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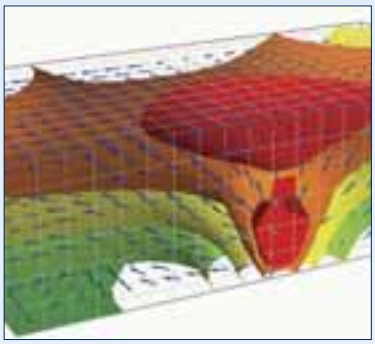

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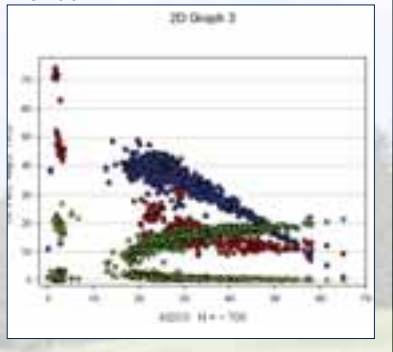

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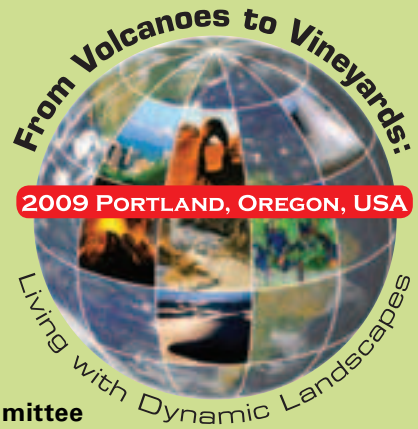
SCIENCE ARTICLE

Cover: Icebergs in Kangia (Jakobshavn Isfjord) close to the town of Ilulisaat, West Greenland. These icebergs mostly originate from the calving terminus of Jakobshavn Isbrae, which collapsed catastrophically in the late 1990s. Many scientists believe this collapse was driven by warmer air and/or sea surface temperatures. See "Back to the future: Greenland's contribution to sea-level change" by A.J. Long, p. 4–10.



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***GSA TODAY* STAFF:**
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Science Editors: Stephen T. Johnston, University of Victoria, School of Earth & Ocean Sciences, Victoria, British Columbia V8W 3P6, Canada, stj@uvic.ca; and David E. Fastovsky, University of Rhode Island, Department of Geosciences, Woodward Hall, Rm. 317, Kingston, Rhode Island 02881, USA, defastov@uri.edu.
Managing Editor: Kristen E. Asmus, kasmus@geosociety.org
Graphics Production: Margo Y. Sajban

ADVERTISING:
Classifieds & Display: Ann Crawford, +1-800-472-1988, ext. 1053, +1-303-357-1053, Fax +1-303-357-1070; acrawford@geosociety.org

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Back to the future: Greenland's contribution to sea-level change

Antony J. Long, *Department of Geography, Durham University, Science Site, South Road, Durham DH1 3LE, UK, a.j.long@durham.ac.uk*

ABSTRACT

The Greenland Ice Sheet is presently making a significant contribution to global sea-level rise. Predictions for the future suggest that this will continue and likely accelerate during the remainder of this century. However, a comprehensive understanding of ongoing mass balance flux has only become possible in the last decade or so, following the development of satellite and other new observational technologies. As a result, it is not clear whether the patterns observed today are typical of the past or not. In this paper, I review predictions for Greenland's contribution to future sea-level rise and then place these estimates in the context of the evidence for change during the twentieth century, the last few millennia, and the Eemian interglacial. There is evidence that the ice sheet responds sensitively to changes in conditions in the adjacent North Atlantic, leading to a hypothesis that annual and decadal fluctuations in Atlantic air and sea surface temperatures shape the ice sheet's contribution to global sea-level change. The recent loss of ice needs also to be seen in the context of an overall increase in ice sheet size and the related advance of the ice sheet margin by tens of kilometers during the past few millennia. I conclude by arguing that in order to better constrain the role of the Greenland Ice Sheet in future sea level, improvements in our understanding of present-day change in the ice sheet must be matched by equal strides in understanding how the ice sheet evolved in the past.

INTRODUCTION

The Greenland Ice Sheet shares center stage with the Antarctic Ice Sheet in current debates about the nature and impacts of global warming. Data suggest that rising northern hemisphere temperatures are causing accelerated ice sheet melting, and according to recently published data collected by the Gravity Recovery and Climate Experiment (GRACE; e.g., Wouters et al., 2008), the Greenland Ice Sheet has contributed ~15%–30% of the global sea-level rise since 2003. Several studies (discussed below) suggest that the Greenland Ice Sheet is capable of contributing >0.5 m of global sea-level rise by the end of this century, with potentially profound social and economic consequences.

But the new data behind such predictions cover only a relatively short time interval, often less than a decade or so, and in the case of GRACE, only since 2002. Short time series such as these need interpreting with caution, since deep boreholes through the ice sheet show that patterns of mass accumulation vary significantly over space and time (e.g., Andersen et al., 2006). Because of this variability, it is important that recent trends in ice sheet mass balance are considered in a longer-term context. Although each successive year of observation generates ever more data, the only way to provide meaningful decadal to century-scale perspectives on Greenland's behavior is to look to the past. We can estimate temperature changes from weather stations for much of the twentieth century (e.g., Chylek et al., 2006) and compute mass balance of the ice sheet from 1958 to 2007 (Rignot et al., 2008) and the surface mass balance back to 1866 (Wake et al., 2009). However, consideration of earlier changes requires examination of proxy records of ice sheet behavior drawn from ice cores, glacial geomorphology, and other paleoclimate archives from Greenland and its adjoining seas.

FUTURE SCENARIOS

The Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (2007) predicts that the Greenland Ice Sheet will make a relatively modest contribution to sea-level rise in the next 100 years. Using different low to high emission scenarios, Greenland is estimated to contribute between 0.01 and 0.12 m of global sea-level rise by 2099, out of a total of between 0.18–0.59 m (5%–95% range, based on the interval between 1980 and 1999 and 2090–2099). Thermal expansion of the world's oceans is predicted to be by far the largest contributor to future sea-level rise, accounting for 0.1–0.41 m of sea-level rise by the end of this century. The IPCC recognizes that Greenland's contribution (and that of Antarctica) may be an underestimate, since at the time of the writing of the fourth assessment report, quantitative estimates of the potential dynamic contribution of the ice sheet through accelerated discharge via its outlets could not be made with high confidence. More recent research has sought to quantify what this dynamic contribution could be under high but physically plausible scenarios of ice flux. Using this approach, Pfeffer et al. (2008) conclude that Greenland could contribute between 0.16 and 0.54 m to global sea-level rise by A.D. 2100. When the approach is also applied to Antarctica and other ice caps and glaciers, the combined projection of high, but plausible, sea-level rise by A.D. 2100 lies between 0.78 and 2.08 m, which includes the effects of thermal expansion of the oceans.

How reasonable is it to hypothesize that global sea level might rise several meters within a century and that the Greenland Ice Sheet might contribute >0.5 m to that rise? Some support for such high rates of sea-level rise is forthcoming from a recent study of sea-level changes during the last (Eemian, Marine Isotope Stage 5e) interglacial, ca. 120,000 years ago. At their maximum, global mean temperatures then were comparable to those predicted in the coming century, and sea level

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was several meters higher than present, most likely because much of the Greenland Ice Sheet had melted (Cuffey and Marshall, 2000). Using a Red Sea stable oxygen isotope record from planktonic foraminifera, Rohling et al. (2008) reconstructed average rates of sea-level rise of up to 1.6 m per century during this interglacial. These rates are for periods when sea level was higher than present and are therefore not associated with large glacial-interglacial fluctuations in ice volume. Rohling et al. (2008) did not attribute the source of these large oscillations in sea level, but they note that rates as high as 1.6 m per century would melt the equivalent of the Greenland Ice Sheet in approximately four centuries. There are some important caveats to this work: the height uncertainties are rather large (each sample point has a one-sigma height uncertainty of 6 m), the Red Sea cores used are only partly dated, and the high rates of sea-level variability reported are not fully replicated between the two cores studied. Moreover, equivalent meter-scale fluctuations in sea level are not recorded in the later part of the current interglacial, suggesting a mode of ice sheet dynamic hitherto not seen in the Holocene. Nevertheless, if valid, the research of Rohling et al. (2008) suggests that rapid rates of sea-level rise are possible in the future, especially when sea level is higher than present, although an implication of the Pfeffer et al. (2008) study is that, on its own, Greenland would only be able to contribute about a third of the proposed 1.6 m rise per century, and probably less given the ice sheet's reduced size at this time.

So, it is plausible that the Greenland Ice Sheet might contribute >0.5 m of global sea-level rise in the next century, and some believe that such high rates of global sea-level rise have occurred in the past. Such a rise would require a sustained high flux of ice over the entire coming century. However, there is considerable evidence from the past to show that the mass balance of the Greenland Ice Sheet fluctuates on a decadal basis, experiencing phases of positive and negative mass balance that change broadly, in tune with variations in air and sea surface temperatures over Greenland and the neighboring North Atlantic.

GREENLAND'S CONTRIBUTION TO TWENTIETH-CENTURY SEA LEVEL

Tide gauge and satellite observations show that global sea level rose during the twentieth century, but the rate of rise was not constant. Thus, Cazenave et al. (2008) estimate that global sea-level rise between January 1993 and February 2008 was 3.1 ± 0.1 mm/a (Fig. 1), which compares with an average rate during the past 50 years of ~1.7 mm/a (Church and White, 2006; Holgate, 2007). Estimates obtained from remotely sensed data of Greenland's changing mass during the past decade vary widely, but all suggest the ice sheet today is making a positive contribution to global sea-level rise. Initial observations suggested that peripheral thinning of the ice sheet was offset by thickening above 2000 m (Krabill et al., 2000; Thomas et al., 2006) such that the overall sea-level contribution was negligible (Zwally et al., 2005). However, more recent observations by the GRACE satellites show significant mass loss from the higher parts of the ice sheet as well, due to longer and more intense melt seasons, especially in 2007 (Wouters et al., 2008) (Fig. 2).

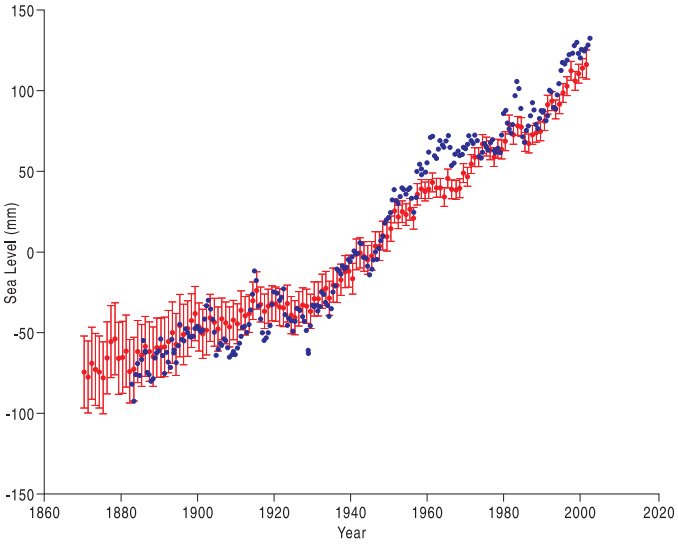

Figure 1. Estimates of twentieth-century global sea-level change (Cazenave et al., 2008). Red dots are from Church and White (2006) and blue dots are from Jevrejeva et al. (2006).

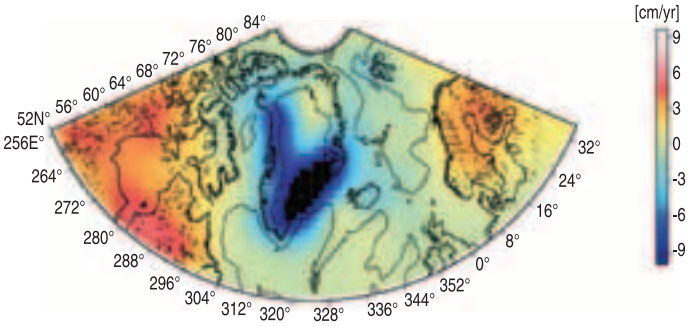

Figure 2. Changes in equivalent water height over Greenland between February 2003 and January 2008 as observed by the Gravity Recovery and Climate Experiment (GRACE) (Wouters et al., 2008).

The cause of this mass loss seems clear: rising temperatures are causing increased melting. For example, summer temperatures have risen by an average of 1.7 °C over the southern part of Greenland between 1991 and 2006, and this has lengthened the melt season (Hanna et al., 2008). Many outlet glaciers here and elsewhere in Greenland have accelerated their speed (Rignot and Kanagaratnam, 2006; Luckman et al., 2006; Howat et al., 2008), and many coastal glaciers have also thinned significantly (Thomas et al., 2006). Water generated by greater surface melt may percolate to the bed of the ice sheet and reduce basal friction, causing the rate of flow of the glaciers to speed up (Zwally et al., 2002), although the significance of this process is debated (Joughin et al., 2008). Moreover, warm ocean currents penetrating fjords are also associated with increased melting of glaciers and ice streams with marine termini (Holland et al., 2008; Hanna et al., 2009). But the broader implications of some of these recent changes for the long-term decadal to century-scale ice sheet stability are uncertain. In the past few years, several of the retreating glaciers have slowed or even started to re-advance (Howat et al., 2007). Moreover, Nick et al. (2009) use a numerical model to demonstrate that tidewater outlet glaciers are very sensitive to changes in their terminus

boundary conditions and adjust quickly and dynamically to short-term climate fluctuations. They warn that recent dynamic instabilities in the Helheim Glacier in southeast Greenland, and potentially elsewhere, do not provide a reliable basis for long-term prediction of ice sheet mass balance change.

The recent loss of mass from Greenland means it is now making an increasingly positive contribution to global sea-level rise. Estimates from GRACE since 2002 vary between 100 and 270 Gt/a, which is equivalent to a sea-level rise of ~0.4–0.7 mm/a (Velicogna and Wahr, 2006; Ramillien et al., 2006; Chen et al., 2006; Luthcke et al., 2006; Wouters et al., 2008). The variability in these estimates reflects differences in the time period of observation, data sources, and methods used in data analysis, as well as real spatial and temporal variations in ice sheet volume. Cazenave et al. (2008) concluded that since 2003 the rate of global sea-level rise decreased from 3.1 ± 0.1 to 2.5 ± 0.5 mm/a largely due to reduced thermal expansion of the oceans. Recent GRACE estimates show that Greenland is presently contributing between ~15%–30% of global sea-level rise, well above the IPCC estimates.

A longer-term twentieth-century perspective is provided by modeling experiments that accurately account for vertical changes in both the sea surface and the sea floor when ice sheets gain or lose mass. Thus, Mitrovica et al. (2001) analyzed spatial trends in rates of tide-gauge measured sea level for 23 selected sites. They observed that rates of twentieth-century sea-level rise in European sites were lower than the global average and concluded that this sea-level "fingerprint" is compatible with a Greenland contribution to global sea level of ~0.6 mm/a during the twentieth century. This estimate is within the range cited from the GRACE studies of recent Greenland contribution to global sea-level rise (~0.4–0.7 mm/a). Resolving the ongoing spatial pattern of sea-level fingerprints is likely to be complex, not least due to non-uniform variations in thermal expansion. Nevertheless, this important analysis suggests a persistent and significant positive Greenland contribution to global sea level during the twentieth century.

Greenland and the North Atlantic

The Greenland Ice Sheet owes much of its existence to the large moisture source provided by the adjacent North Atlantic; although the ice sheet responds to variations in a variety of forcing factors, including volcanic activity and solar output (e.g., Hanna et al., 2005), it is no surprise to find that it is also sensitive to changes in atmospheric and oceanographic conditions in the North Atlantic region. This sensitivity is illustrated by considering how the climate over Greenland responds to fluctuations in the North Atlantic Oscillation (NAO) and the Atlantic Multi-decadal Oscillation (AMO). The mechanisms that cause fluctuations in these indices are not certain, although it seems probable that they respond at least in part to the non-linear dynamics of the extratropical atmosphere and variations in the strength of the thermohaline circulation (Hurrell et al., 2001; Sutton and Hodson, 2005). Neither is presently predictable to any significant degree and, for example, a return to cooler conditions over Greenland in future decades might be expected if their previous pattern of variability continues into the future.

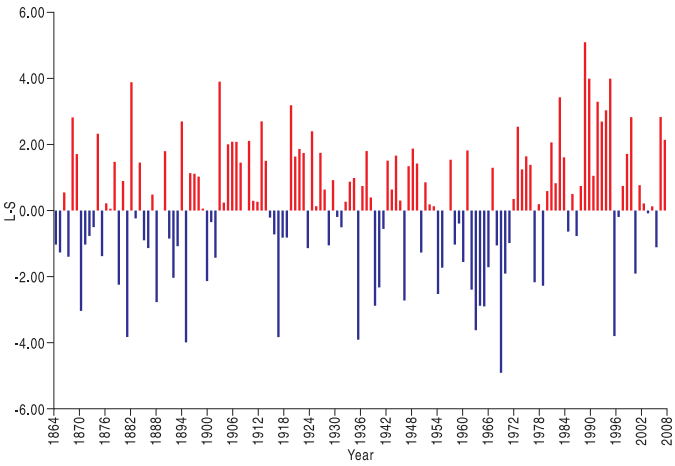

Figure 3. Winter (Dec.–Mar.) index of the North Atlantic Oscillation (NAO) based on the difference of normalized sea-level pressure between Lisbon (L), Portugal, and Stykkisholmur/Reykjavik (S), Iceland, since 1864. Positive values of the index indicate stronger-than-average westerlies over the middle latitudes (http://www.cgd.ucar.edu/cas/jhurrell/indices.html).

The NAO describes a redistribution of atmospheric mass between the Arctic and the subtropical Atlantic. Variations in NAO phases generate large changes in surface air temperature, winds, storminess, and precipitation over the Atlantic and also influence the oceans by causing changes in heat content, gyre circulations, salinity, high-latitude deep-water formation, and sea ice cover (Hurrell et al., 2001). There is no agreed method for defining the NAO, although one measure is provided by the varying sea-level pressure between the Icelandic low and the Azores subtropical high pressure system (Fig. 3). The NAO is positive when the Icelandic low is deep, causing enhanced westerly air flow across the North Atlantic, with cold and dry conditions over Greenland. A shift to a weaker or negative NAO (associated with a weaker Icelandic low) brings warmer conditions and higher precipitation over Greenland. Higher air temperatures over Greenland since the early 1990s (Hanna et al., 2008), as well as the penetration of warmer ocean currents into the fjords of south Greenland since the mid-1990s (Holland et al., 2008), are compatible with the gradual shift from a positive to a more negative NAO since the mid 1980s (Box, 2002; Hanna et al., 2008) (Fig. 3).

Further evidence of the close link between conditions in the North Atlantic and across the Greenland Ice Sheet is provided by the AMO. The AMO describes a 65–75 year variation (0.4 °C range) in North Atlantic sea surface temperatures (SST). Expressed as deviations from the 1961–1990 mean, the AMO is characterized by warm (1930–1960) and cool (1905–1925 and 1970–1990) SST phases. The AMO returned to more positive values again in the 1990s (Fig. 4A). There is widespread evidence that changes in the AMO are related to multi-decadal variations in a range of climate records, including Atlantic hurricanes and North American and European summer climate (e.g., Knight et al., 2006).

Temperature records from coastal stations in Greenland show that the recent increase in temperatures is not unprecedented in the last century and that an earlier episode of warmer than average temperatures is likely linked to changes in the

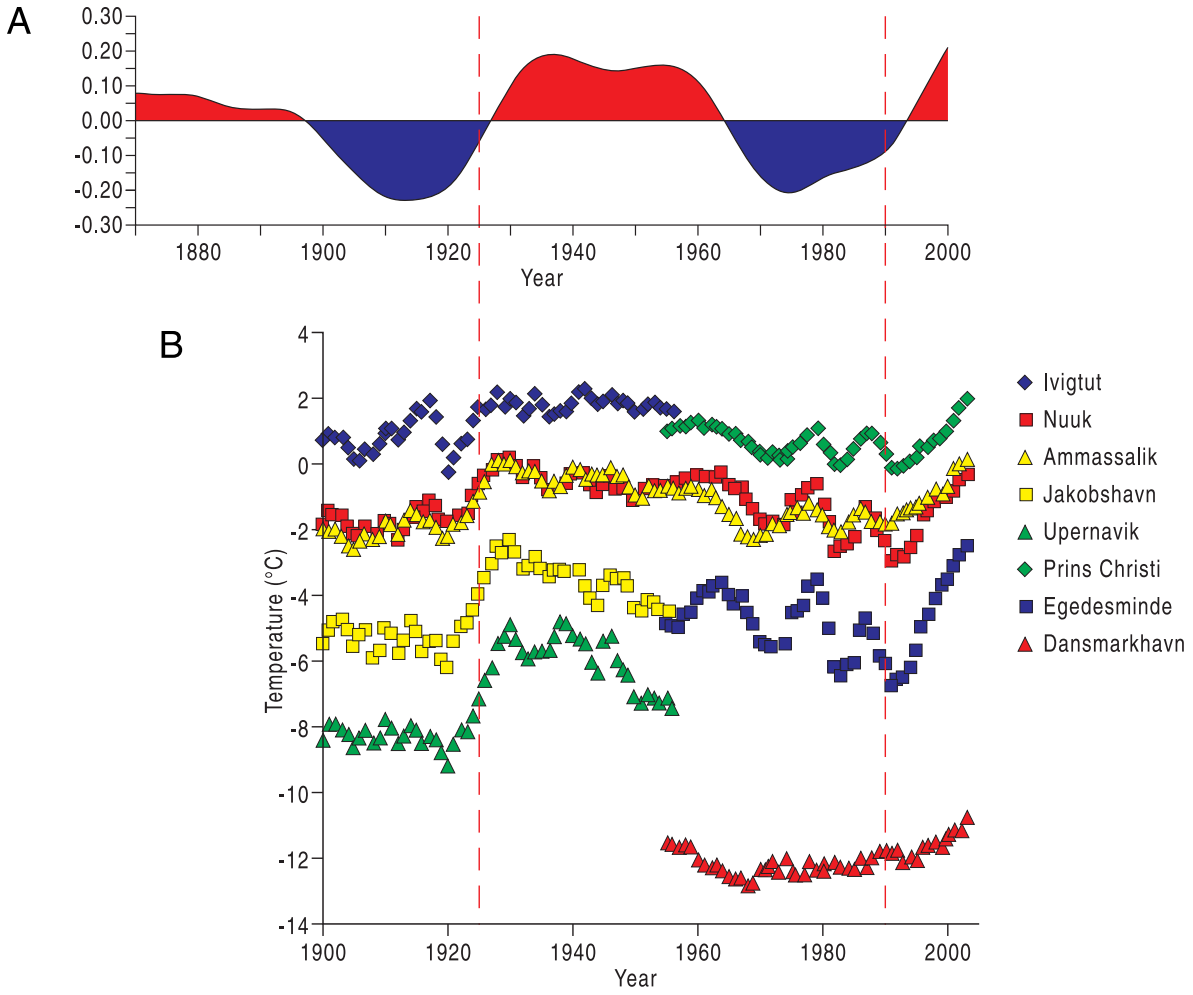

Figure 4. (A) Index of the Atlantic Multi-decadal Oscillation, 1871–2003. The index was calculated by averaging annual mean sea surface temperature observations over the region 0°N to 60°N, 75°W to 7.5°W. The units on the vertical axis are degrees Celsius (Sutton and Hodson, 2005). (B) Annual average temperatures from eight weather stations in Greenland showing similar warming in the periods 1920–1930 and 1995–2005 (Chylek et al., 2006).

AMO. Thus, Chylek et al. (2006) conclude that the rate of warming in Greenland between 1930 and 1940 was ~50% higher than that observed between 1995 and 2005 (Fig. 4B). Both warm phases broadly coincide with periods when the AMO shifted from a cooler to a warmer phase. These climate fluctuations almost certainly impacted the mass balance of the ice sheet. A recently published mass balance history for the ice sheet extending back to 1958 reconstructs mass deficit during the warm 1960s (110 ± 70 Gt/a), near balance in the cool 1970s–1980s (30 ± 50 Gt/a), and accelerated loss since the 1990s (up to 267 ± 38 Gt/a in 2007) (Rignot et al., 2008). These estimates are in broad agreement with reconstructed trends in surface mass balance by Hanna et al. (2005). Wake et al. (2009) identify a distinct change from positive to negative surface mass balance anomalies during the pronounced warming that began in the 1920s and continued until ca. 1960. They conclude that the surface mass balance changes between 1995 and 2005 are not exceptional within the past 140 years.

Is there any proven link between these ice mass fluctuations in Greenland, temperatures, and changes in the rate of twentieth-century global sea level? Although the overall trend in twentieth-century sea level was upward, there have been periods of faster and slower rates of change. The two decades showing the fastest increase in global sea level are centered on 1980 (+5.31 mm/a) and 1939 (+4.68 mm/a), while the lowest rates of change are centered on 1964 (−1.49 mm/a) and 1987 (−1.38 mm/a) (Holgate, 2007). Woodworth et al. (2008) reviewed possible links between periods of accelerated and reduced rates of global sea-level rise and variations in the NAO and AMO and a range of other climate indicators that include the Pacific Decadal Oscillation, Arctic Oscillation, and the Southern Oscillation Index. They concluded that many of these indices change in phase with the major variations in the rate of global sea-level rise. In terms of Greenland's contribution to these sea-level fluctuations, the warmth of the 1980s and the cool period of the 1960s coincide with changes in ice sheet mass balance identified by Rignot et al. (2008). Moreover, the change modeled by Wake et al. (2009) in the 1920s coincides with the acceleration in global sea level noted at this time by Holgate (2007) and Woodworth et al. (2008), although the Wake et al. (2009) analysis did not include potential variations in ice sheet dynamic contributions and estimates

for outlet glacier discharge in their study. Given these findings, it is reasonable to propose that decadal variations in the mass balance of the Greenland Ice Sheet were, in part at least, responsible for variations in the rate of global sea-level rise during the twentieth century.

GREENLAND'S CONTRIBUTION TO SEA LEVEL DURING THE LAST FEW MILLENNIA

Neoglacial Ice Sheet Growth

The "neoglacial" extends from ~4000 years ago to the end of the Little Ice Age and is characterized by a shift to cooler conditions. According to temperature profiles from the Dye 3 and GRIP ice cores, this was equivalent to a 2 °C fall in average air temperatures over the center of the ice sheet between 4000 and 2000 years ago, with further cool periods ca. A.D. 1500 and A.D. 1750 (Dahl-Jensen et al., 1998). There is geomorphological and sea-level evidence from Greenland to suggest that the ice sheet margin advanced over the duration of the neoglacial (Kelly, 1980; Weidick, 1993; van Tatenhove et al., 1996; Long et al., 2009). This evidence includes reworked organic material ripped up from former tundra surfaces by advancing ice, reworked late Holocene marine faunas in recent moraines adjacent to tidewater glaciers, and a rise in relative sea level in west and south Greenland driven, in part at least, by renewed ice loading during the late Holocene (Kelly, 1980).

Reconstructing the magnitude and timing of the neoglacial advance is difficult because a growing ice sheet destroys former ice limits. Ice sheet models provide the best means of estimating ice volume changes, especially when they are constrained by sea level and other geomorphological evidence. Current models suggest that despite the 50–100 km advance of the ice sheet margin, especially in west Greenland where it was most pronounced, the neoglacial regrowth of the ice sheet caused a relatively small draw-down of global sea level, amounting to <0.2 m (Tarasov and Peltier, 2002; Fleming and Lambeck, 2004; Simpson et al., 2009). This is equivalent to a rate of sea-level fall of ~0.05 mm/a when averaged over the past 4000 years.

In reality, it is likely that regrowth of the ice sheet and its associated impact on global sea-level varied over time. The most pronounced periods of neoglacial cooling recorded in the ice cores occurred between 4000 and 2000 B.P., A.D. 1000–1500, and ca. A.D. 1850 (Dahl-Jensen et al., 1998). If we assume that these cooler intervals coincided with ice sheet expansion, then these are the periods that Greenland is most likely to have slowed global sea-level rise. Conversely, warmer conditions identified by Dahl-Jensen et al. (1998) occur between 0 and 1000 A.D., A.D. 1500–1750, and after A.D. 1850, and it is reasonable to hypothesize that these intervals were associated with positive global sea level contributions. Beyond Greenland, there is no evidence for coherent variations in the rate of sea-level change during the late Holocene that can be unambiguously attributed to variations in the neoglacial volume of the Greenland Ice Sheet, although an acceleration during the past 100–150 years seems widespread and may have a Greenland origin (e.g., Gehrels et al., 2008).

The record from the last few thousand years shows that the Greenland Ice Sheet has experienced a significant increase in mass during the cooler conditions of the "neoglacial." All around the margins of the present ice sheet are fresh moraines that mark the maximum position of this advance, reached at the end of the Little Ice Age (the late nineteenth or early twentieth century). Most of these lie within a few kilometers of the present ice sheet margin, showing that the ice sheet was more extensive in the recent past. Although retreat is obvious in many areas, in west Greenland there remains a considerable distance between the present ice margin and its position at the start of the neoglacial, when model experiments suggest that the margin lay many tens of kilometers inland of its present position (e.g., Simpson et al., 2009).

CONCLUSIONS

Predictions suggest that the Greenland Ice Sheet could contribute >0.5 m of global sea-level rise by the end of this century, and one sensitivity study predicts that rates of mass loss would match those last seen as far back as ~10,000 years ago, at the time of fastest ice sheet retreat (Pfeffer et al., 2008). Satellite and field observations show that the evolving mass of the Greenland Ice Sheet is making an increasingly positive contribution to global sea-level rise and, although estimates vary, GRACE data indicate this contribution is between 0.4 and 0.7 mm/a, equal to ~15%–30% of the total global rise in sea level measured since 2003. The present contribution is considerably larger than predicted by the Fourth IPCC Assessment Report but is less than some high-end estimates of sea-level rise from Greenland in the next century (e.g., Pfeffer et al., 2008) and the range of high rates of sea-level rise reconstructed from the last interglacial (Rohling et al., 2008).

The improved spatial and temporal resolution of recent geodetic methods means that we are gaining new and unprecedented insights into the dynamics of the ice sheet, its glaciers, and ice streams. These observations are rapidly changing our understanding of how Greenland responds to climate change. There is, for example, growing evidence that the surface mass balance and glacier dynamics in Greenland are related to changes in air and ocean temperatures that vary in phase with changing conditions in the adjacent North Atlantic. Two periods of rapid atmospheric warming in the twentieth century, one in the 1980s and the other in the 1920s, coincide with phase shifts in the AMO and likely saw Greenland making a positive contribution to accelerations in the rate of global sea-level rise recorded by tide gauge records. But advances in current-change monitoring must be matched by the development of new understanding regarding the past behavior of the ice sheet. We still know very little regarding the mass balance history of the ice sheet during the past few centuries, despite the large climate changes that existing records suggest have occurred. Future research must bridge the gap between geological reconstructions and recent direct observations if we are to establish firm decadal and century-scale trends in ice sheet mass balance and hence determine whether the variations we observe today are within or beyond normal ice sheet variability. Only then will we reduce the considerable uncertainty that presently exists regarding the contribution of the Greenland Ice Sheet to past and future sea-level change.

ACKNOWLEDGMENTS

I thank my collaborators on this project for their insightful discussions, especially Glenn Milne, Sarah Woodroffe, and Roland Gehrels. I also thank Jerry Mitrovica, an anonymous referee, and *GSA Today* science editor Stephen Johnston for their helpful comments on this paper during review. This paper is a contribution to International Geological Correlation Programme (IGCP) Project 495 "Quaternary Land-Ocean Interactions: Driving Mechanisms and Coastal Responses" and the International Union for Quaternary Research (INQUA) Commission on Coastal and Marine Processes. This research draws on work conducted under Natural Environment Research Council (NERC) Grant NE/C519311/1.

REFERENCES CITED

Andersen, K.K., Ditlevsen, P.D., Rasmussen, S.O., Clausen, H.B., Vinther, B.M., Johnsen, S.J., and Steffensen, J.P., 2006, Retrieving a common accumulation record from Greenland ice cores for the past 1800 years: Journal of Geophysical Research, v. 111, doi: 10.1029/2005JD006765.

Box, J.E., 2002, Survey of Greenland instrumental temperature records: 1873–2001: International Journal of Climatology, v. 22, p. 1829–1847, doi: 10.1002/joc.852.

Cazenave, A., Lombard, A., and Llovel, W., 2008, Present-day sea-level rise: A synthesis: Comptes Rendus Geoscience, v. 340, p. 761–770, doi: 10.1016/j.crte.2008.07.008.

Chen, J.L., Wilson, C.R., and Tapley, B.D., 2006, Satellite gravity measurements confirm accelerated melting of Greenland Ice Sheet: Science, v. 313, p. 1958–1960, doi: 10.1126/science.1129007.

Church, J.A., and White, N.J., 2006, A 20th century acceleration in global sea-level rise: Geophysical Research Letters, v. 33, doi: 10.1029/2005GL024826

Chylek, P., Dubey, M.K., and Lesins, G., 2006, Greenland warming of 1920–1930 and 1995–2005: Geophysical Research Letters, v. 33, doi: 10.1029/2006GL026510.

Cuffey, K.M., and Marshall, S.J., 2000, Substantial contribution to sea-level rise during the last interglacial from the Greenland Ice Sheet: Nature, v. 404, p. 591–594, doi: 10.1038/35007053.

Dahl-Jensen, D., Mosegaard, K., Gundestrup, N., Clow, G.D., Johnsen, S.J., Hansen, A.W., and Balling, N., 1998, Past temperatures directly from the Greenland Ice Sheet: Science, v. 282, p. 268–271, doi: 10.1126/science.282.5387.268.

Fleming, K., and Lambeck, K., 2004, Constraints on the Greenland Ice Sheet since the Last Glacial Maximum from sea-level observations and glacial-rebound models: Quaternary Science Reviews, v. 23, p. 1053–1077, doi: 10.1016/j.quascirev.2003.11.001.

Gehrels, W.R., Hayward, B.W., Newnham, R.M., and Southall, K.E., 2008, A 20th century sea-level acceleration in New Zealand: Geophysical Research Letters, v. 35, doi: 10.1029/2007GL032632.

Hanna, E., Huybrechts, P., Janssens, I., Cappelen, J., Steffen, K., and Stephens, A., 2005, Runoff and mass balance of the Greenland Ice Sheet: 1958–2003: Journal of Geophysical Research, v. 110, doi: 10.1029/2004JD005641.

Hanna, E., Huybrechts, P., Steffen, K., Cappelen, J., Huff, R., Shuman, C., Irvine-Fynn, T., Wise, S., and Griffiths, M., 2008, Increased runoff from melt from the Greenland Ice Sheet: A response to global warming: Journal of Climate, v. 21, p. 331–341, doi: 10.1175/2007JCLI1964.1.

Hanna, E., Cappelen, J., Fettweis, X., Huybrechts, P., Luckman, A., and Ribergaard, M.H., 2009, Hydrologic response of the Greenland Ice Sheet: The role of oceanographic warming: Hydrological Processes, doi: 10.1002/hyp.7090 (in press).

Holgate, S., 2007, On the decadal rates of sea level change during the twentieth century: Geophysical Research Letters, v. 34, doi: 10.1029/2006GL028492.

Holland, D.M., Thomas, R.H., De Young, B., Ribergaard, M.H., and Lyberth, B., 2008, Acceleration of Jakobshavn Isbrae triggered by warm subsurface ocean waters: Nature Geoscience, v. 1, p. 659–664, doi: 10.1038/ngeo316.

Howat, I.M., Joughin, I., and Scambos, T.A., 2007, Rapid changes in ice discharge from Greenland outlet glaciers: Science, v. 315, p. 1559–1561, doi: 10.1126/science.1138478.

Howat, I.M., Joughin, I., Fahnestock, M., Smith, B.E., and Scambos, T.A., 2008, Synchronous retreat and acceleration of southeast Greenland outlet glaciers 2000-06: Ice dynamics and coupling to climate: Journal of Glaciology, v. 54, p. 646–660, doi: 10.3189/002214308786570908.

Hurrell, J.W., Hoerling, M.P., and Folland, C.K., 2001, Climatic variability over the North Atlantic: Meteorology at the Millennium: 150th Anniversary of the Royal Meteorological Society, London, Academic Press, p. 143–151.

IPCC, 2007, Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change: Cambridge, UK, Cambridge University Press, 996 p.

Jevrejeva, S., Grinsted, A., Moore, J.C., and Holgate, S., 2006, Nonlinear trends and multiyear cycles in sea level records: Journal of Geophysical Research, doi: 10.1029/2005JC003229.

Joughin, I., Das, S.B., King, M.A., Smith, B.E., Howat, M., and Mooni, T., 2008, Seasonal speedup along the western flank of the Greenland Ice Sheet: Science, v. 320, p. 781–783.

Kelly, M., 1980, The status of the Neoglacial in Western Greenland: Rapport Grønlands Geologiske Undersøgelse, v. 96, 24 p.

Knight, J.R., Folland, C.K., and Scaife, A.A., 2006, Climate impacts of the Atlantic Multidecadal Oscillation: Geophysical Research Letters, v. 33, doi: 10.1029/2006GL026242.

Krabill, W., Abdalati, W., Frederick, E., Manizade, S., Martin, C., Sonntag, J., Swift, R., Thomas, R., Wright, C., and Yungel, Y., 2000, Greenland Ice Sheet: High-elevation balance and peripheral thinning: Science, v. 289, p. 428–430.

Long, A.J., Woodroffe, S.A., Dawson, S., Roberts, D.H., and Bryant, C.L., 2009, Late Holocene relative sea level rise and the Neoglacial history of the Greenland ice sheet: Journal of Quaternary Science, doi: 10.1002/jqs.1235.

Luckman, A., Murray, T., de Lange, R., and Hanna, E., 2006, Rapid and synchronous ice-dynamic changes in East Greenland: Geophysical Research Letters, v. 33, L03503, doi: 10.1029/2005GL025428.

Luthcke, S.B., Zwally, H.J., Abdalati, W., Rowlands, D.D., Ray, R.D., Nerem, R.S., Lemoine, F.G., McCarthy, J.J., and Chinn, D.S., 2006, Recent Greenland ice mass loss by drainage system from satellite gravity observations: Science, v. 314, p. 1286–1289, doi: 10.1126/science.1130776.

Mitrovica, J.X., Tamisiea, M., Davis, J.L., and Milne, G.A., 2001, Recent mass balance of polar ice sheets inferred from patterns of global sea-level change: Nature, v. 409, p. 1026–1029, doi: 10.1038/35059054.

Nick, F.M., Vieli, A., Howat, I.M., and Joughin, I., 2009, Large-scale changes in Greenland outlet glacier dynamics triggered at the terminus: Nature Geoscience, v. 2, p. 110–114, doi: 10.1038/ngeo394.

Pfeffer, W.T., Harper, J.T., and O'Neel, S., 2008, Kinematic constraints on glacier contributions to 21st-century sea-level rise: Science, v. 321, p. 1340–1343, doi: 10.1126/science.1159099.

Ramillien, G., Lombard, A., Cazenave, A., Ivins, E.R., Llubes, M., Lemy, F., and Biancale, R., 2006, Interannual variations of the mass balance of the Antarctica and Greenland ice sheets from GRACE: Global and Planetary Change, v. 53, p. 198–208, doi: 10.1016/j.gloplacha.2006.06.003.

Rignot, E., and Kanagaratnam, P., 2006, Changes in the velocity structure of the Greenland ice sheet: Science, v. 311, p. 986–990.

Rignot, E., Box, J.E., Burgess, E., and Hanna, E., 2008, Mass balance of the Greenland ice sheet from 1958 to 2007: Geophysical Research Letters, v. 35, doi: 10.1029/2008GL035417.

Rohling, E.R., Grant, K., Hemleben, C.H., Siddall, M., Hoogakker, B.A.A., Bolshaw, M., and Kucera, M., 2008, High rates of sea-level rise during the last interglacial period: Nature Geoscience, v. 1, p. 38–42, doi: 10.1038/ngeo.2007.28.

Simpson, M.J.R., Milne, G.A., Huybrechts, P., and Long, A.J., 2009, Calibrating a glaciological model of the Greenland Ice Sheet from the last glacial maximum to present-day using field observations of relative sea level and ice extent: Quaternary Science Reviews (in press).

Sutton, R.T., and Hodson, D.L.R., 2005, Atlantic Ocean forcing of Northern American and European summer climate: Science, v. 309, p. 115–118, doi: 10.1126/science.1109496.

Tarasov, L., and Peltier, W.R., 2002, Greenland glacial history and local geodynamic consequences: Geophysical Journal International, v. 150, p. 198–229, doi: 10.1046/j.1365-246X.2002.01702.x.

Thomas, R., Frederick, E., Krabill, W., Manizade, S., and Martin, C., 2006, Progressive increase in ice loss from Greenland: Geophysical Research Letters, v. 33, L10503, doi: 10.1029/2006gl026075.

van Tatenhove, F.G.M., van der Meer, J.J.M., and Koster, E.A., 1996, Implications for deglaciation chronology from new AMS age determinations in central west Greenland: Quaternary Research, v. 45, p. 245–253, doi: 10.1006/qres.1996.0025.

Velicogna, I., and Wahr, J., 2006, Acceleration of Greenland ice mass loss in spring 2004: Nature, v. 443, p. 329–331, doi: 10.1038/nature05168.

Wake, L.M., Huybrechts, P., Box, J.E., Hanna, E., Janssens, I., and Milne, G.A., 2009, Surface mass-balance changes of the Greenland Ice Sheet since 1866: Annals of Glaciology, v. 50, p. 178–184, doi: 10.3189/172756409787769636.

Weidick, A., 1993, Neoglacial change of ice cover and the related response of the Earth's crust in West Greenland: Rapport Grønlands Geologiske Undersøgelse, v. 159, p. 121–126.

Woodworth, P.L., White, N.J., Jevrejeva, S., Holgate, S.J., Church, J.A., and Gehrels, W.R., 2008, Evidence for the accelerations of sea level on multi-decade and century timescales: International Journal of Climatology, doi: 10.1002/joc.1771.

Wouters, B., Chambers, D., and Schrama, E.J.O., 2008, GRACE observes small-scale mass loss in Greenland: Geophysical Research Letters, v. 35, doi: 10.1029/2008GL034816.

Zwally, H.J., Abdalati, W., Herring, T., Larson, K., Saba, J., and Steffen, K., 2002, Surface melt-induced acceleration of Greenland ice-sheet flow: Science, v. 297, p. 218–222, doi: 10.1126/science.1072708.

Zwally, H.J., Giovenetto, M.B., Li, J., Corneio, H.G., Beckley, M.A., Brenner, A.C., Saba, J.L., and Yi, D.H., 2005, Mass changes of the Greenland and Antarctic ice sheets and shelves and contributions to sea-level rise: 1992–2002: Journal of Glaciology, v. 51, p. 509–527, doi: 10.3189/172756505781829007.

Manuscript received 16 January 2009; accepted 24 March 2009. ❄

DIALOGUE

Industry is *Not* the Enemy

Judith (Judy) Totman Parrish, *Dept. of Geological Sciences, Mines 322, University of Idaho, Moscow, Idaho 83844-3022, USA; jparrish@uidaho.edu*

Judy Parrish

Recently, GSA Headquarters staff and officers have received what seems to be an increasing number of complaints from our members regarding our associations with industry, particularly the resources industry. I don't want to paint with too broad a brush, but the gist of some of these remarks seems to be that these industries are inherently evil and that GSA should have nothing to do with them. The opinion seems to be that, by associating themselves with GSA, these "dirty" companies are attempting to "greenwash" themselves. Recently, this was discussed within the Executive Committee, and we are in agreement that these complaints represent a disturbing trend that threatens both the Society and, indeed, our entire profession. Thus, it falls to me, as your president, to explain why and to ask that you make yourselves more aware of how industry operates and how our association with industry has been and should continue to be beneficial to us, to industry, and, ultimately, to society.

In some ways, I'm finding it hard to devolve some of the issues, because in a very real way, industry is part of us, regardless of sponsorships, advertisements, and booths in the exhibit hall at the annual meeting. It's a little like saying that I'm going to analyze the functioning of an arm independent of the health of the rest of the body. But here are some observations:

1. Many GSA members work for companies, both private and public. You know a lot of them. Ask them sometime about how they like their jobs, how they feel about working for industry. You might be surprised at the answer. A friend of mine, an engineer and project manager, works for one of the largest oil companies. She is proud of the company and its approach to business around the world, the way it respects the world's many cultures, offering both goods and financial assistance in natural disasters, supporting education, and being circumspect in looking for and delivering on ways to develop Earth's resources. Her company provides thousands of jobs to people here as well as in the poorest and neediest parts of the world. And the company demonstrated flexibility and care for her by supporting her very sensitively when her husband underwent a long-term terminal illness. How far the petroleum industry has come in minimizing environmental impacts was outlined by ecologist Jared Diamond in his 2004 book, *Collapse*, in which he noted that, to his surprise, the footprint of an oil rig in environmentally sensitive New Guinea was extremely small.
2. Most of the largest companies, which seem to be the objects of much of the ire, are public companies. The petroleum industry is currently running an advertisement that many of us might not like, but which is accurate: very large portions of these companies are owned by members of the public, including GSA members. Those of us with retirement savings in diversified stock funds own parts of these companies and have benefited from their profits. Indeed, in the current financial crisis, the resource industries are keeping our funds from sliding even further—we will be that much less dependent on our fellow taxpayers for our well-being in retirement, so that scarce tax resources can be used to help those who are truly in need.
3. A large proportion of our students end up working in industry. The just-released report by the American Geophysical Institute (AGI) on geosciences employment sectors indicates that 21% of recent M.S. degree recipients and 3% of recent Ph.D. recipients work in the petroleum industry, and the demand for such workers is only going to increase over the next 25 years (AGI, 2009). If we wanted to have good graduate programs, but somehow could take only students who were committed to working just in academia or government, not only would we be limiting our students' options, we would be limiting our own programs. Moreover, when our students do go into industry, they don't undergo personality changes to become evil, and we don't shun them, either. Every company, including the big ones, is the sum of its employees. There is no independent entity apart from the people in the company. Indeed, if we have taught our students well—that is, if we have taught them to be honorable and ethical—the fact that they go into industry should be heartening in two ways: (a) we've sent honorable and ethical employees to that company, and (b) the company has hired honorable and ethical people who have perhaps the best chance of heading off potential corporate misdeeds because they can work from within. Sure, those students might hold low-level positions at first, but they will work their way up. Meanwhile, they are making good salaries—the best in the geosciences—and saving for their own retirements, all of which benefit the national economy now and in the future.
4. The sponsorship agreements that GSA signs with companies are of great benefit to the Society. Yes, these companies get their names on things, but the benefit accrues mostly to the science and allows GSA to offers services at a lower cost to its members.

5. Our civilization is based on the use of natural resources and will continue to be dependent on them for a very long time. Our responsibility is to make sure that we continue to develop means of extraction that are less environmentally damaging and means of remediation that are more effective. We are the best-qualified people to do this, and our students are the best ones to carry these methods into the companies that do the work. The demand for resources will not go away, and the companies will not stop meeting that demand just because some parts of the process offend our sensibilities. It is our responsibility to make sure that the demand is met as safely and responsibly as possible.

Do all the employees of companies behave honorably and ethically? No, and we have seen the scandals. But I want to make a few additional observations. First, we only hear about scandals in big companies for the very reason that if it happens within a big company, it's news—everything, including the amount of money involved, is scaled up. But small companies are just as susceptible—arguably more so because of the lower level of scrutiny—to corporate misdeeds. There is nothing inherently bad about big companies. They're just big. Second, we hear about these things, and the miscreants are caught and punished. If ever there were a glass-half-full situation, it's this. Third, our students who are now employees don't like it any more than we do; when they reach positions of power within their companies, they can influence the corporate decision making. Fourth, those who hold mutual funds in stocks benefit from the success of large companies. We can hold the feet of our fund managers to the fire to do their due diligence in ensuring that corporate management is honorable and ethical. Our collective power as stockholders is enormous. Just ask those companies who have run afoul of Calpers (managers of the enormous California public retirement system) or CREF (College Retirement Equities Fund, in which many professors have their 403[b]s)! Finally, no institution is immune. Universities have had scandals. Even GSA had its own corporate scandal a few years ago, and only in the last couple of years can we say we've fully recovered and set into place the structure that will prevent such an occurrence again. Does that mean universities and GSA are evil? No, of course not.

Like most of you, I'm not particularly happy with CEO compensation and the wage gap, but, again, our power as stockholders and our students' power as employees can change things—these are already matters of intense debate in the business world, and we are beginning to see some deliberate changes. In the meantime, dissociating ourselves from industry would be like throwing the baby out with the bathwater. The energy some of our members put into excoriating the association with our colleagues in industry is misplaced and should be directed toward making sure that the managers of companies honor their obligation to behave well.

REFERENCES CITED

American Geological Institute (AGI), 2009, Status of the Geoscience Workforce: Washington, D.C., American Geological Institute (See especially Chapter 3, Geoscience Employment Sectors).

Diamond, J.S., 2004, Collapse: New York, Viking Adult, 592 p.

GEOLOGIC PAST

Highlighting Articles from Past Issues of *GSA Bulletin*

"The Problem of Petroleum"

Frederick G. Clapp, *GSA Bulletin*, March 1939

In an "Anniversary Day" address to the Society at its semicentennial celebration in December 1938, Frederick G. Clapp tackles "the problem of petroleum" with a global historical view of the science of petroleum geology, an analysis of the economics of "over- or undersupply" (p. 370), and a call for scientific foresight. His speech was published in *GSA Bulletin* in March 1939 (v. 50, p. 361–374).

First, Clapp addresses the question, "Who was the first petroleum geologist?" (p. 362). Clapp wisely argues that this person or persons would not "be found among our fathers, uncles, or contemporary teachers" (p. 362), but rather would have lived at the edge of recorded history. The first petroleum geologist could have been a Chinese engineer, a Babylonian navigator, a general of Alexander the Great, or even Lot, the nephew of Abraham.

According to Clapp, the subject of petroleum was not raised in scientific circles until the latter part of the nineteenth century, when the "anticlinal theory" for location of petroleum and natural gas gradually evolved. "For decades this theory quietly smoldered in oil circles, prevented from breeding an army of petroleum geologists only because of limited demand for oil products and the inherent conservatism of a majority of operators, few of whom had at that time faith that oil geology was more than a passing fad" (p. 363).

One of the perceived most valuable functions of geologists in the very early days of petroleum exploration was "showing where *not* to drill" (p. 364). Technical advances were driven by increasing demand and professional competition. "Commencing with two small consulting offices in 1908 … the number of practicing geologists in the United States slowly increased … as it became fashionable for oil operators to have their properties 'detailed' in advance of drilling" (p. 365).

With the rise of geophysics, petroleum geologists and operators gained new exploration and location methods. However, Clapp writes, "A note of warning must be sounded which might have saved millions of dollars if it had been radioed over the world when geophysics came into use. Far from being an infallible means of oil discovery when used alone, the new science is useful only when its method and practice are controlled by a supervising geologist" (p. 366).

Yet this was not "the problem of petroleum," and neither was the need for improvements in geologic technique and in understanding petroleum origin. The problem, according to Clapp, was "how to produce and distribute the volume of petroleum which is economically necessary at any given time" (p. 368). Clapp blames fluctuations in the balance between supply and demand for price swings "between 10 and 20 cents per barrel" (p. 369)—perhaps a pittance given the present-day economic situation, but still, a 100% variance.

Clapp emphasizes the fact, as is widely acknowledged today, that "there are only a certain number of possible oil-bearing States, as is likewise the case with foreign countries. Consequently, even if technique should advance to an unlimited extent, new discoveries … will in time cease" (p. 369). Clapp also predicts that even if the United States curtailed its consumption of oil products, other nations would increase demand, "particularly the Asiatic countries, some of which have hardly begun to expand commercially" (p. 370).

While the main effects of the "depression-oversupply cycle" were, and still are, economic and political, this "vicious circle," writes Clapp, also affected the quality of geologic education and employment. On the one hand, education of young geologists declined, and on the other, geologists found it difficult to obtain positions in oil exploration—"Consequently, geologic talent was wasted as well as oil" (p. 371).

It is interesting to note Clapp's opinion that progress in the petroleum industry was, even then, hampered by public perception. Clapp, a petroleum geologist for the U.S. Geological Survey with a point of view delicately balanced between his profession and pure science, seems to mix accuracy, partiality, and prescience as he writes, "Any problem in the oil industry is ignorantly or maliciously made much of by journalists, politicians, and government agencies, with seemingly no general desire to find a solution. This attitude results in outside interference, unjust criticism, unwise regulation, and unnecessarily burdensome taxes" (p. 373).

Clapp ends his address with a call for scientific foresight: "Since we always have too much oil or too little, it behooves us to look ahead" at least 20 years (p. 372). "The role of The Geological Society of America is, of course, purely scientific," Clapp writes, while noting that, as part of the "geologic fraternity," GSA and other societies, the USGS, academia, industry, and government were duty bound to coordinate efforts toward "leveling out inequalities between flush and lean production" (p. 374).

2009 Events & Deadlines ✷ Portland, Oregon, USA

23 June
- Space request deadline

11 August
- Abstract submission deadline

14 September
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- Housing deadline

21 September
- Registration cancellation deadline

13–17 October
- Premeeting field trips

16–18 October
- Short courses & workshops

17 October
- GSA Presidential Address & Awards Ceremony: Sat., 7–9 p.m.

18 October
- GSA Gold Medal Lectures: Sun., 5–7 p.m.
- Welcoming Party & Exhibits Opening: Sun., 7–9 p.m.
- Exhibit Hall open 7–9 p.m.

18–21 October
- Technical Program: Sun.–Wed.
  Oral sessions
  Full-day poster sessions
- Lunchtime Keynote Lectures: Sun.–Wed., 12:15–1:15 p.m.

19 October
- Darwin Day
- Group alumni reception: Mon., 7–9:30 p.m.
- Private alumni receptions
- Public Forum

19–20 October
- Exhibit Hall open Mon.–Tues., 9 a.m.–6 p.m.

21 October
- Exhibit Hall open Wed., 9 a.m.–2 p.m.

22–24 October
- Postmeeting field trips

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I invite you to Portland, Oregon, USA, to attend the 2009 GSA Annual Meeting & Exposition on 18–21 October. As chair of the meeting's local planning committee, I can assure you that the local geoscience community has thought hard about what to feature of our rich, dynamic landscape and city.

First, we have developed dozens of field trips covering nearly all the Northwest, from coastal jaunts to fossil beds, live volcanoes to fishing holes, and geology via mass transit to river floats. Let's not forget the practical side of geology and soils—our field trips cover both the Walla Walla and the Willamette Valley wine appellations.

Portland straddles the banks of the Willamette River just below the confluence with the mighty Columbia. Mount Hood and Mount St. Helens volcanoes define the skyline.

I invite you to relax with friends and colleagues downtown as you easily travel via light rail and streetcar from your hotel to your choice of local brew pubs or nationally recognized restaurants. Take in Powell's Books, an independent bookstore so spacious you need a map to get around!

Portland has a rich and vibrant arts and music scene. You will have an array of plays, dance, and live music venues to choose from for entertainment, as well as museums and art galleries. Go exploring with the family at the Oregon Museum of Science and Industry or take in a geology-related movie at their OMNI MAX theatre.

Finally, enjoy the people who live and work in Portland. We are a friendly and tolerable bunch. Come sit with us in Pioneer Square, Portland's living room, and enjoy the pleasant fall weather.

See you in October,

Vicki S. McConnell, *Oregon State Geologist*
Chair, 2009 GSA Annual Meeting & Exposition Local Planning Committee

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Do you need a travel visa to attend the meeting? See p. 39.

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International Division Travel Grants

Application deadline: 1 August 2009

GSA's International Division is offering travel grants to assist the participation of international scientists and students in the annual meeting of the Society. Funds are limited; these grants will never cover the full cost of attending the meeting but are intended to help defray the combined cost of registration, housing, and travel. To apply, please go to the GSA International Division's Web page, **www.geosociety.org/sectdiv/idiv/travelGrants.htm.**

Questions?

Contact John Wakabayashi at jwakabayashi@csufresno.edu.

STUDENTS: SAVE $$ by VOLUNTEERING at the Annual Meeting

Volunteers will earn

- FREE registration by volunteering 10 hours or more
- A US$25 stipend for every 5 hours volunteered
- A FREE *Abstracts with Programs* volume by volunteering 15 hours or more

To register as a volunteer, go to **http://rock.geosociety.org/student_vol/.**

For more information, contact Eric Nocerino enocerino@geosociety.org +1-303-357-1060.

See page 16 of this issue to learn how to save more with student travel grants.

STUDENT TRAVEL GRANTS

Application deadline: 14 September 2009

GSA offers the following two grants for GSA student members to attend the annual meeting. Check **www.geosociety.org/meetings/2009/travelgrants.htm** for the e-application form, which will be available sometime in early June. You can apply for both grants but may only receive one award.

Please note: Applying for a travel grant *does not* register you for the meeting. You must register for the meeting at **www.geosociety.org/meetings/2009/reg.htm** BEFORE you can apply for a grant.

Notification of grant status will be made by e-mail. Those receiving grants must pick up their checks in person (with photo ID) on site in Portland.

1. GSA Student Travel Fund and Section Travel Grants

The Student Travel Fund and the GSA Section Travel Grants have been combined into one program, so you only need to submit one application. Also, the GSA Foundation has made US$4,500 available to each of the six GSA Sections. This, combined with equal funds from the Sections and donations from meeting registrants, can help more GSA student members (grad & undergrad) make it to the meeting! For eligibility requirements, please visit the Section Web sites listed below or contact the Section secretary directly.

Cordilleran: www.geosociety.org/sectdiv/cord/travelGrants.htm

Rocky Mountain: www.geosociety.org/sectdiv/rockymtn/index.htm

North-Central: www.geosociety.org/grants/ncgrant.htm

South-Central: www.geosociety.org/sectdiv/southc/index.htm#travel

Northeastern: www.geosociety.org/grants/negrant.htm

Southeastern: core.ecu.edu/geology/neal/segsa/travel.html

GSA members, guests, and friends: You can help support the next generation of geoscientists by contributing to the Student Travel Fund when you register for the annual meeting. One-hundred percent of the contributions received will go to help fund student travel.

2. GSA Student Travel Grant for Minorities, Women, and Persons with Disabilities

GSA's Minorities and Women in the Geosciences Committee and the GSA Foundation are offering funds for one or more eligible students to travel to the annual meeting. The primary goal of this student travel scholarship is to encourage the participation of women, minorities, and persons with disabilities in GSA's annual meetings. Each of the successful candidates will receive a complimentary GSA membership for 2010 and an average cash award of US$500 to be used for roundtrip airfare, hotel accommodations, meeting registration, and/or meals.

Eligible applicants must be full-time students (grad or undergrad) majoring in geology, earth science, or a related field and enrolled at an accredited university or college for the fall semester 2009. Applicants must also be U.S. citizens or have permanent residency status with a valid social security number. Preference will be given to students presenting papers/posters at the meeting, either as primary or secondary authors. Applicants must also be GSA student members at the time of application.

Awardees are expected to attend the entire meeting and to participate in GeoScience Day, an annual meeting event designed to encourage interest in the geosciences in middle- and high-school students.

Please apply online at **www.geosociety.org/meetings/2009/travelgrants.htm** (a paper application [PDF format] will be available if this is not possible). Questions? Contact GSA at +1-303-357-1000.

Publish with GSA

GSA's top-rated journals—*GSA Bulletin*, *Geology*, *Geosphere*, and *Lithosphere*—publish scientific papers on all aspects of earth science, with science editors at the forefront of their fields overseeing a rigorous peer-review process for all manuscripts.

GSA Bulletin has published definitive geoscience works since 1890—and it's as timely, relevant, and whip-smart as ever. Join a top-notch roster of international contributors: submit a paper to *GSA Bulletin*. Impact factor 3.354; cited half-life: >10 years. Submit online: http://www.editorialmanager.com/gsabulletin/

Geology articles are innovative, provocative, and timely. Of interest to a broad audience, papers in *Geology* often describe a significant advance in the field. Impact factor 3.754; cited half-life: 9 years. Submit online: http://www.editorialmanager.com/geology/

Geosphere targets an international audience with its high-quality research results from all geosciences fields. An online format encourages extensive use of color, animations, and interactivity. Submit online: http://www.editorialmanager.com/geosphere/

Lithosphere, launched in February, highlights research that addresses how the surface, crust, and mantle interact to shape the physical and chemical evolution of the lithosphere at all spatial and temporal scales. Submit online: http://www.editorialmanager.com/lithosphere/

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Have a whole session's worth of papers? Consider making a permanent record of these talks by publishing a GSA Special Paper organized and edited by you and your colleagues. GSA Special Papers are carefully prepared, are published quickly after acceptance, and have a worldwide distribution in print and online. Please communicate your interest by submitting a proposal to Don Siegel or Pat Bickford (GSA Books Editorial Office, Department of Earth Sciences, Syracuse University, 204 Heroy Geology Lab, Syracuse, NY 13244-1070, USA, +1-315-443-7300, gsabooks@syr.edu).

GUEST PROGRAM

All annual meeting attendees and guests are welcome to register for the following tours. Tour fees offset the cost of guides, transportation, admission, and gratuities. Tours may be cancelled if minimum attendance is not met, so please register early!

Tour participants should check in at the Guest Hospitality Suite to be directed to the trip departure location. Please plan to arrive at least 15 minutes early so that you don't miss the bus. GSA is unable to refund tour costs if you miss the scheduled departure time.

For Guest Hospitality Suite hours, information about free guest seminars, and more go to **www.geosociety.org/meetings/2009/.**

View of Hawthorne Bridge and Gov. Tom McCall Waterfront Park, Portland. Photo courtesy Travel Portland/Robert Reynolds and the Portland Oregon Visitors Association.

Sunday, 18 October

101. City Tour—Weird and Wonderful!

9 a.m.–1 p.m. Cost: US$79; min.: 20.

The "city of roses" trip would not be complete without time to see the highlights and explore both the beautiful and the unusual. Board your luxury motor coach this morning with your guide to see the financial district, the smallest park in the world, and Old Town before you reach Chinatown for your walking tour. Descend underground to have a flashlight tour of the legendary "Shanghai tunnels," and learn the historical stories of people finding themselves on an ocean-going voyage without their permission! Hear about scandals and other controversies as you continue through Old Town, down Broadway, named for New York and full of special theaters, a stop at VooDoo Donuts, and on up to beautiful Washington Park. We'll stop at Washington Park to see the picturesque Rose Garden and its international test beds, which boasts over 10,000 blooms on display in the summer.

Monday, 19 October

102. Seashells at the Seashore and Rogue Ale Too!

8 a.m.–5 p.m. Cost: US$125, lunch included; min.: 20.

Your journey will take you to the "blue Pacific" and the central Oregon fishing village of Newport. Pass through Lincoln City, a town 20 miles long and one mile wide on the way. We will stop at Yaquina Head to see Oregon's tallest lighthouse and its exquisite view. Next, it is on to the aquarium to view Pacific Northwest sea life. Known for its ocean animal rescue missions, this aquarium has an international history. Your lunch will be at the famous Rogue Ales Brewery. Following lunch is a tour of the beer and spirits area—plus, you won't want to miss the famous "bathroom tour." This will be such fun! After a walk on the wharf and a bit of time to browse or talk to the sea lions, we'll return to Portland late afternoon.

103. Birds of a Feather—Including the Eagles!

8 a.m.–4 p.m. Cost: US$140, includes box lunch; min.: 10.

This will be an 8-hour driving and walking tour of one of the Pacific Northwest's most significant winter waterfowl and raptor refuges. We will look for some 40 bald eagles that fly every morning onto the island to look for prey, as well as the thousands of ducks and geese that make the fields and wetlands of Sauvie Island and surrounds their winter home. Other raptors we may encounter include peregrine falcons, merlins, rough-legged and red-tailed hawks, and northern harriers, and the trip may be highlighted by sightings of Sandhill cranes, tundra swans, and the dusky Canada geese from Alaska's Copper River Delta. A box lunch and lots of fun are included in this tour.

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Tuesday, 20 October

104. Mighty Mount Hood
9 a.m.–3 p.m. Cost: US$97, lunch included; min.: 20.

About a 90-minute drive from the busy city of Portland is mighty Mount Hood, with an elevation of 11,235 feet. This snow-capped volcano in the Cascade Mountain Range is Oregon's highest peak and the home to historic Timberline Lodge. Mount Hood is also the site for year-round skiers, and is the summer training area for the Olympic ski team. We will visit timberline with time to explore and view the glacial fields as well as the panoramic alpine views. Lunch is included and cooked by a well-known chef in the Timberline Lodge dining room.

Mount Hood in summer. Photo courtesy Travel Portland/Jeff Krausse and the Portland Oregon Visitors Association.

Wednesday, 21 October

105. Magnificent Columbia Gorge
9 a.m.–3 p.m. Cost: US$62; min.: 20.

Enjoy the breathtaking views from the Crown Point Vista House located on the historic scenic highway ~700 feet above the mighty Columbia River. The motor coach will pass waterfalls and forested vales to reach Multnomah Falls, the fourth highest falls in North America, with a vertical drop of ~620 feet. Observe the unusual rock formations on your way to Bonneville Dam, the first federal dam on the Columbia River. There you will visit the interpretive center and the fish hatchery to learn the salmon life cycle and see an 80-year-old Sturgeon fish, descendant of prehistoric eras. Continue a bit farther to the Bridge of the Gods. Your guide will tell you the wonderful legend about where the bridge connects the states of Washington and Oregon. This six-hour tour includes time for lunch with a view of the river.

Columbia River Gorge. Photo courtesy Travel Portland/Mr. Janis Miglavs and the Portland Oregon Visitors Association.

Childcare at the GSA Annual Meeting & Exposition

THE GEOLOGICAL SOCIETY OF AMERICA®

Sat.–Wed., 17–21 October ✷ Oregon Convention Center

For the fourth consecutive year, GSA is proud to offer KiddieCorp's professional childcare services for children ages 6 months to 12 years. Children enjoy games, story time, arts and crafts, and other activities planned around the program hours and ages of the children. Fees are US$7 per hour, per child, with a two-hour minimum.

Register at www.kiddiecorp.com/gsakids.htm by 14 Sept. 2009 to secure your child's spot!

For more information, contact the Meetings Department at meetings@geosociety.org. Childcare services are a contractual agreement between each individual and the childcare company. GSA assumes no responsibility for the services rendered.

What parents are saying:

"Excellent! I am very grateful for this service and will use it again."

"This was great—thank you very much. I hope to see them at all meetings."

SPECIAL EVENTS

2009 GSA GOLD MEDAL LECTURES

Sunday, 18 Oct., 5–6:30 p.m. Location TBA.

Continue the celebration! The GSA Presidential Address and Awards Ceremony on Saturday, 17 Oct., is just the beginning—please join us on Sunday for the inaugural **GSA Gold Medal Lectures,** a special public event hosted by GSA to honor its awardees. The 2009 Penrose, Day, and Donath medalists are scheduled to speak and reflect on their scientific careers, and questions from the audience are encouraged. GSA President Jean Bahr will chair the program. *No reservations, tickets, or invitations required.*

GSA LUNCHTIME KEYNOTE ADDRESSES

Oregon Convention Center, Sun.–Wed., 12:15–1:15 p.m.

Please plan to attend GSA's new series of lunchtime keynote addresses. Speakers will cover broad, overarching topics relevant to today's world. Look for information on each speaker in the coming issues of *GSA Today*.

PRESIDENT'S STUDENT BREAKFAST RECEPTION

Sunday, 18 Oct., 7–8:30 a.m. Location TBA.

Sponsored by ExxonMobil

Hosted by GSA THE GEOLOGICAL SOCIETY OF AMERICA®

GSA President Jean M. Bahr invites all students to a free breakfast buffet sponsored by ExxonMobil Corp. Bahr and members of GSA's leadership, along with ExxonMobil staff members, will be on hand to answer questions and address student issues. This is one of the most popular student events at the annual meeting, and each student registered for the meeting will receive a complimentary ticket to attend. This is a wonderful opportunity to network and honor student award recipients. We hope to see you there!

SPECIAL EVENTS

OTHER SPECIAL EVENTS AND TICKETED FUNCTIONS

301. Paleontological Society Reception Buffet: Sat., 17 Oct. Professional: US$35 (301A); student: US$10 (301B).

302. Society of Economic Geologists (SEG) Awards Dinner: Sat., 17 Oct. Professional: US$51 (302A); student: US$25 (302B).

303. National Association of Geoscience Teachers (NAGT) and GSA Geoscience Education Division Awards Luncheon: Sun., 18 Oct., US$34.

304. Association for Women Geoscientists (AWG) Breakfast: Mon., 19 Oct. Professional: US$27 (304A); student: US$15 (304B).

305. American Institute of Professional Geologists (AIPG) Luncheon: Mon., 19 Oct. Professional: US$34 (305A); student: US$15 (305B).

306. GSA Engineering Geology Division Luncheon and Awards Ceremony: Mon., 19 Oct. US$34.

307. GSA History of Geology Division Luncheon & Business Meeting: Mon., 19 Oct. Professional: US$34 (307A); student: US$15 (307B).

308. L.A. Theater Works: "The Great Tennessee Monkey Trial": Mon., 19 Oct. US$25.

309. Geoscience Information Society (GSIS) Luncheon: Tues., 20 Oct. US$34.

310. GSA Hydrogeology Division 50th Anniversary Reception, Luncheon, and Awards Ceremony, plus Business Meeting: Tues., 20 Oct. US$34.

311. Mineralogical Society of America (MSA) Awards Luncheon: Tues., 20 Oct. US$34.

312. Mineralogical Society of America (MSA)–Geochemical Society (GS) Joint Reception: Tues., 20 Oct. Professional: US$10 (312A); student: US$5 (312B).

ANNUAL GEOSCIENCE EDUCATORS' SOCIAL RECEPTION

Saturday, 17 Oct., 5–7 p.m. Location TBA.

GSA's Committee on Education, the National Association of Geoscience Teachers (NAGT), the GSA Geoscience Education Division, Cutting Edge, the IRIS Consortium, the American Geological Institute (AGI), Deep Earth Academy, EarthScope, the National Earth Science Teachers Association (NESTA), and UNAVCO invite all educators to this relaxing forum for socializing, sharing ideas, and meeting other geoscience community members interested in education. The GSA Education & Outreach staff will be on hand to meet you as well. *Appetizers and cash bar provided.*

SUBARU

SUBARU OUTDOOR LIFE LECTURE

Yvon Chouinard
Oregon Convention Center, Monday, 19 Oct., 6–7 p.m.

Yvon Chouinard published *Climbing Ice* in 1978, and has been extraordinarily influential in ushering in the "clean climbing" movement in North America. Chouinard was one of the leading climbers of the Golden Age of Yosemite Climbing, participating in the second ascent of The Nose on El Capitan in 1960 and, using no fixed ropes, the ascent of the North American Wall in 1964.

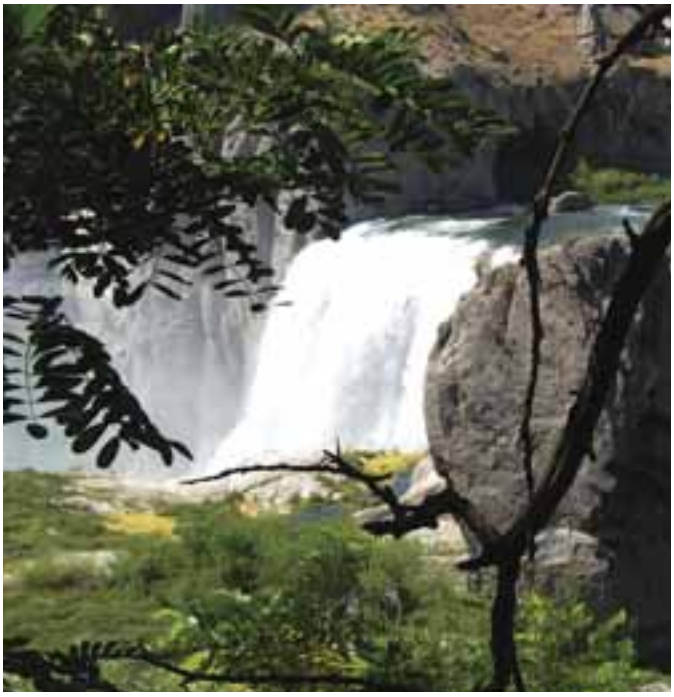
Chouinard is founder and owner of Patagonia Inc., which followed from his initial interest in the 1950s in designing, manufacturing, and distributing high-quality rock-climbing equipment. As Patagonia gained popularity and expanded in the 1980s, Chouinard turned his vision toward finding solutions to environmental crises. In 1985, Patagonia instituted an "Earth Tax," pledging 1% of sales to aid the preservation and restoration of the natural environment. Patagonia is also a leader in using pesticide-free cottons. Other environmental organizations supported by Chouinard and Patagonia include One Percent for the Planet, the Common Threads Garment Recycling Program, and the World Trout Initiative.

Chouinard is an inveterate outdoorsman, spending much of his time outdoors or, if he has to be indoors, talking about the outdoors with environmental groups and businesses around the world.

Yvon Chouinard; photo courtesy of Patagonia.

PHOTO CONTEST & EXHIBIT

Theme: ***Visions of the Dynamic Landscape: How Geology Tells the Stories of Planetary Change***



Shoshone Falls, Idaho, USA. Photo by K.E. Asmus.

Geologic processes have sculpted this planet for more than 4.5 billion years. Volcanoes erupt, magma chambers seethe, rivers erode, hillslopes fail, and faults shift the planetary playing field. This exhibition will feature images of places or processes that are important in understanding and witnessing the changing landscape, especially in the Pacific Northwest. The images exhibited should (a) show geology in all its glory and have scientific merit in depicting an active process or past dynamic landscape; and (b) have photographic and artistic merit. Both color and black-and-white photographs are eligible, and image size may be eight to 36 inches wide.

The submitted image must be accompanied by a 100–250-word description, including information on the geologic process(es) the image depicts. These descriptions will be posted alongside the photograph.

Images will be juried into the show by a nationally known nature photographer, a geologist, and an artist. We have room for a maximum of eight images in each of the following five categories. However, all submitted images will be considered for inclusion in a possible GSA volume/photo book aimed at the general public.

CATEGORIES

Pacific Northwest geology: The Pacific Northwest features one of the planet's most dynamic landscapes. Images in this category should depict some aspect of present (Mount St. Helens, coastal waves, etc.) or past (faults, mountain ranges, erosional landforms, tsunamis) geologic activity in the area.

Abstract images: This may include maps, photomicrographs, images derived from scanning electron microscopy, etc., that capture some dynamic process (deformational offsets or zoning in minerals, for example).

Active geologic processes across the planet: Erupting volcanoes, floodwaters, active landslides, for example, especially in places not well known to the public or to geologists.

Past processes and events found in the geologic record: Images specific to processes or that depict a feature resulting from a specific process; for example, images of imbricated cobbles as bellwethers of ancient rivers, images of lava flows that represent ancient eruptions, etc.

Iconic landscapes of change and time: Iconic, commonly visited landscapes in national parks, monuments, or other public places that represent, or are part of, an important process. Examples: Yellowstone geysers, the Grand Canyon, Glacier National Monument, etc.

SUBMISSION

Please send .jpg files 1MB or smaller to Ellen Bishop via e-mail at paleobishop@gmail.com. Photo files over 1MB should be sent on a CD to Oregon Paleo Lands Institute, Attention: Ellen Bishop, 333 Fourth Street, P.O. Box 104, Fossil, Oregon 97830, USA. Please send only .jpg files no larger than 4MB; 300 dpi is preferred.

A jury of three—a photographer, an artist, and a geologist—will select images for the show. If your image is selected for display by the local jury, you will be contacted and asked to send a print at final size (up to 24" × 36"), rolled, plus US$50.00 for local framing. We will mount the print in standard Plexiglas, with a single black mat, for display, along with the description provided. GSA participants will vote on favorite images, with a prize (TBD) awarded to the top two images in each category.

DEADLINES

Initial submission: 1 August 2009
Final submission of juried selections: 15 September 2009

PARDEE KEYNOTE SYMPOSIA

Invited Papers

These Pardee Keynote Symposia are special events of broad interest to the geoscience community. The sessions are interdisciplinary, representing issues on the leading edge of a scientific discipline or area of public policy and addressing broad, fundamental issues. All speakers are invited. *The Pardee Keynote Symposia are made possible by a grant from the Joseph T. Pardee Memorial Fund.*

P1. Crisis in the Cryosphere: Impacts of Planetary Meltdown, Wed., 21 Oct., 1:30–5:30 p.m.
Cosponsors: American Quaternary Association (AMQUA); GSA Geology and Health Division; GSA Quaternary Geology and Geomorphology Division; International Union for Quaternary Research (INQUA); National Association of Geoscience Teachers (NAGT); GSA Geology and Society Division
Conveners: George T. Stone, Milwaukee Area Technical College, Milwaukee, Wis.; Andrew M. Buddington, Spokane Community College, Spokane, Wash.; Michael E. Mann, Pennsylvania State University, University Park, Penn.
Description: All components of the cryosphere are in decline: ice sheets and outlet glaciers, ice caps and valley glaciers, ice shelves and sea ice, permafrost. This worldwide meltdown presages catastrophic impacts on water supplies, sea level, and coastlines.

P2. Crustal Tectonic Deformation as Revealed by Seismic Anisotropy, Mon., 19 Oct., 1:30–5:30 p.m.
Cosponsors: GSA Structural Geology and Tectonics Division; GSA Geophysics Division
Conveners: David Okaya, University of Southern California, Los Angeles, Calif.; Kevin Mahan, University of Colorado, Boulder, Colo.; Mark T. Brandon, Yale University, New Haven, Conn.; Nikolas I. Christensen, University of Wisconsin, Madison, Wis.
Description: Observations of seismic anisotropy indicate the presence of wave-altering structure or internal material properties. This session examines the role of deformation-related rock fabrics to produce crustal seismic anisotropy and new approaches to probe at all crustal levels.

P3. Earth *et al.*—Our Planets from the Hadean to Today, Tues., 20 Oct., 8 a.m.–noon
Cosponsors: GSA International Division; GSA Sedimentary Geology Division; GSA Planetary Geology Division; Society for Sedimentary Geology (SEPM); Paleontological Society; American Geological Institute; NASA Astrobiology Institute; Mineralogical Society of America; Geochemical Society of America
Conveners: Nora Noffke, Old Dominion University, Norfolk, Va.; Kurt Konhauser, University of Alberta, Edmonton, Alberta
Description: The evolution of life and its paleoenvironmental context from the Hadean to the modern: Earth and beyond.

P4. First Global View of the Geology of Mercury: Dynamic Landscapes on the Innermost Planet, Tues., 20 Oct., 1:30–5:30 p.m.
Cosponsor: GSA Planetary Geology Division
Conveners: Louise Prockter, Applied Physics Lab, Laurel, Md.; Sean C. Solomon, Carnegie Institution of Washington, Washington, D.C.
Description: *MESSENGER*'s two flybys of Mercury in 2008 provided the first detailed views of the planet in three decades and revealed a rich geological history marked by widespread volcanism, prolonged contractional tectonics, and pervasive impact cratering.

P5. Geodynamics from the Cascadia Margin to the High Lava Plains, Wed., 21 Oct., 8 a.m.–noon
Cosponsors: GSA Geophysics Division; GSA Structural Geology and Tectonics Division
Conveners: Anita L. Grunder, Oregon State University, Corvallis, Ore; G. Randy Keller, University of Oklahoma, Norman, Okla.; K; Rick W. Carlson, Department of Terrestrial Magnetism, Washington, D.C.; Michael Brudzinski, Miami University of Ohio, Oxford, Ohio; Bernie Housen, Western Washington University, Bellingham, Wash.; Basil Tikoff, University of Wisconsin, Madison, Wis.
Description: This session is dedicated to understanding the geodynamic evolution of the Cascadia margin and High Lava Plains, from the Miocene (18 Ma) to the present. The session will synthesize geological, geophysical, and geochemical research that addresses modification of the lithosphere through tectonism and magmatism.

Pardee Keynote Symposia continued

P6. Google Earth to Geoblogs: Digital Innovations in the Geosciences, Sun., 18 Oct., 1:30–5 p.m.
Cosponsors: GSA Geoinformatics Division; GSA Geoscience Education Division; Google, Inc.; National Association of Geoscience Teachers (NAGT)
Conveners: P. Kyle House, University of Nevada, Reno, Nev.; John Bailey, University of Alaska, Fairbanks, Alaska; Ronald C. Schott, Fort Hays State University, Hays, Kans.; Mano Marks, Google Inc., Mountain View, Calif.; Glenn A. Richard, Stony Brook University, Stony Brook, N.Y.; Peter A. Selkin, University of Washington, Tacoma, Wash.
Description: Digital technologies, such as Web 2.0 services, virtual globes, and new applications of digital photography, can enhance understanding of geology at all levels and across all disciplines. This session will highlight particularly novel and innovative applications of these technologies.

P7. Hazards and Health: Preventing Disaster and Building Resilience on the Ring of Fire, Mon., 19 Oct., 8 a.m.–noon
Cosponsors: GSA Geology and Health Division; GSA Engineering Geology Division; GSA Geoinformatics Division; GSA Limnogeology Division; GSA Quaternary Geology and Geomorphology Division; GSA International Division; GSA Geology & Public Policy Committee; Geological Society of New Zealand; International Medical Geology Association; International Union of Geological Sciences; International Union for Quaternary Research (INQUA)
Conveners: Monica E. Gowan, University of Canterbury, Christchurch, New Zealand; David Applegate, U.S. Geological Survey, Reston, Va.; Scott F. Burns, Portland State University, Portland, Ore.; John J. Clague, Simon Fraser University, Burnaby, British Columbia; David Johnston, GNS Science/ Massey University, Lower Hutt, New Zealand
Description: Uniting the efforts of natural and social scientists is vital to the well-being of disaster-prone communities. This session highlights new interdisciplinary directions for managing risk at the emerging crossroads of hazards, health, and emergency management.

P8. The Evolution of Basaltic Landscapes: Time and the River and Lava Flowing, Sun., 18 Oct., 8 a.m.–noon
Conveners: Gordon E. Grant, USDA Forest Service, Corvallis, Ore.; Katharine Cashman, University of Oregon, Eugene, Ore.; Oliver A. Chadwick, University of California, Santa Barbara, Calif.
Description: This session will focus on the life and death of basaltic landscapes around the world, from lava-flow emplacement and dynamics to soil and hydrologic development, biological colonization, and channel incision and landscape evolution.

Do you need a travel visa to attend the meeting? See p. 39.

CALL FOR PAPERS

Portland, Oregon, USA ✷ 18–21 October 2009

Topical Sessions

This year, GSA is offering 160 topical sessions for you to choose from, each designed to promote the exchange of interdisciplinary, state-of-the-art information. A listing of GSA's topical sessions is online at www.geosociety.org/meetings/2009/sessions/topical.asp. In addition to these proposed sessions, GSA will have a multitude of discipline sessions. Discipline sessions are equally vital to completing our technical program. See page 26 for a list of discipline categories and Joint Technical Program Committee (JTPC) review group contact information. All speakers must pay the meeting registration fee in order to present papers and/or posters at the meeting.

Tips for Preparing and Submitting an Abstract

Abstract submission deadline: 11 August

1. Determine the best discipline category for your paper; you may also select up to three other relevant categories. Discipline category selection is an essential first step, even if you are submitting to a topical session.
2. Select your preferred mode of presentation: Oral, Poster, or either (no preference). You may present two volunteered abstracts at the meeting, *as long as one of them is a poster presentation*. The program organizers will do their best to fit you into your preferred mode; however, they will override your original mode selection if they feel your paper would fit well in a particular session with other compatible abstracts. The decision of the program organizers is final. Learn more about how to prepare your presentation at www.geosociety.org/meetings/2009/techprog.htm.
3. Pick a title for your paper and select up to five keywords.
4. Gather the name and contact information for all authors (e-mail addresses for each co-author must be provided for communication purposes). No more than 10 authors may be listed on a paper, and group names will not be accepted.
5. Write the body of your abstract. Please keep it to 2,000 characters or less, not counting spaces. Check the spelling of the abstract's body and title using your own word processor (we won't check or edit it for you). If your abstract includes more than one complicated equation, or a table, or a lot of subscripts, superscripts, or Greek letters, we suggest that you type the characters using HTML coding. If you try to copy-and-paste the abstract into the submission form, you will lose some or all of those special elements. For information on how to include HTML codes, see http://gsa.confex.com/gsa/fonts.htm. If you are planning to copy and paste your abstract into the online submission form, add an extra line between paragraphs or they will run together when displayed.
6. Have a credit card ready to cover the submission fee. A non-refundable fee of US$30 for professionals and US$20 for students (graduate and undergraduate) will be charged per abstract. Payment must be made upon submission or your paper will not be considered for the meeting.

The Geological Society of America is changing!

Here's what's different for this year's Technical Program.

- **Later Abstracts Deadline.** The abstracts deadline (11 Aug.) has been extended three weeks. This new date reflects GSA's effort to better serve people who typically do fieldwork during the summer.
- **The *Abstracts with Programs* book** will not be mailed to you prior to the annual meeting because of this later abstract deadline. If you ordered the book with your membership application or renewal, it may not reach your address until after the annual meeting has begun. Books will be available for sale at the meeting.
- **The Personal Scheduler** has been improved. The Personal Scheduler is designed so that you may easily browse all events scheduled for this meeting, create your own schedule of events, record notes, and download to your PDA or other mobile device or print for easy reference.

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POSTER PRINTING SERVICE

GSA has made arrangements with DP_i Printing to offer presenters the option of having their posters printed in advance and available for pick up in the Exhibit/Poster Hall at the Oregon Convention Center. The approximate cost for a 4-ft by 8-ft poster will be US$100.

Please note that all orders must be pre-paid and received on or before 14 October. Poster files must be in PDF format and can be submitted electronically at http://ftp.dpi-sf.com. Login name: GSA; password: dpisf.

Valid ID is required for pick up. If you have questions regarding poster printing orders, contact DP_i Printing at +1-415-216-0031

DISCIPLINE CATEGORIES

2009 Technical Program Chair
Richard C. Berg, berg@isgs.illinois.edu

GSA Technical Program Manager
Nancy Wright, nwright@geosociety.org

Abstracts deadline: 11 August

Review Group	Discipline	JTPC Contact(s)
GSA Archaeological Geology Division	archaeological geology	Art Bettis, art-bettis@uiowa.edu
GSA Coal Geology Division	coal geology	Jack Pashin, jpashin@gsa.state.al.us
GSA Engineering Geology Division	engineering geology	Dave Rogers, rogersda@mst.edu
Environmental Geoscience	environmental geoscience	Neal C. Grasso, ngrasso@gradientcorp.com
GSA Geobiology & Geomicrobiology Division	geomicrobiology	Jack D. Farmer, jack.farmer@asu.edu Stuart Birnbaum, stuart.birnbaum@utsa.edu
Geochemical Society	geochemistry; geochemistry, organic	Briant A. Kimball, bkimball@usgs.gov
GSA Geoinformatics Division	geoinformatics	Dogan Seber, seber@sdsc.edu
GSA Geology and Health Division	geology and health	Monica Gowan, monica.gowan@canterbury.ac.nz *-or-* gowan.monica@mayo.edu
GSA Geology and Society Division	public policy	Karen McCurdy, kmccurdy@georgiasouthern.edu
GSA Geophysics Division	geophysics/tectonophysics/ seismology	Catherine M. Snelson, snelson@ees.nmt.edu Kevin Mickus, kevinmickus@missouristate.edu
GSA Geoscience Education Division National Assoc. of Geoscience Teachers	geoscience education	Eric J. Pyle, pyleej@jmu.edu Mike Taber, mike.taber@coloradocollege.edu
Geoscience Information Society Association of Earth Science Editors	geoscience information/communication	Jody Bales Foote, jbfoote@ou.edu Monica Gaiswinkler Easton, monica.easton@ontario.ca
GSA History of Geology Division	history of geology	Vic Baker, baker@hwr.arizona.edu
GSA Hydrogeology Division	hydrogeology	Ed Harvey, feharvey1@unl.edu Bill Cunningham, wcunning@usgs.gov
GSA International Division		John Wakabayashi, johnwako@sbcglobal.net
GSA Limnogeology Division	limnogeology	Michael Rosen, mrosen@usgs.gov
Marine/Coastal Geology	marine/coastal science	Mark Kulp, mkulp@uno.edu
Mineralogical Society of America	mineralogy/crystallography; petrology, experimental; petrology, igneous; petrology, metamorphic; volcanology	James Beard, jim.beard@vmnh.virginia.gov Philip Brown, pbrown@geology.wisc.edu
Paleoceanography/Paleoclimatology	paleoclimatology/paleoceanography	Sharon Kanfoush, skanfoush@utica.edu
Paleontological Society	paleontology, biogeography/biostratigraphy; paleontology, diversity, extinction, origination; paleontology, paleoecology/taphonomy; paleontology, phylogenetic/morphological patterns	Rowan Lockwood, rxlock@wm.edu Andrew Bush, andrew.bush@uconn.edu Ellen Currano, ecurrano@smu.edu
GSA Planetary Geology Division	planetary geology; remote sensing/ geographic information system	Louise Prockter, louise.prockter@jhuapl.edu Jayne Aubele, jayne.aubele@state.nm.us
Precambrian Geology	Precambrian geology	Joe Meert, jmeert@geology.ufl.edu
GSA Quaternary Geology and Geomorphology Division	geomorphology; Quaternary geology	Marith Reheis, mreheis@usgs.gov Paul Bierman, pbierman@zoo.uvm.edu
GSA Sedimentary Geology Division	sediments, carbonates; sediments, clastic; stratigraphy	Mark Kulp, mkulp@uno.edu Troy Rasbury, troy.rasbury@sunysb.edu
Society of Economic Geologists	economic geology	John H. Dilles, dillesj@geo.oregonstate.edu
GSA Structural Geology and Tectonics Division	neotectonics/paleoseismology; structural geology; tectonics	Michele Cooke, cooke@geo.umass.edu Scott Johnson, johnsons@maine.edu

FIELD TRIPS

From accreted terranes to viticulture terroir, this year's field trips will emphasize the "Volcanoes to Vineyards" theme of the meeting, but also cover a range of Pacific Northwest geoscience topics and geoscientist hangouts. Learn how tectonism, volcanism, stupendous flood basalts, cataclysmic flooding, and landslides have shaped the Northwest and now influence hazards, resources, and human habitation. Remarkable scenery, whitewater boating, and brew pubs and wineries are requisite elements of the Northwest experience and will be integral to several trips.

Field Trip chairs: Becky Dorsey, rdorsey@uoregon.edu; Ian Madin, ian.madin@dogami.state.or.us; and Jim O'Connor, oconnor@usgs.gov. Please contact them or Eric Nocerino, enocerino@geosociety.org, for general information. If you have questions about a particular trip, please contact the trip leaders directly. Find leader contact information and trip descriptions at **www.geosociety.org/meetings/2009/fieldTrips.htm.**

All trips begin and end at the Oregon Convention Center in Portland unless otherwise indicated. Fees include transportation during the trip; other services, such as meals and lodging, are noted by the following abbreviations: B—breakfast; L—lunch; R—refreshments; D—dinner; ON—overnight lodging.

Before the Meeting

401. Floods of Water and Lava on the Columbia River Plateau: Analogs for Mars

Tues.–Sat., 13–17 Oct. US$800 with over-flight; US$500 without over-flight (4ON). Cosponsored by GSA's Planetary Geology Division. **Leaders:** Laszlo P. Keszthelyi, USGS Astrogeology Team; Windy L. Jaeger; Victor Baker.

402. The Great Missoula Floods and the Channeled Scabland

Tues.–Sun., 12–17 Oct. US$515 (L, R, 5ON). Cosponsored by GSA's Sedimentary Geology and Quaternary Geology and Geomorphology Divisions. **Leaders:** Richard B. Waitt, USGS–Cascades Volcano Observatory; Roger Denlinger; Jim O'Connor.

403. Central and Eastern Portions of the Columbia River Flood-Basalt Province—An Overview of Our Current State of Knowledge of Flood-Basalt Stratigraphy, Vent Geometries, Flow Emplacement Mechanisms, and Tectonics

Wed.–Sat., 14–17 Oct. US$365 (L, R, 1D, 3ON). **Leaders:** Terry L. Tolan, GSI Water Solutions; John D. Kaufmann; Barton S. Martin; Stephen P. Reidel.

404. Hydrogeology of the Columbia River Basalt Group (CRBG) in the Columbia Plateau

Wed.–Sat., 14–17 Oct. US$363 (L, R, 1D, 3ON). Cosponsored by GSA's Hydrogeology Division. **Leaders:** Kevin L. Lindsey, GSI Water Solutions; Dimitrios Vlassopoulos; Frank Spane; Erick Burns; Ken Lite; Dave S. Morgan; Terrence D. Conlon.

405. Geology and Geo-Archaeology of Hells Canyon, Oregon and Idaho

Wed.–Sat., 14–17 Oct. US$850 (B, L, D, R, 3ON). Cosponsored by Oregon Paleo Lands Institute. **Leader:** Ellen M. Bishop, Oregon Paleo Lands Institute.

406. Late Triassic to Late Jurassic Petrotectonic History of the Oregon Klamath Mountains

Thurs.–Sat., 15–17 Oct. US$328 (L, 2ON). **Leaders:** Doug Yule, California State Univ. at Northridge; Bob Murray; Allan Kays; Tom Wiley.

407. Linking Deep- and Shallow-Crustal Processes in a Continental Arc, North Cascades, Washington

Thurs.–Sat., 15–17 Oct. US$370 (B, L, 2D, R, 2ON). Cosponsored by GSA's Structural Geology and Tectonics Division. **Leaders:** Robert B. Miller, San José State University; Stacia Gordon; Noah McLean; Donna L. Whitney; Sam Bowring.

408. Paleogene Calderas of Central and Eastern Oregon: Sources of Widespread Ash-Flow Tuffs in the John Day and Clarno Formations

Thurs.–Sat., 15–17 Oct. US$350 (L, 2ON). Cosponsored by the Oregon Dept. of Geology and Mineral Industries and Portland State University. **Leaders:** Jason D. McClaughry, Oregon Dept. of Geology and Mineral Industries; Martin J. Streck; Karyn A. Patridge; Caroline L. Gordon; Mark L. Ferns.

409. Fire and Water: Volcanology, Geomorphology, and Hydrogeology of the Central Cascades and Adjacent Areas, Oregon

Thurs.–Sat., 15–17 Oct. US$455 (B, L, D, R, 2ON). Cosponsored by GSA's Hydrogeology Division, Gordon Grant, Marshall Gannett, and Katharine Cashman. **Leaders:** Gordon Grant, U.S. Forest Service PNW Research Station; Marshall W. Gannett; Katharine Cashman.

410. Newberry Volcano

Thurs.–Sat., 15–17 Oct. US$372 (L, 1D, R, 2ON). **Leaders:** Julie M. Donnelly-Nolan, USGS–Menlo Park; Daniele McKay; Robert A. Jensen.

411. A Tectonic Transect through the Salmon River Suture Zone along the Salmon River Canyon in the Riggins Region of West-Central Idaho

Thurs.–Sat., 15–17 Oct. US$345 (L, D, R, 2ON). **Leaders:** David E. Blake, Univ. of North Carolina–Wilmington; Scott Giorgis; Basil Tikoff; Keith Gray.

412. Freshwater Streams and Wetlands, Artesian Wells, Hot Springs, and Alkali Lakes: High Desert Hydrogeology of Steens Mountain, Southeastern Oregon
Thurs.–Sat., 15–17 Oct. US$380 (B, L, D, R, 2ON). Cosponsored by GSA's Hydrogeology Division, Portland State University Dept. of Geology, and Malheur Field Station. **Leaders:** Michael L. Cummings, Portland State University; Robert B. Perkins; Sherry Cady.

413. Seismogenic Landslides on the Winter Ridge Escarpment, Summer Lake, Oregon
Thurs.–Sat., 15–17 Oct. US$355 (L, R, 2ON). **Leaders:** Thomas C. Badger, Washington State Dept. of Transportation; Robert J. Watters.

414. Northwest River Rendezvous: Geomorphology, Whitewater Rafting, and Fly Fishing in the Lower Deschutes Basin
Thurs.–Sat., 15–17 Oct. US$460 without fishing package; US$660 with fishing package (L, D, 2ON). Cosponsored by Western Oregon University. **Leaders:** Stephen Taylor, Western Oregon University; Jim Eisner.

415. The Chiwaukum Structural Low, Eastern Cascade Range, Washington
Thurs.–Sat., 15–17 Oct. US$345 (L, R, 2ON). Cosponsored by GSA's Sedimentary Geology and Structural Geology and Tectonics Divisions. **Leader:** Eric S. Cheney, Univ. of Washington.

416. Terroir Tour of the Northern Willamette Valley I
Fri., 16 Oct. US$105 (L, R). Cosponsored by GSA's Engineering Geology, Hydrogeology, and Quaternary Geology and Geomorphology Divisions; GSA's Cordilleran Section; the International Association of Hydrogeologists; and Groundwater Resources Association of California. **Leaders:** Scott F. Burns, Portland State University.

417. Folds, Floods, and Fine Wine: Geologic Influences on the Terroir of the Columbia River Basin
Fri.–Sat., 16–17 Oct. US$362 (L, D, R, 1ON). **Leader:** Kevin R. Pogue, Whitman College.

418. Archaeology and Geomorphology of the Oregon Coastal Zone
Fri.–Sat., 16–17 Oct. US$225 (L, R, 1ON). Cosponsored by GSA's Archaeological Geology Division. **Leaders:** Loren Davis, Oregon State University; Steve Jenevein; Jay Noller.

419. Paleo-Landslides in the Tyee Formation and Highway Construction, Central Oregon Coast
Sat., 17 Oct. US$97 (L, R). Cosponsored by the Oregon Dept. of Transportation; Yaquina River Constructors JV (Granite Construction Co. and Wilder Construction Co.); URS Corporation; and Cornforth Consultants, Inc. and its division of Landslide Technology. **Leaders:** Charles M. Hammond, Landslide Technology; Dan Meier.

420. From Disaster to Recovery: The Hydrogeomorphic, Ecologic, and Biologic Responses to the 1980 Eruption of Mount St. Helens
Sat., 17 Oct. US$75 (L, R). Cosponsored by GSA's Engineering Geology and Quaternary Geology and Geomorphology Divisions. **Leaders:** Jon Major, USGS–Cascades Volcano Observatory; Peter Frenzen; John Bishop.

421. Lavatubes of the Mount St. Helen's Region: Geology, Biology, and More!
Sat., 17 Oct. US$135 (L, D, R). Cosponsored by the National Cave and Karst Research Institute. **Leaders:** Penelope J. Boston, National Cave and Karst Research Institute; Gus Frederick.

422. Snowpack Data Collection in the Western U.S. Using SNOTEL and Geologic Hazards and Features Related to Snowmelt
Sat., 17 Oct. US$115 (L, R). Cosponsored by GSA's Hydrogeology Division. **Leader:** Michael L. Strobel, USDA-NRCS National Water and Climate Center.

423. The Boring Volcanic Field: Anomalous Volcanism in the Cascadia Forearc
Sat., 17 Oct. US$85 (L, R). **Leaders:** Russell C. Evarts, USGS–Menlo Park; Richard M. Conrey.

424. Terroir Tour of the Northern Willamette Valley II
Sat., 17 Oct. US$95 (L, R). Cosponsored by GSA's Engineering Geology, Hydrogeology, and Quaternary Geology and Geomorphology Divisions; GSA's Cordilleran Section; the International Association of Hydrogeologists; and the Groundwater Resources Association of California. **Leader:** Scott F. Burns, Portland State University.

425. Breached Dam Overlook at Mount St. Helens
Sat., 17 Oct. US$95 (L, R). Cosponsored by Steven A. Austin, Timothy L. Clarey, Kurt P. Wise, and John Whitmore. **Leaders:** Steven A. Austin, Austin Research Consulting.

During the Meeting

426. Portland Geology by Tram, Train, and Foot
Sun., 18 Oct. US$35. **Leader:** Ian P. Madin, Oregon Dept. of Geology and Mineral Industries.

427. Kirk Bryan Field Trip: Quaternary Geology and Geomorphology of the Columbia River Gorge
Tues., 20 Oct. US$75 (L, R). Cosponsored by GSA's Quaternary Geology and Geomorphology Division. **Leaders:** Jim O'Connor, USGS-Portland; Scott Burns.

After the Meeting

428. Landscape and Hydrologic Recovery in the Williamson River Basin Following the Holocene Eruption of Mount Mazama to form Crater Lake, Cascade Volcanic Arc
Wed.–Fri., 21–23 Oct. US$360 (L, D, R, 2ON). Cosponsored by Portland State University Dept. of Geology. **Leaders:** Michael L. Cummings, Portland State University; Jeffrey S. Conaway.

429. Mesozoic Sedimentation, Magmatism, and Tectonics in the Blue Mountains Province, Central Oregon
Wed.–Sat., 21–24 Oct. US$572 (L, D, R, 3ON). **Leaders:** Todd LaMaskin, University of Oregon; Ken Johnson, Art Snoke, Joshua Schwartz.

430. Geological and Geophysical Perspectives on the Magmatic and Tectonic Development of the Northwest Basin and Range
Wed.–Sat., 21–24 Oct. US$400 (L, R, 3ON). Cosponsored by GSA's Geophysics and Structural Geology and Tectonics Divisions and GSA's Cordilleran Section. **Leaders:** Andrew Meigs, Oregon State University; Anita Grunder; Tim Grove; Richard Carlson; Ray Weldon; Kaleb Scarberry.

431. Terroir Tour of the Columbia Gorge
Thurs., 22 Oct. US$95 (L, R). Cosponsored by GSA's Engineering Geology, Hydrogeology, and Quaternary Geology and Geomorphology Divisions; GSA's Cordilleran Section; the International Association of Hydrogeologists; and the Groundwater Resources Association of California. **Leader:** Scott F. Burns, Portland State University.

432. Eruption-Related Lahars and Sedimentation Response Downstream of Mount Hood
Thurs., 22 Oct. US$79 (L, R). Cosponsored by GSA's Quaternary Geology and Geomorphology and Sedimentary Geology Divisions. **Leaders:** Thomas C. Pierson, USGS–Cascades Volcano Observatory; Patrick Pringle; W.E. Scott; James W. Vallance.

433. Fluvial Response to Removal of Marmot Dam, Sandy River, Oregon
Thurs., 22 Oct. US$80 (L, R). Cosponsored by GSA's Quaternary Geology and Geomorphology Division. **Leaders:** J. Rose Wallick, USGS-Portland; Charles J. Podolak; Jim O'Connor; Jon Major.

434. Mega Breccias and Subglacial Meltwater Outburst: Evidence from Whidbey Island, Washington
Wed.–Fri., 21–23 Oct. US$368 (B, L, D, R, 2ON). Cosponsored by GSA's Quaternary Geology and Geomorphology Division and the American Quaternary Association (AMQUA). **Leaders:** Eugene Domack, Hamilton College; David Sharpe.

435. Coastal Geomorphology, Hazards, and Management Issues along the Pacific Northwest Coast of Oregon and Washington
Thurs.–Fri., 22–23 Oct. US$305 (L, D, R, 1ON). **Leaders:** Jonathan Allan, Oregon Dept. of Geology and Mineral Industry Newport Coastal Field Office; Peter Ruggiero; Robert Witter.

436. Tuff Cones, Tuff Rings, and Maars of the Fort Rock–Christmas Valley Basin, Oregon: Exploring the Vast Array of Pyroclastic Features that Record Violent Hydrovolcanism at Fort Rock and the Table Rock Complex
Thurs.–Sat., 22–24 Oct. US$283 (L, R, 2ON). Cosponsored by the University of Washington. **Leaders:** Brittany D. Brand, Univ. of Washington; Grant Heiken.

437. Columbia River Basalts and Structure from the Gorge through the Forearc to the Washington-Oregon Coast: Tracing Subaerial Lavas to Lava Deltas, Submarine Pillow Breccias, and Mega-Invasive Flows
Thurs.–Sat., 22–24 Oct. US$335 (L, R, 2ON). **Leaders:** Ray E. Wells, USGS–Menlo Park; Alan Niem; Jonathan Hagstrum; Russ Evarts; Terry Tolan.

438. Paleobotany of the John Day Fossil Beds, Central Oregon
Thurs.–Sat., 22–24 Oct. US$300 (B, L, D, R, 2ON). Cosponsored by Evolving Earth Foundation, Western Oregon University, The Burke Museum of Natural History and Culture, and the University of Washington. **Leaders:** Richard Dillhoff, University of Washington; Thomas Dillhoff; Regan Dunn; Caroline Stromberg; Jeff Myers.

439. Hydrogeology of the Columbia River Basalt Group (CRBG) in the Willamette Valley, Oregon
Thurs.–Sat., 22–24 Oct. US$206 (L). Cosponsored by GSA's Hydrogeology Division. **Leaders:** Walt Burt, GSI Water Solutions Inc.; Larry Eaton; Ken Lite; Karl Wozniak; Terrence Conlon; Terry Tolan.

440. Geothermal Geology and Utilization in Oregon
Thurs.–Sat., 22–24 Oct. US$327 (L, 1D, R, 2ON). Cosponsored by the Oregon Institute of Technology. **Leaders:** John W. Lund, Oregon Institute of Technology Geo-Heat Center; Sara Marcus; Toni L. Boyd; Harriet Cornachione; Anne Hiller-Clark.

SHORT COURSE PROGRAM

The following short courses are open to all. **Early registration is recommended;** registration after 14 Sept. is an additional US$30.

You can attend a short course regardless of whether you are registered for the annual meeting; however, payment of a nonregistrant fee of US$40 will be required along with the course fee. The good news is that this nonregistrant fee can be applied toward the cost of meeting registration if you decide to attend. GSA K–12 teacher members: You are exempted from paying the nonregistrant fee.

Continuing Education Units (CEUs): Most professional development courses and workshops offer CEUs. One CEU comprises 10 contact hours (a contact hour equals 60-minutes of classroom/field instruction) of participation in an organized continuing education experience under responsible sponsorship, capable direction, and qualified instruction.

Learn more at **www.geosociety.org/meetings/2009/courses.htm/** or e-mail Jennifer Nocerino, jnocerino@geosociety.org. **Cancellation deadline:** 21 Sept.

501. INTERFACE WORKSHOP: Recent developments in the methods and applications of terrestrial laser scanning (ground based LiDAR) in geologic research and education

Fri., 16 Oct., 8 a.m.–5 p.m. **Fee:** US$130, includes lunch. *Limited financial support is available for students; see the Short Course Series page at* ***http://unavco.org*** *for details.* Limit: 20. CEU: 0.8. **Instructors:** John Oldow and Carlos Aiken, Univ. of Texas at Dallas; and David Phillips, UNAVCO.

This workshop will provide faculty, students, and professionals with the basic principles of Terrestrial Laser Scanning (TLS), aka ground-based LiDAR, workflows and best practices for the acquisition and processing of TLS data, an overview of various TLS platforms, and examples of science and education applications. This one-day workshop will consist of lectures and hands-on application of TLS equipment and data processing. TLS provides very high-resolution images over relatively small areas, is relatively inexpensive to acquire, and has been used successfully to support a wide range of geoscience investigations from outcrop mapping to deformation monitoring.

502. InSAR for geoscience applications

Fri., 16 Oct., 9 a.m.–5 p.m. **Fee:** US$235, includes continental breakfast and lunch. Limit: 40. CEU: 0.8. **Cosponsors:** the USGS–Cascades Volcano Observatory and GSA's Structural Geology and Tectonics Division. **Instructor:** Zhong Lu, USGS.

This short course will provide an introduction to the theory, processing, and applications of synthetic aperture radar (SAR) interferometry (InSAR). The first part of the course covers the basics of SAR imaging. It provides principles to interpret SAR images and compares between optical-sensor and radar remote sensing. The second part focuses on InSAR processing, illustrating how InSAR works, demonstrating InSAR processing procedures, and detailing how to interpret InSAR imagery. The third portion of the course is dedicated to an overview of InSAR applications to the geosciences. The course ends with information on the availability and access of satellite SAR/InSAR data and processing software.

503. Hazard zone delineation for debris flows, lahars, and rock avalanches using LAHARZ and GIS

Fri.–Sat., 16–17 Oct., 8 a.m.–5 p.m. **Fee:** US$280. Limit: 20. CEU: 1.6. **Instructors:** Richard Iverson, Steve Schilling, Julie Griswold, and Scott Graham, USGS–Cascades Volcano Observatory.

Learn the fundamentals of statistically based hazard-zone delineation for lahars, debris flows, and rock avalanches in a geographic information system (GIS) environment. Course content includes the physical and statistical basis of the LAHARZ model, LAHARZ software instruction, and techniques for hazard map generation. Participants should have rudimentary GIS experience, including use of projections, grid functions, and basic ArcMap tools, and may bring laptops with ArcGIS version 9.3. Vans will transport participants between the Oregon Convention Center and a nearby USGS facility in Vancouver, Washington, USA. GIS users, geotechnical engineers, and applied geologists in government agencies, private consulting, or academia may benefit from this class.

504. Sequence stratigraphy for graduate students

Fri.–Sat., 16–17 Oct., 8 a.m.–5 p.m. **FREE** to students, who must pre-register. Limit: 55. CEU: 1.6. **Cosponsors:** ExxonMobil Exploration Company, British Petroleum, and GSA's Sedimentary Geology Division. **Instructors:** Art Donovan, BP Upstream Technology Directorate, and K.M. Campion, ExxonMobil Upstream Research.

This FREE short course is designed to teach graduate students the principles, concepts, and methods of sequence stratigraphy. Sequence stratigraphy uses stratal surfaces to subdivide the stratigraphic record; this methodology allows the identification of coeval facies, documents the time-transgressive nature of classic lithostratigraphic units, and provides geoscientists with an additional way to analyze and subdivide the stratigraphic record. Using exercises that utilize outcrop, core, well-log, and seismic data, the course provides hands-on experience. Exercises include classic case studies from which many sequence stratigraphic concepts were originally developed.

505. Fundamentals of seismic structural analysis and hydrocarbon entrapment analysis for graduate students

Fri.–Sat., 16–17 Oct., 8 a.m.–5 p.m. **FREE** to students, who must pre-register; includes continental breakfast and lunch. Limit: 30. CEU: 1.6. **Cosponsors:** ConocoPhillips, ExxonMobil Exploration Co., and GSA's Structural Geology and Tectonics Division. **Instructors:** Peter Vrolijk and J. Steve Davis, ExxonMobil Upstream Research Co., and Peter Hennings, ConocoPhillips.

The purpose of this FREE course is to introduce geoscience graduate students to the fundamentals of seismic interpretation of structural systems in exploration and production settings, as well as the application of structural interpretations to the problems of petroleum trapping and the interaction of multi-phase fluids with geologic structures and rocks in the subsurface. The intended audience includes M.S. and Ph.D. candidates. The course lasts two days; participants need to participate both days.

506. Structural and stratigraphic concepts applied to basin exploration

Fri.–Sat., 16–17 Oct., 9 a.m.–5 p.m. **FREE** to students, who must pre-register; includes continental breakfast and lunch. Limit: 30. CEU: 1.6. **Cosponsors:** ExxonMobil Exploration Company and GSA's Sedimentary Geology Division. **Instructors:** Lori Summa and Bob Stewart, ExxonMobil Exploration Company.

This FREE course will explore concepts, methods, and tools of petroleum geoscience used on a day-to-day basis in the energy industry. The focus is on how we make decisions with limited information, evaluate risk versus uncertainty, and maximize value from integrated teams. Day one reviews fundamental stratigraphic and structural concepts; day two is an applied problem in basin exploration. Students will make play maps, bid on prospective acreage, and analyze individual prospects within that acreage. Throughout the course, we stress integration across disciplines and scales, focusing on interaction and expression of basin formation, fill, and evolution processes from regional to prospect scale.

507. Helping your students investigate plate tectonics just like scientists

Sat., 17 Oct., 8 a.m.–noon. **Fee:** US$90, includes materials. Limit: 50. CEU: 0.4. **Instructors:** William A. Prothero, Univ. of California at Santa Barbara (emeritus), and Sabina F. Thomas, Baldwin-Wallace College.

This workshop will focus on learners' use of Earth data to investigate the geometry and motion of the major tectonic plates. The use of these data for science investigations and example activities will be presented. Content will include the theory of plate tectonics, how the major plate boundaries can be studied using Earth data, how a science paper can be used to reinforce concepts and science processes, and how lectures, quizzes, course readings, and other activities support student success. All materials and data access tools will be provided on the "LearningWithData" CD-ROM.

508. Education Research I: Conducting qualitative geoscience education research

Sat. 17 Oct., 8 a.m.–noon. **Fee:** US$110. Limit: 35. CEU: 0.4. **Instructor:** Julie Sexton, Univ. of Northern Colorado.

Participants will learn qualitative education data collection and analysis methods used in science education research. Case studies, demonstrations, and hands-on activities will be used to teach participants how to develop qualitative research studies, collect qualitative data (e.g., interviews), and analyze qualitative data (e.g., coding). This short course is designed for students, university and K–12 educators, and researchers who are engaged in or who plan to be engaged in geoscience education research. This course can be taken alone or in conjunction with the short course "Education Research II: Conducting quantitative geoscience education research."

509. Education Research II: Conducting quantitative geoscience education research

Sat., 17 Oct., 1–5 p.m. **Fee:** US$110. Limit: 35. CEU: 0.4. **Instructor:** Julie Sexton, Univ. of Northern Colorado.

This interactive, activity-based course serves as an introduction to quantitative education research methods. It is designed for geoscience faculty or students who are or will be conducting quantitative education studies. Topics include developing quantitative education research questions, designing a quantitative study (e.g., selecting appropriate designs and statistical tests), collecting quantitative data (e.g., surveys), analyzing education data using statistical tests (e.g., ANOVA), and investigating causality. This course can be taken alone or in conjunction with the short course "Education Research I: Conducting qualtitative geoscience education research."

510. Three-dimensional geologic mapping

Sat., 17 Oct., 8 a.m.–5 p.m. **Fee:** US$60, includes continental breakfast and lunch. Limit: 65. CEU: 0.8. **Cosponsor:** GSA's Geology & Public Policy Committee. **Instructors:** Richard C. Berg, Illinois State Geological Survey; L. Harvey Thorleifson, Minnesota Geological Survey; and Hazen A.J. Russell, Geological Survey of Canada.

There is an increasing need for high-quality 3-D regional geological information as attention to environmental and land-use issues, as well as evaluation of regional groundwater systems and their long-term sustainability, continues to grow. Demands for this information are becoming increasingly compelling, but there is a continuing lack of high-quality data, maps, and models. This workshop focuses on experimenting with new ways to deal with large data sets, integrating data of variable quality with high-quality data, and developing methods to construct 3-D geologic models that can be used for hydrogeologic modeling and similar applications.

511. Laser Ablation ICP-MS: An overview of the technique and a look at new advances in quantitative microanalyses for geological, biological, and environmental applications

Sat., 17 Oct., 8 a.m.–5 p.m. Fee: US$315, includes continental breakfast and lunch. Limit: 40. CEU: 0.8. **Cosponsor:** GSA's Sedimentary Geology Division. **Instructors:** Alan E. Koenig and Todor Todorov, USGS.

This course will cover the basics of laser ablation inductively coupled plasma–mass spectrometry (ICP-MS) as applied to a wide range of geological, environmental, and biological samples. Both fundamentals of the technique and applications to minerals, fluid inclusions, teeth, bones, corals, tree rings, rock, and ore powders and others will be presented. The instructors will cover the topics by including practical information about

KEY: —Faculty; —Graduate Student; —K–12—Teacher; —Professional

how these applications are tackled and what future directions are possible. New directions for laser ablation (LA)-ICP-MS, such as isotopic analyses by multi-collector ICP-MS, analyses of tissue samples, and single fluid inclusions, will be presented.

512. Establishing and sustaining an undergraduate research program: A professional development workshop for new and future faculty

Sat., 17 Oct., 8 a.m.–5 p.m. **Fee:** US$20; includes continental breakfast and lunch. Limit: 30. CEU: 0.8. **Cosponsor:** Council on Undergraduate Research (CUR). **Instructors:** Lydia Fox, Univ. of the Pacific, and Laura Guertin, Penn State–Brandywine.

This day-long workshop is targeted at early-career faculty and postdoctoral scientists/graduate students seeking an academic career. Topics in the morning include integrating research practices into the classroom and effective approaches to mentoring undergraduate researchers. Topics in the afternoon include identifying funding sources for undergraduate research and tips for preparing successful proposals. Based on the demographics of our participants, we may also include a section on how to get a job at an academic institution (primarily undergrad. institution or regional university). Participants may join for the full day or either half of the workshop.

513. Teaching climate change and earth history using ocean drilling data in introductory geoscience courses

Sat., 17 Oct., 8 a.m.–5 p.m. **Fee:** US$30, includes continental breakfast and lunch. Limit: 35. CEU: 0.8. **Cosponsors:** U.S. National Science Foundation, the Consortium for Ocean Leadership, and GSA's Sedimentary Geology Division. **Instructors:** Kristen St. John, James Madison Univ.; Mark Leckie, Univ. of Massachusetts–Amherst; Megan Jones, North Hennepin Community College; and Kate Pound, St. Cloud State Univ.

This one-day short course is for faculty teaching undergraduate introductory geoscience courses in climate change, oceanography, historical geology, or earth science in which data and content on climate change, geologic time, age determination, and earth history are important. Learning materials introduced in the short course will be anchored in fundamental practices and discoveries of scientific ocean drilling research programs (IODP, legacy DSDP and ODP, and ANDRILL), and will infuse essential scientific observational, analytical, and synthesis skills, and critical thinking into inquiry-based classroom exercises for group work in both small and large classes. If you have questions about class content, please e-mail stjohnke@jmu.edu.

514. Pacific Northwest earthquakes and tsunamis for middle school teachers

Sat., 17 Oct., 8 a.m.–5 p.m. **Fee:** US$10, includes refreshments. Limit: 30. CEU: 0.8. **Cosponsor:** The National Association of Geoscience Teachers (NAGT). **Instructors:** Robert Butler, Univ. of Portland; Frank Granshaw, Portland Community College; Roger Groom, Mount Tabor Middle School; Chris Hedeen, Oregon City High School; Jenda Johnson, USArray E&O; Bonnie Magura, Jackson Middle School; Beth Pratt-Sitaula, Central Washington Univ.; and Jill Whitman, Pacific Lutheran Univ.

By exploring inquiry-based lesson plans featuring Cascadian earthquakes and tsunami geology, participating teachers will gain understanding of (1) Pacific Northwest plate tectonics and earthquakes; (2) earthquake seismology and tsunami science; and (3) how EarthScope science is advancing knowledge of active continental margin geology. Activities will combine science content sessions with pedagogical sessions led by middle school and high school teachers of earth science. Participants will receive teaching resources, including computer animations of plate tectonic, earthquake, and volcanic processes, and virtual field experiences featuring Cascadia tsunami geology and Pacific Northwest geologic hazards. This class will be held at the Univ. of Portland; please contact Robert Butler, butler@up.edu, for more information.

515. Introduction to the acquisition, visualization, and interpretation of airborne LiDAR-derived digital elevation models

Sat., 17 Oct., 9 a.m.–6 p.m.; Sun., 18 Oct., 9 a.m.–12 p.m. **Fee:** US$160. Limit: 48. CEU: 1.2. **Cosponsors:** GSA's Structural Geology and Tectonics Division, the Portland State University Geosciences Dept., and the Oregon Dept. of Geology and Mineral Industries. **Instructors:** Ian Madin, Oregon Dept. of Geology and Mineral Industries; Ralph Haugerud, USGS; Michael Oskin, Univ. of California at Davis; Chris Crosby, Univ. of California at San Diego; and Ramon Arrowsmith, Arizona State Univ.

LiDAR-derived elevation datasets are becoming widely available and offer digital elevation models (DEMs) of unprecedented resolution and accuracy. This course will teach geoscientists to acquire, visualize, and analyze LiDAR-based DEMs. Guided tutorials on individual workstations will use ESRI ArcGIS software, GEON software products, and LiDAR viewing freeware. The field portion of the class will compare recent high-resolution LiDAR images with the real environment of the surrounding area. The instructors are geologists who have worked with LiDAR data for many years at UC-Davis, Arizona State Univ., the GEON program, and the Puget Sound and Oregon LiDAR Consortia.

516. Introduction to geographic information systems (GIS) using ArcGIS for geological and environmental science applications

Sat.–Sun., 17–18 Oct., 9 a.m.–5 p.m. **Fee:** US$118, includes lunch. Limit: 20. CEU: 1.6. **Cosponsor:** ESRI. **Instructors:** Ann Johnson and Willy Lynch, ESRI.

Participants will be introduced to the use of GIS in geosciences and environmental-related applications through brief lectures, demonstrations, and hands-on computer exercises. Participants do not need experience with ArcGIS, but familiarity with the Windows OS would be most helpful. A brief introduction to spatial concepts and GIS using ArcGIS ArcMap and Spatial and 3D Analyst extensions will follow with the creation of a project covering many analysis techniques (geoprocessing using Toolbox tools and ModelBuilder). Use of Geodatabase Model schema and resources for accessing data will be explored.

517. Reducing student misconceptions about plate tectonics using interactive methods

Sun., 18 Oct., 8 a.m.–12 p.m. **Fee:** US$20. Limit: 30. CEU: 0.4. **Cosponsor:** GSA's Geoscience Education Division. **Instructors:** Karen M. Kortz, Community College of Rhode Island and Univ. of Rhode Island; and Jessica J. Smay, San José City College.

Participants will learn about classroom techniques (such as Lecture Tutorials, Conceptests, and Think-Pair-Shares) designed to make lectures more interactive. Techniques will be presented in the context of introductory-level plate tectonics, and student misconceptions about plate tectonics will be discussed. Each teaching technique will be demonstrated, providing participants practice with classroom-ready examples, practical advice, and guidance as they create their own examples. In addition to the examples presented, participants will receive references for additional information. This workshop is geared toward instructors who teach plate tectonics in an introductory course.

518. Watch faults grow before your very eyes! Using a deformational sandbox in high school and middle school earth science classrooms

Sun., 18 Oct., 8 a.m.–5 p.m. **FREE**; includes refreshments. Limit: 40. CEU: 0.8. **Cosponsors:** GSA's Structure and Tectonic Division and the National Science Foundation. **Instructors:** Michele Cooke, Univ. of Massachusetts–Amherst; and Mary Ellsworth, Gallaudet Univ.

Teachers will learn how to use a deformational sandbox to enhance student understanding of Earth's deformation using visual and hands-on activities. The sandbox can be used to directly and experimentally investigate concepts related to plate tectonics, fault systems, earthquakes, scientific modeling, and the nature of experimental science. Teachers will learn how to conduct specific experiments using the sandbox, to encourage student exploration of the sandbox as a model of real earth processes, and to support student learning, writing, and reporting activities with the sandbox. Instructions for building a classroom sandbox will be provided.

519. When worlds collide: Communication between scientists and emergency managers during crises

Sun., 18 Oct., 9 a.m.–5 p.m. **Fee:** US$103. Limit: 25. CEU: 0.8. **Instructors:** Jeff Rubin, Tualatin Valley Fire & Rescue; Cynthia Gardner, USGS–Cascades Volcano Observatory; and Jay Wilson, Clackamas County Emergency Management.

Low-probability, high-consequence natural events such as volcanic eruptions and earthquakes require effective interaction between scientists who study and forecast them and emergency managers who plan for and respond to them. This includes understanding roles and responsibilities, inherent uncertainties in forecasting natural phenomena, critical decision timelines, and effective communication with the public and policy makers. This course provides an introduction to the Incident Command System used by emergency managers and responders at all levels of government during crises, along with tips for effective public communication. Participants will engage in practical applications—realistic in-class exercises offering collaboration with practitioners from multiple disciplines.

520. Using and developing historical image archives to investigate landscape change

Sun., 18 Oct., noon–3 p.m. **Fee:** US$10; includes lunch. Limit: 40. CEU: 0.4. **Cosponsors:** U.S. National Science Foundation and GSA's Quaternary Geology and Geomorphology, Sedimentary Geology, and Geoscience Education Divisions. **Instructors:** Paul Bierman, Christine Massey, and Jamie Russell, Univ. of Vermont.

Images, including photographs and drawings, provide a powerful means of documenting Earth's changing surface over time scales ranging from seconds to centuries. This course will show how images can be used to document a wide variety of Earth and environmental processes, including human impacts on varied landscapes, the effect of warming climate on glaciers, and the response of hill slopes and stream channels to deforestation. You will learn the pitfalls and promises of building your own image collections as well as how to interest students of all ages in earth science by using historic images to study change over time.

Photo below: Sand Point, Columbia County, Oregon. Photo by Tim Jewett courtesy the Portland Oregon Visitors Association.

KEY: —Faculty; —Graduate Student; —K–12—Teacher; —Professional

HOUSING INFORMATION

Making Your Reservation

To take advantage of the special GSA convention rates, please book your reservation by **14 September.** After this date, room blocks will be released and hotels may charge higher rates.

Please make your reservations using only *one* of the following four options:

- Reserve your room online via link at www.geosociety.org/meetings/2009
- Fax the downloaded form to +1-503-275-9782
- Mail the downloaded form to GSA–Travel Portland Housing, 1000 SW Broadway, Suite 2300, Portland, OR 97205, USA
- Phone GSA–Travel Portland Housing at +1-877-678-5263 #2 or +1-503-275-9293, Mon.–Fri. between 8:30 a.m. and 5 p.m.

Questions? E-mail housing@travelportland.com or call the Travel Portland Housing Bureau at one of the numbers above.

Modify/Cancel Your Reservation

Before 9 October: Changes to name, address, stay dates, or special requests can be made online via www.geosociety.org/meetings/2009–OR–by contacting the Travel Portland Housing Bureau at +1-877-678-5263 #2 or +1-503-275-9293, Mon.–Fri. between 8:30 a.m. and 5 p.m.

After 9 October: All changes and cancellations must be made directly with your assigned hotel, but please DO NOT contact the hotel directly until after this date.

Cancellation requests received after 14 Sept. 2009 will be subject to a US$25 cancellation fee. Cancellations made within 72-hours of the scheduled arrival date are subject to a fee equal to one night's room rate plus tax. These fees will be charged to the credit card used to make the reservation.

Oregon Convention Center. Photo by Bruce Forster courtesy the Portland Oregon Visitors Association.

HOUSING ALERT!

GSA has selected Travel Portland as our official housing bureau. Neither GSA nor Travel Portland will telephone or send faxes offering "special" Portland hotel reservations. In the event you have any problems with your reservation or accommodations, GSA can only assist in reconciling those issues if the reservation was booked through Travel Portland. If you have questions about an unauthorized solicitation, the online system, or about housing in general, please contact Becky Sundeen, bsundeen@geosociety.org.

GSA Annual Meeting Bulletin Board

Use the GSA Travel & Housing Bulletin Board to find roommates and share housing, make carpool arrangements, plan activities, and coordinate your schedule with other meeting attendees.

It's easy and it's free! Go to

http://rock.geosociety.org/forumstudenttravel/

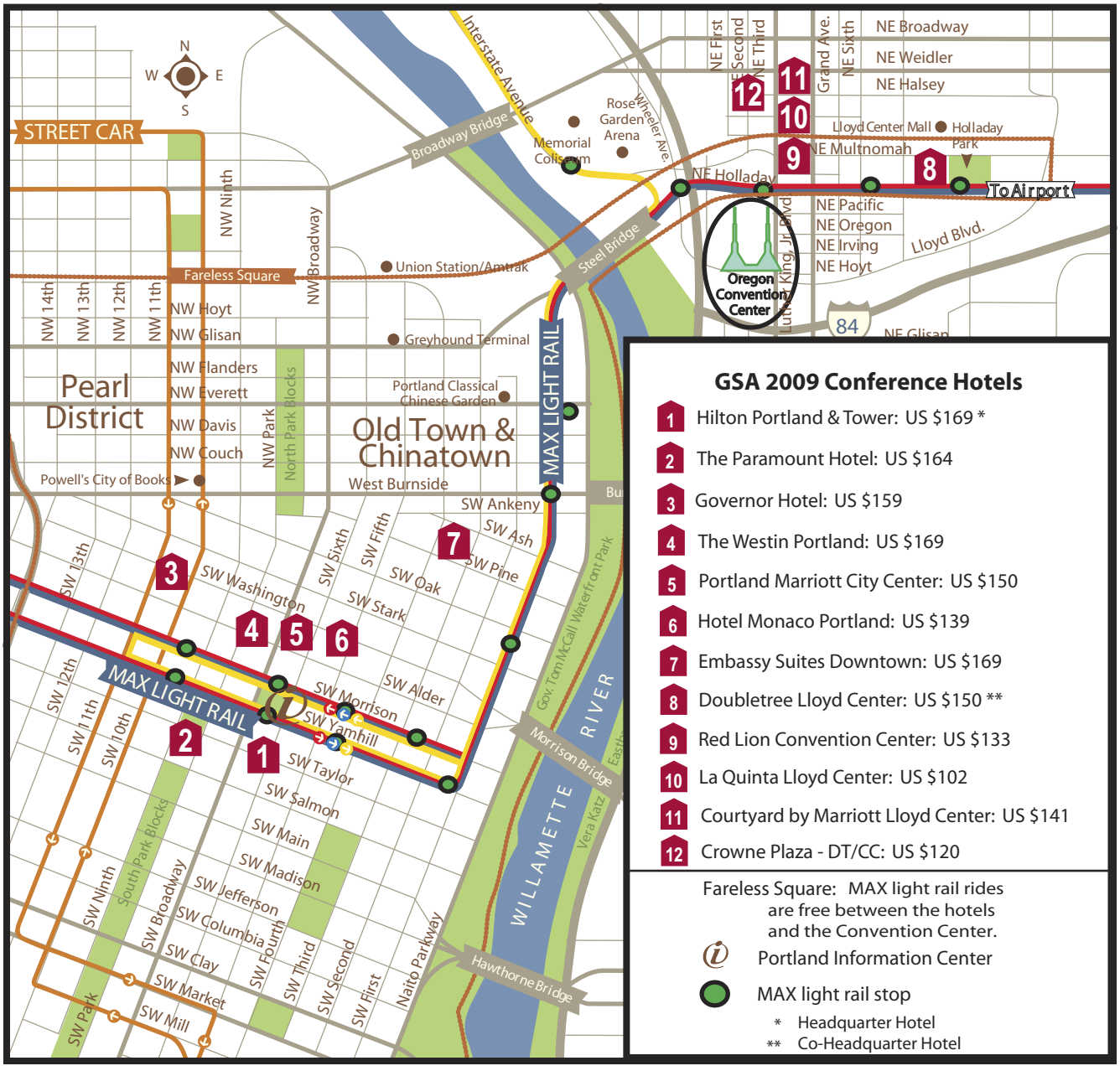
to get started today.

Thanks

for your support of GSA's exhibitors!

Check **www.geosociety.org/meetings/2009/exhibits.htm** for an up-to-the-minute listing.

HOTEL MAP ✷ PORTLAND, OREGON



GSA 2009 Conference Hotels

1. Hilton Portland & Tower: US $169 *
2. The Paramount Hotel: US $164
3. Governor Hotel: US $159
4. The Westin Portland: US $169
5. Portland Marriott City Center: US $150
6. Hotel Monaco Portland: US $139
7. Embassy Suites Downtown: US $169
8. Doubletree Lloyd Center: US $150 **
9. Red Lion Convention Center: US $133
10. La Quinta Lloyd Center: US $102
11. Courtyard by Marriott Lloyd Center: US $141
12. Crowne Plaza - DT/CC: US $120

Fareless Square: MAX light rail rides are free between the hotels and the Convention Center.

ⓘ Portland Information Center

MAX light rail stop

* Headquarter Hotel

** Co-Headquarter Hotel

HOTEL DESCRIPTIONS ✷ PORTLAND, OREGON

Hotel	Cost*	Description*	Parking*
Courtyard by Marriott Lloyd Center Downtown 435 NE Wasco St., Portland, OR 97232	Single: $141 Double: $141 Triple: $151 Quad: $161	Location just 2 blocks from the Oregon Convention Center and 2 blocks from the MAX light rail system, the Marriott offers complimentary wired internet access in all guest rooms. All rooms are non-smoking and feature new bedding with pillowtop mattresses, triple sheeting, and plush pillows. The hotel has an indoor pool and fitness center, a full-service restaurant (open weeknights only), and room service from 5 p.m.–11 p.m. daily.	On-site parking: $12 per day.
Co-Headquarters Hotel **Doubletree Hotel & Executive Meeting Center** 1000 NE Multnomah St., Portland, OR 97232	Single: $150 Double: $150 Triple: $165 Quad: $180	This co-headquarters hotel is 4 blocks from the Oregon Convention Center and is adjacent to the MAX light rail system. All rooms are non-smoking and feature the Sweet Dreams by Doubletree plush-top bed. Rooms also have large work desks, two phones, and a coffee/tea maker. In-room wired or wireless internet is $9.95 per 24-hr period. The hotel provides a complimentary 24-hr business center, a fitness center, two restaurants, and room service from 6:30 a.m.–11 p.m. daily.	GSA hotel guest self-parking, including in-and-out privileges: $9. Day parking for meeting attendees: $5/day. Add $4 for valet parking.
Embassy Suites Hotel Portland Downtown 319 SW Pine St., Portland, OR 97204	Single: $169 Double: $169 Triple: $194 Quad: $219	This historic hotel, est. 1912, is three-quarters of a mile from the Oregon Convention Center and 2 blocks from the MAX light rail. In-room wireless internet is $9.95 per 24-hr period. This all-suite hotel offers a great range of amenities, and the room rate includes a complimentary cooked-to-order breakfast and evening manager's reception. The on-site restaurant is open for lunch and dinner; room-service hours are 11 a.m.–11 p.m. Sun.–Thurs. and 11 a.m.–12 a.m. Fri.–Sat.	On-site self-parking: $18; valet parking: $28.
The Governor Hotel 614 SW 11th Ave., Portland, OR 97025	Single: $159 Double: $159 Triple: n/a Quad: n/a	The Governor is 2 miles from the Oregon Convention Center and 1 block from the MAX light rail. A Portland landmark, this hotel combines historical ambience with modern convenience. All rooms are non-smoking and feature pillowtop mattresses, plush linens, and terrycloth robes. In-room wireless internet is complimentary, as is the hotel fitness center. The onsite restaurant is open for breakfast, lunch, and dinner; room-service hours are 7:30 a.m.–10 p.m.	Overnight parking: $27 per night.
Headquarters Hotel **Hilton Portland & Executive Tower** 921 SW Sixth Ave., Portland, OR 97204	Single: $169 Double: $169 Triple: $179 Quad: $189	The headquarters hotel is 1 mile from the Oregon Convention Center and 2 blocks from the MAX light rail. This Hilton is the largest hotel in Oregon and consists of two separate buildings: the main building and the executive tower. All rooms are non-smoking and feature the Hilton Serenity Bed, coffeemaker with complimentary coffee, desk, and wired internet access at $9.95 per 24-hr period. Hotel amenities include an athletic club (add'l fees apply), hot tub, sauna, and indoor lap pool. Two on-site restaurants are open for breakfast, lunch, and dinner; room-service hours are 6:30 a.m.–11 p.m.	Self-parking: $20 per night; valet parking: $27 per night.
Crowne Plaza Hotel Portland–Downtown/ Convention Center 1441 NE 2nd Ave., Portland, OR 97232	Single: $120 Double: $120 Triple: $130 Quad: $140	This hotel, 3 blocks from the Oregon Convention Center and 3 blocks from the MAX light rail, offers a free area shuttle that will take you anywhere within a five-mile range (based on shuttle availability), as well as to and from the airport. All newly renovated guest rooms include Crowne Sleep Advantage bedding, a 32" flat panel TV, CD player, free high-speed wireless internet, coffeemaker, microwave, and mini-refrigerator. The on-site restaurant is open for breakfast, lunch, and dinner, with room service from 6 a.m.–10 p.m.	Self-parking: $10 per night.

Housing reservation deadline: 14 September.

HOTEL DESCRIPTIONS ✷ PORTLAND, OREGON

Hotel	Cost*	Description*	Parking*
Hotel Monaco Portland 506 SW Washington at 5th Ave., Portland, OR 97204	Single: $139 Double: $139 Triple: $159 Quad: $179	The Monaco is 1.5 miles from the Oregon Convention Center and 2 blocks from the MAX light rail. Rooms include a 32" flat-screen plasma TV, high-thread count linens, and new furnishings that reflect Monaco signature style and luxury. Pet-friendly rooms are available, and the hotel provides complimentary internet access, a nightly wine reception, and a fitness center. The on-site restaurant is open for breakfast, lunch, and dinner, with 24-hr room service.	Valet parking: $31 per night.
La Quinta Inn Lloyd Center 431 NE Multnomah, Portland, OR 97232	Single: $102 Double: $102 Triple: $102 Quad: $102	This non-smoking hotel is only 1.5 blocks from the Oregon Convention Center and 1 block from the MAX light rail. All rooms include complimentary high-speed internet, data port phones, a coffee-maker, and a microwave. The fitness center and indoor pool are open 24 hours, as is the business center. There is no on-site restaurant, but the hotel offers a complimentary, trademarked Bright Side Breakfast.	Free on-site parking.
The Paramount Hotel 808 SW Taylor St., Portland, OR 97205	Single: $164 Double: $164 Triple: $179 Quad: $194	This hotel is 1.5 miles from the Oregon Convention Center and 1 block from the MAX light rail. All rooms are non-smoking and include plush pillows, triple-sheeted beds, custom designed comforters, a large work desk, a deluxe lounge chair with ottoman, complimentary wireless internet, a personal refrigerator, and iron and ironing board. The hotel fitness center is open 24 hours. The on-site Dragonfish Asian Café is open for breakfast, lunch, and dinner; room service is 7 a.m.–10 p.m.	Valet parking: $28 per night.
Portland Marriott City Center 520 SW Broadway, Portland, OR 97205	Single: $150 Double: $150 Triple: $175 Quad: $200	This Marriott is 1.5 miles from the Oregon Convention Center and 2 blocks from the MAX light rail. The hotel is non-smoking and has a fitness center. Room amenities include a coffeemaker, hair dryer, and iron and ironing board. Wired internet access is $9.95 per 24-hr period. The on-site restaurant, Mez, is open for breakfast, lunch, and dinner; room-service hours are 6 a.m.–11 p.m.	Valet parking: $29 per night.
Red Lion Hotel Portland Convention Center 1021 NE Grand Ave., Portland, OR 97232	Single: $133 Double: $133 Triple: $148 Quad: $163	This non-smoking hotel is adjacent to the Oregon Convention Center and the MAX light rail. Amenities include complimentary wireless internet access, refrigerators, and coffeemakers in all rooms. The on-site restaurant is open for breakfast, lunch, and dinner, and room service is available during restaurant hours.	Overnight parking: $10 per night.
The Westin Portland 750 SW Adler St., Portland, OR 97205	Single: $169 Double: $169 Triple: $194 Quad: $219	The Westin is 1.5 miles from the Oregon Convention Center and 2 blocks from the MAX light rail. All rooms are non-smoking and feature registered-trademark Westin Heavenly Bed and Heavenly Bathrooms. Wireless or wired internet access is available in guest rooms for $12.95 per 24-hr period. The hotel has a complimentary health and fitness facility and an on-site restaurant that serves breakfast, lunch, and dinner. Room service is available 24 hours, with a limited menu after 10 p.m.	Valet parking: $29 per night.

Note: All hotels are in the "Fareless Square" area for the MAX light rail, streetcar, and bus system. Trips that begin and end within the Fareless Square are free, all day, every day. A printable PDF map of Fareless Square and MAX Light Rail information is available at http://trimet.org/fares/fareless.htm. All hotels are handicap-accessible.

*All prices are in U.S. dollars and do not include applicable taxes.

Housing Alert! *Beware of unauthorized solicitations:* Travel Portland is GSA's official housing bureau; neither Travel Portland nor GSA will phone or fax you with special hotel rate offers.

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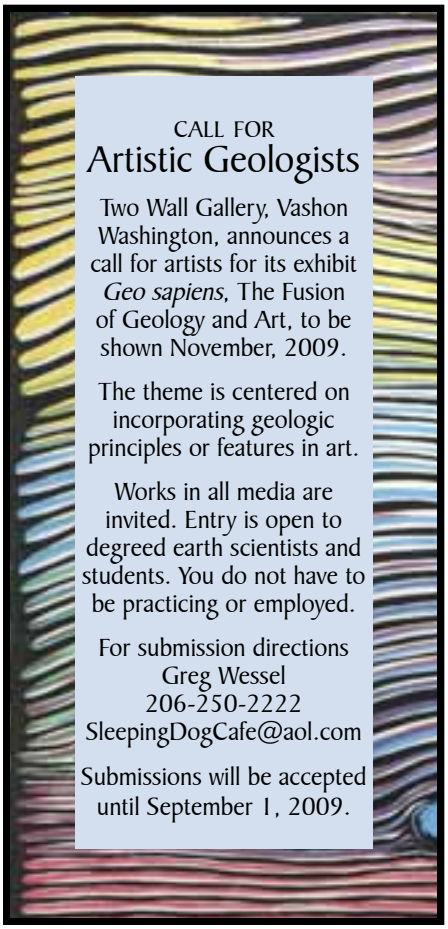

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- Roger Nielsen, Oregon State University, nielsenr@geo.oregonstate.edu
- Paul Pedone, Natural Resources Conservation Service, paul.pedone@or.usda.gov
- Herman Zimmerman, retired, hzimmerm@comcast.net

TRAVEL & TRANSPORTATION

AIRLINES

Alaska Airlines, www.alaskaair.com

Receive a discount on all roundtrip tickets purchased for the GSA Annual Meeting by using the meeting code **ECCMB0852.** The discount is applicable for travel 15 Oct.–23 Oct. 2009 only and is valid *only* for reservations made online at www.alaskaair.com. Be sure to input the meeting code in the discount box when you are filling out the Flights Search box. Reservations booked by calling the Group Desk will incur a US$15 ticketing fee.

United Airlines, +1-800-521-4041

Receive an up to 10% discount on domestic and international roundtrip flights for the GSA Annual Meeting by using the meeting code **585KH** when you call the United MeetingsPlus reservation line at +1-800-521-4041. Discounts are applicable for travel 15 Oct.–24 Oct. 2009 only and reservations must be made by phone.

GROUND TRANSPORTATION

See Portland International Airport's Web site, **www.portofportland.com/PDX_Grnd_Trnsprtn.aspx,** for detailed information on ground transportation.

Trimet's MAX Light Rail
+1-503-238-7433, www.trimet.org/max

At Portland International Airport, go to the lower level, baggage claim area, and follow the signs to the MAX light rail red line. The one-way cost is only US$2.30! MAX light rail hours are 5 a.m.–11:56 p.m., with trains running every 15 minutes. The trip between the airport and downtown takes about 38 minutes and requires an all-zone fare. You can easily roll your luggage on board for convenient and inexpensive travel to downtown Portland.

MAX light rail in downtown Portland. Image courtesy Travel Portland.

Car Rental
Enterprise Rent-a-Car, www.enterprise.com, +1-800-593-0505

Book your car online and enter the group code **46W2750** in the optional account box. On the next screen, enter the first three letters of the event name, "GEO," and press enter. You may also book over the phone by calling +1-800-593-0505.

Taxi Service

The pick-up area for taxis is located in the center section of the airport terminal's lower roadway on the baggage claim and departure level. Most transportation providers serve downtown Portland, which is about 20 to 40 minutes from Portland International Airport. The average taxi fare is US$35 one-way, not including gratuity.

Shuttle Service

Portland International Airport has many shuttle services. Shuttles depart from the center section of the airport terminal's lower roadway on the baggage claim level. The average shuttle fare is US$15–$20 one-way. Some shuttle services require advance reservations.

DO YOU NEED A VISA?

Most travelers to the United States must hold a valid visa and a passport valid for at least six months longer than the intended visit. Please go to **www.geosociety.org/meetings/2009/visa.htm** to determine if you require a travel visa to attend the Annual Meeting.

If you do need a visa, please understand that the visa application process may take several months. An interview appointment is required for a visa application at all embassies and consulates. The wait time for this appointment varies, but may be as long as three months, with processing taking an additional month or more. You can check the U.S. State Department's Web site, http://travel.state.gov/visa/temp/wait/tempvisitors_wait.php, for estimates of visa application wait times. As soon as you decide to attend the meeting, you should begin the process of applying for a visa.

The United States has made some important changes to the US-VISIT program, which was instituted in 2004. The program now requires most foreign visitors to have a set of complete fingerprints taken along with a digital photograph to verify identity at consulates as well as the port-of-entry. Most Canadians are currently exempt from US-VISIT requirements. A departure confirmation program, as part of US-VISIT, is also now currently in place. This program applies to all visitors, including those from visa waiver countries.

GSA ASSOCIATED SOCIETIES

We invite you to Portland!

Members of GSA's Associated Societies can register for the meeting at the GSA member price (see p. 15).

AASP - The Palynological Society

American Association of Petroleum Geologists (AAPG)

American Institute of Professional Geologists (AIPG)

American Quaternary Association (AMQUA)

American Rock Mechanics Association (ARMA)

American Society of Limnology and Oceanography (ASLO)

American Water Resources Association (AWRA)

Asociación Geológica Argentina (AGA)

Association for Women Geoscientists (AWG)

Association of American State Geologists (AASG)

Association of Earth Science Editors (AESE)

Association of Environmental & Engineering Geologists (AEG)

Association of Geoscientists for International Development (AGID)

The Clay Minerals Society (CMS)

Council on Undergraduate Research Geosciences Division (CUR)

Cushman Foundation (CF)

Environmental & Engineering Geophysical Society (EEGS)

Geochemical Society (GS)

Geological Association of Canada (GAC)

Geological Society of Australia (GSAus)

Geological Society of London (GSL)

Geological Society of New Zealand (GSNZ)

Geological Society of South Africa (GSSA)

Geoscience Information Society (GSIS)

Groundwater Resources Association of California (GRA)

History of Earth Sciences Society (HESS)

International Association of Geochemistry (IAGC)

International Association of Hydrogeologists (IAH)

International Medical Geology Association (IMGA)

Karst Waters Institute (KWI)

The Mineralogical Society (MS)

Mineralogical Society of America (MSA)

National Association of Black Geologists and Geophysicists (NABGG)

National Association of Geoscience Teachers (NAGT)

National Association of State Boards of Geology (ASBOG®)

National Cave and Karst Research Institute (NCKRI)

National Earth Science Teachers Association (NESTA)

National Ground Water Association (NGWA)

Paleontological Research Institution (PRI)

Paleontological Society (PS)

Seismological Society of America (SSA)

Sigma Gamma Epsilon (SGE)

Sociedad Geológica Mexicana, A.C. (SGM)

Society for Sedimentary Geology (SEPM)

Society of Economic Geologists (SEG)

Society of Vertebrate Paleontology (SVP)

Soil Science Society of America (SSSA)

GSA MENTOR PROGRAMS

JOHN MANN MENTORS IN APPLIED HYDROGEOLOGY PROGRAM

This program underwrites the cost for up to 25 students to attend the Hydrogeology Division Luncheon and Awards Presentation and meet some of geoscience's most distinguished hydrogeologists. **Students eligible for this honor** are those who have (1) indicated a professional interest in hydrology/hydrogeology on their GSA membership application, *and* (2) registered for the Annual Meeting by 14 September. The first 25 students who respond to an **e-mail invitation** based on these criteria will receive FREE tickets for the luncheon.

WOMEN IN GEOLOGY

Sponsored by Subaru of America, Inc.
Sun., 18 Oct., noon–1:30 p.m.

This mentor program addresses the issues faced by women in geology. Designed as a networking reception, the session begins with key speaker commentary, followed by a relaxing forum for socializing, sharing ideas, and meeting other women in geology. *Appetizers provided; registration is not required.*

GEOLOGY IN GOVERNMENT

Sponsored by the GSA Foundation
Mon., 19 Oct., 11:30 a.m.–1 p.m.

This popular annual event for undergraduate and graduate students features a FREE lunch with a select panel of mentors representing various government agencies. These mentors will answer students' questions, offer career planning advice, and comment on the prospects for current and future job opportunities with their agencies. *Registration is not required.*

GEOLOGY IN INDUSTRY

Sponsored by ExxonMobil
Tues., 20 Oct., 11:30 a.m.–1 p.m.

Undergraduate and graduate students: Enjoy a FREE lunch with a select panel of mentors representing a variety of companies. These mentors will answer your questions, offer advice about preparing for a career in industry, and comment on the prospects for current and future job opportunities with their companies. *Registration is not required.*

Full program descriptions are available at **www.geosociety.org/mentors/.**

Questions? Contact Jennifer Nocerino jnocerino@geosociety.org.

SPECIAL EVENTS FOR K–12 EDUCATORS

Geoscience Educators' Social Reception

Saturday, 17 Oct, 5–7 p.m.

Join other educators and the GSA Education & Outreach staff at this relaxing forum for socializing, sharing ideas, and meeting other geoscience community members interested in education. *Appetizers and cash bar provided.*

Darwin Day at GSA

Monday, 19 Oct.

This day of events is devoted to Darwin and his work, beginning with a discussion panel at 11 a.m. that will include Judge Jones from the Dover County Intelligent Design trial. In the afternoon, we will have a number of free lectures, and the evening will feature the L.A. Theater Works presentation of the "Great Tennessee Monkey Trial." All Darwin Day participants will receive a free pass to the GSA Exhibit Hall.

Short Courses

The following courses are designed especially for teachers. Read about all the short courses beginning on p. 30.

507. **Helping your Students Investigate Plate Tectonics Just Like Scientists.** Sat., 17 Oct., 8 a.m.–noon. US$90. Limit: 50. CEU: 0.4.

514. **Pacific Northwest Earthquakes and Tsunamis for Middle School Teachers.** Sat., 17 Oct., 8 a.m.–5 p.m. US$10, includes refreshments. Limit: 30. CEU: 0.8.

518. **Watch Faults Grow Before Your Very Eyes! Using a Deformational Sandbox in High School and Middle School Earth Science Classrooms.** Sun., 18 Oct., 8 a.m.–5 p.m. Free. Limit: 40. CEU: 0.8.

520. **Using and developing historic image archives to investigate landscape change.** Sun., 18 Oct., noon–3 p.m. US$10; includes lunch. Limit: 40. CEU: 0.4.

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GRADUATE SCHOOL INFORMATION FORUM

Sun., 18 Oct., 8 a.m.–5:30 p.m.,
with 7–9 p.m. (during the welcoming reception) optional

Mon.–Wed., 19–21 Oct., 8 a.m.–5:30 p.m.

Take advantage of this opportunity to promote your school and meet face-to-face with over 1,500 prospective students in a relaxed, informal setting.

The forum begins Sunday, 18 Oct., from 8 a.m.–5:30 p.m., with an option to stay at the booth from 7–9 p.m. so that students at the welcoming party will have a chance to stop by. Monday–Wednesday, the forum is open 8 a.m. to 5:30 p.m.

Booths may be booked for one day or up to all four days, but space is limited, so we recommend that you reserve early. Sunday and Monday will be the first to sell out. Schools reserving multiple days will be assigned first and to the most visible booths. Participating schools will be promoted in the September *GSA Today* (pending submittal date of the reservation form), the 2009 Annual Meeting Program, and e-mail links on the GSA Web site so prospective students may schedule appointments.

Reserve your space **at https://rock.geosociety.org/registration?meetingid=09GSIF**

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Z
Zanfel Laboratories Inc.

*As of press time for this issue.

GREENING THE MEETING

I am often asked what GSA is doing to "green our meeting." As we open registration for our 2009 Annual Meeting & Exposition in one of the greenest cities in the United States, I wanted to tell you about some of what GSA has been doing and will be doing going forward to help decrease the carbon footprint left behind at these scientific exchanges.

Reduce

- Choosing cities that are walk-able or that have a visitor-friendly public transit system (such as Portland);
- Utilizing water pitchers or large water jugs instead of bottled water;
- Providing bulk products for coffee breaks and concessions (i.e., creamers, sugar, condiments);
- Keeping handouts to a minimum;
- Switching to laptops in meeting rooms instead of desktops to reduce energy use;
- Offering a bulletin board site where attendees can find carpooling to the meeting or roommates at the meeting.

Reuse

- Working with hotel chains who offer the option to not have bed linens and towels changed every day;
- Utilizing promotional information for multiple years if possible.

Recycle

- Recycling badge holders;
- On-site recycling of programs and other paper products;
- Using recycled paper and vegetable-based inks for program books and the *Abstracts with Programs* volume;
- Providing larger poster-area recycling bins;
- Working with facilities that offer recycling in meeting rooms and hotel rooms;
- Donating leftover food to food banks or for composting.

This is just a glimpse of what GSA is doing to help reduce our carbon footprint. We have been doing some of these things for years, and others are new as it becomes easier to "be green" in today's world.

Our meeting Web site includes a list of some things that you can do as attendees to help with this effort. We have also partnered with a local business to provide a carbon calculator so you can see the amount of CO_2 that is expelled when you travel to and from our meeting destination. This company will also offer you the opportunity to offset this CO_2 by donating money to a Portland-area project.

While we believe that meetings for networking with colleagues and for the scientific exchange of information are extremely important, we also believe in being good Earth stewards.

Melissa Cummiskey, *CMP, GSA Senior Director of Meetings and Events*

Call for GSA Committee Service

THE GEOLOGICAL SOCIETY OF AMERICA®

Impact the Future of Geoscience— Serve on a GSA Committee!

2010–2011 COMMITTEE VACANCIES
Deadline to apply or submit nominations: 15 July 2009

GSA invites you to volunteer or nominate one of your fellow GSA members to serve on a Society committee or as a GSA representative to other organizations. Learn more about each position at **www.geosociety.org/aboutus/committees.**

Terms begin **1 July 2010** unless otherwise indicated. If you have questions or cannot find the information you need on the GSA Web site, please contact Pamela Fistell, pfistell@geosociety.org, +1-303-357-1044, or +1-800-472-1988, ext. 1044.

COMMITTEE, SECTION, AND DIVISION VOLUNTEERS:

COUNCIL THANKS YOU!

GSA Council acknowledges the many member-volunteers who, over the years, have contributed to GSA and to our science through involvement in the affairs of the GSA. Your time, talent, and expertise help build a solid and lasting Society.

COMMITTEES REQUIRING VOLUNTEERS/NOMINEES:

Academic and Applied Geoscience Relations Committee (AM, T/E)	*(3-year term)*
Annual Program Committee (AM, B/E)	*(4-year term)*
Arthur L. Day Medal Award (T/E)	*(3-year term)*
Committee on Education (AM, B/E, T/E)	*(4-year and 2-year term)*
Geology and Public Policy (AM, B/E, T/E)	*(3-year term)*
Joint Technical Program Committee (T/E)	*(3-year term)*
Membership (B/E)	*(3-year term)*
Minorities and Women in the Geosciences (AM)	*(3-year term)*
Nominations (B/E, T/E)	*(3-year term)*
Penrose Conferences and Field Forums (T/E)	*(3-year term)*
Penrose Medal Award (T/E)	*(3-year term)*
Professional Development (T/E)	*(3-year term)*
Publications (AM, B/E, T/E)	*(4-year term)*
Research Grants (B/E; extensive time commitment required 15 Feb.–15 Apr.)	*(3-year term)*
Young Scientist Award (Donath Medal) (T/E)	*(3-year term)*

GSA REPRESENTATIVES TO OTHER ORGANIZATIONS

GSA Representative to the GSA and AASG Selection Committee for the John C. Frye Memorial Award in Environmental Geology	*(3-year term)*
North American Commission on Stratigraphic Nomenclature (AM, possibly B/E)	*(3-year term, Nov. 2010–Nov. 2013)*

AM—Meets at the Annual Meeting • B/E—Meets in Boulder or elsewhere • T/E—Communicates by phone or electronically

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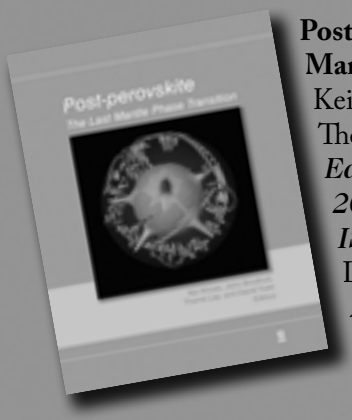

Post-Perovskite: The Last Mantle Phase Transition
Kei Hirose, John Brodholt, Thorne Lay, David Yuen, *Editors*
2007, 287 pp., hardbound.
ISBN 978-0-87590-439-9
List Price: $104.00
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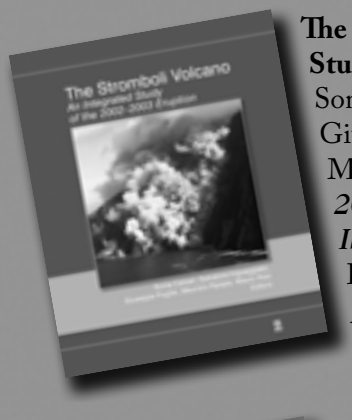

The Stromboli Volcano: An Integrated Study of the 2002–2003 Eruption
Sonia Calvari, Salvatore Inguaggiato, Giuseppe Puglisi, Maurizio Ripepe, Mauro Rosi, *Editors*
2008, 399 pp., hardbound.
ISBN 978-0-87590-447-4
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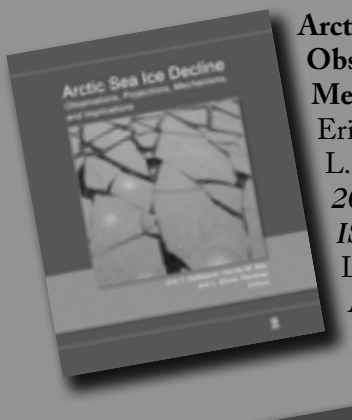

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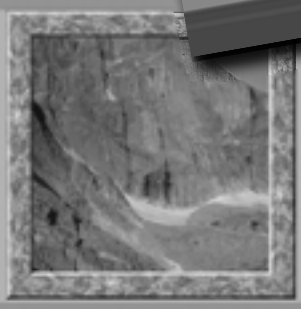


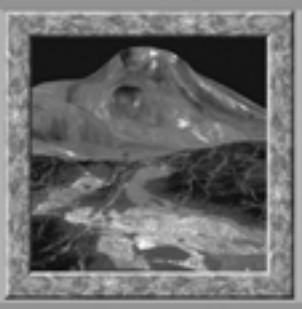

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AGU

Upcoming

GSA GeoVentures Trips

26 June: Teacher trip, **"Galapagos Islands—A Place Born of Fire,"** convenes and runs through 6 July.

5 July: Teacher trip, **"Hawaii—The Big Island: Living on an active hot-spot volcano,"** convenes and runs through 11 July.

18 July: Teacher trip, **"Australian Earth Adventure: Earth Science and Technology,"** convenes and runs through 29 July.

31 July: The **"Geology of the Galapagos Islands"** trip for everyone convenes and runs through 10 August.

29 August: The **"Geology of the Middle Fork of the Salmon River, Idaho"** trip for everyone convenes and runs through 4 September.

www.geosociety.org/geoventures

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Because the best geologists have seen the most rocks!

Nominate Your Next Officers and Councilors!

Nominations accepted through 15 July 2009

The GSA Committee on Nominations requests nominations for Officers (vice president and treasurer) and Councilors to serve on GSA Council beginning in 2010. Each nomination should be accompanied by basic data and a description of the qualifications of the individual for the position recommended.

The online nomination form is available at www.geosociety.org/aboutus/officers.htm or you may send materials for officer and councilor nominations to Pamela Fistell, GSA, P.O. Box 9140, Boulder, CO 80301-9140, USA, pfistell@geosociety.org.

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Painting the Past: From Scientific Research to Art

Patricia Vickers-Rich, *School of Geosciences, Monash University, Melbourne, Australia, pat.rich@sci.monash.edu.au*

Understanding the physical and biological conditions that led to the development of complex, multicellular life requires the interaction of researchers with diverse backgrounds. Differences of detail, scale, and terminology between disciplines can confuse. Focused (Eriksson et al., 2004; Valentine, 2004; Schopf and Klein, 1992) and general (see Fedonkin et al., 2007) reviews on Precambrian physical and biological events have helped to bridge gaps between disciplines and have brought about a better understanding of Earth's history. Art can also be a critical "Lingua Franca," allowing cross-disciplinary communication, fueling discussion, and generating new ideas and new approaches to old enigmas.

Major climatic events have become the focus of intense scrutiny, including those at 2400–2200 and 750–560 Ma, when Earth was gripped by cold. The Neoproterozoic cold spell is of special interest to paleontologists attempting to understand the driving forces behind the appearance and diversification of early metazoans. Neoproterozoic climate conditions may have been responsible for the development of dynamic, "weedy," or disturbed environments, which favor evolutionary novelty. Unfortunately, early metazoans (the Ediacarans) lacked hard parts. It is the hard skeletal materials of an organism that most commonly survive post-mortem decay. An additional problem is that the Ediacarans were preserved by environments dominated by microbial mats, making it difficult to develop a detailed understanding of these biota. The Ediacarans contain many taxa with body symmetries unlike those that have come to us via the Phanerozoic, making interpretation a challenge, so much so that the quest for the origin of the major phyla is proving to be problematical. Furthermore, identification of the specific driving forces that led to the origin and radiation of the earliest metazoans and their relationships to the Cambrian explosion of metazoan life are far from being understood.

Figure 1. *Bradgatia* from the Neoproterozoic of Newfoundland, an early rangeomorph Ediacaran.

Here I argue that art can aid in improving our understanding of past life. Peter Trusler is an artist who has worked to render reconstructions of past environments and their inhabitants from the Neoproterozoic to Recent. His art, like that produced by others helping to re-create past life and environments, requires scientists and artist to work together, and provides a summary of our current understanding of the environments populated by now extinct biological entities.

For example, Trusler is developing a series of reconstruction illustrations of the Ediacaran time period. These include the cold depths of the Mistaken Point and Fermeuse biotas of Newfoundland (with Guy Narbonne) ca. 580 Ma (Fig. 1); the faunal assemblages from the type section of the Ediacaran in Australia (with Jim Gehling; Fig. 2); the White Sea biota of northern Russia (with Mikhail Fedonkin and colleagues); and the latest Neoproterozoic Nama Group of Namibia (with K.H. Hoffmann and colleagues). The strata at these sites were deposited during and after the last of the "Snowball Earth" glaciations (see also www.geosci.monash.edu.au/precsite and www.press.jhu.edu/books/Fedonkin_Timeline.pdf). These reconstructions of the Ediacaran serve as a focus for discussion and provide the public access to complex scientific ideas.

Our methodology involves Trusler working directly on site, analyzing the excavation environs as well as fossil collections. The final synthesis of geological, taphonomic, and morphological

GSA Today, v. 19, no. 6, doi: 10.1130/GSATG32GW.1

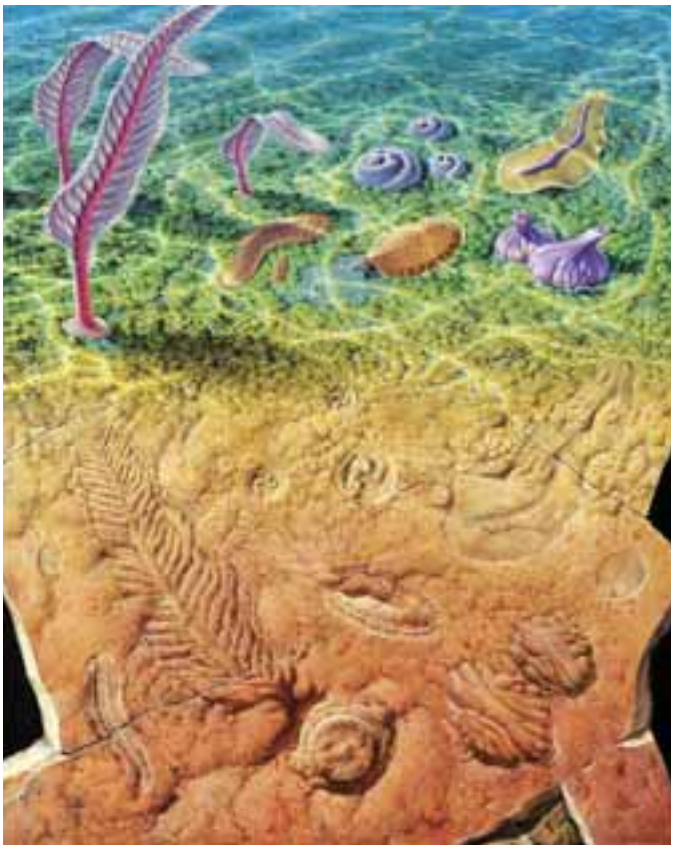

Figure 2. Ediacaran fossils and their reconstruction from the Neoproterozoic of South Australia (courtesy of the Australia Post). This image formed the basis for the stamp issue funded by the Australia Post.

Figure 3. *Pteridinium* fossils emplaced in the terrain of southern Namibia, where they were discovered in the Neoproterozoic Nama Group.

data involves scientists and the artist in transforming them into three-dimensional artistic depictions for scientific scrutiny. Having the artist work directly with researchers has been fundamental. The reconstructions that have resulted encompass paleo-ecological hypotheses and present novel species that can vary significantly from traditional interpretations.

An example illustrates my point. New fossils of tubular organisms, carbonaceous algal remains, abundant *Pteridinium,* and a new specimen of Rangea have been recovered from Namibia (Fig. 3). Trusler concurred that the new preservation styles of these fossils provided insight into understanding the enigmatic "Rangeomorphs." The fossil assemblage was preserved within a small paleochannel that was full of Rangea, close to the place they had lived. While my colleagues and I carefully mapped where the fossils came from, Trusler sketched rock sequences and fossils.

The data, along with our field notes and photographs as well as sketches of other taxa associated with the Rangea, made up the rest of our observations. Back in the lab, this material was examined along with the sketches and notes taken at other fossil sites around the world. Lengthy discussion with Trusler and my colleagues ensued, and this was complemented by more sketching as well as creation of clay models. The process was long and meticulous; however, the results, a final set of reconstructions of morphologies and settings, made the effort worthwhile.

The old saying "a picture is worth a thousand words" is not such a cliché; the use of art, and the involvement of an artist, Trusler in our case, has provided insights that words never will.

Manuscript received 29 October 2008; accepted 28 January 2009.

REFERENCES CITED

Eriksson, P.G., Altermann, W., Nelson, D.R., Mueller, W.U., and Cantuneanu, U., editors, 2004, The Precambrian Earth: Tempos and Events: New York, Elsevier, Developments in Precambrian Geology, v. 12, 966 p.

Fedonkin, M.A., Gehling, J.G., Grey, K., Narbonne, G.M., and Vickers-Rich, P., 2007, The Rise of Animals. Evolution and Diversification of the Kingdom Animalia: Baltimore, Johns Hopkins University Press, 327 p.

Schopf, J.W., and Klein, C., editors, 1992, The Proterozoic Biosphere—A Multidisciplinary Study: Cambridge, Cambridge University Press, 1383 p.

Valentine, J.W., 2004, On the Origin of Phyla: Chicago, University of Chicago Press, 614 p.

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The Department of Earth Science at Rice University has an opening for a postdoctoral researcher to work on the structure, mechanics, and deformation of large volcanic edifices on Earth and the terrestrial planets. A particular emphasis will be on data analysis and numerical modeling of Martian volcanoes. The candidate should have a recent Ph.D. in geophysics, geomechanics, or geology, and demonstrated expertise in one or more of the following areas: analysis of in-situ and/or remote sensing data (e.g., imagery, topography, gravity, geodesy, seismic), and numerical and/or analogue modeling of deformation and stress in large-scale geologic systems. Appointment is for one year, renewable for up to two additional years depending on performance and availability of funds. To apply, please submit a brief statement of research interests, curriculum vita including list of publications, and names of three references to Julia Morgan, Department of Earth Science, Rice University, 6100 Main Street, MS 126, Houston, TX 77005, USA; morganj@rice.edu.

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LECTURER POSITION MICHIGAN TECHNOLOGICAL UNIVERSITY

The Department of Geological and Mining Engineering and Sciences at Michigan Tech seeks applications for a 9-month (academic year) lecturer (non-tenure-track) position. A Ph.D. in geology or a related field is desirable, but applicants with M.S. degrees, particularly with significant professional experience, will also be considered. Candidates will be evaluated based on their potential for being effective teachers and student mentors. Teaching responsibilities are nominally 3 courses per semester for the academic year and some departmental service in support of the undergraduate programs, for example, assessment. Candidates should possess sufficient educational background and experience to teach our large-lecture course in physical geology. Those candidates with expertise in depositional systems, structural geology, geomorphology, and environmental geology are especially desirable. Teaching opportunities potentially exist for the summer semester. We also value candidates with expertise that would allow them to become involved in research and field activities.

Michigan Tech has a total student population of about 6,300 and is located in Michigan's Upper Peninsula, a pristine area on the south shore of Lake Superior. The department is committed to a strong educational focus and values basic and applied interdisciplinary research. Undergraduate and graduate programs are offered in Geology, Geological Engineering and Applied Geophysics. Interested candidates can learn more about the department programs, courses, and research and find contact information for faculty at www.geo.mtu.edu.

Only electronic applications will be accepted, preferably, as a single, complete PDF file that includes a cover letter outlining the applicant's interest in and qualifications for the position, a curriculum vitae, and teaching statement (philosophy and interests). A request for references will be made after the initial applicant screening. Applications should be e-mailed to geosearch@mtu.edu.

We intend to fill the position in time for the Fall 2009 semester. Applications received by 1 July 2009 will receive the fullest attention. Michigan Tech is an ADVANCE institution, one of a limited number of universities in receipt of NSF funds in support of our commitment to increase diversity and the participation and advancement of women in STEM. Michigan Tech is an equal opportunity educational institution/equal opportunity employer.

Opportunities for Students

Teaching Assistantship (Geomorphology) for M.S. or Ph.D. Student, University of North Dakota. Teaching Assistantship (Geomorphology) for M.S. or Ph.D. student starting Fall 2009. New projects starting in landscape evolution and surface processes involving LIDAR and cosmogenic isotope analysis. For more information contact Jaakko Putkonen, Jaakko.putkonen@und.edu. More info on the department at www.geology.und.edu/. Preference given to early applicants. To apply, go to www.graduateschool.und.edu/html/admissionshome.html.

Ph.D. opportunity at Dept. of Earth Sciences, ETH Zurich, Switzerland. We are inviting applications for a Ph.D. position in numerical modeling of magmatic processes, namely the emplacement of intrusions and the relations between magma convection and volatile release relevant to ore deposit formation. The position is funded for three years and involves multidisciplinary interaction with geophysical, geochemical, and petrological groups at ETH.

Details are available at http://www.igmr.ethz.ch/research/fluids/PhD2009.

For questions and applications, please contact Dr. Thomas Driesner at thomas.driesner@erdw.ethz.ch.

The Kerry Kelts Research Awards of the Limnogeology Division

Application Deadline: 3 August 2009

GSA's Limnogeology Division's Kerry Kelts Research Awards for undergraduate or graduate student research offers up to three awards of US$400 each for use in research related to limnogeology, limnology, and paleolimnology.

To apply: Send a summary of the proposed research, its significance, and how the award will be used (in PDF format; five-page max.) along with your name and a short CV (two-page max.) to Michael Rosen, chair of the Limnogeology Division, mrosen@usgs.gov. Awards will be announced at the Limnogeology Division Business Meeting and Reception at the October 2009 GSA Annual Meeting in Portland, Oregon, USA.

If you are interested in supporting this awards program, please send your donations, designated for the Kerry Kelts Research Awards of the Limnogeology Division, to GSA, P.O. Box 9140, Boulder, CO 80301-9140, USA.

GSA International Ambassador Program

GSA has launched an International Ambassador Program and seeks help from members traveling outside of North America to geoscience meetings where GSA is not represented. As GSA International Ambassadors, members will promote GSA programs, meetings, membership, and the new International Section during international conferences.

GSA leadership invites members to fulfill this important role in expanding the global recognition of GSA. A resource packet of information will be provided that includes program flyers, sample publications, membership forms, a GSA PowerPoint presentation, and International Section information. If you are interested in serving as a GSA International Ambassador, or if you have questions, please contact Wesley Hill, +1-303-357-1005, whill@geosociety.org.

Coming to *GSA Today* in July

- **Science article:** "The impact of snowmelt on the late Cenozoic landscape of the southern Rocky Mountains, USA," by Jon D. Pelletier
- GSA's 2009 Medal and Award Recipients
- GSA Division Awards
- New GSA Fellows
- 2009 Research Grant Recipients

GSA Today articles from 1995 on are open access via link at **www.geosociety.org/pubs/.**

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New Zealand
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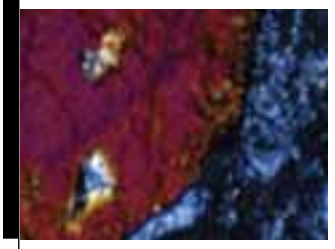

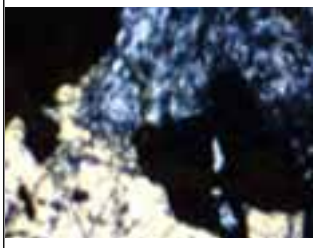

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