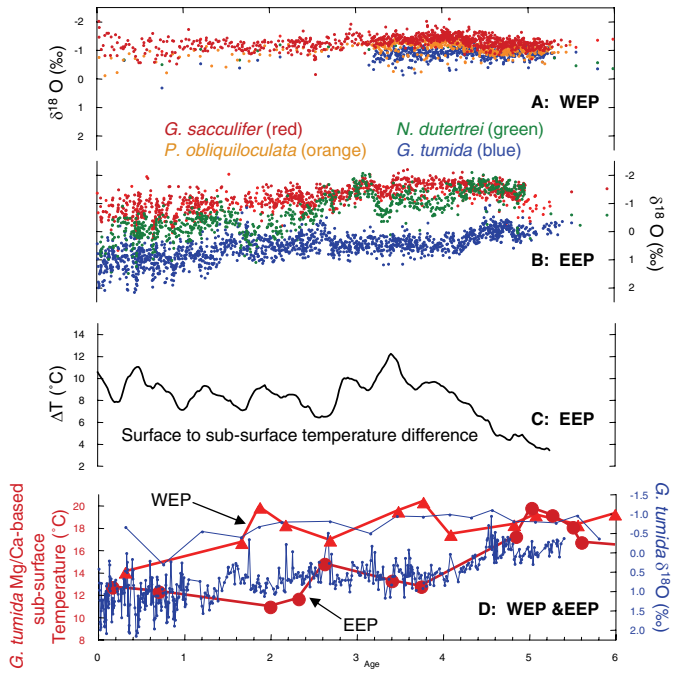

Figure 5. (A) Oxygen isotopic records of multiple species of planktonic foraminifera at western equatorial Pacific (WEP) Deep Sea Drilling Project site 586 and Ocean Drilling Project (ODP) site 806 (data from Whitman and Berger, 1995; Chaisson and Ravelo, 2000; Billups et al., 1998; Wara et al., 2005). (B) Oxygen isotopic records of multiple species of planktonic foraminifera at eastern equatorial Pacific (EEP) ODP site 847 and 851 (data from Chaisson and Ravelo, 2000; Cannariato and Ravelo, 1997; Wara et al., 2005). (C) Difference (Δ °C) between the calcification temperatures of *G. sacculifer* (without sac) and *G. tumida* at eastern equatorial Pacific ODP site 847 calculated by assuming that the difference between their $\delta^{18}O$ entirely reflects temperature and that $\Delta\delta^{18}O/0.21$ = Δ °C. Calculated by subtracting 0.2 Ma Gaussian (~35 data points per window) smoothed curves derived from *G. sacculifer* and *G. tumida* data in (B). (D) Comparison of subsurface conditions between western equatorial Pacific ODP site 806 and eastern equatorial Pacific ODP site 847. Oxygen isotope measurements of *G. tumida* (blue) from sites 806 (Chaisson and Ravelo, 2000) and 847 (Wara et al., 2005) and subsurface temperature estimates (red) are based on the Mg/Ca of *G. tumida* from 806 and 847 (Rickaby and Halloran, 2005). Both the $\delta^{18}O$ and the Mg/Ca-based temperature records indicate cooling of the subsurface water (especially in the eastern equatorial Pacific) through the Pliocene as the thermocline shoaled.

Ravelo, 2000; Wara et al., 2005; Whitman and Berger, 1992) indicates that the range of $\delta^{18}O$ among surface and subsurface dwelling foraminifera was always relatively small (no more than ~2‰) over the past 6 m.y. (Fig. 5A). A small $\delta^{18}O$ range among species that grow at different depths suggests that the assemblage was calcifying over a relatively small temperature and salinity range; this would be expected when cool water in and beneath the thermocline was below the photic zone where foraminifera proliferate. The $\delta^{18}O$ data therefore indicate that the mixed layer and thermocline were deep in the western equatorial Pacific throughout the Pliocene and Pleistocene. It is not possible to precisely quantify thermocline depths below the photic zone since the foraminifera species analyzed live mainly in the photic zone, and the $\delta^{18}O$ composition of their shells would not have been sensitive to fluctuations in thermocline depth below the photic zone.

The $\delta^{18}O$ measurements of multiple species in the eastern equatorial Pacific (Cannariato and Ravelo, 1997; Chaisson and Ravelo, 2000; Wara et al., 2005) indicate that there have been changes in thermocline conditions over the past 6 m.y. Specifically, the range of $\delta^{18}O$ among species was less during the interval from ca. 6 to 4.3 Ma compared to the time interval from 4.3 to 0 Ma (Fig. 5B). This indicates that the thermocline was deeper (or warmer) until ca. 4.3 Ma, after which time it shoaled or cooled, thereby bathing the deep-dwelling foraminifera in cooler water. A close look at the *N. dutertrei* record indicates that there may have been a number of changes to the thermocline structure throughout the Pliocene. But the interpretation of the *N. dutertrei* record is confounded by its erratic depth ecology and the fact that the data older than ca. 3.0 Ma are from measurements of its ancestor, *N. humerosa* (Cannariato and Ravelo, 1997), a species whose test is generally smaller in size and whose depth ecology may have been different from that of *N. dutertrei*. More straightforward reconstructions of thermocline depth can be made using *G. tumida*, a species that seems to consistently grow near the bottom of the photic zone (~100 m) (Ravelo and Fairbanks, 1992). *G. tumida* $\delta^{18}O$ values relative to those of the surface dwelling species, *G. sacculifer* (without the sac-like final chamber), reflect the difference in calcification temperature between the two species and indicate that subsurface water at ~100 m was ~5 °C warmer in the earliest Pliocene relative to today, reflecting a deeper thermocline (Fig. 5C).

Mg/Ca measurements of *G. tumida* provide a more quantitative estimate of subsurface temperature changes and agree with the interpretations based on $\delta^{18}O$ of multiple species. Mg/Ca data were used to generate low-resolution subsurface temperature records from the western equatorial Pacific (ODP site 806) and eastern equatorial Pacific (ODP site 847) (Rickaby and Halloran, 2005) (Fig. 5D). Their data indicate that while early Pliocene subsurface temperatures in the western equatorial Pacific were similar to today, they were 4–5 °C warmer than today in the eastern equatorial Pacific (Fig. 5D), in agreement with the $\delta^{18}O$ of *G. tumida* data. The warm subsurface temperatures in the eastern equatorial Pacific during the early Pliocene resemble conditions in the western equatorial Pacific today where the thermocline is relatively deep. The interpretation of Rickaby and Halloran (2005), that the warm early Pliocene subsurface temperatures in the eastern equatorial Pacific are an indication of a relatively shallow thermocline, is not supported given the depth ecology of *G. tumida* (Niebler et al., 1999; Ravelo and Fairbanks, 1992). Instead, warm calcification temperatures of *G. tumida* indicate that the cool thermocline was deep, below the depth habitat of *G. tumida*. Furthermore, the Mg/Ca data indicate that, during the earliest Pliocene, the subsurface temperature in the eastern equatorial Pacific was so warm that it was similar to that in the western equatorial Pacific (close to 17 or 18 °C), much like it is during an El Niño event (Fig. 2), again attesting to the symmetry of conditions across the equatorial Pacific during the early Pliocene warm period.

The east-west subsurface temperature difference (and therefore thermocline depth), as indicated by the Mg/Ca and $\delta^{18}O$ data of *G. tumida* (Fig. 5D), and east-west surface temperature difference, as indicated by the Mg/Ca and $\delta^{18}O$ data of *G. sacculifer* (Fig. 4), increased through the Pliocene as global climate cooled. As would be expected, development of surface and subsurface east-west asymmetry go hand-in-hand because as the thermocline shoaled in the eastern equatorial Pacific, it influenced SST through upwelling. Walker circulation, sustained by air-sea feedbacks that depend on the east-west difference in SST, must have also increased through the Pliocene.

SUMMARY AND IMPLICATIONS

Compilation of data from across the tropical Pacific indicates that surface and thermocline conditions were similar on both sides of the basin, resembling a permanent El Niño, during the warm Pliocene, and that the modern-day east-west asymmetry of the equatorial Pacific developed through the Pliocene as climate cooled. What are the global implications of this transition in tropical Pacific conditions over the past 5 m.y.? The transition is thought to have a global impact on terrestrial climate because data-based reconstructions of continental climate anomalies during the early Pliocene compared to today have an El Niño–like fingerprint (Molnar and Cane, 2002); however, the nature of teleconnections between tropical and extratropical regions that operate over long time scales will need further investigation. Observational data support the idea that the depth of the thermocline determines the strength of air-sea interactions that sustain Walker circulation with far-field global effects (Philander and Fedorov, 2003b). More specifically, shoaling of the thermocline in the eastern equatorial Pacific occurred as the amplitude of glacial-interglacial cycles increased; it appears that as the thermocline shoaled, air-sea coupling increased, and the feedbacks that amplify solar forcing of glacial-interglacial cycles were strengthened (Ravelo et al., 2004). Studies that show further strengthening of the east-west SST difference across the Pacific at the mid-Pleistocene transition (de Garidel-Thoron et al., 2005; McClymont and Rosell-Melé, 2005; Medina-Elizalde and Lea, 2005) also attest to the possible role of tropical Pacific air-sea interactions in the amplification of climate variability.

The theoretical link between strong Walker circulation and global climate conditions has been explored in modeling studies that speculate that northern hemisphere cooling and glaciation could be intimately tied to changes in the tropical Pacific mean state. These studies indicate that tropical-extratropical climate is linked in both directions. Low latitude regions are influenced by high latitude Pliocene boundary conditions through

atmospheric (Haywood and Valdes, 2004) and oceanic (Philander and Fedorov, 2003b) processes. In addition, permanent El Niño–like conditions can induce global warming through changes in global albedo (e.g., due to fewer low level stratus clouds in the eastern equatorial Pacific) (Barreiro et al., 2005). While there is growing evidence that permanent El Niño–like conditions are an important feature of the Pliocene global climate, there is still no widely accepted theory for how and why the tropical changes occurred in the first place. Comparisons of paleoclimatic records from various locations mainly in the northern hemisphere indicate that cooling occurred at different times in different regions, possibly because climatic and oceanic processes that link different regions or respond to perturbations and forcings are nonlinear, making it difficult to identify the ultimate cause of tropical reorganization, extratropical cooling, and Northern Hemisphere glaciation in the Pliocene (Ravelo et al., 2004; Raymo, 1994).

Regardless of the ultimate cause of cooling after the warm Pliocene, there is much we can learn from studying the early Pliocene warm period itself. Probably the most productive work in the future will come from paleoceanographers working together with climate theorists and modelers to understand the circumstances and conditions under which the long-term east-west tropical SST gradient and thermocline tilt can change, and the relationship of those changes to shorter-term climate variability. State-of-the-art atmosphere-ocean general circulation models predict a wide range of possibilities for how the mean state of tropical Pacific will change with greenhouse warming. However, if the models that simulate ENSO variability most accurately are to be believed, then the mean state should not change significantly (Collins, 2005). But do these same models have the ability to maintain reduced east-west SST and thermocline gradients as observed in the Pliocene? Attempts to model the warm Pliocene would be an excellent test of how well air-sea coupling, including parameterizations of physical processes, in the tropical Pacific is understood. Theoreticians could play a key role in developing strategies for data collection in order to constrain conditions in critical regions. Future observational studies documenting early Pliocene conditions must include (1) verification that SSTs in the western equatorial Pacific warm pool were not warmer than today; (2) reconstructions of latitudinal gradients that are also indicative of El Niño–like conditions; and (3) more detailed records of subsurface temperatures with more spatial resolution, because the three dimensional structure of the thermocline can lend insight into changes in surface currents and the wind field.

The fact that subsurface temperature changes, or thermocline conditions, were different in the early Pliocene warm period compared to today is an important clue that should be used to advance our understanding of how and why the mean state of tropical climate, and potentially global mean conditions and climate sensitivity, might change with time. In addition to the upwelling region in the eastern equatorial Pacific, subtropical upwelling regions in the Atlantic and Pacific were also warmer than present during the early Pliocene (Haywood et al., 2005; Herbert and Schuffert, 1998; Marlow et al., 2000), indicating that warm subsurface conditions due to a deeper thermocline were in fact a global characteristic of the warm Pliocene. This highlights the importance of future investigations of the processes that determine conditions in the global thermocline and their relevance for predicting global climate change.

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Information: Neil Suneson, Oklahoma Geological Survey, University of Oklahoma, 100 E Boyd St., Rm N131, Norman, OK 73019-0628, +1-405-325-3031, nsuneson@ou.edu

NORTHEASTERN SECTION

20–22 March 2006
Radisson Penn Harris Hotel and Convention Center
Camp Hill/Harrisburg, Pennsylvania
Information: Noel Potter, Dickinson College, Dept. of Geology, Carlisle, PA 17013-2896, +1-717-245-1340, pottern@dickinson.edu

SOUTHEASTERN SECTION

23–24 March 2006
Marriott Hotel, Knoxville, Tennessee
Information: Claudia Mora, University of Tennessee, Dept. of Earth and Planetary Sciences, 1412 Circle Drive, Knoxville, TN 37996-1410, +1-865-974-5499, cmora@utk.edu

NORTH-CENTRAL SECTION

20–21 April 2006
Student Center, University of Akron, Akron, Ohio
Early Registration Deadline: 20 March 2006
Information: John Szabo, Dept. of Geology, University of Akron, Akron, OH 44325-4101, +1-330-972-8039, jpszabo@uakron.edu

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Thurs.–Fri., 20–21 April, 11:30 a.m.–1 p.m.
Mann Mentors in Applied Hydrogeology Program:
Thurs., 20 April, 5–6:30 p.m.

NORTHEASTERN SECTION MEETING
Radisson Penn Harris Hotel and Convention Center
Camp Hill/Harrisburg, Pennsylvania
Shlemon Mentor Program Luncheons:
Mon.–Tues., 20–21 March, 11:30 a.m.–1 p.m.
Mann Mentors in Applied Hydrogeology Program:
Mon., 20 March, 5–6:30 p.m.

CORDILLERAN SECTION MEETING
University of Alaska, Anchorage, Alaska
Shlemon Mentor Program Luncheons:
Mon.–Tues., 8–9 May, 11:30 a.m.–1 p.m.
Mann Mentors in Applied Hydrogeology Program:
Tues., 9 May, 5–6:30 p.m.

SOUTHEASTERN SECTION MEETING
Marriott Hotel, Knoxville, Tennessee
Shlemon Mentor Program Luncheons:
Thurs.–Fri., 23–24 March, 11:30 a.m.–1 p.m.
Mann Mentors in Applied Hydrogeology Program:
Thurs., 23 March, 5–6:30 p.m.

ROCKY MOUNTAIN SECTION MEETING
Western State College, Gunnison, Colorado
Shlemon Mentor Program Luncheons:
Wed.–Thurs., 17–18 May, 11:30 a.m.–1 p.m.
Mann Mentors in Applied Hydrogeology Program:
Wed., 17 May, 5–6:30 p.m.

2004–2005 Congressional Science Fellow Final Report

Back to Academia: Lessons learned from a year on the Hill

Sarah K. Noble, *2004–2005 GSA–U.S. Geological Survey Congressional Science Fellow*

This is my final report for *GSA Today*. My adventures in Congress have ended, for now anyway. I am currently a post-doc at the National Aeronautics and Space Administration's (NASA) Johnson Space Center in Houston, which means that I have gone suddenly from writing NASA policy to living it.

After a year walking the hallowed halls of our nation's Capitol, I have chosen to return to academia. Believe it or not, I have chosen the road less traveled. Many congressional fellows have decided to stay in the policy arena. Some are continuing in the jobs they held as fellows; some are moving on to new jobs with lobbying firms or within agencies. To be sure, I am not alone: there are others going back to academia, but we are definitely the minority. DC, as it turns out, is a hard place to leave. The phenomenon is so common, it even has a name: Potomac fever. Though much less deadly than the avian flu, Potomac fever should not be underestimated—it is very difficult to shake once you're infected.

Returning to academia was not an easy decision for me. I thoroughly enjoyed my time on the Hill. The fellowship was everything I expected: challenging, thrilling, a wonderful learning experience. I leave knowing that I made a difference. I had an impact, a small impact maybe, but definitely an impact. So why am I leaving? I miss research. I miss doing science and the thrill of figuring something out that no one has ever figured out before. As exciting as working for Congress was, it doesn't match that thrill.

One month into my return to academia, I have found the transition to be in some ways easy and in other ways difficult. On the one hand, it's nice to again be surrounded by geologists; it feels comfortable, like the jeans and T-shirts I have returned to wearing after a year of suits and skirts. It is wonderful to be able to discuss science with people who know what I'm talking about and to not have to explain for the thousandth time that space weathering (my research) is not the same as space weather.

On the other hand, I find myself somewhat disoriented. I tried to keep up with my field last year, I really did. I spent many weekends doing science. I presented at a couple of conferences; I finished up revisions on a paper and got it published; I even reviewed an article or two. But, predictably, my efforts were not enough. I spent the first week of my post-doc finding and photocopying all the articles I should have read last year. The stack was two inches thick, double-sided—daunting, to say the least.

Reading through my research notes from last year, I find that they are now barely comprehensible to me. The notations and symbols that were second nature to me are now Greek (well, technically, some of them were Greek to begin with). There are cryptic notes in the margins that I am sure are important, and they are clearly in my handwriting, yet their significance escapes me. I remember somewhere hearing a rule of thumb that if you are away from your research for more than a year or two it is almost impossible to go back. I was gone for a year and a half, and I would say that that's a pretty good rule of thumb. Things are slowly coming back to me, and I am sure that in time I will be back up to speed as though I never left.

In my absence, academia hasn't changed much, but I have, in ways big and small. My view of my role as a scientist, of my role within NASA, of NASA's role in the world, has been altered. What does that mean for me, for my research, my career path? I'm honestly not sure yet.

I had forgotten how much slower the pace is in research. Deadlines are known weeks, even months, in advance (though that rarely stops us from waiting until the last minute). Not so in Congress. There, deadlines come fast and furious. Opportunities appear and disappear so capriciously, and an opportunity missed may not come again. I learned last year that fast but sloppy is often better than too slow to be useful. This, I am afraid, is something I may have to unlearn in the lab, where "sloppy" is almost never good.

Something I didn't even realize I missed until I returned: academia allows for—requires even—time for contemplation, time to think a problem through, to examine it from different angles, assess the evidence, and follow the logic. That kind of time is a luxury rarely afforded to congressional staffers. There are too many issues to dwell on any one topic for very long. Staffers often rely instead on others, like the national academies, to do our contemplating, and they do a great job, but knowledge that is handed to us is rarely appreciated as much as knowledge that is earned.

My short stint "in the real world" has also made me more appreciative of the great freedom we have as academics to pursue our own interests. Few other careers allow that; in fact, almost no one has as much freedom as a post-doc. That freedom is something I sincerely hope I don't squander during the next couple of years.

There are other lessons I will take away from my experiences. I learned that the members of Congress are people too. They have their own fears and ambitions, ideas and goals. They often work very long hours, and most of them genuinely want to do the best they can for their constituents and make the world a better place to live.

I learned that everything takes longer than you expect, no matter how low your expectations are. As frustrating as that can be at times, it's important to remember that our system of government was designed to be slow on purpose. It should be difficult to make something into a law.

I learned that science is only one factor in any given policy decision, and it is often not a major factor. Science tends to be used when it's convenient, when it supports an argument. When it doesn't support the argument, it is often ignored, discounted, or worse: warped until it does. Climate change science is a par-

ticularly troubling area right now: the Senate held a climate change hearing last fall with Michael Crichton, the science fiction author, as the expert witness. In the House, we saw something of a new low this year when Rep. Joe Barton, Chair of the Energy Committee, questioned the validity of peer-reviewed, published results and tried to intimidate the authors in order to discredit them. Things are not all bad, though. I found the House Science Committee to be something of an oasis: there, both science and scientists are respected. Scientists are listened to; their opinions carry weight. The Science Committee Chair, Rep. Sherwood Boehlert, was quick to condemn Rep. Barton for his actions. Still, even in our own little oasis, science was often trumped by economics or politics. Science has a vital role to play in making sound policy decisions, and it is up to us as scientists to make sure that our voices are heard, even if they are not always heeded.

As much as I missed science when I worked for Congress, now that I have returned to research, I miss policy. My friends and former colleagues in DC keep me fairly well informed about what is going on, and I am looking for ways to be more involved as a geologist, like going back to the Hill for congressional visits day and participating on GSA's Geology and Public Policy Committee. I realize now that you don't have to work for Congress to have an impact on science policy; you just have to be willing to put forward some effort. For now, I am quite happy to be doing research, yet I imagine the day will come when policy will lure me back to DC. I am not immune to Potomac fever.

This fellowship has been a fantastic experience; it has opened many doors and provided me with many opportunities. I am grateful to GSA and the U.S. Geological Survey for the opportunity. Thanks to the staff at GSA and the American Association for the Advancement of Science for all their support last year. Thanks also to the Science Committee staff, who were so welcoming and helpful to me, particularly Dick Obermann, my mentor and boss, who was endlessly patient and taught me so much.

This manuscript is submitted for publication by Sarah Noble, 2004–2005 GSA–U.S. Geological Survey Congressional Science Fellow, with the understanding that the U.S. government is authorized to reproduce and distribute reprints for governmental use. The one-year fellowship is supported by GSA and by the U.S. Geological Survey, Department of the Interior, under Assistance Award No. 04HQGR0168. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government. *Noble can be reached at sarah.noble@mail.house.gov.*

2005–2006 Congressional Science Fellow Report

Toto, I'm not in Kansas anymore: A geologist's observations of Capitol Hill

Nicole Gasparini,
2005–2006 GSA–U.S. Geological Survey Congressional Science Fellow

When I was nine years old, my family took a road trip around the southwestern United States. Because we visited such amazing sites as the Grand Canyon, Zion, and Bryce National Parks, Death Valley, and Canyon de Chelly, one might think this trip set in motion my career as a geomorphologist. If it did, it was a very slow start—what I remember most from that trip was the shocking discovery that some of the animals that lived in those parks were endangered and that species might disappear in my lifetime. I started a journal, recording the name of every endangered species I learned about, and promised myself that no animal would go extinct on my watch. Unfortunately, I was not able to keep my promise.

I have always been one to set ambitious, if not somewhat unrealistic, goals. When I learned last spring that GSA had selected me as this year's Congressional Science Fellow, I was thrilled. This was an opportunity I couldn't turn down. I obsessively follow politics, and I am passionate about environmental issues as well as the importance of research and education. I would definitely be able to do something important during my time with Congress. I just didn't know exactly what that "something important" would be.

As I was moving to Washington, D.C., I had my epiphany. Hurricane Katrina had just hit the Gulf Coast. Who better to attack the problem of how to reduce the destruction of future hurricanes and rebuild New Orleans than a fluvial geomorphologist? I imagined congressional offices clamoring for my services. I couldn't wait to start.

Before I could let the offices fight over me, I had to attend a two-week crash course on the federal government, run by the American Association for the Advancement of Science (AAAS), which runs the Congressional Fellows program. The course devoted an entire day to the budget. I was insulted. I was a math major as an undergraduate; I didn't need a whole day to learn about adding and subtracting numbers. Soon, however, I realized that the budget is more about politics, special interests, and constituents than it is about math. I learned quickly that I had a lot to learn.

After the orientation, the AAAS let us loose on Capitol Hill to find a congressional office in which to work for the year. Feeling a bit dazed and confused about how a bill becomes a law (hint: it's much more complex than a Saturday morning cartoon) but still fairly confident that I could accomplish something significant related to the rebuilding of New Orleans, I left my résumé with House, Senate, and Committee offices.

As I waited for the flood of calls, I had some time to attend hearings. The purpose of a hearing is to educate members of Congress and their staffs about issues pertinent to a committee. Experts give statements and answer questions from the committee members. I attended a hearing held by the Senate Committee on Environment and Public Works titled "The Role of Science in Environmental Policy Making." The star witness was Michael Crichton, a medical doctor with undergraduate and medical degrees from Harvard, but who is better known for writing science fiction. He talked about the degree of rigor in medical research and noted how "the protocols of climate science appear considerably more relaxed," asserting that "suspect values are deleted because a scientist deems them erroneous." I wondered if elected officials and others really think that scientists throw out data at whim.

Later in the hearing, William Gray, an atmospheric scientist at Colorado State University, gave his view of climate change. Gray presented a spaghetti diagram—a figure with lots of boxes and circles and crossing arrows—illustrating the complex interactions between atmosphere, land, and ocean. This diagram showed that, in Gray's words, "it is impossible to write computer code to represent such complexity and then realistically integrate hundreds of thousands of times steps into the future." After taking a semester-long graduate-level class on land-atmosphere interactions, I know this is not something Senators can grasp in 20 minutes, regardless of their intelligence. I use a numerical model to study landscape evolution; in my opinion, my bread-and-butter numerical models were being misrepresented. There were no other scientists at the hearing to present the other side of climate change science or explain how climate models are used.

In Gray's opinion, recent rises in global temperatures are almost solely the result of natural climate change. Senator Barbara Boxer countered Gray by pointing out that large, international, and reputable scientific societies like the American Geophysical Union (over 41,000 members) and the American Meteorological Society (over 11,000 members) have policy statements recognizing that human activities play a role in global climate change. Senator Hillary Rodham Clinton also pointed out that Crichton's critique of climate change is published in a fiction novel, not in a peer-reviewed scientific journal.

Gray, on the other hand, talked about how non-mainstream scientists need to keep their mouths shut or "be punished

if they do not accept the current views of their funding agents." I couldn't help but wonder if the nonscientists in the room understood the practice of peer review, for both publishing and obtaining funding. Those who have never been part of the funding and publishing race could be led to think that the current system is highly biased, that it doesn't allow for naysayers like those who, many years ago, wouldn't give in to the belief that Earth was flat. Maybe I'm an optimist, but I think the review system works fairly well.

Clearly, Capitol Hill is not academia. I started to wonder if I'd miscalculated about what I could accomplish as a scientist on "the Hill." In one of my interviews, the office staff told me that science doesn't play a role in policy and that many policy decisions are made in opposition to scientific studies. This office was an extreme exception; most offices were friendly and welcoming. However, no office was willing to make any statements about plans for rebuilding New Orleans, let alone about tackling longer-term issues like the destruction of wetlands or how broader problems, besides the breaching of levees, had contributed to the disaster.

My goals for this year have changed. While working in Congress, I hope to learn as much as I can about science policy and the legislative process. I will not be rebuilding levees or restoring habitat for endangered species. I've always intended to return to academia and integrate what I will have learned about policy this year into the science classroom. If I can grasp how science and scientists contribute to the policy-making process, I will be able to apply that to any number of issues for my students.

With this in mind, I decided to work in the office of Massachusetts Congressman Edward Markey. Markey's office has a long history of working with science fellows; some have even remained in his office as permanent staff after their fellowship year. I knew I was already a duck-out-of-water, so I decided to lessen the blow a bit by joining a science-friendly office. I've already been impressed with the office's general respect for scientists and scientific studies. This may seem trivial, but I've learned not to take anything for granted on the Hill.

Returning to endangered species, my original inspiration: in September 2005, the House passed the Threatened and Endangered Species Recovery Act of 2005. Congressman Richard Pombo, sponsor of the legislation, maintains that the Endangered Species Act (ESA) of 1973 needed fixing. Although many environmentalists agree that the ESA needs some changes, they also believe that Pombo's legislation could have devastating effects on endangered species. One criticism of the bill is that it requires the federal government to pay landowners for profits lost due to habitat protection. Many argue that this could be an incentive to build in areas with sensitive habitat. Pombo's bill must pass in the Senate before it becomes law. It is now in the hands of the Senate Committee on Environment and Public Works, the same committee before which Crichton and Gray appeared as expert witnesses. I may not see the end of this legislation before I leave Congress, and most likely I will not be able to save the endangered animals this year, but I will follow future hearings on the fate of this legislation.

This manuscript is submitted for publication by Nicole Gasparini, 2005–2006 GSA–U.S. Geological Survey Congressional Science Fellow, with the understanding that the U.S. government is authorized to reproduce and distribute reprints for governmental use. The one-year fellowship is supported by GSA and by the U.S. Geological Survey, Department of the Interior, under Assistance Award No. 05HQGR0141. The views and conclusions contained in this document are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government. Gasparini can be reached at nicole.gasparini@yale.edu.

FIELD FORUM SCHEDULED

Tectonic significance of vertical boundaries in the Cordillera

30 July–5 August 2006

A field investigation of the western Idaho shear zone, on the western edge of the Idaho Batholith in the area surrounding McCall, Idaho

Conveners:

Scott Giorgis, *Department of Geosciences, State University of New York–Geneseo, 1 College Circle, Geneseo, New York 14454, USA, giorgis@geneseo.edu*

Basil Tikoff, *Department of Geology and Geophysics, University of Wisconsin, Madison, Wisconsin 53706, USA, basil@geology.wisc.edu*

William McClelland, *Department of Geological Sciences, University of Idaho, Moscow, Idaho 83844-3022, USA, wmcclell@uidaho.edu*

Description: The objective of this field forum is to gather geoscientists from a variety of disciplines with a range of geographic expertise to examine a particularly well-exposed Cordilleran vertical boundary: the western Idaho shear zone. The western Idaho shear zone is a midcrustal exposure of a Late Cretaceous, lithospheric scale, intra-arc shear zone on the western edge of the Idaho Batholith. Our purpose is to gather a critical mass of geoscientists on the outcrop to debate the role of vertical boundaries in Cordilleran tectonics, with special emphasis on the Baja–British Columbia controversy. In particular, we will evaluate two hypotheses concerning the vertical boundaries in the Cordillera, and specifically the western Idaho shear zone: (1) the vertical boundaries are responsible for the northward translation of terranes; and (2) in contrast, the vertical boundaries dominantly record collision. To this end, we will examine the evidence for strike-slip–dominated kinematics vs. collisional kinematics and discuss the role of reactivation in reorienting preexisting kinematic indicators. The conveners encourage structural geologists, geochronologists, petrologists, paleomagnetists, geodesists, seismologists, and geochemists, and others with research interests in the processes associated with the initiation, development, and reactivation of vertical boundaries to participate. Researchers with an interest in the tectonic history of the North American Cordillera, from Baja to Alaska, modern or ancient, are encouraged to apply. Additionally, we invite those researchers with interest in vertical boundaries in other orogens from around the world. Our goal is to reflect on how a deeper understanding of the processes active at subvertical lithospheric-scale boundaries can refine our vision of the evolution of the North American Cordillera.

Outline: The conference is centered on a five-day field trip to examine exposures of the western Idaho shear zone near McCall, Idaho, followed by a half-day wrap-up and discussion session. Participants will fly into the Boise airport and travel by van two hours north to McCall. During the five days in the field, we will examine fabrics and their implications for the kinematics of deformation on the western Idaho shear zone, evidence for the timing of ductile deformation, and the timing and nature of extensional reactivation. We will devote at least one half-day session to presentations by participants.

Access: The majority of outcrops are on the sides of well-maintained Forest Service gravel roads. However, several stops require more substantial foot travel. Participants should be prepared to hike up to ~2.5 km on a backpacker's trail with

Lava Ridge looking north toward the Salmon River gorge. In the Miocene the Columbia River flood basalts (brown) poured out over this region, filling topographic lows and creating buttress unconformities with the underlying Cretaceous granites (white) of the western border zone of the Idaho Batholith.

an elevation gain of >1000 ft. McCall is at an elevation of ~5,000 ft; therefore, the hiking will be moderately strenuous. The longest hikes will occur toward the end of the conference, giving participants time to acclimatize.

Venue: The conference will be held at the University of Idaho–McCall Field Campus. Lodging consists of bunkhouse group-sleeping quarters with shared bathroom facilities. Meals will be provided in the mess hall on the field campus with bag lunches for the field day. Presentations by participants and the final wrap-up session will be held in yurt-style classrooms. The estimated registration fee of US$640 will cover transportation (van transport to and from the Boise airport), lodging, meals, and guidebook.

Application Deadline: 10 May 2006

Geoscientists of all specializations with an interest in Cordilleran tectonics and/or the tectonic processes active on vertical boundaries from orogens around the world are encouraged to apply. Potential participants should send a letter of application via e-mail to Scott Giorgis, giorgis@geneseo.edu, that includes a brief statement of interests and the relevance of the applicant's recent work to the themes of the meeting. Partial support is available to interested graduate students. Invitations will be e-mailed to participants by the end of May 2006.

Registrants with Special Needs: If you require special arrangements or have special dietary concerns, please contact on of the conveners. However, as noted above, applicants should keep in mind the physical demands inherent in the planned excursion.

UPCOMING AWARD DEADLINES

NOMINATIONS DUE

Funds supporting all but the national awards are administered by the GSA Foundation.

31 Mar. 2006:	**John C. Frye Environmental Geology Award.*** For details, follow the link at http://www.geosociety.org/aboutus/awards/ or see the October 2005 issue of *GSA Today*.
4 Apr. 2006:	**Don J. Easterbrook Distinguished Scientist Award.**** Quaternary Geology and Geomorphology Division. Send nominations to John E. Costa, U.S. Geological Survey, 1300 SE Cardinal Court, Bldg. 10, Suite 100, Vancouver, WA 98683, USA, jecosta@usgs.gov.
4 Apr. 2006:	**Farouk El-Baz Award for Desert Research.**** Quaternary Geology and Geomorphology Division. Send nominations to Jack F. Shroder, Jr., Dept. of Geography and Geology, University of Nebraska, Omaha, NE 68182-0199, USA, jshroder@mail.unomaha.edu.

*You may also contact Diane Lorenz-Olsen, Grants, Awards, and Recognition, P.O. Box 9140, Boulder, CO 80301-9140, USA, +1-303-357-1028, awards@geosociety.org.

**Award details are in the January 2006 issue of *GSA Today* and at http://www.geosociety.org/aboutus/awards/divisions.htm.

PENROSE CONFERENCE SCHEDULED

Arc Crustal Genesis and Evolution

9–15 July 2006

Valdez, Alaska

Conveners:

Peter Kelemen, *Columbia University, 58 Geochemistry Building, Lamont-Doherty Earth Observatory, Palisades, New York 10964, USA, +1-845-365-8728, peterk@ldeo.columbia.edu*

Brad Hacker, *Geological Sciences and Institute for Crustal Studies, University of California, Santa Barbara, California 93106-9630, USA, +1-805-893-9752, hacker@geol.ucsb.edu*

Description: Presentations will integrate recent results on well-exposed arc crustal sections—in the Jurassic Talkeetna arc in south-central Alaska and in the Cretaceous Ladakh-Kohistan arc in northern Pakistan and India—with important new developments in active-arc geochemistry, petrology, and geophysics. The Talkeetna and Ladakh-Kohistan arcs provide exposures of relatively complete sections from Moho depth (30–40 km in both cases) to volcanic rocks and volcaniclastic sediments. Both have been the subject of large, multidisciplinary projects over the past decade and provide depth sections and temporal progressions that are not accessible in active oceanic arcs.

Intensive, recent investigations of arc plutonic suites elsewhere complement these projects. New data from the U.S. National Science Foundation MARGINS Program, Sierra Nevada Continental Dynamics projects, Aleutian studies, and similar international initiatives provide constraints on crustal thickness and volcanic fluxes in active arcs. Advances in the study of melt inclusions have dramatically improved the understanding of volatiles in primitive arc magmas. Studies of ultra–high pressure metamorphic rocks and new experimental methods have yielded insights into mantle wedge melt generation and subduction zone dehydration and anatexis. This conference will provide an opportunity to synthesize these results, with a focus on using direct observations of arc crustal sections, from the uppermost mantle to the volcanics, to constrain arc processes and their role in the genesis and evolution of continental crust.

The enthusiastic response of the invited keynote speakers (only one out of twenty-four declined the request for letters of commitment) indicates to us that the time is right for this conference and that it will attract an excellent group of well-informed participants with much to discuss.

To complement research presentations, the conference will include at least two field trips to accessible outcrops of volcanic and the Moho sections of the Talkeetna arc. Depending on the level of interest, there may also be another (expensive, helicopter supported, multi-day) field trip to the Klanelneechina klippe, which will be open to participants with experience in backcountry travel in alpine terrain.

Tentative Schedule

Sunday, 9 July:	Bus trip from Anchorage; Sheep Mountain field trip along the way
Monday, 10 July:	Setting the stage: Alaska tectonics, geochronology, arc tectonics
Tuesday, 11 July:	Crustal bulk composition, conditions and processes of crystallization
Wednesday, 12 July:	Bernard Mountain field trip and informal discussions (all day)
Thursday, 13 July:	Metamorphic petrology, deformation, and arc geophysics
Friday, 14 July:	Crustal dynamics, mantle dynamics, melt production
Saturday, 15 July:	Bus trip back to Anchorage
Post-conference:	Possible multi-day field trip to Klanelneechina klippe

Field trips: 9 July: field trip to view outcrops of the volcanic section of the Jurassic Talkeetna arc, which is accessible via a short bushwhack from the highway about halfway between Anchorage and Valdez. 12 July: all-day field trip to view some Moho depth exposures of gabbronorite, mafic garnet granulite, pyroxenite, and residual harzburgite in the Talkeetna arc section, starting at a trailhead about two hours' drive from Valdez. Both field trips will involve some moderate, off-trail hiking (brush on 9 July, talus on 12 July). Trips are weather permitting; 15 July may serve as rain date for one of the trips.

We may also offer an optional (expensive, helicopter-supported) field trip to the lower crustal rocks of the Klanelneechina klippe for participants experienced in alpine backcountry travel. Lithologies record equilibration at ~700 °C and 7 kb and include garnet two-pyroxene quartz diorites (granulites) and garnet tonalite veins. Garnet is igneous in both of these lithologies, as revealed by heavy rare earth element enrichment. There are also variably retrograded granulite facies mylonites in the klippe. Let the conference conveners know if you are interested.

Application deadline: 31 March 2006

To apply: This Penrose Conference is limited to about 80 participants, and participants must apply to attend. Please contact the conveners by e-mail (peterk@ldeo.columbia.edu, hacker@geol.ucsb.edu) with a letter of intent that includes a brief statement of interests and the relevance of the applicant's recent work to the themes of the conference, the subject of a proposed presentation, and contact information. Interested graduate students are strongly encouraged to apply; partial support is available for student attendees from GSA. Once

you have been selected to participate, GSA will send you detailed registration information.

Travel and costs: Buses will meet participants at the Anchorage International Airport, and one or two downtown locations to be announced, on the morning of 9 July, and buses will return participants to these locations on 15 July in the afternoon or early evening. We will stay in the Best Western Valdez Harbor Inn, and the conference, together with lunches and dinners, will take place at the Civic Center in Valdez, one block from the Inn. Cost: US$1125 per person, round-trip from Anchorage, based on double occupancy. Those requesting a single room (limited availability) will be charged an additional US$350 for the week.

The relatively easy air access to Anchorage and the somewhat modest hotel make this an average cost for a Penrose Conference, despite the rather remote location. We are still in the process of applying for and allocating additional funding to help defray travel costs for some participants, so the price could go down. If cost is a major problem, making the difference between attending and not being able to come, please let the conference conveners know via e-mail.

Some participants may wish to make their own plans for travel back from Valdez to Anchorage; for example, via the Alaska State Ferry system from Valdez to Whittier (go to www.dot.state.ak.us/amhs/ for ferry information) and then by bus or train from Whittier through the new tunnel to Anchorage (www.themagicbus.com or www.alaskarailroad.com). ***If you choose this option,*** you may wish to make bookings on the train or bus as soon as you receive your registration confirmation because the public transportation can fill up with cruise-ship groups, and please notify the conference organizers via e-mail as soon as possible so that the cost for our scheduled bus transportation from Valdez to Anchorage can potentially be reduced.

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

Donna L. Russell, *Director of Operations*

THANK YOU FOR YOUR SUPPORT!

On behalf of the GSA Foundation Board of Trustees and the GSA Foundation staff, I would like to take this opportunity to express our sincere appreciation for your financial support throughout 2005. The Foundation ended fiscal year 2005 (July 2004–June 2005) with over 5,500 gifts, for a total of over US$1.1 million donated. The Foundation staff is working hard to make this success a reality in fiscal year 2006 as well; with your continued financial support, we can achieve our goal.

The Foundation has 84 funds that support a variety of programs and awards. One such fund is the Greatest Needs Fund, which provides support for a multitude of GSA programs, including the following over this past year:

- Research Grants—GSA's annual program to provide research grants to students;
- GeoCorps America™—a program that partners geoscience interns with our National Parks, National Forests, and Bureau of Land Management lands;
- Matching Student Travel Grants—provides matching dollars to the GSA Sections for student travel to Section meetings or the GSA Annual Meeting;
- GSA Public Service Award—given at the GSA Annual Meeting to recognize exceptional service to the Society;
- International Travel Grants—supports travel to GSA Annual Meetings through the International Division;
- Congressional Science Fellow—supports a geoscientist on the Hill in Washington, D.C.; and
- Miscellaneous—provides support for other programs, such as Education and Outreach, Publications, and Meetings.

We hope you will continue to give generously. Remember, any US$50 gift entitles you to a free copy of *GeoTales*, volume I or II. You may make a contribution by mail using the coupon below or go to www.geosociety.org and click on "Donate to GSA" to be transferred to a secure site that provides further information and options for donating.

As a special thank-you, a complete listing of our donors for 2005 is enclosed in this issue of *GSA Today*.

Most memorable early geologic experience:

As a twenty-year-old, I went on a research cruise to the Antarctic to collect geophysical data. For someone who had only been out of the country once before, this trip to glaciers, icebergs, and sea ice was an eye-opening trip to the end of the Earth.

—Bruce F. Molnia

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drussell@geosociety.org

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☐ $2,500 ☐ $1,000 ☐ $500 Other: $_____.
☐ Complimentary copy of *A Guide to Creative Planned Giving*
☐ Please send a copy of *GeoTales* ☐ volume I ☐ or volume II

PLEASE PRINT

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City/State/ZIP

Phone

The Geological Society of America

2005 OEST AWARD Recipients Named

GSA Congratulates Outstanding Earth Science Teachers

The National Association of Geoscience Teachers (NAGT) 2005 Outstanding Earth Science Teacher (OEST) Award recipients were announced in December 2005.

2005 Section Awardees

(No awardees were selected for the Central, Far Western, Midcontinent, and North-Central Sections.)

Bernard Picklo
Eastern Section
Bradford Area High School
Bradford, Penn.

Anita M. Honkonen
New England Section
Lincoln Sudbury Regional High School
Sudbury, Mass.

Lynda Sanders
Pacific Northwest Section
Sunset Middle School
Coos Bay, Ore.

Rose Lummus
Southeast Section
Dyersburg Middle School
Dyersburg, Tenn.

Chris Donovan
Southwest Section
Desert View High School
Tucson, Ariz.

Heather Marshall
Texas Section
Frisco High School
Frisco, Tex.

2005 OEST State Awardees

(No state awardees were selected for Minnesota.)

Ashley Allen
OEST Alabama
Oneonta High School
Oneonta, Ala.

Gregory Lee Bailey
OEST Georgia
Southeast Whitfield High School
Dalton, Ga.

Carole Sue Diehl
OEST Maryland
Fort Hill High School
Cumberland, Md.

Ray Kucklinca
OEST New Jersey
Moorestown High School
Moorestown, N.J.

Eugene Genova
OEST New York
Sachem High School
Holbrook, N.Y.

Kathy Bosiak
OEST North Carolina
Lincolnton High School
Lincolnton, N.C.

Ida Wideman
OEST South Carolina
St. Andrews Middle School
Columbia, S.C.

Rose Lummus
OEST Tennessee
Dyersburg Middle School
Dyersburg, Tenn.

David Kielbowick Jr.
OEST Virginia
Lloyd C. Bird High School
Chesterfield, Va.

Mark Anderson
OEST Washington
Housel Middle School
Prosser, Wash.

Ronald Sacco
OEST West Virginia
Warwood School
Wheeling, W.Va.

OEST awards, recognized by the National Association of Geoscience Teachers (NAGT), are given to outstanding pre-college teachers who have made exceptional contributions to the stimulation of interest in the earth sciences. Each NAGT section selects a section winner. Sections may also have state winners. For more information on this award and the NAGT, go to www.nagt.org/nagt/programs/oest.html.

The OEST award is administered by the Geological Society of America; GSA awards the section recipients $500 travel money to attend a GSA meeting, and awardees can also apply for up to $500 for classroom supplies. The award includes a certificate and a complimentary membership to GSA for three years for section recipients and one year for state recipients.

Call for GSA Committee Service

Stimulate Growth and *Change*

Serve on a GSA Committee!

Terms begin 1 July 2007 (unless otherwise indicated).

2007–2008 COMMITTEE VACANCIES

GSA is seeking candidates to serve on Society committees and as GSA representatives to other organizations. Contribute to our science by volunteering or nominating others you think should be considered for any of the following openings. Younger members are especially encouraged to become involved in Society activities. Graduate students are eligible to serve on GSA committees as full members, and Council encourages you to volunteer or nominate others for committee service. Whether you volunteer or make recommendations, please give serious consideration to the specified qualifications for serving on a particular committee. **Please be sure that your candidates are GSA Members or Fellows and that they fully meet the requested qualifications.**

You may now volunteer or nominate online! The nomination form and instructions are available at **www.geosociety.org/aboutus/commtees.** Click on "Nominate Online for 2007–2008" to access a secure form. If you prefer, you may download and complete a paper nomination form, also located on this Web site, and return it to Pamela Fistell, GSA, P.O. Box 9140, Boulder, CO 80301-9140, USA, fax +1-303-357-1070. For questions pertaining to nominations, please contact Pamela Fistell, pfistell@geosociety.org, +1-303-357-1000 ext. 0, +1-800-472-1988 ext. 0.

Nominations received at GSA headquarters by **1 August 2006** (on the official form) will be forwarded to the Committee on Nominations. Information provided on the form will assist the Committee members with their recommendations for the July 2007 committee vacancies. *Please use one form per candidate.* The committee will present at least two nominations for each open position to Council at its fall meeting. Appointees will then be contacted and asked to serve, thus completing the process of bringing new expertise into Society affairs.

ACADEMIC AND APPLIED GEOSCIENCE RELATIONS COMMITTEE (AM, T/E)—3-YEAR TERMS

Nine vacancies: eight member-at-large; one councilor/former councilor

Strengthens and expands relations between GSA members in the academic and applied geosciences. Proactively coordinates the Society's effort to facilitate greater cooperation between academia, industry, and government geoscientists. **Qualifications:** must be Members from academia, industry, or government who are committed to developing better integration of applied and academic science in our meetings, publications, short courses, field trips, and education and outreach programs.

ANNUAL PROGRAM COMMITTEE (AM, B/E, T/E)—4-YEAR TERMS

One Councilor/former Councilor vacancy

Develops a long-range plan for increasing the quality of the annual meeting and other Society-sponsored meetings in terms of science, education, and outreach. Evaluates the technical and scientific programs of the annual meeting. **Qualifications:** broad familiarity with different disciplines, previous program experience, or active involvement in applying geologic knowledge to benefit society and raise awareness of critical issues.

ARTHUR L. DAY MEDAL AWARD (T/E)—3-YEAR TERMS

Two member-at-large vacancies

Selects candidates for the Arthur L. Day Medal Award. **Qualifications:** knowledge of those who have made "distinct contributions to geologic knowledge through the application of physics and chemistry to the solution of geologic problems."

EDUCATION (AM, T/E)—4-YEAR TERMS

Three vacancies: one undergraduate level educator; one student representative; one member-at-large

Stimulates interest in the importance and acquisition of basic knowledge in the earth sciences at all levels of education and promotes the importance of earth science education to the general public. **Qualifications:** ability to work with other interested scientific organizations and science teacher groups to develop pre-college earth science education objectives and initiatives.

GEOLOGY AND PUBLIC POLICY (AM, B/E, T/E)—3-YEAR TERMS

One member-at-large vacancy

Translates knowledge of earth sciences into forms most useful for public discussion and decision making. **Qualifications:** experience in public policy issues involving the science of geology; ability to develop, disseminate, and translate information from the geologic sciences into useful forms for the general public and for GSA members; familiarity with appropriate techniques for the dissemination of information.

HONORARY FELLOWS (T/E)—3-YEAR TERMS

Two member-at-large vacancies

Selects candidates for Honorary Fellows, who are usually non–North Americans. **Qualifications:** knowledge of geologists throughout the world who have distinguished themselves through their contributions to earth science.

July 2007 Committee Vacancies • *Extensive time commitment required • AM—Meets at Annual Meeting B/E—Meets in Boulder or elsewhere • T/E—Communicates by phone or electronically

JOINT TECHNICAL PROGRAM COMMITTEE (T/E)—3-YEAR TERMS
One marine/coastal geology representative *(term begins 1 January 2008)*

Assists in finalizing the technical program of the annual meeting; reviews abstracts or provides names of reviewers to evaluate abstracts, participates in Web-based activities in the selection and scheduling of abstracts, and participates in Topical Session proposal review. **Qualifications:** must be familiar with computers and the Web, be a specialist in one of the specified fields, and be available in mid- to late July for the organization of the electronic technical program.

MEMBERSHIP (B/E)—3-YEAR TERMS
Two member-at-large vacancies

Evaluates membership benefits and develops recommendations that address the changing needs of the membership and attracts new members. **Qualifications:** experience in benefit, recruitment, and retention programs is desired.

MINORITIES AND WOMEN IN THE GEOSCIENCES (AM)—3-YEAR TERMS
Three member-at-large vacancies

Stimulates recruitment and promotes the positive career development of minorities and women in the geoscience professions. **Qualifications:** familiarity with the education and employment issues of minorities and women; expertise and leadership experience in such areas as human resources and education desired.

NOMINATIONS (B/E, T/E)—3-YEAR TERMS
Two member-at-large vacancies

Recommends nominees to Council for the positions of GSA Officers and Councilors, committee members, and Society representatives to other permanent groups. **Qualifications:** familiarity with a broad range of well-known and highly respected geoscientists.

PENROSE CONFERENCES AND FIELD FORUMS (T/E)—3-YEAR TERMS
Two member-at-large vacancies

Reviews and approves Penrose Conference proposals and recommends and implements guidelines for the success of the conferences. **Qualifications:** past convener of a Penrose Conference or Field Forum.

PENROSE MEDAL AWARD (T/E)—3-YEAR TERMS
Two member-at-large vacancies

Selects candidates for the Penrose Medal Award. Emphasis is placed on "eminent research in pure geology, which marks a major advance in the science of geology." **Qualifications:** familiarity with outstanding achievers in the geosciences who are worthy of consideration for the honor.

PROFESSIONAL DEVELOPMENT (T/E)—3-YEAR TERMS
Two vacancies: one student representative; one councilor/former councilor

Directs, advises, and monitors GSA's professional development program, reviews and approves proposals, recommends and implements guideline changes, and monitors the scientific quality of courses offered. **Qualifications:** familiarity with professional development programs or adult education teaching experience.

PUBLICATIONS (AM, B/E, T/E)—4-YEAR TERMS
One member-at-large vacancy

Nominates candidates for editor positions, approves editorial boards, reviews the quality and health of Society publications, and explores the initiation of new ventures, including electronic publishing. **Qualifications:** extensive publications experience. **Extensive time commitment.**

RESEARCH GRANTS* (B/E)—3-YEAR TERMS
Six member-at-large vacancies

Evaluates student research grant applications and selects grant recipients. **Qualifications:** should have experience in directing research projects and in evaluating research grant applications. **Extensive time commitment**.

***TREATISE ON INVERTEBRATE PALEONTOLOGY* ADVISORY COMMITTEE (AM)—3-YEAR TERMS**
One member-at-large vacancy (paleontologist)

Advises Council, the Committee on Publications, and the *Treatise* editor in matters of policy concerning this publication. **Qualifications:** must be a paleontologist.

YOUNG SCIENTIST AWARD (DONATH MEDAL) (T/E)—3-YEAR TERMS
Two vacancies: one member-at-large; one councilor/former councilor

Committee members investigate the achievements of young scientists who should be considered for this award and make recommendations to Council. **Qualifications:** knowledge of young scientists with "outstanding achievement(s) in contributing to geologic knowledge through original research which marks a major advance in the earth sciences."

GSA Representatives to Other Organizations:

GSA/AASG SELECTION COMMITTEE FOR THE JOHN C. FRYE MEMORIAL AWARD—3-YEAR TERMS
One GSA representative vacancy *(term: 1 July 2007–30 June 2010)*.

Annual award given to recognize the outstanding paper in environmental geology published by a state geological survey or GSA during the preceding three calendar years.

Committee, Section, and Division Volunteers: Council Thanks You!

The GSA Council acknowledges the many member-volunteers who, over the years, have contributed to the Society and to our science through involvement in the affairs of the GSA.

July 2007 Committee Vacancies • *Extensive time commitment required • AM—Meets at Annual Meeting B/E—Meets in Boulder or elsewhere • T/E—Communicates by phone or electronically

IN MEMORIAM

Carl E. Carlson
Chula Vista, California
25 November 2005

Richard E. Ernst
Ottawa, Ontario
Notified 6 December 2005

Charles V. Guidotti
Orono, Maine
1 May 2005

John C. Maxwell
Austin, Texas
23 January 2006

Ernest H. Muller
Houston, Texas
Notified 30 November 2005

Norman D. Newell
New York, New York
1 April 2005

James J. Norton
Rapid City, South Dakota
16 November 2005

Richard S. Rhodes II
Iowa City, Iowa
29 November 2005

G.D. Robinson
Victoria, British Columbia
Notified 21 November 2005

Mark S. Roth
Astoria, New York
Notified 21 November 2005

Donald N. Smith
Sparta, New Jersey
1 September 2005

John E. Szatai
Greenwich, Connecticut
25 November 2005

Clifford L. Willis
Alexandria, Virginia
30 April 2005

Rainer Zangerl
Urbana, Illinois
Notified 30 November 2005

Please contact the GSA Foundation at +1-303-357-1054 or drussell@geosociety.org for information on contributing to the Memorial Fund.

Classified Rates

Ads (or cancellations) must reach the GSA Advertising office one month prior to issue. Contact Advertising Department: advertising@geosociety.org; +1.800.472.1988 x1053; +1.303.357.1053. Complete contact information, including mailing and email address, must be included with all correspondence.

Classification	Per Line for 1st month	Per line each addt'l month (same ad)
Situations Wanted	$2.75	$2.40
Positions Open	$7.50	$6.50
Opportunities for Students		
First 25 lines	$0.00	$3.35
additional lines	$2.35	$3.35

To estimate cost, count 54 characters per line, including all punctuation and blank spaces. Actual cost may differ if you use capitals, centered copy, or special characters.

Positions Open

INSTRUCTOR IN GEOLOGY
UNIVERSITY OF SOUTHERN INDIANA

The Department of Geology at the University of Southern Indiana invites applications for a full-time (9-month) position at the Geology Instructor level, beginning August 2006 and renewable on a yearly basis. The Department seeks a creative and energetic person with a Masters degree in any area of geology or geo science education. The successful applicant will teach and develop introductory laboratory sessions (including field experiences) at the undergraduate level, offer an evening course in Introductory Geology, and will maintain and enhance the department's introductory-level teaching collections and materials. The University is committed to excellence in teaching, scholarship and professional activity, and service to the University and community. Please submit a letter of application including a brief statement of teaching experience and scholarly interests, a resume, copies of transcripts, and contact information for three references to: Dr. Paul K. Doss, Chairman, Department of Geology and Physics, University of Southern Indiana, 8600 University Blvd., Evansville, IN 47712. Review will begin 1 April 2006 and will continue until the position is filled. Additional information may be obtained from www.usi.edu/science/geology/.

The University of Southern Indiana is an Affirmative Action/Equal Opportunity Employer

GROUNDWATER MODELING SCIENTIST
UNIVERSITY OF DELAWARE

The Delaware Geological Survey (DGS) at the University of Delaware (UD) is seeking qualified candidates for a groundwater modeling position. Major responsibilities include developing and conducting projects on numerical modeling of flow and transport in porous media and ground water-surface water interactions, communicating project results through publication and oral presentation, and advising government agencies, consultants, and the public on the water resources of Delaware. The position requires a M.S. with at least 6 years of progressive experience, or a Ph.D. with at least 4 years of progressive experience in geology, hydrology, or related field.

Candidates must have a proven record of developing successful project proposals, conducting independent and collaborative research, and publishing research results. Strong written and oral communication skills and ability to interact with other researchers, resource managers, and the public are necessary. The DGS is a state-funded unit of UD dedicated to geologic and hydrologic research and public service. The DGS has a dynamic staff of 19 scientists and support personnel housed in a modern facility at the university's attractive Newark, Delaware campus, ideally situated in a small community near Philadelphia, New York, Baltimore, and Washington, D.C. The DGS is a research and service unit of UD, thereby providing opportunities to collaborate with faculty and students in other departments and research groups at UD. Scientific staff may also have the opportunity to teach and serve as advisors of graduate research. For further information about the DGS, visit our Web site www.udel.edu/dgs. The position is available on or about 1 May 2006; the exact starting date is negotiable. This is a full-time, permanent position with 12-month appointment subject to annual review. We offer a competitive comprehensive Benefits package. To apply, send a statement of interest, resume, and names and addresses of 3 references to: Chair, Modeler Search Committee, Delaware Geological Survey, DGS Building, University of Delaware, Newark, DE 19716 by 15 April 2006.

The UNIVERSITY OF DELAWARE is an Equal Opportunity Employer which encourages applications from Minority Group Members and Women.

RED ROCKS COMMUNITY COLLEGE
LAKEWOOD, COLORADO GEOLOGY FACULTY

Teach geology classes using traditional and alternative methods of instruction. Advise students. Hold office hours. Master's degree in Geology and 1 year teaching experience required. For detailed job announcement and application information, visit our Web site at www.rrcc.edu/hr/jobs.htm. Application deadline: 31 March 2006.

All positions contingent on funding. EOE.

UNIVERSITY OF COLORADO–BOULDER
SCIENCE EDUCATION
DEPARTMENT OF GEOLOGICAL SCIENCES

Applications are invited for a post-doctoral Teaching Fellow in Science Education in the Department of Geological Sciences at the University of Colorado–Boulder. The position is part of the Science Education Initiative at CU-Boulder; a program focused on the enhancement of teaching and learning in our undergraduate courses. Candidates must hold a doctoral degree in geological sciences, possess a strong commitment to science education, and have excellent organizational and interpersonal communication skills. Familiarity with current pedagogy research and assessment techniques is not required, but advantageous.

The Teaching Fellow will serve as the departmental liaison with the Center for Science Education, directed by Professor Carl Wieman of the Department of Physics. Responsibilities include working in coordination with geological science faculty to: develop an integrated plan of course evaluation and innovation; identify specific learning goals that represent faculty-consensus; develop valid assessments of student learning for undergraduate courses; participate in and supervise the development of techniques, materials and practices for improving student learning in the undergraduate courses; and publish assessment tools and findings in earth science education journals. The Fellow will collaborate with and learn from Fellows working towards similar goals in other Center-funded departments.

The salary for this one-year, renewable appointment will be competitive and commensurate with experience. Applicants should submit a vita and a statement of teaching philosophy and experiences, and have three letters of recommendation sent to: Professor David A. Budd, Department of Geological Sciences, University of Colorado, 399 UCB, Boulder, CO 80309-0215.

Review of applications will begin on 10 March 2006 and continue until the position is filled. Women and minorities are encouraged to apply.

ILLINOIS STATE GEOLOGICAL SURVEY
ASSOCIATE GEOLOGIST I–SEDIMENTOLOGY

Conduct and/or support original research in glacial/fluvial sedimentology to define and map the distribution and character of sand and gravel deposits for industrial mineral application and groundwater assessment. Prepare scientific reports and develop service program related to mapping and industrial mineral resources. Visit existing pits and mines to build contacts and acquire geological information to expand the Survey's databases. M.S. in geology or related field with 4 years experience in fluvial sedimentology with emphasis on glacial sand and gravel deposits, or new Ph.D. Starting annual salary range: $40,000–$50,000. Closing date: 3/31/06. For required application form and more information contact walston@isgs.uiuc.edu or visit www.isgs.uiuc.edu. EEO/ADA Employer.

VASSAR COLLEGE

The Department of Geology and Geography at Vassar College invites applications for a one year sabbatical replacement position, renewable for up to 3 years. The position will begin August 2006 and will be at the rank of visiting assistant professor. Vassar College is an equal opportunity/affirmative action employer and is strongly and actively committed to diversity within its community.

Candidates should have completed or be nearing completion of a Ph.D. in geology or earth science at the time of appointment. The successful candidate will teach physical geology and historical geology at the introductory level, and an advanced level course in his or her specialty. In addition, she or he will be expected to advise undergraduate research work.

Vassar College is a private liberal-arts college in New York's Hudson River valley. The Geology and Geography department presently consists of 4 geologists with specialties in geophysics, sedimentology, and Quaternary geology, and 4 geographers with specialties

in cultural, urban, and physical geography. The geology program emphasizes surficial processes and is active in the environmental studies programs. The program has ~20 students and graduates 6–8 students per year.

Instrumentation in the department includes XRD, laser-particle size analyzer, coulometer, fully equipped sedimentology, paleoclimatology, and clay mineralogy laboratories, GIS computer lab, various geophysical instruments, and a meteorological station. In addition, the department shares an ICPAES with the Department of Chemistry. Vassar College also owns a 500-acre ecological preserve with a laboratory field station.

Send a letter of application that includes a description of teaching experience as well as a description of the proposed advanced level course. Please also include a curriculum vita the names and addresses of at least 3 references. Address these materials to: Department Chair, Department of Geology and Geography, Box 735, Vassar College, Poughkeepsie, NY 12604. geo@vassar.edu.

Review of applications will begin 15 March 2006.

ASSISTANT PROFESSOR, MINERALOGY/ RHEOLOGY, UNIVERSITY OF MAINE

The Department of Earth Sciences at the University of Maine invites applications for a full-time tenure-track Assistant Professor position in mineralogy, petrology, and the material behavior of the earth. The successful candidate will be appointed with 50% Research and 50% Teaching responsibilities, as well as expected Service components. We are seeking applicants with an interest in the dynamic and chemical interactions of earth materials during reaction and deformation. The specific areas of research are open and can include: non-equilibrium thermodynamics, metamorphic petrology, rheology of the lithosphere, coupled reaction and deformation, fluid-solid interaction, or ice dynamics. The Department has four areas of emphasis: Geodynamics, Climate and Quaternary Studies, Marine Geology and Sedimentology, and Environmental Geology/Geochemistry, and a strong history of interdisciplinary links with the Climate Change Institute (formerly the Institute for Quaternary Studies), the School of Marine Studies, and other research units on campus, as well as the Maine Geological Survey. Information on related programs can be viewed at: www.geology.um.maine.edu/index.html and www.ume.maine.edu/iceage/.

We seek candidates who are primarily interested in applying petrological and geochemical approaches to geodynamic processes, but we welcome interaction with other areas of emphasis. The successful applicant will be responsible for teaching the basic undergraduate mineralogy course, developing and teaching other courses on material behavior at undergraduate and graduate levels, and for supervising graduate and undergraduate research projects.

A Ph.D. at the time of appointment is required. Applicants are invited to submit a curriculum vitae, a complete list of publications, up to 3 reprints/preprints that exemplify their scientific methods and interests, a written statement of research and teaching interests, and the names and addresses of at least three references to: Peter O. Koons, Chair of the Search Committee, Department of Earth Sciences, Bryand Global Sciences Center, University of Maine, Orono, Maine, 04469-5790. Preliminary inquiries may be made by contacting peter.koons@maine.edu. The anticipated starting date is 1 September 2006. Review of applications will begin 15 March 2006 and will continue until the position is filled. The University of Maine is an Equal Opportunity/Affirmative Action employer.

GEOLOGICAL SCIENCE—ASSISTANT PROFESSOR MICHIGAN STATE UNIVERSITY TENURE SYSTEM, 9-MONTH BASIS, 100% TIME

Duties: Sedimentology/Stratigraphy. The Department of Geological Sciences announces a position in sedimentology/stratigraphy. The candidate will be expected to develop a strong, externally funded research program, be committed to excellence in teaching at both the graduate and undergraduate level, and be able to contribute enthusiastically to both the intellectual and collegial life of the department. This position is broadly defined to attract outstanding applicants. All areas of sedimentology/stratigraphy will be considered, but the successful candidate will be expected to conduct research with the potential to intersect with one or more of the Department's three research foci: (1) Water and other fluids in the environment; (2) Crustal composition and dynamics; and (3) Global and biological change. Additional information on the Department can be obtained on our web page at www.geology.msu.edu.

Qualifications: Ph.D.

Applications: Due 15 March 2006. Position to begin Fall 2006. Late submissions will be considered if a suitable candidate pool is not identified by the deadline. Women and minorities are encouraged to apply. Send vita, official transcripts, a statement of teaching and research interests, and the names and contact information for three references to Ralph E. Taggart, Chair, Department of Geological Sciences, 206 Natural Science Building, Michigan State University, East Lansing, MI 48824.

DIRECTOR, DIVISION OF EARTH SCIENCES NATIONAL SCIENCE FOUNDATION ARLINGTON, VA

NSF's Directorate for Geosciences seeks candidates for the position of Director, Division of Earth Sciences (EAR). The Division supports proposals for research geared toward improving the understanding of the structure, composition, and evolution of the Earth and the processes that govern the formation and behavior of Earth's materials. Information about the Division's activities may be found at Web site: www.nsf.gov/geo/ear/about.jsp.

Appointment to this Senior Executive Service position may be on a career basis, on a one to-three year limited term basis, or by assignment under the Intergovernmental Personnel Act (IPA) provisions.

Announcement S20060036-C, with position requirements and application procedures are posted on NSF's home page at Web site www.nsf.gov/about/career_opps/. Applicants may also obtain the announcements by contacting Executive Personnel Staff at +1-703-292-8755 (Hearing impaired individuals may call TDD +1-703-292-8044). Applications must be received by 20 March 2006.

NSF is an Equal Opportunity Employer.

WILLIAM E. WHITE POSTDOCTORAL SCHOLARSHIP IN GEOLOGICAL SCIENCES AND GEOLOGICAL ENGINEERING, QUEEN'S UNIVERSITY AT KINGSTON, ONTARIO, CANADA

The Department of Geological Sciences and Geological Engineering of Queen's University, one of Canada's premier earth-science departments, invites applications for its William E. White Postdoctoral Scholarship, created from a fund endowed by the estate of William E. White. The award will be made for one year and may be renewed for a second year. The annual stipend is $43,000.

The William E. White Postdoctoral Scholarship will be awarded to an outstanding scientist who has completed the Ph.D. degree, normally within the two-year periods preceding the time of the appointment. The area of research is open, but the scholar's research must be complementary to that being pursued in the Department of Geological Sciences and Geological Engineering. The research program to be undertaken and the level of support of research costs and moving expenses will be negotiated with a faculty member at the time the award is made. Potential applicants may obtain an outline of current research interests on the Departmental Web site www.geol.queensu.ca_and are strongly encouraged to initiate contact with a potential faculty supervisor in advance of applying. Fit with the research interests of the Department and the research excellence of the candidate will be the primary considerations in the selection process.

The Department invites applications from all qualified individuals. Queen's University is committed to employment equity and diversity in the workplace and welcomes applications from women, visible minorities, aboriginal people, persons with disabilities, and persons of any sexual orientation or gender identity. All qualified candidates are encouraged to apply; however, Canadian citizens and Permanent Residents will be given priority.

Applicants should send a curriculum vitae, a statement of research interests, and samples of research writing to the following address. Applicants must arrange for at least three confidential letters of reference to be sent to the same address. Review of complete applications will begin on 31 March 2006.

Professor R.W. Dalrymple, Department Head, Department of Geological Sciences and Geological Engineering, Queen's University, Kingston, Ontario, Canada, K7L 3N6, Fax: 613-533-6592, zarichny@geol.queensu.ca.

Opportunities for Students

***CHRONOS* Internship Opportunities. Summer 2006.** The *CHRONOS* program seeks applications from U.S. graduate and advanced undergraduate students interested in earth history, paleobiology, stratigraphy and paleoceanography for one-month paid internships in Summer 2006 at Iowa State University. *CHRONOS* is a team of geoscientists and information technology specialists creating a cyberinfrastructure that delivers open access to a global federation of earth history databases, tools, and services to geosciences researchers, and a source of earth history data and visualization tools for educators and students. Interns will have the opportunity to utilize *CHRONOS* data sets and services in their own research or work with *CHRONOS* scientists and programmers on programs that are already in progress.

For more information see: www.chronos.org.

For further information about internships, contact Cinzia Cervato (cinzia@iastate.edu). Interested applicants should submit a brief cover letter (including the outline of a proposed project that specifically involves the use of data or tools accessible through *CHRONOS*), resume, and the name and e-mail address of their research advisor to: Timothy J. Bralower (Department of Geosciences, Pennsylvania State University, University Park, PA 16802; bralower@geosc.psu.edu). Application deadline: 15 March 2006.

Graduate research in the GeoStructure group, University of Oklahoma. The GeoStructure group in the School of Geology and Geophysics, Univ. of Oklahoma, solicits highly-motivated students for its M.Sc. and Ph.D. programs. The group focuses on the analysis of fundamental structural processes and their applications to petroleum geology and earthquake processes. The students of the GeoStructure program are supported by research and/or teaching assistantships.

Interested candidates are invited to visit our page at geostructure.ou.edu, and to contact Shankar Mitra (smitra@ou.edu) or Ze'ev Reches (reches@ou.edu). Suitable candidates for graduate studies will be invited to visit the University of Oklahoma, and their domestic travel expenses will be cover by the School of Geology and Geophysics.

Michigan State University—Graduate Research Assistantship. A graduate research assistantship is available for a qualified student to pursue a PhD. Research will consist of analyzing variability of soil and plant growth parameters across a wide range of spatial scales and incorporating it in multi scale modeling of soil carbon sequestration processes. Desired: B.S. or M.S. degree in soils, agronomy, or related field; good mathematical skills and a strong interest in quantitative methods of data analysis and modeling. Send a letter of application, a C.V., copies of transcripts, and names, phone numbers, and e-mail addresses of 3 references to Dr. Sasha Kravchenko, Department of Crop and Soil Sciences, Michigan State University, East Lansing, MI 48824-1325; e-mail: kravche1@msu.edu.

Summer Internships Available in Scientific Drilling. DOSECC (Drilling, Observation and Sampling of the Earth's Continental Crust) invites students to apply for summer 2006 internships in scientific drilling. The internships promote student involvement in projects where drilling has provided data and materials for study. Interns can undertake research related to ongoing or past drilling efforts. The internships are open to college students (graduate or undergraduate) and primary and secondary schoolteachers. Applicants do not have to be attending a DOSECC Member Institution to be considered for this award. Internship funding will be available in the summer of 2006 and budgets of $2000 to $5000 are appropriate. Applications must be received by 1 March 2006 and awardees will be announced 1 April 2006. For additional information contact a DOSECC representative at a member institution, consult the information posted on the DOSECC Web site (www.dosecc.org), or email David Zur, DOSECC's Education and Outreach Manager (dzur@dosecc.org).

Graduate Student Opportunities in Near-Surface Geophysics. Highly-motivated graduate students are sought in the newly-formed Environmental Geophysics Research (EGR) Lab at the University of Tennessee (www.geophysics.tennessee.edu). Ph.D. students are preferred although highly-qualified M.S. candidates should apply. Current projects include: imaging Pleistocene sediments within lakes on Baffin Island for climate-related studies (NSF); environmental site characterization on Fort Wainwright & Fort Richardson, Alaska (DOD), Chattanooga Creek, TN, and Oak Ridge National Lab; glacio-geophysics research at Matanuska Glacier, Alaska (NSF); archaeo-geophysics studies on a 4th Century Roman fort in Humayma, Jordan (NSF); a joint EPA/Forest Service ecosystem management project involving restoration of wet meadows in the Great Basin of Nevada; and a 3D tracer mapping project in the fractured bedrock of Altona Flats, New York (NSF).

An additional project (sponsored by NSF) involves promoting diversity in the geosciences by providing unique opportunities to underrepresented student populations (BGP; www.bgp.buffalo.edu). We are particularly targeting self-motivated students interested in working on the cutting edge of near-surface geophysical imaging. Students will be encouraged to work on existing projects or develop their own projects.

Evaluation of candidates for assistantship positions (TA & RA) will begin 1 February 2006 and continue until the positions are filled. Up $250 is available automatically for all applicants to visit UT, with supplementary funds available for the remainder of expenses based on qualifications of the student.

For additional information contact: Dr. Gregory S. Baker, Jones/Bibee Endowed Professor of Geophysics, Department of Earth & Planetary Sciences, University of Tennessee, 1412 Circle Drive, Knoxville, TN 37996-1410, email: gbaker@tennessee.edu, phone: +1-865-974-6003. To apply, go to http://web.eps.utk.edu/.

Graduate Fellowships at Indiana University. The Department of Geological Sciences at Indiana University (Bloomington) solicits applicants for at least five graduate fellowships in the following areas: Geobiology/Stratigraphy, Geophysics, Geomorphology, Petroleum Geology, and Clay Mineralogy. The fellowships offer up to $18,000 per year plus tuition waiver. The duration of the fellowship varies but Ph.D. and M.Sc. students are guaranteed 4 and 2 years of support within the Department, respectively. Applicants for the 2006–2007 academic year should contact Dr. Mark Person, Director of Graduate Studies, Indiana University, Department of Geological Sciences, maperson@indiana.edu, +1-812-855-4404.

Research and Teaching Assistantships available for Fall 2006 at Temple University: Research and Teaching Assistantships are available for the Fall term (September 2006) in our Masters Program in Geology at Temple University. The 2-year Masters Program offers advanced courses and thesis research opportunities in **environmental geology, hydrogeology, geochemistry, environmental geophysics, soil science/paleosols, stratigraphy/sedimentology, and materials science**. Financial support for every student includes stipend and full tuition for 2 years. Graduates of our program have an excellent record of employment in consulting and education professions and acceptance into doctoral programs. For information and applications please write, call or e-mail Dr. George Myer, Department of Geology, Temple University, Philadelphia, PA 19122, Tel. +1-215-204-7173, Fax +1-215-204-3496, e-mail gmyer@temple.edu. Applications will be accepted until these positions are filled. Please visit our Web site at www.temple.edu/geology for additional information. Be sure to fill out the graduate information survey at www.temple.edu/geology/gradsurvey.html for more information about particular aspects of our program.

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Please send a CV and statements of research and teaching interests to:
Energy Search Committee
Earth Science Department, MS-126
Rice University, PO Box 1892, Houston, TX 77251-1892.

Information about the department can be found at http://earthscience.rice.edu.
Rice is an equal opportunity affirmative action employer.

Graduate Research Opportunities: The Department of Geosciences at Texas Tech University solicits applicants for its M.S. and Ph.D. programs. The department has research opportunities across all Geoscience disciplines. We particularly encourage applications from students wishing to pursue research projects in environmental/low temperature geochemistry, structural geology/tectonics, remote sensing and GIS, and geophysics. Assistantships are available on a competitive basis, beginning Fall 2006. For more information, please see the departmental Web sites at www.gesc.ttu.edu/ or contact the geology graduate advisor, Dr. Moira Ridley (moira.ridley@ttu.edu).

Tulane University

Graduate Opportunities in Earth and Environmental Sciences

We have several openings for graduate students for the Fall 2006 semester. In addition to teaching assistantships, research assistantships are available for top applicants for the PhD program, both through competitive fellowships and NSF-funded projects. Annual stipends range from $18,000 to $20,000. The department has a strong focus on river-ocean studies that are primarily field- and lab-based, with access to a research vessel and a variety of analytical and computing facilities. We are particularly interested in applicants who are excited by the many challenges faced by the Gulf Coast in the recovery from Hurricane Katrina. Many research opportunities are directly or indirectly related to this; particular strengths are in sedimentology, stratigraphy, marine geology, paleoclimatology, neotectonics, isotope geochemistry, and environmental geochemistry. There are also opportunities in structural geology, paleontology, petrology, and volcanology. Applicants that provide a clear statement of research interests and career goals will be considered with the greatest interest. Applications should be submitted online at www.tulane.edu/%7Egradprog/ and should include a CV, transcripts, GRE scores, TOEFL scores (for international applicants), and three recommendation forms. The deadline is April 15, 2006. More information about the department can be obtained via our website (www.tulane.edu/~eens/) and from Dr. Nancye H. Dawers (ndawers@tulane.edu). Women and minorities are encouraged to apply.

NOTICE of Council Meeting

GSA Council meetings are open to all Fellows, Members, and Associates of the Society, who may attend as observers, executive sessions excluded. Only Councilors and officers may speak to agenda items, except by invitation of the chair.

The next Council meeting will be Saturday, 29 April 2006, 8 a.m.–5 p.m., and Sunday, 30 April 2006, 8 a.m.–12 p.m., at GSA Headquarters in Boulder, Colorado, USA.

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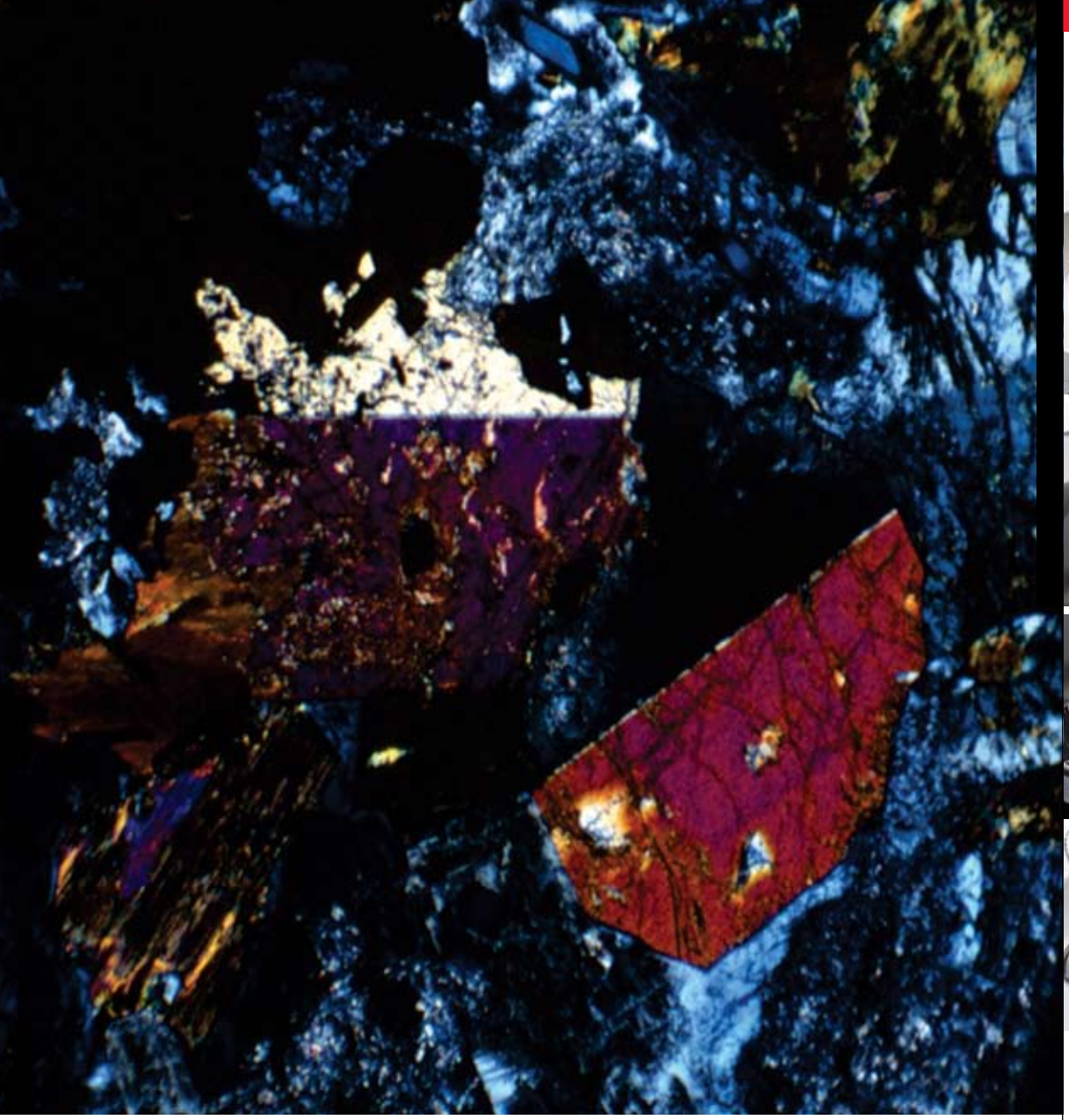

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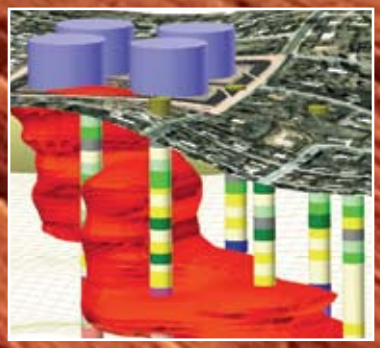

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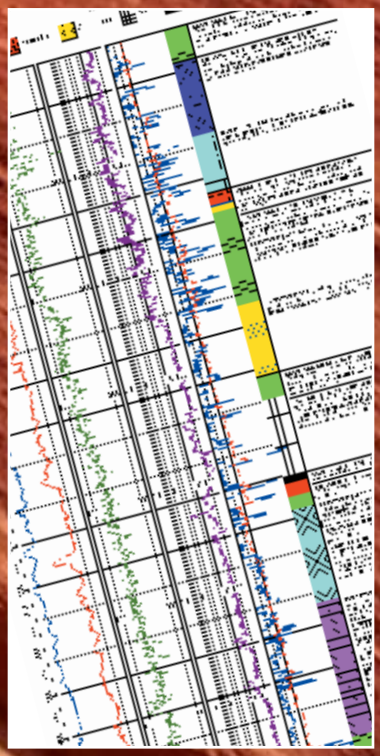

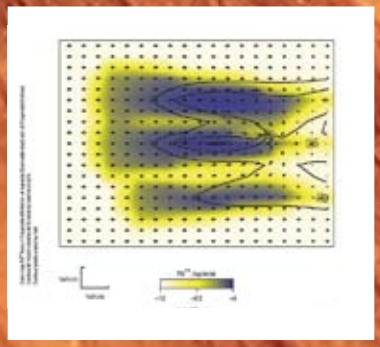

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