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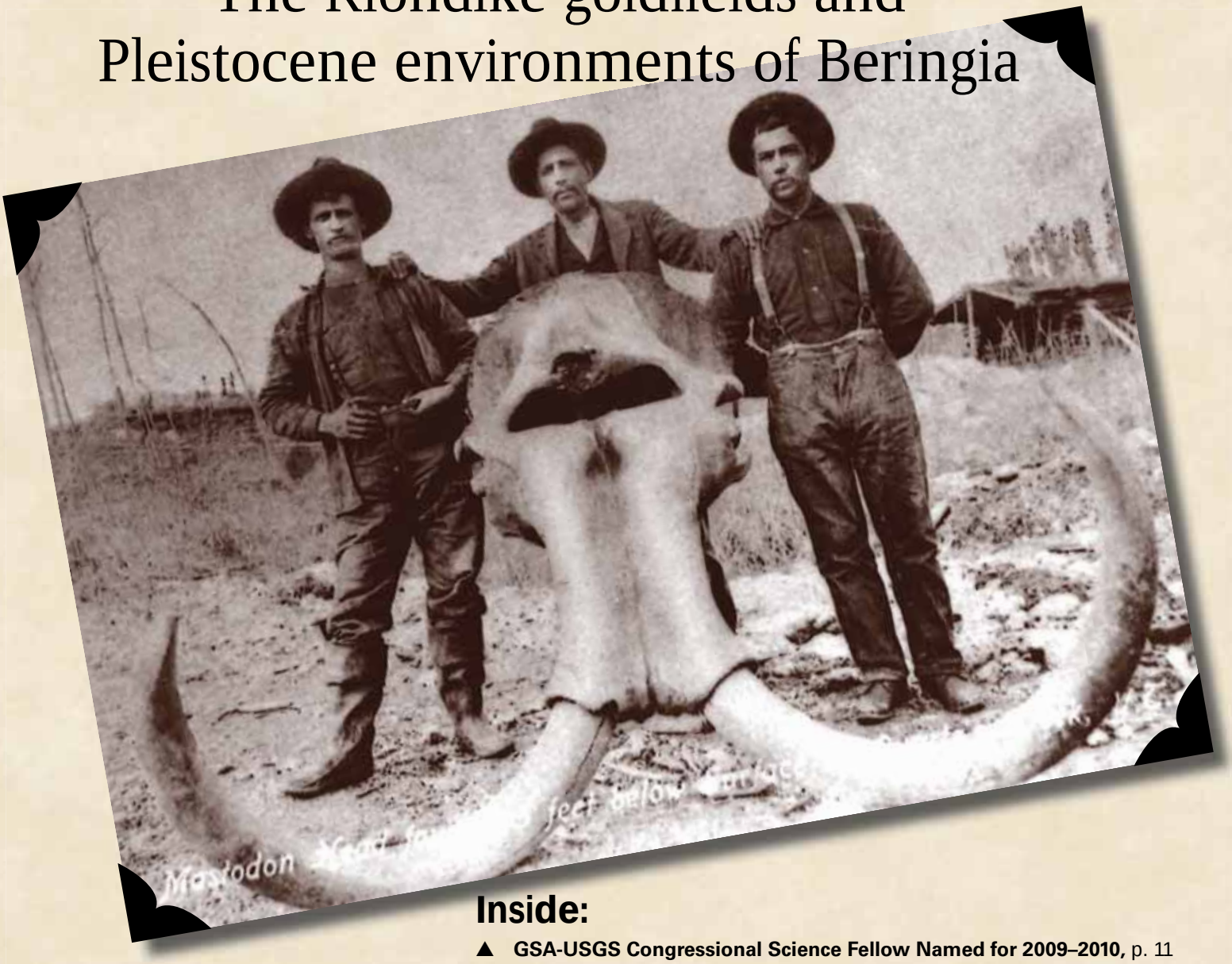
The Klondike goldfields and Pleistocene environments of Beringia



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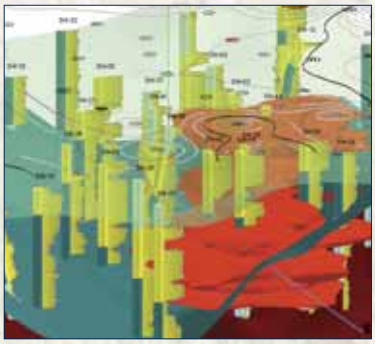

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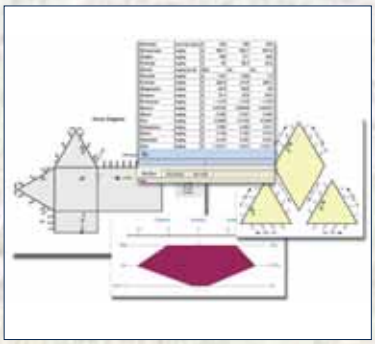

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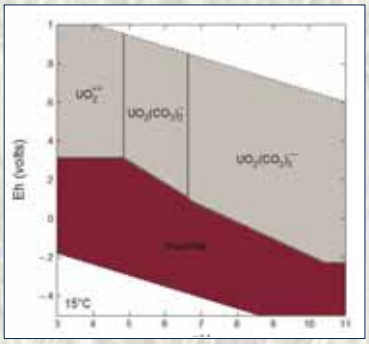

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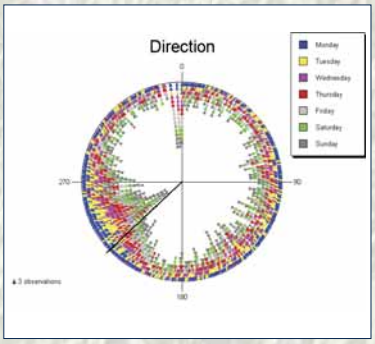

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SCIENCE ARTICLE

Cover: Following the footsteps of stampeders to the Klondike creeks, scientists from across Canada and abroad were lured to the area by reports of spectacular ice-age fossils from the permafrost, including this mammoth skull (not mastodon as written) recovered from Quartz Creek following the Gold Rush. Photo courtesy Dawson City Museum Archives (1990.54.35). See "The Klondike goldfields and Pleistocene environments of Beringia" by D.G. Froese et al., p. 4–10.

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The Klondike goldfields and Pleistocene environments of Beringia

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ABSTRACT

The Klondike goldfields of Yukon, Canada, contain a key record of Pleistocene Beringia, the region of Alaska, Siberia, and Yukon that remained largely unglaciated during the late Cenozoic. A concentration of mining exposures, with relict permafrost that is locally more than 700,000 years old, provides exceptional preservation of paleoenvironmental archives and a new perspective on the nature of paleoenvironments during the Pleistocene. A critical feature is the stratigraphic association of distal tephra beds with these paleoenvironmental archives, which facilitates their regional correlation and, in many cases, provides independent ages for the paleoenvironmental assemblages. Paleoenvironmental analyses of fossil arctic ground-squirrel middens and buried vegetation indicate the presence of cryoxerophilous ("steppe-tundra") vegetation growing on well-drained substrates with deep active layers (seasonal thaw depths) during cold intervals of the Pleistocene. Studies of full-glacial paleosols and cryostratigraphic relations of associated ground ice indicate the importance of active loess deposition and surface vegetation cover in maintaining the functionally distinct mammoth-steppe biome, which supported grazing mega-fauna populations, including mammoth, horse, and bison.

INTRODUCTION

Swedish biogeographer Eric Hultén introduced the concept of Beringia to explain the distribution of arctic and boreal plants around the Bering Strait. He proposed that a continuous Holarctic refugium beyond the continental ice sheets of North America existed during the Quaternary (Hultén, 1937). Hultén originally considered Beringia as the region of the continental shelf exposed when lowered sea level connected eastern Asia with North America, but we now consider it more broadly to

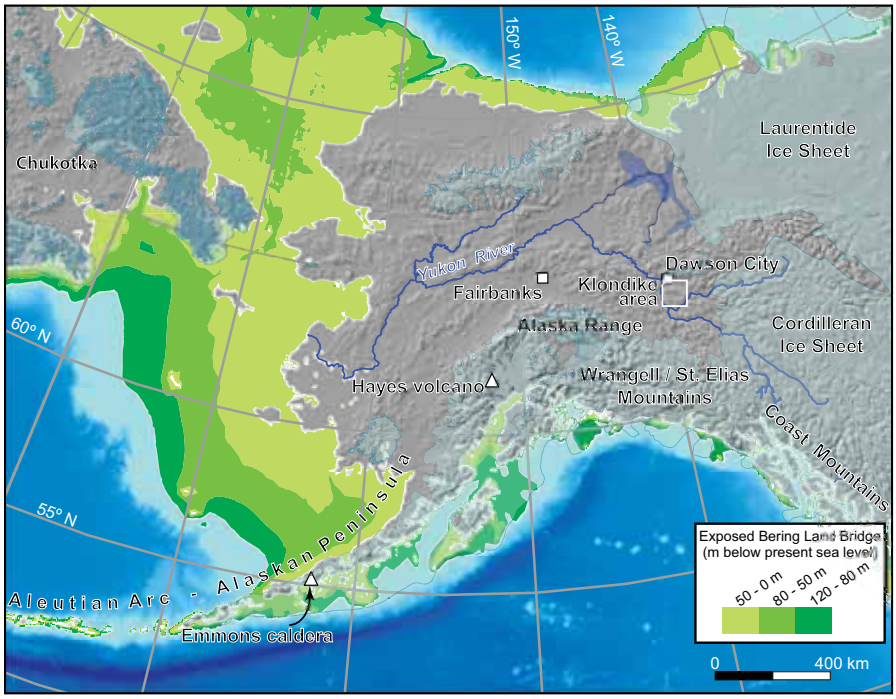

Figure 1. Eastern Beringia during the last glacial maximum with eustatic sea level lowering of 120 m. The region was largely unglaciated with the exception of local uplands that supported alpine glaciers (glacier limits from Ehlers and Gibbard, 2004).

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include the unglaciated landmass from the Kolyma River in Siberia to Yukon, Canada. This area extends ~3000 km across, and includes the Klondike region toward the eastern edge of that boundary (Fig. 1).

Beringia represents the largest contiguous Arctic expanse to remain unglaciated during the Pliocene and Pleistocene and preserves an exceptional sedimentary archive spanning the past several million years. Relict permafrost (Kotler and Burn, 2000; Froese et al., 2008) in Beringia has preserved a diversity of exceptional paleoenvironmental archives, including mammals (Guthrie, 1990), paleobotanical remains (Goetcheus and Birks, 2001; Zazula et al., 2003), and ancient DNA (Shapiro et al., 2004). Critical to stratigraphic integrity, and to understanding the paleoenvironmental significance of these archives, is the presence of widespread (>10^6 km^2) and numerous distal volcanic ash layers or tephra beds (Westgate et al., 2001). These tephra beds are datable by a variety of methods, including glass fission-track (Westgate et al., 2001) and associated radiocarbon ages (Froese et al., 2002), but they also provide correlative timelines between sites based on their unique geochemistry. The presence of these tephra beds within the perennially frozen late Cenozoic sediments of eastern Beringia is unique to this area of the northern hemisphere. Similar permafrost-preserved records are found in Siberia (e.g., Sher et al., 2005), but the lack of readily datable materials there, namely a rich tephrostratigraphy, is a challenge to developing chronologies beyond the range of radiocarbon dating (~50,000 years).

Substantial progress has been made since Hultén's time in documenting the biogeographic significance of Beringia (Hopkins et al., 1982; Brigham-Grette, 2001), including its role as an evolutionary center (Sher, 1997) and as the crossroads for faunal exchanges between Asia and North America (e.g., Sher, 1999; Repenning and Brouwers, 1992; Shapiro et al., 2004). However, considerable debate has focused on how Beringia could support a diverse grazing megafauna under Pleistocene glacial climates (Guthrie, 1990). Discussion is based largely on interpretations of lacustrine paleoecological records that differ from those derived from river bluff exposures and, especially, exposures in the Fairbanks placer mining region (Hopkins et al., 1982; Guthrie, 1990). Until recently, however, the Klondike region has received comparatively little attention beyond the analysis of late Pleistocene vertebrate fossils (Harington, 2003). Here, we highlight recent study of the tephrostratigraphy and associated paleoenvironmental archives in the Klondike region, which has led to new understanding of late Pleistocene environments of Beringia.

REGIONAL SETTING

The interior of Yukon and Alaska has a strongly continental climate due to the pronounced rain shadow of the Coast and St. Elias Mountains of western Canada and the Alaska Range and Wrangell Mountains of southern Alaska (Fig. 1). This aridity was likely established by the Pliocene (White et al., 1997; Froese et al., 2000), such that during Plio-Pleistocene glacial intervals, the interior of Yukon and Alaska was cold enough to support ice sheets but too dry for extensive glaciation. The Klondike region lies at the eastern edge of this unglaciated area, within 150 km of the last glacial maximum Cordilleran Ice Sheet (Fig. 1).

Figure 2. *Bison priscus* skull recovered from sediments associated with the late Pleistocene Dawson tephra on a tributary to Dominion Creek. Pleistocene fossils are still actively recovered from perennially frozen placer mining exposures in the Klondike, particularly in narrow valleys and near hillslopes where loessal "muck" deposits have aggraded.

Since the discovery of placer gold in the Klondike in 1896 and the subsequent gold rush, mining has produced tremendous exposures of surficial sediments within the Klondike goldfields, along with the recognition of abundant Pleistocene fossil bones (e.g., Harington and Clulow, 1973). Prior to the gold rush, G.M. Dawson and R.G. McConnell of the Geological Survey of Canada (Dawson, 1894) had collected fossils from the area, and the Muséum d'histoire naturelle de Paris, the U.S. Biological Survey, and the American Museum of Natural History sent researchers to collect ice-age fossils in the early 1900s. Perhaps the most noteworthy of all paleontologists to have worked in the Klondike is C.R. Harington, who made sizable vertebrate collections for the Canadian Museum of Nature during the 1960s–1990s. Hundreds to thousands of fossils are still produced every year from placer gold mining and provide an invaluable research resource (Fig. 2).

Nearly all drainages of King Solomon Dome (Fig. 3) have produced gold, with total production estimated at ~15,000,000 oz; active mining produces >50,000 oz annually, largely from small, independently owned mines. Development of radiating drainage from King Solomon Dome (Fig. 3) during the Cenozoic released gold from bedrock sources, and, coupled with slow rates of uplift, produced prominent terraces in major valleys dating to the Pliocene and early Pleistocene (McConnell, 1907; Froese et al., 2000). In the valley bottoms, local creek gravels are associated with ice-rich loess, or "muck" deposits (Fig. 4).

TEPHROSTRATIGRAPHIC FRAMEWORK

The presence of numerous distal silicic tephra beds has been instrumental in the development and interpretation of the late Cenozoic sedimentary and paleoenvironmental record in the Klondike region (Preece et al., 2000; Westgate et al., 2001).

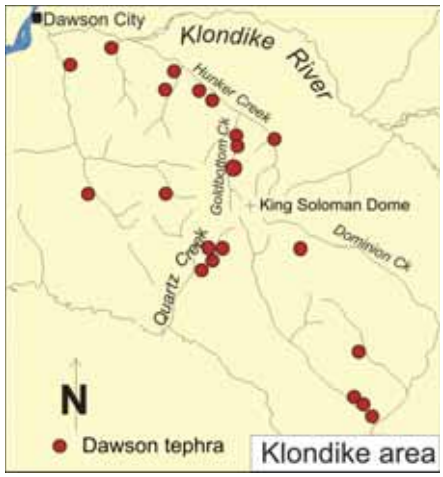

Figure 3. Klondike area map of late Pleistocene Dawson tephra locations (after Froese et al., 2006).

Figure 4. Ice-rich loessal deposits, or "muck," of the Klondike goldfields. Aggradation of loess with permafrost has led to exceptional preservation of paleoenvironmental archives in the Klondike area. Paleoenvironmental reconstruction from these muck deposits, sometimes called "Pleistocene in a blender," was largely avoided because of their complexity. Detailed tephrostratigraphy has led to new understanding of their significance for reconstructing Pleistocene environments of eastern Beringia.

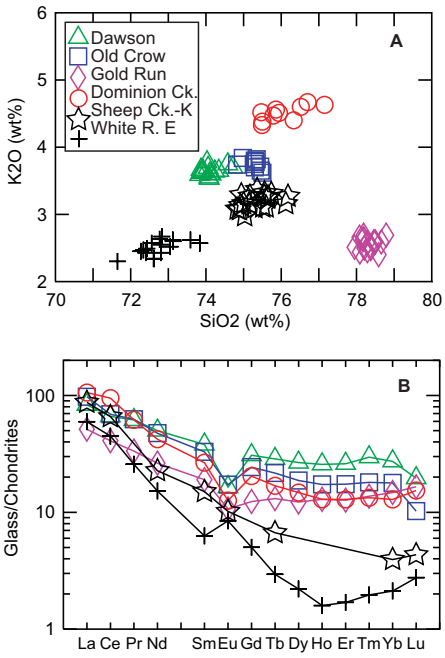

Figure 5. (A) Bivariate plot of SiO_2-K_2O in glass shards illustrating differences in geochemistry for some Klondike area tephra beds. (B) Rare earth element profiles for tephra beds shown in A. Data are normalized to chondrites using the values of Sun and McDonough (1989). Dawson, Old Crow, and Dominion Creek tephra beds have Type I characteristics, while Sheep Creek-K and White River Ash–east lobe (White R. E) have Type II characteristics. Gold Run tephra has a distinctive mix of characteristics, with glass trace-element compositions similar to Type I and mineralogy similar to Type II (data sources and analytical methods: Preece et al., 2000; Westgate et al., 2001, 2008; Pearce et al., 2004; this paper).

The glass morphology, mineral content, and geochemistry of each tephra bed help to reveal its provenance and suggest two broad volcanic source areas (Fig. 5; Preece et al., 2000). Tephra beds from the Aleutian arc–Alaska Peninsula, or Type I beds, have few crystals, mainly bubble-wall glass shards, abundant pyroxene, and rare earth element (REE) profiles with a well-developed negative Eu anomaly (Fig. 5). In contrast, Type II beds, derived from the Wrangell Volcanic Field (and Hayes volcano), have abundant crystals and glass that is mainly in the form of highly inflated pumice; hornblende is abundant, and REE profiles are steep, with a weakly developed Eu anomaly (Fig. 5). Physical and chemical properties, together with stratigraphic and paleoecological context, allow identification of tephra beds and their correlation between sites (Fig. 5). At least seven Type I beds are known in the Klondike, including Dawson (25.3 ^{14}C ka B.P.), Dominion Creek (82 ± 9 ka), and Old Crow (131 ± 11 ka); the 26 known Type II beds include White River Ash (1.2 and 1.7 ka) and Sheep Creek-K (ca. 80 ka). Six "other" beds are also present in the Klondike; these are either too mafic for classification or, like the Gold Run tephra (740 ± 60 ka), have characteristics of both Type I and II tephra beds.

The most commonly observed bed is the late Pleistocene Dawson tephra, one of the largest Quaternary eruptions in eastern Beringia, likely exceeding 50 km^3 (Fig. 6; Froese et al., 2002, 2006; Mangan et al., 2003). Dawson tephra has been identified at more than 20 sites in the area (Fig. 3), where it typically occurs as a 30–80-cm-thick bed in "muck" deposits (Fig. 7). Bracketing radiocarbon ages on plant macrofossils provide a mean age of ca. 25,300 ^{14}C yr B.P. and a calendar year estimate of ca. 30,000 yr B.P. (Froese et al., 2006; Demuro et al., 2008); Dawson tephra marks the onset of glacial conditions of Marine Isotope Stage (MIS) 2 in central Yukon (Zazula et al., 2006). Other beds provide similar time markers in the Klondike: Old Crow tephra for late MIS 6 (131 ± 11 ka; Péwé et al., 2009), directly below the last interglacial (MIS 5e) thaw unconformity; Sheep Creek-C tephra (ca. 90 ka) for late MIS 5 interglacial conditions; and Sheep Creek-K tephra (ca. 80 ka) for the MIS 5–4 transition (Westgate et al., 2008). Collectively, these and other beds provide key marker horizons for discrete timeslices between sites in the Klondike, allowing integration of diverse paleoenvironmental archives from relict permafrost, plant and insect macrofossils, pollen, and vertebrate remains.

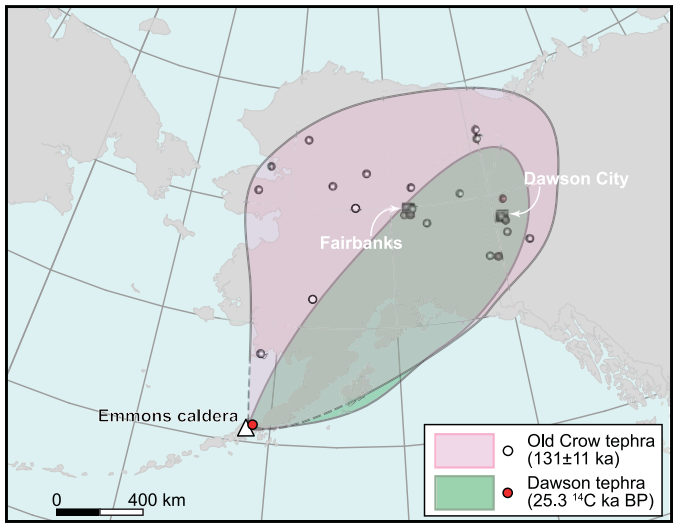

Figure 6. Dawson and Old Crow tephra distribution (after Froese et al., 2002).

Figure 8. Ice wedge cross-cutting late MIS 5 forest bed at head level of person in photo along Dominion Creek. Sheep Creek tephra-K (ca. 80 ka) is present about midway through the silts (arrow), marking the late MIS 5–4 transition in central Yukon.

Figure 7. Late Pleistocene Dawson tephra (25,300 ^{14}C yr B.P.) overlying syngenetic ice wedge at Quartz Creek. Depression of tephra into the wedge top (upper right) marks the former depression of the polygonal ground network, indicating the ice wedge was active when the tephra was deposited. Arrows mark arctic ground squirrel middens; tephra thickness is ~40 cm.

Figure 9. Graminoid-rich paleosol with roots overlying ice wedge, marking the paleo-active layer when the soil was formed. The paleosol is cross-cut by secondary ice wedge growth (vertical arrow at left) and includes beds of Dominion Creek tephra (82 ± 9 ka; horizontal arrow), marking early MIS 4 glacial conditions. Ice axe: 80 cm.

"MUCK": BERINGIA'S ICE AGE FREEZER

Muck deposits in the Klondike are part of a broader complex of silts that blanket much of Beringia and are usually considered to be loess and locally re-transported loess from creeks and river valleys that aggraded with permafrost (Péwé, 1975; Fraser and Burn, 1997; Muhs et al., 2003; Fig. 8). In the discontinuous permafrost zone (50%–90% frozen ground), which includes the Klondike and Fairbanks regions, these ice-rich loessal deposits are found on north- and east-facing slopes and within narrow valleys along hillslopes. The frozen deposits have high organic carbon content (Fraser and Burn, 1997; Sanborn et al., 2006), reflecting aggradation of the permafrost table with silt deposition, and may reach tens of meters in thickness. These combined processes buried soils before their associated root detritus and other plant material could decompose (Fig. 9), preserving Pleistocene organic remains in permafrost at some sites for more than 700,000 years (Froese et al., 2008). Similar Pleistocene deposits are present in Siberia, where they are termed Yedoma, though it is not well accepted that these are, sensu stricto, eolian deposits (Sher, 1997; Schirrmeister et al., 2008).

The influence of surface vegetation cover on permafrost reveals important functional differences between the reconstructed Pleistocene glacial steppe-tundra environment (Zazula et al., 2003) and the modern boreal forest environment of interior Yukon and Alaska. Most sites with mucks present are north- and east-facing or in narrow valleys with black spruce (*Picea mariana*) forests and are characterized by thick covers of moss and partially humified vegetation litter. The thermal properties of this groundcover promote deep winter cooling and insulate the ground from summer heat, resulting in poorly

drained substrates with permafrost and shallow active layer depths. Recovery of MIS 2 and 4 arctic ground-squirrel middens and paleosols from muck deposits at these sites reveals that substrates were better drained during Pleistocene glacial intervals than they are at present (Zazula et al., 2005; Sanborn et al., 2006). In fact, arctic ground squirrels are absent from the Klondike region today, suggesting important expansion of their ranges during Pleistocene glacial intervals (Zazula et al., 2005). Present-day ground squirrels, in southern Yukon and the north slope of Alaska, require well-drained soils with active layer depths of ~1 m for burrowing and successful hibernation. The translocation of paleosol A-horizon material in the paleoactive layer and truncation of underlying ice bodies provide additional evidence for deeper active layers (Sanborn et al., 2006; Fig. 9). Thus, despite summer air temperature depression of several degrees Celsius during the glacial intervals (e.g., Elias, 2001), soils were better drained with deeper active layers due to the presence of graminoid vegetation cover, which lacked the insulating properties of modern soils in the region. Well-drained soils with deeper active layers and additions of soil nutrients from loess deposition would have enabled greater nutrient turnover, essential for a herbaceous steppe-tundra habitat that supported herbivores, such as woolly mammoths and horses (Laxton et al., 1996).

QUATERNARY MAMMAL FOSSILS

The Klondike is one of North America's most productive localities for the recovery of late Pleistocene mammal fossils (Harington, 2003). Most Klondike faunas are dominated by the "big-three" of Beringia—steppe bison (Fig. 2; *Bison priscus*), woolly mammoth (*Mammuthus primigenius*), and Yukon horse (*Equus lambei*). Fossils of less common species are recovered occasionally, including the western camel (*Camelops hesternus*), American mastodon (*Mammut americanum*), American lion (*Panthera leo atrox*), short-faced bear (*Arctodus simus*), and helmeted muskox (*Bootherium bombifrons*). Mummified or freeze-dried partial carcasses recovered from the Klondike highlight the role of permafrost in the preservation of the late Pleistocene paleontological record. Impressive mummified carcasses include black-footed ferret (*Mustela nigripes*) and Yukon horse (*Equus lambei*), whose stomach contents have provided important dietary information (Harington, 2007). The exceptional preservation of Klondike vertebrate bones has led to recent ancient biomolecule studies using mitochondrial DNA sequencing and radiocarbon dating to establish phylogenetic histories for bison (Shapiro et al., 2004), horse (Weinstock et al., 2005), and mammoth (Debruyne et al., 2008).

PALEOENVIRONMENTAL ARCHIVES

Questions concerning the nature of terrestrial ecosystems in Beringia have been a major research focus for Quaternary paleoecologists for decades (Hopkins et al., 1982; Guthrie, 1990; Birks and Birks, 2000). Although the Klondike region has been well known for Pleistocene mammal fossils for the past century, there has been little systematic paleoecological research in the region until the last decade. The abundance of Pleistocene vertebrate faunas and well-constrained stratigraphic records makes the Klondike a valuable region for resolving questions concerning the relations between mammals, glacial vegetation, and Pleistocene climates.

Recent paleoecological work in the Klondike has focused on detailed analysis of fossil middens (nests, seed caches, and burrows) of arctic ground squirrels (*Spermophilus parryii*) (Zazula et al., 2003, 2007). In the Klondike, over 100 middens have been recovered and analyzed systematically in association with the Sheep Creek-K–Dominion Creek tephras (ca. 80 ka) and Dawson tephra (ca. 25.3 ^{14}C ka), providing paleoenvironmental records for MIS 4 and early MIS 2, respectively. Plant macrofossils (seeds, fruits, leaves) from the middens are dominated by grasses, dryland sedges, sage, and a wide variety of flowering forbs. Together, these plants formed an open, grass- and forb-rich steppe-tundra community that thrived on the well-drained, deeply thawed loessal soils in the Klondike during Pleistocene cold intervals.

CONCLUSIONS

The Klondike goldfields provide an exceptional record of Pleistocene Beringia. The development of a robust tephrostratigraphic and chronologic framework for the perennially frozen deposits has facilitated integration of paleoenvironmental archives from vertebrate remains and paleobotanical, paleosol, and cryostratigraphic observations. This mammoth-steppe environment was characterized by graminoid and forb-rich vegetation with better-drained loessal substrates and deeper active layers despite summer temperature depressions. Collectively, these records support the notion that functional differences between the cryoxeric steppe-tundra and the modern boreal environment provides a means to explain the existence of a rich grazing fauna during Pleistocene glacial intervals.

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LETTERS

Dear Dr. Parrish,

I would like to thank you for your defense of industry, (*GSA Today*, v. 19, no. 6, p. 11–12), especially big industry, in spite of the fact that I, personally, was never particularly happy working for large companies.

I would like to add to your comments that it takes two to tango. We would not have environmental problems associated with mining and energy production on the scale that we do if the demand were not there, and the demand is us, every single last one of us.

We demand low-cost goods and low-cost energy, and we happily buy ever larger houses and cars and ever more things to go in them. We travel more and more. We also have powerful institutions and incentives to keep the population growing and, hence, increasing demand.

These actions lead inevitably to larger and larger holes in the ground in more and more sensitive places. If we each paid as much attention to reducing our footprint on the planet as many of us do to "saving" this and that aspect of nature, nature could take care of itself and our civilization would last a lot longer. Those who criticize industry's environmental damage should look in the mirror.

Thank you,

John Berry, *John Berry Associates, jlbassoc@flash.net*

To the editor of *GSA Today*,

The evident need for the column by President Parrish in the June issue was a surprise and a disappointment to me. I've been one of the evil resource-extraction polluters for more than 50 years. If I ever encountered a fellow geoscientist who took offense at my occupation, I was too dumb to notice. It saddens me that such folks are out there.

The article offered several items in defense of industry people. That shouldn't be necessary, but since it seems to be, I think it is worthwhile to point out two other factors: (1) no governmental or academic employee could possibly survive in this day and age without the benefits of extracted mineral or hydrocarbon resources; and (2) nor could these same people earn their living without benefit of industry. Their funding ultimately derives from taxes on tangible goods that have been created and sold by industry. The truth is, geoscientists in both resource and non-resource arenas need each other. So enough of this holier-than-thou business.

John T. (Ted) Schulenberg, *schulen@ktc.com*

Send letters to GSAToday@geosociety.com or Managing Editor, GSA Today, P.O. Box 9140, Boulder, CO 80301-9140, USA. Please keep your letter to 300 words or fewer. *GSA Today* reserves the right to edit letters for space and clarity, and opinions presented do not reflect official positions of the Society. Read letters at www.geosociety.org/gsatoday/letters/.

Earth Science Literacy Initiative

The Earth Science Literacy Initiative has released its **Earth Science Literacy Principles**—nine "Big Ideas" outlining what every Earth citizen should know about earth science.

The Earth Science Literacy Initiative is funded by the U.S. National Science Foundation and cosponsored by such major geological organizations as GSA, AGU, AGI, and the USGS. The nine principles and 75 supporting concepts were assembled through the cooperation of many hundreds of earth scientists and educators and represent the current state of understanding in the earth-science research community.

GSA members can help spread the word about this research-backed framework of essential earth-science principles. Learn how at **www.earthscienceliteracy.org.**

Mark Gabriel Little

GSA-USGS Congressional Science Fellow Named for 2009–2010

GSA is pleased to announce that Mark Gabriel Little has been selected as the 2009–2010 GSA–U.S. Geological Survey Congressional Science Fellow. Little anticipates that his diverse background in earth science, public policy, and social entrepreneurship will provide the basis for an exciting year of service. Little graduated *magna cum laude* from Harvard University in 2001 after completing coursework in environmental geochemistry and a research project in planetary science at the Massachusetts Institute of Technology. After a brief respite coaching track in New York, he began graduate school at Rice University, investigating the geochemical mechanisms of soil formation in Tanzania and the theoretical relationships between physical erosion and chemical weathering. Little also developed and taught courses on climate, energy, and sustainable development from a natural resources perspective. Concurrent with his graduate studies, Little organized forums at the James A. Baker III Institute for Public Policy on such topics as human trafficking, military interrogation, and domestic HIV/AIDS.

After completing a Ph.D. in geochemistry, Little spent one year in Beijing as a Luce Scholar, researching organic air pollution and lecturing on climate and energy in the Department of Urban and Environmental Sciences at Peking University. This experience not only provided an immersion into a distinctly different society but also fresh perspectives on life, politics, and science in the United States. While in China, Little worked with Chinese colleagues to create an international organization dedicated to addressing climate change and other global environmental issues by engaging all stakeholders. Since returning to the United States, Little has been working as a postdoctoral research associate at Duke University, determining the potential environmental impacts of geologic carbon sequestration, and consulting for the University of North Carolina and the Biofuels Center of North Carolina on a Strategic Crop Initiative.

Little's pursuits, scientific or otherwise, are motivated by the belief that both knowledge and the will to act are required to overcome problems like climate change as well as to realize the promise of non-traditional energy production. He hopes that this fellowship will provide him the opportunity to give a strong voice to the knowledge of the scientific community amongst the din of diverse and competing voices on the Hill.

GSA MENTOR PROGRAMS

MENTORING TOMORROW'S GEOSCIENCE LEADERS

Two of the most popular events for students at GSA Section Meetings are the Roy J. Shlemon Mentor Program in Applied Geology and the John Mann Mentors in Applied Hydrogeology Program. These meetings, which include a free lunch, are supported by the GSA Foundation through gifts from Roy J. Shlemon and John Mann.

The Shlemon and Mann mentor programs support undergraduate and graduate students interested in applied geology or hydrogeology as a career and extend the mentoring reach of professionals in applied geology by providing a forum for brief presentations, informal conversation, and networking. Both mentors and students leave these events expressing feelings of personal and professional growth.

The 2009 Section Meeting mentor events were exceptionally successful; Shlemon Program funds provided 324 students the chance to meet with 50 mentors, and the Mann Program brought together 135 students and 28 mentors. Mentor volunteers—from private and public businesses and government agencies—represented a broad range of backgrounds, education, and experience.

STUDENT COMMENTS:

- "Excellent insight for job-hunting and what to expect in industry."
- "Everyone's passion for their work was both contagious and encouraging. I enjoyed their ability to speak so honestly with us. Thank you!"
- "It was very interesting to talk to geologists in the work force. They also discussed job opportunities in the current recession, which was very helpful."

GSA gratefully acknowledges the following mentors for their individual gifts of time and for sharing their insight with GSA's student members. For more information about these programs, or to be a mentor at a future meeting, please contact Jennifer Nocerino, jnocerino@geosociety.org.

The Roy J. Shlemon Mentor Program in Applied Geology

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Photos from left to right: Caladesi Island State Park, Florida. Photo courtesy of Visit St. Petersburg/Clearwater. Dallas, Texas skyline. Photo courtesy Melissa Fenton. Bug Light Park, Portland, Maine. Photo courtesy Convention and Visitors Bureau of Greater Portland. Juvenile *Tyrannosaurus rex*, Jane. Photo courtesy Rockford Area Convention and Visitors Bureau. Squally Point, Okanagan Lake, British Columbia, Canada. Photo courtesy Robert Young. Early Jurassic strata in Capitol Reef National Park at sunset, 2007. Photo by B. Kowallis.

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THE GEOLOGICAL SOCIETY OF AMERICA®

FIELD FORUM SCHEDULED

Significance of along-strike variations for the 3-D architecture of orogens: The Hellenides and Anatolides in the eastern Mediterranean

16–22 May 2010

CONVENERS

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NASA satellite photo of Samos, Greece.

DESCRIPTION

Along-strike variations are a common characteristic of orogens and have been described in the European Alps, the North American Cordillera, the Andes, and the Hellenide-Anatolide orogen of southeastern Europe. The causes for along-strike variations might be different, but preorogenic paleogeography, continental architecture, and kinematic/geometric variations at the lithospheric scale potentially play an important role. Along-strike changes in orogens have a profound impact on how major orogenic processes proceed in time and space.

For the Hellenide-Anatolide orogen, along-strike variations can be well studied in westernmost Turkey and the adjacent Greek island of Samos. This field forum will focus on the following observables:

- topography;
- structures (from surface structures to geophysical data);
- paleogeographic domains;
- magmatic and metamorphic rock distribution; and
- the geometry of extensional faults and shear zones, associated sedimentary basin distribution and geothermal fields.

From the observables, we will try to infer processes, such as

- the spatial and temporal progression of subduction-zone retreat in the region;
- the dynamics of crustal accretion;
- the thermal-mechanical evolution of the orogenic belt; and
- the dynamics of continental extension.

SIGNIFICANCE

The idea for this broad, field-based international conference is borne of recent transdisciplinary field-based studies pointing out major along-strike variations in the Hellenide-Anatolide orogen that bear strongly on future research directions. These studies showed that differences in preorogenic paleogeography caused the Hellenide orogen of eastern Greece and the Anatolide Belt of western Turkey to evolve in sharply different ways. We believe that better identification and understanding

of those differences will potentially clarify how eastern Mediterranean subduction zones evolved, how preorogenic architecture controls crustal thickening and the subsequent exhumation of high-pressure rocks, and how large-scale continental extension evolves.

Recent geodetic studies and numerical models also address the problem of lateral variations in orogens; however, model assumptions outstrip field-based observations, the latter of which are much more complicated and exceed the capacity of any numerical and scaled analog material simulations, especially in 3-D.

These studies also bear on a number of new and innovative methods for interpretation of geochronologic data for direct dating of deformation and metamorphism. Deciphering temporal aspects of orogenic processes is an important objective in tectonics. The key to successful dating of orogenic processes directly depends on appropriate sampling in the field; therefore, it is crucial that this aspect be discussed thoroughly in the field.

The key objective of this field forum is to bring together modelers and geodetic experts with colleagues from the more traditional, observational approaches of seismology, structural geology, petrology, and geochronology in the field to discuss outcrops in the field. Topics covered will include what conclusions can be drawn from field observations, how critical it is to sample appropriately, and what sorts of information can be retrieved from a certain outcrop. The conveners expect that this mixture of scientists and topics will provide a basis for better integrated research strategies for investigating along-strike variations in orogens, subduction-zone processes, and subsequent continental extension.

The spatial and temporal evolution of the Hellenide-Anatolide orogen is also significant economically because of its key importance to understanding spatial controls on faults and basins for hydrocarbon generation, metallogeny, and geothermal resources.

ITINERARY

Participants will arrive on Sunday, 16 May 2010, on the Greek island of Samos, where the first two days of the Field Forum will take place. Samos is located in the internal zone of the Hellenide orogen, which is mainly made up by the Cycladic Blueschist Unit, the most deeply exhumed unit in the central Hellenides. The forum ends in western Turkey on Sunday, 23 May.

Day 1, 17 May: The first field trip will introduce the participants to the Cycladic Blueschist Unit (CBU) to observe in detail at the contact between the CBU and the underlying Kerketas Nappe. The contact is superbly exposed along a 1–2-km ridge section and then again at the top of the 1400-m-high mountain. The latter is considered part of the Tripolitza Unit, which is well exposed farther south in the External Hellenides but is also exposed in a few windows within the Internal Hellenides (i.e., on Samos).

Day 2, 18 May: This day will be devoted to talks and discussions. Key participants will give ~30-minute overview talks highlighting the problems and consequences of along-strike variations. We will also ask a few other participants to give ~15-minute talks, and most participants will be encouraged to present posters.

Day 3, 19 May: In the morning, the group will take the ferry from Samos to the town of Kusadasi on the Turkish west coast. In western Turkey, the Menderes Nappes occur structurally below the Cycladic Blueschist Unit. The Menderes Nappes have an entirely different paleogeographic and tectonic history than the Kerketas Nappe in Samos. We intend to overnight in the town of Selcuk, from which critical outcrops can be reached within less than one hour, including outcrops of the Cycladic Blueschist Unit and the Ephesus fault. There will also be an opportunity to visit the ruins of Ephesus at the end of the day.

Day 4, 20 May: We will examine the cross section at Ballikaya Tepesi in the Aydin Mountains, where the juxtaposition of the Cycladic Blueschist Unit and the Menderes Nappes is well exposed. The outcrops provide evidence for the thrusting of the Cycladic Blueschist Unit onto the Menderes Nappes. The mylonites have been dated, and field discussions may focus on how mylonitization can be dated directly.

Day 5, 21 May: We will concentrate on the southern margin of the Menderes Massif between Lake Bafa and Selimiye. The Lake Bafa area provides access to the contact between multiply deformed magmatic and metapelitic rocks within the Menderes Nappes. The Selimiye shear zone is a controversial feature, interpreted both as extensional and contractional. This shear zone is of key importance for understanding the emplacement of the high-pressure rocks of the Cycladic Blueschist Unit above greenschist-facies rocks of the Menderes Nappes. We will provide evidence for sustained contractional deformation across the Menderes Nappes.

Day 6, 22 May: This cross section across the Bozdag and Aydin Mountains will wrap up nicely the tectonics of the region. The cross section provides an outline of the geometry of the Alpine nappe stack, including the fabric evolution that was used to define the tectonic units. The section also provides an overview of the low-angle detachments and the high-angle normal faults that define the young extensional history and the topographic evolution of the central Menderes Massif, which is distinctly different from that of the adjacent Greek islands. There may also be the opportunity to visit a geothermal site.

EXPRESSIONS OF INTEREST

Logistical constraints limit participation to 35 people. Participant selection will ensure broad representation by nationality, occupation (i.e., faculty, graduate students, and industry and government scientists), and research interest (i.e., structural geology, metamorphic petrology, isotope geochronology, sedimentology, geomorphology, and geodynamics). Interested individuals should inform the organizing committee by 9 Dec. 2009 of their desire to participate by sending an e-mail outlining how they will contribute to the theme of the forum to Uwe Ring at uwe.ring@canterbury.ac.nz. Registration fees are still to be determined; please check www.geosociety.org for updates.

Portland, Oregon, USA • 18–21 October 2009

LAST

▶▶ CALL FOR PAPERS ◀◀

Deadline: 11 August 2009

GUIDELINES FOR SUBMITTING AN ABSTRACT

- Submit abstracts online only at **www.geosociety.org/meetings/2009/techprog.htm**;
- Your abstract must be no more than 2,000 characters and should not include title or authors;
- Fees per abstract submission (non-refundable): professionals, US$30; graduate and undergraduate students, US$20;
- Payment by credit card must be made upon submission or your paper will not be considered for the meeting;
- You may submit two abstracts, *as long as one of these abstracts is for a poster presentation*;
- All presenters must pay the registration fee to attend the annual meeting;
- The annual meeting *Abstracts with Programs* book will not be mailed prior to the meeting in order to accommodate the later abstracts submission deadline;
- Joint Technical Program organizers will decide whether to place your paper in a poster or oral session, and their decision is final.

POSTER PRESENTERS

- GSA will provide a horizontal, freestanding 8-ft by 4-ft display board and Velcro for hanging your poster;
- Posters will be on display 9 a.m.–6 p.m.;
- Each poster booth will share a 6-ft by 30-inch table with another poster presenter.

Poster Printing Service

New this year! GSA and DP_i Printing are pleased to offer printing and delivery services to annual meeting poster presenters. All orders must be pre-paid (estimated cost: US$100 for a 4 × 8 ft. poster) and received at DP_i by 14 October. Submit your poster files in PDF format to **http://ftp.dpi-sf.com,** using login name **GSA** and password **dpisf**. Valid ID is required for poster pick up. If you have questions regarding this service, contact DP_i Printing at +1-415-216-0031.

ORAL PRESENTERS

- The normal length of an oral presentation is 12 minutes, plus three minutes for Q&A.
- You *must* visit the Speaker Ready Room at least 24 hours before your scheduled presentation.
- All technical session rooms are equipped with a laptop computer.
- If your presentation was created on a Mac, you must save it to run on a PC. Please test it before coming to the meeting as well as in the Speaker Ready Room.
- If your presentation includes embedded video, please convert any .mov files to .avi format, or create a link in your slide show to an external .mov file. If you choose the latter, your animation will play in a separate QuickTime window outside of your PowerPoint presentation.

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From Volcanoes to Vineyards: 2009 Portland, Oregon, USA Living with Dynamic Landscapes

planetearth® Earth Sciences for Society

DISCIPLINE CATEGORIES

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

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

Abstracts deadline: 11 August

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

2009 GSA Annual Meeting
Portland, Oregon, USA

Lunchtime Keynote Lectures

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

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

Sally M. Benson

Lunchtime Keynote Lecture 2: Can Sequestration of Carbon Dioxide in Deep Geological Formations Help Solve the Global Warming Problem?

Sally M. Benson, Michel T. Halbouty Distinguished Lecturer

Monday, 19 Oct. 2009

Sally M. Benson, director of the Global Climate and Energy Project, is also a professor in the Dept. of Energy Resources Engineering at Stanford University's School of Earth Sciences. Her research group investigates fundamental characteristics of CO_2 storage in geologic formations as a means of climate-change mitigation, and she teaches classes on these topics.

A groundwater hydrologist and reservoir engineer, Benson has conducted research on a range of issues related to energy and the environment. For the past ten years, she has studied how to reduce greenhouse gas emissions by capturing CO_2 from power plants and pumping it into deep underground formations for permanent sequestration and was a coordinating lead author on the 2005 IPCC Special Report on Carbon Dioxide Capture and Storage. Her research interests include technologies and energy systems for a low-carbon future, groundwater quality and remediation, selenium biogeochemistry, and geotechnical instrumentation for subsurface characterization and monitoring.

In little more than a decade, CO_2 capture and sequestration has emerged as one of the most important options for reducing CO_2 emissions. Two major challenges stand in the way of realizing this potential: the high cost of capturing CO_2 and increasing confidence in the capacity, safety, and permanence of sequestration. Building on laboratory and field-based studies of multiphase CO_2 flow in porous rock, this talk will address the current prospects for carbon dioxide sequestration, including

- Which formations can provide safe and secure sequestration?
- At what scale will this be practical, and is this scale sufficient to significantly reduce emissions?
- What monitoring methods can be used to provide assurance that CO_2 remains trapped underground?
- What if a leak develops?
- What are the potential impacts on groundwater resources, and how can these be avoided?

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Check future issues of* GSA Today *as we unveil subsequent lectures. You'll be surprised by who's to come!

GUEST PROGRAM

As part of GSA's Guest Program, we offer the following seminars in the Guest Hospitality Suite at the Convention Center. In addition to these seminars, we will provide light snacks and refreshments, special giveaways and drawings, and have a local expert on restaurant and activities in the Portland area on hand to answer your questions.

For Guest Hospitality Suite hours and information, go to **www.geosociety.org/meetings/2009/guests.htm.**

Seminars

Lewis and Clark: The Science of Discovery

Sunday, 18 Oct., 10–11 a.m.

When Lewis and Clark pushed their boats into the Missouri River in May 1804, they changed history forever. The Corps of Discovery was assembled to mount an expedition for science, but no scientists were on the roster! Presenters will discuss the reasons behind this as well as the contributions made to science by this unlikely but innovative group. An examination of methods and comparison of tools of discovery then and now will bring home the phenomenal nature of their achievements. We will also become acquainted with some of the Native American tribes who helped the expedition and the landscapes in which they lived.

Mountain Men, Trappers & Traders

Monday, 19 Oct., 10–11 a.m.

In full mountain-man regalia, our presenter will describe the earliest days of the Oregon Territory and how men and women survived using their wits and weapons. Dozens of objects for close examination will include clothing, furs, trade goods and tools, as well as trapping, hunting, and camping accessories (but no actual weapons).

Fashions of the Oregon Territory

Tuesday, 20 Oct., 10–11 a.m.

Textile specialist Marge Harding will entertain you with her in-costume presentation "Dress & Decorum"—the rules governing proper behavior when Oregon was a Territory from 1849 to 1859. Examine the exquisite workmanship of a beautifully handmade reproduction dress, copied from the museum's collections, and its nine layers of complicated undergarments (hoops, hooks, bone, and split drawers). Hear Harding recall the raucous political debate on Oregon's fate—to become British or American—and the coin toss that determined it all.

On the Oregon Trail & Pioneer Life

Wednesday, 21 Oct. 10–11am.

Using excerpts from a fictional pioneer woman's diary, participants will journey with a family as they prepare to leave Indiana, headed for the Oregon Territory. We discuss what items people took with them and what may have been left behind. A collection of artifacts and replicas will help to illustrate life on the trail and the daily perils that pioneers faced. Women, especially, were the journalists of pioneer travels, and their unique perspective is heard in this retelling. The degree of skill and perseverance needed to thrive in a new land and survive the toils of daily life are vividly illustrated in this seminar.

Tours

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

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

Sunday, 18 October

101. City Tour—Weird and Wonderful!

9 a.m.–1 p.m. Cost: US$79; min.: 20.

The "city of roses" trip would not be complete without time to see the highlights and explore both the beautiful and the unusual.

Monday, 19 October

102. Seashells at the Seashore and Rogue Ale Too!

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

Your journey will take you to the "blue Pacific" and the central Oregon fishing village of Newport.

103. Birds of a Feather—Including the Eagles!

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

This will be an 8-hour driving and walking tour of one of the Pacific Northwest's most significant winter waterfowl and raptor refuges.

Tuesday, 20 October

104. Mighty Mount Hood

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

Visit Mount Hood, which has an elevation of 11,235 feet and is just a 90-minute drive from Portland.

Wednesday, 21 October

105. Magnificent Columbia Gorge

9 a.m.–3 p.m. Cost: US$62; min.: 20.

Enjoy a motor coach ride and breathtaking views from the Crown Point Vista House located on the historic scenic highway ~700 feet above the mighty Columbia River.

GSA Annual Meeting Bulletin Board

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

It's easy and it's free!

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

HOUSING INFORMATION

Making Your Reservation

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

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

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

Questions? E-mail housing@travelportland.com or call the Travel Portland Housing Bureau.

Modify/Cancel Your Reservation

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

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

Cancellation requests received after 14 Sept. 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.

HOUSING ALERT!

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

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

UPCOMING GSA DEADLINES & EVENTS*

August

11 **LAST DAY to submit abstracts** for the 2009 GSA Annual Meeting in Portland, Oregon, USA. Go to **www.geosociety.org/meetings/2009/techprog.htm** for a link and instructions.

29 **GSA GeoVentures** trip for everyone, "Geology of the Middle Fork of the Salmon River, Idaho," meets in Stanley, Idaho, USA, through 4 Sept.

September

9 **GSA Penrose Conference,** "Low $\delta^{18}O$ rhyolites and crustal melting: Growth and redistribution of the continental crust," convenes in Twin Falls, Idaho, USA, through 13 Sept.

13 **GSA Field Forum,** "Structure and neotectonic evolution of the northern Owens Valley and the Volcanic Tableland, California," convenes in Bishop, California, USA, through 19 Sept.

14 **2009 GSA Annual Meeting** early registration, housing, and student travel grants deadlines.

21 **Annual Meeting** registration cancellation deadline.

October

4 **GSA Penrose Conference,** "Tectonic development of the Amerasia Basin," convenes at the Banff Centre, Alberta, Canada, through 9 Oct.

17 **2009 GSA Annual Meeting** Presidential Address & Awards Ceremony.

18 **2009 GSA Annual Meeting** Gold Medal Lectures and Welcoming Party & Exhibits Opening.

25 **Y.E.S. Congress 2009:** The first world Young Earth-Scientists Congress meets in Beijing, China. Learn more at **www.yescongress2009.org.**

*See next month's *GSA Today* or **www.geosociety.org/meetings/2009/** for a detailed listing of events for the 2009 GSA Annual Meeting.

NOTICE
of Council Meeting

2009 GSA Annual Meeting
Portland, Oregon, USA

Saturday, 17 Oct., 8 a.m.
and Wednesday, 21 Oct., 8 a.m.

Meetings of the GSA Council are open to Fellows, members, and associates of the Society, who may attend as observers, except during executive sessions. Only Councilors and officers may speak to agenda items, except by invitation of the chair.

Coming to *GSA Today* in September

- **Science article:** "The Portland Basin: A (big) river runs through it," by R.C. Evarts et al.
- **2009 GSA Annual Meeting & Exposition Information**
  - Topic of the Presidential Address
  - Third Lunchtime Keynote Lecturer announced
  - More about Darwin Day
  - Meeting Extras
- **Groundwork article:** "Late Holocene relative land- and sea-level changes: Providing information for stakeholders," by I. Shennan et al.

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

Donna L. Russell, *Director of Operations*

GSA Foundation's Development Committee

David A. Stephenson, *GSA Foundation President*

The GSA Foundation has formed a new Development Committee with the goal of increasing interaction with, and promoting contributions from, GSA's members and other geoscientists and friends of the Society. The Development Committee will operate with the guidance and oversight of the GSA Foundation Board of Trustees, and will assist the Board and the Foundation president in planning and executing its fund-raising activities on behalf of GSA.

Committee membership is composed of the entire Board of Trustees plus 20–25 others selected primarily from the GSA membership. Committee member demographics will be ~45% from industry, ~30% from academia, ~20% from agencies and other societies, and ~5% private citizens or from other foundations.

COMMITTEE MEMBER RESPONSIBILITIES

- Participate in strategic planning for the Foundation's development function, highlighting those GSA programs that need immediate funding;
- Identify and evaluate fund-raising prospects;
- Provide leadership and inspiration to advance the Foundation's interests and activities; and
- Potentially develop a new, several-year Capital Campaign to celebrate the Foundation's 30th anniversary (in 2011) and the Society's 125th anniversary (in 2013).

Michael Thonis has been appointed to chair the Development Committee. Thonis is currently managing director and chief operating officer of the Charlesbank Capital Partners in Boston, Mass., USA. He is a GSA Fellow, an Honorary Foundation Trustee, and has a B.S. in geology from Syracuse University, an M.S. in geology from MIT, and an MBA from Harvard.

The inaugural meeting of this new committee will be during the GSA Annual Meeting in Portland in October. Additional information on the Development Committee and the action plan will be forthcoming in a future GSA Foundation Update article.

Most memorable early geologic experience:

Travel with faculty and fellow graduate students to distant annual meetings in Atlantic City, Denver, Pittsburgh, San Francisco, and elsewhere. Shared low-budget rooms, chance to meet the giants of geology, and debate the needs for a hydrogeology division stand out together with field trips. Happy to share my experience of walking through a glass-plated door at the Denver Hilton.

—Richard Parizek

Is the Foundation in Your Will?

If you have named the GSA Foundation in your will, please check the space on the coupon below. Your name will be added to the Pardee Coterie, which is the Foundation's planned giving roster. Please use the following verbiage in your bequest:

"I hereby give, devise, and bequeath to the Geological Society of America Foundation, Inc., the sum of $X. It is my desire that this bequest to the Geological Society of America Foundation Inc. be used for the following purposes: (please specify a Foundation fund)."

If you prefer, you may also give a percentage of your estate/trust instead of a specific dollar amount. For a free copy of "Update Your Will," please contact the Foundation office at drussell@geosociety.org or +1-303-357-1054.

All members of the Coterie will be invited to attend a special breakfast during the GSA annual meeting.

Support GSA Programs

Donate now!

1 **Enclosed is my contribution in the amount of $**_____

2 Please credit my contribution to the:
- ❑ Greatest Need
- ❑ GSA's Government Affairs & Public Policy Office
- ❑ Other:_____Fund
- ❑ I've named GSA Foundation in my Will *(please contact me)*

3 Name _____

Address _____

City / State / Zip _____

Phone _____

4 Mail to:

GSA Foundation
P.O. Box 9140
Boulder, CO 80301

cut out or copy

Or donate online at **www.gsafweb.org**

UNIVERSITY OF MICHIGAN

FACULTY POSITIONS

Glaciology/Quaternary Geology

The Department of Geological Sciences is searching for an assistant professor with expertise in the response of glaciers and ice sheets to climate change. Areas of interest include, but are not limited to, studies of ice dynamics and mass balance; glacial and sub-glacial hydrology; bed characteristics; marine ice sheets; and rates and responses of ice sheets, glaciers, and proglacial landscapes to past climate change. The successful candidate will be expected to establish an independent research program and contribute to undergraduate and graduate teaching. Applicants should send a cover letter, curriculum vitae, statements of research and teaching interests, and names of at least three references. Applications should be sent by September 10, 2009 to: Glaciology Search Committee, Department of Geological Sciences, University of Michigan, 1100 N. University Ave., Ann Arbor, MI 48109-1005; or by email to: glacsearch@umich.edu.

Climate Change Impacts

The Department of Geological Sciences is searching for an assistant professor with expertise in the impacts of climate change on land-surface processes, the hydrologic cycle, terrestrial ecosystems or coastal processes using observational and/or modeling techniques. The successful candidate will be expected to establish an independent research program and contribute to undergraduate and graduate teaching. Applicants should send a cover letter, curriculum vitae, statements of research and teaching interests, and names of at least three references. Applications should be sent by September 10, 2009 to: Climate Change Search Committee, Department of Geological Sciences, University of Michigan, 1100 N. University Ave., Ann Arbor, MI 48109-1005; or by email to impactsearch@umich.edu.

Climatology/Oceanography

The Department of Geological Sciences is searching for an assistant professor with expertise in understanding the physical climate system and its response to climate change. Areas of interest include the use of observational and/or theoretical techniques to study oceanographic, atmospheric, cryospheric or land-surface processes and their interactions and climate impacts on regional or global scales. The successful candidate will be expected to establish an independent research program and contribute to undergraduate and graduate teaching. Applicants should send a cover letter, curriculum vitae, statements of research and teaching interests, and names of at least three references. Applications should be sent by September 10, 2009 to: Climatology Search Committee, Department of Geological Sciences, University of Michigan, 1100 N. University Ave., Ann Arbor, MI 48109-1005; or by email to climsearch@umich.edu.

The University of Michigan is an equal opportunity/affirmative action employer. Women and minorities are encouraged to apply. The University is supportive of the needs of dual career couples.

www.lsa.umich.edu/geo

Classified Rates—2009

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

Classification	Per Line for 1st month	Per line each addt'l month (same ad)
Positions Open	$8.50	$8.25
Opportunities for Students		
First 25 lines	$0.00	$4.50
Additional lines	$4.50	$4.50
Fellowship Opportunities	$8.50	$8.25

Positions Open

SURFICIAL GEOLOGY
MINOT STATE UNIVERSITY

The Department of Geosciences at Minot State University invites applications for a tenure-track faculty position in surficial geology. This appointment will be at the assistant professor level starting fall 2010. A Ph.D. in geological sciences or related field by time of appointment is expected. We seek someone with a broad, field-based background in surficial processes. Teaching expectations include upper-level courses in geomorphology, soils, and global climate change; introductory GIS; and contribution to introductory courses (environmental geology and physical geology).

Applicants for the position should demonstrate potential for excellence in undergraduate teaching, active engagement in research and scholarship, and enthusiasm for developing the geology curriculum and growing the major. Research expectations include development of an active research program that would ideally include local field-based studies involving undergraduate students. The department is well equipped for material characterization (XRD, SEM-EDS), water analysis (ICP, GFAA, GCMS), and geospatial investigations (Topcon total station, ESRI 9.2 ArcEditor Suite, Trimble GeoXT). More information about this position can be found at www.minotstateu.edu/hr/jobs_01.shtml.

Applicants should send a cover letter, CV, copies of transcripts, statement of research interests, and statement of teaching interests/philosophy to: Dr. Allen Kihm, Geoscience Search Committee Chair, Division of Science, Minot State University, Minot, ND 58707, USA. Applicants should arrange to have three letters of reference sent directly to the search committee. Review of applications will begin on 30 September 2009. However, applications will be accepted and considered until the position is filled. Minot State University is an equal opportunity employer and actively seeks diversity among its employees.

POSTDOCTORAL POSITION,
ANTARCTIC METEORITE RECOVERY
AND PLANETARY RESEARCH
CASE WESTERN RESERVE UNIVERSITY

The Antarctic Search for Meteorites (ANSMET) programs at Case Western Reserve University is seeking applications for a multi-year postdoctoral research position (title will vary with experience). Duties will include leadership during Antarctic meteorite fieldwork and active involvement in ongoing planetary research. Successful candidates must have a Ph.D. in geology, planetary science, or a related field. Candidates must also have a valid passport or be able to obtain one, and be capable of passing the stringent physical and dental examinations required for Antarctic deployment. Candidates with previous Antarctic experience and/or prior research in planetary studies are preferred. For more details, visit http://geology.cwru.edu/~ansmet/postdoc_ad.pdf.

To apply, send a letter of application with a summary of your research interests and experience, curriculum vitae, and contact information for three professional references to Dr. Ralph Harvey, rph@case.edu, via e-mail. Review of applications will begin immediately and continue until the position is filled. Case Western Reserve University is an EEO/AA institution.

TENURE-TRACK FACULTY POSITION
MONCRIEF CHAIR IN PETROLEUM GEOLOGY
WESTERN STATE COLLEGE OF COLORADO

Western State College of Colorado invites applications for the tenure-track faculty position of Moncrief Chair in Petroleum Geology starting January or August 2010. Teaching responsibilities include courses in an expanded petroleum geology curriculum and core courses in the geology curriculum. Requirements include a doctorate in geology or related field and a commitment to undergraduate education and excellence in teaching. For full position information and application procedures, visit www.western.edu/hr/jobs. Applications will be accepted until the position is filled. AA/EOE

GEOSCIENCES DEPARTMENT
ONE-YEAR VISITING POSITION
HAMILTON COLLEGE

The Geosciences Department at Hamilton College invites applications for a one-year visiting position for the calendar year 2010 (1 January to 31 December). The successful candidate will be expected to teach a course on sedimentary geology, a topical introductory course, and a sophomore-level elective course in the candidate's specialty (e.g., glacial geology or soils). In addition, the candidate will be encouraged to supervise senior projects for several Geosciences concentrators. The ideal candidate will be committed to teaching undergraduate students, have a broad field and laboratory background, and will provide our students with a balance of classroom, field, and laboratory experiences. The Department has extensive laboratory and field equipment, including a laser particle size analyzer, isotope mass spectrometer, XRF and XRD, ion chromatograph, and SEM/TEM. Send curriculum vitae, transcripts, and recommendation letters to Todd Rayne, Chair, Geosciences Department, Hamilton College, 198 College Hill Road, Clinton, NY, 13323. Application deadline is 1 September 2009.

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Opportunities for Students

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Stipend, tuition at domestic rate, field and laboratory costs, and conference attendance are available as part of a project supported by the Marsden Fund.

For more information and application details, contact Dr. J. Michael Palin, michael.palin@otago.ac.nz, or Dr. Candace E. Martin, candace.martin@otago.ac.nz.

GSA Awards 2009 Prize for Intel Science Fair Excellence

Congratulations to these students!

Kelsey Meacham, Courtney Jackson, Andrea Monzon, Adriana Sarro, and GSA rep. Rich Loring.

At the 2009 Intel International Science and Engineering Fair in Reno, Nevada, USA, GSA awarded prizes for science and engineering projects investigating Earth and related sciences. The winners and their schools will receive a free subscription to *GSA Today* as well as a cash prize. Projects were judged on their demonstration of a high level of understanding of earth science concept(s), how Earth is a system, and use of innovative methods to explain concepts. GSA sincerely thanks our volunteer special awards judge, Rich Loring of Reno, Nevada, USA.

Kelsey Ann Meacham, 15, West Anchorage High School, Anchorage, Alaska, USA. **First Award: US$1,500,** for EA013: "Cook Inlet: Correlation between air temperature trends and intra-seasonal sea ice extent variability."

Andrea Carolina Monzon, 14, and **Adriana Cristina Sarro,** 15, Academia del Perpetuo Socorro, San Juan, Puerto Rico. **Second Award: US$1,000,** for EA303: "The impact of 2008 tropical cyclones in the phytoplankton community of an estuarine system: Second year study."

Courtney Catherine Jackson, 16, Cloquet Senior High School, Cloquet, Minnesota, USA. **Third Award: US$500,** for EA009: "Mapping Venus: The use of *Magellan* radar data to determine the geologic history of a circular low on Venus, how the area varies in space and time and if it formed by endogenic or exogenic processes, phase two."

GROUNDWORK
Furthering the Influence of Earth Science

Mineral resource geology in academia: An impending crisis?

***Murray Hitzman**, Dept. of Geology and Geological Engineering, Colorado School of Mines, Golden, Colorado 80401, USA, mhitzman@mines.edu; **John Dilles**, Dept. of Geosciences, Oregon State University, 104 Wilkinson Hall, Corvallis, Oregon 97331-5506, USA, dillesj@geo.oregonstate.edu; **Mark Barton**, Dept. of Geosciences, University of Arizona, Gould-Simpson Building #77, 1040 E. 4th Street, Tucson, Arizona 85721, USA, barton@geo.arizona.edu; and **Maeve Boland**, Dept. of Geology and Geological Engineering, Colorado School of Mines, Golden, Colorado, 80401-1885, USA, mboland@mines.edu*

INTRODUCTION

With continued industrialization in the developing world, prices for metals and other mineral products reached new heights from 2005 to 2008. Though currently at lower levels, prices are likely to rebound sharply when the global economy recovers. A primary driver of high prices was a slowdown in the addition of new supplies via discovery and an inability to expand production from known deposits. Increasing demand also highlighted vulnerabilities in the supply chain of minerals critical for industrial production and national security. Despite these economic and political drivers, the numbers of mineral-resource ("economic") geologists being trained in the West has decreased significantly over the past three decades. The current downturn is likely to cement this trend.

The decrease in economic geologists is particularly evident in the United States, where long-term trends foreshadow the demise of economic geology education and research in the coming decade. What will happen to U.S. competitiveness, a sustainable supply of mineral resources, and the nation's ability to engage in scientifically sound planning and land management if economic geology disappears from academia?

ECONOMIC GEOLOGY AND THE U.S. ECONOMY

Economic geology encompasses the study of mineral resources. In current usage, "mineral resources" includes metals, industrial minerals, construction aggregates, and uranium but excludes carbon-based energy resources. With regard to economic value, the United States led the world in non-fuel minerals produced and processed in 2007, at US$575 billion (U.S. Geological Survey, 2008). These raw materials supported major industries that accounted for more than US$2 trillion (~15%) of the 2007 U.S. gross domestic product. The United States is the largest single consumer of mineral products and had a net trade deficit of US$43 billion in processed mineral materials in 2007—much smaller than the nation's oil bill, but still roughly one month's worth of the total U.S. trade deficit.

The United States is striving for increased energy independence, but it should also be concerned about mineral sustainability, as highlighted by the 2008 National Research Council report, "Minerals, Critical Minerals, and the U.S. Economy." The U.S. Geological Survey (USGS) indicates that the United States imported over 50% of 44 mineral commodities in 2007 and was 100% reliant on imports for 19 mineral commodities. For example, the United States imports all its heavy rare earth elements (HREEs), mainly from China; HREEs are utilized in virtually every computer hard drive.

EVOLUTION OF ECONOMIC GEOLOGY IN THE UNITED STATES

U.S. mineral sustainability can only be achieved if we have the in-country expertise to (1) address critical vulnerabilities in our industrial and military supply chains; (2) help find and responsibly develop, process, and environmentally manage our mineral resources; and (3) accurately assess and contribute to the sustainable development of world mineral supplies.

The field of economic geology developed in the late nineteenth to early twentieth centuries as an outgrowth of mining geology. Economic geology flourished from the end of World War II into the early 1970s, with major academic programs at such schools as Harvard, Yale, Michigan, and Stanford. The USGS and the U.S. Bureau of Mines conducted substantial government research, while the National Science Foundation (NSF) funded research at academic institutions. Several mining companies had major in-house economic geology research groups.

By the mid-1990s, the landscape for economic geology in the United States changed dramatically. A 1994 survey of U.S. and Canadian academia indicated that economic geology faculty were, on average, 50 years old and that many predicted they would not be replaced upon retirement (Einaudi, 1996). There were few hires of young professors, and economic geology was abandoned altogether at many higher-ranked institutions. Mining industry research centers virtually disappeared. Congress abolished the U.S. Bureau of Mines in 1995, and economic geology research at the U.S. Geological Survey shrank significantly.

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Table 1. Summary results from 2002 survey of economic geology faculty in U.S. and Canadian universities

2002 Faculty Demographics*	Avg.	S.D.
Faculty Ph.D. year	1982	8
Hire year	1985	10
Expected retirement year	2017	8
Years of industry employment	4.5	5

Replacement would be hired in economic geology (probably, certainly)	30%
Replacement would *not* be hired in economic geology (certainly not, almost certainly not, probably not)	70%

Year-to-year comparisons	1982	1992	2002
M.S. students per faculty (avg. yearly)	5.8	4.2	3.3
Ph.D. students per faculty (avg. yearly)	1.9	2.0	2.0
Percent economic geology courses of total taught		33%	24%

Note: Based on 47 responses to an e-mail questionnaire sent to 102 U.S. and 45 Canadian universities by J.H. Dilles. Full survey data is available at www.geosociety.org/pubs/ft2009.htm as GSA Supplementary Data item 2009192. This survey also collected historical data. S.D.—standard deviation.
*n = 47: 42 programs with 57 economic geology faculty.

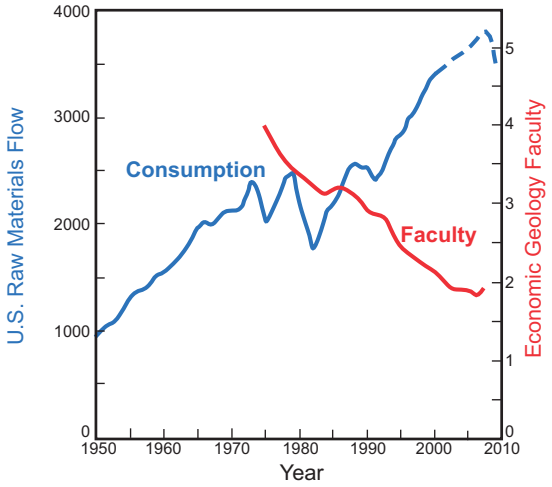

Figure 1. Graph illustrating a steady increase in U.S. consumption of raw materials (Wagner, 2002) and a steady decline in economic geologists as a percentage of total geoscience faculty (AGI, 1975–2007).

A follow-up survey in 2002 (Table 1; supplementary data[1]) found that most professors who considered their principal specialty to be economic geology did 75% of their teaching in their secondary fields of geochemistry or petrology/mineralogy and relied principally on government grants for research funding. Graduate student numbers had declined, and 70% of these professors predicted their position would not be filled with an economic geologist when they retired in an average of 15 years.

CURRENT STATE OF U.S. ACADEMIC ECONOMIC GEOLOGY

A more recent, less comprehensive poll conducted in 2006 indicated that fewer than 70 of the ~100 economic geology professors at U.S. universities remain active in the field. For comparison, the total number of active U.S. economic geology faculty is equivalent to an engineering department at a large state university. In 2006, ~150 graduate students were working in economic geology in the United States. Given average times for degree completion, this indicates that the United States is graduating fewer than 40 graduate-level economic geologists a year. This is probably less than half the number required to offset annual retirements in the domestic mining industry alone, much less in other organizations that require related expertise.

It is clear that the academic base for the field shrank considerably over the past three decades (Fig. 1). Market forces alone may reinvigorate economic geology in the United States, but there was no evidence of this during the four years of high metal prices. Could we be facing the collapse of the science that underpins the long-term supply and stewardship of the mineral resources on which our nation depends? The United States has one of the world's best mineral endowments and an increasing public and corporate commitment to sustainability; unfortunately, without the necessary expertise, we may be unable to manage and, as appropriate, develop these resources.

The demands of the academic environment must be considered if the United States is to reinvigorate economic geology research and education. Increasingly, tenure decisions are based largely on the amount of fully overheaded research funding obtained by individual faculty members. Perhaps more important, decisions about how to fill faculty vacancies are made on the same basis. Given that faculty typically hold tenured positions for decades, loss of expertise cannot be easily or quickly redressed.

Unlike the steadily increasing demand for minerals, NSF research funding for economic geology has stagnated or decreased, perhaps because this research is perceived as applied rather than basic in nature. Federal programs that had provided funding for economic geology projects, such as the Department of Energy's "Industries of the Future" program, have been cut. USGS funding for academic economic geology research has been limited and unpredictable.

Presently, many of the remaining U.S. academic programs in economic geology receive industry funding. However, most corporate-sponsored research is highly applied, limited in time and scope, and frequently does not include full overhead to the academic institution. Such "underfunded" research projects are rarely viewed favorably by academic administrations struggling to make ends meet. Moreover, industry funding is often directed to other countries, such as Canada and Australia, where matching funds from governments are typically available. Although the mining industry can help by increasing research funding, it might be more effective for it to support the restoration of dedicated federal funding, because, in the long run, federal funding directly sustains most academic research, including those fields with direct societal applications, whether biomedicine or mineral resources sustainability.

THE FUTURE

There is no consensus among federal and state agencies, the mining industry, and the U.S. academic community regarding the importance of economic geology to future U.S. competitiveness.

[1]GSA supplemental data item 2009192, 2002 survey by John Dilles of economic geologists at U.S. and Canadian universities, is available at www.geosociety.org/pubs/ft2009.htm; copies can also be requested from GSAToday@geosociety.org.

Without such consensus—followed by action—the current downward spiral in U.S. academic economic geology will continue, with the near-term loss of the expertise essential to the discovery, utilization, and management of mineral resources.

We invite the minerals industry, government, and institutions with a stake in mineral resources to initiate a dialogue and develop a new strategy, perhaps mediated by the National Research Council, to take U.S. academic economic geology successfully into the twenty-first century.

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GEOLOGIC PAST

***Highlighting articles from past issues of* GSA Bulletin**

"The Role of Minerals in the Present International Situation"

C.K. Leith, *GSA Bulletin,* March 1939

This essay by C.K. Leith (*GSA Bulletin,* v. 50, p. 433–442) is derived from his Anniversary Day address at GSA's semicentennial celebration in December 1938. Leith summarizes the "recent efforts of Germany, Italy, and Japan to improve their mineral positions" (p. 435) and examines possible solutions to the mineral resource problems faced by these and other "have not" nations.

"The inequalities of mineral distribution among the nations are stubborn facts which cannot be greatly changed by wishful thinking or political measures," he writes (p. 439). The United States was not immune to these inequalities: Although the United States was the "world's largest producer, the largest consumer, and the largest distributor of minerals and their products" (p. 441), its mineral-resource deficiencies (especially "in the ferro-alloy group") barred the country from self-sufficiency. According to Leith, "If all our imports were cut off, our industry would indeed return to the 'horse and buggy' days. We could build neither automobile nor a battleship" (p. 441). Leith continues, "The ramifications of use of all these minerals are so complex in modern industry that the *lack of a single one* often has far-reaching consequences" (p. 442; italics added).

In closing, Leith calls for the United States and "other democratic nations" to not only focus on the defense of their "material and ideologic position" but also on "alleviating the raw material grievances of the 'have not' nations in the interest of world welfare and peace" (p. 442). The role of geologists, he writes, is not to "settle these questions" but to "make highly significant contributions to both the immediate problem and the long-range problem of using our mineral power in trust for the world welfare." The essay's concluding sentence warns that this "responsibility should not be avoided" (p. 442).

Charles Kenneth (C.K.) Leith (1875–1956) was president of the Society of Economic Geologists (SEG) in 1925 and of GSA in 1933 and received Penrose Medals from both societies. Leith was head of the University of Wisconsin–Madison geology department for 31 years (having performed graduate work there in 1902 and retiring in 1945), and, after retirement, was a member of the U.S. Atomic Energy Commission's Combined Development Agency. Among his many papers and books, Leith wrote "The Economic Aspects of Geology" (1921, New York, H. Holt and Company, xv, 457 p. illus. 22 cm, 1921), which was recently re-released as an eBook by Project Gutenberg for free download or online viewing at http://www.gutenberg.org/catalog/world/readfile?fk_files=1066580.

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Editors: D J J van Hinsbergen, M A Edwards and R Govers

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Edited By D. J. Evans and R. A. Chadwick

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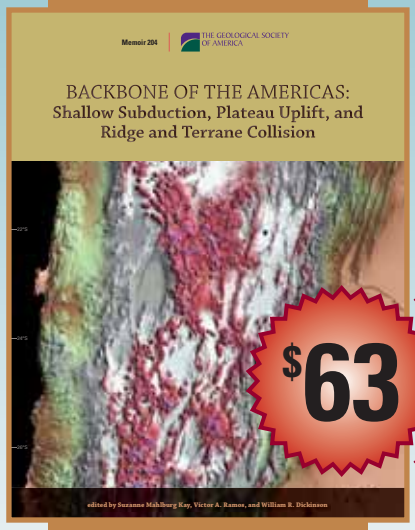

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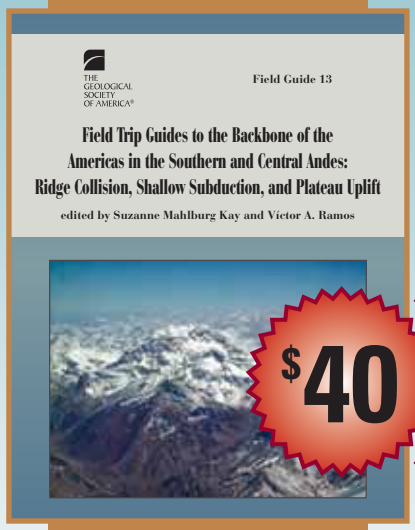
The American Cordilleras form a continuous orogen that extends for 12,500 km along the eastern flank of the Pacific Ocean from Arctic to Antarctic latitudes as an integral part of the circum-Pacific orogenic belt. Following two summary chapters on the overall anatomy and evolution of North and South American segments of the orogenic system, this volume includes ten seminal chapters dealing with salient aspects of the key geodynamic processes that have accompanied Cordilleran geotectonic evolution: forearc terrane accretion, arc magmatism, shallow subduction, and backarc intracontinental deformation. The papers in this volume were selected from those presented at the 2006 Backbone of the Americas Meeting, which was sponsored jointly by multiple North and South American geological societies in Mendoza, Argentina.

Field Guide 13



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edited by Suzanne Mahlburg Kay and Víctor A. Ramos

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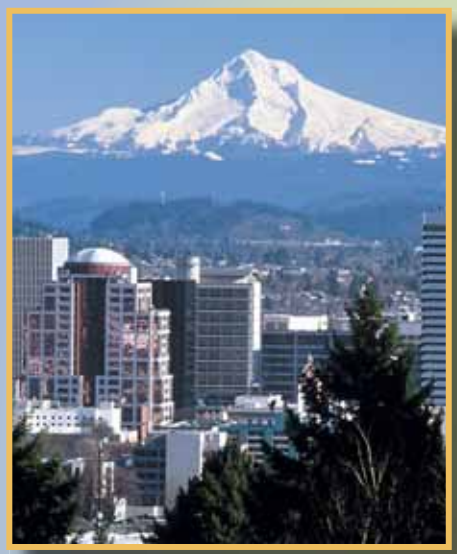

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