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The big picture: A lithospheric cross section of the North American continent

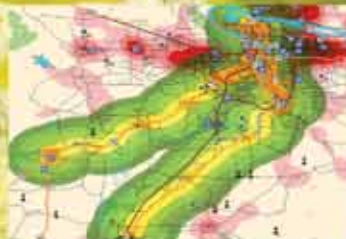
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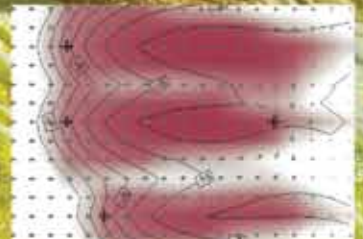
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Philip T.C. Hammer, Ron M. Clowes, Fred A. Cook, K. Vasudevan, and Arie J. van der Velden

Cover: Vibroseis trucks generating crustal-scale seismic reflection data, an important component of coordinated geological, geochemical, and geophysical studies crossing the North American continent. Location: Coast Mountains, British Columbia, Canada. Photo by Philip Hammer. See related article, p. 4–10.



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The big picture: A lithospheric cross section of the North American continent

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ABSTRACT

A lithospheric cross section constructed within a 6000-km-long corridor across southern Canada and its margins at 45–55°N illuminates the assembly of the North American continent at an unprecedented scale. Based on coordinated, multidisciplinary research, the profile emphasizes lithospheric-scale relationships between orogens—plate collisions and accretions have sequentially stacked orogen upon orogen such that the older crust forms basement to the next younger. This large-scale perspective highlights the similarities among crustal structures produced by orogenic processes despite the broad range of age from the Mesoarchean to the present. Heterogeneities in the lithospheric mantle suggest that, in certain situations, relict subducted or delaminated lithosphere can remain intact beneath, and eventually within, cratonic lithospheric mantle. In contrast, the dominantly subhorizontal Moho appears to be re-equilibrated through mechanical and/or thermal processes; few crustal roots beneath orogens are preserved.

INTRODUCTION

A unique cross section of the North American continent represents a synthesis of more than two decades of coordinated research conducted by Lithoprobe, Canada's national geoscience project. Based on existing interpretations within eight study regions, or transects, that are linked directly or by projection along strike, we have constructed a transcontinental lithospheric profile (Fig. 1 and poster insert¹). From west to east, this 6000-km profile crosses the Juan de Fuca oceanic plate, the active Cascadia subduction zone, the southern Cordillera (0.19 Ga–present), the Alberta and Trans-Hudson orogens (1.92–1.8 Ga), the Superior Province (3.82–2.60 Ga), the Mid-Continent Rift System (1.1–1.0 Ga), the Grenville orogen (1.19–0.99 Ga), the Newfoundland Appalachian orogen (0.47–0.28 Ga), the Grand Banks continental shelf, and the Atlantic passive margin (0.2 Ga). The diversity of tectonic history and ages included in the section facilitates direct comparison of the secular and spatial variation of orogenic processes.

Data and interpretations are based on coordinated multidisciplinary research combined with a strong, steadily improving base of regional geotectonic knowledge. The structures displayed are primarily based on active-source seismic (reflection and refraction) data. However, the regional geometry and interpretations of the structure and tectonic processes utilize the full array of geological, geochemical, and geophysical data available for that region. Appendix 1 (see GSA's supplemental data repository²) summarizes how the cross section was constructed. A complete listing of references used to construct the cross section is provided in Appendix 2 (see footnote 2). In addition, Hammer et al. (2010) provide an in-depth description and two complementary lithospheric cross sections.

The cross section is portrayed in terms of the "tectonic age" within the crust. We define this as the time since the most recent episode of significant tectonic deformation (Fig. 1 and insert [see footnote 1]). Tectonic age was chosen over more typical designations (e.g., geology or terranes/domains) because it simplifies the interpreted cross section to highlight comparative structures and to convey the sequence of orogenic development based on the current structural interpretations. In some areas, we chose to modify the tectonic age designations in order to convey key aspects of structure as well as the sequence of orogenic development based on current structural interpretations. For example, the Archean Sask, Hearne, and Superior continents were welded together in the Paleoproterozoic Trans-Hudson Orogen (1.92–1.80 Ga), yielding the core of the Laurentian craton. The largely unexposed Sask craton, discovered by Lithoprobe seismic studies (e.g., Lucas et al., 1993; Lewry et al., 1994; Hajnal et al., 2005), lies almost entirely beneath juvenile crustal imbricate structures. Although the Sask craton dates to 2.45–3.3 Ga, the lithospheric fragment was likely deformed by the Paleoproterozoic orogeny. However, to clarify its role in the assembly of Laurentia, we have chosen to label it with an Archean tectonic age but stippled to indicate Paleoproterozoic modification. Similar display procedures have been applied in other parts of the lithospheric cross section.

OBSERVATIONS

Orogenic Crustal Structures

A first-order observation from the interpreted cross section is that, despite the wide range of age, geometry, and complexity of the many orogens crossed, there is a remarkable similarity in orogenic style. The orogens are doubly vergent and exhibit a

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¹Insert: Full-scale view of Lithoprobe's lithospheric cross section. See supplemental data item 2011191 (footnote 2) for a full explanation of its construction.

²GSA supplemental data item 2011191, a summary of the construction of the cross section (insert; see footnote 1), is available online at www.geosociety.org/pubs/ft2011.htm. You can also request a copy from GSA Today P.O. Box 9140, Boulder, CO 80301-9140, USA; gsatoday@geosociety.org.

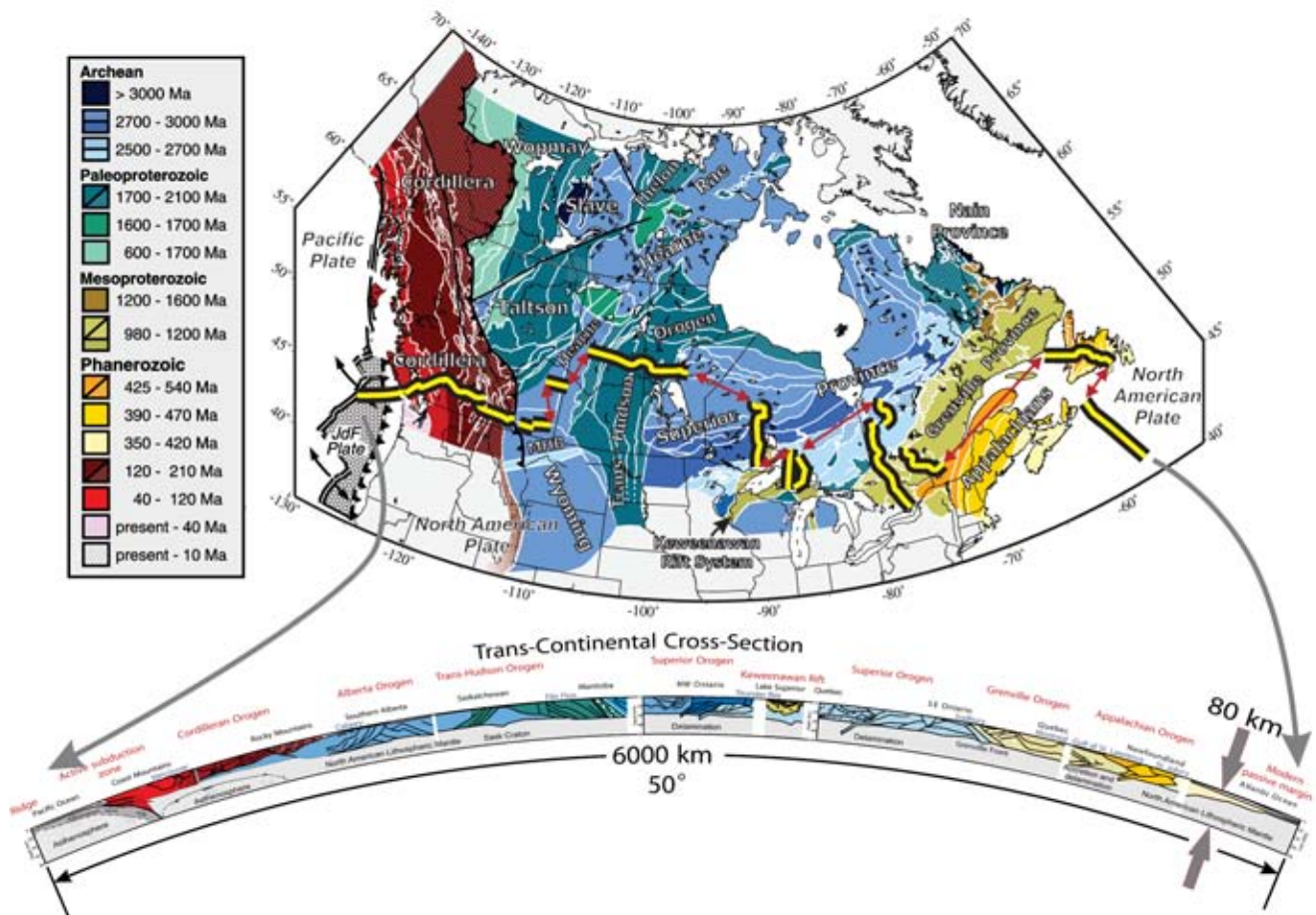


Figure 1. Location of transcontinental corridor (yellow lines) on a simplified tectonic age map of northern North America. Tectonic age is defined as the time since the most recent episode of tectonic deformation. Red arrows show along-strike offsets linking profile segments. The interpreted cross section incorporates Earth curvature and is displayed using a vertical exaggeration of 2:1. At this scale, features are difficult to identify; see insert (text footnote 1) for a 1:1 version extended to full lithospheric depth.

stacked or wedged form that is indicative of the thermal and compositional state of the orogen as it formed and, in some cases, of post-orogenic processes. The preserved collisional zones exhibit structures that fall into three categories: (1) subcretion (mechanical underplating), as is observed in subduction/accretion zones (e.g., southwestern Cordilleran orogen); (2) tectonic wedging with either the overriding crust ramping up a full crustal-scale décollement from the Moho (e.g., the eastern Cordilleran, Grenville, and Trans-Hudson orogens; insert [see footnote 1] and Fig. 2); or (3) mid-crustal wedging (e.g., the Appalachian and Superior orogens). Subcretion of small terranes and sediments in a subduction zone (e.g., Ellis and Beaumont, 1999) is imaged within the southwestern Cordilleran orogen, and remnants of these types of structures are interpreted to be trapped within virtually all of the older orogens. Moore and Wiltschko (2004) show that although the crust-mantle boundary is the natural interface for syncollisional delamination, intracrustal delamination will take place if a mafic lower crust is eclogitized, providing sufficient density contrast to subduct or subcrete the lower crust with its lithospheric mantle. This provides a mechanism for the obduction of thin slivers or accreted terranes.

Archean cratons and their boundaries contain structures that are very similar to those observed in Proterozoic and Phanerozoic orogens. This leads to the conclusion that fundamental tectonic processes in the Neoproterozoic were similar to those in present-day plate tectonics and provides geometric data that are inconsistent with large-scale gravity driven overturn of the crust (e.g., van der Velden et al., 2006).

Magmatism related to subduction, post-orogenic extension, or orogenic collapse does not dominate the cross sections. Although intrusions are detected in the upper crust (generally as poorly reflective zones), the passage of large volumes of melt apparently does not destroy the gently dipping structures in the mid-lower crust. Examples of this can be found in many regions, including the southeastern Superior Province (inset C on insert [see footnote 1]) and in the Newfoundland Appalachians (insert). This requires that the conduits are (a) offset from the two-dimensional seismic profiles; (b) narrower than the seismic data can resolve; or (c) overprinted by postmagmatic deformation (e.g., van der Velden et al., 2004).

The preserved structures document the integrated orogenic effects, although these are often dominated by late deformation sequences. This overprinting complicates the structure and

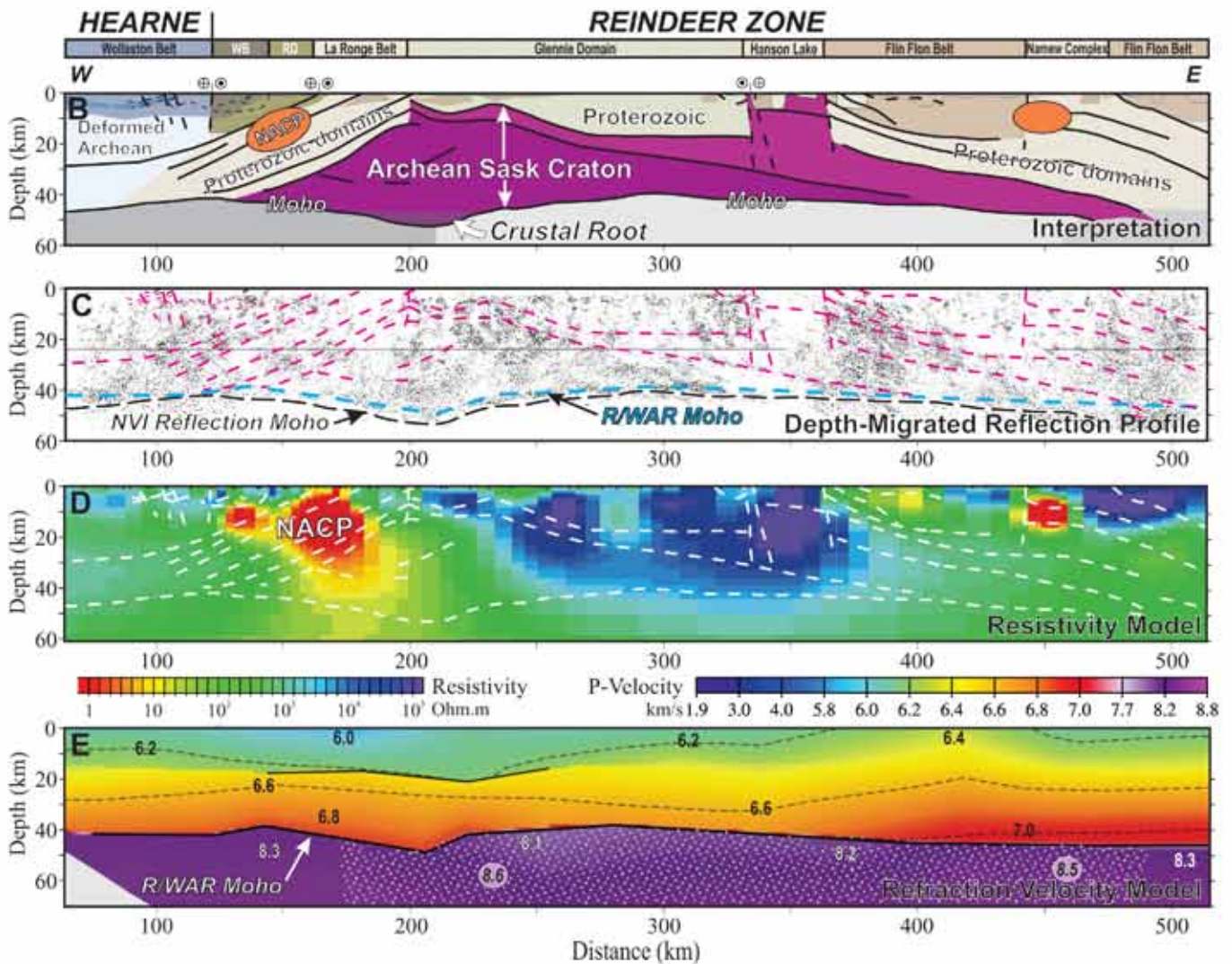
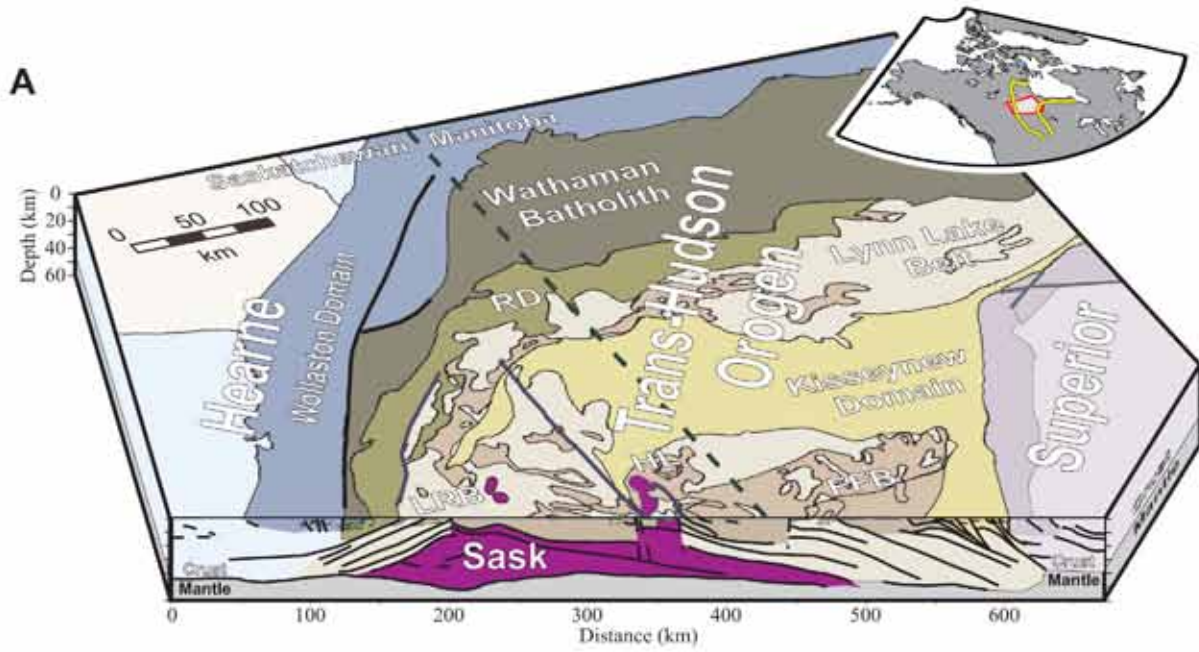


Figure 2. Results from the Trans-Hudson orogen (THO) transect. (A) Simplified tectonic element map and interpretation across the orogen on the front face. FFB—Flin Flon belt; HL—Hanson Lake block; LRB—La Ronge belt; RD—Rottenstone domain. Inset location map includes yellow lines that outline the bounds of the THO. (B) Simplified interpretation based on geological, near-vertical incidence (NVI) reflection, refraction/wide-angle reflection (R/WAR), and magnetotelluric studies. The Archean Sask craton is a previously undiscovered microcontinent separate from either the Hearne to the west or the Superior to the east. Bar at top identifies the different domains crossed by the section. WB—Wathaman batholith; NACP—North American Central Plains conductivity anomaly; orange ovals identify regions of high conductivity from interpretation of magnetotelluric (MT) results shown in D. (C) Depth-migrated seismic section. Pink dashed lines show interpreted crustal domain boundaries or prominent structures (adapted from White et al., 2005). (D) Resistivity model derived from MT surveys (adapted from Jones et al., 2005a). Very low resistivity at 160 km is the NACP. White dashed lines show interpretation from reflection data. (E) Interpreted velocity model across the THO (adapted from Németh et al., 2005). Solid lines, including the Moho, identify locations from which wide-angle reflections were identified. Dashed lines are iso-velocity contours. Numbers are P-wave velocities in km/s. Circled numbers show velocities in a direction perpendicular to the plane of the figure, thus indicative of velocity anisotropy. Stippled area in the mantle identifies the limited region showing velocity anisotropy.

←

makes interpretation challenging, particularly in situations such as the reversal of subduction polarity (e.g., eastern Trans-Hudson orogen) or where an internal zone is caught between colliding continents (e.g., Trans-Hudson, Appalachian, and Grenville orogens). However, interpretations of orogenic structures may be improved or validated when geological, geochemical, and geophysical studies for a given orogen are combined with geodynamic modeling applied to test hypotheses directly against the multidisciplinary data for that orogen (e.g., Beaumont and Quinlan, 1994; Beaumont et al., 2010).

The Moho, Crustal Thickness, and The Crust-Mantle Transition

More than 20,000 km of seismic profiling in Canada reveals that, although there are variations in Moho depth, the transition remains remarkably flat (~33–43 km deep) despite the great diversity of overlying crustal properties (topography, age, composition, and degree of exhumation) (e.g., Cook et al., 2010; Hammer et al., 2010). Small excursions (<5 km) in Moho depth are observed in many locations. These often correlate with geotectonic boundaries but not with topography. In contrast, large crustal roots are unusual, even beneath much of the Canadian Cordillera.

Crustal roots extending down 60–70 km are well documented beneath the active Himalaya and Andean orogens. However, despite superb preservation of crustal structure in the Lithoprobe transects, few crustal roots associated with collisional tectonics were imaged; three are within the transcontinental profile. The Sask craton (Trans-Hudson orogen, 1.92–1.80 Ga) has a root that extends to 52 km depth, bulging 14–20 km below the adjacent crust (Fig. 2 and insert [see footnote 1]). A second, smaller root (47 km maximum depth adjacent to ~40-km-thick crust) lies beneath the Grenville front (1.19–0.99 Ga; see insert). The metamorphic grade of exposed rock in the region

suggests the crust was thickened up to 70 km (e.g., Carr et al., 2000); the observed root is interpreted to have been preserved by eclogitization (e.g., Eaton, 2005). Some orogens are thermally supported and do not form a root. For example, the majority of the Canadian portion of the Phanerozoic Cordilleran orogen exhibits a shallow (33–36 km depth) and exceptionally flat Moho. Only beneath the easternmost Cordillera does the crust thicken to 45–50 km (see insert). Therefore, the Lithoprobe dataset indicates that crustal roots are not always formed beneath orogens and, if there is crustal thickening, the roots are not commonly preserved. Syn- or post-orogenic re-equilibration of the Moho must therefore be a widespread process.

The preservation of orogenic roots may be associated with the relative lack of post-orogenic heating (e.g., the Trans-Hudson orogen; White et al., 2005). In contrast, the relatively uniform crustal thickness throughout most of Canada indicates that either (a) thick crustal roots are not commonly formed beneath orogens (e.g., obduction of thin terranes [Cordillera] or weak continental lithosphere during orogeny); or (b) the Moho has been reset to a shallower, roughly subhorizontal boundary. Re-equilibration could occur through mechanical (shear, extension, delamination) and/or thermal (metamorphism, partial melting) processes (e.g., Eaton, 2005; Cook et al., 2010).

Finally, it remains possible that in some situations, the Moho and the base of seismic reflectivity do not represent the petrologic crust-mantle boundary. Eclogitization of the lower crust could yield rock that is seismically indistinguishable from other mantle. In that case, the Moho, representing an eclogitic metamorphic front, would be shallower than the petrologic crust-mantle boundary (e.g., Cook and Vasudevan, 2003; Moore and Wiltschko, 2004; Eaton, 2005). A second scenario could occur in a subduction setting where fluids and associated serpentinization may reduce mantle velocities such that the petrologic base of the crust may be shallower than the Moho indicates. This possibility has led to debate over the depth of the subducting Juan de Fuca plate beneath northern Cascadia (inset A on insert [see footnote 1]). Recent teleseismic analyses (Nicholson et al., 2005; Bostock et al., 2010) position the plate boundary where several different active source seismic studies (e.g., Clowes et al., 1987; Hyndman et al., 1990; Ramchandran et al., 2006; Calvert et al., 2006) have consistently interpreted a zone of lower crustal reflectivity associated with a combination of shear, fluids, and accretionary duplexing. This conflict remains unresolved and has implications for understanding the earthquake dynamics in the region.

Heterogeneity in the Upper Mantle

Heterogeneity in the upper mantle is observed in three forms: (1) crustal structures penetrating into the mantle; (2) seismic wave scattering that may be indicative of compositional variation; and (3) seismic anisotropy (e.g., Clowes et al., 2010). In the majority of orogens, reflection data display structures dipping from the crust into the uppermost mantle (e.g., van der Velden and Cook, 2005). These reflections are consistent with collisional geometries and are interpreted as subducted or subcreted lithosphere preserved beneath and eventually within cratonic lithospheric mantle. In some cases, reflections are spectacular, with relict subducted crust well-defined to 35–50 km beneath the Moho (e.g., Calvert et al., 1995; inset C on insert

[see footnote 1]). A comparable but even more extensive structure was imaged by reflection (e.g., Cook et al., 1999) and refraction (Oueity and Clowes, 2010) data and by teleseismic receiver functions (Mercier et al., 2008) beneath the Wompay orogen (1.84–1.88 Ga) in northwestern Canada. More commonly observed are dipping lower crustal reflections that penetrate ~5 km beneath the Moho, linking directly to crustal reflections above which are associated with mid-crustal delamination (e.g., western Superior [inset B on insert] and Appalachian orogens) or full-crustal décollements (e.g., Trans-Hudson orogen; Fig. 2 and insert). Virtually all of the preserved subduction/subcretion reflections dip beneath the older cratonic crust, suggesting that mantle reflections are more likely to be preserved beneath older domains or that, during final phases of accretion, subduction preferentially dips beneath the craton.

In many cases, long-offset refraction/wide-angle seismic profiles (e.g., Németh et al., 2005; Clowes et al., 2010), teleseismic studies (e.g., Bostock et al., 2010), and magnetotelluric (MT) investigations (e.g., Jones et al., 2005a; Craven et al., 2001) show evidence for significant structure and/or anisotropy within the subcrustal lithosphere. The structures vary in scale from those that are tens to hundreds of kilometers in lateral extent and are identified on a deterministic basis (e.g., traveltimes modeling of refracted or wide-angle reflected phases, receiver function analyses, and inversion of MT data) to fine-scale heterogeneities on the scale of tens of kilometers to less than a kilometer (e.g., Clowes et al., 2010).

Thickness of the Lithosphere

Estimates of lithospheric thickness vary depending on the technique used (Artemieva, 2009). To be consistent across the cross section, recent syntheses by Artemieva (2009) and Shapiro and Ritzwoller (2002) were used (insert [see footnote 1]). However, many other observations carried out along or near the corridor constrain lithospheric thickness. These include teleseismic studies (e.g., Bostock et al., 2010), xenolith and deep volcanic studies (e.g., Abraham et al., 2005), geodynamic modeling (e.g., Perry and Forte, 2010), magnetotelluric profiles (e.g., Jones et al., 2005b), and wide-angle reflection studies (e.g., Clowes et al., 1995). Although the constraints on lithospheric thickness are not always strong, the lithosphere is very thin (55–70 km) beneath the Cordillera, thickens to about 200 km beneath the Alberta and Trans-Hudson orogens, to 250–270 km beneath the Superior craton, and then thins eastward beneath the Appalachians and Atlantic margin (insert).

CONCLUSIONS: A LOOK FORWARD

The continental-scale lithospheric cross section provides a unique perspective on four billion years of crustal assembly, recycling, and reorganization. The cross section presented here is one “slice” through the North American continent at one geologic time—today. Because it traverses orogens that span a large fraction of Earth’s history, it may provide a representative view of the geometry of orogenic evolution through time. In addition, the continent-wide scale of the cross section offers an opportunity to formulate questions that may not be apparent on much smaller scales, such as within a single orogen. A few such thoughts are presented here:

1. The Moho is remarkably flat even in regions with substantial structural relief (10+ km) within the crust. This likely resulted from late to post-orogenic heating, but the uniformity of depth (33–43 km), with a few exceptions as noted previously, is surprising and deserving of more thorough investigation.
2. Orogenic structures appear to have been formed by horizontal tectonic forces in all of the orogens of Canada, regardless of age. This is strong evidence that some form of plate tectonism has been operating throughout the past 2.5–3.0 Ga of Earth’s history (e.g., van der Velden et al., 2006). Furthermore, because orogens are commonly “stacked,” with older orogens forming the basement to younger orogens, continental evolution in Canada appears to have been dominated by recycling, with minimal crustal growth. How such recycling occurred (e.g., whether some crustal material ended up in the lower lithosphere, whether it proceeded to deeper in the mantle, or whether both occurred) remains a target for future research.
3. Complexity in the subcrustal lithosphere is increasingly revealed by multidisciplinary studies. For example, imbricated or stacked mantle lithosphere, as proposed by Cook (1986) and Helmstaedt and Schulze (1989), was interpreted from seismic data (e.g., Cook et al., 1998, 1999) and later affirmed by studies of mantle xenoliths (e.g., Canil, 2008). In a different setting, Frederiksen et al. (2007) use teleseismic and magnetotelluric methods to demonstrate a stratified lithospheric mantle beneath the Grenville Front (inset B on insert [see footnote 1]). Geodynamic modeling (e.g., Beaumont et al., 2010) illuminates how lithospheric structure and crust-mantle relationships can develop through changing crustal coupling, slab breakoff, post-convergent extension, and other orogenic processes. Despite the successes, the internal structure of the lithospheric mantle remains difficult to image, largely due to its seismic homogeneity. It is uncertain, for example, whether seismic anisotropic effects (e.g., Clowes et al., 2010; insert) are related to structural variations, such as imbricates, or whether they may be a consequence of preferred crystal orientations, as with c-axis orientation of orthorhombic olivine. The Lithoprobe dataset indicates that combining active-source seismic experiments with passive seismic and magnetotelluric studies and deep geological sampling over the same regions may resolve some of the uncertainties.

Advancing our understanding of lithospheric processes and the structures they create requires a research approach that integrates all applicable earth-science disciplines. Lithoprobe’s success as a project and in generating the detailed continental lithospheric cross section was possible because of its scientific approach, which involved focusing multidisciplinary studies in selected areas of investigation.

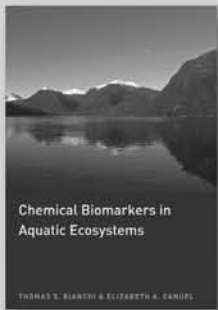
ACKNOWLEDGMENTS

As a project- and continent-scale synthesis of over two decades of research, this paper pulls together the superb work done by hundreds of researchers. A detailed reference listing of the publications contributing to the cross section is provided in the data repository (see text footnote 2). We thank all of the researchers who made Lithoprobe a success and whose work contributes to this synthesis. Journal reviewer Peter Cawood provided highly constructive comments that better focused the content of the paper. Lithoprobe’s primary funding agencies were the Natural Sciences and Engineering Research Council (NSERC) and the Geological Survey of Canada; however, many other sources of funds and support were provided

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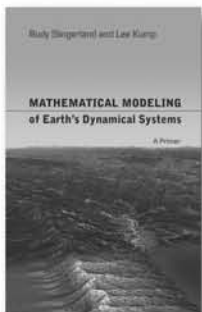
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Manuscript received 31 Mar. 2010; accepted 12 Dec. 2010. 



Comment AND Reply POSTED ONLINE

No Late Cambrian shoreline ice in Laurentia

COMMENT: Ed Landing, page e19, doi: 10.1130/G113C.1;
www.geosociety.org/gsatoday/comment-reply/pdf/i1052-5173-21-4-e19.pdf.

REPLY: Anthony C. Runkel, Tyler J. Mackey, Clinton A. Cowan, and David L. Fox, page e19, doi: 10.1130/G124Y.1;
www.geosociety.org/gsatoday/comment-reply/pdf/i1052-5173-21-4-e20.pdf.

Read the original article (v. 20, no. 11, p. 4–10) by A.C. Runkel et al., “Tropical shoreline ice in the late Cambrian: Implications for Earth's climate between the Cambrian Explosion and the Great Ordovician Biodiversification Event,” at www.geosociety.org/gsatoday/archive/20/11/article/i1052-5173-20-11-4.htm.

To view an archive of *GSA Today* comment & reply articles, go to

www.geosociety.org/gsatoday/comment-reply/.

To learn more and submit a comment regarding a *GSA Today* science or Groundwork article, go to www.geosociety.org/pubs/gsatguid.htm.

ARCHEAN to ANTHROPOCENE

the past is the key to the future

Message from the 2011

GSA Annual Meeting & Exposition Local Planning Committee Chair



*Dear GSA and Associated Society members,
students, and educators,*

I invite you to Minneapolis, Minnesota, USA, to attend the 2011 GSA Annual Meeting & Exposition on 9–12 October. The geoscience community across the upper Midwest has worked hard to make this meeting the best it can be in relation to your interests and needs.

There are lots of reasons for you to attend, starting with a remarkable array of interesting, exciting, enjoyable, and carefully planned field trips, all at the peak of fall colors thanks to our mild early October weather. As you visit, you will be reminded that our geology is diverse. Minnesota and our neighboring states and provinces range from Phanerozoic cover to Archean shield and from the Mississippi drainage to the Hudson Bay watershed, all within the limit of continental glaciation.

Our theme captures this diversity—Archean to Anthropocene; the past is the key to the future—stressing the broad research and education agenda of the GSA community as a whole, as well as the application of our work to society.

And, of course, we will have a superb array of sessions, short courses, workshops, and events so that you will have something of great interest to do throughout your stay. Remember: You haven't been here in a long time! (GSA was last in Minneapolis in 1972—so you need to come!)

Air connections to the middle of the continent are excellent, and the taxi or light-rail ride from the airport is short. You will see that the Twin Cities are a pleasant, safe, and well-equipped community, with diverse running trails, cycling paths, arts, sports, and restaurants.

I hope that you have enjoyed our poster that accompanied the December 2010 issue of *GSA Today*! This was another in a series of posters that goes back to the 2005 North-Central Section Meeting in Minneapolis. How many seconds did it take before you saw something in that poster that you have never noticed before?

Brace yourselves—The Minneapolis meeting is going to be great!

Harvey Thorleifson, Minnesota State Geologist



Neoproterozoic Soudan banded iron formation, NE Minnesota; photo courtesy Mark Jirsa.

Events & Deadlines

CALENDAR

Space request deadline:

Tues., 7 June

Abstracts deadline:

Tues., 26 July

Early registration deadline:

Tues., 6 Sept.

Housing deadline:

Tues., 6 Sept.

**Registration cancellation
deadline:**

Mon., 12 Sept.

Pre-Meeting Field Trips:

Tues.–Sat., 4–8 Oct.

Short Courses & Workshops:

Fri.–Sun., 7–9 Oct.

NEW TIMES!

Exhibits Opening:

Sun., 9 Oct., 2–6:30 p.m.

**Presidential Address & Awards
Ceremony:**

Sun., 9 Oct., 6:30–8:30 p.m.

Awards & Welcoming Reception:

Sun., 9 Oct., 8:30–9:30 p.m.

TECHNICAL PROGRAM

Oral Sessions:

Sun.–Wed., 9–12 Oct.

Poster Sessions

(posters are to be hung all day;
authors present a.m. or p.m.):

Sun.–Wed., 9–12 Oct.

EXHIBIT HALL HOURS

Sun., 9 Oct., 2–6:30 p.m.

Mon.–Tues., 10–11 Oct.,
9 a.m.–6 p.m.

Wed., 12 Oct., 9 a.m.–2 p.m.

Lunchtime Lectures:

Sun.–Wed., 9–12 Oct.,
12:15–1:15 p.m.

Private Alumni Reception:

Mon., 10 Oct.; evening times vary

Group Alumni Reception:

Mon., 10 Oct., 7–9:30 p.m.

Post-Meeting Field Trips:

Thurs.–Sat., 13–15 Oct.

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2011 GSA Annual Meeting & Exposition
Minneapolis, Minnesota, USA
9–12 October 2011

PARDEE KEYNOTE SYMPOSIA

Pardee Keynote Symposia represent leading-edge, interdisciplinary science and address broad, fundamental geoscience issues and/or areas of public policy. Sessions are selected on a competitive basis by the Annual Program Committee; all speakers are invited. *Pardee Keynote Symposia are made possible by a grant from the Joseph T. Pardee Memorial Fund.*

Joseph T. Pardee



P1. The Frontiers of Quaternary Geochronology: Extension or Overextension of Dating Methods for Quaternary Geology and Geomorphology? A formidable array of Quaternary geochronological techniques has been developed over the last decade. This session brings together established scientists who have been instrumental in methodological developments for or applications of radiocarbon, optically stimulated luminescence, and cosmogenic nuclide dating as well as researchers who are now striving to take those techniques further. The latest advances will be placed in a context that will allow both seasoned professionals and students to scrutinize the techniques and evaluate their utility for future projects.

Date/Time: Sun., 9 Oct., 8 a.m.–noon

Cosponsors: GSA Quaternary Geology and Geomorphology Division; GSA Archaeological Geology Division; American Quaternary Association; Association for Women Geoscientists; Colorado Scientific Society

Disciplines: Quaternary Geology; Geomorphology; Archaeological Geology

Conveners: Kenneth Lepper, North Dakota State University; Shannon A. Mahan, USGS



Arthur Holmes

P2. Honoring British Geologist Arthur Holmes (1890–1965) for Contributions to Geochronology, Plate Tectonics, and the Origin of Granite. One-hundred years ago, British geologist Arthur Holmes (1890–1965), while still an undergraduate student, established the technique to date rocks by the radioactive decay of U to Pb. Holmes

also made highly significant contributions to the study of plate tectonics and the origin of granite.

Date/Time: Sun., 9 Oct., 1:30–5:30 p.m.

Cosponsors: Geological Society London; GSA International Section; International Association of GeoChemistry; GSA History and Philosophy of Geology Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division; GSA Structural Geology and Tectonics Division

Disciplines: Geochemistry; History and Philosophy of Geology; Tectonics

Conveners: Russell S. Harmon, North Carolina State University; Jon Davidson, University of Durham

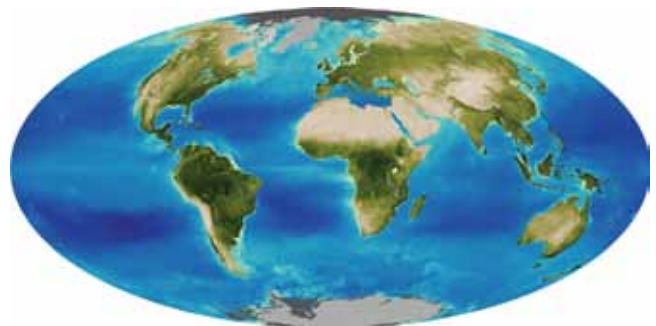
P3. Exploration of the Deep Biosphere. Current uncertainty in the distribution, activity, and ecology of microbial species in the deep biosphere is vast. This session is dedicated to highlighting advances in deep biosphere research in terrestrial and marine settings. Presentations will highlight the geomicrobiology, microbial ecology, physiology, and biogeography of deep, subsurface environments. Speakers are encouraged to discuss the development of field-based and theoretical observatories, as well as the application of new in situ technologies for measurements, sample collection, and experimentation.

Date/Time: Mon., 10 Oct., 8 a.m.–noon

Cosponsor: GSA Geobiology & Geomicrobiology Division

Discipline: Geomicrobiology

Conveners: Brandy M. Toner, University of Minnesota; Jeffrey Gralnick, University of Minnesota



NASA images created by Rob Simmon and Jesse Allen using ocean chlorophyll data provided courtesy of the SeaWiFS Project and vegetation data courtesy of the Global Inventory Modeling & Mapping Studies (GIMMS) project. Caption by Holli Riebeek; <http://earthobservatory.nasa.gov/IOTD/view.php?id=38889>.

P4. Rare Earth Elements and Critical Minerals for a Sustainable and Secure Future. Widespread deployment of clean energy technologies can reduce greenhouse gas emissions, mitigate climate change, and reduce dependence on foreign oil. Many emerging technologies—such as wind turbines, solar cells, and electric vehicles—depend on rare earth elements (REEs) and other scarce elements that currently lack diversified sources of supply. For example, China accounts for 95% of the world production of REEs although, according to the U.S. Geological Survey, it has only 36% of identified world reserves. This session explores REEs

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and critical minerals in the context of emerging energy technologies and recent legislation and reports.

Date/Time: Mon., 10 Oct., 1:30–5:30 p.m.

Cosponsors: GSA Geology and Society Division; GSA Geology and Public Policy Committee; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division

Discipline: Public Policy; Economic Geology

Convener: Craig Schiffries, Geological Society of America

P5. **The EarthScope Program: Recent Results and Future Project.**

EarthScope is a continental-scale geophysical and geological experiment to study the lithosphere of the United States. To date, several experiments involving broadband seismology, long-period magnetotellurics, the Plate Boundary Observatory, and the San Andreas Fault Observatory at Depth have investigated over half the lithosphere of the lower 48. The USArray seismic component is working its way eastward and is currently within the central United States. This session will highlight the research of all components of EarthScope. The design of future experiments in the central and eastern United States will also be detailed.

Date/Time: Tues., 11 Oct., 8 a.m.–noon

Cosponsors: GSA Geophysics Division; GSA Structural Geology and Tectonics Division; GSA Geoinformatics Division; GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division

Disciplines: Geophysics/Tectonophysics/Seismology; Tectonics; Public Policy

Conveners: Matthew J. Fouch, Arizona State University; Kevin Mickus, Missouri State University; Paul A. Bedrosian, USGS

P6. **Prairie Ice Streams.** Session leaders are interested in understanding the deglacial dynamics and impact of terrestrial ice streams, ancient and modern. Questions concern how they propagate up-ice and at what rates they draw down their catchment areas; how the evolution is reflected in the sediment record down-ice; what basal conditions allow ice streams to maintain momentum and form lobes; how the

record of subglacial conditions is preserved in the sediment and landforms; how the ultimate stagnation of the lobe affects the dynamics of the tributary ice streams; and how lobe stagnation affects local climate, including permafrost, ecosystems, and groundwater recharge.

Date/Time: Tues., 11 Oct., 1:30–5:30 p.m.

Cosponsor: GSA Quaternary Geology and Geomorphology Division

Disciplines: Quaternary Geology; Paleoclimatology/Paleoceanography; Geomorphology

Conveners: Carrie E. Jennings, University of Minnesota; Martin A. Ross, University of Waterloo; B. Brandon Curry, Illinois State Geological Survey

P7. **Earth's Early Atmosphere and Surface Environment.**

Investigations of the chemical state of Earth's early surface and atmosphere have been guided by geological evidence, cosmochemical analysis, and comparisons to other terrestrial bodies. This session will provide for presentation and discussion of several, often contradictory, models for the early Earth.

Date/Time: Wed., 12 Oct., 8 a.m.–noon

Disciplines: Precambrian Geology; Geochemistry; Planetary Geology

Conveners: Robert O. Pepin, University of Minnesota; George H. Shaw, Union College

P8. **Global Water Sustainability:** This session will address the full spectrum of present and future issues and challenges facing humanity's requirement for water, its most critical resource.

Date/Time: Wed., 12 Oct., 1:30–5:30 p.m.

Cosponsors: Mineralogical Society of America; Geochemical Society

Disciplines: Hydrogeology; Environmental Geoscience; Public Policy

Conveners: Martin B. Goldhaber, USGS; John B. Brady, Smith College; Chen Zhu, Indiana University

Trout Lake Watershed, Wisconsin; photo courtesy Carl Bowser.



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SPECIAL EVENTS



Minneapolis, Minnesota, skyline at night. Photo by Greg Benz, <http://carbonsilver.com/blog>.

President's Student Breakfast Reception

Sunday, 9 Oct., 7–8:30 a.m.

GSA President John Geissman invites students to this free breakfast buffet sponsored by ExxonMobil Corporation. Each student registered for the meeting will receive a complimentary ticket to attend. Use this time to network, ask questions and bring up issues directly to GSA leadership and ExxonMobil staffers, meet fellow students, and warm up for the meeting!

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ANNUAL Geoscience Educators Reception

Saturday, 8 Oct., 5–7 p.m.

The GSA Education Committee, the National Association of Geoscience Teachers (NAGT), the GSA Geoscience Education Division, Cutting Edge, the IRIS Consortium, the American Geological Institute (AGI), and UNAVCO would like to invite all educators to a relaxing forum for socializing, sharing ideas, and meeting other geoscience community members interested in education.

Appetizers and cash bar provided.

TICKETED FUNCTIONS

When you register for the meeting, don't forget to register for these special events at the same time. Tickets must be purchased in advance; due to food/beverage limitations, onsite ticket sales are restricted. Don't be excluded from the fun! All fees are in U.S. dollars.

Society of Economic Geologists (SEG) Awards

Dinner: Sat., 8 Oct., 6:30–10:30 p.m.
Professionals: \$50; students: \$30.

National Association of Geoscience Teachers (NAGT) and GSA Geoscience Education Division Awards

Luncheon: Sun., 9 Oct., 11:30 a.m.–1 p.m. \$40.

Association for Women Geoscientists (AWG) Breakfast and Awards Ceremony:

Mon., 10 Oct., 6:30–8:30 a.m.
Professionals: \$23; students: \$15.

GSA Environmental and Engineering Geology Division Luncheon and Awards Ceremony:

Mon., 10 Oct., 11:45 a.m.–2:30 p.m. \$40.

GSA History and Philosophy of Geology Division Luncheon, Business Meeting, and Awards Ceremony:

Mon., 10 Oct., noon–2 p.m. \$40.

GSA Hydrogeology Division Luncheon, Awards, and Business Meeting:

Tues., 11 Oct., 11:30 a.m.–3 p.m. \$40.

Geoscience Information Society (GSIS) Luncheon:

Tues., 11 Oct., noon–1:30 p.m.
Professionals: \$40, student/first-year GSIS Member \$25.

Minnesota Ground Water Association (MGWA) Outstanding Service Award Luncheon Honoring Otto Strack:

Tues., 11 Oct., noon–1:30 p.m. \$40.

Mineralogical Society of America (MSA) Awards Luncheon:

Tues., 11 Oct., 12:30–2:15 p.m. \$40.

Paleontological Society Reception Buffet:

Tues., 11 Oct., 5:30–8:30 p.m.
Professionals: \$45; students: \$10.

Joint Reception of MGPV with MSA and GS: Tues., 11 Oct., 5:45–7:30 p.m. Professionals: \$10; students: \$5.

GSA Planetary Geology Division 30th Anniversary Dinner and Celebration:

Tues., 11 Oct., 7–10 p.m. \$50.

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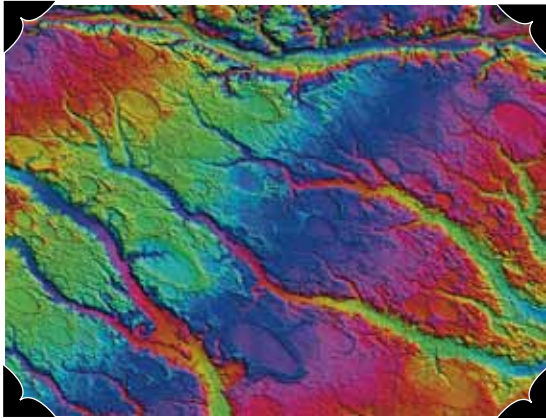
Call for Entries

THIRD ANNUAL

PHOTO EXHIBITION

Primary submission deadline: 19 August

Members of GSA and GSA's Associated Societies are invited to share their best images in the Third Annual Geological Society of America Photo Exhibition.



Abstract: Michael Davias, Carolina Bays



Geologic Processes: Ulrich Wortman, Aeolian Foresets

Categories

- 1. Regional Geology:** Landscapes, features, or geologic activity within the GSA North-Central Section region.
- 2. Abstract Images:** The patterns of geology at any scale, photomicrographs to satellite images.
- 3. Geologic Processes Past and Present:** Processes or features resulting from a specific process; for example: an erupting volcano or volcanic rocks that represent ancient eruptions, etc.
- 4. Iconic Landscapes:** Iconic geologic landscapes and features; for example: Grand Canyon, Death Valley, etc.

Process

Timeline: Please submit your .jpg files by 19 August. Winners will be notified by 31 August and must submit final files for printing by 15 September.

Images must be the work of the submitter and must be transmitted as .jpg files no larger than 1 MB. Larger files cannot be considered. Images and descriptions should be emailed to the contest managers at geosocphotos@gmail.com. Max: Two entries per category. By submitting image(s) to this contest and exhibition, the photographer provides consent to gratis use of images by GSA in calendars, slide shows, and promotional materials. Photographers with winning images who wish to participate in the exhibition must have their images printed by the contest's printer to maintain quality and uniformity for the exhibit. Winners should be prepared to support these costs at ~US\$35–\$60 per image hung.



Iconic Landscapes: Allison Pluda, Lower Falls, Yellowstone

Questions may be directed to Ellen Bishop, paleobishop@gmail.com; Marli Miller, millerm@uoregon.edu; and/or Steve Weaver, sweaver@coloradocollege.edu. This contest is open only to GSA members and members of GSA's Associated Societies.

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GUEST PROGRAM



Minneapolis, Minnesota, skyline at night. Photo by Greg Benz, <http://carbonsilver.com/blog>.

SEMINARS

All seminars take place in the Guest Hospitality Suite.

SUNDAY, 9–10 a.m.

Meet Minneapolis

Arts and adventure: That's what awaits you in Minneapolis. Nationally renowned dining experiences, beautiful sports venues, top-class theatre and museum attractions, and fashion-forward shopping define this city. We'll answer your questions and point out something new even to the experienced Minnesotan—all so you can experience the full richness the city has to offer!

MONDAY, 10–11 a.m.

Gifts from the North Star

"Gifts from the North Star" is an insightful look into how Minnesota and its people have shaped the world. Innovations from the University of Minnesota begin with beer, apple breeding (think Honeycrisp!), seat belts, and synthetic rubber and run all the way up to atomic energy, a beating heart and lungs in the laboratory, and the first heart transplant. Minnesota has also seen the conception of successful stage shows, including *Mister Roberts* and *The Lion King*. Hollywood icons who herald from Minnesota include James Arness, Peter Graves, Ann Southern, E.G. Marshall, Judy Garland, Richard Dean Anderson, and Jessica Lange, as well as writer/directors Joel and Ethan Cohen. *Presented by J.B. Eckert, local actor and historian.*

TUESDAY, 9–10 a.m.

Photo and Memory Celebration

Your life, your story, your way. Creative Memories, a St. Cloud, Minnesota, company, is committed to helping people enjoy the special moments, stories, and photos of their lives. Join Beth Gibson Lilja, photo and memory celebration coach for Creative Memories, as she offers expertise and encouragement to help you express yourself and tell your stories, one meaningful page at a time.

WEDNESDAY, 9–10 a.m.

Bounty from the Orchards (Minnesota Landscape Arboretum)

This unique arboretum experience offers a flavorful gathering with abundance from the earth. The University of Minnesota is known worldwide for its apple breeding program, and everyone will be an apple aficionado at the end of this experience. This presentation features apple varieties released by Arboretum scientists over the years—think Honeycrisp, Zestar, and Sweetango, to name a few. Participants will learn how scientists go about developing a new variety, including how a new apple gets its name. In addition, your group will receive take-home samples to conduct your own apple taste tests.

KIDDIECORP CHILDCARE

Sat.–Wed., 8–12 October • Minneapolis Convention Center

Registration deadline: 9 September • **Cost:** US\$7 per hour per child; 2-hour minimum • **Ages:** Six months to 12 years

Minimum and maximum enrollment requirements apply; we encourage you to sign up early.

KiddieCorp has provided high-quality programs to children at conventions, trade shows, and corporate events throughout the United States and Canada since 1986; GSA has worked with KiddieCorp since 2005.

Comments from GSA meeting attendees:

"Brilliant—thanks! So convenient and my child really enjoyed it."

"I really appreciate the service—it's great!!!"

"Very impressive staff, caring and professional."



For more information, contact GSA's meetings department at meetings@geosociety.org.

Child care services are a contractual agreement between each individual and the child care company. GSA assumes no responsibility for the services rendered.

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TOURS

All Annual Meeting attendees and guests are welcome to register for the following tours, running Sun.–Wed., 9–12 October. The prices for these tours cover transportation, professional tour guide fees, admission, and gratuities. Tours may be canceled if minimum attendance is not met, so please register early. We also recommend that you periodically check the meeting website, www.geosociety.org/meetings/2011/, for updates and news about these tours.

SUNDAY

101. **Guthrie Theatre Backstage Tour—Minnesota History Center with Lunch**

10:30 a.m.–3:30 p.m. US\$64; minimum 25.

This tour begins at the Guthrie Theatre, located in the historic Mills District on the banks of the Mississippi River in downtown Minneapolis. The original Guthrie Theatre opened on 7 May 1963 with a production of *Hamlet*, directed by Sir Tyrone Guthrie, the theater's founder. While the Guthrie Theater's mission and artistic excellence have remained constant, this updated 250,000-square-foot theatre center was inaugurated in June 2006.

Our behind-the-scenes tour of the new Guthrie Theatre promises to excite and surprise you. Discover the stunning and expanded features of the state-of-the-art facility, designed by French architect Jean Nouvel, and view unique building highlights and key architectural elements. We will also visit rehearsal rooms, workshops, dressing rooms, and the backstage area and learn about the underworld of stage elevators and trap doors.

Next we'll head to Saint Paul to visit the Minnesota History Center. An interactive museum with both permanent and changing exhibits, the Minnesota History Center hosts concerts, lectures, family days, and other special events. The building is also home to the Minnesota Historical Society library and archives, a research destination for schoolchildren, family historians, and academics.

While at the museum, we'll have lunch at Café Minnesota. The Café offers self-service dining, with a full grill and entrée, deli, and dessert stations. The food is exceptional!

102. **Aamodt's Apple Festival**

1:30–5 p.m. US\$35; minimum 25.

For three generations, the Aamodt family has nurtured the finest apples. You're invited to turn back the time to 1948 when the orchard was first planted and sample the good life on this picturesque farm.

At Aamodt's Apple Festival, you'll enjoy sweet and juicy Honeycrisp apples—a seasonal treat! You can also try the famous cider donuts, apple brats, and fresh apple cider. Jump on a hay wagon ride, explore the hay bale maze, visit the goat farm, and buy fresh apples.

Tour 102 continued...

Aamodt's is also the only apple orchard in Minnesota with a vineyard. Taste award-winning local wines, grown and produced on site.

MONDAY

103. **Twin Cities Highlights Tour**

1:30–4:30 p.m. US\$30; minimum 25.

Get ready to experience a sampling of what makes the Twin Cities—Minneapolis and St. Paul—so fantastic! The culture, attractions, restaurants, shops, entertainment, and recreational opportunities in Minneapolis are unsurpassed in the Midwest. First, we'll take in a view of the Minneapolis skyline. The contemporary skyscrapers, with their dazzling variety of colors, shapes, and sizes, herald the city's dynamic growth and vibrant, thriving lifestyle. We will explore the famous Nicollet Mall, the Skyway network, the Minneapolis Sculpture Garden, the Milwaukee Train Depot, Orchestra Hall, the television home of Mary Tyler Moore, and St. Anthony Falls, the city's birthplace.

Minnesota's oldest tourist attraction is Minnehaha Falls, where the 22-mile Minnehaha Creek, which flows from Lake Minnetonka through the western suburbs of Minneapolis and into the city, meets the Mississippi River. The 53-foot falls were immortalized in Henry Wadsworth Longfellow's *Song of Hiawatha* and are visited by thousands of tourists and locals every year.

Saint Paul—Minnesota's capital city—is a contrast of old-world charm, with magnificent Victorian and art deco reminders of the past situated among sleek, modern skyscrapers. We will explore Rice Park, Ordway Center for the Performing Arts, Landmark Center, the Children's Museum, Mickey's Diner, the Fitzgerald Theater, Minnesota History Center, and the Minnesota State Capitol. We'll also visit the magnificent Cathedral of Saint Paul, the fourth largest cathedral in the United States. Built in the classical Renaissance style, the cathedral dome is modeled after St. Peter's Basilica.

We'll also drive along Summit Avenue, one of the longest stretches of virtually uninterrupted Victorian architecture in the United States. This monumental boulevard of homes, churches, synagogues, and schools would not have been uncommon in the nineteenth century, but in most American cities, these thoroughfares have completely lost their character to progress. Some homes to note along the way are the James J. Hill House, the former home of F. Scott Fitzgerald, and the Governor's Mansion.

TUESDAY

104. **Stillwater—Birthplace of Minnesota**

10:15 a.m.–4:15 p.m. US\$59; minimum 25.

Located on the St. Croix River, Stillwater is Minnesota's oldest town, the birthplace of the Minnesota Territory in 1849. Stillwater is steeped in history, architectural gems, and beautiful natural surroundings.

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Tours *continued*

For more than 50 years, lumbermen dominated the St. Croix River with camps, mills, log rafts, and steamboats—making Stillwater the Queen City of the river. The hills of Stillwater provided escape from the industrial and commercial riverfront, and this is where the lumbermen, bankers, riverboat men, and mill workers built their homes. The diversity of the population created diversity in home architecture: Queen Anne, Greek Revival, Second Empire, Stick Style, Shingle Style, Neoclassicism, Bungalow, Italianate, Craftsman, and Prairie.

During the motorcoach tour, our guide will provide anecdotes and stories to illuminate the lives of the enchanting river town's immigrants and entrepreneurs. Mansions built by wealthy lumber barons, beautiful old churches on the "Street of Spires," and landmarks on the National Register of Historic Places will all be pointed out along the way.

Next, we'll board a replica of an 1890s paddlewheel riverboat to enjoy the scenic St. Croix River. A delicious buffet lunch will be served on board.

After lunch, you'll be able to walk about the shops on Stillwater's historic streets. Discover original works of art, jewelry, pottery, eclectic gifts/crafts, books, gourmet utensils, wine, clothing, home furnishings, and antiques.

WEDNESDAY

105. **Gangster Tour**

1:30–4:30 p.m. US\$39; minimum 25.

Baby Face Nelson, Machine Gun Kelly, Kid Caan, Ma Barker—these are names that Americans, especially Minnesotans (St. Paulites in particular) became all too familiar with during prohibition. Alvin "Creepy" Karpis once said, "If you were looking for a guy you had not seen in a few months, you usually thought of two places: Prison or St. Paul."

During the prohibition era, things were not always what they seemed—St. Paul was more than a quiet, picturesque river town! We'll see the spot where Dillinger had a shoot-out with St. Paul police, pass the former most-exclusive speakeasy in the area, and visit the Landmark Center, the site of the famous gangster trials (J. Edgar Hoover personally escorted public enemy no. 1 Karpis through the doors for his trial). The restored

federal courts building still commands respect. Originally conceived as a post office, custom house, and courthouse, the building eventually became the headquarters for all federal offices in the upper Midwest. This grand edifice has been honored with numerous awards for its architectural genius.

Next, we'll visit the Wabasha Street Caves. The caves were dug in the early 1800s out of a layer of rock known as St. Peter Sandstone. The sand that forms this rock was the beach of a warm inland sea over 400 million years ago. During our cold Minnesota winters, it is reassuring to see this remnant of a tropical Minnesota. In the 1800s, a mushroom-growing business was established in the caves, then a nightclub and restaurant opened in the 1930s; if you listen carefully, you can still hear the music of the Dorsey Brothers, Cab Calloway, and others. The caves even include a "Gangster Gallery" of some of its more notorious past visitors.

Also while in St. Paul, our guide will provide commentary on Rice Park, Ordway Center for the Performing Arts, Children's Museum, Mickey's Diner, and the Fitzgerald Theater, home to Garrison Keillor's *Prairie Home Companion*.

Let us help you arrange space for your event

Space Requests

Deadline: 7 June 2011

Q: What types of events should be submitted?

A: All events that require a meeting room and that you would like listed in the meeting program book

Q: What information do you need in order to submit an event?

A: Just the information needed to reserve the right size room.

Q: Why do I have to request my space so early?

A: Space is assigned on a first-come, first-served basis.



www.geosociety.org/meetings/2011/ePlan.htm

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DEVIL
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Jon Karr
jkarr@duke.edu
919-660-7418



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LAB WEBSITE: www.biology.duke.edu/jackson/devil/



INTERNATIONAL BOOK SERIES

While supplies last!

Metamorphic Conditions along Convergent Plate Junctions: Mineralogy, Petrology, Geochemistry, and Tectonics—The J.G. Liou Volume

edited by W.G. Ernst and Douglas Rumble III, 2008

This book assembles diverse papers on mineralogy, petrology, geochemistry, and tectonics produced for a symposium held at Stanford University on metamorphic conditions along convergent plate junctions. The scientific contributions, honoring Professor John G. Liou on the occasion of his retirement from the regular Stanford faculty, mirror some of "Louie's" seminal scientific contributions in experimental mineralogy, low-grade and high- to ultrahigh-pressure (HP-UHP) metamorphic petrology-geochemistry, and plate tectonics of subducted Circumpacific and collisional terranes. The book, which emphasizes HP-UHP recrystallization, is divided into a lead section concerned with overarching principles, followed by topical studies of important high- and ultrahigh-pressure terranes around the world, including (1) east-central China, (2) western China–western Himalayas, (3) the south-western Pacific, (4) northern Kazakhstan and the southern Ural Mountains, (5) the western Alps and central European massifs, (6) western Norway–east Greenland, (7) southwestern North American terranes, and (8) central Korea–southwestern Japan.

IBS010, 864 p., ISBN 9780978771003, now \$25.00 (Sorry, no additional discounts.) **REDUCED PRICE!**

\$15.00 each

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Phase Relations, High-Pressure Terranes, P-T-Ometry, and Plate Pushing: A Tribute to W.G. Ernst

edited by J.G. Liou and Mark Cloos, 2006
IBS009, 672 p., ISBN 0966586999

The George A. Thompson Volume: The Lithosphere of Western North America and Its Geophysical Characterization

edited by Simon L. Klempner and W.G. Ernst, 2003
IBS007, 544 p., ISBN 0966586964

Ultra-High Pressure Metamorphism and Geodynamics in Collision-Type Orogenic Belts

co-edited by W.G. Ernst and J.G. Liou, 2000
IBS004, 293 p., ISBN 096658693X

Planetary Petrology and Geochemistry:

The Lawrence A. Taylor 60th Birthday Volume
co-edited by G.A. Snyder, C.R. Neal, and W.G. Ernst, 1999
IBS002, 277 p., ISBN 0966586913

Integrated Earth and Environmental Evolution of the Southwestern U.S.

co-edited by W.G. Ernst and C.A. Nelson, 1998
IBS001, 502 p., ISBN 0966586905

\$10.00 each

Sorry, no additional discounts.

Frontiers in Geochemistry: Konrad Krauskopf Volume 1 (Global Inorganic Geochemistry) and Volume 2 (Organic, Solution, and Ore Deposit Geochemistry)

edited by W.G. Ernst, 2002
Volume 1: IBS005, 324 p., ISBN 0966586948
Volume 2: IBS006, 265 p., ISBN 0966586956

Tectonic Studies of Asia and the Pacific Rim: A Tribute to Benjamin M. Page (1911–1997)

co-edited by W.G. Ernst and R.G. Coleman, 2000
IBS003, 328 p., ISBN 0966586921



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REGISTRATION

Early registration deadline: 6 September

Cancellation deadline: 12 September

www.geosociety.org/meetings/2011/

FEES (all fees are in U.S. dollars)

	Early June–6 Sept.		Standard/On-Site after 6 Sept.	
	Full Mtg.	One day	Full Mtg.	One day
Prof. Member	\$330	\$215	\$410	\$245
Prof. Member 70+	\$255	\$155	\$340	\$175
Prof. Nonmember	\$430	\$285	\$510	\$315
Student Member	\$109	\$70	\$144	\$80
Student Nonmember	\$149	\$90	\$184	\$100
High-School Student	\$40	n/a	\$40	n/a
K–12 Professional	\$50	n/a	\$60	n/a
Field Trip/Short Course only*	\$40	n/a	\$40	n/a
Guest or Spouse*	\$85	n/a	\$90	n/a
Low Income Country [§]	50%	n/a	50%	n/a

GSA will provide each meeting registrant* with an electronic copy (CD-ROM) of the *Abstracts with Programs*, which includes the 2011 Section Meeting abstracts. The *Abstracts with Programs* book purchased along with meeting registration will be provided when you pick up your badge on-site.

*Field trip or short course only & guest or spouse registrants excluded.

[§]Participants from countries classified as “Low or Lower Middle Income Economies” by the World Bank need only pay 50% of their registration category fee for full-meeting or one-day registration. Registrants from these economies will not be able to register online, but a downloadable hard-copy version of the registration form will be available.

TICKETED FUNCTIONS

Don't forget to sign up for field trips, short courses, special tours (see p. 17), luncheons, and other ticketed events when you register.

GSA Student Travel Grants

Application deadline: 6 September

Application forms will be live early this month at www.geosociety.org/meetings/2011/grants.htm.

Please note: Applying for a travel grant does not register you for the meeting—you must register at www.geosociety.org/meetings/2011/reg.htm BEFORE you can apply for a grant. Notification of grant status will be made by e-mail. Those receiving grants must pick up their checks in person (with photo ID) in Minneapolis. Checks that are not picked up will be voided.

CONTRIBUTE TO THE GSA STUDENT TRAVEL FUND!

Your donation to the student travel fund when you register will truly make a positive difference in the lives of the next generation of geoscientists. One-hundred percent of the contributions received, along with US\$1000 contributed by the GSA Foundation, will go to help fund student travel.

Students: GSA's Sections administer the Student Travel Fund. For eligibility requirements, please go to your Section's website or contact the Section secretary directly.

Cordilleran:

www.geosociety.org/sections/cord/travelGrants.htm

Rocky Mountain:

www.geosociety.org/sections/rm/

North-Central:

www.geosociety.org/grants/ncgrant.htm

South-Central:

www.geosociety.org/sections/sc/

Northeastern:

www.geosociety.org/grants/negrant.htm

Southeastern:

www.geosociety.org/sections/se/students.htm

International: www.geosociety.org/sections/International/travelGrants.htm. **Note:** You do not need to be a student to apply for a grant through the International Section. The International Section application deadline is **1 August**.



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GSA DIVISION GRANTS FOR STUDENT TRAVEL

ARCHAEOLOGICAL GEOLOGY DIVISION

Application deadline: 20 September

Information: <http://rock.geosociety.org/arch/>

Application form: <http://rock.geosociety.org/arch/Awards/studentform.htm>

The Richard Hay Student Paper/Poster Award is a US\$650 travel grant provided by the Archaeological Division to a student member presenting a paper or poster at the annual meeting. The grant is competitive and will be awarded based on the scientific merit of the research topic and the clarity of an expanded abstract.

GEOSCIENCE EDUCATION DIVISION

Application deadline: 1 August

The Geoscience Education Division (GED) is offering several travel grants of up to US\$250 to student members who are presenting work in geoscience education at the annual meeting. Grants will be awarded based on merit and financial need. To apply, send the following as a single email attachment to Sadredin (Dean) C. Moosavi at moosavi@charter.net: (1) confirmation of your standing as a student member of the GED (member number); (2) a copy of your accepted abstract; (3) a current CV (limit 2 pages); and (4) a brief itemized budget and statement of your financial needs, including all other sources of funding. Notification of grant status will be made prior to the meeting registration deadline; awards will be made following confirmation of attendance. Smaller grants are also available for students to attend field trips and workshops.

PLANETARY GEOLOGY DIVISION

Application deadline: 24 September

Application form: http://rock.geosociety.org/pgd/awards.html#_travel

The Planetary Geology Division (PGD) is offering two travel grants of US\$500 each to help defray costs for GSA/PGD student members traveling to the annual meeting to present first-authored papers. Please register for the meeting before applying for the grant and then submit a completed travel grant application, current CV, and a short justification (~300–500 words) for why travel funding is needed to Bob Anderson at robert.c.anderson@jpl.nasa.gov. If you are a co-convenor of a session, also give that session's title. You will be notified of your application status in late September, and checks will be presented at the meeting, following your talk or poster.

Information for International Attendees

Most travelers to the United States must hold a valid visa as well as a passport that is valid for six months longer than the intended visit. The visa application process may take several months.

We Recommend...

1. Review your visa status, and find out if you need a U.S. visa or a renewal.
2. An interview appointment is required for visa application at all embassies and consulates. Visit the website of the embassy or consular section where you will apply for your visa to find out how to schedule an interview appointment, learn what fees you may need to pay, and find additional instructions.
3. The wait time for this appointment may be as long as three months (varies by location). Processing time may take an additional month or more. Check the U.S. State Department's website, http://travel.state.gov/visa/temp/wait/wait_4638.html, for specific wait times.
4. Most international visitors are required to have a complete set of fingerprints taken along with a digital photograph to verify identity at consulates as well as the port-of-entry. Canadians are currently exempt from this program.
5. Visitors from countries participating in the Visa Waiver Program must register in the Electronic System for Travel Authorization (ESTA) before entering the country. Check the U.S. State Department's website, http://travel.state.gov/visa/temp/without/without_1990.html, for more information.

International Section Travel Grants

Application deadline: 1 August

GSA's International Section is offering international travel grants to assist with the participation of international scientists and students in the 2011 GSA Annual Meeting. Funds are limited; grants will not cover the full cost of attending the meeting but are intended to help offset the combined cost of registration, housing, and travel.

To apply, please go to www.geosociety.org/Sections/International/travelGrants.htm. If you have questions, please contact Joann Stock, chair of the International Section, at jstock@gps.caltech.edu.



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TRAVEL & TRANSPORTATION

AIR TRAVEL

Minneapolis–St. Paul International Airport (MSP; www.mspairport.com) is ~15 miles southeast of downtown Minneapolis. Twelve commercial passenger airlines service MSP:

Terminal 1–Lindbergh	Terminal 2–Humphrey
Air Canada	Delta Airlines Air Tran Airways
Alaska Airlines	Frontier Airlines Icelandair
American Airlines	United Airlines Southwest Airlines
Continental Airlines	US Airways Sun Country Airlines

TRANSPORTATION OPTIONS TO/FROM MSP

The Terminal 1–Lindbergh ground transportation booth on Level T (tram level) is staffed seven days a week from 7 a.m. to 11:30 p.m. to provide information, directions, and other assistance to travelers.

Light Rail

Light Rail Transit (LRT) trains stop at both terminals and connect travelers to 17 other destinations, including downtown Minneapolis. Trains run every 10–15 minutes during the day, with a lighter schedule at night. The ride to downtown Minneapolis takes ~25 minutes. Go to metrotransit.org for a complete light rail schedule, fare breakdown, and map. All light rail stations are fully accessible.

The **Terminal 1–Lindbergh** light rail station is located below the Transit Center, between the blue and red parking ramps. Take the tram (Level T, one level below baggage claim) to the Transit Center and follow the signs to the underground LRT station.

The **Terminal 2–Humphrey** light rail station is on the north side of the orange parking ramp. From Level 1 near Ticketing, take the elevator or escalator up to the orange ramp skyway. Follow the signs to the LRT station, and take the escalators or elevators down one level to the station platform.

Fares: Tickets are sold at ticket machines at the rail stations and run between US\$1.75–\$2.25, depending on the time of day. Children 5 and under ride free (limit 3) when accompanied by a paid fare. *No ticket is needed to travel between airport terminal stations.*

Taxis

Terminal 1–Lindbergh: Taxi service is accessible via the Tram Level (Level T). Signs will direct you one level up to the taxi starter booth, where airport staff can assist you in obtaining a taxi.

Terminal 2–Humphrey: Taxi service is located on the ground level of the purple parking ramp, directly across from the terminal building.

Fares average US\$37–\$47 to downtown Minneapolis (up to US\$2.50/mile + US\$4 airport access fee).

Bus Service

City bus service (Route 54; metrotransit.org) picks up and drops off outside the Terminal 1–Lindbergh Transit Center on Level 1 of the blue and red parking ramps. From the Lindbergh Terminal, access the Transit Center via the tram on Level T or via the Concourse Connector between concourses C and G. There is no bus pick up at Terminal 2–Humphrey; passengers must take light rail transit (free between terminals) to the Lindbergh Terminal to access city buses.

Shuttle Service

SuperShuttle offers shared ride service to and from the airport (www.supershuttle.com/en/MSPAairportShuttleMinneapolis.html). Shuttles operate daily, serving all downtown hotels to/from the airport for US\$15 each way or US\$24 round-trip (save US\$12 on the round-trip by using discount code J855J when reserving). Use J855J to also save US\$5 each way on private sedan/SUV trips to and from the airport. Advance reservations are highly recommended.

The SuperShuttle ticket counter is in the **Terminal 1–Lindbergh** ground transport center, accessible via the terminal's Tram Level. Follow the signs to the appropriate escalator or elevator up. Travelers arriving at **Terminal 2–Humphrey** can call for pick up at the Super Shuttle kiosk in the ground transport center, located on Level 1 of the purple parking ramp across from the terminal building.

Car Rental

Terminal 1–Lindbergh: Rental car counters are located on the second and third levels between the blue and red parking ramps, which can be reached via tram.

Terminal 2–Humphrey: Rental car counters are located in the ground transport center on the ground level of the purple parking ramp, directly across from the terminal building.

Enterprise Rent-a-Car, www.enterprise.com, +1-800-593-0505: Save 5% when you make your reservation online under “Business Rentals.” The Enterprise Business Rental Program number is 46W2750, and GSA’s pin is “GEO.”

Carbon Offset Donation



We Have The Power
ColoradoCarbonFund.org

GSA Foundation Energy Fund

The Geological Society of America encourages attendees to offset travel emissions via the Geological Society of America Foundation’s Energy Fund. All donations go toward reducing GSA’s HQ footprint on the environment. To participate, please check the box on your registration form, and we’ll collect US\$25 for the fund. Learn more at www.geosociety.org/meetings/2011/reg.htm#carbon.

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GSA'S ASSOCIATED SOCIETIES

(AS OF 30 APRIL 2011)

GSA is proud to partner with the following societies in presenting the best science during our meeting. We invite these Associated Society members to register for the annual meeting at the GSA member rate.

AASP – The Palynological Society	Geological Society of Australia (GSAus)	National Cave and Karst Research Institute (NCKRI)
American Association of Petroleum Geologists (AAPG)	Geological Society of London (GSL)	National Earth Science Teachers Association (NESTA)
American Geophysical Union (AGU)	Geological Society of South Africa (GSSA)	National Ground Water Association (NGWA)
American Institute of Professional Geologists (AIPG)	Geologische Vereinigung (GV)	Nepal Geological Society (NGS)
American Quaternary Association (AMQUA)	Geoscience Information Society (GSIS)	Paleontological Research Institution (PRI)
American Rock Mechanics Association (ARMA)	Geoscience Society of New Zealand (GSNZ)	Paleontological Society (PS)
American Society of Limnology and Oceanography (ASLO)	Groundwater Resources Association of California (GRA)	Seismological Society of America (SSA)
American Water Resources Association (AWRA)	History of the Earth Sciences Society (HESS)	Sigma Gamma Epsilon (SGE)
Asociación Geológica Argentina (AGA)	International Association of Emergency Managers (IAEM)	Sociedad Geológica Mexicana A.C. (SGM)
Association for Women Geoscientists (AWG)	International Association of GeoChemistry (IAGC)	Società Geologica Italiana (SGI)
Association of American State Geologists (AASG)	International Association of Hydrogeologists (IAH)	Society of Economic Geologists (SEG)
Association of Earth Science Editors (AESE)	International Medical Geology Association (IMGA)	Society of Environmental Geochemistry & Health (SEGH)
Association of Environmental & Engineering Geologists (AEG)	Karst Waters Institute (KWI)	Society for Sedimentary Geology (SEPM)
Association of Geoscientists for International Development (AGID)	Microbeam Analysis Society (MAS)	Society for the Preservation of Natural History Collections (SPNHC)
The Clay Minerals Society (CMS)	Mineralogical Association of Canada (MAC)	Society of Vertebrate Paleontology (SVP)
Colorado Scientific Society (CSS)	The Mineralogical Society (MS)	Soil Science Society of America (SSSA)
Council on Undergraduate Research, Geosciences Division (CUR)	Mineralogical Society of America (MSA)	
Cushman Foundation (CF)	Minnesota Ground Water Association (MGWA)	
Environmental and Engineering Geophysical Society (EEGS)	National Association for Black Geologists and Geophysicists (NABGG)	
Geochemical Society (GS)	National Association of Geoscience Teachers (NAGT)	
Geological Association of Canada (GAC)	National Association of State Boards of Geology (ASBOG®)	
Geological Society of Africa (GSaf)		

Partners in pursuit of mutual goals to advance the geosciences, enhance the professional growth of members, and promote the geosciences in the service of humanity.



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FIELD TRIPS

Early October is prime field season in the upper Midwest. Our diverse slate of field trips spans a geologically broad range of topics, including the Precambrian geology of the southern Canadian Shield; the economic geology of the Lake Superior region; Phanerozoic strata in Minnesota, Wisconsin, Iowa, and North Dakota; glacial geology; hydrogeology and limnology; undergraduate and K–12 geoscience field education; the geology and hydrology of the Twin Cities metro area; geology by bicycle; terroir; geoaerology; biogeochemistry; and tours of area research labs and vessels.

This year's field trip co-chairs are Jim Miller, mille066@umn.edu; George Hudak, ghudak@d.umn.edu; Chad Wittkop, chad.wittkop@mnsu.edu; and Patrick McLaughlin, pimclaughlin@wisc.edu. Please feel free to contact them or GSA's field trip coordinator, Beth Engle, bengle@geosociety.org, for more information. If you have questions about a particular trip, please contact the trip leaders directly (see www.geosociety.org/meetings/2011/fieldtrips.htm). Be sure to sign up for your trip(s) when you register to ensure that you'll be a part of the action!

All trips begin and end at the Minneapolis Convention Center unless otherwise indicated. Trip fees include transportation during the trip; other services, such as meals and lodging, are noted with each trip by the following: B—breakfast; L—lunch; R—refreshments; D—dinner; ON—overnight lodging. Some trips cross into Canada; participants should carry valid passports. *All fees are in U.S. dollars.*

Premeeting

401. **Classic Volcanogenic Massive Sulfide Deposits of the Southern Canadian Shield.** Tues.–Sat., 4–8 Oct. US\$858 (B, L, R, 5ON). Cosponsors: *Precambrian Research Center; Society of Economic Geology*. Leaders: George J. Hudak, Univ. of Minnesota–Duluth; Mark Smyk. This trip begins in Thunder Bay, Ontario, Canada, and ends in Minneapolis; **passports required.**
402. **Structural Geology of the Subprovince Boundaries in the Archean Superior Province of Northern Minnesota and Adjacent Ontario.** Wed.–Sat., 5–8 Oct. US\$484 (L, R, 3ON). Cosponsor: *GSA Structural Geology and Tectonics Division*. Leaders: Basil Tikoff, Univ. of Wisconsin–Madison; Robert L. Bauer; Dyanna M. Czeck; Peter Hudleston. This trip will cross into Canada; **passports required.**
403. **An Excursion to the Classic Bedrock Localities of Northern Minnesota with a Focus on Teaching and Learning in the Field.** Thurs.–Fri., 6–7 Oct. US\$245 (B, L, D, R, 1ON). Cosponsor: *National Association of Geoscience Teachers*. Leaders: Karl R. Wirth, Macalester College; Dexter Perkins; Alison Stokes.
404. **Cu-Ni-PGE Deposits of the Duluth Complex.** Thurs.–Sat., 6–8 Oct. US\$370 (B, L, D, R, 2ON). Leaders: Mark J. Severson, Natural Resources Research Institute, Univ. of Minnesota–Duluth; Richard Patelke; David Oliver; Kevin Boerst; Neil Smith; Al Samis; Harold Noyes; Chris White; Dean M. Peterson.
405. **Pedagogical Strategies for Introductory Geology Field Trips through an Examination of the Mississippi River Valley in the Twin Cities.** Fri., 7 Oct. US\$75 (L, R). Cosponsor: *National Association of Geoscience Teachers*. Leaders: Kate S. Pound, St. Cloud State Univ.; Karen M. Campbell; Lee Schmitt.
406. **3.5 Billion Years of Geologic History: A Teachers' Guide to the Rocks of Southern Minnesota.** Fri.–Sat., 7–8 Oct. US\$215 (B, L, D, R, 1ON). Cosponsor: *GSA Geoscience Education Division*. Leader: Sadredin C. Moosavi, Univ. of Massachusetts–Dartmouth.
407. **Late Paleoproterozoic Deformational, Metamorphic, and Magmatic History of East-Central Minnesota.** Fri.–Sat., 7–8 Oct. US\$232 (B, L, R, 1ON). Leaders: Terrence J. Boerboom, Univ. of Minnesota; Daniel Holm; W.R. Van Schmus.
408. **Southern Outlet and Basin of Glacial Lake Agassiz.** Fri.–Sat., 7–8 Oct. US\$181 (L, R, 1ON). Cosponsors: *GSA Divisions: Limnogeology; Quaternary Geology and Geomorphology*. Leaders: Timothy G. Fisher, Univ. of Toledo; Allan C. Ashworth; Ken Lepper; Howard Cory Hobbs.
410. **Classic Precambrian Geology of Northeastern Minnesota.** Fri.–Sat., 7–8 Oct. US\$222 (L, R, 1ON). Leaders: Mark A. Jirsa, Univ. of Minnesota; John C. Green.
411. **The History of Glacial Lake Benson.** Fri.–Sat., 7–8 Oct. US\$232 (B, L, D, R, 1ON). Cosponsor: *GSA Limnogeology Division*. Leaders: James F.P. Cotter, Univ. of Minnesota–Morris; Heather E. Arends; Tammy M. Rittenour.
412. **A Glacial Record Spanning the Pleistocene in Southern Minnesota.** Fri.–Sat., 7–8 Oct. US\$214 (L, D, R, 1ON). Cosponsor: *GSA Quaternary Geology and Geomorphology Division*. Leaders: Carrie Jennings, Univ. of Minnesota; Alan R. Knaeble; Barbara A. Lusardi; Gary N. Meyer; Terry Bovee.
413. **Groundwater and Surface Water of the Northern Highlands Lake District of Northern Wisconsin: 30 Years of Research in the Trout Lake Watershed.** Fri.–Sat., 7–8 Oct. US\$207 (B, L, D, R, 1ON). Cosponsors: *North Temperate Lakes LTER/Univ. of Wisconsin Center for Limnology; Univ. at Buffalo; USGS Wisconsin Water*

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The University of Minnesota's research vessel *Blue Heron* plies the waters of the North American Great Lakes; photo courtesy Brett Groehler. See Field Trip 414.

- Science Center*. Leaders: Christopher Lowry, Univ. at Buffalo; Randall J. Hunt; John Walker; Emily H. Stanley; Noah Lottig.
414. **Geology under the Surface: Lake Superior and the Research Vessel *Blue Heron***. Sat., 8 Oct. US\$105 (L, D). Leaders: Richard D. Ricketts, Univ. of Minnesota–Duluth; Steven Colman; Thomas C. Johnson.
415. **Cycling the Mississippi River Gorge**. Sat., 8 Oct. US\$68 (B, L, R). Cosponsors: *Cities of Minneapolis and Saint Paul; Fort Snelling State Park; Freewheel Bike Co-op; Mill City Museum; Minnesota Historical Society; National Park Service; Nice Ride Minnesota; Subaru of America; Trek Bicycles; Minnesota Ground Water Association; Univ. of Minnesota–St. Anthony Falls Laboratory and Dept. of Geology & Geophysics; U.S. Army Corps of Engineers*. Leaders: Scott C. Alexander, Univ. of Minnesota; Kent Kirkby; Rebecca Clotts.
416. **Southeastern Minnesota Karst Hydrogeology: New Insights from Data Loggers, Tracing, LiDAR, and Hydrophysics**. Sat., 8 Oct. US\$113 (L, D, R). Cosponsors: *Driftless Area Initiative; Minnesota Ground Water Association; National Cave and Karst Research Institute; National Speleological Society; Trout Unlimited; GSA Divisions: Hydrogeology, Geobiology & Geomicrobiology, Environmental and Engineering Geology, Geology and Society, Quaternary Geology and Geomorphology*. Leaders: E. Calvin Alexander, Univ. of Minnesota; Jeffrey A. Green; Anthony Runkel; Katherine J. Logan.
417. **Geology of the Ice Age Trail**. Sat., 8 Oct. US\$91 (L, R). Leaders: David M. Mickelson, Univ. of Wisconsin–Madison; Mark D. Johnson; Kent M. Syverson.

418. **Application of LiDAR and Geophysics to Archeological Investigations in the Upper Mississippi River Valley**. Sat., 8 Oct. US\$92 (L, R). Leaders: Ronald C. Schirmer, Minnesota State Univ.–Mankato; Chad Wittkop.
419. **Flaming Meteors, Dark Caves, and Raging Waters—Geological Curiosities of Western Wisconsin**. Sat., 8 Oct. US\$84 (L, R). Leaders: Jean Cunningham, Crystal Cave Inc.; William S. Cordua; S. Blaze Cunningham; Holly A.S. Dolliver.
420. **St. Anthony Falls Laboratory: Flumes, Experimental Landscapes, and a Waterfall**. Sat., 8 Oct. US\$70 (L). Cosponsors: *National Center for Earth-Surface Dynamics; St. Anthony Falls Laboratory; Univ. of Minnesota College of Science and Engineering*. Leaders: Chris Paola, Univ. of Minnesota; Karen M. Campbell.
421. **Interpreting Genetic Origins of Landform Sediment Assemblages within the Upper Mississippi River Valley and Tributaries in the Twin Cities Area of Minnesota**. Sat.–Sun., 8–9 Oct. US\$200 (L, D, R, 1ON). Cosponsors: *Foth Infrastructure & Environment LLC; GSA Divisions: Archaeological Geology; Quaternary Geology and Geomorphology*. Leaders: Curtis M. Hudak, Foth Infrastructure & Environment LLC; Edwin R. Hajic; Jeffrey J. Walsh.

During the Meeting

422. **The Wines and Terroir of Southeastern Minnesota**. Tues., 11 Oct. US\$120 (L, R). Leaders: James F.P. Cotter, Univ. of Minnesota; Morris Wanda Hanlon.
423. **A Hidden Geologic Treasure: A River, A Waterfall, A City: A Field Trip for Undergraduate and Graduate Students**. Tues., 11 Oct. US\$70 (L). Leaders: Karen M. Campbell, Univ. of Minnesota; Stephanie Day; Laura Triplett.
424. **Subterranean Twin Cities**. Tues., 11 Oct. US\$62 (R). Cosponsors: *Minnesota Ground Water Association; GSA Divisions: Environmental and Engineering Geology; Hydrogeology*. Leader: Greg Brick, Univ. of Minnesota.
425. **The Minneapolis Chain of Lakes by Bicycle: Glacial History, Human Modifications, and Paleolimnology of an Urban Natural Environment**. Tues., 11 Oct. US\$67 (R). Cosponsor: *GSA Limnogeology Division*. Leaders: Marylee Murphy, Water Resources, Three Rivers Park District; Amy Myrbo; Valerie L. Stanley.
426. **Kirk Bryan Field Trip: Holocene Landscape Evolution and Erosional Processes in the Le Sueur River, Central Minnesota**. Wed., 12 Oct. US\$93 (L, R). Cosponsor: *GSA Quaternary Geology and Geomorphology Division*. Leaders: Karen Gran, Univ. of Minnesota–Duluth; Patrick Belmont; Carrie Jennings; Chad Wittkop.

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Glacial Lake Duluth strandline, Carlton County, Minnesota; photo courtesy Andy Breckenridge.

427. **Springs and Waterfalls of the Twin Cities.** Wed., 12 Oct. US\$62 (R). Cosponsors: *Minnesota Ground Water Association*; *GSA Hydrogeology Division*. Leader: Greg Brick, Univ. of Minnesota.

Postmeeting

429. **Crustal Evolution of Archean Rocks from the Minnesota River Valley: Geologic, Geochronologic, and Isotopic Constraints.** Wed.–Fri., 12–14 Oct. US\$272 (L, R, 2ON). Leaders: Robert L. Bauer, Univ. of Missouri; Marion E. (Pat) Bickford; David L. Southwick; Aaron Satkoski; Scott Samson.
430. **The Baraboo District—An American Classic.** Wed.–Fri., 12–14 Oct. US\$262 (L, R, 2ON). Leaders: L. Gordon Medaris, Univ. of Wisconsin–Madison; Robert H. Dott; John Craddock; Stephen Marshak.
431. **Distal Signatures of Late Ordovician Oceanic Anoxia—New Data and Interpretations of a Classic Eperic Ramp Transect.** Wed.–Sat., 12–15 Oct. US\$418 (L, R, 3ON). Cosponsor: *Great Lakes Section SEPM*. Leaders: Patrick McLaughlin, Wisconsin Geological and Natural History Survey; Norlene Emerson; Brian J. Witzke; Bryan Sell; Poul Emsbo.
432. **Stratigraphy, Physical Volcanology, Hydrothermal Alteration, and Mineralization Associated with the Neoproterozoic Vermilion Greenstone Belt, NE Minnesota.** Wed.–Sat., 12–15 Oct. US\$429 (L, R, 3ON). Cosponsors: *Precambrian Research Center at the Natural Resources Research Institute, Univ. of Minnesota–Duluth*. Leaders: George J. Hudak, Univ. of Minnesota–Duluth; John Heine.
433. **The North Shore Volcanic Group: A 9-km-Thick Plateau Lava Sequence in the Mesoproterozoic Midcontinent Rift System.** Wed.–Sat., 12–15 Oct. US\$400 (B, L, R, 3ON). Leaders: John C. Green, Univ. of Minnesota–Duluth (emeritus); Terrence J. Boerboom; Thomas J. Fitz; Susanne T. Schmidt.
434. **Late Glacial History of the Western Lake Superior Region.** Wed.–Sat., 12–15 Oct. US\$373 (B, L, R, 3ON). Cosponsor: *GSA Limnogeology Division*. Leaders: Howard Cory Hobbs, Univ. of Minnesota; Andy J. Breckenridge; Brian A.M. Phillips; Fred J. Dean.
435. **Hydrostratigraphy of a Fractured Urban Aquitard.** Thurs., 13 Oct. US\$85 (L, R). Leaders: Anthony Runkel, Minnesota Geological Survey, Univ. of Minnesota–Twin Cities; Julia Anderson; Robert G. Tipping; Kelton Barr; E. Calvin Alexander.
436. **Enhancing Access to Fieldwork: A Participatory Exploration of Cave Geology for Mobility-Impaired Students.** Thurs., 13 Oct. US\$220 for self; US\$234 for self and personal assistant (L, R). Cosponsors: *International Advisory for Geoscience Diversity*; *National Cave and Karst Research Institute*; *National Speleological Society*; *GSA Geoscience Education Division*. Leaders: Christopher Atchison, Ohio State Univ.; Brett Gilley; Alison Stokes; Dianne Gillespie.
437. **Retreat of the Laurentide Ice Sheet: Landforms, Sediments, Timing.** Thurs.–Fri., 13–14 Oct. US\$290 (B, L, R, 1ON). Leaders: Phillip Larson, Duluth Metals Ltd.; Howard D. Mooers; Alan R. Knaeble. This trip ends in Silver Bay, Minnesota, USA.



Neoproterozoic Soudan banded iron formation, NE Minnesota; photo courtesy Mark Jirsa.

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438. **Groundwater–Surface-Water Exchange and Geologic Setting of Northern Minnesota’s Lakes, Wetlands, and Streams: Modern-Day Relevance of Tom Winter’s Legacy.** Thurs.–Fri., 13–14 Oct. US\$188 (L, R, 1ON).
Cosponsors: *GSA Divisions: Hydrogeology; Limnogeology; Quaternary Geology and Geomorphology.* Leaders: Donald Rosenberry, U.S. Geological Survey; David R. Lee; Perry M. Jones; Kelton D. Barr; Howard D. Mooers.
439. **Geology and Sedimentology of the Paleoproterozoic Animikie Group: The Pokegama Formation, the Biwabik Iron Formation, and Virginia Formation of the Eastern Mesabi Iron Range, and the Thomson Formation near Duluth, Northeastern Minnesota.** Thurs.–Fri., 13–14 Oct. US\$242 (B, L, D, R, 1ON).
Leaders: Richard W. Ojakangas, Univ. of Minnesota–Duluth; Mark J. Severson; Peter K. Jongewaard.
440. **Anatomy of a Mineralized (Cu-Ni-PGE) Mafic System: the South Kawishiwi Intrusion of the Duluth Complex.** Thurs.–Sat., 13–15 Oct. US\$340 (L, R, 2ON).
Cosponsor: *Duluth Metals Ltd.* Leaders: Dean M. Peterson, Duluth Metals Ltd.; Joshua Feinberg; Kevin Boerst.
441. **Sudbury Meteorite Impact Layer in the Western Lake Superior Region.** Thurs.–Sat., 13–15 Oct. US\$363 (B, L, D, R, 2ON). Cosponsor: *GSA Planetary Geology Division.*
Leaders: Mark A. Jirsa, Univ. of Minnesota; Philip Fralick; Paul W. Weiblen; Jennifer L.B. Anderson. This trip will cross into Canada; **passports required.**
442. **Late Quaternary Landscape Dynamics beyond the Ice Margin in the Upper Mississippi Valley.** Thurs.–Sat., 13–15 Oct. US\$342 (L, R, 2ON). Leaders: Joseph A. Mason, Univ. of Wisconsin–Madison; Peter M. Jacobs; J. Elmo Rawling; Paul R. Hanson; Douglas J. Faulkner.
443. **Copper Deposits of the Western Upper Peninsula, Michigan.** Thurs.–Sat., 13–15 Oct. US\$344 (B, L, D, R, 2ON). Leader: Theodore J. Bornhorst, Michigan Technological Univ.
444. **Layered Intrusions of the Duluth Complex.** Thurs.–Sat., 13–15 Oct. US\$315 (L, D, R, 2ON). Cosponsor: *GSA Mineralogy, Geochemistry, Petrology, and Volcanology Division.* Leaders: James D. Miller, Univ. of Minnesota–Duluth; Ryan N. Dayton.
445. **Event History and Sequence Architecture of the Middle–Upper Devonian Epeiric Carbonate Platform of the Iowa Basin.** Thurs.–Sun., 13–16 Oct. US\$350 (L, R, 3ON). Cosponsors: *Great Lakes Section SEP; Illinois State Univ. Dept. of Geography & Geology; International Commission on Stratigraphy–Subcommission on Devonian Stratigraphy; North-Central Section GSA; GSA Divisions: Geobiology & Geomicrobiology; Sedimentary Geology.*
Leader: James (Jed) E. Day, Illinois State Univ.



Resistant felsic volcanic units along the north shore of Lake Superior form prominent cliffs such as Palisade Head (foreground) and Shovel Point (background); photo courtesy Karl Wirth.



Autumn view over Wausawanagin Bay on Lake Superior near the Canadian border; Pigeon Point is in the distance and Isle Royale is on the horizon; photo courtesy Jim Miller.

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SHORT COURSE PROGRAM

Early registration deadline: 6 September

Registration after 6 September costs an additional \$30




Cancellation deadline: 12 September



The following short courses are open to everyone. Early registration is highly recommended to ensure course viability. All fees are in U.S. dollars.

Can I take a short course if I'm not registered for the meeting? YES! You're welcome to—just add the meeting nonregistrant fee (\$40 by 6 Sept.) to your course enrollment cost. Should you then decide to attend the meeting, your nonregistrant payment will be applied toward meeting registration. **GSA K-12 teacher members:** You are welcome to take short courses without registering for the meeting or paying the nonregistrant fee.



Continuing Education Units (CEUs): Most professional development courses and workshops offer CEUs. One CEU comprises 10 hours of participation in an organized continuing education experience under responsible sponsorship, capable direction, and qualified instruction.



See www.geosociety.org/meetings/2011/courses.htm or contact Jennifer Nocerino, jnocerino@geosociety.org, for additional information.



   501. **The Emerging CCS Industry: An Overview.** Sun., 9 Oct., 8 a.m.–5:30 p.m. \$100; includes lunch. Limit: 50. CEU: 0.95. Teresa Nealon, Univ. of Wyoming; James Myers, Univ. of Wyoming.



  502. **Sequence Stratigraphy for Graduate Students.** Fri.–Sat., 7–8 Oct., 8 a.m.–5 p.m. \$25; includes continental breakfast and lunch. Limit: 55. CEU: 1.8. Cosponsors: *ExxonMobil Exploration Company; Chevron Energy Technology Company; British Petroleum; GSA Sedimentary Geology Division.* Art Donovan, British Petroleum; Kathryn Lamb-Wozniak, ExxonMobil Exploration Co.; Morgan Sullivan, Chevron Energy Technology Co.



  503. **Field Safety Leadership.** Fri.–Sat., 7–8 Oct., 8 a.m.–5 p.m. \$25; includes continental breakfast and lunch. Limit: 24. CEU: 1.8. Cosponsors: *ExxonMobil Upstream Research Company; ExxonMobil Exploration Company.* Stephen Oliveri, ExxonMobil Upstream Research Co.; Kevin Bohacs, ExxonMobil Upstream Research Co.; Amy Ruf, ExxonMobil Upstream Research Co.



  504. **Fundamentals of Seismic Structural Analysis and Hydrocarbon Entrapment Analysis.** Fri.–Sat., 7–8 Oct., 8 a.m.–5 p.m. \$25; includes continental breakfast and lunch. Limit: 30. CEU: 1.8. Cosponsors: *ExxonMobil Upstream Research Company; ExxonMobil Exploration Company; ConocoPhillips; GSA Structural Geology and Tectonics Division.* Peter Vrolijk, ExxonMobil Upstream Research Co.; Peter Hennings, ConocoPhillips; J. Steve Davis, ExxonMobil Upstream Research Co.



  505. **Geological Factors (and Certification) to Determine Radon in Homes and Well Water.** Fri.–Sat., 7–8 Oct., 9 a.m.–5 p.m. \$270. Limit: 20. CEU: 1.6. Douglas Mose, George Mason Univ.





  506. **Structural and Stratigraphic Concepts Applied to Basin Exploration.** Fri.–Sat., 7–8 Oct., 9 a.m.–5 p.m. \$25; includes continental breakfast and lunch. Limit: 30. CEU: 1.6. Cosponsors: *ExxonMobil Exploration Company; ExxonMobil Upstream Research Company; GSA Sedimentary Geology Division.* Lori Summa, ExxonMobil Upstream Research Co.; Bob Stewart, ExxonMobil Exploration Co.

  507. **Preparing for the Tenure Process.** Fri., 7 Oct., 5 p.m.–8 p.m. \$20; includes a light dinner. Limit: 35. CEU: 0.3. Cosponsors: *On the Cutting Edge; GSA Geoscience Education Division.* Kristen St. John, James Madison Univ.; R. Mark Leckie, Univ. of Massachusetts–Amherst.

  508. **Near-Surface Geophysics for Non-Geophysicists.** Sat., 8 Oct., 8 a.m.–5 p.m. \$78; includes course materials. Limit: 45. CEU: 0.9. Gregory Baker, Univ. of Tennessee.

  509. **Three-Dimensional Geologic Mapping.** Sat., 8 Oct., 8 a.m.–5 p.m. \$55; includes continental breakfast and lunch. Limit: 65. CEU: 0.9. Richard Berg, Illinois State Geological Survey; Harvey Thorleifson, Minnesota Geological Survey; Hazen Russell, Geological Survey of Canada.

  510. **Terrestrial Laser Scanning (Ground-Based LiDAR) Methods and Applications in Geologic Research and Education.** Sat., 8 Oct., 8 a.m.–5 p.m. \$33; includes lunch. Limit: 20. CEU: 0.9. Cosponsor: *UNAVCO.* David Phillips, UNAVCO; John Oldow, Univ. of Texas at Dallas; Carlos Aiken, Univ. of Texas at Dallas.

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

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-   **511. Establishing and Sustaining an Undergraduate Research Program: A Professional Development Workshop for New and Future Faculty.** Sat., 8 Oct., 8 a.m.–5 p.m. \$30; includes continental breakfast, lunch, and course materials. Limit: 30. CEU: 0.9. Cosponsor: *Council on Undergraduate Research Geosciences Division*. Lydia Fox, Univ. of the Pacific; Ed Hansen, Hope College.
-   **512. Virtual Field Experiences in Geoscience Education.** Sat., 8 Oct., 8 a.m.–5 p.m. \$50; includes continental breakfast and lunch. Limit: 30. CEU: 0.9. Richard Kissel, Paleontological Research Institution; Don Duggan-Haas, Paleontological Research Institution; Frank Granshaw, Portland Community College. **Attendees will need to bring laptop computers.**
-   **513. Gale/Underworld Framework Tutorial.** Sat., 8 Oct., 8 a.m.–5 p.m. FREE; includes continental breakfast and lunch. Limit: 50. CEU: 0.9. Cosponsor: *Computational Infrastructure for Geodynamics*. Louis Moresi, Monash Univ.; Patrice Rey, Univ. of Sydney; Walter Landry, CIG/Caltech. **Attendees will need to bring laptop computers.**
-   **514. Introduction to the Acquisition, Visualization, and Interpretation of Airborne LiDAR Data.** Sat., 8 Oct., 8 a.m.–5 p.m. \$110. Limit: 30. CEU: 0.9. Cosponsors: *OpenTopography*; *GSA Quaternary Geology and Geomorphology Division*; *GSA Structural Geology and Tectonics Division*; *GSA Environmental and Engineering Geology Division*; *GSA Geoinformatics Division*. Ian Madin, Oregon Dept. of Geology and Mineral Industries; Chris Crosby, Univ. of California at San Diego.
-   **515. Setting up a GeoSciML Data Service to Publish Your Geological Map Data.** Sat., 8 Oct., 8 a.m.–5 p.m. \$50; includes continental breakfast and lunch. Limit: 20. CEU: 0.9. Cosponsors: *American Geological Institute*; *YES Network*; *Arizona Geological Survey*. Steve Richard, Arizona Geological Survey; Leila Gonzales, American Geological Institute; Joanna Brayson, YES Network; Ryan Clark, Arizona Geological Survey. **Laptop computer with WiFi connection required.**
-   **516. Teaching about Earth's Climate History.** Sat., 8 Oct., 8 a.m.–5 p.m. \$50; includes continental breakfast and lunch. Limit: 35. CEU: 0.9. Cosponsors: *National Science Foundation*; *Wiley Blackwell Publishers*; *GSA Sedimentary Geology Division*; *GSA Geoscience Education Division*. Kristen St. John, James Madison Univ.; R. Mark Leckie, Univ. of Massachusetts–Amherst; Kate Pound, St. Cloud State Univ.; Megan Jones, North Hennepin Community College; Larry Krissek, Ohio State Univ.
-   **517. Using GIS and Remote Sensing to Teach Geoscience in the 21st Century.** Sat., 8 Oct., 8 a.m.–5 p.m. \$45; includes continental breakfast and lunch. Limit: 40. CEU: 0.9. Cosponsor: *On the Cutting Edge*. Barbara Tewksbury, Hamilton College; Brian Hynek, Univ. of Colorado.
-   **518. Education Research I: Conducting Qualitative Geoscience Education Research.** Sat., 8 Oct., 8 a.m.–noon. \$60; includes lunch. Limit: 35. CEU: 0.4. Julie Sexton, Univ. of Northern Colorado.
-   **519A. Teaching Students How to Learn.** Sat., 8 Oct., 8 a.m.–noon. \$35 for one course—or, get two-for-one!—\$35 for combined courses (519C or 519D); includes lunch. Limit: 40. CEU: 0.4. Cosponsors: *GSA Geoscience Education Division*; *National Association of Geoscience Teachers*. Dexter Perkins, Univ. of North Dakota; Karl Wirth, Macalester College.
-   **519B. Teaching Climate Science with Active Learning Strategies.** Sat., 8 Oct., 8 a.m.–noon. \$35 for one course—or, get two-for-one!—\$35 for combined courses (519C or 519D); includes lunch. Limit: 40. CEU: 0.4. Cosponsors: *GSA Geoscience Education Division*; *National Association of Geoscience Teachers*. Karin Kirk, Science Education Resource Center; Susan Buhr, CIRES.
-   **519C. Retooling Your Geosciences Class: Strategies to Assess Learning and Improve Student Success.** Sat., 8 Oct., 1–5 p.m. \$35 for one course—or, get two-for-one!—\$35 for combined courses (519A or 519B); includes lunch. Limit: 40. CEU: 0.4. Cosponsors: *GSA Geoscience Education Division*; *National Association of Geoscience Teachers*. David McConnell, North Carolina State Univ.; David Steer, Univ. of Akron.
-   **519D. Teaching with Google Earth.** Sat., 8 Oct., 1–5 p.m. \$35 for one course—or, get two-for-one!—\$35 for combined courses (519A or 519B); includes lunch. Limit: 40. CEU: 0.4. Cosponsors: *GSA Geoscience Education Division*; *National Association of Geoscience Teachers*. Peter Selkin, Univ. of Washington–Tacoma; Declan De Paor, Old Dominion Univ.
-   **520. Applied Geoscience Skills for Students: What You Need to Know Beyond Undergrad and Grad School.** Sat., 8 Oct., 9 a.m.–5 p.m. \$73. Limit: 40. CEU: 1.6. Ben Burke, Noble Energy.
-   **521. Geological Applications of Cosmogenic Nuclides: Advances from the CRONUS–Earth Project.** Sat., 8 Oct., 9 a.m.–5 p.m. \$72; includes lunch and course materials. Limit: 30. CEU: 0.8. Fred Phillips, New Mexico



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Institute of Mining and Technology; John Stone, Univ. of Washington; Shasta Marrero, New Mexico Tech; Marc Caffee, Purdue Univ.



  522. **J-DSP/ESE Tools for Assessing Global Climate Change and Sustainability.** Sat., 8 Oct., 9 a.m.–5 p.m. \$45; includes lunch. Limit: 30. CEU: 0.8. Cosponsor: *National Science Foundation*. Linda Hinnov, Johns Hopkins Univ.; Cindy Parker, Johns Hopkins Univ.; Andreas Spanias, Arizona State Univ.; Karthikeyan Ramamurthy, Arizona State Univ.



  523. **Education Research II: Conducting Quantitative Geoscience Education Research.** Sat., 8 Oct., 1–5 p.m. \$60; includes lunch. Limit: 35. CEU: 0.4. Julie Sexton, Univ. of Northern Colorado.

  524. **Funding Opportunities for Two-Year College Faculty: Possibilities, Challenges, and Successes.** Sat., 8 Oct., 1–5 p.m. \$15; includes a light snack. Limit: 50. CEU: 0.4. Cosponsor: *National Association of Geoscience Teachers*. Eric Baer, Highline Community College; Heather Macdonald, College of William and Mary.


  525. **Magnetic Methods in Environmental Studies.** Sat., 8 Oct., 1 p.m.–5 p.m. \$35; includes a light snack. Limit: 15. CEU: 0.4. Cosponsor: *National Science Foundation*. Bruce Moskowitz, Univ. of Minnesota; Julie Bowles, Univ. of Minnesota; Richard Reynolds, USGS.

  526. **Teaching with Spreadsheet Modules: Geology of National Parks.** Sat., 8 Oct., 1 p.m.–5 p.m. \$15; includes a light snack. Limit: 20. CEU: 0.4. Cosponsor: *National Science Foundation*. H.L. Vacher, Univ. of South Florida; Judy McIlrath, Univ. of South Florida; Tom Juster, Univ. of South Florida; Mark Rains, Univ. of South Florida. **Attendees will need to bring laptop computers.**

  527. **Introduction to Geographic Information Systems (GIS) Using ArcGIS for Geological and Environmental Science Applications.** Sat.–Sun., 8–9 Oct., 8 a.m.–5 p.m. \$99; includes continental breakfast and lunch. Limit: 20. CEU: 1.8. Cosponsor: *ESRI*. Joseph Kerski, ESRI; Colin Childs, ESRI.





  528. **Common Misconceptions about Plate Tectonics, Earth's Interior, and the Rock Cycle, with Active Learning Approaches to Correct Them.** Sun., 9 Oct., 8 a.m.–12 p.m. \$20; includes continental breakfast. Limit: 40. CEU: 0.4. Cosponsors: *GSA Geoscience*





Education Division; National Association of Geoscience Teachers. Scott Clark, Univ. of Wisconsin–Eau Claire; Karen Kortz, Community College of Rhode Island; Jessica Smay, San José City College.

 529. **Hands-on, Inquiry-Based Activities in Earth Sciences: Workshop for Middle- and High-School Teachers.** Sun., 9 Oct., 8 a.m.–5 p.m. \$20; includes continental breakfast and lunch. Limit: 25. CEU: 0.9. Cosponsors: *National Association of Geoscience Teachers; National Center for Earth-Surface Dynamics*. Lee Schmitt, Hamline Univ.; Katherine Pound, St. Cloud State Univ.; Karen Campbell, National Center for Earth-Surface Dynamics.

GSA ASSOCIATED SOCIETY COURSES





GSA will not be handling registration for these courses; contact conveners listed with the course.

    **Society of Economic Geologists (SEG) Ni-Cu-PGE Short Course.** Fri.–Sat., 7–8 Oct., 8:30 a.m.–5 p.m. Sponsor: *SEG*. Early registration (on or before 6 Sept.): members, \$395; nonmembers, \$495; member students, \$195; non-member students, \$245. Late registration: members, \$495; nonmembers, \$595; member students, \$245; non-member students, \$295. Limit: 100. **Course registration through SEG only** at www.segweb.org/activities/ or by phone +1-720-981-7882. Chusi Li, Indiana Univ.; Edward M. Ripley, Indiana Univ.; Sarah-Jane Barnes, Université du Québec à Chicoutimi; and C. Michael Lesher, Laurentian Univ.

    **Corals and Reef Evolution: Crises, Collapse, and Changes.** Sat., 8 Oct., 8 a.m.–5 p.m. Sponsor: *The Paleontological Society*. FREE. Limit: 200 (pre-registration is not necessary—just show up to attend!). George Stanley, University of Montana.

Continuing Education Credits

GSA's Annual Meeting offers an excellent opportunity to earn CEUs toward your general continuing education requirements for your employer or K–12 school. After the meeting, please contact Beth Engle at bengle@geosociety.org for a meeting evaluation form. Once you've completed and returned that form, we'll mail you your CEU certificate.

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

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GSA MENTOR PROGRAMS

WOMEN IN GEOLOGY

Sun., 9 Oct., 5–6:30 p.m.



This mentor program, sponsored by Subaru of America Inc. and supported by the Association for Women Geoscientists and EnPro Assessment Corp., addresses issues faced by women in geology. This informal gathering begins with remarks from a few key women speakers, followed by time for networking, sharing ideas, and getting to know other women geoscientists and geosciences educators. *Appetizers provided.*

GEOLOGY IN GOVERNMENT

Mon., 10 Oct., 11:30 a.m.–1 p.m.



This popular program, supported by the GSA Foundation, features a FREE lunch for undergraduate and graduate students with a panel of mentors representing a variety of government agencies. These mentors will answer questions, offer advice about preparing for a career in government, and comment on the prospects for current and future job opportunities with their agencies.

STUDENT NETWORKING LUNCHEON

Mon., 10 Oct., 11:30 a.m.–1 p.m.

This luncheon, supported by industry donations and organized by the YES Network, GSA, and AGI, features a FREE lunch for undergraduate and graduate students with an exciting opportunity to network with 40+ geoscience professionals. They will answer questions, offer advice about career plans, and comment on job opportunities within their fields. Preregistration is necessary, and you must bring your luncheon ticket to be admitted. Learn more at www.networkyes.org/index.php/meetings/gsa_2011/.

GEOLOGY IN INDUSTRY

Tues., 11 Oct., 11:30 a.m.–1 p.m.



ExxonMobil



Alpha Natural Resources

Chevron, Alpha Natural Resources, ExxonMobil, and the Society of Economic Geologists support this mentor program, which features a FREE lunch for undergraduate and graduate students with a panel of mentors representing various industries. These mentors will answer questions, offer advice about preparing for a career in industry, and comment on the prospects for current and future job opportunities with their companies.

JOHN MANN MENTORS IN APPLIED HYDROGEOLOGY PROGRAM

This program underwrites the cost for 25 students to attend the Hydrogeology Division Luncheon and Awards Presentation and meet some of geoscience's most distinguished hydrogeologists. Students eligible for this honor are those who have (1) indicated a professional interest in hydrology/hydrogeology on their GSA membership application; and (2) registered for the Annual Meeting by 6 September. The first 25 students who respond to an e-mail invitation on 7 September based on these criteria will receive FREE tickets for the luncheon.

Full program descriptions are available at www.geosociety.org/mentors/. Questions? Contact Jennifer Nocerino, jnocerino@geosociety.org.



Geology in Industry. 2010 GSA Annual Meeting in Denver, Colorado, USA.



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Tel. 800.272.4327

jgipson@ascscientific.com



34th International Geological Congress



IGC
AUSTRALIA 2012

Brisbane, Queensland
5 to 10 August 2012

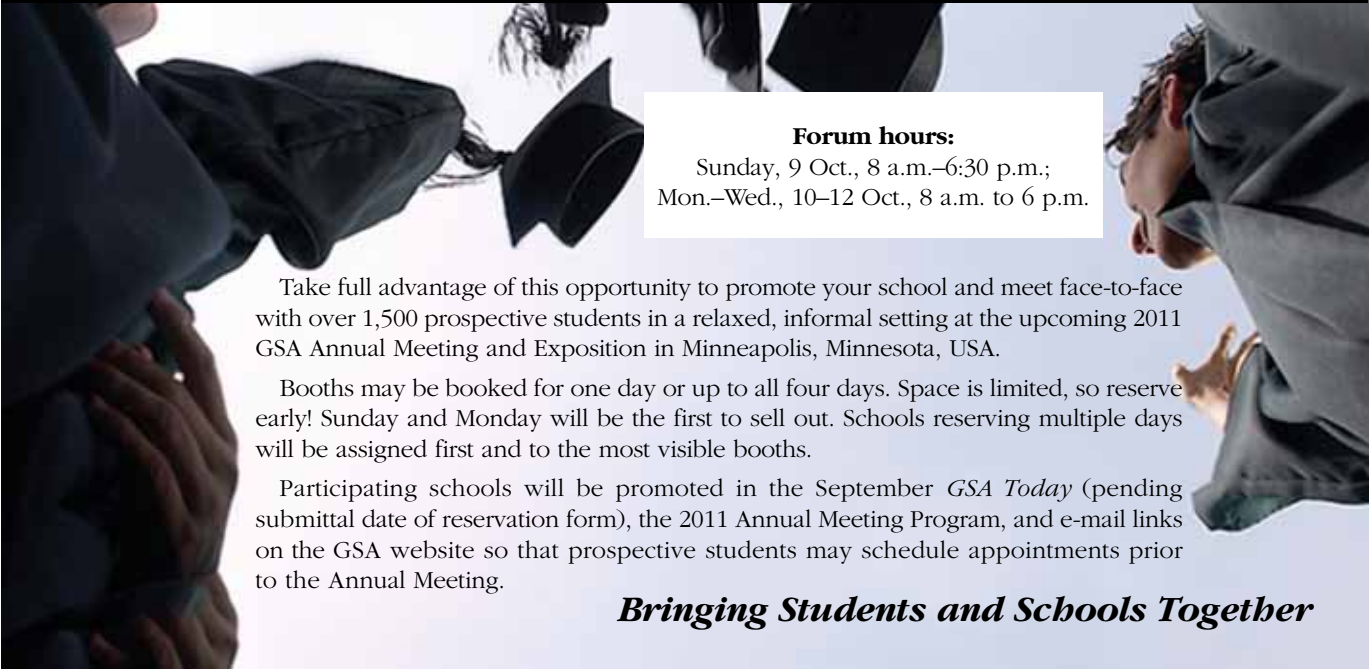


www.34igc.org



SEE US AT THE GSA MEETING **Booth 756** IGC/IUGS (NEAR USGS)

GRADUATE SCHOOL INFORMATION FORUM



Forum hours:

Sunday, 9 Oct., 8 a.m.–6:30 p.m.;
Mon.–Wed., 10–12 Oct., 8 a.m. to 6 p.m.

Take full advantage of this opportunity to promote your school and meet face-to-face with over 1,500 prospective students in a relaxed, informal setting at the upcoming 2011 GSA Annual Meeting and Exposition in Minneapolis, Minnesota, USA.

Booths may be booked for one day or up to all four days. Space is limited, so reserve early! Sunday and Monday will be the first to sell out. Schools reserving multiple days will be assigned first and to the most visible booths.

Participating schools will be promoted in the September *GSA Today* (pending submittal date of reservation form), the 2011 Annual Meeting Program, and e-mail links on the GSA website so that prospective students may schedule appointments prior to the Annual Meeting.

Bringing Students and Schools Together

Reserve at <https://rock.geosociety.org/registration?meetingid=11GSIF> today!

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HOUSING INFORMATION

Reservation deadline: 6 September

Making Your Reservation

Please make your hotel reservations via ONE of the following options:

Internet: www.geosociety.org/meetings/2011/lodging.htm

Fax: +1-612-767-8201

Telephone: +1-888-947-2233 or +1-612-767-8200, Mon.–Fri., 9 a.m.–3 p.m. CST; please have credit card and arrival/departure dates ready.

Mail: GSA Housing Department, c/o Meet Minneapolis, 250 Marquette Avenue South, Suite 1300, Minneapolis, MN 55401, USA.

If you have questions, please send an e-mail to housing@meetminneapolis.com with “GSA Annual Meeting” and your acknowledgement number in the subject line.

Modifying/Canceling Your Reservation

Cancellation requests received after 6 September will be subject to a US\$25 cancellation fee. Cancellations made within 72 hours of the scheduled arrival date are subject to a fee equal to one night’s room rate plus tax. These fees will be charged to the credit card used to make the reservation. Early departures are subject to penalty fees set by the hotel. A charge of the first night’s room and tax will be applied and/or forfeited if you do not cancel and do not arrive.

On or before 29 September: Cancellations and changes to name, stay dates, address, or special requests can be made online at www.geosociety.org/meetings/2011/lodging.htm or via phone, fax, or mail to the Meet Minneapolis Housing Bureau (see above) to modify or cancel your reservation.

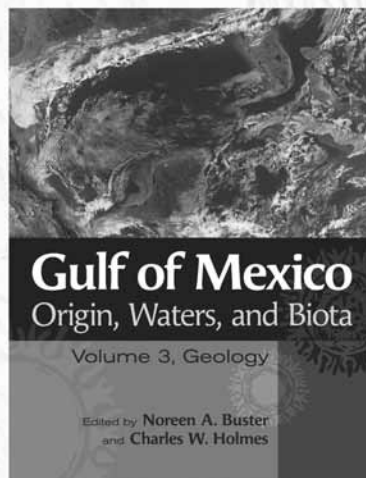
After 29 September: All changes and cancellations must be made directly with the assigned hotel. Please DO NOT contact the hotel directly until after 29 September.

Beware of “Housing Pirates”

“Housing Pirates” are unauthorized companies that phone, fax, or e-mail possible attendees and exhibitors, claiming to offer good deals on hotel rooms. They may falsely claim to be affiliated with GSA. Neither GSA nor Meet Minneapolis will telephone or send faxes offering special Minneapolis hotel rates. You will not be contacted directly by the GSA Housing Bureau/Meet Minneapolis unless there is a question about your existing reservation. For your protection, unless you have initiated the communication, please do not provide anyone with your personal information—especially your credit card number.

Room Sharing

Use the GSA Travel & Housing Bulletin Board at www.geosociety.org/meetings/2011/lodging.htm to arranged shared housing and/or carpool. You can also use this service to make arrangements to meet up with your colleagues.



Gulf of Mexico Origin, Waters, and Biota

Volume 3, Geology

EDITED BY
NOREEN A. BUSTER
AND CHARLES W. HOLMES

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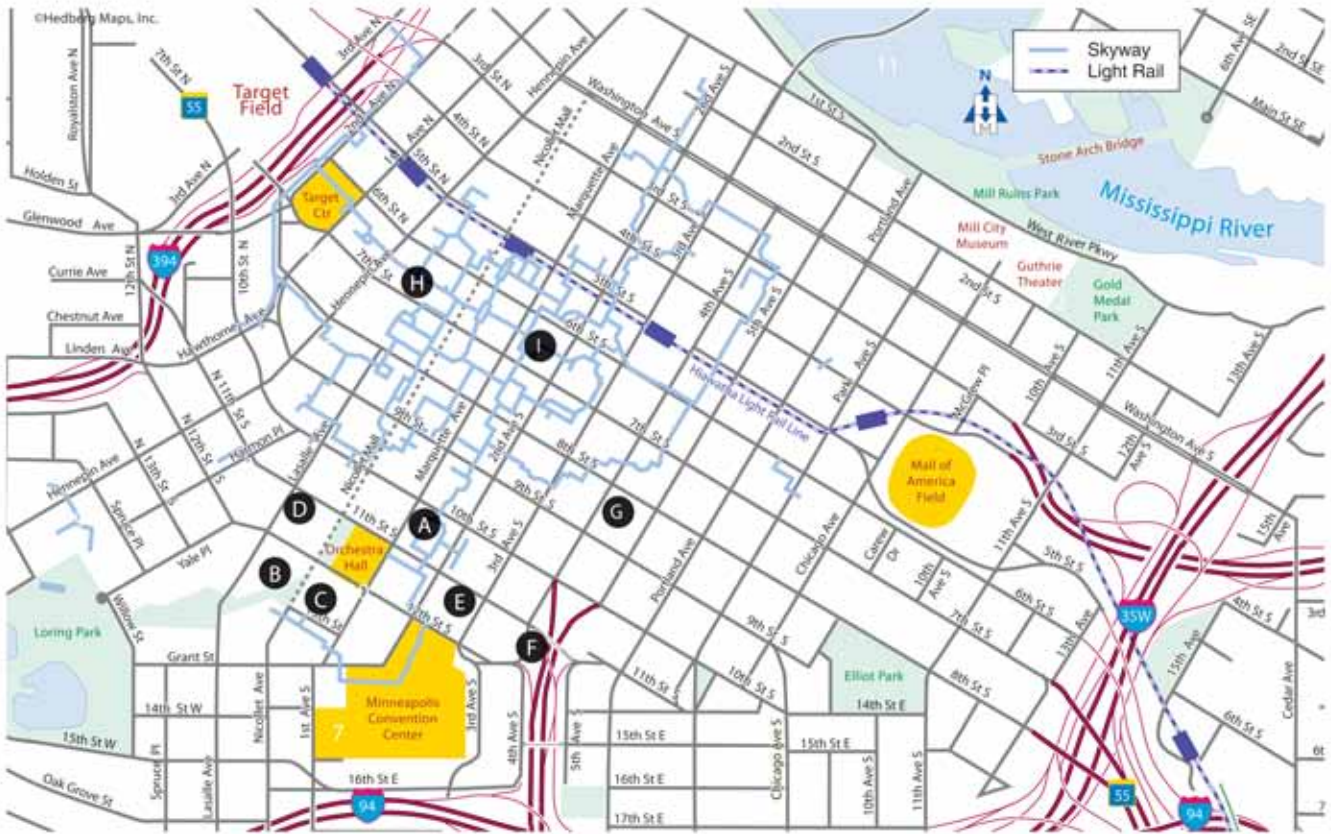
YOU can be an invaluable asset to the meeting.

For more information and to sign up, go to www.geosociety.org/meetings/2011/stuVolunteers.htm.

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MAP OF DOWNTOWN MINNEAPOLIS



GSA Room Block Hotels:

		Single	Double	Triple	Quad
(A)	Hilton Minneapolis - HQ	189.00	189.00	209.00	229.00
(B)	Hyatt Regency - Co-HQ	189.00	189.00	214.00	239.00
(C)	Millennium Hotel	175.00	175.00	190.00	205.00
(D)	DoubleTree Guest Suites	158.00	158.00	173.00	188.00
(E)	Holiday Inn Express Hotel & Suites	165.00	165.00	180.00	195.00
(F)	Hilton Garden Inn	136.00	136.00	151.00	166.00
(G)	Best Western Normandy Inn	139.00	139.00	154.00	169.00
(H)	Marriott City Center Hotel	167.00	167.00	182.00	197.00
(I)	Crowne Plaza Northstar	162.00	162.00	172.00	182.00

A 13.40% state and city tax will be added to the room rate. Taxes are subject to change. Rates are in U.S. dollars.



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ANNUAL MEETING HOTELS

Reserve at www.geosociety.org/meetings/2011/lodging.htm

Hotel	Rates Single/Double/ Triple/Quad	Distance to Convention Center	Restaurants	Internet	Parking
A Hilton Minneapolis (Headquarters Hotel) 1001 Marquette Avenue (55403)	\$189/\$189/\$209/\$229	1.5 blocks	Yes	\$13.95/24-hr wireless only	\$13 self \$23 valet
B Hyatt Regency Minneapolis (Co-Headquarters) 1300 Nicollet Mall (55403)	\$189/\$189/\$214/\$239	1 block	Yes	\$9.95/24-hr	\$17 self \$28 valet
C Millennium Hotel Minneapolis 1313 Nicollet Mall (55403)	\$175/\$175/\$190/\$205	1 block	Yes	\$9.95/24-hr wireless	\$15 (no in/out privileges)
D Doubletree Guest Suites 1101 LaSalle Avenue (55403)	\$158/\$158/\$173/\$188	4.5 blocks	Yes	\$9.95/24-hr	\$17 self
E Holiday Inn Express Hotel & Suites 225 South 11th Street (55403)	\$165/\$165/\$180/\$195	1 block	No, but offers complimentary express breakfast	complimentary wireless	\$12 self
F Hilton Garden Inn Minneapolis Downtown, 1101 4th Avenue South (55404)	\$136/\$136/\$151/\$166	1 block	Yes	complimentary wireless	\$24 valet
G Best Western Normandy Inn 405 South 8th Street (55404)	\$139/\$139/\$154/\$169	5 blocks	Yes	complimentary wireless	\$7 self
H Marriott City Center Hotel 30 South 7th Street (55402)	\$167/\$167/\$182/\$197	7 blocks	Yes	\$14.95/24-hr wired only	\$19 self \$29 valet
I Crowne Plaza Minneapolis Northstar Downtown, 618 2nd Avenue South (55402)	\$162/\$162/\$172/\$182	5 blocks	Yes	\$9.95/24-hr	\$20 (Su–Th) \$11 (F–Sa)

Rates are in U.S. dollars; taxes not included. Information provided is subject to change; please contact the hotel directly with any questions. Smoking is allowed only in rooms at the Hilton Garden Inn; all others are non-smoking.

GSA Appreciates Your Support in Booking within the Official GSA Hotel Block. In the event you have problems with your hotel reservation or accommodations, GSA can only assist in reconciling those issues if your reservation was booked through Meet Minneapolis. If you have questions about an

unauthorized solicitation, the online system, or about housing in general, contact Becky Sundeen, bsundeen@geosociety.org. Please book your hotel by **6 Sept.** to take advantage of the GSA convention rates; after this date, room blocks will be released and hotels may charge higher rates.

GeoCorps™ America Fall/Winter 2011–2012



Application deadline: 1 July 2011

The next GeoCorps™ America fall/winter season runs from September 2011–May 2012. GeoCorps America provides paid, short-term geoscience jobs on public lands managed by the U.S. National Park Service, Forest Service, and Bureau of Land Management. All levels of geologists—students, educators, professionals, retirees, and others—are encouraged to apply.

Past/Current GeoCorps Participants: Please consider attending this fall's GSA Annual Meeting, which will feature the second annual GeoCorps Alumni Reception as well as provide a great venue for presenting your GeoCorps work!

www.geosociety.org/geocorps/

Inset 1: Mark Hagemann, cave resources technician at Tongass National Forest, Summer 2010. **Background:** Erin Lynch, cave resources technician at Tongass National Forest, Summer 2010. **Inset 2:** Andrea Johnson, geology education specialist at Rocky Mountain National Park, Summer 2010.

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GSA EXHIBITOR LISTING BY CATEGORY

(AS OF 30 APRIL 2011)

Computer Software

ESRI
GPR-SLICE

Gems/Minerals Dealers, Jewelry/Gifts

Cal Graeber
Finesilver Designs & Jewelry
Gems & Crystals Unlimited
GEOGRAPHICS
IKON Mining & Exploration
Janice Evert Opals
Komodo Dragon
Nature's Own

General Educational Products

Cengage Learning
Gemological Institute of
America
LectureTools Inc.
Little River Research &
Design
PALEOMAP Project
Ward's Natural Science
Waveland Press

Geographic Supplies and Related Equipment

Forestry Suppliers
Rite in the Rain

Geological Society of America

GSA Engineering Geology
Division
GSA Geology and Society
Division
GSA Geology and Public
Policy Committee
GSA Geoscience Education
Division
GSA History and Philosophy
of Geology Division and
the History of Earth
Sciences Society
GSA Hydrogeology Division
GSA Limnogeology Division
GSA Planetary Geology
Division

Geological and Geophysical Instrumentation

ASC Scientific
Beckman Coulter
Bruker AXS
elementar Americas Inc.
EmCal Scientific Inc.
Gatan Inc.

Geophysical Survey Systems
Inc.

Horiba Instruments Inc.
In-Situ Inc.
IsotopX Inc.
Leica Microsystems Inc.
Los Gatos Research
MALA Geoscience USA Inc.
Meiji Techno America
Optech Inc.
Picarro Inc.
Retsch Inc.
Rigaku America Corporation
Sensors & Software Inc.
SPEX SamplePrep
Thermo Scientific
UNAVCO

Government Agencies (Federal, State, Local, International)

British Geological Survey
Minnesota Dept. of Natural
Resources
National Science Foundation
U.S. Bureau of Land
Management
U.S. Forest Service
U.S. National Park Service

Other

Consortium for Ocean
Leadership
Consortium of Universities
for the Advancement of
Hydrologic Science
EarthScope
IRIS Consortium
Jonathan H. Wells
Subaru of America Inc.
Sundial Solar

Professional Societies and Associations

2012 Brisbane IGC and
International Union of
Geological Sciences
AAPG Bookstore & Student
Programs
AASP - The Palynological
Society
American Geological Institute
American Geophysical Union
American Institute of
Professional Geologists
American Meteorological
Society
American Quaternary
Association

Association for Women
Geoscientists
Association of American State
Geologists
Association of Earth Science
Editors
Association of Environmental
& Engineering Geologists
Clay Minerals Society
Council on Undergraduate
Research
Cushman Foundation
EARTHTIME
Geochemical Society
Geological Association of
Canada
Geological Society London
Geoscience Information
Society
GeoScienceWorld
IAH—International Association
of Hydrogeologists
International Association of
GeoChemistry
Mineralogical Association of
Canada
Mineralogical Society of
America
Minnesota Ground Water
Association
National Association of Black
Geologists & Geophysicists
National Association of
Geoscience Teachers
National Association of State
Boards of Geology
National Cave & Karst
Research Institute
National Earth Science
Teachers Association
Paleontological Society
SEPM Society for
Sedimentary Geology
Sigma Gamma Epsilon
Society for the Preservation
of Natural History
Collections
Society of Economic
Geologists

Publications, Maps, Films

Cambridge University Press
Colorado Plateau Geosystems
Elsevier
Kendall Hunt Publishing
Company
McGraw-Hill Higher
Education

Micropaleontology Project
Mountain Press Publishing
Company
Nature Publishing Group
Paleontological Research
Institution
Pearson
Springer
Taylor & Francis
The University of Chicago
Press—The Journal of
Geology
Treatise on Invertebrate
Paleontology
University of California Press
W.H. Freeman & Company
W.W. Norton Publishing
Company
Wiley
Yale University Press

Services (Exploration, Laboratories, Consulting, and Others)

Beta Analytic
Big Rock Exploration
Environmental Isotope Lab
GNS Science: Rafters
Radiocarbon
Isotope Tracer Technologies
Olympus Innov-X Systems
Wells Research Laboratory
Inc.

State Surveys

Illinois State Geological
Survey

Universities/Schools

Baylor University Dept. of
Geology
Duke's Nicholas School of
the Environment
Geocognition Research Lab
Geoinformatics for the
Geosciences
Kansas State University
Mississippi State University
Southern Illinois University
IGERT Program in
Watershed Science &
Policy
The University of Texas at
Austin Jackson School of
Geosciences
University of Nevada—Las
Vegas
University of Nevada—Reno

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TAKE YOUR MEETING TO THE NEXT LEVEL WITH WEB 2.0

www.geosociety.org/meetings/2011/fusion.htm

You'll find several ways to get involved in the meeting and network with your peers—before, during, and after your trip—through a variety of Web 2.0/social media innovations. Adding social media to your meeting experience gives you a greater sense of its broader impacts and can also bring the meeting before a wider audience by including geoscientists around the world who aren't able to attend.

GSA's Meeting Bulletin Board

Here you'll have a chance to contact other meeting attendees and talk about whatever you want, whenever you want. Meet new people, coordinate your schedules, plan activities, or start a science discussion forum. You can even save money by sharing travel and lodging expenses. Information entered to this bulletin board is secure and only accessible by login. Go to http://rock.geosociety.org/forumstudenttravel/forum_topics.asp?FID=36 to get started.

GSA is @geosociety on Twitter

GSA has a community of more than 2,100 followers on Twitter—a global audience that includes geoscientists, academics, students, institutions, agencies, and geoscience companies. Get regular meeting updates by following @geosociety (and GSA's followers!) on Twitter.

What is Twitter?

Twitter, originally developed as a short messaging service, much like cell-phone texting, is now considered an essential "microblogging" tool. It helps get your 140-character reports (and links) out to people who *want* this information—people who have elected to "follow" your tweets or search your subject hashtag.

What are Hashtags?

Hashtags are words or phrases (without spaces) preceded by the # symbol, which allows them to become searchable, much like keywords or metadata. Typical hashtags used by GSA include #geoscience and #citizenscience. This year's meeting hashtag is #GSAMinn.

Join Our Twitter Roll

Tweeting from the meeting? If so, add your Twitter ID to our Twitter Roll at www.geosociety.org/meetings/2011/fusion.htm. Tweet with the #GSAMinn hashtag to create a rolling Twitter narrative and stretch the meeting's virtual boundaries.

Blog Roll

Are you planning to blog about the meeting? Please add your blog to our blog roll at www.geosociety.org/meetings/2011/fusion.htm. Your posts will be monitored by GSA newsroom staff and added to our annual meeting news coverage Web page.

Facebook

GSA has two Facebook pages—a group page created by GSA members and friends for GSA members and friends, and a fan page, created and updated by GSA. The group has over 1,700 members, and the "official GSA page" has almost 6,500 fans. You can post comments, information about your interests at the meeting, and questions for other group members on the group page. Look for meeting updates and meeting-related blog posts on the fan page.

Fan page: www.facebook.com/pages/Geological-Society-of-America/67821277078

Group page: www.facebook.com/group.php?gid=23118032000



Learn more about the intersection of geoscience and social media at www.scientificamerican.com/blog/post.cfm?id=social-media-for-science-geological-2011-03-17.

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CALL FOR PAPERS

Abstract submission deadline: 26 July 2011

www.geosociety.org/meetings/2011/techProg.htm

SUBMITTING AN ABSTRACT

- Upload your abstract at **<http://gsa.confex.com/gsa/2011AM/cfp.epl>**.
- Fees per abstract: Professionals: US\$35; students: US\$20; digital posters: US\$80. (**NEW!** See next page for details.)
- You may present two volunteered abstracts during the Annual Meeting, *as long as one of these abstracts is for a poster.*

Oral Presenters

The normal length of an oral presentation is 12 minutes plus three minutes for questions and answers. You must visit the Speaker Ready Room at least 24 hours before your scheduled presentation.

All technical session rooms will be equipped with a PC; if your presentation was created on a Mac, please save it to run

on a PC and test it before coming to the meeting as well as in the speaker ready room. *New this year:* We will have a switch in each of the technical sessions so that you can run your presentation from your laptop if it will not work on the PC.

Poster Presentations

GSA will provide one 8-foot-wide × 4-foot-high freestanding display board and Velcro for hanging the poster. Each poster booth will share a 6-foot × 30-inch table, and electricity will be available at no charge. Posters will be on display all day, 9 a.m.–6 p.m., with authors present either 9–11 a.m. or 2–4 p.m. Authors are also encouraged to be present during the afternoon beer reception from 4:30–6:30 p.m. See next page for information on digital posters.

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Present Anything You Want Directly from Your Laptop!

GSA is gearing up for **digital poster** presentations during the Annual Meeting in Minneapolis. You can choose this dynamic and interactive form of presenting your science via the online abstracts submission screen.

YOU WILL BE PROVIDED:

- One horizontal, freestanding 8-foot × 4-foot display board along with Velcro for hanging a poster;
- A monitor (~40 to 46 inch) on a 6-foot × 30-inch table;
- Electricity for your laptop (bring your own laptop); and
- A VGA cable along with sound. Mac Users: Bring your own white dongle.

PROPOSED DIGITAL SESSIONS

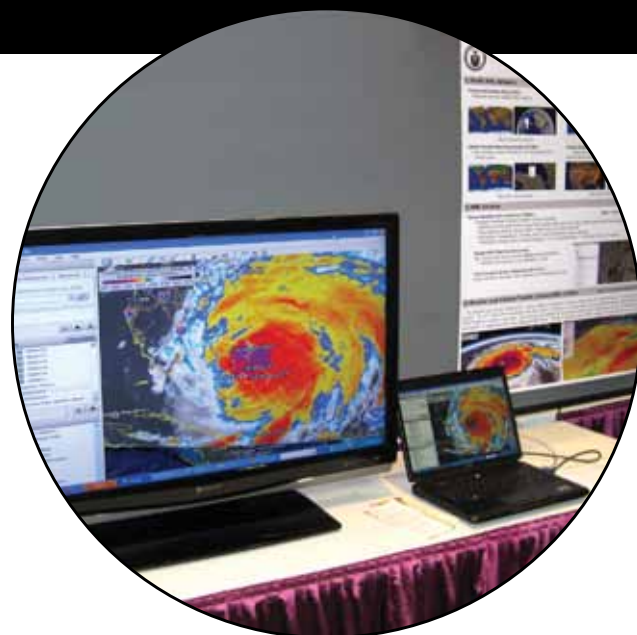
The leaders of the following topical sessions encourage you to submit a digital poster abstract. The submission fee of US\$80 will help offset equipment costs.

T95. Visualizations in Geology: Advancing the Science Using Digital Tools (Digital Posters). Geologic science using complicated visualization or modeling approaches is difficult to present using standard poster formats. This session allows geologic research to be communicated in a digital poster session format.

Cosponsor: GSA Hydrogeology Division

Advocates: Todd Halihan, Oklahoma State University; Daniel A. Lao Davila, Oklahoma State University; Priyank Jaiswal, Oklahoma State University

T110. Techniques for Measuring Shoreline Change (Digital Posters). This session will explore the state of the science of shoreline change measurement and where we should be heading in terms of equipment, data gathering techniques, and methods of analysis.



Cosponsor: GSA Quaternary Geology and Geomorphology Division

Advocate: Chester W. Jackson, Georgia Southern University

T149. Virtual Reality in Geoscience Education (Digital Posters). This session covers virtual reality in formal and informal geoscience education at all levels: Google Earth, OmniGlobe, LiDAR, GigaPan, full-dome digital planetaria, caves, and resources for handheld devices, such as iPads and smart phones.

Cosponsors: GSA Geoscience Education Division; GSA Structural Geology and Tectonics Division; GSA Geoinformatics Division; GSA Planetary Geology Division; National Association of Geoscience Teachers; Google Inc.; Oxford University Press; Minnesota Planetarium Society

Advocates: Declan G. De Paor, ddepaor@odu.edu, Old Dominion University; Steven J. Whitmeyer, whitmesj@jmu.edu, James Madison University; John E. Bailey, jbailey@gi.alaska.edu, University of Alaska–Fairbanks. **Note:** Please contact the session chairs **BEFORE** submitting an abstract to session T149.



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DISCIPLINE CATEGORIES

Can't find a topical session that fits your abstract? No problem! GSA also offers a variety of discipline sessions, which are equally vital to a robust technical program and essential to the fulfillment of overall meeting goals. Please feel free to contact the JTPC member associated with your discipline regarding the suitability of your abstract for a technical or discipline session.

2011 Technical Program Chair

Dave Bush, dbush@westga.edu

GSA Technical Program Manager

Nancy Wright, nwright@geosociety.org

Review Group	Discipline	Contact(s)
GSA Archaeological Geology Division	archaeological geology	Catherine Yansa, yansa@msn.edu; Kathleen Nicoll, kathleen.nicoll@gmail.com
GSA Coal Geology Division	coal geology	Sue Rimmer, srimmer@geo.siu.edu; Margo D. Corum, mcorum@usgs.gov
GSA Environmental and Engineering Geology Division	engineering geology	William H. Schulz, wschulz@usgs.gov; Norman S. Levine, levinen@cofc.edu
Environmental Geoscience	environmental geoscience	John F. Bratton, jbratton@usgs.gov
GSA Geobiology & Geomicrobiology Division	geomicrobiology	Stuart Birnbaum, stuart.birnbaum@utsa.edu; Nora Noffke, nnoffke@odu.edu
Geochemical Society	geochemistry; geochemistry, organic	TBD
GSA Geoinformatics Division	geoinformatics	Steve Richard, steve.richard@azgs.az.gov
GSA Geology and Health Division	geology and health	Syed Hasan, hasans@umkc.edu; Robert B. Finkelman, bobf@utdallas.edu
GSA Geology and Society Division	public policy	Karen McCurdy, kmccurdy@GeorgiaSouthern.edu; Joan E. Fryxell, jfryxell@csusb.edu
GSA Geophysics Division	geophysics/tectonophysics/seismology	Audrey D. Huerta, huerta@geology.cwu.edu
GSA Geoscience Education Division; National Assoc. of Geoscience Teachers	geoscience education	Steven H. Schimmrich, schimmrs@sunyulster.edu; Elizabeth Wright, ewright@saic.edu; Sadredin C. Moosavi, smoosavi@charter.net
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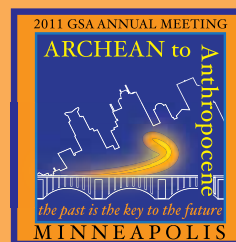
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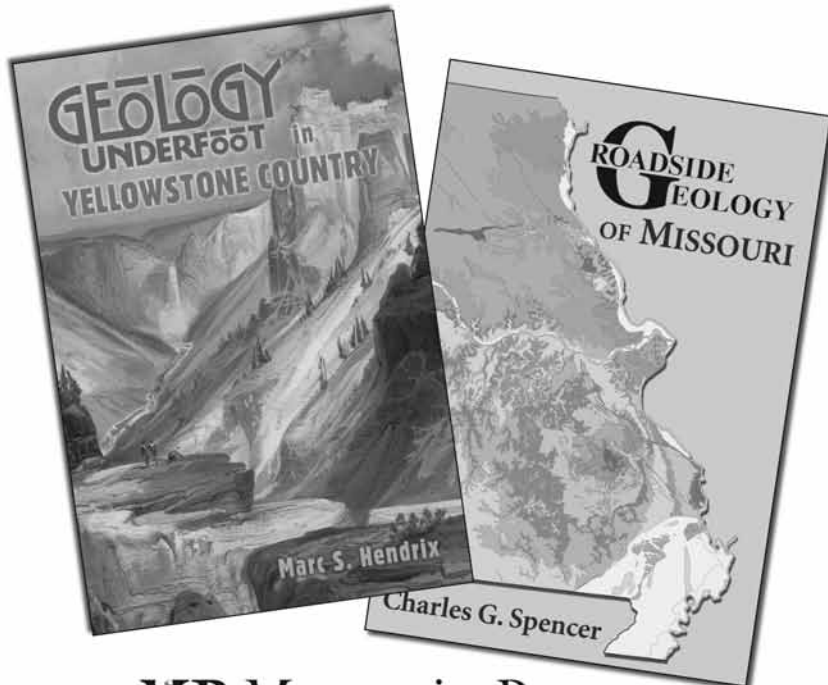
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GSA Council acknowledges the many member-volunteers who, over the years, have contributed to the Society and to our science through involvement in the affairs of the GSA. Your time, talent, and expertise help build a solid and lasting Society.

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GSA Position Statement Draft

THE IMPORTANCE OF TEACHING EARTH SCIENCE

GSA members are invited to submit comments and suggestions regarding the following *Position Statement draft* by **15 July 2011** at www.geosociety.org/geopolicy/. Go to www.geosociety.org/positions/ to learn more.

Position Statement: The Geological Society of America (GSA) recognizes that basic knowledge of Earth science is essential to meeting the environmental and resource challenges of the twenty-first century. It is critical that Earth-science education begin at the K–12 level and include advanced offerings at the secondary school level and that highly qualified Earth-science teachers provide the instruction. GSA recommends that the study of Earth science be an integral component of science education in public and private schools at all levels, from kindergarten through twelfth grade.

Purpose: This position statement (1) summarizes the consensus views of GSA on the importance of teaching Earth science at K–12 levels; (2) advocates for training at the college level that will produce highly qualified Earth-science teachers; and (3) provides specific recommendations and opportunities for advocacy and action by GSA members.

RATIONALE

This is a critical time for students to understand how Earth works as a system and how humans interact with Earth. Understanding the causes and potential societal consequences of natural Earth processes (e.g., earthquakes, floods, landslides, tsunamis, volcanic eruptions, weather, and global climate change) and the production, availability, and potential depletion of natural resources (e.g., water, soil, mineral, and energy) are of particular importance because they impact our economy, our security, and the safety and sustainability of our environment. The context for understanding modern Earth processes lies in deciphering records of Earth's past. Investigating these records, as well as human interaction with modern Earth processes and resources, is therefore critical to the well-being of humanity and the planet. Empowering students with scientific knowledge, skills, and dispositions to make informed decisions as citizens of our common home is a vital undertaking and a key responsibility for science educators and geoscientists.

Earth science is an integrated science, bringing together biology, chemistry, and physics as they apply to the workings of Earth. The applied, and often visual, nature of Earth science helps learners see the connections and relevance of science to their lives and their communities. Engaging students in learning about Earth supports the development of problem solving and critical thinking skills and highlights the importance of science, technology, engineering, and math

(STEM) careers to society. Therefore, Earth science can serve as an introduction to the life and physical sciences or as a capstone course requiring students to apply their knowledge of these sciences. Earth science can also serve as a framework for investigating life and physical sciences in museums and other informal education venues.

RECOMMENDATIONS

GSA encourages and supports the following:

- Teaching Earth science at all levels of K–12 education;
- Teaching Earth science at the same academic level as physics, chemistry, and biology;
- Teaching Earth science as a high-school laboratory capstone science course that contributes toward college admission credit;
- Inclusion of undergraduate and/or graduate geoscience courses in all teacher candidate preparation for those seeking elementary and middle childhood licensures, depending upon state and institutional requirements;
- Teaching Earth science as part of a common core as developed by the National Academies;
- The adoption of National Science Education Standards by all public and private school systems, including incorporation of the study of Earth science into all educational levels from kindergarten through twelfth grade;
- Increased research on Earth-science education;
- Innovative teaching by highly qualified teachers of relevant, modern Earth-science models, concepts, and theories that contribute to informed public decision making.

Opportunities for GSA and Its Members to Help Implement Recommendations

The Geological Society of America encourages its members to

- Support the adoption of the Earth Science Literacy Principles (ESLP) and the National Science Education Standards (NSES) by all public and private school systems and by other science education organizations. These documents can be used as guiding frameworks to support your efforts in teaching and communicating about the importance and relevance of Earth science to society and the environment.
- Become involved with Earth-science certification programs for pre-service teachers at institutions of higher education;

- Become involved with teacher candidate programs at their institutions or in their region to help formalize required undergraduate/graduate coursework in geosciences in their pre-service tracks;
- Encourage states to include Earth-science laboratory courses in high school science curricula and require that Earth-science content be part of proficiency exams for graduating high school seniors;
- Encourage colleges and universities to recognize high school Earth science courses as fulfilling college admissions requirements for laboratory science;
- Form partnerships with Earth-science educators (formal and informal) focused on promoting the use of Earth-science data to develop engaging, level-appropriate, relevant activities and lessons;
- Become involved in local school activities (running for school board, joining ad hoc district or curriculum committees, participating in parent-teacher organizations);
- Demonstrate the value of geoscience education and outreach by elevating the importance of broader impacts in funded geoscience research;
- Encourage institutions to recognize engagement in education and outreach activities as contributing toward awarding tenure and promotions;
- Engage in communicating Earth science to the public, including at local schools. The research findings of the scientific community must be clearly communicated to non-scientists, including students, the general public, and policy makers, to enable informed decision making.

Opportunities for All to Broaden the Teaching of Earth Science in Schools

GSA encourages the following actions:

Scientists:

- Develop a Research Experience for Teachers program in your field or laboratory research;
- Provide talks to audiences of all ages in a variety of venues, such as schools, museums, libraries, scouting events, and other appropriate events;
- Partner with educators in your local area; visit their school in person or virtually; take on the role of an informal mentor to a student;
- Partner with K–12 faculty; provide data and tools to support the engagement of their students in geoscience investigations by working with educators to create lessons and activities;
- Participate in a “communicating science to the public” workshop offered at a GSA, AGU, or AAAS meeting.

K–12 Educators:

- Seek out and participate in online professional development opportunities, such as the Science Educational Resource Center’s (SERC) Teach the Earth,

Earth Exploration Toolbook, Digital Library for Earth Science Education (DLESE), and others;

- Get involved in professional organizations such as GSA, NAGT, NSTA, and NESTA; attend their meetings and participate in workshops and field trips that they sponsor;
- Partner with geoscience faculty at local colleges and universities to learn about their research and the tools they use;
- Assist colleagues of all grade levels with Earth-science content and pedagogy to ensure that best practices are employed.

School Administrators:

- Require Earth science in the district program of studies and require all students to take Earth-science courses along with chemistry, physics, and biology;
- Support curricular decisions that include rigorous high school-level Earth-science courses.

School Boards and Parent-Teacher Associations/Organizations:

- Invite Earth-science professionals to speak to the school board about the role of Earth-science education in preparing students for college, careers, and their future;
- Support teacher initiatives that promote and celebrate Earth-science education.

Parents and Students:

- Participate in discussions about global and local Earth-science–related topics that you see in the news;
- Seek out informal science venues to continue learning about Earth-science topics outside school settings.

Public Officials:

- Educate yourself on the role of research in Earth science;
- Promote a thorough and comprehensive education that includes Earth science.

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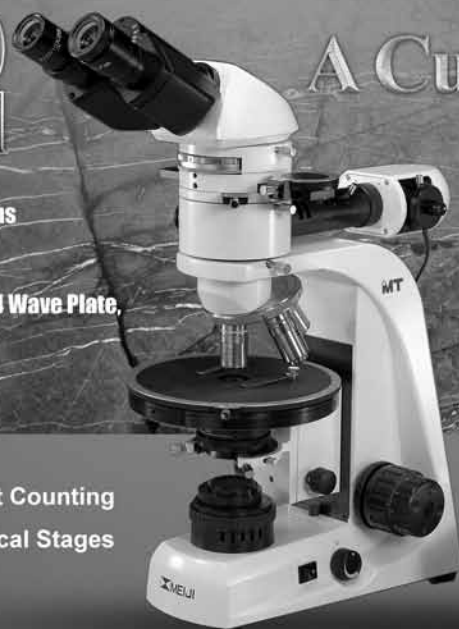
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Obstacles to the recruitment of minorities into the geosciences: A call to action

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INTRODUCTION

In 2008, >85,000 Hispanic, Black (U.S. National Science Foundation [NSF] term), and American Indian/Native Alaskan students, collectively called underrepresented minorities, received bachelor degrees in science, technology, engineering, and mathematics (STEM). Of that number, only 192 Hispanic, 89 Black, and 28 American Indian/Native Alaskan students (NSF, 2010; Fig. 1) earned degrees in geoscience. Between 2000 and 2008, underrepresented minorities earned 16%–17% of STEM degrees and only 5%–7% of geoscience degrees.

The lack of geoscience undergraduates has been attributed to many factors (Velasco and Velasco, 2010), especially pre-college exposure (Levine et al., 2007). Most college-bound students do not study geoscience in high school, and this lack of exposure cuts across ethnic and socioeconomic divisions. Thus, high school non-preparation does not explain the discrepancy in percentages of white students versus minority students earning geoscience degrees.

For more than a decade, NSF program directors have been concerned about the lack of underrepresented minorities in the geosciences. A 2000 NSF workshop (see Prendeville and Elton, 2001) led to the NSF “Opportunities for Enhancing Diversity in the Geosciences” initiative, which provided funds for programs that had the potential to recruit underrepresented minorities into the geosciences.

Successful approaches to recruiting a more diverse geoscience undergraduate population are described in the Dec. 2007 *Journal of Geoscience Education* (v. 55, <http://nagt.org/nagt/jge/abstracts/dec07.html>) and include attention to the geoscience pipeline (Levine et al., 2007). Subsequent articles show that summer research experiences (Hallar et al., 2010) and paired programs with historically Black Colleges and Universities (HBCUs) (Stassun et al., 2010) are effective.

We agree that a multifaceted approach is necessary in order to attract a diverse student body. In 2008, 47% of U.S. births were non-white minorities (Hamilton et al., 2010). These children will begin entering college around 2027; geoscientists need to start attracting them now in order to maintain healthy departments and provide geoscientists to the workforce in the future.

ATTRACTORS TO GEOSCIENCE MAJORS

With little pre-college exposure, what attracts anyone to the geosciences? Holmes and O'Connell (2005) identify three main attractors, accounting for 80% of geoscientists: (1) positive undergraduate experiences, (2) love of the outdoors, and (3) family influences. Here we examine why these attractors may not be working as well for underrepresented minority students and suggest ways geoscientists can be more proactive in their efforts to recruit a representative student body.

Undergraduate Experience

Undergraduate experiences attract most geoscientists to the major. These experiences include becoming excited by a great course in college, a formative relationship with a professor, and interaction within a small, supportive department (Holmes and O'Connell, 2005). An informal survey of members of the National Association for Black Geologists and Geophysicists found that its members were attracted by a positive undergraduate experience (C. Ellis, 2006, personal commun.). This is in keeping with studies showing the influence of interaction with faculty on student self-confidence and academic success (Komarraju et al., 2010).

This type of undergraduate experience is restricted for many underrepresented minorities; HBCUs produce 38% of the black male and 41% of the black female STEM bachelor degrees. Unfortunately, most HBCUs do not offer geoscience, limiting this crucial recruiting path. Between 2000 and 2008, only 66 geoscience bachelor degrees were awarded to HBCU students (NSF, 2010). Tribal Colleges produce <2% of American Indian/Native Alaskan STEM bachelor degrees and none in geoscience. Largely Hispanic-serving institutions award a little over 30% of Hispanic STEM bachelor degrees and about 25% of Hispanic geoscience bachelor degrees, but these institutions are primarily large state schools, where big classes may hamper faculty-student interaction.

Love of the Outdoors

Geoscientists celebrate their connection with the outdoors, but a survey of 620 high school and college students taking a geoscience course in California revealed little outdoor appeal to underrepresented minority students (Whitney et al., 2005). In the same study, underrepresented minority students were less likely than whites to “prefer to work on a science project in an outdoor setting rather than in a research laboratory” and were significantly less likely to respond positively to statements like “I enjoy going hiking, camping or boating.”

Another measure of the enjoyment of outdoor life is visitation to U.S. National Parks. A 1997 Yellowstone National Park visitor survey showed only 1.5% African-Americans and 1% Hispanics present (Wilkinson, 1999). A 2002 survey of visitors to Florida's Everglades National Park and California's Sequoia and King Canyon National Parks found that 90% of the visitors were white (Kelly, 2006). Oprah Winfrey made news in 2010 when she visited Yosemite at the request of a Black park ranger (Oprah, 2010).

The lack of participation by Hispanics in outdoor activities like fishing, canoeing, backpacking, or birdwatching has been noted by marketing agencies (Adams et al., 2010). Their research shows that in the past year, <15% of Hispanic youths had engaged in these kinds of outdoor sports. Because 78% of Hispanic youths rely on their families for leisure activity ideas (Adams et al., 2010), this lack of outdoor tradition is apt to continue.

It is likely, therefore, that underrepresented minorities may find geoscience's emphasis on fieldwork and the outdoors a deterrent to majoring in the discipline.

Recommendation: Let students know that geoscience offers a wide variety of exciting opportunities to work indoors. Scenic vistas may not attract underrepresented minorities as much as images of well-equipped laboratories. Ensure that these are featured on departmental websites and in talks and publications.

Family Influence

Geoscience is an unknown or even negative career path for many people. Snieder and Spiers (2002) and Hoisch and Bowie (2010) found that negative perceptions of the geosciences were common and included low pay and low prestige. Most underrepresented minorities responded negatively to the statement, "My family would be very supportive if I decided to become a geoscientist." White students in the same study were more likely to have greater family support to pursue a geoscience major (Whitney et al., 2005).

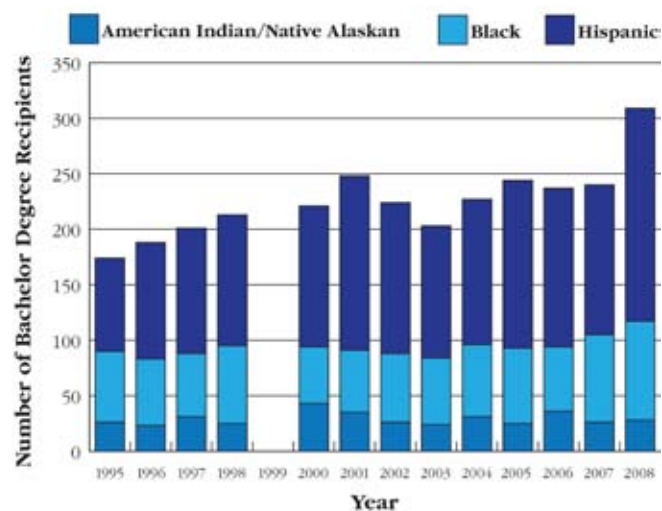


Figure 1. Number of geoscience bachelor degrees awarded to Blacks, Hispanics, and American Indian/Native Alaskans. In 2008, this number was two standard deviations higher than the previous 10-year average (NSF, 2010).

Family influence is crucial. Black and Hispanic students are more likely to be first-generation college students (Horn and Nuñez, 2000). Families have a disproportionate influence on the selection of majors of first-generation college students (Davis, 2010), who tend to select majors that lead to well-paying jobs.

Recommendation: Emphasize geoscience careers (especially of alumni) on department websites to make it easier for students to share this information with family. Images should include geoscientists working in offices and labs, not just in the field. Collin Powell, the first Black Secretary of State and a retired four-star general, majored in geology.

CONCLUSIONS

Geoscientists need to increase exposure to the geosciences and geoscience careers at all educational levels. Precollege, successful afterschool, outdoor, and parent programs can increase awareness and relevance of the geosciences. At the college level, geoscience faculty should (1) extend themselves to underrepresented minority students, (2) provide information about geoscience careers, and (3) provide students with information to help their families endorse geoscience.

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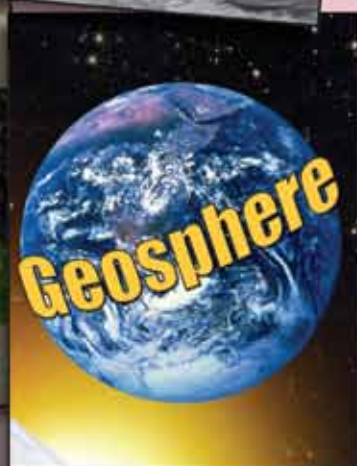
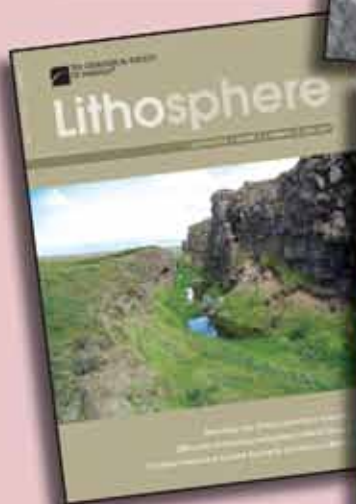
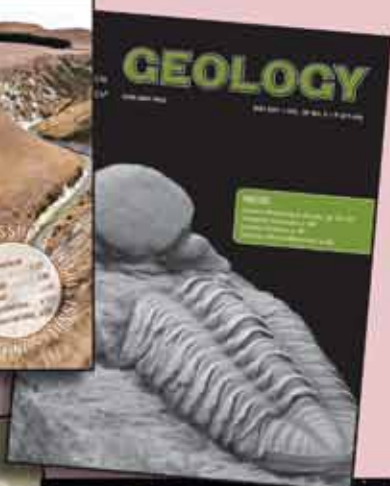
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