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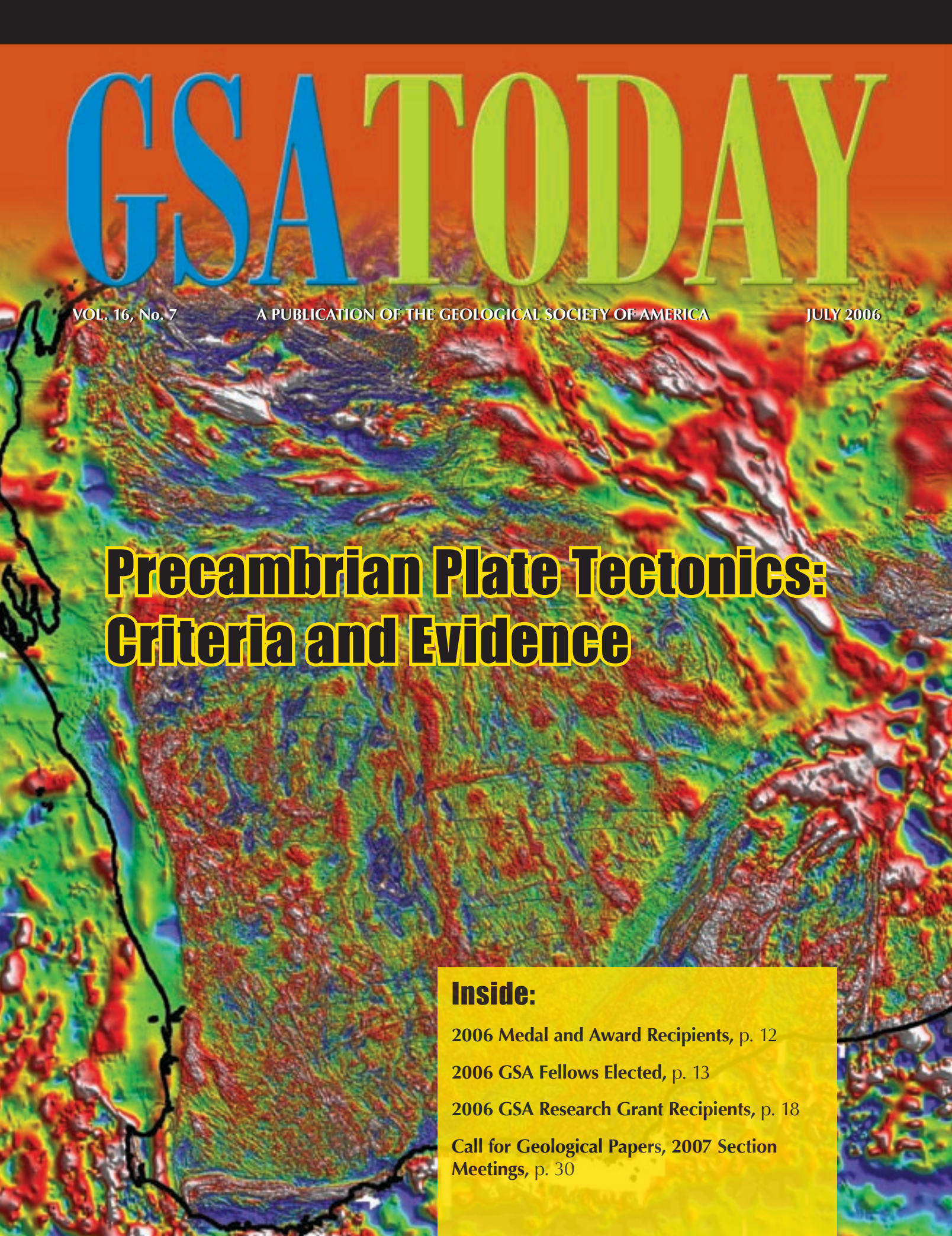

Precambrian Plate Tectonics: Criteria and Evidence

Inside:

Wetlands through Time

Edited by Stephen F. Greb and William A. DiMichele

The importance of wetlands in the global ecology is undisputed. This is not only true of present wetlands, but has been true of wetlands for at least the last 400 million years. In fact, with changing flora and fauna, there has been an evolution of wetland functions and ecological links. Because many wetlands are located in lowland habitats and have poorly oxygenated substrates, they have the potential for rapid burial with little erosion and high potential for preservation. For these reasons, abundant fossil flora and fauna have been found in association with ancient wetlands, which are a cornerstone of the terrestrial fossil record and of our understanding of earth history. Likewise, the coals we use as an energy resource are ancient wetland deposits. *Wetlands through Time* contains 14 research papers on the ecology and importance of ancient wetlands, spanning the time from the initial colonization of plants on land to an ice-age mammoth-bearing wetland.

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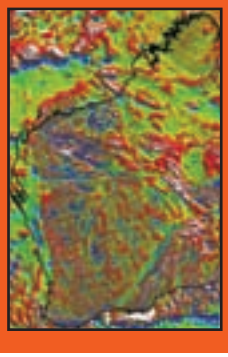

Cover: Magnetic anomaly map of part of Western Australia, showing crustal blocks of different age and distinct structural trends, juxtaposed against one another across major structural deformation zones. All of the features on this map are Precambrian in age and demonstrate that plate tectonics was in operation in the Precambrian. Image copyright the government of Western Australia. Compiled by Geoscience Australia, image processing by J. Watt, 2006, Geological Survey of Western Australia. See "Precambrian plate tectonics: Criteria and evidence" by Peter A. Cawood, Alfred Kröner, and Sergei Pisarevsky, p. 4–11.

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SCIENCE ARTICLE

Precambrian plate tectonics: Criteria and evidence

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ABSTRACT

Paleomagnetic, geochemical, and tectonostratigraphic data establish that plate tectonics has been active since at least 3.1 Ga. Reliable paleomagnetic data demonstrate differential horizontal movements of continents in Paleoproterozoic and Archean times. Furthermore, the dispersal and assembly of supercontinents in the Proterozoic requires lateral motion of lithosphere at divergent and convergent plate boundaries. Well-preserved ophiolites associated with island-arc assemblages and modern-style accretion tectonics occur in the Paleoproterozoic Trans-Hudson orogen of the Canadian Shield, the Svecofennian orogen of the Baltic Shield and in the Mazatzal-Yavapai orogens of southwestern Laurentia. These rocks have trace element signatures almost identical to those found in rocks of modern intra-oceanic arcs and include ore deposits typical of modern subduction settings. The discovery of Archean eclogites in the eastern Baltic Shield; the presence of late Archean subduction-related Kuroko-type volcanogenic massive sulfide deposits in the Abitibi greenstone belt of the Canadian Shield; the discovery of mid-Archean island arc volcanics, including the oldest known boninites and adakites; and isotopic data from the world's oldest zircons all argue for modern-style subduction processes possibly back to the Hadean. Seismic images of preserved Paleoproterozoic and Archean suture zones further support this view. These data require a tectonic regime of lithospheric plates similar to the Phanerozoic Earth.

INTRODUCTION

Earth's surface is sculptured by plate tectonics and reflects the presence of a rigid surface layer, the lithosphere, which is broken into a series of plates that move horizontally with respect to each other. This motion is a response to heat loss and cooling within Earth's interior, and also occurs through episodic emplacement of mantle-derived magma in large igneous provinces. The relative contribution of, and control exerted by, these two mechanisms of heat loss may have varied through time perhaps in response to decreasing heat flow (e.g., Davies, 1999). Thus, how long plate tectonics has been Earth's modus operandi is debated (Eriksson et al., 2004). We outline criteria and evidence for the operation of plate tectonics in the Precambrian[1].

Arguments against plate tectonics generally invoke either the absence of specific features (e.g., ophiolites, ultrahigh-pressure rocks) or differences between modern and ancient rock associations (e.g., komatiites generally only found in the Archean) and structural styles, and cite temporal changes in Earth's heat flow as an underlying cause for these differences (e.g., Davies, 1999). Such comparisons ignore or minimize the significant similarities in data sets between modern and ancient rock sequences and, by inference, tectonic processes (Windley, 1995).

CRITERIA

Establishing evidence for or against the operation of plate tectonics requires a clear understanding of its distinctive and unique features, which are preserved within the rock record. We consider the most crucial feature to be the differential horizontal motion of plates, resulting in significant changes in their spatial relationship over time. Many geological features, such as rift zones, continental margin depositional environments, calc-alkaline volcanic-plutonic belts, lithospheric sutures, and orogenic belts follow from this plate motion process.

Differential plate motion gives rise to divergent, transform, and convergent plate boundaries. Divergent motion results in the development of rifts and passive margins on continental lithosphere and oceanic lithosphere at mid-oceanic-ridge spreading centers. Convergent motion through subduction leads to growth of continental lithosphere through the addition of magmatic arc systems (Fig. 1) and, ultimately, to collision between buoyant pieces of lithosphere. Orogenic belts initiated, formed, and deformed within a Wilson cycle tend to be linear, in contrast to tectonic elements formed through non–plate tectonic processes, such as large igneous provinces, which tend to be more equidimensional. However, not all features generated through plate motion are unique to this process. For example, lithospheric extension and dike emplacement could also occur in a mantle plume–dominated environment (Fig. 1). We suggest that paleomagnetic evidence for independent lateral motion of lithospheric blocks, geochemical data for magmatic arc activity and associated ore deposits related to subduction of oceanic-type lithosphere, seismic imaging of fossil subduction zones, and tectonostratigraphic associations indicating assembly of continental lithosphere along linear orogenic belts demonstrate that plate tectonics has been an active component of Earth processes possibly since the formation of the first continental crust at >4.3 Ga.

[1]The Precambrian covers the period of Earth's history prior to 542 Ma and consists of the Hadean (pre-3.8 Ga), Archean (3.8–2.5 Ga), and Proterozoic (2.5–0.54 Ga).

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PALEOMAGNETIC EVIDENCE

Phanerozoic apparent polar wander paths are reasonably well established for major continental blocks, but this is not the case for the Precambrian due to a propensity for overprinting by younger processes. Despite a significant Precambrian paleomagnetic database (Pisarevsky, 2005), only a few Precambrian paleopoles can be considered reliable and well dated.

Nevertheless, several paleomagnetic results from Archean and Paleoproterozoic rocks, supported by field tests, suggest that the geomagnetic field has existed since at least 3.5 Ga (Merrill et al., 1998), and paleomagnetism is a valuable tool for ancient paleogeographic reconstructions. Additionally, recent paleointensity studies, estimates of secular variations of the Archean-Paleoproterozoic geodynamo (Smirnov and Tarduno, 2004), and magnetostratigraphy patterns in Paleoproterozoic sedimentary rocks (Pisarevsky and Sokolov, 2001) all indicate that the Archean and Paleoproterozoic geomagnetic field had characteristics similar to the present field.

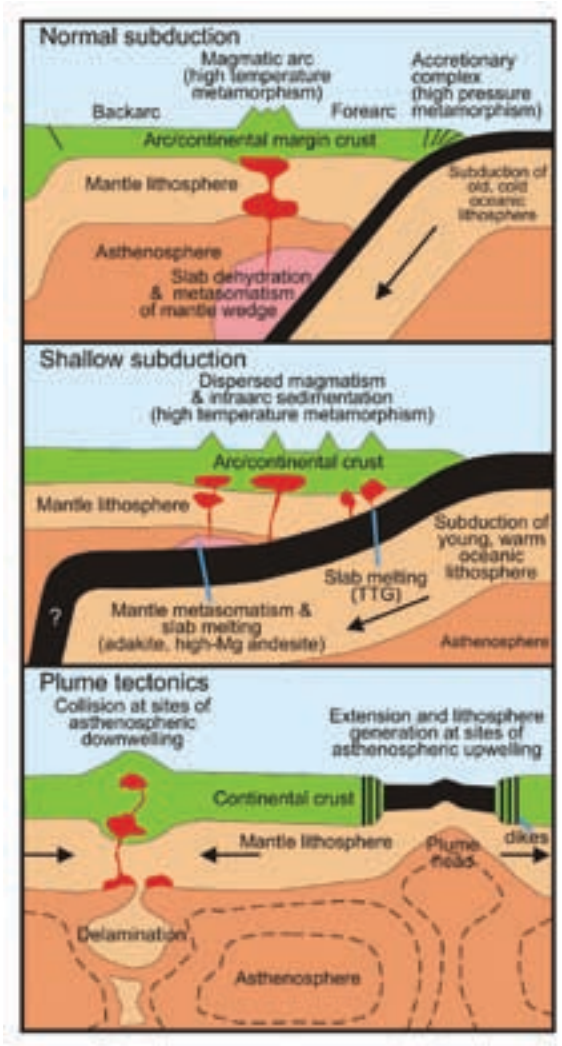

Figure 1. Precambrian tectonic regimes may have ranged from normal subduction similar to Phanerozoic Earth (top panel), to a modified form involving shallow subduction of thickened, more buoyant, oceanic lithosphere (middle panel), to a setting dominated by mantle plumes (bottom panel). On modern Earth, both plate- and plume-related mechanisms operate, and it is likely that a similar relationship existed on early Earth. In three dimensions, plate tectonic boundaries for linear belts are tied to, and influence, asthenospheric convection, whereas in plume settings, the lithosphere moves over generally fixed zones of asthenospheric upwelling.

Table DR1[2] contains selected paleopoles from the Archean Kaapvaal and Superior cratons and from the two Paleoproterozoic continents of Baltica and Australia, which were assembled in the late Paleoproterozoic. We selected only those poles that allow coeval comparisons of these blocks at two different time intervals (Fig. 2). Most of these poles were retrieved from stratified rocks, undeformed and layered igneous intrusions, or near-vertical dikes, so their paleohorizontals are interpreted as either barely changed or easily restorable. The primary nature of these results is supported by field tests, rock magnetic studies, and/or evidence such as bipolar magnetization especially with a magnetostratigraphy pattern. For each of the pole pairs shown in Figure 2, one continent is fixed and the two polarity options are shown for the alternate block. Longitude is unconstrained for both blocks, meaning that they could occur at any longitude at the prescribed latitude for that time interval. Even with these restrictions, Figure 2A demonstrates a significant difference between the relative paleopositions of Kaapvaal and Superior at 2680 and 2070 Ma, with both latitudinal displacement and azimuthal rotation occurring during this time interval. Figure 2B also suggests that displacements and rotations occurred between Baltica and Australia between 1770 and 1500 Ma. Both examples demonstrate that continents drifted independently, requiring the generation and consumption of lithosphere between these blocks on a constant-radius Earth. Importantly, in both examples, angular and latitudinal differences show minimal relative movements and maximum age range for movements between the two pairs of continents. Real movements were likely more complicated and occurred over shorter time frames. Other examples are given in Pesonen et al. (2003).

The development of several linear ca. 1.8 Ga and ca. 1.0 Ga collisional orogenic belts was instrumental in the formation of proposals for global late Paleoproterozoic and end Mesoproterozoic supercontinents (Zhao et al., 2002; Hoffman, 1991), but their exact configuration is disputed because of the paucity of reliable well-dated paleomagnetic poles.

EVIDENCE FOR PRE-NEOPROTEROZOIC SUBDUCTION, OPHIOLITES, AND SEAFLOOR SPREADING

The Paleoproterozoic Trans-Hudson orogen in Canada, the Svecofennian orogen in SW Finland, and the Mazatzal-Yavapai orogens in southwestern Laurentia provide excellent examples of modern-style subduction tectonics. The Trans-Hudson orogen contains an accretionary collage of distinct tectonostratigraphic terranes consisting of ocean floor, ocean plateau, and island-arc assemblages that record ongoing subduction and accretion at 1.92–1.84 Ga (Lucas et al., 1996). This history is corroborated by field observations, petrological, chemical, and isotopic data (e.g., Stern et al., 1995), as well as suture-zone

[2]GSA Data Repository Item 2006141, Table DR1: Selected Archean and Proterozoic paleomagnetic poles, is available on the Web at www.geosociety.org/pubs/ft2006.htm. You can also obtain a copy of this item by writing to editing@geosociety.org.

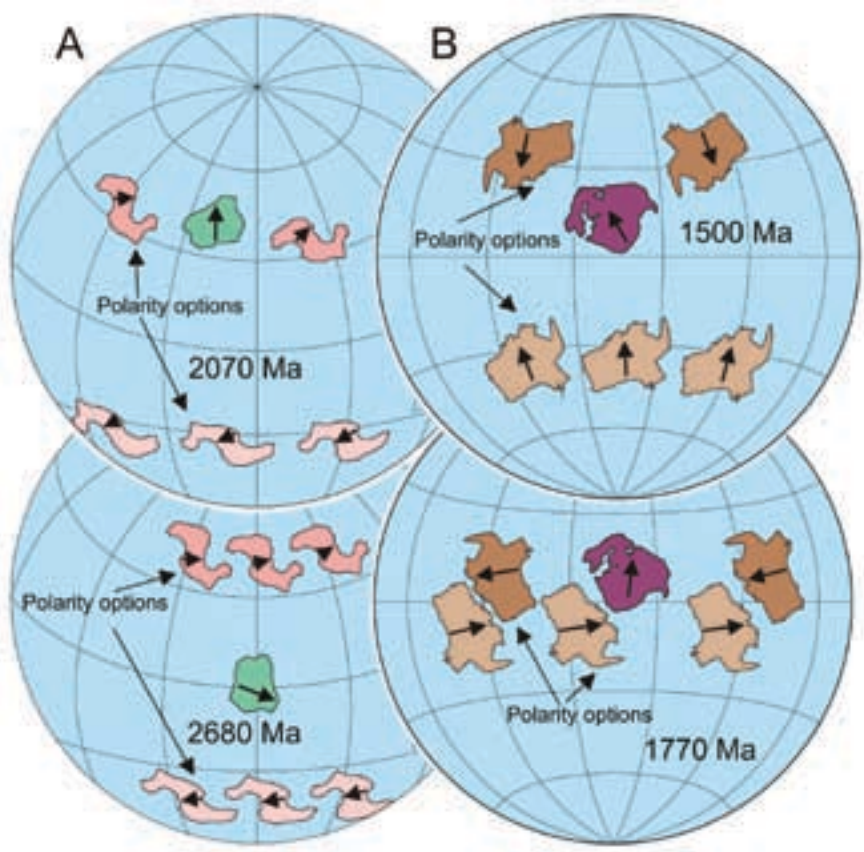

Figure 2. (A) Paleolatitudinally constrained positions for Kaapvaal (green) and Superior (pink) cratons at 2070 Ma and 2680 Ma, based on data in Table DR1 (see text footnote two). For each time interval, the position of the Kaapvaal craton is fixed, and the two polarity options are shown for Laurentia (light and dark pink). (B) Paleolatitudinally constrained positions for Baltica (purple) and Australia (orange) at 1500 Ma and 1770 Ma, based on data in Table DR1. For each time interval, the position of Baltica is fixed, and the two polarity options are shown for Australia (light and dark orange). Multiple copies of Superior and Australia for each option shown in (A) and (B) highlight latitudinal uncertainty in craton position. Lines of longitude and latitude are shown in 30° increments. Arrows indicate present-day north. Reconstructions prepared using utilities from the Visual Paleomagnetic Database (Pisarevsky and McElhinny, 2003).

geometry recording final collision with the Superior craton as revealed by seismic reflection profiling (White et al., 2002). Paleomagnetic data from the Trans-Hudson orogen were interpreted by Symons and Harris (2005) to suggest that the Archean Hearne and Superior cratons were separated by the ~5500-km-wide Manikewan ocean during ca. 1875–1855 Ma but that this ocean had closed by ca. 1815 Ma because of subduction beneath the Hearne craton and generation of a continental margin arc. The Trans-Hudson orogen also contains one of the best-preserved and most unequivocal Paleoproterozoic ophiolites, the Purtuniq complex (Scott et al., 1992). This shows that seafloor spreading and associated oceanic-crust formation was an established mechanism of plate tectonics by at least 2 Ga. The Svecofennian orogen in SW Finland is interpreted to involve opening of an ocean around 1.95 Ga and progressive accretion of arc complexes to the Karelian craton ca. 1.91–1.87 Ga, followed by extensional collapse (Nironen, 1997). Some of the accreting terranes probably had older cores that acted as crustal indentors during the collision; extensional collapse at a late stage, as seen in modern orogens, has also been inferred (Korja and Heikkinen, 2005). The belt contains a dismembered suite of mafic and ultramafic rocks, known as Jormua ophiolite, interpreted to represent a practically unbroken sample of seafloor from an ancient ocean-continent transition zone (Peltonen and Kontinen, 2004).

Between 1.8 and 1.2 Ga, a series of well-developed convergent margin accretionary orogens formed along the margin of a combined Laurentia and Baltica (e.g., Karlstrom et al., 2001). Geochemical and isotopic data from the accretionary Mazatzal and Yavapai provinces indicate that juvenile volcanic sequences formed in oceanic arcs or arcs built on only slightly older crust and include the 1.73 Ga Payson ophiolite, which is interpreted to have formed in an intra-arc basin (Dann, 1997).

The Trans-Hudson, Svecofennian, and Mazatzal-Yavapai orogens provide evidence for plate convergence lasting tens of millions of years and producing rock assemblages strikingly similar in rock type, structural evolution, and tectonic setting to modern plate boundary zones such as those in the southwest Pacific. Such similarities for these and other Precambrian orogens have been pointed out by many authors (see summaries in Windley, 1995; Condie, 2005). Ophiolites such as those at Purtuniq, Jormua, and Payson occur within this convergent plate margin framework, and we argue against the ideas of Stern (2005) that such ophiolites only record short-lived or aborted seafloor spreading, as well as those of Moores (2002) that ophiolites older than ca. 1 Ga are fundamentally different from those of younger times.

Ocean-crust subduction in the present plate tectonic regime ultimately produces high-pressure metamorphic assemblages (Fig. 1, top panel), including eclogites, and such rocks are now increasingly recognized in pre-Neoproterozoic terranes. Examples of Paleoproterozoic and inferred Archean eclogites derived from a mid-oceanic-ridge–type protolith and prescribed to oceanic lithosphere subduction have been described from Tanzania and Russia, respectively (Konilov et al., 2005; Möller et al., 1995; Volodichev et al., 2004). Exhumation rates

of the Tanzanian examples are similar to Phanerozoic eclogite and blueschist terranes (Collins et al., 2004). M. Brown (2006, personal commun.) has pointed out that ultrahigh temperature granulite metamorphism occurs from the late Neoarchean to early Paleozoic and is inferred to have developed in settings analogous to modern backarc and arc settings. Complementary belts of medium-temperature eclogite–high-pressure granulite metamorphism span a similar time range and are related to subduction or collision zone metamorphism. The presence of these dual Precambrian high-pressure and high-temperature assemblages is similar to the metamorphic patterns of modern convergent plate settings.

There have been numerous attempts to link Archean granite-greenstone terranes to modern-style plate tectonic processes (e.g., Kerrich and Polat, 2006), and although unambiguous Archean ophiolites with sheeted dyke complexes have not been convincingly documented, the Superior Province of the Canadian Shield is arguably the best documented example for late Archean arc formation and accretion (Kerrich and Polat, 2006). The various components of this province were assembled progressively from north to south during discrete orogenic events. There is also seismic evidence for a late Archean subducted slab beneath part of the Abitibi belt (Fig. 3; Calvert et al., 1995).

Cook et al. (1999) seismically documented what can be interpreted as a frozen east-dipping subduction surface associated with magmatic arc development as a result of Paleoproterozoic plate convergence on the margin of the Slave craton in the northern Canadian Shield. Seismic data also reflect arc accretion in the Svecofennian orogen of Finland (Korja and Heikkinen, 2005).

Hamilton's (2003) view of greenstone belts representing anastomosing networks of upright synforms between large, diapiric, composite batholiths is not compatible with many field relationships, particularly those in West Greenland (e.g., Myers and Kröner, 1994; Friend and Nutman, 2005) and southern Africa (De Wit and Ashwal, 1997), which show significant horizontal shortening consistent with horizontal plate tectonic motion. A particularly well-documented example occurs in the Nuuk region of southwest Greenland and shows evidence for extensive late Archean thrust imbrication (Fig. 4). Both vertical and horizontal tectonic processes are likely to have operated in the Archean, and plate tectonic processes can also be assumed from linear structural patterns that extend for hundreds, if not thousands, of kilometers across some Archean cratons (Van Kranendonk, 2004).

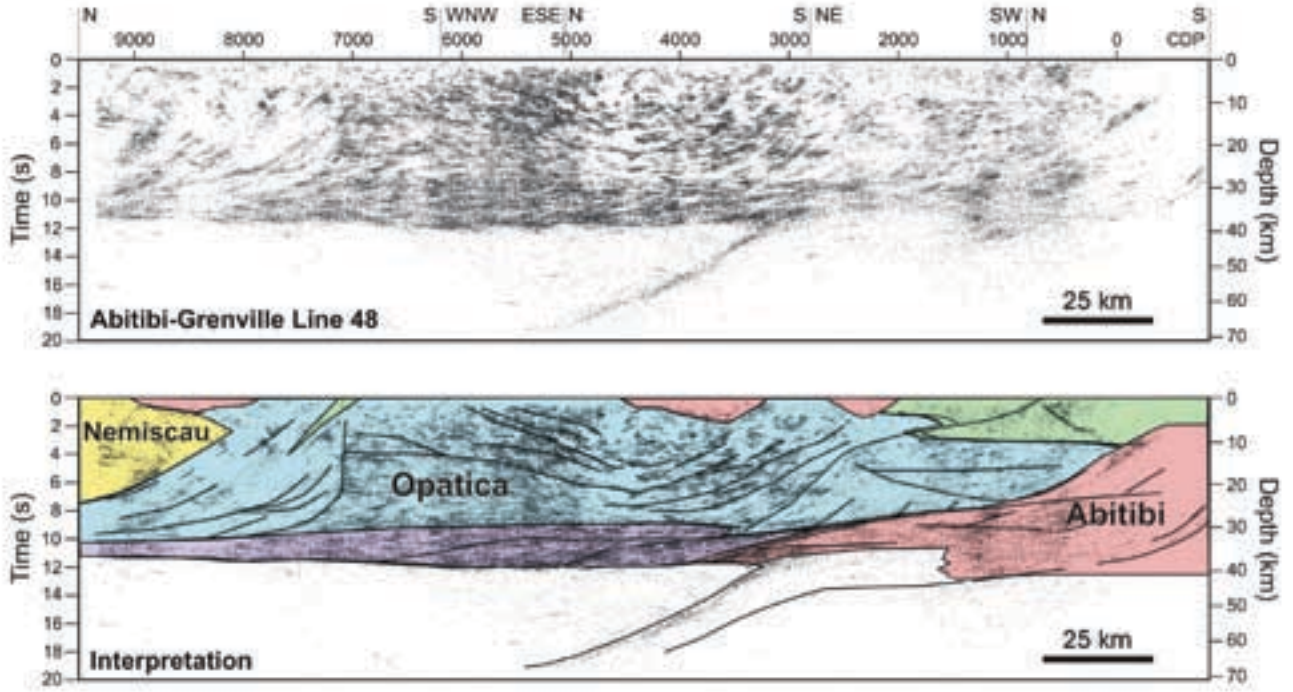

Figure 3. Top: Coherency filtered migrated stack of lithoprobe seismic reflection profile 48 displayed at true scale and extending from the northern Abitibi granite-greenstone subprovince across the largely plutonic Opatica belt and terminating in the metasedimentary Nemiscau subprovince, southeastern Superior Province, Canada. Depth is approximate, converted from two-way travel times with velocities of 6.5 km/s to 40 km and 8.0 km/s below 40 km. Numbers along top border are common depth point (CDP) locations along the line. Letters along top border show line directions for this crooked line profile. Bottom: Interpretation of the seismic section at true scale. The section shows the signature of a collision between a younger, oceanic arc terrane (the 2.76–2.72 low-grade Abitibi subprovince) and an older continental arc block (the ca. 2.83 Ga amphibolite-grade Opatica belt). The subduction zone across which the collision occurred is preserved as a fossil subducted oceanic slab. The features are identical to those expected from a modern collisional orogen. Unlabeled colors: green—greenstone belts; pink—plutons; blue—tonalitic gneiss and mid-lower crust of the Opatica belt; yellow—metasedimentary rocks of the Nemiscau subprovince. Lines indicate interpretation of major features between and within the major tectonic elements crossed. The dipping slab in white, bounded by lines, should be identified as a relict Archean oceanic slab. Modified from Calvert et al. (1995); image provided by Ron Clowes.

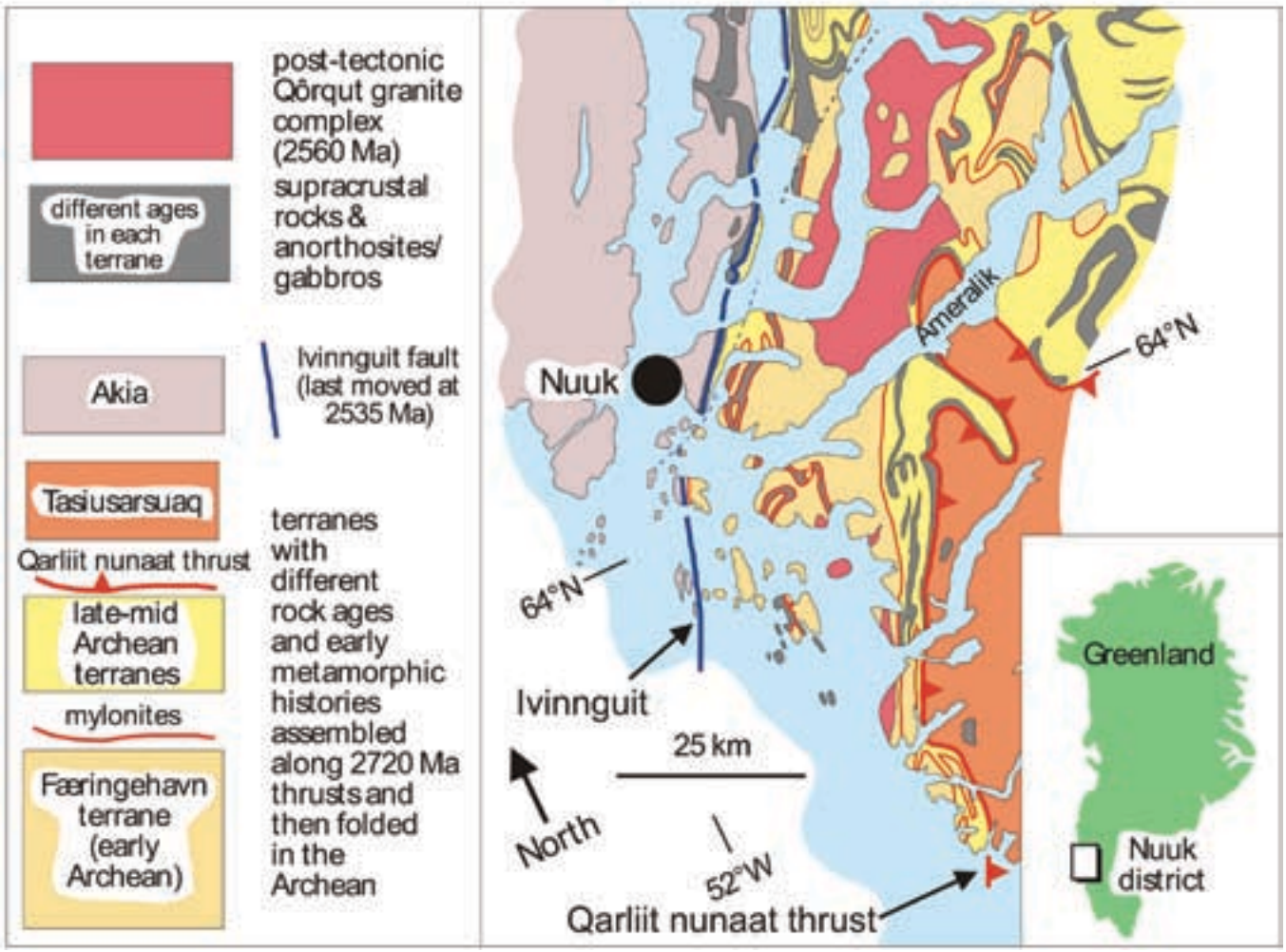

Figure 4. Map of the southern part of the Nuuk district of SW Greenland showing an extensive thrust stack formed at 2720 Ma, subsequently affected by isoclinal folding. Topmost to the SE is the Tasiusarsuaq terrane (2920–2800 Ma orthogneisses with 2800 Ma granulite facies metamorphism—restricted to that terrane), then the Tre Brødre terrane (yellow) with 2825 Ma orthogneisses, and no granulite facies, even though they are structurally overlain by a terrane with 2800 Ma granulite facies. Deepest is the Færingehavn terrane of early Archean rocks. The lower parts of this stack show polybaric 2720–2700 Ma metamorphism during exhumation. Dating of granite sheets intruded synkinematically along the bounding mylonites indicate juxtaposition ca. 2720 Ma. The Akia terrane to the west (3225–2970 Ma orthogneisses with 2970 Ma granulite facies) reached its final disposition as late as 2530 Ma via last movement on the Ivinnguit fault. Figure drafted and provided by Allen Nutman. Additional information available from Friend and Nutman (2005, and references therein).

GEOCHEMICAL EVIDENCE

Many Precambrian magmatic sequences show remarkable geochemical, petrological, and isotopic similarities to modern subduction environments (Condie, 2005), implying formation in an analogous setting. The paucity of well-developed forearc basin and subduction complex assemblages in association with some pre-Neoproterozoic magmatic arcs likely reflects their erosion and recycling through subduction erosion (D.W. Scholl and R. von Huene, 2006 personal commun.) rather than the absence of convergent plate margin processes. Indeed, given that subduction erosion may have operated through time, as proposed by these authors, the preservation of any Precambrian arc systems is remarkable.

A particularly well-documented example is the Paleoproterozoic Trans-Hudson orogen of the Canadian Shield, where subduction-related assemblages have trace element signatures almost identical to those found in rocks of modern intra-oceanic arcs (e.g., Stern et al., 1995). Boninitic rocks, similar to those occurring in modern forearc settings, were also reported from this orogen (Wyman, 1999), from the 3.12 Ga Whundo assemblage in the Pilbara (Smithies et al., 2005), and from the >3.7 Ga Isua greenstone belt (Polat and Kerrich, 2004). Other examples of subduction zone settings are the Svecofennian terranes of SW Finland and Sweden (Lahtinen and Huhma, 1997), the Paleoproterozoic Capricorn Orogen of Western Australia (Cawood and Tyler, 2004), the ca. 2.1 Ga Birimian oceanic plateau and arc terranes of West Africa (Abouchami et al., 1990), the 2.45–1.9 Ga Pechenga-Varzuga belt in the Kola Peninsula of Russia (Sharkov and Smolkin, 1997), and the 1.8–1.6 Ga Mazatzal and Yavapai provinces of the southwestern United States (Karlstrom et al., 2001).

Finally, chemical and oxygen isotope systematics in diamond-bearing eclogites from the mantle underneath the Archean Man and Guyana Shields suggest that subduction was operating at least since the Neoarchean because anomalously

high oxygen isotope values are interpreted to reflect alteration on the ancient seafloor prior to subduction and deep tectonic burial (Schulze et al., 2003).

Undoubtedly, conditions in the early Earth differed from the Phanerozoic (e.g., Davies, 1999; Condie, 2005). For example, higher mantle temperatures probably led to great degrees of melting at mid-oceanic ridges, which, in turn, resulted in thicker oceanic crust of likely picritic composition and perhaps flatter-dipping subduction zones (Fig. 1; Foley et al., 2003; Smithies et al., 2003). However, numerous studies involving geochemical modeling have also emphasized the role that subduction of oceanic lithosphere played in magma generation and construction of continental lithosphere in the Archean (e.g., McCulloch and Bennett, 1994; Foley et al., 2003). Generation of tonalite and trondhjemite, the most widespread and oldest rocks in the Archean (Hamilton, 2003), requires melting of hydrated oceanic crust, and seafloor spreading and subduction are the most efficient mechanisms for this process (Kerrich and Polat, 2006). Furthermore, Kerrich and Polat (2006) summarized the occurrence of Cenozoic-type active margin associations in the Archean, including boninites, Mg-andesites, and adakites and concluded that arc-trench migration occurred at this time. Although heat flow is inferred to have been higher in the Archean, numerical modeling by van Thienen et al. (2005) shows that for a steadily (exponentially) cooling Earth, plate tectonics is capable of removing all the required heat at a rate similar to, or even lower than, the current rate of plate movement.

METAL DEPOSIT EVIDENCE

Ore deposits are a consequence of the tectonic setting in which they occur, and numerous examples have been described where pre-Neoproterozoic mineralizations resemble Phanerozoic deposits related to subduction environments (Kerrich et al., 2005). Examining global orogenic gold deposits, Goldfarb et al. (2001) observed that the important periods of Precambrian orogenic gold deposit formation, ca. 2.8–2.55 and 2.1–1.8 Ga, correlate well with episodes of growth of juvenile continental crust. Similar characteristics of the Precambrian orogenic gold ores to those of Phanerozoic age have led to the premise that Cordilleran-style plate tectonics were also ultimately responsible for these deposits (Kerrich et al., 2005).

Porphyry Cu deposits show one of the clearest relationships to subduction magmatism (Kerrich et al., 2005) and are found back to 3.3 Ga in age (Barley, 1982). Their metallogenetic, petrologic, and structural features seem to have changed little through time, suggesting that broadly similar tectonomagmatic processes were responsible for their formation (Seedorf et al., 2005).

Other deposits that have a well-defined tectonic and environmental signature reflecting a subduction setting are the 2.7 Ga volcanogenic massive sulfide (VMS) Cu-Zn deposits such as Kidd Creek and Noranda in the Abitibi belt in the Canadian Shield (Wyman et al., 1999a, 1999b) and the Paleoproterozoic VMS deposits in the Trans-Hudson orogen (Syme et al., 1999) and in the Svecofennian of Sweden (Allen et al., 1996). The oldest known subduction-related VMS deposit is probably the 3.46 Ga Big Stubby deposit in the Warrawoona Group of the Pilbara craton, Western Australia (Barley, 1992).

A synthesis of metallogenetic provinces of all ages led Kerrich et al. (2005) to conclude that plume intensity was more widespread and voluminous in the Archean than in later times, but that many ancient metal deposits have remarkable affinities to modern plate margin processes, suggesting that some form of plate tectonics has operated.

WHEN DID PLATE TECTONICS BEGIN?

The accretion of Earth ca. 4.55 Ga, its differentiation into core, mantle, and crust, and its consequent thermal history requires an evolving tectonic regime. Horizontal movement, a component of plate tectonics, becomes important at the surface following the formation of a stiff lithosphere. Although no record of Earth's lithosphere during its first 550 m.y. is preserved, Ti-thermometry and oxygen isotope data for the oldest known detrital zircons from Jack Hills, Western Australia, imply that a cool water–laden surface may have existed by ca. 4.4 Ga (Watson and Harrison, 2005). This suggests that a rigid lithosphere, a prerequisite for plate tectonics, also existed by this time. The isotopic systematics of these old Jack Hills zircons indicate formation in a continental environment characterized by calc-alkaline magmatism and crustal anatexis, features seen in modern Earth in convergent margin settings, implying that subduction may have been established by 4.4 Ga (Harrison et al., 2005). Contrary to Hamilton (2003), structural styles in the oldest tonalite-trondhjemite-granodiorite (TTG) gneiss assemblages resemble those in younger orogenic belts (Myers and Kröner, 1994; Windley, 1995; Nutman et al., 2002), and although there are Archean greenstone sequences resting on older TTG crust, the majority of greenstone-gneiss contacts is tectonic, and the oldest known greenstone sequences, in southwest Greenland, do not have a felsic basement (Appel et al., 2003). The scarcity or absence of ≥3.5 Ga detrital zircons in early Archean greenstone sediments suggests these rocks formed in juvenile accretionary environments (e.g., Nutman et al., 2004). The well-preserved 3.0 Ga Ivisaartoq greenstone belt in West Greenland is interpreted as one of the best documented examples of Archean forearc crust (Polat et al., 2006).

Condie (2005) argued that the major phases of juvenile continental crust generation at 2.7 and 1.8 Ga were mantle plume–related and thus overlapping with evidence for plate tectonic regimes, which likely existed since at least the Mesoarchean (Smithies et al., 2005; Barley, 1992) but perhaps back to the early Archean (Nutman et al., 2002; Polat and Kerrich, 2004), as supported by boninitic komatiites from the Barberton greenstone belt (Parman et al., 2003). This suggests a spatial and temporal variation in the switch from a plume to plate regime and is consistent with geodynamic modeling that implies a period of oscillation between the two modes before plate tectonics became dominant (Muhlhaus and Regenauer-Lieb, 2005).

CONCLUSIONS

Paleomagnetic, geological, geochemical, metamorphic, seismic reflection, and geochronological data from Archean and Paleoproterozoic rock units require relative lateral movement of lithosphere and the subduction of oceanic lithosphere to generate arc magmas, mineral deposits, and eclogites. These data,

in our view, require a tectonic regime of lithospheric plates similar to the Phanerozoic Earth; any arguments against a plate tectonics scenario must provide viable alternative mechanisms for their generation.

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THE GEOLOGICAL SOCIETY OF AMERICA

SCIENCE ▪ STEWARDSHIP ▪ SERVICE

GSA Names 2006 Medal and Award Recipients

The GSA medals and awards for 2006 will be presented during the Presidential Address & Awards Ceremony at the Annual Meeting in Philadelphia on Saturday, 21 October, at the Pennsylvania Convention Center in the Auditorium Lecture Hall.

PENROSE MEDAL
Robert D. Hatcher Jr.
University of Tennessee

ARTHUR L. DAY MEDAL
Frank M. Richter
The University of Chicago

YOUNG SCIENTIST AWARD
(DONATH MEDAL)
Elizabeth J. Catlos
Oklahoma State University

GSA DISTINGUISHED SERVICE AWARD
Abhijit Basu
Indiana University

David E. Fastovsky
University of Rhode Island

Roger L. Kaesler
University of Kansas

GSA PUBLIC SERVICE AWARD
Richard A. Kerr
American Association for the Advancement of Science, Washington, D.C.

HONORARY FELLOWS
Sierd A. Cloetingh
Vrije University, Netherlands

David G. Roberts
Rockall Geoscience, Ltd., UK

SUBARU OUTSTANDING WOMAN IN SCIENCE AWARD
(Sponsored by Subaru America, Inc.)
Elizabeth S. Cochran
University of California, Los Angeles

AGI MEDAL IN MEMORY OF IAN CAMPBELL
Robert D. Hatcher Jr.
University of Tennessee

JOHN C. FRYE ENVIRONMENTAL GEOLOGY AWARD
Ralf Topper, Karen L. Spray, William H. Bellis, Judith L. Hamilton, and **Peter E. Barkmann,**
Colorado Geological Survey
Special Publication 53: Ground Water Atlas of Colorado (2003).

RIP RAPP ARCHAEOLOGICAL GEOLOGY AWARD
Peter J. Mehringer
Washington State University

GILBERT H. CADY AWARD
(Coal Geology Division)
James C. Hower
University of Kentucky

E.B. BURWELL, JR., AWARD
(Engineering Geology Division)
Martin G. Culshaw
British Geological Survey

GEORGE P. WOOLLARD AWARD
(Geophysics Division)
Kenneth P. Kodama
Lehigh University

MARY C. RABBITT AWARD
(History of Geology Division)
Sandra Herbert
University of Maryland, Baltimore County

O.E. MEINZER AWARD
(Hydrogeology Division)
Karsten Pruess
Lawrence Berkeley National Laboratory

DISTINGUISHED CAREER AWARD
(International Division)
Eldridge M. Moores
University of California, Davis

G.K. GILBERT AWARD
(Planetary Geology Division)
Michael J. Gaffey
University of North Dakota

KIRK BRYAN AWARD
(Quaternary Geology and Geomorphology Division)
David R. Montgomery
University of Washington

Mark T. Brandon
Yale University

LAWRENCE L. SLOSS AWARD
(Sedimentary Geology Division)
Gerald M. Friedman
Brooklyn College and Northeastern Science Foundation

CAREER CONTRIBUTION AWARD
(Structural Geology and Tectonics Division)
John F. Dewey
University of California, Davis

GSA Presidential Address & Awards Ceremony

Sat., 21 Oct., 7–9 p.m.

Auditorium Lecture Hall

Pennsylvania Convention Center

Reception to follow!

2006 GSA FELLOWS

Elected by Council on 30 April 2006

THE GEOLOGICAL SOCIETY OF AMERICA

SCIENCE ▪ STEWARDSHIP ▪ SERVICE

GSA's newly elected Fellows will be recognized at the Presidential Address & Awards Ceremony at the Annual Meeting in Philadelphia on Saturday, 21 October, at the Pennsylvania Convention Center.

J. David R. Applegate
Senior Science Advisor, U.S. Geological Survey, Reston

Elected to Fellowship as the 2005 GSA Public Service awardee.

David W. Blowes
Canada Research Chair in Groundwater Remediation, University of Waterloo, Canada

Elected to Fellowship as the 2006 Hydrogeology Birdsall-Dreiss Lecturer.

Anne E. Carey
Associate Professor, Ohio State University

Anne Carey was elected for insightful contributions to four interdisciplinary aspects of hydrologic sciences. These are coastal aquifer dynamics; the role of urbanization and agriculture on water quality; the relationship between weathering and landscape evolution; and the determination of geochemical mass balances on the watershed scale.
Nominated by Carol M. Wicks

David M. Diodato
Senior Professional Staff, U.S. Nuclear Waste Technical Review Board

David Diodato is cited for creating a World Wide Web portal "The Hydrogeologists Web Page" in 1995, which is a successful outreach in the field of hydrogeology. Contributions to the profession include founding the Software Spotlight column, chairing a Pardee Symposium, and technical analysis at the DOE nuclear disposal program at Yucca Mountain, Nev.
Nominated by Ira D. Sasowsky

Duane A. Eversoll
Professor, University of Nebraska

Duane A. Eversoll has been very active and taken the lead in GSA, particularly in the Engineering Geology division. He has had sustained contributions to both the profession and to the public.
Nominated by Marvin P. Carlson

Xiahong Feng
Associate Professor, Dartmouth College

Professor Xiahong Feng is nominated for her significant contribution to a wide spectrum of geological sciences using stable isotopes, including climate dynamics, hydrology and hydrochemistry, biogeochemistry and biogeochemical cycles, and geochemical kinetics.
Nominated by Youxue Zhang

C. Reid Ferring
Professor, University of North Texas

Elected to Fellowship as the 2005 GSA Rip Rapp awardee.

Andrew T. Fisher
Professor, University of California, Santa Cruz

Andrew Fisher is an influential leader within the field of marine hydrogeology. His innovative research on fluid flow and heat transfer in upper igneous basement utilizes a blend of empirical science, observatory science, and modeling. Andy has contributed significantly to scientific ocean drilling as a panel member and Co-Chief Scientist.
Nominated by Michael B. Underwood

Duncan M. FitzGerald
Associate Professor, Boston University

Duncan FitzGerald has earned a world-wide reputation as a leader in the study of tidal estuaries and other coastal features. He has given generously of his time to committee and editorial work for national geologic organizations. He is a popular teacher, and his "Beaches and Shorelines" class is always over-subscribed.
Nominated by D.W. Caldwell

David A. Foster
Professor, University of Florida

David Foster has earned the right to Fellowship in the GSA by his superb research record in particular addressing the history and timing of the deformation of Eastern Australia and the Western U.S. using $^{40}Ar/^{39}Ar$ dating techniques. Twice he has received the Stillwell award for best paper in the *Australian Journal of Earth Science.*
Nominated by Neil D. Opdyke

Shaun K. Frape
Professor, University of Waterloo, Canada

Shaun K. Frape is a scientific leader in the field of hydrogeochemistry and has made numerous seminal contributions over an academic career that spans more than 30 years. He specializes in the application of geochemical and isotopic tracers to large-scale field studies. These field studies are in environments as diverse as deep sedimentary basins, deep crystalline shields, and extreme environments such as those associated with the ocean drilling project or permafrost regions of the earth. His peer reviewed papers (over 70) and symposium papers (over 40) are a mixture between the themes of water-rock interaction in shields and basins, groundwater interaction with surface waters and development of geochemical and isotopic tools as tracers of natural systems and contaminants in the natural environment.
Nominated by Edward A. Sudicky

Alan E. Fryar
Associate Professor, University of Kentucky

Alan Fryar uses hydrogeology and environmental geochemistry to examine rates and chemical evolution of groundwater recharge and contaminant attenuation. Research has focused on regional aquifers in Bengal Basin, Texas High Plains, Kentucky, and Gulf coastal plain. He has convened seven GSA topicals and is

co-editor of *Environmental & Engineering Geoscience.*
Nominated by
Joseph J. Donovan

Shemin Ge
Associate Professor, University of Colorado, Boulder

Shemin Ge was elected to Fellowship in GSA for her significant contributions to earthquake hydrology, tectonic effects on fluid flow, and fluid flow in fractured rocks. Her outstanding work on the role of fluid flow in basin-scale geologic processes and active tectonic margins is widely recognized. In the past decade, she has made an impact in educating and mentoring younger hydrogeologists and provided a wide range of services to the hydrogeologic community and beyond.
Nominated by
You-Kuan Zhang

John C. Gosse
Professor, Dalhousie University, Canada

Elected to Fellowship as the 2005 Kirk Bryan awardee.

F. Edwin (Ed) Harvey
Associate Professor, University of Nebraska

Ed Harvey was elected for his insightful study of the hydrogeology and hydrochemistry of regional aquifers. His work supports our understanding of groundwater resources and surface-water interactions within the context of climate change. His service to GSA has supported wide dissemination of the activities of the Hydrogeology Division, fostering a cohesive professional community.
Nominated by Janet S. Herman

Peter J. Heaney
Professor, Penn State

Peter Heaney has devoted his career to the advancement of the knowledge of mineralogy and to the perpetuation and enhancement of community and public interest in mineralogy. This effort is reflected in over 50 refereed publications, numerous symposia organized, extensive service to the mineralogical community, and awards for teaching.
Nominated by Lee R. Kump

David W. Hyndman
Associate Professor, Michigan State University

David Hyndman is a distinguished professor and hydrogeologist at Michigan State University. His interdisciplinary research includes the application of geophysics and tracers to aquifer characterization. He was a Darcy Distinguished Lecturer in 2002, has received awards for teaching and reviewing, and is associate editor for the *Journal of Ground Water* and *Water Resources Research.*
Nominated by Robert H. Webb

Paul L. Koch
Professor, University of California, Santa Cruz

Paul Koch was elected to Fellowship in recognition of his outstanding achievements in paleobiology and paleoecology, and his contributions to the development of stable and radiogenic isotope proxies.
Nominated by James C. Zachos

Kyger C. Lohmann
Professor, University of Michigan

Kyger Lohman was elected for Fellowship because of his innovative contributions to the isotopic and elemental geochemical study of carbonates, which have yielded novel records of the temperature and chemistry of precipitating fluids and of past environmental histories, and for exceptional accomplishments in the professional training of geologists and the earth science education of nonscientists.
Nominated by Philip A. Meyers

Margaret T. Mangan
Research Geologist, U.S. Geological Survey, Menlo Park

Margaret Mangan was elected to Fellowship for her innovative research in field and laboratory petrology and volcanology, editorial service in scientific publishing, leadership of monitoring and research teams at volcano observatories, and effective communication of science to the public.
Nominated by Charles R. Bacon

Jonathan B. Martin
Associate Professor, University of Florida

Jonathan B. Martin is a chemical hydrologist with a distinguished record of research sponsored by numerous state, federal, and international hydrologic organizations. His research focuses on constraining elemental fluxes in submarine discharges, both from continents and in accretionary prisms, and on understanding groundwater behavior in subtropical Karst systems.
Nominated by Paul A. Mueller

Fred J. Molz
Professor, Clemson University

Fred J. Molz has made significant contributions in the areas of aquifer evaluation and the role of aquifer heterogeneity on fluid flow and transport in the subsurface. His work on upscaling has dramatically advanced our predictive modeling of aquifer contamination.
Nominated by Scott W. Tyler

Peter I. Nabelek
Professor, University of Missouri

Peter Nabelek is a leader in the study of granite-aureole systems. He is a pioneer in the application of stable isotope geochemistry to the study of metamorphic fluid-rock interaction. He has worked extensively with the Harney Peak, South Dakota, and Notch Peak, Utah, magmatic systems.
Nominated by Theodore C. Labotka

Yaoling Niu
Professor, University of Durham, UK

Yaoling Niu is a leading petrologist and geochemist who has made significant contributions to our understanding of mid-oceanic-ridge magmatism, solid earth geochemistry, chemical geodynamics, and mantle convection.
Nominated by Zheng-Xiang Li

James H. Reynolds
Associate Professor, Brevard College

Despite a near-fatal stroke in 1980, James Reynolds has become an important leader in the science of geology. Perhaps most significant is his having initiated the first students-only GSA GeoVentures™ field trip as well as the geology minor at Brevard College.
Nominated by
Stanley N. Williams

Margaret E. Rusmore
Professor, Occidental College

Margi Rusmore is one of the leaders in studies of the

GSA Fellows Elected by Council on 30 April 2006

tectonic evolution of western North America and of the formative processes of convergent margins. Her research in western Canada has contributed critical new insights into the genetic links between terrane accretion, batholith emplacement, and uplift of the Coast Mountains. Margi has also been exemplary in involving undergraduate students in her research.
Nominated by George Gehrels

Demian M. Saffer
Assistant Professor, Penn State

Elected to Fellowship as the 2005 Donath medalist.

Bradley B. Sageman
Professor, Northwestern University

Bradley Sageman has been elected to Fellowship in recognition of his fundamental advances in the understanding of the Cretaceous rock record, the history of biogeochemical cycles preserved in it, and the response of biological systems to perturbations in the ancient carbon cycle.
Nominated by Seth A. Stein

Stephen M. Testa
Executive Officer, California Board of Geology and Mining

Stephen M. Testa is an accomplished, widely published scholar and researcher, a skilled and highly sought after applied geology practitioner, and a dedicated nationally recognized leader in our profession.
Nominated by Larry D. Woodfork

Richard P. Tollo
Associate Professor, George Washington University

Richard Tollo has ten publications (three major papers) on the origin of Iapetan rift-related granites and five publications (two major papers) on the origin of Grenvillian plutonic rocks within the Appalachians. He was principal editor for GSA Memoir 197 (2004) and published earlier papers on Mesozoic igneous rocks and ultramafics.
Nominated by Mervin J. Bartholomew

Paul J. Umhoefer
Associate Professor, Northern Arizona University

Paul Umhoefer has advanced understanding of Mesozoic to present-day strike-slip and transtensional faulting through field studies of structure and stratigraphy in the western Cordillera from Baja California to Alaska. His research illuminates the importance of such faulting for coastwise transport of terranes and opening of the Gulf of California.
Nominated by Darrel S. Cowan

Peter D. Warwick
Research Geologist, U.S. Geological Survey, Reston

Peter W. Warwick was elected to Fellowship in recognition of his outstanding contribution to coal geology. His work on structure, quality, assessment, and coal gas in the U.S. Gulf region and Asia has significantly contributed to assessing world coal resources and understanding environmental consequences of coal use.
Nominated by Leslie F. Ruppert

Anthony B. Watts
Professor, Oxford University, UK

Elected to Fellowship as the 2005 Woollard awardee.

Donald O. Whittemore
Chief, Geohydrology Section, Kansas Geological Survey

Donald O. Whittemore was elected to Fellowship for his applied research concerning (1) identification and delineation of brine impacting fresh water, (2) factors controlling variations in the quantity and quality of water resources in stream-aquifer systems, and (3) mentorship and leadership as chief of the geohydrology section, Kansas Geological Survey, University of Kansas.
Nominated by Ralph K. Davis

Lynda B. Williams
Associate Research Professor, University of Arizona

Lynda B. Williams is nominated for her exceptionally broad impact on the field of low-temperature geochemistry. Lynda has made major intellectual contributions to the understanding of water/rock interactions, developing boron isotope systematics, origin of biopolymers, and the potential public health implications of clay minerals.
Nominated by Lynn M. Walter

Lionel Wilson
Professor Emeritus, Lancaster University, UK

Elected to Fellowship as the 2005 Gilbert awardee.

Tzen-Fu Yui
Professor, Academia Sinica, Taiwan

Tzen-Fu Yui is known for his discovery of the lowest oxygen isotopic value from coesite-bearing rocks from China, multi-phase inclusions in Kokcheteav microdiamonds in northern Kazakhstan, and is the best metamorphic petrologist in Taiwan.
Nominated by Juhn G. Liou

Hongbin Zhan
Associate Professor, Texas A&M University

Hongbin Zhan was elected to Fellowship for his significant contributions to mathematical solutions for groundwater flow and contaminant transport processes. His outstanding work in the analysis of flow to horizontal wells and aquitard controls on groundwater flow and transport is widely recognized.
Nominated by Chunmiao Zheng

William L. Zinsmeister
Professor, Purdue University

Bill Zinsmeister is a prominent paleontologist with an extensive bibliography, primarily related to the Arctic and Antarctic regions. He has been a full professor since 1991 and has outstanding research and teaching credentials. He has been an active member of GSA for many years.
Nominated by Terry R. West

Vitaly A. Zlotnik
Professor, University of Nebraska

Vitaly Zlotnik has made fundamental contributions to understanding the hydraulics of subsurface fluid flow and well hydraulics, including analytical modeling of horizontal and vertical wells, stream depletion, borehole-flowmeter logging, single-well, dipole, and tracer tests. He has distinguished himself as an educator and a member of the professional community of hydrogeologists.
Nominated by Robert W. Ritzi

GSA Fellows Elected by Council on 30 April 2006

GSA FELLOWS!

As a GSA Fellow, it is up to you to pass on the distinction of Fellow to your colleagues, friends, or other deserving geoscientists. Keep GSA Fellowship strong and vibrant by sending in your nominations today!

Please go to www.geosociety.org/members/fellow.htm for guidelines and nomination forms. Questions? Please e-mail awards@geosociety.org or call +1-800-472-1988 ext. 1028 or +1-303-357-1028.

THE GEOLOGICAL SOCIETY OF AMERICA

THE GEOLOGICAL SOCIETY OF AMERICA

GSA Celebrates New 50-Year Members for 2006

GSA salutes the following Members and Fellows for their 50-year membership to GSA. We appreciate their dedication and loyalty to GSA for all these years! The following lists only those Members and Fellows who are celebrating their 50-year membership in 2006. You can see a full list of all 50-year–plus Members at www.geosociety.org/grants/.

Richard C. Anderson
Paul A. Bailly
Donald L. Ballmann
Paul B. Barton
Harold W. Borns Jr.
Robert E. Boyer
Howard C. Brooks
Robert L. Christiansen
H. Basil Cooke
Bernard J. Cunningham
John M. Dennison
James Diaz
George A. Doumani
Joseph J. Durek
Richard E. Eggleton
W.G. Ernst
William R. Farrand
Paul C. Franks
Alfred J. Frueh Jr.
Hubert Gabrielse
Richard W. Galster
Carlos Garcia-Gutierrez
Bruno J. Giletti
Arthur Grantz
Otto Hackel
Clarence A. Hall Jr.
William K. Hamblin
Paul E. Hammond
Wallace R. Hansen
John C. Harms
Joseph H. Hartshorn
John B. Hayes
Henry G. Healy
F.D. Holland Jr.
Albert C. Holler
Frank H. Howd
William R. Keefer
George D. Klein
Carl Koteff
Phillip S. Kistler
Richard E. Kucera
Hans Laubscher
Seymour Mack
Paul A. Manera
Milton R. Marks
Ronald J. Marr
Peter H. Mattson
Malcolm C. McKenna
Donald G. Metzger
Charles P. Miller
Arthur Mirsky
Bruce W. Nelson
Paul W. Nygreen
Ralph B. Peck
W. Robert Power
Raymond Alexander Price
William C. Prinz
Elizabeth Pretzer Rall
Allan D. Randall
Claire A. Richardson
Joaquin Rodriguez
Samuel I. Root
Robert B. Ryan
Pierre Saint-Amand
Dwight L. Schmidt
John J. Schulte
Antonio V. Segovia
Everett R. Sharp
Daniel R. Shawe
Samuel J. Sims
Orrin Lee Slind
Foster D. Smith
John L. Snyder
Julian Soren
George C. Soronen
John G. Stone II
Donald F. Stott
Rudolph G. Strand
Sanford I. Strausberg
Alan F. Thomson
Samuel B. Treves
Neil H. Twelker
Page C. Twiss
Willis W. Tyrrell
Peter R. Vail
Marc B. Vuagnat
Paul A. Witherspoon Jr.
Alice E. Weis
Charles B. Wheeler

THANKS FOR YOUR MEMBERSHIP!

NEW: GSA Celebrates 25-Year Members!

GSA salutes the following Members and Fellows for their 25-year membership to GSA. We appreciate their dedication and loyalty to GSA! The following lists only those Members and Fellows who are celebrating their 25-year membership in 2006. You can see a full list of all 25-year–plus Members at www.geosociety.org/grants/. Asterisks indicate GSA Fellows.

THE GEOLOGICAL SOCIETY OF AMERICA

John L. Appel
Dean C. Armstrong
Robert L. Badger
Gordon C. Baird
James R. Bauder
Paul W. Bauer
L. Sue Beard
David J. Becker
E. Arthur Bettis III
Philip R. Bigsby
Peter Bird
Eugene L. Blanck Jr.
Charles Blome
Paul A. Bogseth
Paulette A. Bond
Theodore J. Bornhorst*
Carol W. Bowers
G. Patrick Bowling
Susan Carol Bradford
Bruce W. Bridenbecker
Mark E. Bryant
Thomas Fitts Bullard
George J. Burwasser
William H. Busch
Ann Bykerk-Kauffman
Maryellen Cameron*
Michael D. Campbell
Brian J. Cardott
John R. Carpenter*
Theodore H. Chenoweth
Frederick M. Chester
Gerald H. Clark
David B. Codding
James T. Constantopoulos
Francesco V. Corona*
Jean M. Crespi
David P. Crisman
Alan K. Crockett
Bruce L. Cutright*
Clyde Dabbs
Dennis E. Dahms
John W. S. Davis Jr.
Althea DeBellis
Julett R.P. Denton
David L. Dilcher
Roy K. Dokka*
Anna Dombrowski
Mary E. Dowse
Mark S. Drummond*
Steve J. Drussell
James P. Evans
Jan D. Falteisek
Martin B. Farley
John R. Farver
Glen L. Faulkner
Craig S. Feibel*
John J. Flynn
Kenneth A. Foland*
Annabelle M. Foos
Dennis E. Fries
Karen H. Fryer
Eldon M. Gath
William H. Gillespie
Matthew P. Golombek*
Connie J. Gough
Susan A. Green
Howard J. Grey
David Grooms
John R. Groves
Mae Sexauer Gustin
Claudia J. Hackbarth*
Ann G. Harris
Timothy S. Hayes
Vance T. Holliday*
Kurt T. Hollocher
Kermit Jamison
A.S. Jayko
Jeffrey A. Johnson
Leslie H. Kanat
Anatoly A. Kaplan
George C. Kendrick
Charles Frederick Kluth*
Melissa M. Kolb
Robert W. Krantz
Chris M. Kravits
Robert J. Krumm
Ralph R. Kuhns Jr.
Dorian Elder Kuper
Tarik M. Labib
Robert J. Lillie
John P. Lockridge*
Aubrey L. Long
Walter L. Manger*
Bill McClelland
Cecelia McCloy
Linda B. McCollum
John P. McCullough
Jude McMurry
John G. McPherson
Robert E. Meintzer
Carol Metcalf-Gardipe*
Donald D. Miller
Robert B. Miller*
Steven K. Mittwede
William N. Mode
Mark P. Molinari
Judy E. Moore
Craig G. Moseley
Cheryl Johnson Moss
Daniel Muhs*
Eric P. Nelson
Christopher G. Newhall
Hallan C. Noltimier
Dag Nummedal
Yujiro Ogawa*
Patrick F. O'Hara
William A. Parisi
Larry C. Peterson
Thea Welsh Phinney
James L. Pindell
James E. Pizzuto*
Clifford R. Pollock
Richard M. Powers
L. Bruce Railsback*
John H. Raymer
Kathleen Anne Riedel
Catherine A. Rigsby
Robert J. Rogers
Joseph G. Rosenbaum
Unni H. Rowell*
David B. Sams
Ira D. Sasowsky*
Jay R. Scheevel
Carol Simpson*
Virginia B. Sisson*
Suzanne M. Smaglik
William A. Smith
Stephen A. Sonnenberg*
Kent A. Sundell
Neil Suneson
Susan J. Tewalt
Thomas M. Tharp
David P. Thetford
Laura Toran*
Robert J. Traylor
R. Rexford Upp
Stephen F. Urschel
David H. Voorhees
Alan R. Wallace
Peter D. Warwick
Tim C. Welch
Patricia A. Whalen
Jerry C. Wilson
W.D. Bruce Winfield
James C. Witcher
Pamela B. Zohar

THANKS FOR YOUR MEMBERSHIP!

Look for a listing of our 25- and 50-year members at GSA's Annual Meeting **Hall of Fame** at the Pennsylvania Convention Center, beginning 21 October and on display through 25 October 2006.

GSA Celebrates Its 100-Year-Old Member

Happy birthday to our 100-year-old Senior Fellow! **Edward C. Dapples** of Peoria, Arizona, will be celebrating his centennial this year. GSA extends our best wishes and proudly honors his 60-plus years of GSA membership.

2006 GSA Research Grants Awarded

The GSA Committee on Research Grants met at GSA Headquarters in Boulder, Colorado, on Saturday, 24 March 2006, and awarded US$516,480 to 263 graduate students. The committee also selected ten alternate candidates in the event that any grantees return all or part of their funds due to a change in their research project or receipt of funds from another source. The sixteen committee members for 2006 were Eric Erslev (chair), Laurie Brown, Allen Dennis, Katherine Cashman, Amy Draut, Andrew Gombos, Stephen Hasiotis, Stephen Harlan, Vincent Matthews, Julia Sankey, Dibyendu Sarkar, Sheila Seaman, Robert Shuster, Bruce Simonson, Sally Sutton, and Carol Wicks.

Fewer students applied in 2006 than 2005 due to the change in application rules. In an effort to fund more new GSA Student Members, students may now only receive GSA graduate student research grant money once at the master's level and once at the Ph.D. level.

2006 Student Research Grant Statistics

Total proposals received	555
Total proposals funded	263
Total dollars awarded	US$516,480
Average award	US$1,963

2006 Partial List of Funding Sources

	US$
Joseph T. Pardee Memorial Fund	$235,000
Partial GSA Funding	**$235,000**

Geophysics Division (to augment Cox Award)	$1,050
Sedimentary Geology Division Award	$1,000
Structural Geology and Tectonics Division Award	$3,600
Geophysics Division Grant	$250
Total Division Funding	**$5,900**

Total National Science Foundation Funding*	**$168,900**

Harold T. Stearns Award Fund	$5,000
Lipman Fund	$5,000
Blechschmidt Award	$1,000
Cox Award (Geophysics Division)	$1,200
Dillon Alaska Award	$2,700
Reed Research Award	$1,900
Sisson Research Award	$2,000
Hydrogeology Division Award	$2,400
Montagne Fund	$600
Research Fund	$8,000
GeoStar	$6,750
Curtis Fund	$4,000
Ross Fund	$4,100
Wanek Fund	$3,000
Snavely	$1,500
Unrestricted	$54,550
Terman (to be awarded in October)	$5,000
Total GSA Foundation Funding	**$108,700**

*NSF grant matched at least 2 to 1 by GSA and GSA Foundation.

2006 GSA Research Grant Outstanding Mentions

The committee recognized 17 of the proposals to be of exceptionally high merit in conception and presentation. This merit will be formally recognized by GSA at the President's Student Breakfast to be held at the GSA Annual Meeting in Philadelphia, Sunday, 22 October, 7–8:30 a.m. At that time, certificates and ribbons will be handed out to the students.

Damon Bassett, University of Missouri, for "A high resolution phosphate $\delta^{18}O$-based paleotemperature reconstruction of the Ordovician."

Gordon Bromley, University of Maine, for "Reconstructing the late Quaternary glacial history of Nevado Coropuna, Cordillera Ampato, Peru."

Kevin Butak, Southern Illinois University, for "Layer-forming mechanisms in mafic-ultramafic intrusions: Constraints from magnetic fabrics and image analysis in the Stillwater Complex, Montana."

Robinson Cecil, University of Arizona, for "New developments in K-Ca geochronology and applications to sedimentary dating."

Burch Fisher, Dartmouth College, for "Bring back the salmon! Understanding the role of LWD in salmon recovery in Downeast Maine."

Christopher Hamilton, University of Hawaii–Manoa, for "Explosive lava-water interaction: Reaction-diffusion modeling of rootless cone group formation based on Icelandic archetypes."

Elaine Jacobs, Colorado State University, for "Quaternary drainage pattern establishment: A case study using the Jemez Volcanic Field."

Brandon Klingensmith, Ohio University, for "GIS-based mapping of brachiopod species ranges in the type Cincinnatian."

Jih-Pai Lin, Ohio State University, for "Taphonomy of the Kaili Biota (middle Cambrian), Guizhou Province, South China."

Moikwathai Moidaki, University of Missouri–Rolla, for "Investigating the deep crustal structure of the nascent Okavango Rift Zone, NW Botswana: Insights from gravity, magnetotelluric and earthquake data."

Eliza Nemser, University of Washington, for "Temporal and spatial evolution of damage zones along small faults adjacent to the seismogenic San Jacinto fault, southern California."

Peter Rose, University of Minnesota, for "Paleoclimatology of North America during the middle Paleocene and the relationship between climate change and mammalian faunal turnover."

Abani Samal, Southern Illinois University, for "Origin of the Florida Canyon gold deposit, Pershing County, Nevada: Relation to magmatism and geothermal activity."

Jennifer Sawyer, San Diego State University, for "Effects of predation on the morphology of Pennsylvanian bellerophontid gastropods."

Eric Shullenberger, University of Wisconsin, Madison, for "Implications of pedogenic features in the reconstruction of paleoclimate and paleoenvironment across the Paleocene/Eocene boundary, Williston Basin."

Nathan Stansell, University of Pittsburgh, for "Holocene glacial variability in the Mérida Andes, Venezuela."

Peggy Stonier, Kent State University, for "EMPA dating of monazite from metaquartzites and metapelites, southern Wisconsin."

2006 GSA Research Grant Specialized Awards

The committee selected recipients of the specialized awards that are named in honor of the donors or as memorials to former members of the Society.

Gretchen L. Blechschmidt Award

The Gretchen Louise Blechschmidt Award Fund was established for women in the geological sciences who have an interest in achieving a Ph.D. in the fields of biostratigraphy and/or paleoceanography, sequence stratigraphy analysis, particularly in conjunction with research in deep-sea sedimentology, and a career in academic research. The 2006 recipient is **Yuxi Jin,** University of Nevada, Reno, for "Testing the paleoecological significance of radiolarian faunal variations from the Lamar Limestone, Delaware Basin, west Texas."

John T. Dillon Alaska Research Award

The John T. Dillon Alaska Research Award honors the memory of John Dillon, who was particularly noted for his radiometric age-dating work in the Brooks Range, Alaska. Two areas that serve as guidelines for selection of the award are field-based studies dealing with the structural and tectonic development of Alaska and studies that include some aspect of geochronology (either paleontologic or radiometric) to provide new age control for significant rock units in Alaska. The 2006 recipient is **Ryan McAleer,** Virginia Tech, for "Late Cenozoic exhumation in a transpressive setting: Fairweather Range, Alaska."

Robert K. Fahnestock Award

The Robert K. Fahnestock Award honors the memory of Robert Fahnestock, a former member of the GSA Research Grants Committee, who died indirectly as a result of service on the committee. The grant is awarded for the best proposal in sediment transport or related aspects of fluvial geomorphology, Dr. Fahnestock's field. The 2006 recipient is **Amanda Henck,** University of Washington, for "Is the Three Rivers region in steady state?"

Lipman Research Award

The Lipman Research Fund was established in 1993 and is supported by gifts from the Howard and Jean Lipman Foundation. The purpose of the fund is to promote and support student research grants in volcanology and petrology. The president of the Lipman Foundation, Peter W. Lipman, was the recipient of a GSA research grant in 1965. The 2006 recipient is **Celestine Mercer,** University of Oregon, for "Textural characterization of dike samples from a hydrous basaltic andesite stratovolcano: Constraints on magma ascent and eruption style."

Bruce L. "Biff" Reed Scholarship Award

The Bruce L. "Biff" Reed Scholarship Fund was primarily established to provide research grants to graduate students pursuing studies in the tectonic and magmatic evolution of Alaska, and also can fund other geologic research. The 2006 recipient is **Josashish Thakurta,** Indiana University, for "Isotopic and geochemical studies on Cu-Ni-PGE mineralization in the Duke Island Ultramafic Complex, Alaska."

Alexander Sisson Research Award

Family members of Alexander Sisson established a fund in his memory to promote and support research for students pursuing studies in Alaska and the Caribbean. The 2006 recipient is **Terrence McCloskey,** Louisiana State University, for "Proxy hurricane records for the western and southern Caribbean."

Harold T. Stearns Fellowship Award

Stearns established the Harold T. Stearns Fellowship Award in 1973 for student research on aspects of the geology of the Pacific Islands and the circum-Pacific region. This year, the committee presented the award to three candidates: **Christopher Harpel,** University of North Dakota, for "2 ka lahar deposit of Misti volcano, Southern Peru"; **Peter Nester,** Cornell University, for "Late Pleistocene terraces of the Atacama Desert"; and **Branwen Williams,** Ohio State University, for "Calibration of gorgonian skeletons as proxy of thermocline depth variability."

John Montagne Fund

The John Montagne Fund was established in 2000 to support one recipient's research in the field of Quaternary geomorphology. The 2006 recipient is **Joel Johnson,** Massachusetts Institute of Technology, for "Canyon incision along the Escalante River, Utah: An evaluation of bedrock erosion models."

Alexander and Geraldine Wanek Fund

The Wanek Fund was established in 2002 to support research dealing with coal and petroleum resources, mapping, and engineering geology, marine resources, petroleum economics, appraisal, and evaluation, and the geology of phosphate resources. The 2006 recipient is **Ross Daniel,** University of British Columbia, for "Controls on gas capacities in marine mudrocks and shales: Unconventional resource for natural gas."

Charles A. and June R.P. Ross Research Fund

The Ross Research Fund was established in 2002 to support research in the fields of biostratigraphy (including, but not lim-

ited to, fossil age dating and the study of evolutionary faunal successions), stratigraphy and stratigraphic correlation, paleogeography and paleobiogeography, interpreting past environments of deposition and their biological significance, and the integration of these research areas into better global understanding of (1) past plate motions (plate tectonics and seafloor spreading); (2) past sea level events, including their identification and ages; and/or (3) climate changes and effects of those climate changes on Earth's inhabitants through geologic time. There should be, over time, a balance of money among the awards across these various subject subfield categories, depending on the merit of the annual project proposals. The 2006 recipient is **Faysal Bibi,** Yale University, for "Evolution and paleoecology of late Miocene Bovidae."

Parke D. Snavely, Jr., Cascadia Research Award Fund

The Parke D. Snavely, Jr., Cascadia Research Award Fund provides US$1,500 to support field-oriented graduate student research that contributes to the understanding of the geologic processes and history of the Pacific Northwest convergent margin, or to the evaluation of its hazard or resource potential. The 2006 recipient is **Valerie Lenhartzen,** Boise State University, for "Dendroclimatological reconstruction of streamflow variability in a small, semi-arid mountain catchment."

The Maurice "Ric" Terman Fund

The Maurice "Ric" Terman Fund provides one-year grants to fund the Ph.D. theses and post-doctoral research of East Asian scientists. Countries currently include Cambodia, China, Indonesia, Japan, Korea, Malaysia, Papua New Guinea, Thailand, and Vietnam. The recipient will be chosen in the fall of 2006.

2006 GSA Research Grant Recipients

A

Achenbach, Kay
Adams, Byron
Allen, Jessica
Altekruse, Jason
Amidon, William
Amidu, Sikiru
Anslow, Faron
Arriola, Tonia
Aswasereelert, Wasinee
Auer, Sara

B

Balogun, Akindele
Baresch, Elizabeth
Barquero-Molina, Miriam
Barresi, Tony
Bartholomaus, Timothy
Bassett, Damon
Basu, Anirban
Bemis, Sean
Beranek, Luke
Bergeron, Melody
Berkelhammer, Max
Bershaw, John
Bibi, Faysal
Bitting, Kelsey
Bitton, Michael
Bolger, Kathleen
Bongino, John
Bose, Sushanta
Boyd, Clint
Bracht, Brandi
Brecke, Devon
Bristow, Thomas
Bromley, Gordon
Buick, Devin
Burdette, Kevin
Burger, Benjamin
Buscher, Jamie
Butak, Kevin
Byars, Rebecca M.

C

Caissie, Beth
Carlson, Michael
Carvajal-Ortiz, Humberto
Cassel, Elizabeth
Cecil, Robinson
Chapman, Alan
Cheversia, Mary Beth
Christianson, Evan
Christie, Michael
Cleaveland, Laura
Cleveland, David
Cole, Joshua
Cook, Brian
Cook, Jennie
Cooper, Frances
Counts, John
Crawford, Tafline
Cross, Gareth
Curry, Megan

D

Daniel, Ross
DeMott, Laura
Diesel, Elizabeth
Dvoretsky, Rachel

E

Erwin, Marty

F

Fall, Leigh
Felis, Jonathan
Fisher, Burch
Flaum, Jason
Fletcher, Kathryn
Forrest, Matthew
Fosdick, Julie
Frades, Matt
Frechette, Jedediah

G

Garcia, Anna
Garcia-Fresca, Beatriz
Gavillot, Yann
Genareau, Kimberly
Getty, Patrick
Ghatak, Arundhuti
Ghoshal, Swati
Gingrich, David
Glaccum, Kate E.
Gold, Ryan
Goldsmith, Steve
Gomez, Carolina
Gonzalez, Edward
Goodman, Emily
Goteti, Rajesh
Gray, Zeitel
Green, Jeremy
Guha, Swagata

H

Hagan, Jeanette
Hajek, Elizabeth
Halfen, Alan F.
Hamilton, Christopher
Haney, Erin
Hansen, Lars
Harpel, Christopher
Hasterok, Derrick
Helmke, Elizabeth
Henck, Amanda
Henry, Heather
Herrick, Morgan
Heuser, Heather
Hinckley, Eve-Lyn
Hnat, James
Hodge, Brendan
Hough, Brian
Howley, Robyn
Huppertz, Tammo Jan
Hutson, Joel

I

Isaacson, Robert

J

Jackson, Kelly L.
Jacobs, Elaine
Jago, Paul
Jin, Yuxi
Johnson, Breck
Johnson, Emily
Johnson, Joel
Johnston, Sarah
Julian, Meaghan

K

Kahmann, Julia
Kanamaru, Kinuyo
Kinabo, Baraka
Kircher, Anya
Klingensmith, Brandon
Knell, Michael
Knorr, Paul
Kopczynski, Sarah
Kuchta, Matthew
Kurz, Gene

L

Lambert, William
Lancaster, Penelope
Landrum, Jeffrey
LaPorte, Dan
Larson, Kyle
Laxton, Sarah
Lenhartzen, Valerie
Levin, Naomi
Lin, Jih-Pai
Loehn, Clayton
Logsdon, M. Grant
Louni, Nazim Fodil

M

Mackey, Katherine
Maclachlan, John
MacLean, John
Maglio, Steven
Majeski, Adam
Marcott, Shaun
Marenco, Katherine
McAleer, Ryan
McCabe, Janice
McCloskey, Terrence
McCune, Julian

McGlashan, Neil
McGlue, Michael
McKay, Moriah
McKay, Nicholas
Meierbachtol, Toby
Mercer, Celestine
Merkel, Ian
Mickiewicz, Susan
Mijal, Brandon
Moeller, Carolyn
Moidaki, Moikwathai
Moore III, Paul J.
Mosolf, Jesse
Mrofka, David
Murray, Bryan
Myer, Caroline

N

Nagar, Rachana
Neku, Amar
Nelson, Gabriel
Nemser, Eliza
Nester, Peter
Neudorf, Christina
Newbrey, Michael
Null, Kimberly

O

O'Connell, Kristin
Oleson, Timothy

P

Pace-Graczyk, Kali
Partey, Frederick
Pearson, Nadine
Pepple, Chris
Peterson, Nils
Peyton, Sara Lynn
Platt, Brian
Price, Nancy
Pyenson, Nicholas

R

Raub, Theresa
Retrum, Julie
Rice, Stephanie
Rice, Steve
Riggleman, Lori
Robert, Genevieve
Rose, Kathryn
Rose, Peter
Roskowski, Jennifer

S

Saari, Brooke
Samal, Abani
Satkoski, Aaron
Sawyer, Carol F.
Sawyer, Jennifer
Schaller, Morgan
Schorzman, Kerri
Schroeder, Jeffrey
Seidman, Lauren
Seigle, Amanda
Shakun, Jeremy
Shamsudduha, Mohammad
Shroat-Lewis, René
Shullenberger, Eric
Shunk, Aaron
Siedlecki, Elizabeth
Silver, Matthew
Slack, Christopher
Smith, Amy
Smith, Christopher
Smith, Colby
Smith, Ursula
Stansell, Nathan
Steinhauer, Elspeth
Stonier, Peggy
Styger, Sheena
Suarez, Celina
Sur, Sohini
Sweeney, Ian

T

Tang, Jennifer E.
Thakurta, Joyashish
Thomas, Stephanie
Thompson, Melanie
Todd, Erin
Trasko, Keith
Tsoflias, Sarah
Tsukui, Kaori
Tully, Justin
Tyra, Mark
Tyson, Amanda

U

Ucar, Estibalitz
Udgata, Devi B.P.
Uroza, Carlos

V

Van Alstine, Jana
Varriale, Frank
Villa, Danielle
Vinson, David

W

Werner, Corey
Whitlow, Katherine
Wilcox, Jeffrey
Wilcox, Robin
Williams, Branwen
Williams, Christopher
Williams, Clare
Willis, Julie
Wiser, Andy
Witherow, Rebecca
Wolaver, Brad
Wydzga, Aleksandra

X

Xie, Xiangyang

Y

Yin, Jun

Z

Zanazzi, Alessandro
Zhang, Nianli
Zhang, Ran
Zinsser, Austin
Zollinger, Henry

2006 Gladys W. Cole and W. Storrs Cole Memorial Research Awards

Elizabeth B. Safran, Lewis and Clark College, was awarded US$8,200 from the Gladys W. Cole Fund for research in geomorphology of semi-arid and arid terrains for her research project "Impact of extrafluvial events on river valley evolution."

Amelia E. Shevenell, University of Washington, was awarded US$7,500 from the W. Storrs Cole Fund for research in invertebrate micropaleontology for her research project "East Australian Current influence on middle Miocene meridional heat/moisture flux."

The 2006 Cole Awards for postdoctoral research are funded by the GSA Foundation.

GSA MEMORIALS: HELP US REMEMBER

Every year, GSA publishes a memorial volume devoted to deceased GSA members. Memorials are written by associates, friends, or relatives of those who have passed away. Each memorial enables us all to learn more about the fascinating individuals who have been part of GSA.

If you would like to honor a friend or colleague with a memorial, please send it as a Microsoft Word–compatible file via e-mail to awards@geosociety.org. The text should be limited to about 2,000 words and include a selected bibliography of the decedent's works in the earth sciences. Published memorials also include a photo, so please send a picture of the person you are memorializing, either as a high-resolution jpg attached (as a separate file) to your e-mail or a glossy photograph sent via post. Complete guidelines for compiling your memorial can be found at www.geosociety.org/grants/index.htm.

The following is a list of GSA members who have passed away since 2003 for whom no memorial has been written. Bold names signify those who passed away in the last year; asterisks with these indicate a memorial is in progress.

Samuel S. Adams
Thos. D. Barber
David F. Barnes
Robert Taylor Bean
Allan P. Bennison
John W. Blagbrough
Ernest W. Blythe Jr.
Bruce A. Bolt
Thomas S. Bond
Francis R. Boyd Jr.
James C. Bradbury
William A. Braddock
H. Gassaway Brown III
Lawrence L. Brown
Ralph S. Brown
Robert P. Bryson
John W. Buffington
Reuben G. Bullard
Arthur E. Burford
James Bush
Donald H. Cadwell
Carl E. Carlson
John J. Chapman
Charles A. Coffindaffer
P.G. Cooray
Bruce C. Corliss
Harmon Craig
Paul E. Damon
Franklin W. Daugherty
Peter P. David
Tudor T. Davies
Steven N. Daviess
Robert W. Decker
David M. Delo
Thomas W. Dibblee Jr.
Robert F. Dill
Jose R. Dominguez
William J. Domoracki
Renaud M. DuDresnay
Edward J. Dwornik
Ernest G. Ehlers
Gus K. Eifler Jr.
Phillip Eisenstatt
Jack G. Elam
Donald P. Elston
Ronald F. Emslie
Pow-Foong Fan
Oscar S. Fent
Richard V. Fisher
Erik Flugel
John A. Fortescue

Charles D. Foss
Sidney S. Galpin
Rudolf A. Gees
Lynn Glover III
Glenn A. Goodfriend
Robert Y. Grant
Sheldon K. Grant
John P. Gries
Gerald R. Grocock
Eugene W. Grutt Jr.
Charles V. Guidotti
William C. Gussow
Michel T. Halbouty
Richard Hamburger
Jake M. Hancock
W. Brian Harland
Elbert Nelson Harshman
Leo A. Herrmann
H. Stanton Hill
Alan D. Hoagland
John H. Hoke
John W. Hook
Stuart P. Hughes
C.S. Hurlbut Jr.
Charles B. John
W.G.Q. Johnston
Michael A. Jordan
Robert F. Kaar
Viktor P. Kahr
Walter D. Keller
Lewis H. King
George F. Koehler
William F. Kohland
Rudolph W. Kopf
Otto C. Kopp
Konrad B. Krauskopf
Robert P. Kunkel
Walter O. Kupsch
Fitzhugh T. Lee
Luna B. Leopold*
S. Benedict Levin
Robert T. Littleton
Lloyd Livingstone
Helen Tappan Loeblich
William W. Lomerson
Frederic B. Loomis
Gary A. Lund
H.W. Mallery
V. Standish Mallory
John A. Mann
Kathleen Mark

John C. Maxwell*
Barney C. McCasland Jr.
Bill J. McGrew
Digby Johns McLaren
Wilton N. Melhorn
Fred J. Menzer
William R. Merrill
Louis H. Michaelson
John C. Mickelson
William R. Moran
Anthony E.L. Morris
David A. Morris
Ernest H. Muller
Kiguma J. Murata
Karl Nebert
Norman D. Newell*
Paul H. Nichols
Tor H. Nilsen
James J. Norton
Donald Eugene Owen
Craig W. Oyen
Elmer D. Patterson
William D. Payne
Wilferd W. Peak
Stephen F. Percival Jr.
Donald W. Peterson
Jack W. Pierce
Wallace S. Pitcher
Jean Piveteau
Gordon W. Prescott*
Victor K. Prest
Anthony Qamar
Thomas L. Quinn
Paul C. Ragland*
Edward L. Reed
John B. Reid Jr.
Jacques R. Renault
Richard S. Rhodes II
Joseph F. Riccio
Salem J. Rice
Ernest I. Rich
Donald H. Richter
Eugene C. Robertson
G.D. Robinson
John Rodgers
Mark S. Roth
Nancy G. Ryan
Nathaniel McLean Sage Jr.
Sigmund D. Schwarz
Paul R. Seaber
Nicholas J. Shackleton*

Robert P. Sharp
Denis M. Shaw
Jack A. Simon
Clay T. Smith
Donald N. Smith
Peter B. Smoor
Parke D. Snavely Jr.
Ronald K. Sorem
John B. Squyres
Harold K. Stager
Kenneth O. Stanley
Robert H. Stebbins
Maria I. Stercho
Daryl Streiff
William K. Summers
John E. Szatai
Ira D. Taylor
James B. Terry
Richard D. Terry
Robert P. Thomas
Harry Ludwig Thomsen
William H. Thornton
Michael A. Tolley
Edward B. Towne
Joshua I. Tracey Jr.
Mortimer D. Turner
Sherwood D. Tuttle
Wilhelmus T. van Middelaar
Robert A. Vargo
Newell F. Varney
William R. Walton
J. Lloyd Watkins
Edwin J. Webb
Karen Weber
Peter W. Weigand
Wilfred R. Welsh
David Archer White
William A. White
Peter V. Wiese
Garner L. Wilde
Alwyn Williams
George Arthur Williams
Clifford L. Willis
Donald L. Wills
William J. Winegard
Erhard M. Winkler
Daniel E. Wonderly
Albert E. Wood
Hatten S. Yoder Jr.
Rainer Zangerl
Aiyun Zhang

Donna L. Russell, *Director of Operations*

GSA Foundation has a new Web page!

Go to **www.gsafweb.org** to learn more about the Foundation's history, its mission, how to make a donation, current events, contact information, and more! You can also access the latest annual report and learn about the current Board of Trustees.

GSA Student Research Grants Come Full Circle

Recently, the GSA Foundation received a bequest from Ruth Jackson, the grandmother of a GSA Student Member, Alberto Reyes. Reyes, a graduate student at the University of Alberta, has been awarded, as he puts it, "very generous research funding from GSA graduate research grants." His grandmother's bequest will in turn go into the GeoStar fund, which is the permanent endowment fund for research grants, and will provide support for future student research.

Based on the merit of his work and his proposals, Reyes received GSA research grants between 2002 and 2005. The results of his first GSA-supported project are published in the January 2006 issue of *Geology*: "Expansion of alpine glaciers in Pacific North America in the first millennium A.D." (p. 57–60). Other topics of Reyes' research include "Tree-ring dating of Little Ice Age glacier advances and associated ice-damaged lakes in Kluane National Park and Reserve, Yukon Territory, Canada (Geological Society of America *Abstracts with Programs*, v. 35, no. 6, p. 133), and "Insights into last interglacial Beringian paleoclimate from tree-rings and stable isotopes" (for which he received his most recent grants).

Each year the GSA Foundation provides ~US$100,000 from several funds for the GSA Research Grants program. The total amount of Foundation funding toward the GSA research grants for 2006 was US$108,700.

GeoScience Day at Philadelphia

The GSA Women and Minorities Committee will be sponsoring GeoScience Day for Philadelphia middle- and high-school minority students. A lunch will be provided for the students, along with a tour through the GSA Annual Meeting Exhibit area and a session with a professional geologist.

If you would like to help support this special event and introduce some students to the profession, please send your contribution to the GSA Foundation. A check-off box has been provided below, or you may donate via our new Web site, **www.gsafweb.org.** Please note that your donation is for GeoScience Day.

Most memorable early geologic experience:

Recovering 1500 feet of salt water with signs of cottonseed oil the first time I authorized a drill stem test for Amoco.

—David E. Dunn

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Enclosed is my contribution in the amount of $_____.

Please credit my contribution for the:

☐ Greatest need ☐ Other: _____ Fund

☐ I have named GSA Foundation in my will.

☐ Geoscience Day

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Phone

Call for GSA Committee Service

Stimulate Growth and *Change*

Serve on a GSA Committee!

Terms begin 1 July 2007 (unless otherwise indicated).

2007–2008 Committee Vacancies

GSA is seeking candidates to serve on Society committees and as GSA representatives to other organizations. Council encourages you to volunteer or nominate others for committee service. Graduate students are eligible to serve on GSA committees as full members. Whether you volunteer or make recommendations, please give serious consideration to the specified qualifications for serving on a particular committee. The position descriptions and qualifications are listed in the March and June issues of *GSA Today* and can be found on the Web at **www.geosociety.org/aboutus/commtees/0708vacancies.htm.** Please be sure that your candidates are GSA Members or Fellows and that they fully meet the requested qualifications.

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

Nominations must be received at GSA headquarters by **1 August 2006** (on the official form) to be forwarded to the Committee on Nominations.

ACADEMIC AND APPLIED GEOSCIENCE RELATIONS COMMITTEE (AM, T/E)—3-YEAR TERMS
Nine vacancies: eight member-at-large; one councilor/former councilor

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

ARTHUR L. DAY MEDAL AWARD (T/E)—3-YEAR TERMS
Two member-at-large vacancies

EDUCATION (AM, T/E)—4-YEAR TERMS
Three vacancies: one undergraduate level educator; one student representative; one member-at-large

GEOLOGY AND PUBLIC POLICY (AM, B/E, T/E) —3-YEAR TERMS
Two member-at-large vacancies

HONORARY FELLOWS (T/E)—3-YEAR TERMS
Two member-at-large vacancies

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

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

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

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

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

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

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

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

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

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

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

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

GSA Representatives to Other Organizations:

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

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

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

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The Kerry Kelts Research Awards of the Limnogeology Division

The application process for the Kerry Kelts Research Awards of the Limnogeology Division is now open. These awards are named in honor of Kerry Kelts, a visionary limnogeologist and inspiring teacher. Up to three awards of US$300 each for use in research related to limnogeology, limnology, and paleolimnology are available. Application for this award is simple and consists of a summary of the proposed research, its significance, and how the award will be used (five-page maximum). Please send your summary in PDF format along with your name and associated information to the chair of the Limnogeology Division, Thomas C. Johnson, tcj@d.umn.edu. **Application Deadline: 10 August 2006.** Awards will be announced at the Limnogeology Division Business Meeting and Reception at the 2006 GSA Annual Meeting in Philadelphia in October.

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

ANNOUNCEMENTS

GSA Adds New Division: Geoinformatics

You may now choose from 17 Divisions to match your specialty (and join more than one)! GSA's newest Division, Geoinformatics, was approved by Council at its April 2006 meeting.

Geoinformatics is a science discipline that utilizes cyber products and tools and the discovery of data and models for exploring integrative solutions to complex earth and planetary systems questions.

The purpose of this new Division is to bring scientists interested in geoinformatics together and to stimulate communication among earth scientists and computer scientists. It is intended to facilitate the presentation and discussion of problems and ideas and to promote research and the publication of results. This Division will also advance the development of new educational technologies, supporting workshops for the community so that it may benefit from the technological and scientific infrastructure, thereby advancing integrative science.

THE GEOLOGICAL SOCIETY OF AMERICA

To join one or more GSA Divisions, go to www.geosociety.org/sectdiv/ or contact GSA Sales and Service +1-303-357-1000 option 3 gsaservice@geosociety.org.

MEETINGS CALENDAR

2006

27 July–8 Aug.	International Geoscience Programme (IGCP) Project 480: Structural and Tectonic Correlation across the Central Asian Orogenic Collage, Ulaanbaatar, Mongolia. **Information:** Boris Natal'in, Istanbul Technical University, Maden Fakultesi, Jeologi Bolumu, Ayazaga 80626, Istanbul, Turkey; natalin@itu.edu.tr; www.igcp.itu.edu.tr/IGCP480-2006.pdf.
31 Oct.–4 Nov.	49th Annual Meeting of the Association of Environmental and Engineering Geologists, Boston, Massachusetts, USA. **Information:** www.ageweb.org, or contact Dick Sherman, dick.sherman@m-e.aecom.com, Metcalf & Eddy, 701 Edgewater Dr., Wakefield, MA 01880, USA, +1-607-471-3049.

2007

29 Apr.–3 May	National Ground Water Association 2007 Ground Water Summit, Albuquerque, New Mexico, USA. **Information:** http://www.ngwa.org/e/conf/0704295095prop.cfm.
2–7 June	44th Annual Meeting of the Clay Minerals Society, Santa Fe, New Mexico, USA. **Information:** www.sandia.gov/clay/.

Visit www.geosociety.org/calendar/for a complete list of upcoming geoscience meetings.

About People

Former GSA President, GSA Senior Fellow, and 1994 Penrose Medalist **Luna B. Leopold** has been posthumously awarded the 2006 Benjamin Franklin Medal in Earth and Environmental Science along with former GSA President, GSA Senior Fellow, and 1999 Penrose Medalist **M. Gordon Wolman.** Both Leopold and Wolman are recognized for advancing the understanding of how natural and human activities influence landscapes. For more information, including brief biographies of the two honorees, go to www.fi.edu/tfi/exhibits/bower/06/earth.html.

Robert J. Weimer, GSA Senior Fellow, is the recipient of AGI's 2006 Legendary Geoscience Award for his long history of scientific achievement and exceptional service to the geoscience profession. Weimer is professor emeritus at the Colorado School of Mines.

GSA Senior Fellow **Michael F. Sheridan** has retired as The State University of New York–University at Buffalo distinguished professor and was honored at an 11–12 May 2006 symposium for his four decade-career dedicated to mitigating geologic catastrophes.

GSA Today Science Editor Changes


Keith Howard


Gerry Ross

Keith Howard has completed his term as *GSA Today* science editor (many thanks for all the good work, Keith!). Howard, a research geologist with the U.S. Geological Survey in Menlo Park, California, has been a GSA Fellow since 1972, and served as an associate editor of *GSA Bulletin* from 1988 to 1990.

Stepping in as our new science editor is Stephen T. Johnston, associate professor in the School of Earth & Ocean Sciences at the University of Victoria in British Columbia. Johnston, a structural geologist, says his research is "rooted in field-based geological mapping of key parts of mountain belts, including the Cordillera of western North America." His research goal is "to understand and elucidate the processes that shape mountain belts and to define the role of mountains in the evolution of Earth's atmosphere, biosphere, continental lithosphere, and deep mantle." As a *GSA Today* science editor, Johnston aims to "bring forward articles that appeal to as broad an audience as possible and that spark debate within our community regarding the major societal and scientific questions facing the earth sciences." Johnston will serve as co-editor with Gerry Ross, whose term runs through 30 June 2007.

Gerry Ross left the Geological Survey of Canada in August of 2004. He is currently using the earth systems approach and applies principles of soil science, aqueous geochemistry, and geomicrobiology to organic agriculture on Maui. He is still part of the Windermere Consortium, an industry–Natural Sciences and Engineering Research Council collaborative project examining turbidites of the Windermere Supergroup in western Canada as an analog for modern deep water turbidite systems, but he spends most of his time trying to grow a good cup of coffee.

GSA Today science editors are charged with obtaining high-quality, focused articles that collectively reflect and summarize current topics and discoveries in the earth sciences. All submissions, whether solicited or volunteered, are reviewed. To submit a science article to *GSA Today*, send your manuscript and figures via e-mail directly to Gerry Ross, lavaboy@hawaiiantel.net, and Stephen Johnston, stj@uvic.ca.


Stephen Johnston

Call for Geological Papers

2007 GSA Section Meetings

Northeastern Section
12–14 March 2007
University of New Hampshire
Durham, New Hampshire
Abstract Deadline: 5 December 2006
Information: Wally Bothner, University of New Hampshire, Dept. of Earth Sciences, James Hall, 56 College Rd., Durham, NH 03824-3578, USA, +1-603-862-3143, wally.bothner@unh.edu.

Southeastern Section
29–30 March 2007
Hyatt Regency Savannah on the Historic Riverfront
Savannah, Georgia
Abstract Deadline: 12 December 2006
Information: Pranoti Asher, Georgia Southern University, Dept. of Geology and Geography, Statesboro, GA 30460-8149, USA, +1-912-681-0338, pasher@georgiasouthern.edu.

Joint Meeting
North-Central and South-Central Sections
12–13 April 2007
Kansas Memorial Union, University of Kansas
Lawrence, Kansas
Abstract Deadline: 23 January 2007
Information: Greg Ludvigson, +1-785-864-2734, gludvigson@kgs.ku.edu—or—Greg Ohlmacher, +1-785-749-4502, ohlmac@kgs.ku.edu; both at Kansas Geological Survey, University of Kansas, 1930 Constant Ave., Lawrence, Kansas 66047-5317, USA.

Cordilleran Section
4–6 May 2007
Western Washington University
Bellingham, Washington
Abstract Deadline: 6 February 2007
Information: Bernie Housen, Western Washington University, Dept. of Geology, MS 9080, 516 High St., Bellingham, WA 98225-5946, USA, +1-360-650-6573, bernieh@cc.wwu.edu.

Rocky Mountain Section
7–9 May 2007
Dixie Center
Saint George, Utah
Abstract Deadline: 13 February 2007
Information: Jerry Harris, Dixie State College, Science Building, 225 South 700 East, Saint George, UT 84770-3875, USA, +1-435-652-7758, dinogami@gmail.com.

FIELD FORUM SCHEDULED

Marine impact craters on Earth: Field investigation of the Wetumpka impact structure, a well-preserved marine impact crater, and the K-T boundary in the Alabama Gulf Coastal Plain

8–11 March 2007

Wetumpka, Alabama, USA

Conveners:

David T. King, Jr., *Department of Geology, Auburn University, Auburn, Alabama 36849, USA, kingdat@auburn.edu*

Jens Ormö, *Centro de Astrobiología, Instituto Nacional de Tecnica Aeroespacial, Ctra de Torrejon a Ajalvir, km 4, Torrejon de Ardoz, 28850 Madrid, Spain, ormo@inta.es*

Description: The objective of this field forum is to discuss the origin, development, preservation, and recognition of marine target impact craters on Earth. During the field excursions, we will examine a well-exposed marine-target impact crater at Wetumpka, Alabama, and visit one or more localities with distant ejecta from the marine-target Chicxulub crater. We will examine some drill cores from Wetumpka impact structure as well.

For most of the geological history of our planet, more than two-thirds of the surface has been covered by lakes, seas, and oceans. Consequently, the same fraction of the cosmic objects striking Earth will have fallen in these aquatic environments. If the water is shallow enough, relative to the diameter of the projectile, a crater can form on the seafloor. This "marine-target" crater can be preserved and can show many special features produced by the water. Such marine-target craters can provide valuable information about the environment at the time of the impact, even long after the sea in which it formed has disappeared.

Marine-target crater characteristics have been obtained from drilling, sampling, and different geophysical methods. Sedimentation subsequent to the impact event has completely covered or subdued the topographic expressions of almost all the known marine-target craters on Earth. This hampers their detection because the surface expression is mostly absent unless later exposed due to subsequent erosion (e.g., the Lockne crater, Sweden). Wetumpka may be an exception; geological data indicate that the rim may have been exposed since the time of its formation. Many craters are only visible in seismic or drill core data. A benefit of sediment cover is that it provides the crater with good protection against later erosion once the seafloor is subaerially exposed; thus, some marine-target craters are among the best-preserved craters in the world.

Outline: This field forum is centered around two field days during which we will examine surface exposures that reveal various aspects of the marine target nature of the Wetumpka impact structure. We will also visit nearby exposures of K-T boundary sections that contain distal ejecta and tsunami deposits. Selected parts of Wetumpka crater drill cores will also be examined.

Venue: We plan for discussions and presentations to take place in the new Wetumpka, Alabama, city civic center, and participants will stay at a local motel. For more information on Wetumpka, "the city of natural beauty," please visit the city Web page at http://wetumpka.al.us/.

Access: The majority of outcrops within Wetumpka impact crater are on the sides of well-maintained paved roads. At the K-T boundary exposures, some low-impact hiking is required and there may be a steep slope to traverse in muddy conditions. Transportation will be by van or small buses.

Wetumpka, Alabama, is served mainly by the major international hub airport in Atlanta, Georgia, but there is also a closer regional airport in Montgomery, Alabama. We plan to assist participants with transportation to and from these airports.

Application Deadline: 8 December 2006.

Geoscientists of all specializations with an interest in marine target impacts and impact effects are encouraged to apply. Potential participants should send a letter of application via e-mail to David King (kingdat@auburn.edu) that includes a very brief statement of interests and the relevance of the applicant's recent work to the themes of the meeting. Invitations will be e-mailed to participants in a timely manner. There will likely be a registration limit of 25 to 30 persons. According to GSA rules, all attendees must be participants; there is no spouse program.

Registrants with Special Needs: If you require special arrangements or have special dietary concerns, please contact David King. However, as noted above, applicants should keep in mind that there are some modest physical demands inherent in the planned excursions.

Artist's conception of Wetumpka impact crater during the early modification stage (after water resurge and collapse of southern rim). Painting by Jerry Armstrong.

GEOLOGIC PAST

Highlighting Articles from *GSA Bulletin*

27 DAYS OF EARTHQUAKES

***GSA Bulletin*, July 1910**

Lawrence Martin: *Alaskan Earthquakes of 1899*

In a paper first presented to the Society at its annual meeting on 29 December 1909 (published in *GSA Bulletin* on 5 July 1910, v. 21, p. 339–406), Lawrence Martin describes the 3–29 September 1899 earthquakes in the Yakutat Bay region, Alaska. He states that seismographs as far away as South Africa and Italy recorded the shocks, "several of which equaled, and one (September 10) far surpassed, the 1906 California earthquake in duration and amplitude" (p. 342). Plate 29 includes a comparison of the seismographs recorded in Catania, Italy, for both the 10 September Alaska "great earthquake" and the 18 April 1906 San Francisco earthquake. Martin is quick to report, however, that "in this wilderness portion of Alaska there was no serious property damage and no recorded loss of life" (p. 342). Local observers of the earthquakes included prospectors, a ship's captain in Yakataga, 100 miles to the west, and telegraph operators along the Klondike trail. Shocks were felt across an estimated 216,000 mi^2.

For the earthquakes on 3 and 10 September, and then for those from 11 to 29 September, Martin includes detailed accounts by observers as close as the coast of the proposed epicenter, Disenchantment Bay, and as far away as the lower Yukon River, 730 miles to the west-northwest. Two-hundred and ten miles away, a U.S. Army captain described the shock of 3 September as causing "groves of cottonwoods to wave like wheat" (p. 351). Prospectors at the "very origin of the earthquake … counted 52 shocks on 10 September, culminating in the great earthquake at noon" (p. 359). Their accounts include an observation of a wave about 20 feet high rushing onto shore, washing several men up onto a moraine, followed by a second wave 20 or 30 feet high. Multiple avalanches were observed, and changes in the level of the land included "uplifts of … 40 to 47 feet on the northwest side" of Disenchantment Bay. Seventeen miles to the southeast, "minor faulting broke a hill into strips" (p. 361).

Much seismographic data is recorded in this paper, and an extensive comparison to other Alaskan earthquakes is included.

Lawrence Martin accompanied the U.S. Geological Survey party during its field observations in the summer of 1905 as special assistant in physiography and glacial geology.

GeoVentures™ 2006 Memories

Geology on the sea. Photo by Wesley Hill.

The Tectonic Development of Southern California, from the Beaches of San Diego to the San Andreas Fault

11–16 March 2006
San Diego, California

Trip Leader: Monte Marshall
Co-leader: Mario Caputo

The weight of the world. Photo by Bill Elliott.

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March 2006 GeoHostel group: front row: (left to right) Wesley Hill, Bill Elliott, Brad Erskine, Mario Caputo (trip co-leader); back row: (left to right) Ted Reeves, Joan Baldwin, Patricia Scott, Ralph Scott, Jack Stanesco, Dale Kunitomi, Ben Harrison, Mary Miller, Grace Kunitomi, George Sharp, Danielle Sharp, Monte Marshall (trip leader), Catherine Ellis, Art Hussey, Bob Shuris, John Williams. Photo by Wesley Hill.

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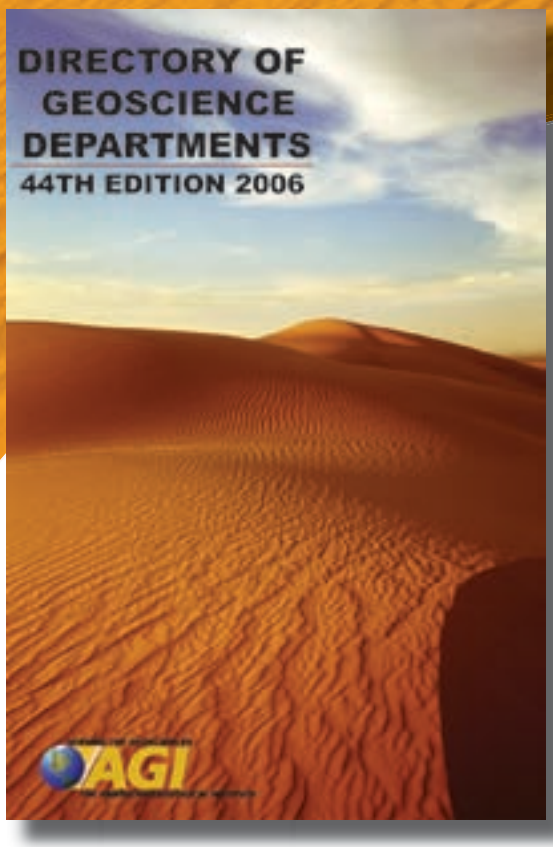

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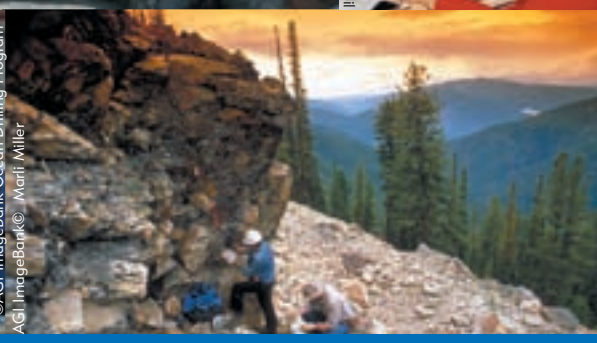

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We will begin reviewing applications on 15 August 2006. To apply, please send a cover letter along with resume, list of publications, teaching and research statements, and a list of contact details for three references. Send application material to: **John I. Garver, Chair, Department of Geology, Union College, 807 Union St., Schenectady NY 12308-2311, USA.**

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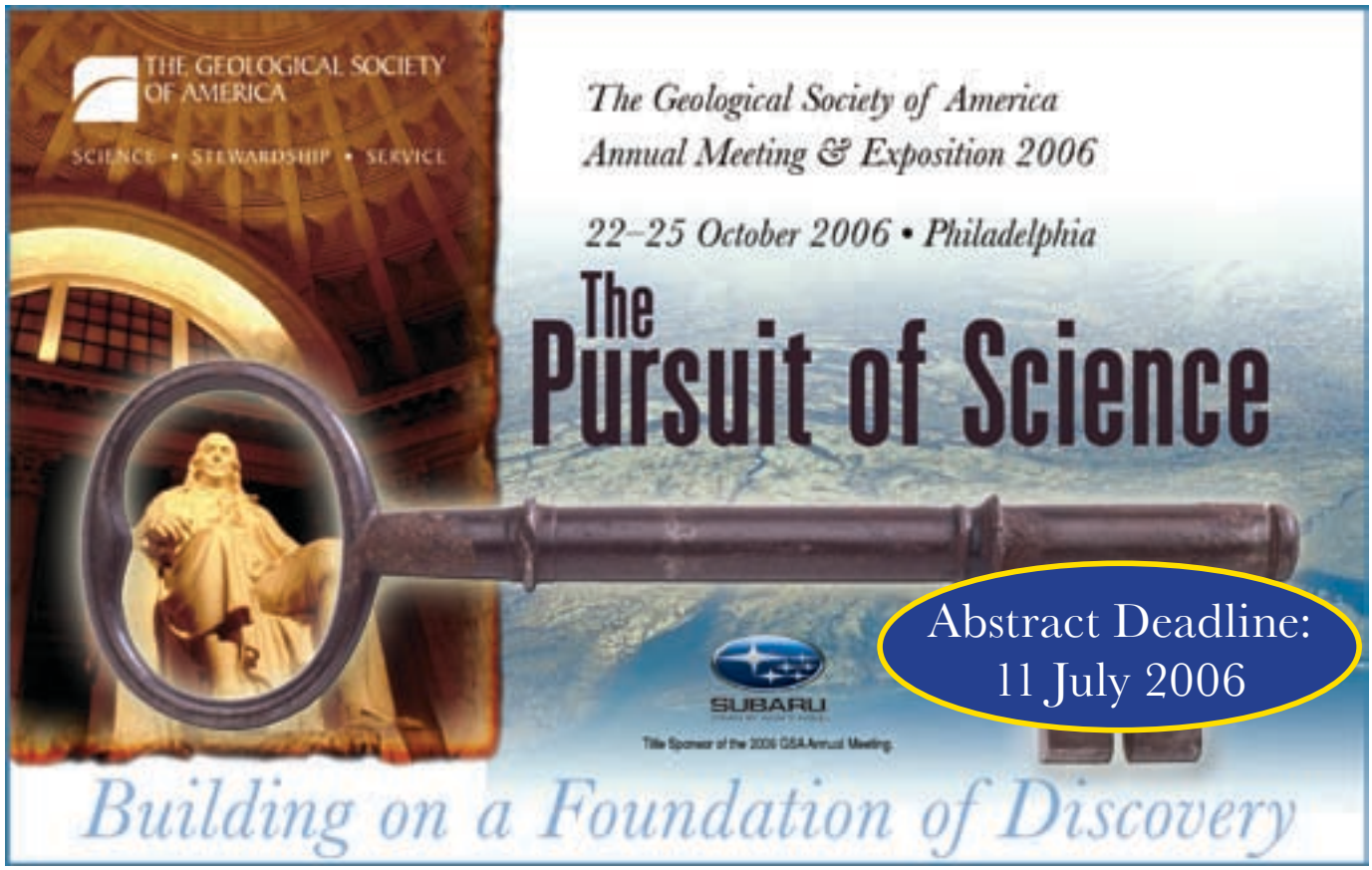

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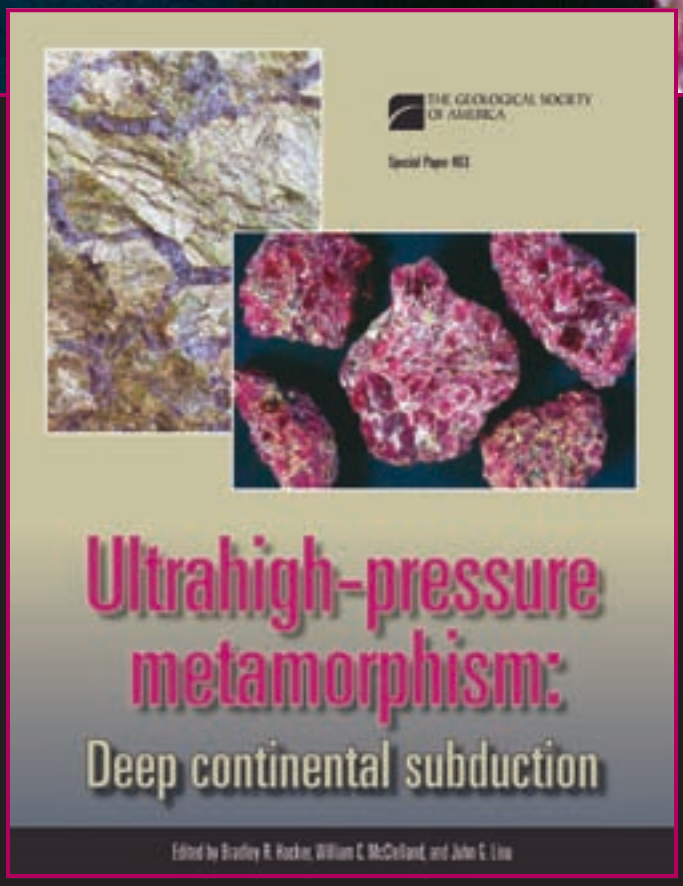

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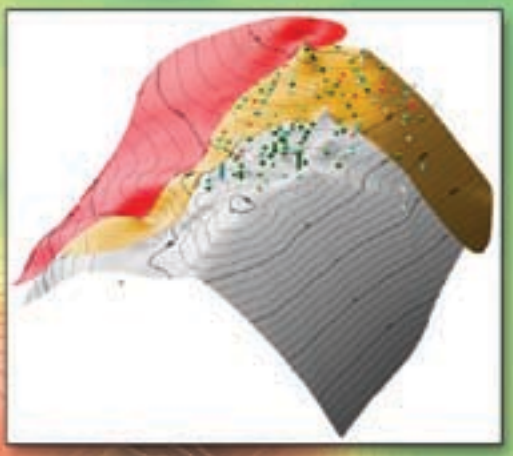

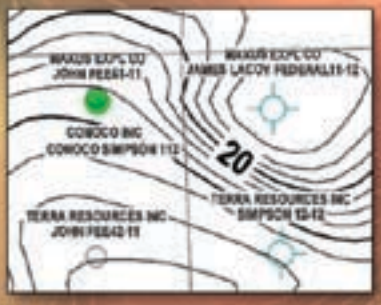

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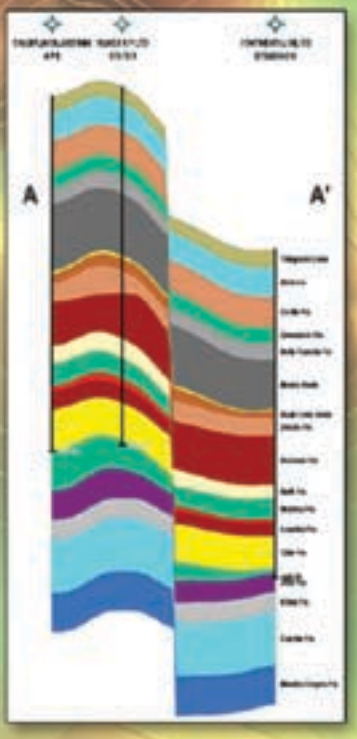

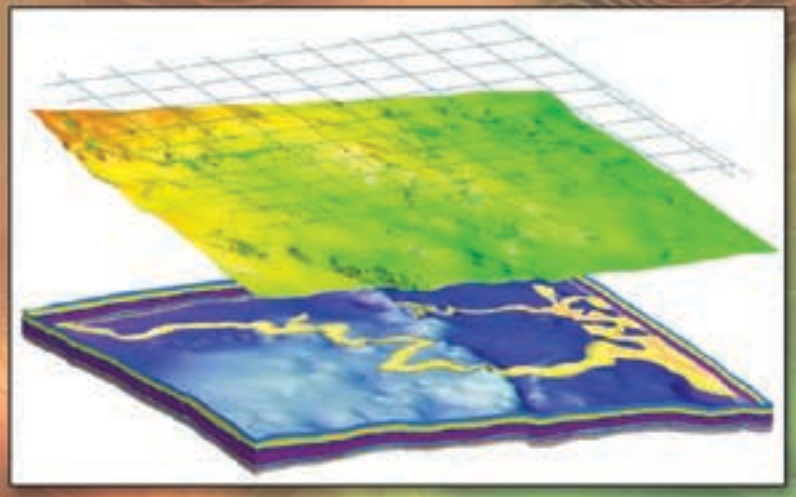

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