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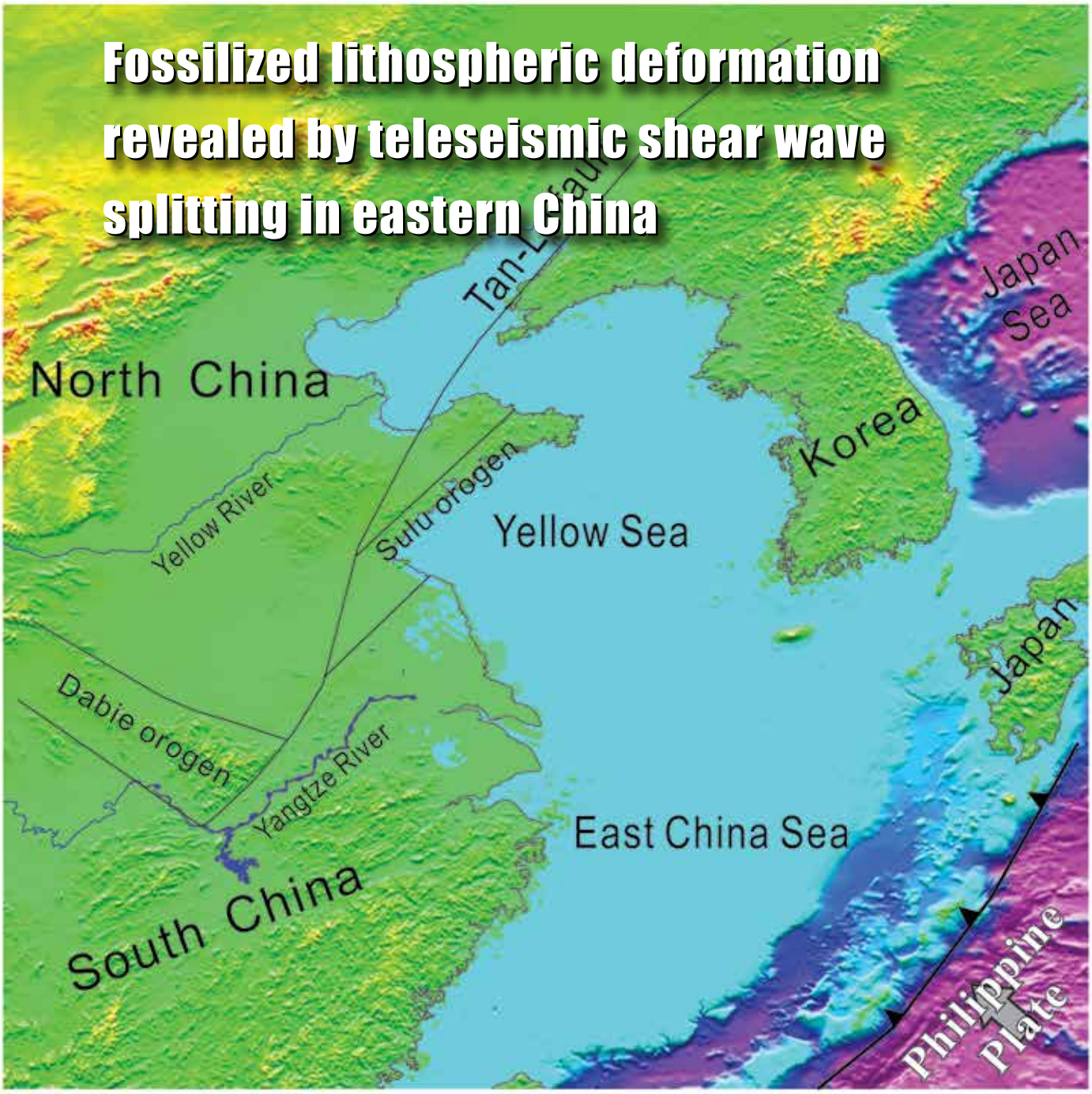
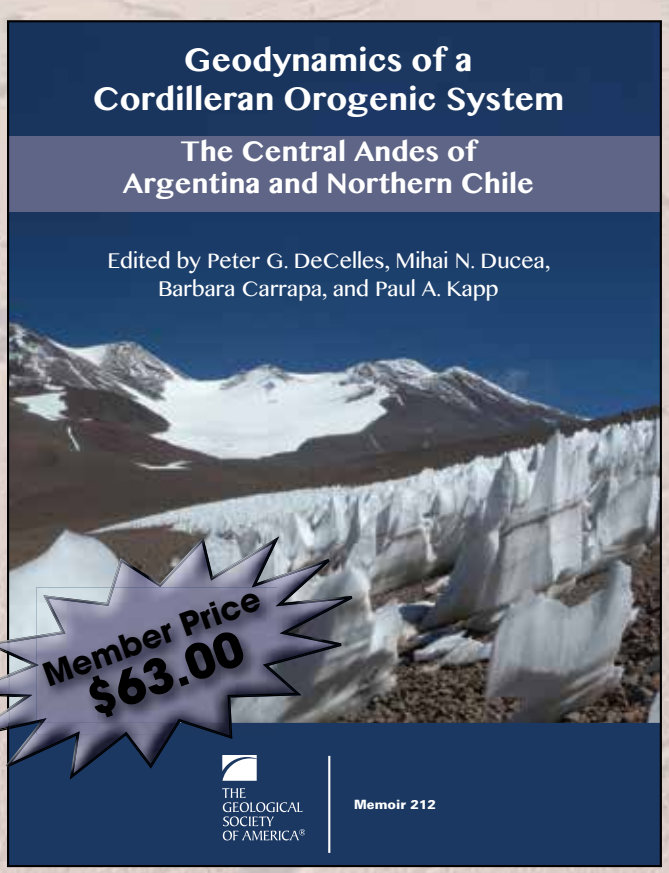


Geodynamics of a Cordilleran Orogenic System

The Central Andes of Argentina and Northern Chile

Edited by
Peter G. DeCelles, Mihai N. Ducea, Barbara Carrapa, and Paul A. Kapp



This memoir brings together results from a six-year, multidisciplinary study of the linkages among processes that have formed the highest, widest part of the Andean Cordilleran orogenic belt in northern Argentina and Chile. The region features a tectonically erosive forearc, protracted arc magmatism, a high-elevation hinterland plateau and strongly shortened retroarc thrust belt, and a Paleocene–Recent foreland basin system. Surface geology records spatially complex shortening, extension, mafic to felsic magmatism, hinterland basin development, elevation change, and regional foreland basin migration. Seismological and geodynamic studies demonstrate a complex, dynamic upper mantle marked by widespread foundering of dense lithosphere formed by magmatic and metamorphic processes beneath the hinterland. Diverse processes operating over the past 60 m.y. in the central Andes define a tectono-magmatic cycle with a periodicity of ca. 25–30 m.y., providing a new framework for interpreting Cordilleran orogenic systems worldwide.

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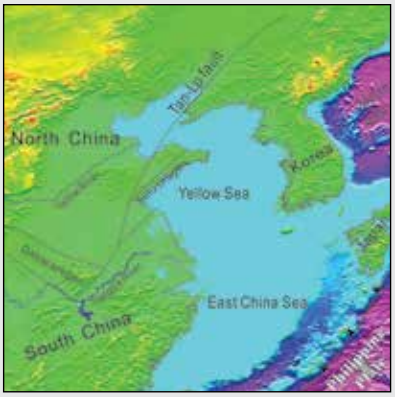
Xiaobo Tian and M. Santosh



Cover: Color-shaded relief map with simplified tectonic units of eastern Asia. Since the Late Cretaceous, lithosphere extension was induced by the subduction of the western Pacific or Philippine plate. The Dabie and Sulu orogens contain the largest ultrahigh-pressure metamorphic belt in the world as a result of the convergence between the North and South China blocks during the Late Paleozoic–Triassic. See related article, p. 4–10.

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Fossilized lithospheric deformation revealed by teleseismic shear wave splitting in eastern China

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ABSTRACT

Global mantle convection significantly impacts the processes at Earth's surface and has been used to gain insights on plate driving forces, lithospheric deformation, and the thermal and compositional structure of the mantle. Upper-mantle seismic anisotropy has been widely employed to study both present and past deformation processes at lithospheric and asthenospheric depths. The eastern China region was affected by extreme mantle perturbation and crust-mantle interaction during the Mesozoic, leading to large-scale destruction of the cratonic lithosphere, accompanied by widespread magmatism and metallogeny. Here we use teleseismic shear wave splitting measurements to evaluate the lithosphere and upper mantle deformation beneath this region. Our results from some of the individual and station averages show WNW-ESE- to NW-SE–trending fast polarization direction, similar to those observed in eastern Asia in some previous studies, consistent with the direction of Pacific plate subduction during the Cenozoic. This feature suggests that the asthenospheric flow beneath the eastern China region is influenced by the subduction of the western Pacific or Philippine plate. However, most of our data show E-W- or ENE-WSW–trending fast polarization direction, which is inconsistent with subduction from the east. The seismic stations in this study are located near the Qinling-Dabie-Sulu orogenic belt, which formed through the collision between the North and South China blocks during the Late Paleozoic–Triassic, and the anisotropy with an E-W- or ENE-WSW–trending fast polarization direction parallel to the southern edge of the North China block suggests lithospheric compressional deformation due to the collision between the North and South China blocks. Although the deep root of the craton was largely destroyed by cratonic reactivation in the late Mesozoic, our results suggest that the "fossilized" anisotropic signature is still preserved in the remnant lithosphere beneath eastern China.

INTRODUCTION

The dynamics of Earth's interior, particularly global mantle convection, significantly impact the processes at Earth's surface. Understanding the global-scale velocity field associated with convection in Earth's mantle is important to constrain plate driving forces, lithospheric deformation, and the thermal and compositional structure of the mantle (e.g., Hager and O'Connell, 1981; Bull et al., 2010; Flament et al., 2014). Seismic anisotropy has been widely employed to gain insights on regional mantle flow patterns and mantle dynamics (e.g., Silver, 1996; Savage, 1999; Long and Becker, 2010; Díaz and Gallart, 2014). When a shear wave propagates through an anisotropic region of the upper mantle, it undergoes shear wave splitting and the quasi-shear wave polarizations, and the delay time between them can be used to constrain the geometry of mantle deformation. Anisotropy describes a medium that has a different elastic property when measured in different directions. Seismic waves in an anisotropic medium travel at different velocities depending both on their propagation and polarization (vibration) directions. The existence of seismic anisotropy indicates an ordered medium. In the middle to lower crust and the upper mantle, the order is produced primarily by the lattice preferred orientation (LPO) of anisotropic minerals in response to finite strain. In the middle to lower crust, the preferred orientations of biotite and amphibole are expected to be the major cause of seismic anisotropy (Barruol and Mainprice, 1993). The seismic anisotropy in upper mantle rocks is attributed mainly to the LPO of olivine (e.g., Silver, 1996), which is the most abundant and deformable mineral in the upper mantle. Seismic anisotropy is a powerful tool for imaging the style and geometry of crust and mantle deformation. For example, olivine LPO can be produced by ongoing deformation and flow of the asthenospheric mantle (Kaminski et al., 2004). However, anisotropy in the lithosphere is also generated from past and present deformational events. It has been demonstrated that earlier orogenic processes can imprint the lithosphere with a crystallographic fabric that remains stable and frozen, even after thermal relaxation, for as long as 2.5–2.7 b.y. (Silver and Chan, 1988). For mapping the seismic anisotropy of the upper mantle at a horizontal scale of several hundreds of kilometers, surface waves are effectively employed; at shorter length scales of a few tens of kilometers, seismic anisotropy can be measured through the splitting of teleseismic core-shear waves (e.g., Savage, 1999).

Eastern China includes the eastern parts of the North China block (NCB) and South China block (SCB), which constitute two of the major continental blocks of the Eurasian continent (Fig. 1). The Triassic collision between these two blocks generated the Qinling-Dabie-Sulu orogenic belt and associated ultra-high

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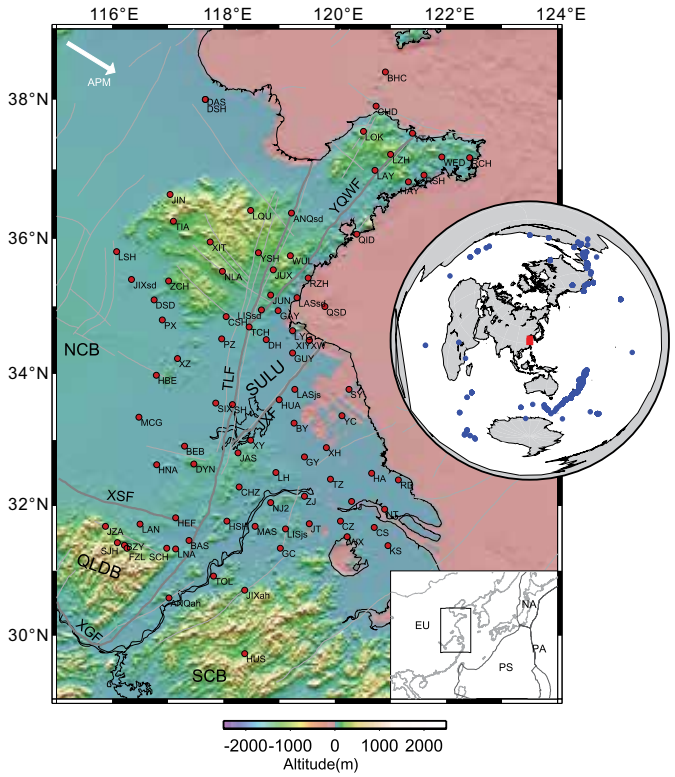

Figure 1. Topography of eastern China and the distribution of seismic stations (red points). Gray lines represent the boundaries between tectonic units or major faults; the large white arrow indicates the absolute plate motion (APM) of the Eurasian plate (Gripp and Gordon, 2002). Blue dots in inset show the spatial distribution of earthquakes used in this study. EU—Eurasian plate; JXF—Jiashan-Xianshui fault; NA—North American plate; NCB—North China block; PA—Pacific plate; PS—Philippine Sea plate; QLDB—Qinling-Dabie orogenic belts; SCB—South China block; SULU—Sulu orogenic belt; TLF—Tan-Lu fault; XGF—Xiangfan-Guangji fault; XSF—Xinyang-Shucheng fault; YQWF—Yintai-Qingdao-Wulian fault. All other abbreviations are station names.

pressure (UHP) metamorphic rocks (Guo et al., 2012; Yin and Nie, 1993). The eastward extension of the orogenic belt is thought to have been offset sinistrally several hundred kilometers by the Tan-Lu fault following the collision (e.g., Li, 1994). Some workers believe the collision first occurred in the east during the Early Triassic and propagated westward (e.g., Guo et al., 2012). However, the direction of convergence and the location of the suture remain ambiguous (e.g., Faure et al., 2001) because of the irregular shape of the northern edge of the SCB and the offset along the Tan-Lu fault (Yin and Nie, 1993). In the east, a north-south direction of convergence has been suggested based on linear aeromagnetic anomalies (Li, 1994). Whether this direction of convergence occurred on a lithospheric scale or not needs to be evaluated geophysically.

Following convergence between the SCB and NCB, extensive cratonic reactivation affected the eastern NCB during the late Mesozoic, and the thick cratonic lithosphere in this region lost a significant proportion of its deep mantle keel (e.g., Griffin et al., 1998). From the Late Mesozoic through the Cenozoic, deformation of the eastern Asian continent was dominated by extensional tectonics leading to the formation of several rift systems (Yin, 2010). The Pacific plate began to subduct along the eastern margin of the Asian continent at 180 Ma (Maruyama et al., 1997). The lithospheric deformation in eastern China caused by the convergence between the SCB and NCB was probably modified during these subsequent tectonic events.

In this study, we present shear wave splitting observations using data sets from eastern China and explore the "frozen" LPO that may be associated with the convergence between the SCB and NCB.

DATA, METHODS, AND RESULTS

We use teleseismic shear wave (including SKS, SKKS, and PKS) splitting measurements to evaluate the lithosphere and upper mantle deformation beneath this region. The broadband seismic data used in this study were recorded during August 2007 to April 2013 employing 75 permanent stations in the eastern China. These stations are widely distributed in the southeastern part of the NCB and the northeastern part of the SCB. Station locations are shown in Figure 1 and are listed in Table S1 (see the GSA Supplemental Data Repository[1]). In order to observe distinct, high signal-to-noise ratio shear wave phases, we systematically selected seismic events with magnitudes (M_W) larger than 5.3 occurring at epicentral distances of 85°–120° and 120°–150° for SKS and PKS phases, respectively. In these epicentral distances, the SKS or PKS phase are both well isolated from other shear-waves and are sufficiently energetic. We obtained 215 events that fit these criteria. All the events are shown in Figure 1 and listed in Table S2 (see footnote 1).

We used the measurement method of Tian et al. (2011) to extract (1) the difference in arrival times (or delay time, δt) between the fast and slow shear waves, which is a function of the thickness and intrinsic anisotropy of the anisotropic medium; and (2) the orientation of the polarization planes of the fast shear wave (or the fast polarization direction, ϕ), which reflects the orientation of the structure. The details of splitting measurement are provided in the supplemental appendix (see footnote 1).

We obtained a total of 1326 pairs of good splitting parameters ϕ (fast polarization direction) and δt (delay time). Figure 2A presents the whole set of individual splitting measurements plotted at each respective station. The station averages computed from the individual measurements are plotted in Figure 2B and listed in Table S1 (see footnote 1). At stations CSH, ANQsd and NLA, we obtained a large number of measurements (56, 44, and 37, respectively) and large back-azimuth variations. These back-azimuth variations of the splitting parameters are clearly not random but rather are well organized. Such back-azimuth variations have been suggested to result from the presence of two anisotropic layers (Silver and Savage, 1994). Following the scheme proposed by these authors, we tried to constrain the possible geometries of these anisotropic layers beneath the three stations. The best fitting models are plotted in Figure 3 and listed in Table S3 (see footnote 1).

[1]GSA supplemental data item 2015006, detailed methods, data tables, and supplementary figures, is online at www.geosociety.org/pubs/ft2015.htm. You can also request a copy from GSA Today, P.O. Box 9140, Boulder, CO 80301-9140, USA; gsatoday@geosociety.org.

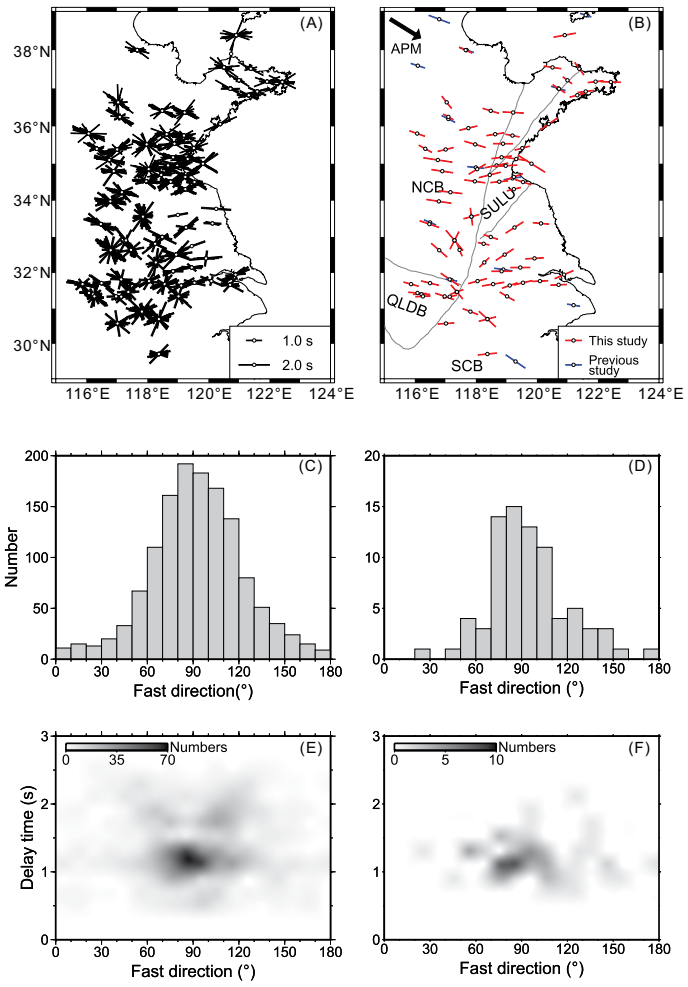

Figure 2. (A) Individual splitting measurements plotted at each station. The orientation and length of the bars correspond to the fast direction and delay time, respectively. (B) Anisotropy map of eastern China presenting the averaged splitting measurements (red bars). Previous results are plotted in blue. APM—absolute plate motion; NCB—North China block; QLDB—Qinling-Dabie orogenic belts; SCB—South China block; SULU—Sulu orogenic belt. (C) and (D) are the histograms of the fast direction for individual and station average, respectively. (E) and (F) show the splitting parameters distribution for individual and station average, respectively.

DISCUSSION

In our individual measurements (see Figs. 2A, 2C, and 2E), most results were characterized by E-W–trending fast polarization direction and delay times of 1.2 s. In addition, some measurements show ENE-WSW- or NW-SE–trending fast polarization directions. Similar features can also be found in station average values (see Figs. 2B, 2D, and 2F), with most averages having ENE-WSW- to E-W (N070°E to N110°E) trending fast polarization direction and delay times of 1.0 s. However, some averages show a NW-SE (N110°E to N150°E) trending fast polarization direction.

Previous studies (Chang et al., 2009; Zhao et al., 2007; Zhao et al., 2013; Zhao and Xue, 2010) have shown a WNW-ESE- to NW-SE–trending fast polarization direction at most stations in the eastern part of China. Based on the wide distribution of the WNW-ESE orientation in the eastern part of China and its coincidence with absolute plate motion (APM), which is assumed to be coupled with the underlying asthenosphere, these studies suggest that the WNW-ESE to NW-SE fast direction anisotropy is produced by the motion of asthenospheric flow.

In our results, some individual values and station averages show such a fast polarization direction, and two-layer model fitting also suggests a lower layer with a N120°E- to N130°E–trending fast polarization direction, which is parallel to the direction of Pacific plate subduction (Fig. 2B) calculated from HS3-Nuvel1A (Gripp and Gordon, 2002). We interpret this fast direction as the asthenospheric flow induced by the subduction of the western Pacific or Philippine plates (see Fig. 4B). Global and regional seismic tomography shows that the subducting western Pacific slab becomes stagnant in the mantle transition zone under eastern China and that there are extensive low-velocity anomalies in the upper mantle (Huang and Zhao, 2006). Mantle convection beneath the overriding plate may be induced by deep slab dehydration (Zhao et al., 2007). Both the low velocity and thinness of the lithosphere imply a hot mantle beneath eastern China (Zhao et al., 2007). The development of LPO becomes much easier under the shear flow in the upper mantle when the viscosity is reduced by high temperature (Karato et al., 2008). Several teleseismic shear wave splitting studies have shown a NW-SE–trending fast polarization direction at many stations in eastern China and have suggested that this feature is caused by the subducting Pacific or Philippine slab-induced flow (Liu et al., 2008).

The ENE-WSW- to E-W–trending fast polarization direction anisotropy in our study region has been noted at several stations in previous studies (Chang et al., 2009; Zhao et al., 2007). This study, based on dense stations and 5–6 years of data, shows this fast direction to be characteristic of most individual measurements and station average values. Two-layer model fitting in this study also suggests that the upper layer is characterized by an ENE-WSW- to E-W–trending fast polarization direction. This direction differs from the direction of plate motion and asthenospheric flow and is considered to have been generated by lithospheric deformation. From the late Mesozoic through the Cenozoic, deformation of the eastern Asian continent was dominated by WNW-ESE–trending extensional tectonics leading to the formation of Cenozoic intracontinental basins (Yin, 2010). We therefore propose that the ENE-WSW- to E-W–trending fast polarization direction represents a "fossilized" anisotropic signature preserved in the lithosphere beneath eastern China.

Continental shortening and thickening accompany the compressional tectonics associated with the convergence between continents. The vertically coherent deformation between crust and lithospheric mantle has been observed in active tectonic regions (Silver, 1996). It is well established that upper mantle minerals, especially olivine, are highly anisotropic and develop LPO in response to finite strain, where the fast direction is predominantly parallel to the strike of the orogenic belt. This has been documented from modern orogenic belts including the Zagros and Caucasus Mountains and the Alps (Silver, 1996). In ancient orogens, the anisotropic signature of deformation can remain "fossilized" in the lithospheric mantle in cases where subsequent intense deformation has not erased this record (Silver and Chan, 1991).

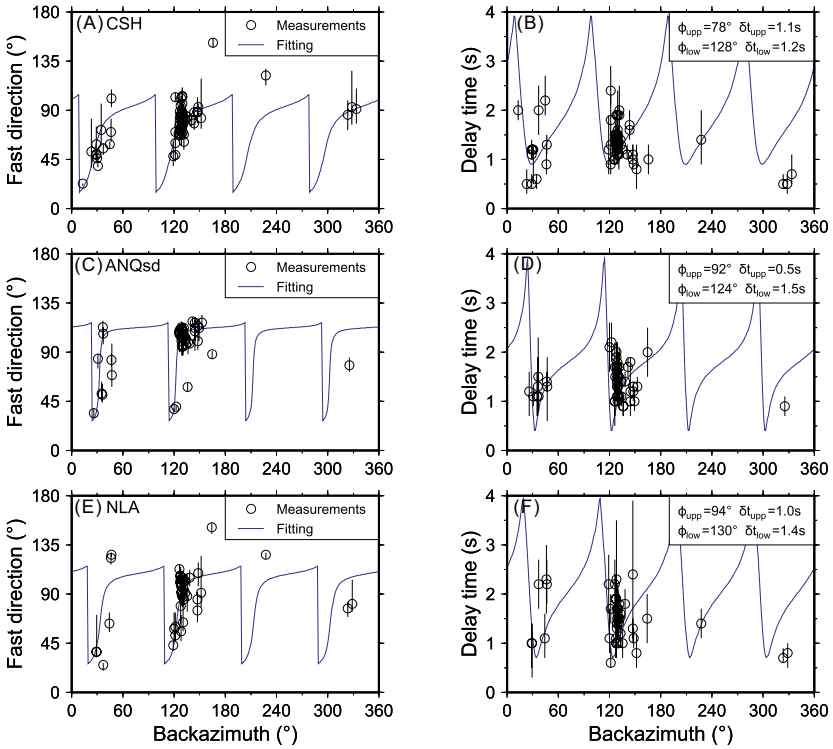

Figure 3. Two-layer anisotropy fitting. Left and right maps show apparent variations of the observed fast direction and delay time (black circle with error bar) as a function of the back-azimuth of the incoming wave, respectively. The best fitting two layer model is shown as blue line. (A) and (B) Station CSH; (C) and (D) Station ANQsd; (E) and (F) Station NLA.

Subduction of the western Pacific oceanic plate (including the Izanagi plate) under eastern China could explain the "fossilized" anisotropy in the continental lithosphere. Subduction of the western Pacific plate had started by 180 Ma (Maruyama et al., 1997). If the western Pacific plate subducted as a flat-slab in a north or north-northwest direction under eastern Asia in the Mesozoic, the overlying continental lithosphere might be expected to have undergone north-south contraction. If so, an ENE-WSW- to E-W–trending fast polarization direction anisotropy could have been produced in the deforming lithosphere. However, neither northward flat-slab subduction nor north-south contractional deformation induced by the flat-slab subduction has received support from other studies in eastern China. On the other hand, if the western Pacific plate subducted at a steep angle in a west or east-northeast direction in the Mesozoic, the asthenospheric flow resulting from slab retreat would also produce an ENE-WSW to E-W fast direction anisotropy. After cooling, the fast direction anisotropy could be preserved in the lower part of the lithosphere. However, in our study region, the lithosphere is only 70–80 km thick (Chen, 2010) and does not adequately explain the 1.0 s delay times in the lower part of the lithosphere.

It is apparent that the crust overlying the lithospheric mantle lid, which is ~30 km thick in the study area (Xu et al., 2014), has a significant effect on the observed total delay time, possibly arising from the LPO in the middle to lower crust. Foliation planes within the crust are usually horizontal, and the splitting of the teleseismic shear wave with vertical propagation is expected to be small. However, dipping foliation planes in the middle to lower crust can be created in convergent plate margins (Barruol and Mainprice, 1993). Some studies (Okaya et al., 1995; Savage et al., 1996) have indicated that an ~10 km thickness of schistose rocks

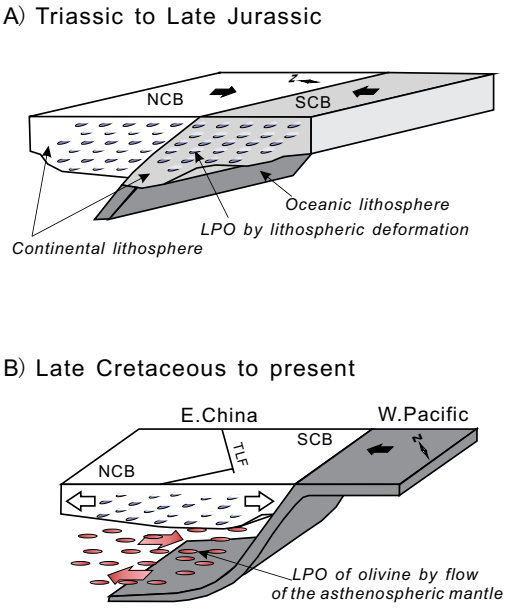

Figure 4. Cartoons illustrating a possible scenario for the origin of anisotropic layering beneath eastern China. (A) Pervasive deformation occurred in the lithosphere during the collision between the South China block (SCB) and North China block (NCB) from the Triassic to Late Jurassic. In response to the NNW-SSE convergence, the lithosphere was thickening and developing lattice preferred orientation (LPO; shown as blue fusiform), the fast direction is predominantly parallel to the strike of collision belt. The thickened and anisotropic lithosphere was destroyed during the late Mesozoic, and only the shallow part of the anisotropic lithosphere survived. (B) Since the Late Cretaceous, lithosphere extension and asthenospheric flow were induced by the Pacific plate subduction beneath eastern China. The LPO of olivine (shown as red fusiform) developed in the asthenospheric flow and trends NW-SE, parallel to the direction of the subduction. TLF—Tan-Lu fault.

with near-vertical foliation planes would be adequate to cause splitting of up to 1.0 s. On the other hand, based on relations between delay time δt, anisotropy magnitude A, and length of the anisotropic path L,

$$A = (\delta t^* V_s)/L$$

(Bonnin et al., 2010), where V_s is velocity of shear wave considered (here SKS), a 70–80-km-thick lithosphere with anisotropy magnitude $A = 0.05$ would produce a delay time of 1.0 s. The continent-continent collision between the North and South China blocks, one of the most important tectonic events in the Asian continent during the Mesozoic, is the potential process that produced the ENE-WSW- to E-W–trending fast polarization direction anisotropy on a whole lithosphere scale. The N-S–directed collision and crustal shortening have been reported in previous studies. Closure of the ocean between the NCB and SCB has been suggested to have occurred through subduction with northward polarity (e.g., Hsu et al., 1987). The lithofacies distribution along the southern margin of the NCB and northern margin of the SCB is consistent with the interpretation (Yin and Nie, 1993) that the southern edge of the NCB was originally a smooth, E-W–trending boundary prior to the collision, whereas the SCB had an irregular geometry with its eastern part extending some 500 km farther to the north than its western counterpart. Based on the study of regional geologic setting, Yin and Nie (1993) considered the left-lateral Tan-Lu strike-slip fault in China and the right-lateral Honam strike-slip fault in Korea to be transform faults that accommodated the northward indentation of the SCB. Triassic to Early Jurassic deformation is widespread in the NCB north of the Sulu belt, probably related to the continent-continent collision. In the northeastern NCB, E-W- to ENE-WSW–trending thrusts and folds involving Permian strata are unconformably overlain by Jurassic strata (Geologic Map of Liaoning Province, 1989), suggesting Triassic crustal shortening in a north-south direction. Triassic to Early Jurassic deformation during the Indosinian orogeny is widespread in Korea. In particular, E-W- to ENE-WSW–trending thrusts and folds developed along and north of the Imjingang belt (Um and Chun, 1984). The suture between the blocks in the region east of the Tan-Lu fault trends E-W or ENE-WSW, as inferred from the analysis of aeromagnetic anomalies (Li, 1994), and extends to the Imjingang belt in the central part of the Korean Peninsula (Yin and Nie, 1993).

As illustrated in Figure 4A, we suggest that the E-W- to ENE-WSW–trending fast polarization direction represents "frozen" anisotropy in the lithosphere produced by the collision between the NCB and SCB during the Late Paleozoic or Triassic. Thus, the convergence of the two blocks in the east is inferred to have been in a NNW-SSE direction. Subsequently, lithosphere shortening induced an LPO with an E-W or ENE-WSW orientation. This proposal is supported by the ENE-WSW fast direction reported from South Korea (Kang and Shin, 2009). During the late Mesozoic, the lithosphere of the eastern NCB lost a significant proportion of its deep mantle keel through cratonic erosion and reactivation (e.g., Griffin et al., 1998; Santosh, 2010; Guo et al., 2013). The thinning of the lithosphere may extend southward into Dabie and Sulu, as well as the northern part of SCB, as inferred from the thin lithosphere in these regions as imaged by seismic studies (Chen, 2010). Although a substantial part of the deep cratonic root has been removed, our results suggest that the "fossilized" anisotropic signature is still preserved in the remnant lithosphere beneath eastern China (Fig. 4B).

Recent studies indicate that the cratonic lithosphere in some regions on the globe has been extensively destroyed or reactivated, resulting in loss or modification of the refractory lithospheric "root." Examples include the North China Craton in East Asia, the southwestern part of the Kaapvaal Craton in South Africa, the Wyoming Craton in North America, and the Brazilian Craton in South America, among which the eastern part of the North China Craton is considered to be one of the best examples for wholesale destruction of cratonic root (Zhang et al., 2013). Following cratonization in the late Paleoproterozoic, the interior part of the North China Craton remained largely quiescent until the Mesozoic when extensive reactivation, erosion of the cratonic keel, and differential destruction of the lithosphere occurred (Zhai and Santosh, 2011, 2013). The craton was in a "superconvergent regime" (Li et al., 2013), caught up among the southward indentation of the Siberian block following the closure of the Mongol-Okhotsk Ocean, the collision between the North and South China Blocks, and the oblique subduction of the paleo-Pacific plate from the east. Our study demonstrates that despite the extensive erosion and destruction of the cratonic root beneath eastern China, a "fossilized" anisotropic signature is preserved in the lithosphere, and this has important bearing on understanding the stability and destruction of ancient cratons.

CONCLUSIONS

Because seismic waves effectively propagate and interact with the internal structure of lithosphere, they provide high-resolution data for studying the structure of the crust and upper mantle, as well as to constrain the geodynamic processes. Similar to the reconstruction of the tectonic evolution of a region based on rock records by geologists, seismologists try to understand the ancient dynamic processes by exploring the structure and rock fabric in the crust and upper mantle, which are not reset during later tectonic events. In eastern China, the collision between the NCB and SCB resulted in lithospheric compressional deformation and constructed the Qinling-Dabie-Sulu orogenic belt during the Late Paleozoic to Triassic. During the late Mesozoic, extensive cratonic reactivation and dramatic lithospheric thinning affected the eastern NCB. From the late Mesozoic through the Cenozoic, deformation of the eastern Asian continent was dominated by extensional tectonics associated with the Pacific plate subduction along the eastern margin of Asia. Whether the deformed lithosphere induced by the convergence between the SCB and NCB was destroyed or reset by these subsequent tectonic events is a topic of wide interest.

In this study, we performed teleseismic shear wave splitting measurements to investigate lithosphere and upper mantle deformation beneath eastern China. Our results show a dominant E-W or ENE-WSW fast direction and a delay time of 1.0 s. Some individual measurements, as well as the station averages, are characterized by a WNW-ESE to NW-SE fast direction. Based on fitting the fast directions and delay times as a function of the back azimuth, the two-layer anisotropic models at three stations show similar features. The fast direction of the upper layer is ENE-WSW or E-W, whereas the lower layer shows a

NW-SE fast direction. The delay times of the upper layer show a large variation from 0.5 s to 1.1 s between the three stations, whereas the delay times of the lower layer show a limited range from 1.2 s to 1.5 s.

We interpret the WNW-ESE to NW-SE fast direction, which is parallel to the direction of Pacific plate subduction, as the asthenospheric flow induced by the subduction of western Pacific or Philippine plates. The E-W to ENE-WSW fast direction was probably produced by lithospheric deformation accompanying the collision between the North and South China blocks in the Late Paleozoic or Triassic. Our results suggest the preservation of a "fossilized" anisotropic signature in the lithosphere beneath eastern China, in spite of the extensive erosion and destruction of the cratonic root during the late Mesozoic.

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CALL FOR NOMINATIONS

GSA DIVISION AWARDS

COAL GEOLOGY

Gilbert H. Cady Award

Nominations due 28 Feb. 2015
Submit nominations to Mark Engle at mercurous@gmail.com.

This award, first presented in 1973, recognizes outstanding contributions in the field of coal geology that advance the science both within and outside of North America. For more information, go to www.uky.edu/KGS/coal/GSA/awards.htm.

ENVIRONMENTAL AND ENGINEERING GEOLOGY

Richard H. Jahns Distinguished Lecturer

Nominations due 28 Feb. 2015
Submit nominations to Matt Crawford at mcrawford@uky.edu.

This lectureship was established in 1988 by the Division in conjunction with the Assoc. of Environmental & Engineering Geologists to commemorate Jahns and to promote student awareness of engineering geology through an annual series of lectures at academic institutions. The award is given to an individual who through research or practice has made outstanding contributions to the advancement of environmental and/or engineering geology. The awardee will speak on topics of earth processes and the consequences of human interaction with these processes or the application of geology to environmental and/or engineering works. Award funds are administered by the GSA Foundation. For more information, go to http://rock.geosociety.org/egd/Awards.html#Jahns.

GEOPHYSICS

George P. Woollard Award

Nominations due 15 Feb. 2015
Submit nominations via e-mail attachment to Samantha Hansen at shansen@geo.ua.edu.

This award recognizes outstanding contributions to geology through the application of the principles and techniques of geophysics. A highlight of the presentation is the honorary George P. Woollard Technical Lecture by the recipient before the award ceremony. To submit a nomination, all you need is a name, contact information, and a short summary of the nominee's qualifications, including his or her specific work or outcomes and how these have contributed to geology. The nominee's CV is helpful but not required. Award funds are administered by the GSA Foundation. For more information, go to www.geosociety.org/divisions/geop/Awards.htm.

GEOSCIENCE EDUCATION

Biggs Award for Excellence in Earth Science Teaching

Nominations due 15 Feb. 2015
Submit nominations at http://community.geosociety.org/gedivision/news/awards/biggsaward. Any questions should be directed to geoedgsa@gmail.com.

This award recognizes innovative and effective teaching in college-level earth science. Earth-science instructors and faculty members from any academic institution engaged in undergraduate education who have been teaching full-time for 10 years or fewer are eligible (part-time teaching is not counted in this requirement). Both peer- and self-nominations will be accepted.

This award, administered by the GSA Foundation, is made possible by support from the Donald and Carolyn Biggs Fund, the GSA Geoscience Education Division, and GSA's Education and Outreach Program. An additional travel reimbursement is also available to the recipient to enable him or her to attend the award presentation at the GSA Annual Meeting. For more information, go to http://community.geosociety.org/gedivision/news/awards/biggsaward.

HISTORY AND PHILOSOPHY OF GEOLOGY

History and Philosophy of Geology Student Award

Nominations due 15 June 2015
Submit nominations to Kathleen Lohff at kathylohff.msn.com.

This award, in the amount of US$1,000, recognizes excellence in a student paper to be given at GSA's Annual Meeting. An award may also be given for second place. The award is made possible by a bequest from the estate of Mary C. Rabbitt. Oral presentations are preferred. Faculty advisors may be listed as second author but not as the lead author of the paper. The proposed paper may be (1) on the history or philosophy of geology; (2) a literature review of ideas for a technical work or thesis/dissertation; or (3) some imaginative aspect of the history or philosophy of geology we have not thought of before. Students should submit an abstract of their proposed talk and a 1,500–2,000-word prospectus for consideration.

Currently enrolled undergraduates and graduate students are eligible as are students who received their degrees at the end of the fall and spring terms immediately preceding the national GSA meeting. The award is open to all students regardless of discipline, provided the proposed paper is related to the history or philosophy of a geological idea/person. For more information, go to www.gsahist.org/hapg_award/awards.htm.

MINERALOGY, GEOCHEMISTRY, PETROLOGY, AND VOLCANOLOGY (MGPV)

Nominations due 15 July 2015
Submit nominations to J. Alex Speer, Mineralogical Society of America, 3635 Concorde Pkwy, Ste 500, Chantilly, VA 20151-1110, USA; jaspeer@minsocam.org.

MGPV awards emphasize achievements in geologic and multidisciplinary approaches. Geologic work is by nature generalistic and has an important field component, with Earth as the natural laboratory. For either award outlined below, please submit (1) a cover letter from an MGPV Division member, no longer than three pages, summarizing the nominee's most important accomplishments in geologic approaches to mineralogy, geochemistry, petrology, and/or volcanology, with special attention paid to describing how the nominee's published work demonstrates field-based multidisciplinary geologic accomplishments of a groundbreaking nature. The letter should include the name, address, and contact information of nominator as well as from whom letters of support can be expected; (2) the nominee's CV; and (3) three letters

of support. Nominees need not be citizens or residents of the United States, and membership in GSA is not a requirement. The awards will not be given posthumously. For more information, go to www.geosociety.org/divisions/mgpv/awards.htm.

MGPV Distinguished Geologic Career Award

This award goes to an individual who, throughout his or her career, has made distinguished contributions in one or more of the following fields of research: mineralogy, geochemistry, petrology, volcanology, with emphasis on multidisciplinary, field-based contributions.

MGPV Early Career Award

The MGPV award will go to an individual near the beginning of his or her professional career who has made distinguished contributions in one or more of the following fields of research: mineralogy, geochemistry, petrology, volcanology, with emphasis on multidisciplinary, field-based contributions. Nominations are restricted to those who are within eight years past the award of their final degree. For example, awards decided before 31 Dec. 2014 included all candidates whose final degree was awarded no earlier than 1 Jan. 2007. Extensions of up to two years will be made for nominees who have taken career breaks for family reasons or because of serious illness.

QUATERNARY GEOLOGY AND GEOMORPHOLOGY

Farouk El-Baz Award for Desert Research

Nominations due 1 Apr. 2015
Submit nominations to Anne Chin at anne.chin@ucdenver.edu.

This award is intended to stimulate research in desert environments by recognizing an individual whose research has significantly advanced the understanding of the Quaternary geology and geomorphology of deserts worldwide. Although the award primarily recognizes achievement in desert research, the funds that accompany it may be used for further research. The award is normally given to one person but may be shared by two people if the recognized research was the result of a coequal partnership. Any scientist from any country may be nominated, but self-nomination is not permitted. Neither nominators nor nominees need be GSA Members. Monies for the award are derived from the annual interest income of the Farouk El-Baz Fund, administered by the GSA Foundation.

Nomination materials should include (1) a statement of the significance of the nominee's research; (2) a CV; (3) letters of support; and (4) copies of no more than five of the nominee's most significant publications related to desert research.

Distinguished Career Award

Nominations due 1 Apr. 2015
Submit nominations to Sarah Lewis at sarah.lewis@oregonstate.edu.

This award recognizes a Quaternary geologist or geomorphologist who has demonstrated excellence in his or her contributions to science. Neither nominators nor nominees need be GSA Members, and self-nomination is not permitted.

Nominations should include (1) a brief biographical sketch of the nominee; (2) a statement of no more than 200 words describing the candidate's scientific contributions to Quaternary geology and geomorphology; (3) a selected bibliography of no more than 20 titles; and (4) a minimum of four letters from colleagues supporting the nomination.

SEDIMENTARY GEOLOGY

Laurence L. Sloss Award for Sedimentary Geology

Nominations due 1 Mar. 2015
Submit nominations to Linda Kah at lckah@utk.edu.

This award is given to a sedimentary geologist whose lifetime achievements best exemplify those of Larry Sloss—i.e., achievements that contribute widely to the field of sedimentary geology and service to GSA. Monies for the award are derived from the annual interest income of the Laurence L. Sloss Award for Sedimentary Geology Fund, administered by the GSA Foundation. Nominations should include (1) a cover letter describing the nominee's accomplishments in sedimentary geology and contributions to GSA; and (2) the nominee's CV. For more information, go to http://rock.geosociety.org/sed/SGD_Awards2.html#Sloss.

STRUCTURAL GEOLOGY AND TECTONICS

Career Contribution Award

Nominations due 10 Mar. 2015
Submit nominations to Jane Gilotti at jane-gilotti@uiowa.edu.

This award recognizes an individual who, throughout his/her career, has made numerous distinguished contributions that have clearly advanced the science of structural geology or tectonics. Nominees need not be citizens or residents of the United States, and membership in GSA is not required. Nominations should include the following information: (1) the name of nominee, present institutional affiliation, and address; (2) a summary statement of the nominee's major career contributions to the science of structural geology and tectonics; (3) selected key published works; and (4) the name and address of nominator. For more information, go to http://rock.geosociety.org/sgt/CareerAward.htm.

Outstanding Publication Award

Nominations due 1 Mar. 2015
Submit nominations to Dyanna Czeck at dyanna@uwm.edu.

This award recognizes a published work (paper, book, or map) of exceptional distinction that clearly advances the science of structural geology or tectonics. Nominations should include (1) a full citation; (2) a written nomination (as short as a paragraph; letters or reviews may also be included); and (3) the name and address of nominator. For more information, go to http://rock.geosociety.org/sgt/BestPaperAward.htm.

Get into the Field with GSA & ExxonMobil

FIELD CAMP SCHOLAR AWARD

Who should apply? Undergraduate students.

Deadline to apply: 17 April

This year's field award will provide US$2,000 each to 20 undergraduate students so they can attend the summer field camp of their choice. These scholarships are based on diversity, economic/financial need, and merit.

BIGHORN BASIN FIELD AWARD

Who should apply? Undergraduate and graduate students and faculty.

Deadline to apply: 17 April
Camp dates: 2–9 August

This award covers all costs for selected students and faculty to take part in a week-long field seminar in the Bighorn Basin of north-central Wyoming that emphasizes multidisciplinary integrated basin analysis.

FIELD CAMP EXCELLENCE AWARD

Who should apply? Anyone, but the award must be used toward field camp operations.

Deadline to apply: 17 April

One field camp instructor/director will receive an award of US$10,000 to assist with his or her summer field season. This award will be based on safety awareness, diversity, and technical excellence.

Questions? Contact Jennifer Nocerino, jnocerino@geosociety.org, +1-303-357-1036.

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GSA Education & Outreach Programs

2015 Section Meetings

Mentor Programs

Plan now to attend a Roy J. Shlemon Mentor Program in Applied Geoscience and/or a John Mann Mentors in Applied Hydrogeology Program luncheon at your 2015 Section Meeting to receive career advice and chat one-on-one with practicing geoscientists. FREE lunches will be served!

If you have questions or want to serve as a mentor, contact Jennifer Nocerino, jnocerino@geosociety.org.

Career Planning

Wondering how to start your career planning process or what employment sector is the best fit for you? Does your résumé need some updating? Take advantage of our three one-hour career workshops, which will run at each Section Meeting.

On To the Future

Will the 2015 GSA Annual Meeting (1–4 Nov. in Baltimore, Maryland, USA) be the first one you attend? Are you a student from an underrepresented group within the geosciences? If so, come by the GSA Foundation booth during your Section Meeting welcome reception to get more information about GSA's On To the Future program and how we can help you get to GSA 2015.

Teacher Advocate Program

Did you know that GSA's Teacher Advocate Program (TAP) has more than 20 resources for teachers to use in their classrooms? The Explore Geoscience resources were developed for teachers by teachers, and they have proven to be very successful in the classroom. Each resource contains background information, pictures, inquiry-based activities that incorporate data for students to manipulate, and 3-D models. GSA's TAP program manager, Davida Buehler, provides teacher trainings at various science teacher conferences. In addition to training teachers on how to use these resources, she provides them with background knowledge on the geoscience topic presented. These conference workshops have proven to be highly successful. During the recent National Science Teachers Association Conference in Orlando, Florida, USA, Davida was able to train more than 200 teachers on rocks, minerals, and earthquakes. These teachers will go on to share what they learned with more than 2,600 teachers. Ultimately, more than 327,000 students will be impacted from this one conference! Teachers do not need to attend a conference to use our resources, which are available in the GSA store at **http://rock.geosociety.org/store/SearchResults.aspx?Category=EDU.** For more information on the Explore Geoscience resources, or for professional development training for your school district, contact Davida Buehler at dbuehler@geosociety.org.

2014 OEST Awards

The National Association of Geoscience Teachers (NAGT) has announced the 2014 Outstanding Earth Science Teacher (OEST) Awards. This annual award recognizes excellence in earth-science teaching at the pre-college level. GSA awards the section recipients with US$500 in travel money to attend a GSA meeting, US$500 for classroom supplies, and complimentary membership in GSA for three years. State winners receive a one-year complimentary GSA membership.

SECTION WINNERS

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Anchorage, Alaska, USA

Georgia

Donna Governor
North Forsyth High School
Cumming, Georgia, USA

Illinois

Keni Rienks
Woodstock North High School
Woodstock, Illinois, USA

Indiana

Martha Hoyt Goings
Huntington North High School
Huntington, Indiana, USA

New Jersey

James Miller
Chatham High School
Chatham, New Jersey, USA

New York

Mark Percy
Williamsville North High School
Williamsville, New York, USA

North Carolina

Mark Townley
Holly Springs High School
Holly Springs, North Carolina, USA

Ohio

Paul Genzman
Put-In-Bay School
Put-In-Bay, Ohio, USA

Oregon

Laura Orr
Ukiah School
Ukiah, Oregon, USA

Pennsylvania

Michael W. Baer
Elizabeth Forward Middle School
Elizabeth, Pennsylvania, USA

Washington

Randy Taylor
Highlands Middle School
Kennewick, Washington, USA

Wisconsin

Beth A. Spear
Central High School
Salem, Wisconsin, USA

The National Association of Geoscience Teachers (NAGT)

Second Announcement and Call for Papers

NORTH-CENTRAL SECTION

49th Annual Meeting of North-Central Section, GSA
Madison, Wisconsin, USA
19–20 May 2015

www.geosociety.org/Sections/nc/2015mtg/

Monona Terrace Community and Convention Center.

From the Proterozoic to the Anthropocene: All the Right Stuff

LOCATION

The 49th Annual Meeting of GSA's North-Central Section will be hosted by the University of Wisconsin–Madison Dept. of Geoscience and by the Wisconsin Geological and Natural History Survey. Technical sessions will take place in the Frank Lloyd Wright–designed Monona Terrace Community and Convention Center overlooking beautiful Lake Mendota in Madison, Wisconsin. The meeting will feature theme sessions and field trips that highlight the geologic diversity of the region, from the Precambrian Midcontinent Rift and the Baraboo Hills, to Paleozoic sedimentary rocks exposed in the nearby Driftless Area, to new interpretations of the Cenozoic evolution of the Lower Wisconsin River, to effects of recent human activities on Earth's water and mineral resources, and to new approaches to analysis of geoscience data and educating the next generation of geoscientists.

Madison, Wisconsin, USA. Photo courtesy GMCVB.

REGISTRATION

Early registration deadline: 13 April
Cancellation deadline: 20 April
REGISTRATION FEES (all fees are in U.S. dollars)

	Early		Standard	
	Full mtg.	1 day	Full mtg.	1 day
Professional Member	$185	$140	$210	$150
Professional Member 70+	$80	$65	$100	$75
Professional Nonmember	$210	$150	$240	$170
Student Member	$65	$40	$75	$50
Student Nonmember	$80	$50	$100	$60
K–12 Professional	$35	$25	$40	$30
Guest/Spouse	$35	$35	$35	$35
Field Trip Only	$35	n/a	$35	n/a

ACCOMMODATIONS

A block of rooms has been reserved at the Hilton Madison Monona Terrace, 9 East Wilson Street, Madison WI 53703, USA, connected via a bridge to the Monona Terrace Community and Convention Center. Group room rates range from US$149 to US$359 plus a room tax of 14.5% (waived for those with State of Wisconsin tax exempt certificates). Reservations must be made by 21 April 2015 to qualify for the block rate. To make your reservation, call +1-866-403-8838 or go to the Hilton Madison Monona Terrace website, www.hiltonmadison.com/index.asp. Use code "NCRC" when making your reservation to ensure that you are booked into the specially priced GSA block.

CALL FOR PAPERS

Abstract deadline: 17 Feb.

Submit your abstract online at **www.geosociety.org/Sections/nc/2015mtg/techprog.htm.** Abstract submission fees: US$10 for students; US$15 for all others. If you cannot submit an abstract online, please contact Heather Clark, +1-303-357-1018, hclark@geosociety.org.

Theme Sessions

T1. **Precambrian Geology of the Great Lakes Region.**
T2. **Shortening, Shearing and Stretching the Midcontinent: Geologic and Geophysical Records of Proterozoic Tectonics.**
T3. **Quantitative Approaches in Stratigraphy and Paleontology: Where Are We Going, and How Will We Get There?**
T4. **Bridging the Gap between Empirical and Model-Driven Views of Geologic History: New Tools and Approaches.**
T5. **Coming Full Circle: From Diagenesis to Modern Aquifer Chemistry—Exploring the Role of Water-Rock Interactions over Time.**
T6. **A Centennial Celebration of USGS Monograph 53: Glacial Geology of the Great Lakes Region.**
T7. **Quaternary Time Machine: Methods and Analyses of Soils and Sediments Reveal Secrets of Past Environments.**
T8. **Non-Glacial Quaternary Research in the Great Lakes Region.**

T9. **Quaternary Paleoecology of the Upper Midwest.**
T10. **Great Lakes Shorelines: Geomorphology, Quaternary History, and Modern Processes.**
T11. **Geomorphology, Hydrology, and Critical Zone Processes in the Anthropocene.**
T12. **Lowland and Wetland Flooding under Changing Climate and Regulatory Conditions.**
T13. **Impacts of Urbanization on the Quality and Quantity of Water Resources.**
T14. **Frac Sand in the Midwest: Geology, Mining, Reclamation, and Environmental Issues.**
T15. **Cultural Geology and Geoarchaeology: Millstones, Dimension Stones, Capitol Buildings, Heritage Stone, and More.** *Cosponsored by the Heritage Stone Task Group of the International Union of Geological Sciences.*
T16. **Applied Geology: Environmental, Engineering, Hydrogeology, Geotechnical, and Applied Geophysics.**
T17. **New Advances in the Use of GIS in Geologic Mapping and Analysis (Posters).**
T18. **From Virtual to Real and Back Again: Emerging 3-D Applications in Paleontology.**
T19. **Teaching and Learning Earth Science: K–16 Educational Pedagogy.**
T20. **Geology in the Classroom and the Community: Reaching a Broader Audience.**
T21. **Geoheritage and Place-Based Education.**
T22. **Thinking outside the Display Case: Innovative Geological Outreach at Museums, Parks, and Surveys.**
T23. **Earth Science Week Activities and Events.**
T24. **Student Research (Posters).** *Cosponsored by the Council on Undergraduate Research Geoscience Division.*
T25. **New Insights into the Midcontinent Rift and Continental Rifting.**

FIELD TRIPS

GSA invites you to join your colleagues on one or more of the following field trips. Trip fees include transportation during the trip as well as a field guide. Some trips also include meals and overnight lodging. All trips begin and end at the Monona Terrace Convention Center. Go to **www.geosociety.org/Sections/nc/2015mtg/fieldTrips.htm** for additional details.

1. **Cambrian and Ordovician Stratigraphy of Southwestern Wisconsin.** Mon., 18 May, 7:30 a.m.–6 p.m. Cost: US$75 (US$45 for students). Jay Zambito, Wisconsin Geological & Natural History Survey, jay.zambito@uwex.edu; Pat McLaughlin, Wisconsin Geological & Natural History Survey, patrick.mclaughlin@uwex.edu.
2. **What's New at Baraboo? A Field Trip for Educators.** Mon., 18 May, 8 a.m.–6 p.m. Cost: US$68. Laurel B. Goodwin, Univ. of Wisconsin–Madison, laurel@geology.wisc.edu; Marcia Bjornerud, Lawrence Univ., marcia.bjornerud@lawrence.edu; John P. Craddock, Macalester College, craddock@macalester.edu; Dyanna M. Czeck, Univ. of Wisconsin–Milwaukee, dyanna@uwm.edu; Robert H. Dott Jr., Univ. of Wisconsin–Madison, rdott@geology.wisc.edu; Stephen Marshak, Univ. of Illinois at Urbana-Champaign, smarshak@illinois.edu; Carol Ormand, SERC–Carleton College, cormand@geology.wisc.edu.
3. **Cultural Geology of Beloit: Geological Aspects of Mills, Mounds, and Historic Dimension Stone.** *Cosponsored by EBY Petrography & Consulting Inc.* Mon., 18 May, 8:30 a.m.–6 p.m. Cost: US$40 (US$15 for students). Joe Hannibal, Cleveland Museum of Natural History, jhanniba@cmnh.org; William Green, Logan Museum, Beloit College; Donald G. Mikulic, Illinois State Geological Survey; Joanne Kluessendorf, Weis Earth Science Museum.
4. **Cliffs, Crater, and Culture: The Geology of Wisconsin's Door Peninsula.** Wed., 20 May, 6 p.m.–Fri., 22 May, 7 p.m. Cost: US$225. Joanne Kluessendorf, Weis Earth Science Museum, joanne.kluessendorf@uwc.edu; Donald G. Mikulic, Illinois State Geological Survey, mikulic@illinois.edu.
5. **Late Cenozoic Evolution of the Lower Wisconsin River Valley.** Thurs., 21 May, 7:30 a.m.–6 p.m. Cost: US$70. Eric Carson, Wisconsin Geological & Natural History Survey, eric.carson@ uwex.edu; Elmo Rawling III, elmo.rawling@ uwex.edu.
6. **Dimension Stone in the 21st Century: Reconnaissance, Selection, and Fabrication of Dimension Stone Elements for New Structures and for Rehabilitation of Historic Structures.** *Cosponsored by Wiss, Janney, Elstner Associates Inc.* Thurs., 21 May, 8 a.m.–noon. Cost: US$10. Brad Shotwell, bshotwell@wje.com; Jim Durham, jdurham@quarrastone.com.

OPENING RECEPTION

Mon., 18 May, 6–8:30 p.m., Grand Terrace of Monona Terrace. Partake in light snacks and a complimentary beverage with your colleagues while browsing exhibits and enjoying the sunset over Lake Monona.

OPPORTUNITIES FOR STUDENTS

Mentor Programs

For more information, contact Jennifer Nocerino at jnocerino@geosociety.org. *Cosponsored by the GSA Foundation.*

Roy J. Shlemon Mentor Program in Applied Geoscience. Tues., 19 May, lunchtime. Students will have the opportunity to discuss career prospects and challenges with professional geoscientists from multiple disciplines over a FREE lunch. Learn more at www.geosociety.org/mentors/shlemon.htm.

John Mann Mentors in Applied Hydrogeology Program. Wed., 20 May, lunchtime. Students interested in applied hydrogeology or hydrology as a career will have the opportunity to network with professionals in these fields over a FREE lunch. Learn more at www.geosociety.org/mentors/mann.htm.

Geoscience Career Workshops

For more information, contact Jennifer Nocerino at jnocerino@geosociety.org. *Cosponsored by the GSA Foundation.*

Part 1: Career Planning and Informational Interviewing. Tues., 19 May, 8 a.m.–9 a.m. Your job-hunting process should begin with career planning, not when you apply for jobs. This workshop will help you begin this process and will introduce you to *informational interviewing.*

Geoscience Career Workshops (*continued from p. 17*)

Part 2: Geoscience Career Exploration. Tues., 19 May, 9 a.m.–10 a.m. What do geologists in various sectors earn? What do they do? What are the pros and cons to working in academia, government, and industry? Workshop presenters, and when possible, professionals in the field, will address these issues.

Part 3: Cover Letters, Résumés, and CVs. Wed., 20 May, 9 a.m.–10 a.m. How do you prepare a cover letter? Does your résumé need a good edit? Whether you are currently in the job market or not, learn how to prepare the best résumé possible. You will review numerous samples to help you to learn important résumé dos and don'ts.

Travel Grants

Application deadline: 13 April

Students who are GSA members and who register for the meeting are eligible to apply for student travel grants. For further information, go to www.geosociety.org/grants/ncgrant.htm

On To the Future (OTF)

Stop by the GSA Foundation booth at the Welcome Reception to ask an onsite representative about applying to OTF, which provides travel support to students underrepresented in the geosciences to attend their first GSA Annual Meeting (the next one is 1–4 Nov. 2015 in Baltimore, Maryland, USA).

Presentation Awards

Awards for best student posters and papers are supported by the GSA North-Central Section and by SEPM (Society for Sedimentary Geology).

LOCAL COMMITTEE

General Chair: Jean Bahr, jmbahr@geology.wisc.edu

Vice-Chair and Exhibits & Sponsorship: M. Carol McCartney, carol.mccartney@uwex.edu

Technical Program Co-Chairs: Michael Cardiff, cardiff@wisc.edu; Eric Carson, eric.carson@uwex.edu

Field Trip Co-Chairs: Phil Brown, pbrown@geology.wisc.edu; Esther Stewart, esther.stewart@uwex.edu

Student Poster Awards: J. Elmo Rawling, elmo.rawling@uwex.edu

Second Announcement and Call for Papers

ROCKY MOUNTAIN SECTION

67th Annual Meeting of the Rocky Mountain Section, GSA
Casper, Wyoming, USA
21–23 May 2015

www.geosociety.org/Sections/rm/2015mtg/

Beautiful Mount Moran in Grand Teton National Park.

Groundbreaking Discoveries in the Rockies: Fractures, Fossils, and Fumaroles

LOCATION

The Casper College Dept. of Earth and Environmental Sciences, the University of Wyoming, and the Wyoming Geological Association (WGA) are excited to host the 67th Annual Rocky Mountain Section Meeting in the booming city of Casper, Wyoming, USA. We have developed a technical program covering a broad scope of topics, including the fields of Cenozoic volcanism; structural geology; paleontology; paleobiology and sedimentology; geomorphology; geophysics and hydrology; applications in GIS; and mining and industry. Our location at the base of Casper Mountain along the North Platte River and the southern margin of the Powder River Basin provides a world-class energy resource and geologic setting for our conference field trips.

REGISTRATION

Early registration deadline: 20 April
REGISTRATION FEES (all fees are in U.S. dollars)

	Early		Standard	
	Full mtg.	**1 day**	**Full mtg.**	**1 day**
Professional Member	$190	$90	$230	$100
Professional Member 70+	$70	$55	$75	$60
Professional Nonmember	$210	$160	$240	$200
Student Member	$50	$30	$60	$40
Student Nonmember	$60	$45	$80	$65
K–12 Teachers	$50	$25	$60	$30
Guest/Spouse	$45	n/a	$55	n/a
Field Trip Only	$30	n/a	$40	n/a

ACCOMMODATIONS

A block of rooms has been reserved at the Best Western Ramkota Hotel, 800 N. Poplar, Casper, WY 82601, USA. Special room rates are US$83 plus tax. To make your reservation, call +1-307-266-6000 and use code "GEOLOG" to ensure that you are booked into the block for this meeting.

CALL FOR PAPERS

Abstract deadline: 17 Feb.

Submit your abstract online at **www.geosociety.org/Sections/rm/2015mtg/.** Abstract submission fee: US$10 for students; US$15 for all others.

Symposia

S1. **Yellowstone/Teton/Snake River Plain Volcano–Tectonic System: Honoring 55 Years of Distinguished Research and the Legacy of Bob Smith.**
S2. **The Continental Triassic: Sedimentary and Paleobiologic Records throughout the Rocky Mountain Region.**
S3. **Brittle Structures of Rocky Mountain Reservoirs and Reservoir Analogs.**
S4. **Quaternary Geoarchaeology: Honoring the Work of John Albanese.**

Theme Sessions

T1. **In Celebration of the Release of the WGA 2014 Wyoming Stratigraphic Nomenclature Chart: Topics in Rocky Mountain Stratigraphy and Sedimentology.**
T2. **Geomorphology and Surficial Processes.**
T3. **Advancements and Issues in Petroleum Extraction Technologies.** *Cosponsored by the Wyoming Geological Association in conjunction with the Enhanced Oil Recovery Institute.*
T4. **General Minerals and Mining.**
T5. **Special Problems in Rocky Mountain Coal Mining.**
T6. **Graduate Student Research.**
T7. **General Paleontology.**
T8. **Paleoclimate, Paleoecology, and Evolution.**
T9. **Mountain Building and Basin Response: New Insights to the Bighorn Mountains and Associated Basins.**

T10. **Geoscience Education and Undergraduate Research.**
T11. **Shallow Geophysics and Water Resources.**
T12. **Applications for GIS and Geospatial Data in the Geosciences.**

WORKSHOPS/SHORT COURSES

Full descriptions for these courses are online at **www.geosociety.org/Sections/rm/2015mtg/workshops.htm.**

1. **Uranium Exploration.** Wed., 20 May, 8 a.m.–noon, Ramkota Inn. Cal Van Holland, UR Energy, cal.vanholland@ur-energyusa.com. US$50; student rate: US$30.
2. **Petroleum Well Site Geology.** Sat., 23 May, 1–5 p.m., Tate Museum Room 121. Arnold Woods, Casper College, awoods@caspercollege.edu. US$50; student rate: US$30. Van transportation provided.
3. **Photogrammetry: 3-D Digital Data Collection in the Lab and Field.** Wed., 20 May, 8 a.m.–5 p.m., Ramkota Inn and Alcova Lake. Brent Breithaupt, BLM, bbreitha@blm.gov; Neffra Matthews, BLM, n1matthe@blm.gov. US$60; student rate: US$35.
4. **Creating Google Tours for Geoscience Education.** Sat., 23 May, 1–5 p.m., Casper College Gateway Building Room 210. Heather Almquist, Univ. of Montana, heather.almquist@umontana.edu. US$40; student rate: US$25. Van transportation provided.

FIELD TRIPS

Please find departure information and full descriptions for these field trips online at **www.geosociety.org/Sections/rm/2015mtg/fieldTrips.htm.**

1. **Tectonics, Climate, and Paleogeomorphology in the Green River Formation.** Sun.–Tues., 24–26 May. Michael E. Smith, Univ. of Northern Arizona, michael.e.smith@nau.edu; Jennifer Scott, Mount Royal Univ., jescott@mtroyal.ca. US$450. Hotels, transportation, and lunches will be reserved and paid with registration funds. Participants will be responsible for paying for breakfast and dinner each day.
2. **Eocene-Oligocene Paleovalleys of the White River Formation.** Emmett Evanoff, Univ. of Northern Colorado, emmett.evanoff@unco.edu. Trip details will be posted online.
3. **Geoscience Educators Field Trip: Alcova Reservoir, Fremont Canyon, and the Cotton Creek Trail.** Wed., 20 May. Terry Logue, Casper College, tlogue@caspercollege.edu. US$40; includes field guide, bus and driver, water, snacks, and box lunch.
4. **Yellowstone and Northwest Wyoming Volcano-Tectonic Field Trip.** Sun.–Tues., 24–26 May. Kent Sundell, Casper College, ksundell@caspercollege.edu; Jamie Farrell, Univ. of Utah, jamie.farrell@utah.edu; Bob Smith, Univ. of Utah, robert.b.smith@utah.edu. US$500; includes transportation in coach bus with restroom, two nights lodging at double occupancy rate, all lunches and four beverages per day, road log of trip, and all National Park entrance fees. All breakfasts and dinners will be on your own.
5. **Powder River Basin: From Outcrop to Oilfield.** Sun., 24 May. Includes lunch, dinner, road log. *Cosponsored by Wyoming Geological Association and Enhanced Oil Recovery Institute.*

OPPORTUNITIES FOR STUDENTS

Mentor Programs

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Student Speaker Awards

Best student speaker awards will be awarded to both graduate and undergraduate students in both oral and poster formats, for a total of four awards.

Job Interviews

Opportunities to interview with local, regional, and international energy resource and mining companies for jobs in Wyoming, the Rockies, and around the world will be arranged. Please check the meeting website for notices on résumé submissions and scheduling of interviews at the meeting.

LOCAL COMMITTEE

General Chair: Kent Sundell, ksundell@caspercollege.edu

Treasurer/Chief Financial Officer: Nancy Doelger, nancy.doelger@gmail.com

Field Trip Chair: Terry Logue, tlogue@caspercollege.edu

Technical Program Co-Chairs: Melissa Connely, mconnely@caspercollege.edu; Beth Wisely, bwisely@caspercollege.edu

Sponsorship Chair: Julia Lemaster, julia@goolsbyfinley.com

Meeting Facilitator and Exhibits Chair: Ann Dalton, adalton@caspercollege.edu

Student Activities Coordinator: Mark Hines, Casper College, mt_hines@yahoo.com

ELECTIONS: GSA OFFICERS and COUNCILORS

GSA ELECTIONS BEGIN 6 MARCH 2015

GSA's success depends on you—its members—and the work of the officers serving on GSA's Executive Committee and Council. Members will receive a postcard with instructions for accessing an electronic ballot via our secure website, and biographical information on the nominees will be online for you to review at that time. Paper versions of both the ballot and candidate information will also be available. Please help continue to shape GSA's future by voting on these nominees.

2015 OFFICER NOMINEES

PRESIDENT
(July 2015–June 2016)

Jonathan G. Price
Jonathan G. Price LLC
Reno, Nevada, USA

We congratulate our incoming president!

VICE PRESIDENT/PRESIDENT-ELECT
(July 2015–June 2017)

Claudia I. Mora
Los Alamos National Laboratory
Los Alamos, New Mexico, USA

TREASURER
(continuing term, July 2014–June 2015)

Bruce R. Clark
The Leighton Group Inc.
Irvine, California, USA

2015 COUNCIL NOMINEES

COUNCILOR POSITION 1
(July 2015–June 2019)

Frank Pazzaglia
Lehigh University
Bethlehem, Pennsylvania, USA

Mark Little
University of North Carolina
Chapel Hill, North Carolina, USA

COUNCILOR POSITION 2
(July 2015–June 2019)

Chuck Bailey
College of William & Mary
Williamsburg, Virginia, USA

Shuhai Xiao
Virginia Polytechnic Institute and State University
Blacksburg, Virginia, USA

COUNCILOR POSITION 3
(Divisions Liaison)
(July 2015–June 2019)

Scott Burns
Portland State University
Portland, Oregon, USA

Mary Kraus
University of Colorado
Boulder, Colorado, USA

Ballots must be submitted electronically or postmarked by 5 April 2015.

Geoscience Jobs & Opportunities

Ads (or cancellations) must reach the GSA advertising office no later than the first of the month, one month prior to the issue in which they are to be published. Contact advertising@geosociety.org, +1.800.472.1988 ext. 1053, or +1.303.357.1053. All correspondence must include complete contact information, including e-mail and mailing addresses. To estimate cost, count 54 characters per line, including punctuation and spaces. Actual cost may differ if you use capitals, boldface type, or special characters. Rates are in U.S. dollars.

Classification	Per Line for 1st month	Per line each addt'l month (same ad)
Positions Open	$9.15	$8.90
Fellowship Opportunities	$9.15	$8.90
Opportunities for Students		
First 25 lines	$0.00	$5.00
Additional lines	$5.00	$5.00

Positions Open

RESEARCH ASSOCIATE IN STABLE ISOTOPE GEOCHEMISTRY NORTHERN ILLINOIS UNIVERSITY

The Dept. of Geology and Environmental Geosciences at Northern Illinois University (NIU) invites applications for a research associate position in stable isotope geochemistry. The successful candidate will hold a full-time, non-tenure track appointment. We seek candidates with a research focus in isotope ratio mass spectrometry, the ability to operate and maintain analytical laboratory facilities supporting allied research across the university, and a desire to train students in analytical laboratory techniques. The capacity to collaboratively develop successful research proposals, publish research results, and successfully generate and conduct contracted analyses is essential to the position. Applicants must have a Ph.D. in geoscience or a related field; postdoctoral experience in a stable isotope laboratory is preferred. Applications including CV, statement of research experience, accomplishments and interests, and three letters of recommendation should be submitted electronically to the Dept. Chair, Mark P. Fischer, at mfischer@niu.edu. Screening of applications will begin March 1, 2015, and continues until the position is filled. For additional information about the position and the department, visit: www.niu.edu/geology. NIU is an AA/EEO institution that values diversity in its faculty, staff and students: we strongly encourage applications from diverse candidates, including women and minorities. A state-mandated pre-employment criminal background investigation is required.

COLLEGE LECTURER DEPARTMENT OF GEOSCIENCES UNIVERSITY OF AKRON

The University of Akron is expanding its teaching strengths in the Dept. of Geosciences by opening two non-tenure track positions with foci on earth systems history and mineralogy. Current faculty members serve approximately 40 M.S. students and 130 undergraduates majoring in geology, environmental science, geographic information systems and geography. Candidates must possess Ph.D. (or abd) in a geosciences field. Competitive earth systems history candidates **(Job #8534)** must have the ability to teach courses including Historical Geology and Paleobiology/Paleontology. Competitive mineralogy candidates (**Job #8535**) must have the ability to teach courses in mineralogy and petrology. We expect strong candidates for both positions to demonstrate the ability to teach Physical Geology, Geology for Engineers, and general education courses that focus on the earth sciences. Successful candidates will be expected to develop field-based experiences for undergraduate courses. In addition to strong abilities in teaching, we anticipate that successful candidates will have records of scholarship.

For complete details and to apply visit www.uakron.edu/jobs. Refer to the job # listed above.

When completing the application be prepared to attach the following documents: (1) a curriculum vitae; (2) a brief statement of teaching philosophy that describes your pedagogical approaches and how your teaching and research experiences will contribute to the growth and success of the department; (3) unofficial transcripts; and (4) contact information for at least 4 references. Applicants should fully describe their qualifications and experience with reference to the minimum and preferred qualifications. Review of applications will begin February 16, 2015. The start date is August 2015. Questions about the Geosciences position can be directed to Dr. Ira Sasowsky at ids@uakron.edu.

The University of Akron is an equal education and employment institution. It is the policy of this institution that there shall be no unlawful discrimination against any individual in employment or in its programs or activities at The University of Akron because of race, color, religion, sex, age, national or ethnic origin, disability, or status as a veteran.

ASSISTANT PROFESSOR NEOTECTONICS (TENURE-TRACK) NEVADA BUREAU OF MINES AND GEOLOGY (NBMG), UNIVERSITY OF NEVADA, RENO

The Nevada Bureau of Mines and Geology (NBMG) at the University of Nevada, Reno seeks applicants with expertise in neotectonics and Quaternary geology. Nevada is one of the most exciting regions in the world to conduct research in the geosciences, particularly in the fields of neotectonics and geologic hazards.

Position Responsibilities: The primary responsibilities of this position will be to develop programs in research and education in the field of neotectonics with emphasis on paleoseismic and earthquake hazard research in Nevada and the surrounding region. Research will focus on landscape evolution primarily as it relates to Quaternary faulting, utilizing innovative approaches, such as LiDAR, to conduct detailed geologic mapping and dating of Quaternary units and surfaces. The successful candidate will also be expected to contribute to the development of datasets and reports on Nevada's Quaternary faults and seismic activity, including periodic assessments and syntheses of hazards facing its major cities and infrastructure. Education will include teaching courses in the successful candidate's area of expertise, such as neotectonics, geologic hazards, and Quaternary geology in the Dept. of Geological Sciences and Engineering and supervising graduate students. Research and educational efforts will involve integrated multi-departmental (e.g. Nevada Seismological Laboratory) and multi-institutional efforts, with scientists from academia, industry, other institutions, and government labs. The successful candidate will be asked to communicate effectively with the public and community leaders regarding natural hazards in Nevada and coordinate mitigation and response efforts with local and federal emergency management agencies.

Qualifications: Applicants must have a doctorate in geology or a related geoscience field by the time of hire and a demonstrated record of research on topics related to neotectonics as indicated by dissertation research, industry experience, and/or peer-reviewed publications. Excellent communication skills, as demonstrated in written application materials; commitment to public service; potential for, or established record of publications; and ability to attract funding are essential. The successful candidate must also have the ability to develop and coordinate programs and work in teams to accomplish major goals.

Preference will be given to candidates with academic or industry experience in neotectonics. Expertise in paleoseismology (e.g. trenching), surficial processes, Quaternary dating techniques, LiDAR, and/or InSAR will be valued. Preference will be given to candidates who have demonstrated research productivity with publications in peer-reviewed literature. The successful candidate will compete for funding from a variety of sources, including federal agencies interested in fundamental and applied geoscience research (e.g., NSF, USGS, Dept. of Energy, and Bureau of Land Management) and industry. Therefore, preference will be given to candidates who explain achievable plans for funded research on Nevada-focused topics in neotectonics in their letters of interest. In addition, preference will be given to candidates who understand the role of NBMG as the state geological survey of Nevada and can articulate how NBMG can better serve stakeholders (citizens, government, and industry) on issues related to geologic hazards.

Salary and Date of Appointment: The position will be a tenure-track faculty appointment at the assistant professor level with an academic-year base salary that is competitive with other research universities. Starting date will be July 1, 2015, or shortly thereafter, depending on availability of the successful candidate.

To apply, please visit: https://www.unrsearch.com/postings/16813. Please submit a letter expressing your interest in the position and research plans; names, e-mail addresses, postal addresses, and telephone numbers of at least three references; a complete curriculum vitae; and electronic copies of up to three of your publications to http://jobs.unr.edu/. Application deadline is **March 10, 2015**. For further information about NBMG, please consult our website (www.nbmg.unr.edu).

The University of Nevada, Reno is committed to Equal Employment Opportunity/Affirmative Action in recruitment of its students and employees and does not discriminate on the basis of race, color, religion, sex, age, creed, national origin, veteran status, physical or mental disability, and sexual orientation. The University of Nevada employs only United States citizens and aliens lawfully authorized to work in the United States. Women and under-represented groups are encouraged to apply.

DIRECTOR
NEW MEXICO BUREAU OF GEOLOGY & MINERAL RESOURCES

The New Mexico Bureau of Geology and Mineral Resources, Socorro, NM, is seeking a new director and state geologist. The bureau, with ~60 employees, is a prominent research and service division of New Mexico Tech and serves as the state geological survey, with a long-standing reputation for excellence in research, service, and outreach. Our mission includes research on the geologic framework of the state, with an emphasis on applied geoscience evaluation of water and energy resources. The bureau works closely with the university academic divisions as well as many state agencies. Full details of the position and information regarding application procedures may be found at http://geoinfo.nmt.edu/DirectorSearch and at www.nmt.edu/hr-jobs-at-nmt. For more information about the application process, contact JoAnn Salome in Human Resources at 575-835-5955 (JSalome@admin.nmt.edu). For more information about the position itself, contact Warren Ostergren, search committee chair, at +1-575-835-5363 (warreno@nmt.edu).

RESEARCH GEOLOGIST/STRATIGRAPHER
INDIANA GEOLOGICAL SURVEY

The Indiana Geological Survey, a research institute of Indiana University, seeks applications for a research geologist/stratigrapher to perform geologic mapping and basic and applied research related to the bedrock stratigraphy of the State of Indiana. Significant duties include participation in the USGS-sponsored STATEMAP projects. Master's degree (Ph.D. preferred), publications record, and 3 years' experience required. Salary range $50-60 K with ample University benefits package. Complete job posting is on the IGS Website (igs.indiana.edu). Application deadline is March 5, 2015, with an anticipated starting date of July 1, 2015.

ASSOCIATE/FULL PROFESSOR FOR DEPT. CHAIR, EARTH & ENVIRONMENTAL SYSTEMS, INDIANA STATE UNIVERSITY

May start as early as June 1, 2015.

The Dept. of Earth and Environmental Systems at Indiana State University seeks an interdisciplinary scientist, with an environmental focus, at the Associate or Professor level to Chair a recently developed, multidisciplinary department. Review of applications begins *Feb 15, 2015*, and remains open until filled, for full consideration apply by March 15, 2015. For more information contact Dr. Kathleen Heath (Kathleen.Heath@indstate.edu) and visit: www.indstate.edu/ees. Candidates must apply at https://jobs.indstate.edu. EOE/Minority/Female/Individual with Disability/Veteran.

ASSISTANT PROFESSOR
STRUCTURAL GEOLOGY AND TECTONICS
DEPT. OF MARINE, EARTH, AND ATMOSPHERIC SCIENCES
NORTH CAROLINA STATE UNIVERSITY, RALEIGH, NC

Founded in 1887, NC State is a land-grant institution distinguished by its exceptional quality of research, teaching, extension, and public service. Located in Raleigh, North Carolina, NC State is the largest university in North Carolina, with more than 34,000 students and 8,000 faculty and staff. National rankings consistently rate Raleigh and its surrounding region among the five best places in the country to live and work, with a highly educated workforce, moderate weather, reasonable cost of living, and a welcoming environment. A collaborative, supportive environment for business and innovation and research collaborations with area universities and the Research Triangle Park are compelling reasons for relocation to the area.

Located within the College of Sciences at NC State, MEAS is one of the largest interdisciplinary geoscience departments in the nation. Opportunities exist for disciplinary and interdisciplinary interactions with more than 30 marine, earth and atmospheric scientists. Additional information about the department and its facilities can be found on the web page: www.meas.ncsu.edu. NC State also hosts large programs in geotechnical and construction materials engineering www.ce.ncsu.edu, and has recently established the Center for Geospatial Analytics: http://geospatial.ncsu.edu.

The department seeks to fill a tenure-track faculty position at the rank of assistant professor in structural geology and tectonics. Possible research areas include, but are not limited to: rock mechanics, neotectonics, thermochronology, sedimentary basin analysis, plate kinematics and geodesy. Candidates that combine field observations with precision measurement techniques, numerical simulations, analogue models, or laboratory experiments are preferred, and applicants should have a strong interest in interdisciplinary collaborations across and beyond the geosciences.

Position Responsibilities: This position will teach an undergraduate-level course in structural geology, as well as other undergraduate and graduate classes commensurate with the candidate's interest and expertise. An interest in participating in the department's capstone undergraduate geology field course also is desirable. MEAS places a high value on excellent instruction and the use of innovative teaching methods.

Minimum Education/ Experience: Applicants must hold a Ph.D. degree in the geosciences or a related field, or equivalent professional experience.

Department Required Skills: The successful candidate must demonstrate strong potential for outstanding accomplishments in research, research supervision, and teaching.

Application Instructions: Review of applications will begin on **10 February 2015;** the position will remain open until filled. The start date of this position is **15 August 2015.** Applications, including cover letters, curriculum vitae, teaching and research statements, and contact information for three references must be submitted online at https://jobs.ncsu.edu/. Please search for position number **#00104417.** You can also apply directly using the link below:

https://jobs.ncsu.edu/postings/46092.

NC State University is an equal opportunity and affirmative action employer. All qualified applicants will receive consideration for employment without regard to race, color, national origin, religion, sex, age, veteran status, or disability. In addition, NC State University welcomes all persons without regard to sexual orientation. Persons with disabilities requiring accommodations in the application and interview process please call +1-919-515-5575.

RESEARCH ASSOCIATE PROFESSOR
GEOTHERMAL SPECIALIST (TENURE TRACK)
NEVADA BUREAU OF MINES AND GEOLOGY
UNIVERSITY OF NEVADA, RENO

The Nevada Bureau of Mines and Geology (NBMG) at the University of Nevada, Reno seeks applicants with expertise in geothermal energy research. Nevada is one of the most exciting regions in the world to do research in the geosciences and one of the best in the U.S. for the study of geothermal resources.

Position Responsibilities: The primary responsibilities of this position will be to develop broad programs in research and education in the field of geothermal energy while serving as Director of the Great Basin Center for Geothermal Energy. The applicant is expected to conduct a nationally competitive research program that will include innovative approaches to understanding the complexities of fluid flow in the crust with a concentration on Nevada and the surrounding Great Basin region. The successful candidate will also be expected to contribute to the development of datasets and reports on Nevada's geothermal resources, maintain geothermal databases as part of NGDS (National Geothermal Data System), and provide state resource assessments. Education will include teaching courses in geothermal related topics in the Dept. of Geological Sciences and Engineering (DGSE), supervising graduate students, and contributing to developing a geothermal curriculum. Research and educational efforts will involve multi-departmental and multi-institutional efforts, with scientists from academia, industry, other institutions, and government labs. The successful candidate will be asked to communicate effectively with the public and community leaders regarding the geothermal resources of Nevada.

Qualifications: Applicants must have a doctorate in geology, geologic engineering, geophysics, or a related geoscience field by the time of hire and a demonstrated record of research on topics related to geothermal energy as indicated by dissertation research, industry experience, and/or peer-reviewed publications. The successful candidate must have at least 5 years of postdoctoral experience (either in industry or academia) in geothermal research in such areas as rock mechanics, 3D modeling, geophysical techniques, reservoir engineering, and/or geochemistry. Excellent communication skills, as demonstrated in written application materials; commitment to public service; potential for, or established record of publications; and ability to attract funding are essential. The successful candidate must also have demonstrated ability to develop/coordinate programs and work in teams to accomplish major goals.

Because the individuals will be competing for funding from a variety of sources, including industry and federal agencies, for fundamental and applied geoscience research (e.g., NSF, DOE, and USGS), preference will be given to candidates who explain

achievable plans for funded research on Nevada-focused topics in geothermal energy in their letters of interest. In addition, preference will be given to candidates who understand NBMG's role as the state geological survey of Nevada, especially to those who can articulate a plan of how NBMG can better serve stakeholders (citizens, government, and industry) on issues related to geothermal resources.

Salary and Date of Appointment: The position will be a tenure-track faculty appointment at the associate professor level with an academic-year base salary that is competitive with other research universities. Starting date will be July 1, 2015, or shortly thereafter, depending on availability of the successful candidate.

Application: Please submit a letter expressing your interest in the position, research plans; names, e-mail, postal addresses, and telephone numbers of at least three references; a complete vita; and electronic copies of up to three of your publications to https://www.unrsearch.com/postings/16685. Application deadline is March 1, 2015. For further information about NBMG, please consult our website (www.nbmg.unr.edu).

The University of Nevada, Reno is committed to Equal Employment Opportunity/Affirmative Action in recruitment of its students and employees and does not discriminate on the basis of race, color, religion, sex, age, creed, national origin, veteran status, physical or mental disability, and sexual orientation. The University of Nevada employs only United States citizens and aliens lawfully authorized to work in the United States. Women and underrepresented groups are encouraged to apply.

VISITING ASSISTANT PROFESSOR OF GEOLOGY, ENERGY
ALLEGHENY COLLEGE

The Geology Dept. at Allegheny College invites applicants for a full-time two-year appointment in energy, starting fall 2015, with the possibility of a two-year renewal and eventual conversion to a tenure-track contract. A Ph.D. is preferred at the time of appointment but strong ABD candidates will be considered. We seek a geoscientist with demonstrated experience in an energy-related field to develop and teach one to two new courses in energy and to help shape a new interdisciplinary minor in energy and society. Our vision for this position is to provide students with rigorous technical training in energy fundamentals, grounded in the geosciences. We seek a candidate who can work with others to analyze the political, economic, and other societal facets necessary to manage properly our existing fossil fuels while we develop and implement sustainable future energy resources. Successful candidates will have a strong commitment to liberal arts undergraduate education and will work as part of a small and active Geology departmental team. Applied work in the energy industry and/or teaching experience will be assets. The appointee will advise and work closely with undergraduate students in course work and advising, including senior research projects, and will provide evidence of excellence in teaching and ongoing scholarship. Other teaching will include physical and/or environmental geology, college-wide first-year/sophomore seminars, and/or additional Geology Dept. courses based on the expertise of the candidate and needs of the department. The teaching load will be two lab courses or three non-lab courses per semester.

Allegheny College is a highly selective private liberal arts college with a dedicated faculty of teacher-scholars. The Dept. of Geology has a tradition of high-quality undergraduate education and active involvement of students in research. Facilities include a computer lab with GIS software, Geoprobe drill rig, Rigaku Miniflex XRD, Dionex Ion Chromatograph, Perkin Elmer Flame/Furnace AAS, JEOL SEM-EDS-CL, and well-equipped instructional labs. Applicants should send electronic copies of a letter of application, teaching statement, research statement, cv, transcripts, and have three letters of reference sent to: Energy Search, Dept. of Geology, Allegheny College, Meadville, PA 16335, GeoEnergySearch2015@allegheny.edu. Review of applications will begin February 16, 2015. More information on Allegheny College and the Dept. of Geology may be obtained at http://sites.allegheny.edu/geo/. Applicant must be authorized to work in the United States to be considered. Allegheny College is an Equal Opportunity Employer, with a strong institutional commitment to develop a diverse faculty and staff. Women, veterans, and members of other under-represented groups are encouraged to apply.

SURVEY DIRECTOR AND STATE GEOLOGIST
WISCONSIN GEOLOGICAL AND NATURAL HISTORY SURVEY
UNIVERSITY OF WISCONSIN–EXTENSION

Madison, Wisconsin, is home to the State Capitol, the flagship campus of the University of Wisconsin System, and the Wisconsin Geological Survey. Surrounded by lakes, our bike-friendly college town is a vibrant hub of art, music, local foods, and outdoor activities. Our city consistently ranks as a top place to live, work, and play.

The University of Wisconsin–Extension (an EEO/AA employer) is seeking a Ph.D.-level geoscientist to serve as Survey Director and State Geologist. The Survey employs 26 professionals and has an average annual budget of $2 million. Our academic atmosphere, focus on research and outreach, and compact size set the WGNHS apart from most geological research organizations. A complete position description is available at: **http://WisconsinGeologicalSurvey.org/jobs**. **Application deadline: February 28, 2015.**

Opportunities for Students

Graduate Student Research Fellowship on the Early Earth History of the White/Inyo Range, California. The University of California, White Mountain Research Center invites graduate students in geology to apply for the Clem Nelson Graduate Student Research Fellowship. In honor of Clemens Nelson, Professor Emeritus, UCLA Dept. of Earth and Space Sciences, and long-time WMRC affiliate, one $3,500.00 award is available for graduate student research on the Early Earth History of the White/Inyo Range in California. Clem Nelson was a world authority on Late Precambrian and Early Cambrian geology, particularly fossils from early-middle Cambrian time. Use of the Clem Nelson Trilobite Collection (www.wmrc.edu/projects/trilobites/default.html) is encouraged but not required. The award may be used for WMRC room and board, research supplies, and travel. The submission deadline for application and three letters of reference is May 31, 2015. Application is available at www.wmrc.edu/student/default.html. For further information please contact Dr. Antony Orme, Director, WMRC (orme@geog.ucla.edu), visit our website (www.wmrc.edu), or phone WMRC (+1-760-873-4344).

Philmont Scout Ranch Volunteer Geologist Program

Cimarron, New Mexico, USA

Sponsored by the Rocky Mountain Association of Geologists

Volunteer to teach and demonstrate area geology in backcountry New Mexico this summer!

Philmont Scout Ranch is one of three national high-adventure bases owned and operated by the Boy Scouts of America. Located in the southern Sangre de Cristo Mountains of northern New Mexico, Philmont is a 137,000-acre ranch dedicated to outdoor activities. The twelve-day backpacking experience serves more than 27,000 high-school-age boys and girls from all over the USA as well as several foreign countries. Learn more about the geology of the area at **http://pubs.usgs.gov/pp/pp_505/html/pdf.html.**

Fifty-four volunteer positions are open this year, to be filled on a first-come, first-served basis. Volunteers will receive a sign-up packet with scout applications (you have to be a scout, at least for the summer!), medical forms, and brochures in May 2015. Students who would like to volunteer must show proof of enrollment in a graduate-level program. The 2015 season begins on Saturday, 13 June; the last week of the program begins on Saturday, 8 August.

For more information and to sign up, contact **Ed Warner,** 62 South Ash Street, Denver, CO 80246, USA, +1-303-331-7737, **ewarn@ix.netcom.com.** Alternate contact: Bob Horning, P.O. Box 460, Tesuque, NM 87574, USA, +1-505-820-9290, rrhorning@gmail.com.

COMING SOON!

GeoCareers Guide

Check out the May issue of *GSA Today* for new career development articles.

Looking for more information on a career in industry?

Want tips on how to network at national conferences?

GSA is always open to ideas about the career-related information you would like to see. Send an e-mail **Tahlia Bear** at tbear@geosociety.org to submit your ideas.

CALL FOR PROPOSALS

PENROSE CONFERENCES bring together multidisciplinary groups of geoscientists and facilitate an open and frank discussion of ideas in an informal atmosphere that also stimulates individual and collaborative research: **www.geosociety.org/penrose/.**

THOMPSON FIELD FORUMS offer both the opportunity to get out into the field and to bring together experts on the topic at hand to exchange current knowledge, ideas, and theories: **www.geosociety.org/fieldforums/.**

THE GEOLOGICAL SOCIETY OF AMERICA®

2015 GeoVentures & Field Camps

Tasman Valley-Aoraki Mount Cook, New Zealand. Photo by David Briody
Great Geysir" in Haukadalur, Iceland. Photo by Petr Brož
Illinois Basin Map used with permission from USGS
Mammoth Cave, Kentucky. Photo by Daniel Schwen
Longs Peak, Colorado. Photo used with permission from Wikipedia Commons
Halema'uma'u crater, Hawaii. Photo used with permission from USGS
Acadia National Park, Maine. Photo used with permission from Wikipedia Commons

GeoVentures

2–15 July: Explore New Zealand—Life on a Plate Boundary!

20–31 July: Explore Dynamic Iceland!

5–12 August: Explore Hawaiian Volcanoes for K–12 Teachers

Field Camps

14–18 June: Illinois Basin Field Camp

20–25 June: Rocky Mountain Field Camp

12–18 July: Mammoth Cave Field Camp

26 July–1 August: Acadia Field Camp

These trips are fantastic for K–12 teachers, students, informal educators, and pre-service teachers!

For more information on GeoVentures contact **Gary Lewis** at glewis@geosociety.org.

For more information on Field Camps contact **Davida Buehler** at dbuehler@geosociety.org.

"Because the best geologists are the ones that have seen the most rocks!"

John W. (Jack) Hess, *GSA Foundation President*

On To the Future Program—Success in Vancouver

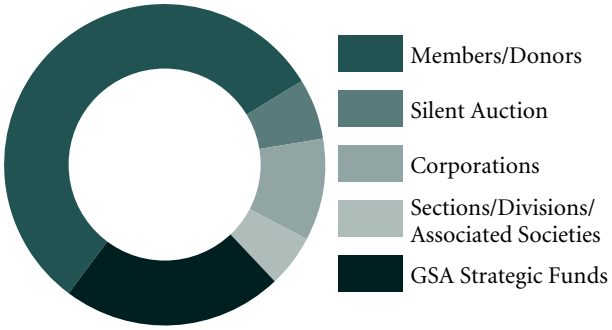
GSA 2014 OTF scholars.

It is a pleasure to share an update on the On To the Future Program (OTF), which recently convened for a second time at the 2014 GSA Annual Meeting in Vancouver, British Columbia, Canada. Launched during GSA's 125th Anniversary year, OTF seeks to bring 125 students from diverse backgrounds to attend their first GSA Annual Meeting. The program has already helped more than 245 students from diverse and underrepresented backgrounds experience the energy, science, and collegiality of the annual meeting. Consider the difference in several key metrics achieved in one year:

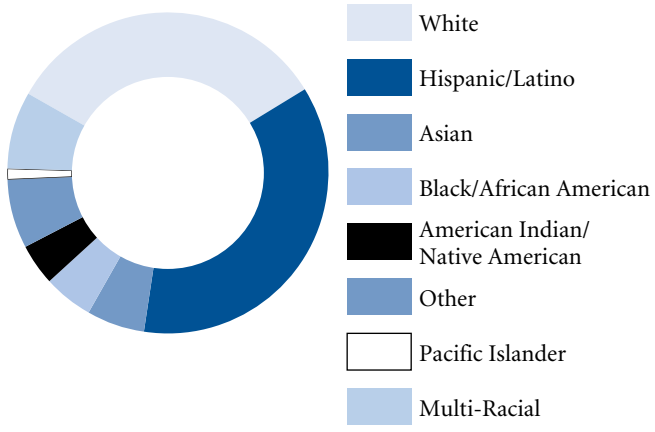
- Intensified marketing resulted in a 38% increase in completed applications;
- First-generation college students comprised 50% of the 2014 OTF cohort;
- 23 GSA members were paired with OTF participants in one-on-one mentor relationships; and
- OTF partnered with the International Association of Geoscience Diversity (IAGD) to support eight students with physical disabilities among the OTF cohort.

As OTF begins its third year, its grassroots spirit remains an important part of the recruitment, mentoring, and funding of the program going forward. Of course, financial and human resources are also an essential part of establishing and sustaining a successful program. A generous three-year pledge from GSA member Paula Gural and her husband Jeffrey, in combination with continued support from members and partners, will enable the program to build on its early successes. The Society has also committed significant strategic, term-limited funding to hire a full-time diversity

2014 OTF Funding Sources



2014 OTF Ethnicity



program manager. These resources will bolster program evaluation, streamline volunteer efforts, and coordinate partnerships with organizations interested in participating with OTF.

An innovative idea boldly brought forward by GSA members, OTF has become a leading component of meeting the Society's mission to increase diversity to the geosciences. If you value the importance of GSA's role in building a diverse geoscience workforce, I welcome your financial support of GSA's On To the Future Program.

Comments from OTF participants:

"The OTF mentorship program was phenomenal. Thank you so much for putting that together."

"I was extremely happy with the exposure to both other students as well as the scheduled speakers that came to talk to us. The information they provided was exactly what I needed to begin pursuing my interests. Prior to the OTF meetings, I was completely clueless on how to even begin. They provided a direction, and I was able to ask questions of the right people. I feel much better about my options academically and professionally!"

The **On To the Future** (OTF) Program is an initiative of GSA's Diversity in the Geosciences Committee and administered by the GSA Education & Outreach Department. OTF aims to fulfill GSA's strategic goal to "develop and foster a robust, diverse, and sustainable professional geoscience community" (G.3). OTF has emerged as a pivotal program working toward increasing diversity in the geosciences. The overall goal of OTF is to enable a cohort of diverse students to attend their first GSA Annual Meeting and engage these students in ongoing career development and leadership opportunities that will lead to an increasingly diverse workforce. Visit the On To the Future webpage to support OTF at **http://community.geosociety.org/OTF/home/.**

Letters

The following letters to the editor concern the November 2014 *GSA Today* Groundwork article, "Evolution of paleontology: Long-term gender trends in an earth-science discipline," by R.E. Plotnick et al. (v. 24, no. 11, p. 44–45, doi: 10.1130/GSATG219GW.1; online at http://www.geosociety.org/gsatoday/archive/24/11/article/i1052-5173-24-11-44.htm).

Sex =/= Gender

First, thank you for doing this study (Plotnick et al., 2014). It's good to see some numbers on conference participation quantified for our field. There is one issue, however, that I want to point out. In your study, you conflate gender and sex. Sex is a person's physical state (male/female/intersex). Gender is what they are mentally (man/woman/non-binary). In most people's cases it will be a moot point, but it's still an important distinction to make in order to be accurate. At least one of the NAPC presenters you counted as both female and a woman is not cisgender, but this would not be evident from their name or even necessarily personal knowledge as they are non-binary. It would be unreasonable to expect you to check with every single person in your study, but a statement in your methods noting that you do recognize the distinction and are using sex and gender as proxies for one other given the low odds of them conflicting would have been prudent.

Jess Miller-Camp, *Univ. of Iowa, 14 Nov. 2014*

Reply to Jess Miller-Camp

We thank Miller-Camp for her thoughtful and thought provoking comment. We agree that we should have clarified our terminology for the reasons given. Additional studies that focus on gender identity would be a great contribution to understand the dynamics of participation in science.

Roy E. Plotnick, *Univ. of Illinois at Chicago, and* ***Alicia Stigall,*** *Ohio Univ., 25 Nov. 2014*

Send letters by e-mail to gsatoday@geosociety.org or by post to Managing Editor, *GSA Today*, P.O. Box 9140, Boulder, CO 80301-9140, USA. Please keep your letter to 300 words or fewer; letters longer than 300 words will not be published. The *GSA Today* managing editor will edit letters for length and clarity. All letters will be forwarded to the *GSA Today* science editors for review before publication, and *GSA Today* reserves the right to reject any letter at the discretion of the science editor. Opinions presented do not reflect official positions of the Society.

Next Generation Science Standards: A call to action for the geoscience community

Nicole D. LaDue, *Dept. of Geology and Environmental Geosciences, Northern Illinois University, DeKalb, Illinois 60115, USA, and* ***Cheryl Brown Manning,*** *Evergreen High School, Evergreen, Colorado 80439, USA*

How do we ensure the health of our geology departments with a steady stream of majors and build an informed public prepared to make important decisions on geoscience issues? The Next Generation Science Standards (NGSS) are a critical step, and they require the support of geoscientists nationwide.

The NGSS demonstrate an expanded emphasis on earth-science topics (such as natural resource distribution, human impacts on climate, and geologic history) compared to previous standards (NGSS, 2012; National Research Council, 1996). The NGSS present a rare opportunity to significantly improve K–12 earth-science education nationally because they (1) include up-to-date, timely topics important for public decision making; and (2) increase the rigor and prominence of earth-science content in K–12 classrooms. However, adoption of the NGSS requires state-level legislative action. Without support from geoscientists at the state level, the implementation of NGSS nationwide is threatened.

High-quality K–12 earth-science education is important for recruiting the necessary workforce to meet society's needs. Although recent enrollment in geoscience majors has dropped less than 3% in 2013, there is a predicted shortfall of 150,000 geologists to meet the workforce demands in the next decade (Wilson, 2014). The need to boost enrollment to meet this demand is hampered by the lack of quality K–12 earth-science education. Earth science has the fewest trained teachers at the primary and secondary levels, and only 28% of high-school students take an earth-science class (Wilson, 2014). There is also no geoscience Advanced Placement (AP) course. Despite this lack of earth sciences at the secondary level, more than half of geology graduates report having taken a middle or high school earth-science course (Wilson, 2014), suggesting that those who do have K–12 earth sciences exposure may be more likely to pursue geoscience majors.

High-quality K–12 earth-science education is important for geoscience literacy. The public is facing challenging and complex decisions about geoscience topics, such as fracking and carbon emissions. Inadequate K–12 earth-science education leads to misunderstandings about the process of science and uninformed speculation about the causes of earthquakes, volcanoes, landslides, climate change, flooding, massive storms, and droughts—obfuscating and politicizing the impacts of natural disasters on public safety (Smith, 2006). The structure of the NGSS, which infuses science practices and content, has the potential to substantially improve public understanding of the challenges we face as a population with respect to natural disasters, natural resources, economics, and ecological systems. Improved geoscience literacy will lead to an improved response to critical geologic issues, such as the costs and benefits of geologic resources, resource development and consumption, and local and national economic well-being (Smith, 2006).

The structure of the NGSS effectively links the content to the practice of geoscience. Built upon the Framework for K–12 Science Education (National Research Council, 2012), 26 states collaborated to create the first set of standards to be adopted by multiple states. The NGSS present a new opportunity for the geosciences because they have an expanded emphasis on earth science (Wysession, 2014) and are built directly upon a set of geoscience literacy documents developed by the scientific community (Wysession et al., 2012). An important feature of the NGSS is the integration of three dimensions: (1) Disciplinary Core Ideas, (2) Crosscutting Concepts, and (3) Science and Engineering Practices. For example, students must demonstrate that they can "analyze geoscience data to make the claim that one change to Earth's surface can create feedbacks that cause changes to other Earth systems" (NGSS, 2012, HS-ESS2-2). This performance expectation demonstrates how the science practice of *analyzing data to support the claim* is applied to the relevant *earth systems* Disciplinary Core Idea and connects the Crosscutting Concept of *feedbacks* across the science disciplines. This structure requires teachers to engage students in the process of science, rather than presenting geoscience as a set of facts.

The NGSS development process involved stakeholders from science, science education, higher education, and industry and several rounds of public feedback were sought before publication. Numerous groups and associations strongly support the NGSS, including the American Geophysical Union, the Geological Society of America, the National Academy of Science, and the U.S. Army, as well as energy, technology, and insurance companies (NGSS, 2014a, 2014b). This demonstrates the importance of the NGSS for developing the scientifically literate population necessary for continued national and economic stability and success.

CHALLENGES

The adoption of the NGSS by individual states has been slow for numerous reasons, including the lack of federal incentives and an emphasis on the Common Core State Standards Initiative (Heitlin, 2014). However, the greatest controversy is focused on the earth-science standards because they include politically controversial topics: climate change; costs and benefits of exploration, development and use of natural resources; and evolution,

GSA Today, v. 25, no. 2, doi: 10.1130/GSATG233GW.1.

geologic time, and origin of the universe (Workosky, 2014). The very substance of the controversy presents an opportunity to engage students, teachers, and lawmakers in understanding how geoscientists study complex issues and engage in scientific argumentation (Dolphin and Dodick, 2014). The expanded emphasis on earth-science topics and the integration with the practices of science featured in the NGSS have the potential to change misperceptions by increasing the quality and complexity of earth-science content in public schools.

A major hurdle to state-level adoption is the requirement that state legislatures understand the importance of the NGSS, vote for adoption, and allocate resources to support their implementation. Earth science is not currently a mandated part of the science curriculum in many states and is assessed inconsistently across the country (AGI, 2013). The current lack of earth science in K–12 schools means that fewer teachers are prepared to meet the expectations of NGSS. Likewise, many schools currently suggest that students skip earth-science courses in favor of taking AP science courses. Therefore, the expanded focus on earth science presents a great challenge to local area schools even in states adopting the standards. One of the model course maps for implementation proposed in the NGSS suggests that Earth and Space Science Standards be infused into biology, chemistry, and physics courses (NGSS, 2014c, Appendix K). This would require substantial professional development resources to train current biology, chemistry, and physics teachers to teach earth-science content.

SOLUTIONS

What can you do to ensure quality K–12 earth-science education?

1. **Promote the adoption of the NGSS in your state to local lawmakers and popular media.** Check here to learn about NGSS in your state: http://ngss.nsta.org/latest-news/. Major legislative battles are taking place in many states due to push-back on controversial earth-science–relevant topics. Write letters to your lawmakers urging them to support the statewide adoption of NGSS. Write articles for local popular press, or hold a local science café through your institution's STEM outreach office. Stress the importance of the NGSS for preparing an informed public to make decisions about natural resource use, climate change impacts, and natural hazards.
2. **Urge your state commissioners of education to provide adequate resources for teacher training to meet the Earth and Space Science Performance Expectations in the NGSS.** Many local and regional school districts are struggling to adapt to curricular changes as a result of statewide adoption. The resources they need include earth-science content training, curriculum development training, classroom materials, computers, and strategic planning for implementing earth science either as a stand-alone course or infused into their physics, chemistry, and biology courses. The needs and resources of each district vary substantially; however, all schools need teacher training to understand the earth and space science standards and how to best meet the standards within the context of their school districts' curriculum.
3. **Utilize broader impacts of funded projects to provide content knowledge training to regional teachers.** Teachers in your area need a boost in their earth-science knowledge to meet the expectations of the NGSS. Specific challenges relate to understanding how the process of science can be different in the earth sciences as compared to other sciences and how to present politically charged issues, such as climate change, earth history and evolution, and natural resource use (such as fracking). Resources to facilitate your efforts are available through the following organizations and curricular repositories: National Association of Earth Science Teachers, Museum of the Earth, SERC, On the Cutting Edge, and the Geological Society of America, to name a few. Likewise, you can partner with colleagues in a college of education or STEM outreach office to help use the content you provide and to develop appropriate lessons for K–12 classrooms.

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2015 Section Meeting Calendar

Chattanooga, Tennessee, USA.
Photo courtesy of the Chattanooga Convention and Visitors Bureau.

SOUTHEASTERN

19–20 March
Chattanooga, Tennessee, USA
Early registration deadline: 17 Feb. 2015

Karston Creek, Oklahoma, USA.
Image courtesy Stillwater Convention and Visitors Bureau.

SOUTH-CENTRAL

19–20 March
Stillwater, Oklahoma, USA
Early registration deadline: 17 Feb. 2015

Mount Washington Resort, Bretton Woods, New Hampshire, USA.
Image courtesy Mount Washington Resort.

NORTHEASTERN

23–25 March
Bretton Woods, New Hampshire, USA
Early registration deadline: 17 Feb. 2015

Anchorage, Alaska, USA. Photo by Jody Overstreet, courtesy Visit Anchorage.

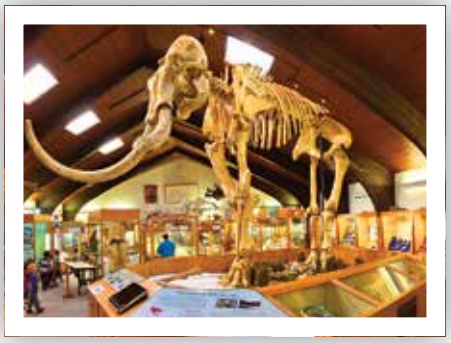
CORDILLERAN

11–13 May
Anchorage, Alaska, USA
Abstracts deadline: 10 Feb. 2015

Madison, Wisconsin, USA. Photo courtesy GMCVB.

NORTH-CENTRAL

19–20 May
Madison, Wisconsin, USA
Abstracts deadline: 17 Feb. 2015

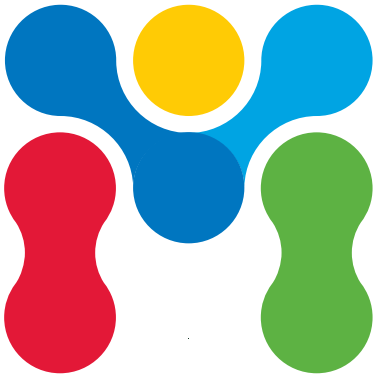


Dee the Mammoth, Casper College Tate Museum. Photo courtesy Visit Casper.

ROCKY MOUNTAIN

21–23 May
Casper, Wyoming, USA
Abstracts deadline: 17 Feb. 2015

www.geosociety.org/Sections/meetings.htm



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