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Antarctic Neogene Landscapes—In the Refrigerator or in the Deep Freeze?

Introduction

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The present Antarctic landscape undergoes very slow environmental change because it is almost entirely covered by a thick, slow-moving ice sheet and thus effectively locked in a deep freeze. The ice sheet–landscape system is essentially stable,

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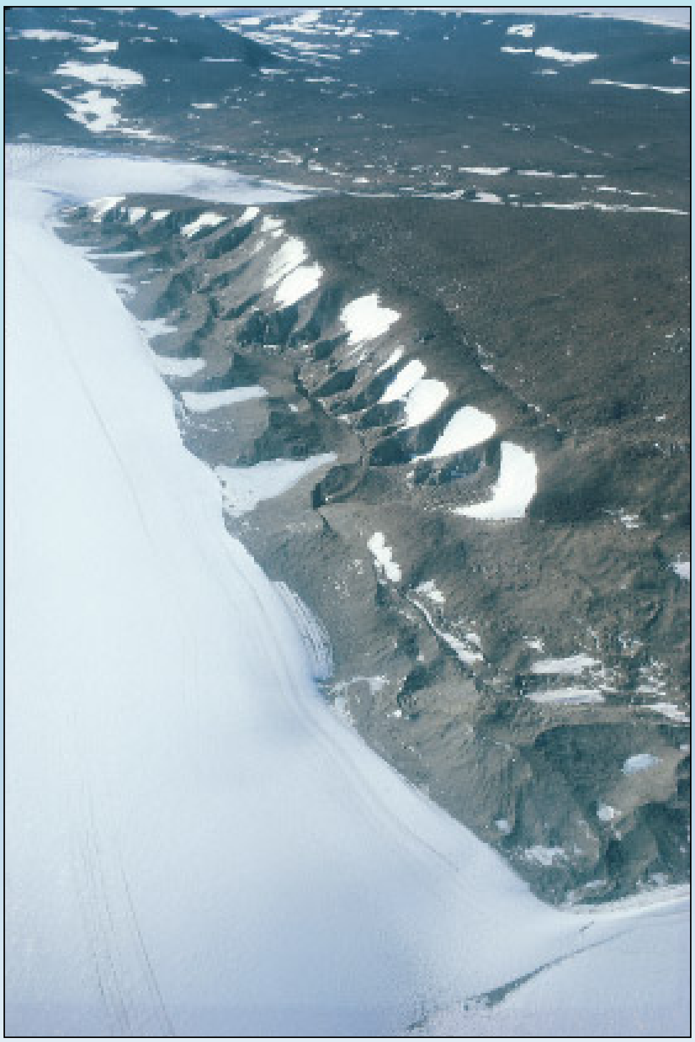

Figure 1. Oliver Bluffs in the Dominion Range at lat 85°S and 1760 m above sea level. The outcrop of the Meyer Desert Formation is fresh, trimmed by the most recent advance of the Beardmore Glacier (Denton et al., 1989), and is eroding. The sequence of the Meyer Desert Formation at Oliver Bluffs comprises ~80 m of interbedded diamictite and laminated mudstone, with minor peat and marl, which represent glacial, fluvial, lacustrine, and marsh or swamp environments that accumulated near sea level and were subsequently uplifted at least 1300 m (Webb et al., 1996). Photo by P.-N. Webb.

Atmospheric Transport of Diatoms in the Antarctic Sirius Group: Pliocene Deep Freeze

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INTRODUCTION

How did young diatoms (including some with ranges from the Pliocene to the Pleistocene) get into the Sirius Group on the slopes of the Transantarctic Mountains? Dynamicists argue for emplacement by a wet-based ice sheet that advanced across East Antarctica and the Transantarctic Mountains after flooding of interior basins by relatively warm marine waters [2 to 5 °C according to Webb and Harwood (1991)]. However, those calling for relative ice-sheet stability since the Miocene have interpreted these diatoms as wind transported (e.g., Denton et al., 1991).

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Glacial Transport of Diatoms in the Antarctic Sirius Group: Pliocene Refrigerator

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INTRODUCTION

The use of marine diatoms to date the Sirius Group (Fig. 1) is a focal point of the debate on Neogene Antarctic glacial history. The Pliocene age of the diatoms is not disputed, as diatom biostratigraphy is well established for this region (Harwood and

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and the preserved terrestrial record of Quaternary glaciations suggests a cold polar ice sheet that expanded and contracted only modestly compared to the much more spectacular comings and goings of the great Northern Hemisphere ice sheets. Over the past 15 years, glacial geologists and others have focused attention on older pre-Quaternary glacial deposits (Sirius Group) in the Transantarctic Mountains that give tantalizing glimpses of a much more dynamic Antarctic ice sheet that existed before the present cold ice sheet. In this earlier much "warmer" ice system with wet-based ice sheets that moved rapidly compared to the cold, dry-based, stable ice sheet of today, the continent was in the refrigerator rather than in the deep freeze. So the Neogene history of the Antarctic contains a remarkable event—the switch from warm-based glaciations to cold-based glaciations as though the ice sheet were taken from the refrigerator and put into the freezer. But controversy rages over when the earlier dynamic "warm" ice sheet was replaced by the present stable "cold" ice sheet. The stabilists say that this occurred before the middle Miocene, while the dynamicists claim that the warm glacial regime persisted until late Pliocene time. The arguments range over many aspects of sedimentology, stratigraphy, geomorphology, biostratigraphy, micropaleontology, paleoecology, glacial geology, geochronology, and marine geology. The resolution of this debate has important ramifications for our understanding of how the present global ocean-earth-atmosphere-cryosphere system became established. Ice in Antarctica plays an important role in this system now and will continue to in the future. Understanding how the ice behaves and its role in the global system requires knowledge of its past behavior. We review here the broad evidence in this debate, and give some of the protagonists the opportunity to discuss one of the central issues in the debate—how to interpret evidence for the age of these dynamic glacial deposits based on interpretation of the apparently age-diagnostic diatoms that they contain.

STABILIST VIEW

Strong evidence supporting the stabilist interpretation of a Miocene switch from warm, dynamic ice sheet to cold, stable ice sheet comes from features at high elevations in the Dry Valleys. There, unconsolidated, unweathered, and uneroded ash beds within a few centimeters from the ground surface and as old as 4 to 15 Ma have been found; their pristine condition apparently precludes the warmer, moister climate implied by a dynamic East Antarctic Ice Sheet (Marchant et al., 1993a, 1993b, 1993c, 1996; Marchant and Denton, 1996). Other convincing glacial, geomorphic, and paleoclimate data from the Dry Valleys suggest that cold polar desert conditions have prevailed there for a very long time (since at least the middle Miocene), and the extent of these conditions has been interpreted to rule out the possibility of a Pliocene dynamic Antarctic ice sheet (Denton et al., 1991, 1993; Sugden et al., 1995).

Supporting evidence for the stabilist interpretation primarily from the marine record of the Southern Ocean was summarized by Kennett and Hodell (1995). On the basis of oxygen isotope data, they concluded that Pliocene sea-surface temperatures were not significantly higher than today and noted that no change in ice-sheet volume was recorded by the distribution of ice-rafted detritus. Since then, cosmogenic exposure-age analyses of clasts suggest long exposure (> 4 m.y.) of the Sirius Group (Kurz and Ackert, 1997; Ivy-Ochs et al., 1995), and ice-sheet modeling supports the stabilist interpretation (Huybrechts, 1993).

Stabilists interpret diatoms of Pliocene age in the Sirius Group as wind-transported, thus obviating the need for a Pliocene age for this deposit and permitting it to be significantly older (Burckle and Potter, 1996; Stroeven et al., 1996).

DYNAMICIST VIEW

Dynamicists have been amassing a large stratigraphic data base and convincing evidence for a wet-based ice sheet (and a warmer Antarctic climate) during their 20+ years of study of the glacigenic deposits and enclosed flora and fauna of the Sirius Group (e.g., McKelvey et al., 1991; Webb et al., 1984; Wilson et al., 1998). Best exposed in the southern Transantarctic Mountains, but also found in the Dry Valleys and the Prince Charles Mountains (Fig. 1; the correlative Pagodroma Group; McKelvey et al., 1995; but note that some question the correlation, but not the age), the Sirius Group is a hodgepodge of diamicts (neither well sorted nor well lithified) and stratified semilithified deposits that record deposition in a variety of glacial, fluvioglacial, glacial-marine, fiord, and lacustrine environments. The reworked marine diatoms in the Sirius Group are thought to have originated in marine seaways in interior East Antarctica; in this scenario, an ice sheet built up in East Antarctica during the Pliocene and transported the diatoms to the Transantarctic Mountains, where they were deposited in the Sirius Group. Unlike deposits of cold-based ice sheets, these deposits occur in packages many meters thick. This and the widespread occurrence of the Sirius Group throughout most of the Transantarctic Mountains and of the correlative Pagodroma Group (which contains in situ bivalves and Pliocene diatoms) in the Prince Charles Mountains in East Antarctica support the existence of an extensive wet-based ice sheet during the Pliocene (Webb et al., 1984; Barrett et al., 1992). As supporting evidence, dynamicists point to data from drillholes on the Antarctic continental margin (Hambrey and Barrett, 1993) and from seismic stratigraphic studies (Anderson and Bartek, 1992; Bartek et al., 1997), to the known Pliocene warming event (Cronin and Dowsett, 1991; Dowsett et al., 1996), and to ice-sheet modeling (Huybrechts, 1993), all of which are consistent with their interpretation of a dynamic, warm, wet-based ice sheet in the Pliocene.

Dynamicists' case for a warm-based ice sheet is bolstered by their recovery of many components of terrestrial ecosystems within the Sirius Group. Their findings include twigs, leaves, moss, pollen, seeds, and insects; much of the material is in excellent condition (Hill et al., 1996; Ashworth et al., 1997); unfortunately, these are not good biostratigraphic indicators. At issue is not the existence of such a biota, but its age: When did temperate conditions last exist in Antarctica?

However, at the same time the warm-based Sirius ice was overwhelming the terrestrial biota, it appears to have been carrying with it recycled marine microfossils, including foraminifera, radiolaria, sponge spicules, and diatoms. Of these, only diatoms are age diagnostic, giving diverse (Tertiary) ages, the youngest of which is Pliocene.

So when did the switch from wet-warm ice sheet to cold-dry ice sheet occur? It is difficult to reconcile the stabilist evidence of cold, polar desert conditions in the Dry Valleys since the Miocene with the specter during the Pliocene of a warm-based ice sheet "next door" to the Dry Valleys in the southern Transantarctic Mountains. Not surprisingly, stabilists favor the interpretation that the Pliocene age for the warm-based ice sheet deposits is erroneously young, citing the well-known proclivity of diatoms for being blown around by wind (Kellogg and Kellogg, 1996). Yet the dynamicists have good reasons for interpreting the diatoms as glacially deposited and thus indicating a Pliocene or younger age for the Sirius Group. They question whether the evidence for polar desert conditions in the Dry Valleys region can be used to interpret the ice-sheet behavior of the entire continent.

The two articles here concern one aspect of this debate: using diatoms to determine the age of the Sirius Group. Stroeven and co-workers (stabilists) summarize work in support of atmospheric transport of diatoms (rendering them useless as age indicators). Harwood and Webb discuss their evidence for glacial transport and a Pliocene age.

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WINDBLOWN DIATOMS IN ANTARCTICA

The discovery of marine diatoms in ice samples from the South Pole demonstrated conclusively that in Antarctica marine diatoms could be transported long distances by eolian processes (Kellogg and Kellogg, 1996). Previously, the contrast between the freshwater diatoms recovered from Last Glacial Maximum ice from East Antarctica and the predominately planktonic marine diatoms of the Sirius Group was used as evidence against eolian transport of Sirius diatoms (Burckle et al., 1988), but recovery of marine, brackish water, and freshwater diatoms in the South Pole ice removed that impediment from the eolian hypothesis.

If diatoms were transported to the Sirius Group by eolian processes, they should also be transported to other surfaces, regardless of age (e.g., Stroeven and Prentice, 1994). In a test of this hypothesis, Paleozoic and Mesozoic sedimentary, metamorphic, and igneous rocks from the Dry Valleys and the Beardmore Glacier area (Transantarctic Mountains) were examined, and diatoms and aggregates of diatoms common in the late Cenozoic Southern Ocean were recovered (Burckle, 1995; Burckle and Potter, 1996). The diatoms must have been introduced into these rocks by eolian processes.

TABLE 1. IDENTIFIABLE DIATOMS RECOVERED FROM SURFACE LAYER AND UNDERLYING SIRIUS GROUP TILLS AT MT. FLEMING, DRY VALLEYS, ANTARCTICA

Diatom species	Surface unit (10 cm)	Till units (10–95 cm)
Actinocyclus actinochilus	3	--
Actinocyclus ingens	1	--
Actinocyclus senarius	1	--
Coscinodiscus marginatus	1	--
Coscinodiscus oculu-iridis	1	--
Eucampia antarctica	5	--
Odontella weisflogii	1	1
Stellarima microtrias	5	--
Thalassiosira inura	2	--
Thalassiosira kolbeii	1	--
Thalassiosira lentiginosa	2	--
Thalassiosira oliverana	2	--
Thalassiosira torokina	4	--
Thalassiosira vulnifica	1	--

Note: Sirius Group till units were mostly barren, but some contained unidentifiable diatom fragments. Compilation includes six samples (2.9 kg) of the surface unit, and 17 samples (>7.4 kg) of the till units. Particles >25 µm were analyzed.

TESTS OF THE EOLIAN HYPOTHESIS WITHIN THE SIRIUS GROUP

If diatoms were wind transported to the Sirius Group, they should be most abundant at or near the surface. As a test, samples were collected at intervals beneath the surface of the Sirius Group (Mt. Fleming, Dry Valleys). The best preserved and most abundant diatoms are in the top 10 cm, and rare, unidentifiable diatoms occur below that to a depth of 95 cm (Table 1; Stroeven, 1994, 1996; Stroeven et al., 1996; Stroeven and Prentice, 1997). The near-surface concentration is consistent with the eolian hypothesis.

Additionally, if Sirius Group sediments recorded drawdown and renewal of the East Antarctic Ice Sheet, one would expect to find diatoms in it that reflect habitats found on a deglaciated Antarctic landscape. Burckle et al. (1996) explored this question through a comparison with the micropaleontology of Scandinavian tills. They found that two persistent features characterized the Scandinavian tills: (1) diatoms found in the tills reflected a wide variety of habitats over which the ice sheet advanced and (2) the diatoms occurred in varying abundances throughout the till. Such is not the case for the Mt. Fleming Sirius Group tills where the diatoms are predominantly of planktic marine origin and occur preferentially in surface layers.

SOURCE OF DIATOMS AND TRANSPORT MECHANISMS

Where did the wind-transported diatoms come from? Stroeven et al. (1996) suggested sea spray and/or uplifted marine sediments. The following scenario is consistent with the diverse substrates (till, ice, and igneous, sedimentary, and metamorphic rocks) ranging widely in age (Paleozoic to Holocene) that have yielded diatoms. Onshore winds pick up nearshore marine and brackish water diatoms as well

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Maruyama, 1992; Winter and Harwood, 1997). The question centers on when and how the diatoms were incorporated into Sirius Group deposits. Webb et al. (1984) suggested that diatoms were eroded by ice from marine strata in subglacial basins of East Antarctica (Fig. 2) and transported to the Transantarctic Mountains, where they were deposited *within* the Sirius Group during the late Pliocene. It was recently proposed that diatoms were deposited by wind *onto* the surface of the Sirius Group as a contaminant, or, that they were associated with the Sirius Group as a result of a Pliocene meteorite impact (2.15 Ma) in the Southern Ocean (Gersonde et al., 1997). In this paper we contrast the characteristics predicted for each of these transport mechanisms (Table 1).

Diatoms on the surface of a Sirius Group deposit probably originate from multiple sources, and care must be taken to distinguish those derived from eolian, glacial, and other processes, on the basis of diatom factors including age, ecology, size, and preservation. In spite of the well-documented wind transport of diatoms and the known ability of strong Antarctic winds to carry gravel-size particles near the ground, we assert that surface contamination via eolian deposition or meteorite ejecta cannot explain the occurrence of Pliocene and older microfossils in the steep and eroding cliffs of the Meyer Desert Formation at Oliver Bluffs, Dominion Range (Figs. 1, 2). Glacial transport provides the simplest and most parsimo-

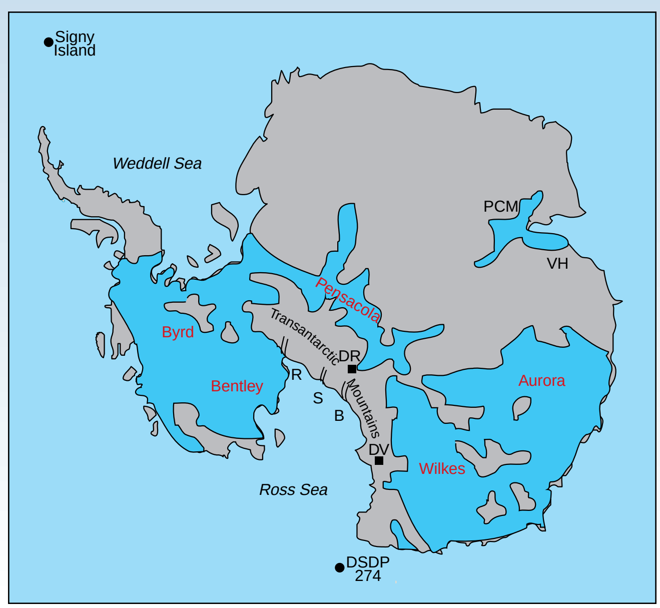

Figure 2. Location map of Antarctica showing locations cited in the text. PCM = Prince Charles Mountains; VH = Vestfold Hills; DV = Dry Valley region; B = Beardmore Glacier; S = Shackleton Glacier; DR = Dominion Range; R = Reedy Glacier; names in red are of subglacial basins shown by the outline, which reflects contour for 1000 m below sea level.

as coastal freshwater forms and carry them inland where they are deposited on various substrates in areas such as the Dry Valleys and elsewhere in the Transantarctic Mountains and in West Antarctic. Occasionally, winds may succeed in airlifting open-ocean marine diatoms as well and transporting them inland to areas such as West Antarctica, the Dry Valleys, and the Beardmore Glacier area. If such winds were the only transporting agent of diatoms in Antarctic rocks, we believe that the diverse occurrences would have immediately been recognized as the product of eolian transport.

We find another transport mechanism compelling. Gersonde et al. (1997) mapped an extensive and chaotic terrain in the southeast Pacific Ocean and found physical evidence for a bolide impact at ~2.3 Ma. Further, the micropaleontological ages of the disturbed sediment (Eocene to Pliocene) matched the ages of the microfossils found in the Sirius Group. They concluded that the bolide impact made airborne a cloud of sea-floor debris, which fell on Antarctica. This bolide impact could have changed both the rain rate and the source of airborne diatoms to the Antarctic continent. Instead of rare brackish and/or freshwater diatoms, it could have caused a marked increase in the rain rate of pelagic diatoms of various Cenozoic ages over the Antarctic continent. Although this bolide hypothesis awaits testing, it answers remaining questions unresolved by the eolian hypothesis.

CONCLUSIONS

On the basis of paleohabitats of diatoms found in Sirius Group sediments and on detailed stratigraphical observations of the Sirius Group on Mt. Fleming, we dismiss inferences that lead to the belief that there was a significant drawdown of the East Antarctic Ice Sheet during the Pliocene, and we conclude that if such deglacial events occurred, they must be Miocene or older.

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nious interpretation of our observations (Webb and Harwood, 1991). We focus on the Meyer Desert Formation at this locality because it is the prime repository of a wide variety of stratigraphic and paleontologic data that has bearing on Antarctic paleoclimate, tectonics, and glacial history (Webb et al., 1996; Ashworth et al., 1997).

SIRIUS GROUP DIATOM ASSEMBLAGES

Diatoms within the Sirius Group have been found at 12 of 14 localities sampled, in varying abundance (Harwood, 1986a, 1986b). They commonly are highly fragmented as both isolated clasts in the matrix and within clasts of diatomite up to 240 µm in diameter (Figs. 3, 4). Most of the recovered diatoms are open marine, planktonic forms, endemic to the Antarctic region; benthic taxa are rare. In the Meyer Desert Formation, 22 of the 60 diatom species recovered are Neogene; their combined ranges indicate a Pliocene age. Diatoms consistently are rare, with a patchy distribution, even within a single stratigraphic section.

CRITICAL ASSESSMENT OF THE EOLIAN HYPOTHESIS

Several lines of evidence indicate that the Meyer Desert Formation diatoms were not transported and deposited by eolian processes.

South Pole Diatoms Are from Patagonia. Diatoms in ice at the South Pole (Kellogg and Kellogg, 1996) led to the suggestion that marine pelagic diatoms in the Sirius Group were wind-borne contaminants (Barrett, 1996). The South Pole assemblages, however, are dominated by freshwater diatoms and small marine benthic taxa. In addition, geochemical analyses of Antarctic ice cores from Vostok and Dome C indicate that dust particles (including diatoms) originate from Patagonian loess and the Argentine continental shelf (Basile et al., 1997), but *not* from Antarctic sources. Diatoms reported by Barrett et al. (1997) in regolith on the surface of the Transantarctic Mountains have a similar non-Antarctic source; 50% of their specimens are of freshwater forms that are absent to rare in the modern and fossil flora of Antarctic lakes (Spaulding and McKnight, 1998).

Size limits of Antarctic Eolian Particles. Diatoms and marine diatomite clasts in the Meyer Desert Formation are too large (>100 µm) to be transported by eolian processes (Fig. 3). The size distribution of eolian particles in the Antarctic ice cores has a mode around 2 µm; maximum sizes (equivalent diameter) are between 10 and 24 µm (Basile et al., 1997). Material transported very long distances in Earth's atmosphere is mostly smaller than 10 µm, and much of it is smaller than 2 µm (Pye, 1987, p. 1). Empty valves of freshwater diatoms are common components in aerosol samples and can be transported around the globe, but these particles are typically <25 µm diameter or 60 µm long (Pye, 1987). These data from different environments indicate that the eolian hypothesis does not represent a suitable mechanism to transport 100 to 240 µm size particles (Figs. 3, 4) to Sirius Group sites high in the Transantarctic Mountains.

No Source Identified for Eolian Diatoms. The present ice sheet obscures most sources for fossil Antarctic diatoms.

Pliocene Refrigerator *continued on p. 6*

Pliocene Refrigerator *continued from p. 5*

If the margin of the East Antarctic Ice Sheet has been at its present position since the middle Miocene (stabilist view), then there has not been a source of Antarctic diatoms available to atmospheric scavenging for 15 m.y. or more. Sea spray is not a viable source; air-trap samples taken on sub-Antarctic islands yielded only very small diatoms and a paucity of planktonic marine taxa (Chalmers et al., 1996).

Diatoms in Paleozoic Rocks. In a search for diatoms on a limited number of pre-Cenozoic sedimentary and igneous rocks Burckle and Potter (1996) recovered well-preserved and abundant diatoms (about 700 *whole* specimens per gram) in sediment filling cracks. The recovered diatoms differ markedly from those of the Sirius Group in being much more abundant, better preserved, and derived from an open ocean setting rather than from a continental shelf. Barrett et al. (1997) reported between 0.2 and 7 diatom fragments per gram from the Sirius Group at Mt. Feather, which is more consistent with our observations of diatom abundance.

Proponents of the eolian hypothesis imply that marine diatom assemblages should be ubiquitous in Antarctic air, soil, and outcrops. Lakes are obvious sediment traps for eolian particles, yet marine diatoms (fossil and recent) are absent or rarely encountered in Antarctic lakes (S. Spaulding, 1997, personal communication). Furthermore, deltaic deposits <10 km inland from McMurdo Sound contain only severely broken marine diatoms with relatively unbroken nonmarine forms (Kellogg et al., 1980).

Limited and Contradictory Data from Mt. Fleming. Harwood (1986a) recovered a few poorly preserved specimens from the Sirius Group deposit at Mt. Fleming. Stroeven et al. (1996) prepared additional samples in Harwood's laboratory, producing more data, but again, diatoms were found to be unevenly distributed and very rare. Harwood identified and characterized the diatoms for this study. Stroeven et al. (1996) and Stroeven and Prentice (1997) interpreted the results to indicate a marked reduction in diatoms from the surface into the deposit. We disagree with this interpretation because of the small number of diatoms and lack of demonstrated statistically significant differences between the samples.

METEORITE EJECTA HYPOTHESIS

Another mechanism for diatom transport, proposed by Gersonde et al. (1997), is based on recognition of a late Pliocene meteorite impact event (~2.15 Ma) in the Southern Ocean. Gersonde et al. suggested that ejecta-borne diatoms may have contaminated the Sirius Group. If this was the source for Pliocene-Pleistocene marine diatoms on the surface of the deposit at Mt. Feather, Dry Valleys, it may allow a pre-Pliocene age for this deposit. However, since Pleistocene time, the Beardmore Glacier (Denton et al., 1989) has been eroding the Meyer Desert Formation in the Dominion Range, and any impact-derived sediment would have been eroded from our sampling sites.

We acknowledge the possibility that Pliocene diatoms in meteorite ejecta could have been incorporated in basal sediments of the Sirius Group deposited by subsequent glacial advance. In either scenario, glacial or ejecta, the youngest elements (Pliocene) of the recycled flora lead us to the conclusion that the Meyer Desert Formation is a post–middle Pliocene deposit. Detailed comparison of the diatom floras within impact debris in the Bellingshausen Sea with Sirius diatom floras is needed to look for agreement and to define the remaining discordance.

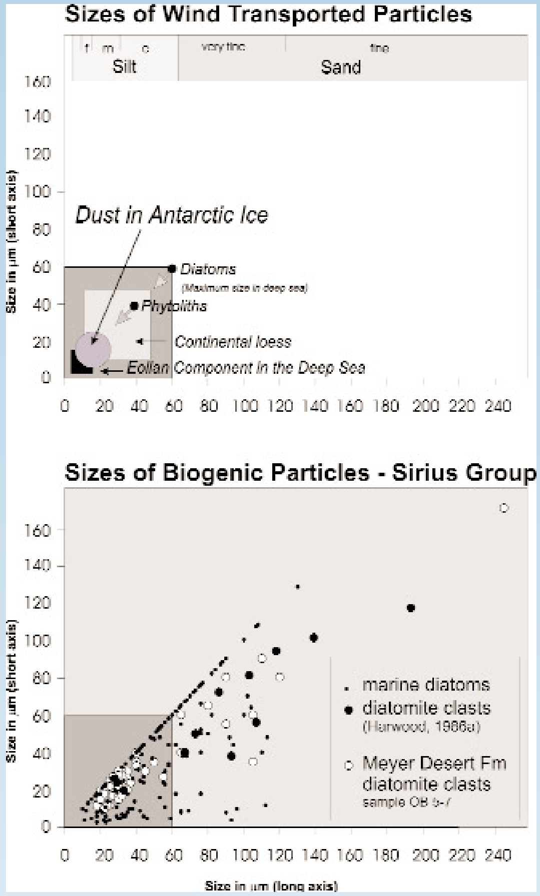

Figure 3. Comparison of the size range (silt) of particles commonly carried by the wind and fossil diatoms and diatomaceous sediment clasts present in the Sirius Group. The largest diatomaceous sediment clast from Oliver Bluffs is 240 × 170 µm in size; a field of similar grains is between 60 and 120 µm. Individual diatom valves recovered from many Sirius Group deposits in the Transantarctic Mountains reach near the normal upper size range for pelagic diatoms—100 to 140 µm—suggesting a mechanism of transport without significant loss of the larger specimens. Wind is unlikely to produce this spectrum, because it would sort for size, leaving the larger particles behind, whereas ice would not discriminate. Size data for eolian particles are from Basile et al. (1997), Pye (1987), and Rea and Hovan (1995).

PLIOCENE WARMTH FROM ANTARCTIC DATA

A wealth of information on Antarctic Pliocene warming can be found in recent

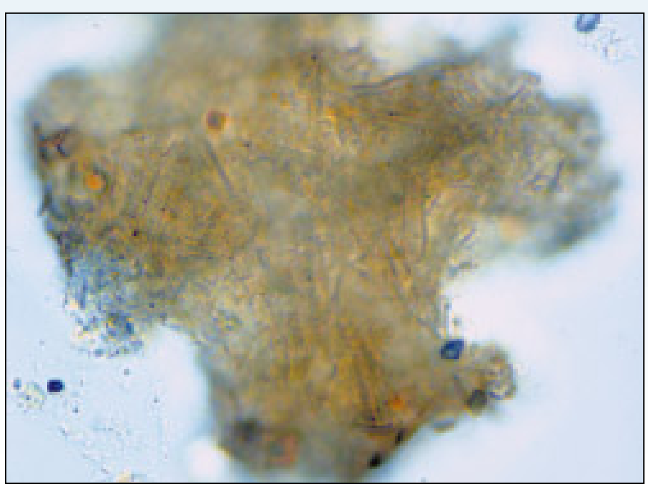

Figure 4. Example of a diatomaceous sediment clast from the Meyer Desert Formation, Dominion Range, sample OB 5-7. Visible through this clast of diatom ooze are abundant fragments of diatoms, as well as high numbers of *Thalassionema* sp. and *Thalassiothrix* sp. This clast is 90 x 80 µm. Assemblages dominated by *Thalassionema* and *Thalassiothrix* are typical of Sirius Group microfloras, reflecting the high productivity of East Antarctic interior basins during times of deglaciation.

TABLE 1. TRANSPORT MECHANISMS FOR DIATOMS IN SIRIUS GROUP, ANTARCTICA

Characteristic	Predicted for Antarctic Eolian Pathway	Predicted for Meteorite Ejecta Pathway	Predicted for Glacial Pathway	Observed in Sirius Group
Largest size of diatoms and diatomite clasts	Small, generally <60 µm (Fig. 3)	Large sizes possible	Large sizes possible	Large diatoms up to 100 µm; clasts of diatomite up to 240 µm
Presence or absence of larger marine microfossils	Absent	Present	Present	Present: foraminifera, sponge spicules, radiolarians, ostracods
Ecology of diatoms recovered	Freshwater and shallow marine predominate	Open marine from Southern Ocean	Mixture*	Mixture †
Source of Antarctic diatoms	Unclear—ice sheet covers landscape (requires deglaciation to expose beds)	Bellingshausen Sea; >3600 km from Transantarctic Mountains	Subglacial basins, possibly from local fjords in some cases	Presumed recycled from subglacial basins (Fig. 2)
Age range of Antarctic microfossils	Narrow §	Wide potentially; late Pliocene and older	Wide #	Wide**
Relation between diatom and diatomite clasts	Not applicable; sediment clasts are too large for distant wind transport	Identical diatoms	Identical; diatoms derived from clasts upon disaggregation in transport and lab preparation	Identical; diatom assemblage composition is similar in diatomite clasts and the till matrix
Presence or absence of volcanic ash	Present; southern Victoria Land ash should be incorporated with diatoms	Absent	Absent? No ash in source basin	Absent
Presence or absence of pollen from outside Antarctica	Present rare	Absent	Absent; no source in Antarctica	Absent
Distribution of diatoms in a stratigraphic section	Surficial; uniform on outcrop surfaces and across diverse landforms	Surficial; uniform on outcrop surfaces and across diverse landforms††	Nonuniform; depends on distribution of diatomite clasts	Nonuniform; productive samples from specific horizons
Presence or absence of diatoms on steep eroding cliffs	Absent	Absent	Present	Present

* All diatoms present in basinal sediments; nonmarine, benthic marine, planktonic marine.
† Predominantly planktonic marine; rare benthic marine and rare freshwater.
§ Unless there are extensive exposures of Paleogene and Neogene marine sediments in Antarctica (now covered by ice sheet).
\# Glacial erosion, not age, selectively favors erosion and transportation of youngest sediment on top of basin fill.
** Cretaceous, Paleocene, late Eocene, late Oligocene, middle Miocene, late Miocene, early Pliocene, mid-Pliocene, Pliocene-Pleistocene.
†† Alternatively, distribution may be within the deposit if ejecta blanketed landscape and was incorporated during subsequent deposition of glacial deposits.

reports and summaries (Abelmann et al., 1990; Wilson, 1995; Quilty, 1996; Dowsett et al., 1996; Gazdzicki and Webb, 1996; Bohaty and Harwood, 1998). The absence of calcareous nannofossils and *Nothofagus* (southern beech) pollen in deep-sea deposits was cited as evidence against warmer Antarctic conditions during the Pliocene (Burckle and Pokras, 1991; Kennett and Hodell, 1995; Prentice et al., 1993); both of these fossil groups subsequently were identified in Deep Sea Drilling Project and Ocean Drilling Program cores. They indicate brief yet significant warming events in the Southern Ocean (Bohaty and Harwood, 1998) and the expansion of mid-Pliocene *Nothofagus* vegetation in the Transantarctic Mountains (Fleming and Barron, 1996). The Antarctic records are consistent with evidence of *global* Pliocene warmth and higher sea level (Cronin and Dowsett, 1991; PRISM Project Members, 1995; Poore and Sloan, 1996). The diverse terrestrial biota of the Meyer Desert Formation suggests that Pliocene mean annual temperatures were ~15 °C warmer than those of today [–16 °C in Francis and Hill (1996) and –9 to –5 °C in Ashworth et al. (1997)]. From these data, it appears that there were brief intervals during the Pliocene when the refrigerator door was left open.

CONCLUSIONS

For the eolian hypothesis to remain viable, the following key questions related to the Meyer Desert Formation must be addressed. How can particles >200 µm in diameter be carried to high elevation, against prevailing wind? How do these biogenic particles penetrate laminated strata in vertical faces without disturbing the stratigraphy? How do diatoms adhere to a near-vertical face of a compact diamicton and penetrate faster than the rate of bluff erosion? And the most important question: Where are the exposures of Pliocene, Miocene, Oligocene, and Eocene strata that provided the source of pelagic Antarctic diatoms?

We feel there is no compelling need to look to the atmosphere to interpret the data from the Meyer Desert Formation. A direct interpretation is grounded in geologic simplicity: Diatoms within glacigenic deposits were deposited by ice. Unless relevant evidence is presented that explains the data from the Meyer Desert Formation more convincingly, the glacially transported origin of diatoms in the Sirius Group, in our view, remains a viable mechanism.

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Summary

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Reconstructing the history of the Antarctic ice sheet during the Neogene is the ultimate geological puzzle, requiring integration of vast arrays of disparate data that relate to only a small part of a large continent. When did the Antarctic ice sheet switch from its wet-based and dynamic "refrigerator" mode to its dry-based and stable "freezer" mode? Whether seen from the stabilist or dynamicist viewpoint, key pieces of the "Neogene Antarctica: refrigerator or deep freeze?" puzzle are missing. Stabilists need to answer questions such as: (1) Is evidence for a Neogene cold polar desert in the Dry Valleys indicative of continent-wide conditions? (2) How can clear evidence of warm Pliocene conditions from elsewhere in Antarctica (e.g., Prince Charles Mountains) be reconciled with evidence for a polar desert in the Dry Valleys since the Miocene? (3) How could landscapes in the Dry Valleys remain unchanged for millions of years during which weathering, periglacial, and eolian processes must have been operating?

Similarly, questions the dynamicists need to answer include: (1) How can a dynamic warm ice sheet have existed at the same time as polar desert conditions in the nearby Dry Valleys? (2) Can the amount of uplift implied by the presence of Pliocene fiordlike deposits within the Sirius Group at an elevation of 1700 m in the Transantarctic Mountains be explained? (3) Can the long exposures indicated by the cosmogenic exposure dating analyses be explained within the context of a dynamic ice sheet in the Pliocene?

Could both the stabilists and the dynamicists be correct? Perhaps pieces of the puzzle are missing. Might one of those pieces fill a gap in understanding by linking the dynamicists' and the stabilists' data and interpretations? Antarctica exerts a major influence on global climate and sea level. If we are to predict future climate change and its effects in Antarctica, we need an unambiguous interpretation of its geologically recent past.

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Valerie G. Brown, *Director of Development, GSA Foundation*

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GSAF Update *continued on p. 10*

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GSAF Update *continued from p. 9*

Joining Exxon and Kennecott, and equal in impact, are many other corporations whose support through this campaign merits particular appreciation:

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American Ground Water Trust
American Institute of Professional Geologists
Amoco Foundation
ARCO Exploration & Production Technology
Battle Mountain Gold Co.
BHP Copper (Magma Copper Co.)
BHP Minerals
Burlington Resources/Meridian Oil
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Xerox Corporation USA

Digging Up the Past

Most memorable early geologic experience:

When I mapped garnet gneisses on the New Hampshire seacoast, Professor Billings assumed I had mixed-up my thin sections—I was outside the garnet zone. Actually, I had extended it.

—Ursula B. Marvin

WASHINGTON REPORT

Bruce F. Molnia, *bmolnia@erols.com*

Washington Report provides the GSA membership with a window on the activities of the federal agencies, Congress and the legislative process, and international interactions that could impact the geoscience community. These reports present summaries of agency and interagency programs, track legislation, and present insights into Washington, D.C., geopolitics as they pertain to the geosciences.

Action Plan Marks 25th Anniversary of Clean Water Act

"For 25 years we have made great progress in cleaning our waters; largely this progress has come by controlling pollution from point sources—from factories and sewage plants. Yet, 40 percent of our nation's waters are still too polluted for fishing and swimming—25 years after the Clean Water Act. That is unacceptable. … We must address the largest remaining challenge to cleaning our waters. We must curtail the runoff from farms, from city streets, from other diffuse sources of pollution that get into our waterways and pollute them."

—President Bill Clinton, February 19, 1998

"I am pleased to join President Clinton today in announcing a new vision and new resources to restore and protect America's rivers, lakes, and coastal waters. While this is a national initiative, it is important to recognize that our action plan responds to, and builds upon, leadership demonstrated by governors and communities across the country."

—Vice President Al Gore, February 19, 1998

On February 19, the Clinton Administration launched a new Clean Water Action Plan designed to address three major goals: (1) enhanced protection from public health threats posed by water pollution, (2) more effective control of polluted runoff, and (3) promotion of water-quality protection on a watershed basis. On October 18, 1997, the 25th anniversary of the Clean Water Act, Vice President Gore had directed the Department of Agriculture (USDA) and the Environmental Protection Agency (EPA) to work with other federal agencies and the public to prepare an aggressive action plan to meet the promise of clean, safe water for all Americans. The plan forms the core of President Clinton's Clean Water Initiative, unveiled in his January 27, 1998, State of the Union Address. The President's FY 1999 budget will propose $568 million of new resources to initiate the plan. In implementing this plan the federal government will support locally led partnerships that include a broad array of federal agencies, states, tribes, communities, businesses, and citizens to meet clean water and public health goals; increase financial and technical assistance to states, tribes, local governments, farmers, and others; and help states and tribes restore and sustain the health of aquatic systems on a watershed basis.

In 1972, I had just completed my Ph.D. degree and was working on pollution and flooding issues relating to the Connecticut River. I vividly remember seeing many rivers across the country clogged with blue-green algae blooms and others being used as open sewers. I remember predictions about the "death of Lake Erie" and frequent fish kills on many streams. It was in this environment that Congress enacted the first comprehensive national clean water legislation, the Clean Water Act, the primary federal law that protects our nation's waters, including lakes, rivers, aquifers, and coastal areas. The act, with its two fundamental national goals of eliminating the discharge of pollutants into the nation's waters and achieving water-quality levels that are "fishable" and "swimmable" was a direct result of a growing public demand for a solution to serious and widespread water pollution.

EPA statistics released with the action plan describe the improvement in the quality of the nation's waters over the past 25 years. In 1972, only one-third of the nation's waters were safe for fishing and swimming; today, it's about two-thirds. In 1972, wetlands losses were estimated at about 460,000 acres annually; today the estimated annual rate of wetlands losses is about 70,000–90,000 acres. In 1972, agricultural runoff resulted in the erosion of 2.25 billion tons of soil and the deposit of large amounts of phosphorus and nitro-

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In Memoriam

John R. Castano
Houston, Texas
April 20, 1997

Thomas L. Kesler
Bellevue, Washington
November 11, 1997

John B. Lyons
Hanover, New Hampshire
February 19, 1998

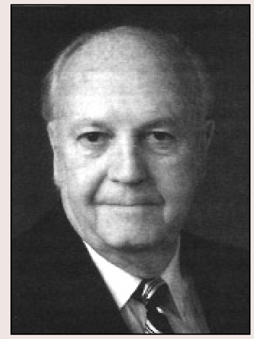
R. William Orr
Muncie, Indiana
August 1997

Thomas A. Simpson
Northport, Alabama
December 14, 1997

Jaan Terasmae
St. Catharines, Ontario
January 20, 1998

Leo Y. Picard
Jerusalem, Israel
April 4, 1997

John F. Mann, Jr.
1921–1998



Well-known hydrogeologist and GSA benefactor John Mann died of a heart attack on March 9, 1998. He was in Bakersfield, California, participating in a meeting concerning groundwater problems in the area of the Oildale suburb and the adjacent massive Kern River Oilfield steam flood.

Over a 50-year career, Mann had become an influential hydrogeologist. His work centered on southern California, where he was an advisor to water districts, communities, companies, and individuals concerned with supply, use, and conservation of water. Mann said he derived great personal as well as professional satisfaction from his chosen specialty, because he felt that the results of his work brought benefits to people that extended beyond mere technical and regulatory solutions.

A major benefactor of the Geological Society of America, in 1994 Mann created a charitable remainder unitrust, of which the GSA Foundation is the remainder beneficiary. His subsequent contributions support the John F. Mann Institute for Applied Geoscience, founded to promote activities of the geoscientific community in contributing to public awareness of environmental issues, and in applying specialized knowledge and experience to professional education and opportunity.

John Mann is survived by his wife, Carol, of La Habra, California; his brother, Jerold F. Mann, of Port Washington, New York; and his sister, Janet McCormick, of Memphis, Tennessee.

Memorial gifts may be sent to the GSA Foundation for the John F. Mann, Jr. Fund.

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gen into many waters; today, the amount of soil lost due to agricultural runoff is about 1.25 billion tons annually and phosphorus and nitrogen levels in water sources are significantly lower. In 1972, sewage treatment plants served only 85 million people; today modern wastewater treatment facilities serve about 173 million people. Still today, about half of our nation's over 2,000 major watersheds have serious or moderate water quality problems.

The philosophy behind the new action plan is to accelerate the improvements of the past 25 years so that the problems in these watersheds will also be corrected, resulting in all Americans having clean water that is safe for fishing and swimming, the nation achieving a net gain of wetlands by preventing additional losses and restoring hundreds of thousands of acres of previously impacted wetlands, and all of the nation's waters being free of the effects of sewage discharges. This plan is built around four key tools to achieve clean water goals: (1) a watershed approach, (2) strong federal and state standards, (3) natural resource stewardship, and (4) informed citizens and officials.

1. **A Watershed Approach.** The action plan proposes a new collaborative effort by state, tribal, federal, and local governments, the private sector, and the public to restore those watersheds not meeting clean water, natural resource, and public health goals and to sustain healthy conditions in other watersheds. In the past, most water-pollution control efforts relied on broadly applied national programs that reduced water pollution from individual sources, such as discharges from sewage treatment plants and factories, and from polluted runoff. The plan recognizes that clean-water strategies built on this foundation and tailored to specific watershed conditions are the key to the future. A watershed focus also helps identify the most cost-effective pollution-control strategies to meet clean-water goals and to bring state, tribal, federal, and local programs together to clean up and protect waters more effectively and efficiently. The action plan proposes a watershed approach built on several key elements, as follows.

Unified Assessments. The plan creates a strategic opportunity for states and tribes, in cooperation with land and resource managers on federal lands, to take the lead in unifying existing efforts and leveraging scarce resources to advance the pace of progress toward clean water. Unified watershed assessments are a vehicle to identify watersheds that will be targeted to receive significant new resources from the President's FY 1999 budget and beyond; clean up waters that are not meeting water quality goals; identify pristine or sensitive watersheds on federal lands where core federal and state programs can be brought together to prevent degradation of water quality; and identify threatened watersheds that need an extra measure of protection and attention.

Restoration Action Strategies. The plan encourages states and tribes to work with local communities, the public, and federal environmental, natural resource, and land management agencies to develop strategies to restore watersheds that are not meeting clean water and natural resource goals. These strategies will spell out the most important causes of water pollution and resource degradation, detail the actions that all parties need to take to solve those problems, and set milestones by which to measure progress. Funds made available to federal agencies through the FY 1999 Clean Water and Watershed Restoration Budget Initiative will be used to help states implement these strategies.

Pollution Prevention. Protecting pristine or sensitive waters and taking preventive action when clean water is threatened by new activities in the watershed can be the most cost-effective approach to meeting clean water goals. The plan encourages states, tribes, and federal agencies to bring core programs and existing resources together to support watershed pollution-prevention strategies to keep clean waters clean.

Assistance Grants. Federal agencies will provide small grants to local organizations that want to take a leadership role in building local efforts to restore and protect watersheds. These grants will ensure that local communities and stakeholders can effectively engage in the process of setting goals and devising solutions to restore their watersheds.

USDA is instructed to develop a strategy for ensuring that agricultural producers in 1000 critical rural watersheds have the technical and financial assistance they need to abate polluted runoff and to comply with applicable standards, using existing federal programs and authorities like

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Washington Report *continued from p. 11*

the Environmental Quality Incentives Program, the Conservation Reserve Program, the Wetlands Reserve Program, and others. USDA is instructed to do this in a manner consistent with its goals for watershed and basin-level planning. USDA is told to give preference to states that have mechanisms in place to ensure effective cooperation among federal, state, and local agencies as well as with local landowners and the public.

The National Oceanic and Atmospheric Administration (NOAA) and EPA are instructed to have coastal non–point-source pollution-control programs in all 29 coastal states by June 30, 1998, beginning with the highest priority watersheds. NOAA and EPA are charged to work with states to ensure that these programs are fully approved by December 31, 1999. NOAA and EPA will also develop an action-oriented strategy to comprehensively address coastal nonpoint source pollution.

2. **Strong Federal and State Standards.** The action plan calls on federal, state, and tribal governments to strengthen existing programs to support an accelerated effort to attack the nation's remaining water-quality problems. Federal, state, and tribal standards for water quality and polluted runoff are key tools for protecting public health, preventing polluted runoff, and ensuring accountability. Some of the specific actions called for in this action plan are identified below.

Improve Assurance that Fish and Shellfish Are Safe To Eat. Federal agencies will work with states and tribes to expand programs to reduce contaminants— particularly mercury and other persistent, bioaccumulative toxic pollutants—that can make locally caught fish and shellfish unsafe to eat, and to ensure that the public gets clear notice of fish-consumption risks.

Ensure Safe Beaches. Federal, state, and local governments will work to improve the capacity to monitor water quality at beaches, develop new standards, and use new technologies such as the Internet to report public-health risks to recreational swimmers.

Expand Control of Storm Water Runoff. EPA will publish final Phase II storm water regulations for smaller cities and construction sites in 1999. EPA will also work with its partners to make sure that existing storm-water control requirements for large urban and industrial areas are implemented.

Improve State and Tribal Enforceable Authorities to Address Polluted Runoff. Federal agencies will work with states and tribes to promote the establishment of state and tribal enforceable authorities to ensure the implementation of controls on polluted runoff by the year 2000.

FUNDING BY AGENCY

	1998 enacted ($, millions)	1999 budget ($, millions)
Environmental Protection Agency		
State Grant Assistance		
Polluted runoff control (Sec. 319)	105	200
State program management (Sec. 106)	96	116
Wetlands protection	15	15
Water-quality cooperative agreements	20	19
Water-quality program management	248	279
Total	484	629
Department of Agriculture		
Natural Resources Conservation Service		
Environmental Quality Incentives Program	200	300
Locally led conservation	0	20
Watershed health monitoring	0	3
Forest Service		
Improve water quality on federal lands	239	308
Agriculture Research Service		
Watershed health research	0	2
Total	439	633
Department of the Interior		
Bureau of Land Management		
Improve water quality on federal lands	133	157
Office of Surface Mining—Clean streams	5	7
U.S. Geological Survey:		
Water monitoring and assessment	125	147
Fish and Wildlife Service		
Wetlands restoration	36	42
Bureau of Indian Affairs		
Improve water quality on tribal lands	0	5
Total	299	358
National Oceanic and Atmospheric Administration		
Polluted runoff and toxic contaminants	0	13
Harmful algal blooms	0	9
Total	0	22
Army Corps of Engineers		
Wetlands program	106	117
Challenge 21: Floodplain restoration initiative	0	25
Total	106	142
Interagency Projects		
Florida Everglades	228	282
California bay and delta	85	143
Elimination of overlap between Everglades and other water programs listed above	-5	-5
Total interagency	308	420
Total clean water and watershed restoration initiative	**1,636**	**2,204**

Define Nutrient Reduction Goals. EPA will establish by the year 2000 numeric criteria for nutrients (i.e., nitrogen and phosphorus) that reflect the different types of water bodies (e.g., lakes, rivers, and estuaries) and different ecoregions of the country and will assist states and tribes in adopting numeric water-quality standards based on these criteria.

Reduce Pollution from Animal-Feeding Operations. EPA will publish and, after public comment, implement an animal feeding operations strategy for important and necessary actions on standards and permits. In addition, by November 1998, EPA and USDA will jointly develop a broad, unified national strategy to minimize the environmental and public health impacts of animal-feeding operations.

The action plan will include a strategy for ensuring that lands and facilities owned, managed, or controlled by federal agencies are national models and laboratories for effective watershed planning and control of polluted runoff. The plan will also include a strategy to ensure that federal actions, programs, and activities do not contribute to the sprawl or other forms of development that may exacerbate the problem of polluted runoff or other water quality problems.

EPA and NOAA are charged with identifying steps to reduce the need for advisories on fish consumption, giving particular attention to toxics that affect fetal and childhood development. The action plan also identifies steps to ensure

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Washington Report *continued from p. 12*

protection of children from exposure to harmful organisms on our beaches and other recreational waters. Additionally, EPA is tasked to identify the major sources of nitrogen and phosphorous in the nation's waters, and to identify actions to address these sources. In particular, EPA is instructed to "accelerate the water quality criteria for waters in every geographic region in the country." Specifically, EPA will establish a schedule so that it and the states are "implementing a criteria system for nitrogen and phosphorous runoff for lakes, rivers, and estuaries by the year 2000." EPA is instructed to "expedite new standards" for targeted problems of polluted runoff. Specifically, EPA "will expedite" its new strategy from animal-feeding operations that produce polluted runoff, and include in that strategy specific commitments to revise outdated regulations. EPA is instructed to have final regulations for polluted runoff from storm water in place by March 1, 1999. The USDA is charged to provide further guidance to the states in submitting proposals "leading to as many agreements as practicable that will address critical water quality, soil erosion, and fish and wildlife habitat needs, including habitat needed for threatened and endangered species." USDA will work with states to identify whether such agreements could be used to protect important habitat for fish "in the Pacific Northwest, California, and other areas where significant natural resources may be affected by diminished water quality."

3. **Natural Resource Stewardship.** Most of the rainfall in the country falls on croplands, pastures, forests, wetlands, and rangelands before it enters rivers, lakes, and coastal waters. Effective management of these lands and other resources is key to keeping water clean and restoring watersheds where water quality is impaired. The action plan commits all federal natural-resource conservation and environmental agencies to focus their expertise and resources to support the watershed approach described above. In addition, these agencies will work with states, tribes, and others to enhance critical natural resources essential to clean water.

Federal Land Stewardship. More than 800 million acres of the United States, including Alaska, is federal land. These lands contain an immense diversity and wealth of natural resources, including significant sources of drinking water and public recreation opportunities. By 1999, the U.S. Department of the Interior (DOI) and USDA will take the lead in developing a unified federal policy to enhance watershed management for the protection of water quality and the health of aquatic systems on federal lands and for federal resource management. Federal land managers will improve water-quality protection for over 2,000 miles of roads and trails each year through 2005 and decommission 5,000 miles each year by 2002. Federal land managers will also accelerate the cleanup rate of watersheds affected by abandoned mines and will implement an accelerated riparian stewardship program to improve or restore 25,000 miles of stream corridors by 2005.

Protect and Restore Wetlands. The action plan sets a goal of attaining a net increase of 100,000 wetland acres per year by the year 2005. This goal will be achieved by ensuring that existing wetland programs continue to slow the rate of wetland losses, by improving federal restoration programs, and by expanding incentives to landowners to restore wetlands.

Protect Coastal Waters. Federal agencies, led by NOAA, will work in partnership to improve the monitoring of coastal waters, expand research of emerging problems like *Pfiesteria,* amend fishery management plans to address water-quality issues, and ensure the implementation of strong programs to reduce polluted runoff to coastal waters.

Provide Incentives for Private Land Stewardship. The action plan relies on a substantial increase in the technical and financial assistance available to private landowners as the primary means of accelerating progress toward reducing polluted runoff from agricultural, range, and forest lands. By 2002, USDA, working with federal, state, tribal, and private partners, will establish two million miles of conservation buffers to reduce polluted runoff and protect watersheds, direct new funding for the Environmental Quality Incentives Program to support watershed restoration, and develop as many new agreements with states as practicable to use the Conservation Reserve Enhancement Program to improve watersheds. The plan also envisions new and innovative methods to provide incentives for private landowners to implement pollution-prevention plans, including risk-management protection for adoption of new pollution-prevention technologies and market recognition for producers that meet environmental goals. In addition, DOI will expand its existing Partners for Wildlife Program, which restores degraded fish and wildlife habitats and improves water quality through partnerships with landowners. The program provides technical and financial assistance, and gives priority to threatened and endangered species.

USDA, in consultation with DOI, will develop a strategy to ensure proper stewardship of federally managed watersheds and to restore watersheds adversely affected by past management practices. The strategy will target the needs to address runoff from abandoned mines, to eliminate unnecessary roads, to improve road maintenance, and to ensure coordinated watershed management strategies regardless of jurisdictional boundaries. Working with local landowners, USDA will develop a strategy for addressing non–point-source pollution in those watersheds that consist of a mix of public and private lands; the aim will be to make more effective use of resources related to high-priority restoration efforts in these watersheds.

4. **Informed Citizens and Officials.** Effective management of water resources requires reliable information about water-quality conditions and new tools to communicate information to the public. Federal agencies, led by the U.S. Geological Survey (USGS), will work with states and tribes to improve monitoring and assessment of water quality, focusing on nutrients and related pollutants. Federal agencies will also work with states and tribes

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Corrections

In "Environmental Change, Geoindicators, and the Autonomy of Nature" by Antony R. Berger, January 1998 *GSA Today* (v. 8, no. 1), the caption printed with Figure 1 (p. 4) is actually the caption for Figure 2 (p. 5), and vice versa.

To make housing reservations at Northern Arizona University for the Rocky Mountain Section meeting please contact Michael Ort, Dept. of Geology, Northern Arizona University, Flagstaff, AZ 86011, Michael.Ort@nau.edu, or Larry Middleton, Larry.Middleton@nau.edu, fax 520-523-9220. The final announcement for this section meeting, in the February issue of *GSA Today,* had the wrong name.

About People

GSA Fellow **George H. Davis,** University of Arizona, Tucson, has been named a Regents Professor, in recognition of national and international contributions in research and scholarship.

Fellow **Robert N. Ginsburg,** University of Miami, will receive the Sorby Medal of the International Association of Sedimentologists this month, for outstanding contributions to sedimentary geology.

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to develop and use state-of-the-art systems, such as EPA's Index of Watershed Indicators on the Internet, to communicate meaningful information to the public about water-quality conditions in their communities.

To support the new and expanded efforts to restore and protect the nation's waters as proposed in this action plan, the President's FY 1999 budget proposes a Clean Water and Watershed Restoration Budget Initiative. The initiative will increase direct support to states and tribes to carry out a watershed approach to clean water; increase technical and financial assistance to farmers, ranchers, and foresters to reduce polluted runoff and enhance the natural resources on their lands; fund watershed assistance programs and grants to engage local communities and citizens in leadership roles in restoring their watersheds; accelerate progress in addressing critical water-quality problems on federal lands, including those related to roads, abandoned mines, riparian areas, and rangelands; expand and coordinate water-quality monitoring programs; and increase efforts to restore nationally significant watersheds, such as the Florida Everglades and the San Francisco Bay and delta.

The publication of the Clean Water Action Plan is just the beginning of what will be in some cases a multidecade effort. Many of the proposed actions will be subject to later public review and comment. The federal agencies are mandated to work closely with states, tribes, and others to ensure successful implementation of specific actions. In addition, regular reports will keep the public apprised of progress and remaining challenges. By the end of the year 2000 and periodically thereafter, status reports on progress in implementing watershed restoration plans and related programs will be provided to the President, the nation's governors, tribal leaders, and the public.

FY 1999 Proposed U.S. Budget Increases

Source: Office of Management and Budget

Funding Summary:

Total 1999 increase: $568 million

Increase for 1999 over 1998: 35%

Total increase 1999–2003: $2,338 million

Total spending 1999–2003: $10,516 million ■

April *BULLETIN* and *GEOLOGY* Contents

The Geological Society of America
BULLETIN
Volume 110, Number 4, April 1998

CONTENTS

Geology Goes to Russia and Nearby Countries

GSA is participating for the fourth year in a program that provides low-cost journal subscriptions for libraries in the former Soviet Union, the Baltic states, and central Eurasia. The Science Journals Donation Program, operated by the Open Society Institute, arranges for distribution of the journals to the libraries and research institutions, which have few resources for acquiring up-to-date scientific information.

In 1998, GSA's journal *Geology* will go to 38 libraries (10 more than in 1997) in Azerbaijan, Latvia, Lithuania, Moldova, Mongolia, Russia, Tajikistan, and Ukraine through the program. GSA ships the journals to New Jersey and New York; from there, the Science Journals Donation Program ships them to the destination countries. The reduced-rate subscriptions—for *Geology* 17.5% of the regular library rate—are purchased by the Open Society Institute Foundation. The journals are distributed free of charge to libraries in the regions served by the Science Journals Donation Program.

GEOLOGY
VOLUME 26
NO. 4
P. 289–384
APRIL 1998

The Geological Society of America

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ASSEMBLY OF A CONTINENT

CALL FOR PAPERS

Geologically, the countries of the North American continent share a set of structural units and geological history. Our theme, *Assembly of a Continent,* has a dual interpretation. It expresses, first, the commonality of the lands we occupy and, second, our hope and expectation that earth scientists will assemble from all areas of the continent, as well as from around the world. We are welcomed by a broad spectrum of Canadian hosts and cosponsors who enthusiastically encourage this assembly of scientists.

DEADLINES

Abstracts due July 13
Preregistration due September 18

FOR MORE INFORMATION

Call: (303) 447-2020 or 1-800-472-1988
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E-mail: meetings@geosociety.org
Web: www.geosociety.org/meetings/98

REGISTRATION AND FULL DETAILS

See the June issue of *GSA Today*.

IS GSA TORONTO ON YOUR OCTOBER CALENDAR? JOIN US OCTOBER 26–29.

Photo of Scarborough Bluffs, Ontario, by Peter Mykusz

Toronto Skyline — Photo by Peter Mintz

The Huron Indians called it "Toronto"—the place of meeting. Today Toronto, the fourth largest metropolitan city in North America, has evolved into one of the most popular meeting destinations in the world, and the single most popular for U.S.-sponsored association meetings outside the United States. Toronto is a city of ethnic mix and cultural diversity that celebrates its exotic cuisines, neighborhood markets, and foreign cultures. Toronto is also the third largest theater center in the world, having many pre-Broadway runs, and is the place for enjoying some of the best theater in North America. The core of the meeting is at the Metro Toronto Convention Centre which is in the heart of the financial and corporate district but also faces the landscaped pathways along Lake Ontario. For a metropolitan city, Toronto is refreshingly safe and clean. Above all, the people are friendly and welcoming. You'll find the exchange rate highly favorable to the U.S. dollar—another welcoming feature of our Toronto meeting. Likewise, the new "open skies" airlines policy, together with easier immigration and customs guidelines, makes crossing the border easier than ever. Put GSA Toronto on your October calendar!

ASSOCIATED SOCIETIES:

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Special Occasions

150th Anniversary of Geology at the University of Toronto

Do the names E. J. Chapman, A. P. Coleman, Duncan R. Derry, J. Tuzo Wilson, M. A. Peacock, and W. A. Parks ring a bell? The traditions established by these geological leaders have become well known to scientists and to the public who have benefited from their academic excellence and commitment to geology. All served as faculty of the University of Toronto's Department of Geology. Congratulations to the present faculty and students of this cornerstone of the science.

50th Anniversary of the American Geological Institute

AGI is only one-third as old as the University of Toronto Department of Geology, but likewise serves the purposes of the geosciences. We congratulate AGI for its leadership and support of its member organizations for 50 years.

Dedication of the Don Valley Brick Works

The public dedication of the Don Valley Brick Works is anticipated in conjunction with GSA's presence in Toronto. Excavations at the site of the former brick works have revealed the most complete record of climate change during the last interglacial period. Once threatened by housing development, the site has now been acquired for public use and geologic displays and education, thanks to the efforts of Toronto's geological community.

PDAC Mining Matters

Congratulations to the Prospectors and Developers Conference ongoing secondary school educational program, funded by more than 50 Canadian mining corporations. In 1997, Mining Matters won the Partnership Focus Award for promoting science literacy for the world of work for the elementary and secondary level. You'll be able to see Mining Matters teaching materials in the University of Toronto's exhibit booth.

How To Submit Your Abstract

SUBMIT ABSTRACTS VIA THE WEB (www.geosociety.org)

Starting on or about April 15, abstracts for this year's GSA Annual Meeting in Toronto can be sent to GSA via the World Wide Web. (About 60% of the abstracts were submitted electronically in 1997.) **Note that you can send electronic abstracts to GSA only via the Web. They may not be sent by ordinary e-mail.**

For the present, this system will accept only abstracts containing pure ASCII content; no graphics, tables, symbols, Greek, superscripts, etc. may be included. If you must use these in your abstract, use the paper form for now. We hope to be able to include non-ASCII material in the future, but for most users the technology for that is not yet in place. However, if your entire content—title, addresses, and abstract body—is pure ASCII and you have access to the Web, the new system will make life much easier by eliminating the more onerous tasks usually connected with preparation of paper forms.

The best part is that it takes only a few seconds to send an abstract and even less to get feedback from GSA. There will be no more mystery about whether we received your submission. You'll receive an immediate confirmation of receipt from GSA, with an abstract number assigned, while you're still on the Web. Note: Some Web client servers cut off their customers prematurely. The Web page has advice about this problem and has suggestions for use of appropriate browser options.

You are now able to test our new system, strictly on a "get acquainted" basis. Nothing you send via this form before April 15 will be saved at GSA or considered by GSA for the 1998 Annual Meeting. Although you will receive an acknowledgment of receipt on any test abstracts you send, that is just part of the test, too, and is meaningless.

To get acquainted with the form from now until April 15, go to *www.geosociety.org.* There you'll find the link, "TEST DRIVE GSA's Web Abstract Form." Just follow the instructions from there. If you discover any glitches in our system during a test, please send a detailed e-mail message to: pubs@geosociety.org. Please include your telephone number so we can call if more details are needed. On or about April 15, the TEST DRIVE link will change to "SUBMIT an Abstract."

PAPER STILL WORKS WELL

The electronic system has not yet replaced the familiar paper version of GSA's abstract form. Rather, the two systems operate in parallel. Paper forms already have been distributed for 1998, and they can be obtained from GSA's Abstracts Coordinator: ncarlson@geosociety.org or call (303) 447-2020, ext. 161.

PLEASE SUBMIT ONLY ONE COPY OF YOUR ABSTRACT—EITHER ELECTRONIC OR PAPER.

Paper abstract forms are available from:

- Abstracts Coordinator at GSA headquarters
- Conveners of symposia
- Advocates of theme sessions
- Geoscience departments of most colleges and universities
- Main federal and state survey offices

ONLY ONE VOLUNTEERED ABSTRACT MAY BE SUBMITTED

Please submit only one volunteered abstract as speaker or poster presenter in discipline and/or theme sessions. *Multiple submissions as speaker-presenter may result in rejection of all your abstracts.* Since almost all of the submitted abstracts are accepted, this helps avoid speaker-scheduling conflicts and gives everyone an equal opportunity to be heard. Note that this limitation does not apply to, nor does it include, invited contributions to symposia.

ABSTRACTS FEE

Costs for implementing an electronic abstract submission system, as well as increasing costs for producing the printed *Abstracts with Programs* books, have led to establishment of a $15 abstract fee for GSA Annual Meetings. Implementation of the fee follows the standard set by many other scientific organizations many years ago. The nonrefundable fee must be sent with both paper copy and electronic submissions.

PRESENTATION MODES

ORAL MODE—This is a verbal presentation before a seated audience. The normal length of an oral presentation is 12 minutes, plus three minutes for discussion. Projection equipment consists of two 35 mm projectors, one overhead projector, and two screens. Requests for video projection and computer display will be addressed on a case-by-case basis. Please let us know when you submit your paper if you have special presentation needs.

POSTER MODE—Each poster session speaker is provided with two horizontal, freestanding display boards approximately 8′ wide and 4′ high. Precise measurements will appear in the **Speaker Guide.** The speaker must be present for at least two of the four presentation hours.

Papers for discipline sessions may be submitted in either oral or poster mode. Papers for theme sessions, however, are to be submitted only in the mode noted in the theme description. If a theme abstract is submitted in the incorrect mode, the abstract will be transferred automatically to a discipline session.

IT'S EASY TO SUBMIT ELECTRONICALLY

1. *Compose your abstract in your favorite word processor.* Please do NOT compose your abstract on-line since *your server* may disconnect during the time lag.
2. *"Save" it as "text."* This will convert your data into pure ASCII.
3. *Copy and paste* this into the appropriate fields of the GSA Web form.
4. *Complete the personal information on the form, including credit card information for abstracts fee payment* (required for both paper and electronic forms).
5. *Hit the "SEND" button.* You're done! We've included instructions, pull-down lists, and helpful hints on the Web form to save you time and confusion. There's even an error checker to make certain you include all the information we must have.

Symposia (Invited Papers)

ABSTRACTS DEADLINE: JULY 13

All invited abstracts (electronic and paper) are to be sent to GSA, which will forward the abstracts to the conveners for review.

NEW FOR '98! INTRODUCING PARDEE KEYNOTE SYMPOSIA

The first of the new Pardee Keynote Symposia will be presented this year. These symposia will be on the leading edge in a scientific discipline or area of public policy, address a broad fundamental problem, be interdisciplinary, or focus on global problems. Proposals included both a rationale for becoming a keynote symposium and a list of proposed speakers. Selection was on a competitive basis. This year's four Pardee Symposia were reviewed and accepted by the Annual Program Committee.

Support for this new keynote symposia series is from the Joseph T. Pardee Memorial Fund that was established with a generous gift from the estate of Joseph T. Pardee.

K1 ■ TECTONIC EVOLUTION OF PRECAMBRIAN NORTH AMERICA I—A SYNTHESIS OF RECENT RESULTS.
Lithoprobe; GSA Structural Geology and Tectonics Division; GSA Geophysics Division; 1998 Annual Meeting Committee. Ron M. Clowes, Lithoprobe, British Columbia, Canada; John A. Percival, Geological Survey of Canada, Ottawa; Karl Karlstrom, University of New Mexico.

K2 ■ PATHFINDER AND GLOBAL SURVEYOR: NEW VIEWS OF MARS.
GSA Planetary Geology Division. Daniel T. Britt, University of Arizona Lunar and Planetary Laboratory.

K3 ■ GEOLOGY AND BIOLOGY OF EARLY ANIMAL EVOLUTION.
Paleontological Society. Desmond Collins, Royal Ontario Museum, Toronto; Nick Butterfield, Cambridge University, United Kingdom.

K4 ■ DEEP CRUSTAL PROCESSES.
International Lithosphere Program; GSA Geophysics Division; GSA Structural Geology and Tectonics Division; Geological Association of Canada, Canadian Geophysical Union; International Association of Geomagnetism and Aeronomy; International Association of Seismology and Physics of the Earth's Interior; International Association of Volcanism and Chemistry of the Earth's Interior; American Geophysical Union. Alan G. Jones, Geological Survey of Canada, Ottawa; David Fountain, University of Wyoming; Walter D. Mooney, U.S. Geological Survey, Menlo Park; Randall Parrish, NERC Isotope Geosciences Laboratory, United Kingdom.

SYMPOSIA

S1 ■ GEOLOGIC CONTEXTS FOR PRE-CLOVIS ARCHAEOLOGICAL DEPOSITS IN THE AMERICAS.
GSA Archaeology Division. C. Reid Ferring, University of North Texas, Denton.

S2 ■ CONTROLS ON SEDIMENTATION AND STRATIGRAPHY IN MAJOR COAL-PRODUCING BASINS OF NORTH AMERICA.
GSA Coal Geology Division. Cortland F. Eble, Kentucky Geological Survey; C. Blaine Cecil, U.S. Geological Survey, Reston.

S3 ■ ENVIRONMENTAL QUALITY VS. ECONOMIC DEVELOPMENT: THE ROLE OF COAL IN DEVELOPING NATIONS.
GSA International Division; GSA Coal Geology Division; U.S. Geological Survey; Geological Survey of Canada; Institute for Environmental Education. Allan Kolker, U.S. Geological Survey, Reston; L. Lynn Chyi, University of Akron; Fari Goodarzi, Geological Survey of Canada, Alberta.

S4 ■ ACCRETING THE CONTINENT'S COLLECTIONS OF EARTH SCIENCE INFORMATION.
Geoscience Information Society. Charlotte R. M. Derksen, East Palo Alto, California; Connie J. Manson, Washington Division of Geology and Earth Resources, Olympia.

S5 ■ THE VOISEY'S BAY Ni-Cu-Co DEPOSIT: A WORLD-CLASS ORE DEPOSIT AT THE JUNCTION OF TWO FORMER CONTINENTS.
Society of Economic Geologists; 1998 Annual Meeting Committee. A. J. Naldrett, University of Toronto.

Don Valley Brick Works Park and Toronto
— Photo by E. B. Freeman

S6 ■ THE LAC DE GRAS DIAMONDIFEROUS KIMBERLITE FIELD, NORTHWEST TERRITORIES, CANADA.
Society of Economic Geologists. A. Lee Barker, Southern Era Resources Ltd., Toronto; Buddy Doyle, Kennecott Canada Exploration, Inc., Vancouver; Jon Carlson, BHP Diamonds, Inc., Kelowna, British Columbia.

S7 ■ MILITARY APPLICATIONS OF ENGINEERING GEOLOGY.
GSA Engineering Geology Division. Judy Ehlen, U.S. Army, Topographic Engineering Center, Alexandria, Virginia; M. Merrill Stevens, University of Missouri—Rolla; Russell S. Harmon, U.S. Army Research Office, Research Triangle Park, North Carolina.

S8 ■ RESEARCH ISSUES IN PETROLEUM AND ENVIRONMENTAL ORGANIC GEOCHEMISTRY.
Geochemical Society (Organic Geochemistry Division). Michael D. Lewan, U.S. Geological Survey, Denver; Barbara Sherwood-Lollar, University of Toronto.

S9 ■ GEOCHEMICAL INDICATORS OF ATMOSPHERIC INPUTS INTO TERRESTRIAL AND MARINE ENVIRONMENTS.
Geochemical Society. Oliver A. Chadwick, University of California, Santa Barbara; Rosemary C. Capo, University of Pittsburgh.

S10 ■ DEVELOPING SUSTAINABILITY CURRICULA: A CHALLENGE FOR EARTH SCIENCES EDUCATORS.
National Association of Geoscience Teachers; Institute for Environmental Education, GSA ad hoc Committee on Critical Issues. Paul H. Reitan, University of Buffalo; Trileigh Stroh, Seattle University; Paul R. Pinet, Colgate University.

S11 ■ STUDENT RESEARCH SYMPOSIUM.
Sigma Gamma Epsilon. James C. Walters, University of Northern Iowa, Cedar Falls; Charles J. Mankin, Oklahoma Geological Survey. POSTER

S12 ■ GEOSCIENCE EDUCATION: PREDICTIONS FOR THE 21ST CENTURY.
National Association of Geoscience Teachers. Barbara J. Tewksbury, Hamilton College, Clinton, New York.

S13 ■ CONVERSATIONS WITH THE EARTH: PHILOSOPHERS AND GEOSCIENTISTS IN DIALOGUE ON THE ROLE OF THE EARTH SCIENCES IN SOCIETY.
Institute for Environmental Education; International Association for Environmental Philosophy. Robert Frodeman, University of Tennessee; Victor R. Baker, University of Arizona.

S14 ■ HUTTON, LYELL, LOGAN—AND THEIR INFLUENCE IN NORTH AMERICA.

GSA History of Geology Division. Gerard V. Middleton, McMaster University, Hamilton; Keith Tinkler, Brock University, St. Catharines, Ontario; Robert H. Dott, Jr., University of Wisconsin, Madison.

S15 ■ IEE ANNUAL ENVIRONMENTAL FORUM: THE SUSTAINABILITY CHALLENGE I: ENERGY FOR THE 21ST CENTURY.

Institute for Environmental Education; GSA ad hoc Committee on Critical Issues. Allison R. (Pete) Palmer, Institute for Cambrian Studies, Boulder, Colorado; E-an Zen, Reston, Virginia.

S16 ■ RESEARCH OPPORTUNITIES IN THE EARTH SCIENCES: A TEN-YEAR VISION.

National Research Council; National Science Foundation. J. Freeman Gilbert and Craig M. Schiffries, National Research Council–National Academy of Sciences, Washington, D.C.; Ian MacGregor, National Science Foundation, Arlington, Virginia.

S17 ■ FAULT REACTIVATIONS, NEOTECTONICS, AND SEISMICITY IN THE GREAT LAKES REGION.

Geological Association of Canada; GSA Structural Geology and Tectonics Division. Robert Jacobi, State University of New York at Buffalo; C. F. M. Lewis, Geological Survey of Canada, Dartmouth, Nova Scotia; Joe Wallach, JLW Geosciences, Russell, Ontario.

S18 ■ DEFORMATION MECHANISMS AND MICROSTRUCTURES.

GSA Structural Geology and Tectonics Division. W. D. Means, University of Albany.

ABSTRACT DEADLINE JULY 13

S19 ■ ACCRETIONARY MARGINS OF NORTH AMERICA.

Cushman Foundation. Charles A. Ross, Western Washington University, Bellingham.

S20 ■ ROLE OF PARTIAL MELTING DURING EVOLUTION OF CONVERGENT OROGENIC BELTS.

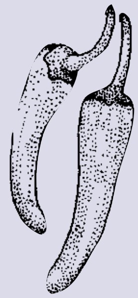
GSA Structural Geology and Tectonics Division. Michael Edwards, State University of New York at Albany; Olivier Vanderhaeghe, Dalhousie University, Halifax, Nova Scotia; Christian Teyssier, University of Minnesota.

S21 ■ EXPERIMENTAL PETROLOGY AND APPLICATIONS: A TRIBUTE TO 35 YEARS OF RESEARCH IN THE GOLDSMITH-NEWTON LABORATORY AT THE UNIVERSITY OF CHICAGO.

Mineralogical Society of America; Geochemical Society. Dexter Perkins, University of North Dakota, Grand Forks; Andrea Koziol, University of Dayton; David Jenkins, Binghamton University, New York; David R. Pattison, University of Calgary.

Hot Topics at Noon

POPULAR SCIENTIFIC DEBATE AND LUNCH



Monday through Thursday, October 26 through 29, 12:15 to 1:15 p.m.

Metro Toronto Convention Centre

- **IS ACCREDITATION OF THE PROFESSIONAL DEGREE IN GEOSCIENCE NEEDED?**
- **CAN STEREOCHEMISTRY EXIST IN SPACE? IMPLICATIONS FOR ORIGIN OF LIFE ON EARTH**
- **NATURAL ATTENUATION—WHAT ROLE IN CONTAMINANT REMEDIATION SCHEMES?**
- **WHAT IS THE FUTURE FOR SCIENTIFIC OCEAN DRILLING?**

S22 ■ LOCATING OLD MANTLE PLUMES.

GSA Geophysics Division; Geophysics Division of the Geological Association of Canada; GSA International Division. Richard E. Ernst and Kenneth L. Buchan, Geological Survey of Canada, Ottawa; Millard F. Coffin, University of Texas at Austin.

S23 ■ NORTH AMERICAN ICE SHEETS DURING MARINE ISOTOPE STAGES 3 TO 1: EXTENT, CHRONOLOGY, DATA, AND MODELING.

GSA Quaternary Geology and Geomorphology Division. John T. Andrews, University of Colorado, Boulder; A. S. Dyke, Geological Survey of Canada, Ottawa.

S24 ■ APPLICATION OF COSMOGENIC NUCLIDES IN SURFICIAL PROCESSES AND GLOBAL CHANGE STUDIES.

GSA Sedimentary Geology Division; GSA Quaternary Geology and Geomorphology Division. John Gosse, University of Kansas; Jeffrey Klein, University of Pennsylvania.

S25 ■ RESPONSE TO HOLOCENE CLIMATE CHANGE ON THE GREAT PLAINS.

GSA Quaternary Geology and Geomorphology Division; Geological Survey of Canada; Global Change and Climate History Program, U.S. Geological Survey. Stephen Wolfe, Geological Survey of Canada, Ottawa; Daniel Muhs, U.S. Geological Survey, Denver.

S26 ■ PALEOECOLOGICAL AND GEOCHEMICAL SIGNATURE OF CRETACEOUS ANOXIC EVENTS: A MEMORIAL TO WILLIAM V. SLITER.

Cushman Foundation; 1998 Annual Meeting Committee. Timothy J. Bralower, University of North Carolina, Chapel Hill; Brian Huber, Smithsonian Institution, Washington, D.C.; R. Mark Leckie, University of Massachusetts.

S27 ■ UNDERSTANDING GROUNDWATER IN ARID AND SEMI-ARID ENVIRONMENTS OF NORTH AMERICA AND AUSTRALIA.

GSA Hydrogeology Division. Todd Halihan and John M. Sharp, Jr., University of Texas at Austin; Craig T. Simmons, Flinders University of South Australia, Adelaide.

S28 ■ MULTIMODAL HETEROGENEITY IN CLASTIC AQUIFERS: QUANTIFYING PERMEABILITY AND LITHOFACIES DISTRIBUTIONS.

GSA Hydrogeology Division; SEPM (Society for Sedimentary Geology). Robert W. Ritzi, Jr., and David F. Dominic, Wright State University, Dayton, Ohio; J. Matthew Davis, University of New Hampshire, Durham.

S29 ■ BREAKING DOWN BARRIERS: COMMUNICATING RELEVANT GEOSCIENCE ISSUES TO THE PUBLIC.

Science Awareness Through Geoscience Education. John J. Clague, and Robert J. Turner, Geological Survey of Canada, Vancouver; Michelle Lamberson, University of British Columbia, Vancouver.

S30 ■ INTERNATIONAL SURVEYS.

1998 Annual Meeting Committee. Richard A. F. Grieve, Canadian Geological Survey. POSTER

International Survey Program

INTERNATIONAL SURVEYS INVITED TO GSA TORONTO

The 1998 Annual Meeting Committee is inviting geologists from international geological surveys to participate in a program in conjunction with the Toronto meeting. As in the program that debuted at the 1997 GSA Annual Meeting in Salt Lake City, the survey delegates will present technical papers and exhibits on new geological or environmental developments in various countries.

Information: Richard A. F. Grieve, Chief Geoscientist, Earth Sciences Sector, Natural Resources Canada, Canadian Geological Survey, Room 209, 601 Booth St., Ottawa, ON K1A 0E8, Canada, (613) 995-5372, impact@gsc.nrcan.gc.ca or rgrieve@gsc.nrcan.gc.ca.

Discipline and Theme Sessions (Volunteered Papers)

ABSTRACT DEADLINE: JULY 13

The full daily technical session schedule appears in the September issue of *GSA Today* and at www.geosociety.org. If you are not a GSA member, please contact us, and we will gladly send you the schedule after September 1.

DISCIPLINE SESSIONS

Papers are submitted to ONE scientific discipline. The JTPC representatives organize the papers in sessions focused on this discipline—for example, hydrogeology or mineralogy.

THEME SESSIONS

Papers are submitted to a specific pre-announced title and to ONE scientific category. Theme sessions are interdisciplinary; each theme may have as many as three categories from which authors may choose ONE. After each theme description below, the categories are identified by name and number as they appear on the 1998 Abstract Form. PLEASE SUBMIT ONLY IN THE MODE AND CATEGORIES INDICATED in the description (oral or poster). An abstract submitted in the incorrect mode will be transferred automatically to a discipline session.

ROLE OF THEME ADVOCATE

Each theme session has been proposed by an advocate. Advocates may not invite speakers; however, they may encourage colleagues to submit abstracts, with the understanding that there is no guarantee of acceptance. JTPC representatives, in consultation with the theme advocates, will organize theme sessions by August 8.

THEME TOPICS

Please check the correct mode of the theme session—poster or oral. If the abstract is submitted inaccurately, it will be transferred automatically to a discipline session.

EXAMPLE SUBMISSION

Theme submissions must include:

- **Theme number**—*T18*
- **Key words of the theme title**—*Methods for Quantifying Unsaturated Permeability*
- **One category**—*Environmental Geology* (#6 on abstract form)
- **Mode for the session**—*Poster*

T01 ■ GOLD DEPOSITS ASSOCIATED WITH ALKALIC ROCKS.

Society of Economic Geologists. A. Lee Barker, Southern Era Resources Ltd., Toronto; Jeremy Richards, University of Alberta; Paul G. Spry, Iowa State University.

A significant number of world-class gold deposits of various types can be spatially and genetically related to alkalic rock suites. This theme session will highlight these deposits through presentations of recent studies directed toward understanding the relationships between deposits and lithology. ORAL

Economic Geology [4], Geochemistry, Other [8], Mineralogy/Crystallography [16]

T02 ■ NATURAL SOURCES OF MERCURY AND ARSENIC: SIGNIFICANCE IN REGIONAL CYCLES AND ENVIRONMENTAL ASSESSMENTS.

Institute for Environmental Education. Mae Sexauer Gustin, University of Nevada, Reno; Alan H. Welch, U.S. Geological Survey, Carson City, Nevada.

This session will explore natural sources of mercury and arsenic in the environment, their contribution to regional biogeochemical cycles and the potential for anthropogenic exacerbation of environmental distribution. ORAL

Environmental Geology [6], Geochemistry, Other [8]

T03 ■ EL NIÑO 1997–1998: EFFECTS ON EARTH SURFACE PROCESSES.

GSA Engineering Geology Division; GSA Quaternary Geology and Geomorphology Division. Scott F. Burns, Portland State University; Vincent Cronin, University of Wisconsin, Milwaukee.

The El Niño of 1997–1998 is the most publicized El Niño event in history. Many people remember the last major event in 1982–1983 when extensive flooding and landslides occurred in various regions of North America. Are similar events happening during this present major climatic event? ORAL

Engineering Geology [5], Quaternary Geology/Geomorphology [26], Geoscience Information [11]

T04 ■ LANDSLIDES AND TRANSPORTATION SYSTEMS.

GSA Engineering Geology Division. Scott F. Burns, Portland State University; Jerry DeGraff, U.S. Forest Service, Sierra National Forest, Clovis, California.

Transportation systems are important to humans. Landslides occur along railroads, waterways, and roads, causing disruption — even endangerment—to human lives. This theme session will focus on case histories of landslides along these important routes in North America. ORAL

Engineering Geology [5], Quaternary Geology/Geomorphology [26], Public Policy [25]

T05 ■ ENVIRONMENTAL AND ENGINEERING GEOLOGY IN QUATERNARY DEPOSITS.

GSA Engineering Geology Division; GSA Quaternary Geology and Geomorphology Division. Scott F. Burns, Portland State University; Paul Karrow, University of Waterloo, Ontario.

Quaternary surficial deposits are abundant in North America. Many environmental and engineering geology problems occur in these glacial, eolian, lacustrine, fluvial, and colluvial deposits. This theme session will focus on North American case histories from these areas. ORAL

Engineering Geology [5], Environmental Geology [6], Quaternary Geology/Geomorphology [26]

T06 ■ GEOMICROBIOLOGY.

Gordon Southam, Northern Arizona University; Kurt Konhauser, University of Leeds, Leeds, United Kingdom.

Geomicrobiology comprises studies of geologically significant transformations of inorganic and organic compounds by microorganisms, including oxidative and reductive mineral dissolution, mineral precipitation, and biogeochemical cycling processes, in both past and present systems. ORAL

Geochemistry, Aqueous/Organic [7], Mineralogy/Crystallography [16]

T07 ■ SOURCES, TRANSPORT, FATE, AND TOXICOLOGY OF TRACE ELEMENTS IN THE ENVIRONMENT.

International Association of Geochemistry and Cosmochemistry, in memory of Helen L. Cannon. Gunter Faure, Ohio State University; David T. Long, Michigan State University.

Reports are invited on the identification of sources of trace elements in the environment,

Abstracts with Programs

Purchase an advance copy through GSA Membership Services, Publication Sales, or pick up a copy on site in the registration area. The *Abstracts with Programs* is not part of your registration fee. For advance sales, contact Publication Sales, GSA headquarters 1-800-472-1988, ext. 152. Member cost: $31, Nonmember cost: $38.75.

JOINT TECHNICAL PROGRAM COMMITTEE FINALIZES PROGRAM: AUGUST 8

The JTPC selects abstracts and determines the final session schedule. Speakers will be notified by August 24 (probably much sooner for abstracts submitted electronically). The JTPC consists of representatives from each of GSA's Associated Societies and Divisions participating in the technical program. The JTPC technical program chairs were nominated by the Toronto Annual Meeting Committee and approved by the GSA Council.

their transport by water in ionic form or by sorption on suspended particles, the medical consequences of transfer into the food chain, and the accumulation of toxic elements in sediment deposited in lakes and reservoirs. ORAL
Geochemistry, Aqueous/Organic [7], Economic Geology [4], Environmental Geology [6]

T08 ■ CONTINENT FORMATION, GROWTH, AND RECYCLING.

Paul J. Sylvester, Australian National University, Canberra, Australia.

Did the continents form in an early big bang, or have they progressively grown in volume because sediment recycling at island arcs and crustal delamination at collision zones have failed to balance new additions from the mantle? After more than 30 years of study, are we any closer to an answer? ORAL
Geochemistry, Other [8], Petrology, Igneous [21], Precambrian Geology [24]

T09 ■ LUMINESCENCE IN GEOLOGY—10TH ANNIVERSARY MEETING OF SOCIETY OF LUMINESCENCE MICROSCOPY AND SPECTROSCOPY.

Society of Luminescence Microscopy and Spectroscopy. William J. Meyers, State University of New York at Stony Brook; Pete Modreski, U.S. Geological Survey, Denver; Maurice Pagel, Université de Paris, Paris, France.

This session focuses on use of luminescence in geologic problems. Geoscientists, whether Society members or not, are encouraged to submit abstracts based on: geochemistry, petrology, structural geology, instrumentation. ORAL
Geochemistry, Other [8], Mineralogy/Crystallography [16], Sediments, Carbonates [28]

T10 ■ FIELD CAMP PEDAGOGIES: ADJUSTING TO MODERN EQUIPMENT AND THE MODERN STUDENT.

Patrick A. Burkhart, Slippery Rock University, Slippery Rock, Pennsylvania; Gregory S. Baker, University of Kansas, Lawrence.

Increasingly, field techniques and tools are associated with portable (laptop) computers and GPS/GIS-related systems. Additionally, today's field camp student often has a nontraditional geology background. This session will provide an opportunity to share innovative pedagogical developments that have been employed successfully to address these developments. ORAL
Geology Education [9]

T11 ■ BREAKING DOWN BARRIERS: COMMUNICATING RELEVANT GEOSCIENCE ISSUES TO THE PUBLIC.

Science Awareness through Geoscience Education; Institute for Environmental Education. John J. Clague and Robert J. Turner, Geological Survey of Canada, Vancouver; Michelle Lamberson, University of British Columbia, Vancouver.

Earth scientists are making considerable progress in making relevant geoscience information more accessible to the public, thereby improving societal geo-literacy. This session deals with success stories—innovative products and programs that inform and educate non-geoscientists. ORAL and POSTER
Geology Education [9], Geoscience Information [11]

T12 ■ TEACHING HYDROGEOLOGY TO UNDERGRADUATE AND GRADUATE STUDENTS.

GSA Hydrogeology Division, National Association of Geoscience Teachers. Science Awareness Through Geoscience Education. Laura L. Sanders, Northeastern Illinois University, Chicago; Tim Allen, Keene State College, Keene, New Hampshire.

Unlike three decades ago, hydrogeology courses are now taught in most geology programs. In this session, presenters share philosophical and pedagogical approaches and describe how to deal with the challenges of teaching hydrogeology. ORAL
Geology Education [9], Hydrogeology [13], Environmental Geology [6]

PLEASE CHECK CORRECT MODE, POSTER OR ORAL

T13 ■ CREATING LEARNING ENVIRONMENTS WITH THE INTERNET AND MULTIMEDIA.

National Association of Geoscience Teachers; American Geological Institute. John C. Butler, University of Houston; Warren Huff, University of Cincinnati; Michelle Lamberson, University of British Columbia, Vancouver.

This session examines experimentation with the Internet and other multimedia applications as potential facilitators for creating learning environments. Abstracts are solicited for four related topics: (1) Learning on the Internet, (2) Learning with the Internet, (3) Assessment of Internet and Multimedia Impact, (4) Internet and Multimedia Success Stories. ORAL
Geology Education [9], Computers [3], Geoscience Information [11]

T14 ■ TEACHING THROUGH INQUIRY IN THE GEOSCIENCES.

National Association of Geoscience Teachers; GSA Geoscience Education Division. Judi Kusnick, California State University, Sacramento; Barbara Manner, Duquesne University, Pittsburgh.

Science education reform efforts at both the K–12 and university level call for students to learn science by asking questions and conducting inquiries to find answers. This session will explore programs at any educational level which include directed or independent inquiry, but which involve students actively investigating earth processes. ORAL
Geology Education [9]

T15 ■ EDUCATION ABOUT THE ENVIRONMENT: WHAT WORKS!

National Association of Geoscience Teachers; Institute for Environmental Education. David Barclay, Paul H. Reitan, and Marcus I. Bursik, University of Buffalo.

Lab, field or classroom: we have lots of experiences that have worked. Let's share them! POSTER
Geology Education [9], Environmental Geology [6]

T16 ■ GEOTECTONICS AT THE FRONTIER: A CENTENARY TRIBUTE TO DEBATE, REJECTION, AND ACCEPTANCE OF CRUSTAL DYNAMICS PARADIGMS IN THE GEOSCIENCES.

John James Murray, University of Manitoba, Winnipeg; Gerald S. Smerchanski, University of Minnesota.

The evolution of ideas associated with the crustal dynamics of Earth and other planets has afforded a century of vigorous debate and revolutionary paradigm change. Papers are encouraged that explore historical, philosophical, pedogogical, and sociological implications of novel concepts in planetary tectonics. ORAL
Geology Education [9], Planetary Geology [23], History of Geology [12]

T17 ■ NORTH AMERICAN GEOLOGY IN THE EARLY TO MIDDLE NINETEENTH CENTURY.

GSA History of Geology Division. Gerard V. Middleton, McMaster University, Hamilton, Ontario; Keith Tinkler, Brock University, St. Catharines, Ontario; Robert H. Dott, Jr., University of Wisconsin, Madison.

This theme session is designed to complement Symposium 14, "Hutton, Lyell, Logan—And Their Influence in North America," but to accommodate submitted papers on a broader range of topics—e.g., the influence of other European scientists on early American geology, or studies of early American geology regardless of European influence. ORAL
History of Geology [12]

T18 ■ RESEARCH OPPORTUNITIES IN THE EARTH SCIENCES: A TEN-YEAR VISION.

National Research Council; National Science Foundation. J. Freeman Gilbert and Craig M. Schiffries, National Research Council–National Academy of Sciences, Washington, D.C.; Ian MacGregor, National Science Foundation, Arlington, Virginia.

This session is designed to assist the National Science Foundation and the National Research Council in developing a long-term vision for basic research in the earth sciences, which will form the basis of a new long-range plan for NSF's Earth Sciences Division. This session complements Symposium #16 and will identify and explore major research opportunities in the earth sciences. POSTER
Public Policy [25]

T19 ■ GEOPHYSICAL STUDIES OF THE CRUST AND LITHOSPHERE.

GSA Geophysics Division; GSA Structural Geology and Tectonics Division. Walter D. Mooney, U.S. Geological Survey, Menlo Park.

This session focuses on the deep structure, composition, and evolution of the crust and subcrustal lithosphere. Relevant data come from seismic reflection and refraction profiles and from studies using nonseismic geophysical techniques. The aim is to highlight new results from the continent, its margins, and adjacent ocean basins. ORAL

Geophysics/Tectonophysics [10], Structural Geology [31]

T20 ■ CONTROLS ON THE STYLE, DISTRIBUTION, AND INTENSITY OF DEFORMATION AROUND FAULTS AND FOLDS.

GSA Structural Geology and Tectonics Division. Mark P. Fischer, Northern Illinois University, Dekalb.

Fluid flow and storage characteristics, reservoir potential, *P-T-t* history, and kinematic evolution are all determined by or interpreted from deformation patterns associated with faults and folds. For this session we seek field, experimental, and modeling studies that clarify how various structural, stratigraphic, and other factors influence these deformation patterns. The aim is to facilitate better predictions of fold- or fault-related deformation. ORAL

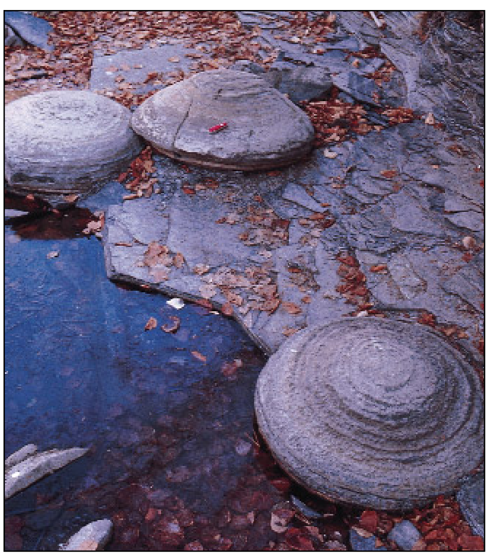
Structural Geology [31], Tectonics [32], Petroleum Geology [19]

T21 ■ FROM CRACKS TO CREEP: EVOLUTION, BEHAVIOR, AND PROCESSES WITHIN MATURE FAULT ZONES.

GSA Structural Geology and Tectonics Division. Joseph Clancy White, University of New Brunswick, Fredericton.

This session invites contributions from field, experimental, and modeling studies that relate to the complex mechanical and chemical evolution of mature fault zones, associated macroscopic behavior, and the micromechanical processes. ORAL

Structural Geology [31], Geophysics/Tectonophysics [10], Petroleum Geology [19]



Concretions, Slate River, Thunder Bay, Ontario — Photo by E. B. Freeman

T22 ■ WHAT ARE WE DATING? UNDERSTANDING THE CRYSTALLOGENESIS OF U-Pb GEOCHRONOMETERS.

GSA Structural Geology and Tectonics Division. Desmond Moser, University of Utah; David Scott, Geological Survey of Canada, Ottawa.

U-Pb geochronology data, fundamental to many tectonic models, are now being obtained from crystal domains in complexly zoned mineral geochronometers (e.g., zircon, monazite). We invite papers that address their poorly understood crystallogenesis, the geologic conditions that affect their morphology and internal structures, and the accuracy of results. ORAL and POSTER

Tectonics [32], Petrology, Metamorphic [22], Geochemistry, Other [8]

T23 ■ DEEP CRUSTAL PROCESSES.

International Lithosphere Program; GSA Geophysics Division; GSA Structural Geology and Tectonics Division; Geological Association of Canada, Canadian Geophysical Union; International Association of Geomagnetism and Aeronomy; International Association of Seismology and Physics of the Earth's Interior; International Association of Volcanism and Chemistry of the Earth's Interior; American Geophysical Union. Alan G. Jones, Geological Survey of Canada, Ottawa; David Fountain, University of Wyoming; Walter D. Mooney, U.S. Geological Survey, Menlo Park; Randall Parrish, NERC Isotope Geoscience Laboratory, Keyworth, United Kingdom.

How is continental lower crust formed? How does it evolve? How does it interact with its overlying upper crust and underlying mantle? These fundamental questions form the core of this session, which will bring together geologists, geochemists, and geophysicists to discuss deep crustal physical and chemical processes. ORAL and POSTER

Tectonics [32], Geophysics/Tectonophysics [10], Geochemistry, Other [8]

T24 ■ TECTONIC EVOLUTION OF PRECAMBRIAN NORTH AMERICA.

Lithoprobe; GSA Structural Geology and Tectonics Division; GSA Geophysics Division;1998 Annual Meeting Committee. Ron M. Clowes, University of British Columbia, Vancouver; John A. Percival, Geological Survey of Canada, Ottawa; Karl Karlstrom, University of New Mexico.

What have we learned about this topic since the Decade of North American Geology? Major new aspects are: (1) geophysical data to provide the third spatial dimension—depth; (2) isotope studies to contribute to understanding of juvenile vs. recycled lithosphere; (3) high-precision geochronology to give the fourth dimension—time; (4) integration of the studies, including geodynamic modeling. ORAL and POSTER.

Tectonics [32], Geophysics/Tectonophysics [10], Precambrian Geology [24]

T25 ■ NAFTA: NORTH AMERICAN FLOATING TERRANE ACCRETION.

International Geological Correlation Program 376. Jarda Dostal, St. Mary's University, Halifax, Nova Scotia; J. Duncan Keppie, Universidad Nacional Autónoma de México, Mexico City.

Correlations of Precambrian, Paleozoic, and Mesozoic-Cenozoic in the Grenvillian, the Appalachian-Ouachitan, and Cordilleran orogens of Canada, the United States, and Mexico will be used to examine North American terrane provenance. ORAL

Tectonics [32], Geophysics/Tectonophysics [10], Geochemistry, Other [8]

T26 ■ ROLE OF PARTIAL MELTING DURING EVOLUTION OF CONVERGENT OROGENIC BELTS.

Michael Edwards, State University of New York at Albany; Christian Teyssier, University of Minnesota; Olivier Vanderhaeghe, Dalhousie University, Halifax, Nova Scotia.

Orogenic evolution is typically characterized by a period of crustal thickening followed by thermal relaxation and late collapse. This session will examine magmatic events during this transition, in both active (e.g., southern Tibet) and collapsed (e.g., American Cordillera) belts. POSTER

Tectonics [32], Structural Geology [31], Petrology, Igneous [21]

T27 ■ APPLIED GEOLOGICAL REMOTE SENSING.

International Union of Geological Sciences. Vern Singhroy, Canada Centre for Remote Sensing, Ottawa.

In this discussion of the application of remote sensing and GIS visualization techniques to geological and environmental studies, particular emphasis will be on case studies using recent SAR, hyperspectral, and high-resolution optical sensors. ORAL

Remote Sensing [27]

T28 ■ ARCHEAN CRATONS: EVOLUTION AND ASSEMBLY.

Tom Skulski, John Percival, and Wouter Bleeker, Geological Survey of Canada, Ottawa.

The Precambrian rock record reveals complex orogenic patterns reflecting growth of Archean cratonic lithosphere. We encourage papers dealing with structural, petrological, geochronological, and geophysical data that constrain models of Archean tectonics and fuel the debate on the role of plate tectonics in Archean continental growth. ORAL

Precambrian Geology [24], Tectonics [32], Geophysics/Tectonophysics [10]

T29 ■ TONALITES, TRONDHJEMITES, AND GRANODIORITES AND RELATED ROCKS: ANCIENT EXAMPLES AND MODERN ANALOGUES.

Robert J. Stern, University of Texas at Dallas; A. Krishna Sinha, Virginia Polytechnic Institute; Makoto Arima, Yokohama National University, Yokohama, Japan.

The TTG suite is an element of Archean basement around the world. Similar rocks occur in juvenile island arcs in the western Pacific and provide natural analogues for the Archean TTG. Models for the TTG origins range from crustal anatexis to slab melting to fractional crystallization. This session will bring together scientists interested in comparing modern and ancient TTG suites. ORAL and POSTER

Petrology, Igneous [21]

T30 ■ ENVIRONMENTS AND TIMING OF THE LAST INTERGLACIATION: VEGETATION, PALEOHYDROLOGY, AND CLIMATE.

GSA Quaternary Geology and Geomorphology Division. B. Brandon Curry, Illinois State Geological Survey, Champaign; Michel Lamothe, Université du Québec à Montréal; Richard G. Baker, University of Iowa.

An appraisal of continental environments during the last interglaciation is timely, given concerns over future climate change. This session

links records of lithology, biostratigraphy, paleohydrology, and geochronology and provides data to compare with marine records and for general circulation models. ORAL
Quaternary Geology/Geomorphology [26], Paleontology/Paleobotany [18], Paleoceanography/Paleoclimatology [17]

T31 ■ THE POWER OF PALEOLIMNOLOGY: STATE OF THE ART AND FUTURE DIRECTIONS.
Marianne S. V. Douglas, University of Toronto; William M. Last, University of Manitoba, Winnipeg.
Papers on advances, regional studies, and integrative paleolimnological techniques will cross traditional boundaries of geology, biology, chemistry, and hydrology to provide insight into future progress. ORAL and POSTER
Quaternary Geology/Geomorphology [26], Paleoceanography/Paleoclimatology [17], Environmental Geology [6]

T32 ■ ON THE NATURE AND ORIGIN OF STONE LINES AND LITHOLOGIC DISCONTINUITIES IN SEDIMENTS AND SOILS.
GSA Quaternary Geology and Geomorphology Division. Randall Schaetzl, Michigan State University; Donald Johnson, University of Illinois, Urbana.
Subsurface stone lines and lithologic discontinuities are an integral, though genetically controversial, part of most tropical, subtropical, and mid- to high-latitude landscapes, including recently deglaciated lands. Papers in this session will explore the nature of and genetic processes that produce stone lines, to improve our models of landscape evolution. ORAL
Quaternary Geology/Geomorphology [26], Archaeological Geology [1]

T33 ■ CONTINENTAL GLACIATIONS: CONTINUING DEBATES.
Steven L. Forman, University of Illinois, Chicago; Julie Brigham-Grette, University of Massachusetts.
Despite recognition for over a century that continents have been glaciated, controversy continues on the nature of Quaternary ice sheets. It extends to defining limits, deglacial dynamics and history, and theories on the intrinsic instability of ice sheets. Geologic observations coupled with understanding of glacier bed dynamics will offer new insights. ORAL
Quaternary Geology/Geomorphology [26], Paleoceanography/Paleoclimatology [17], Marine Geology [14]

T34 ■ TERRESTRIAL RECORDS OF LATE-GLACIAL AND HOLOCENE CLIMATE CHANGE IN THE AMERICAS.
Donald T. Rodbell, Union College, Schenectady; Jan T. Heine, University of Washington; Mel A. Reasoner, Institute of Arctic and Alpine Research, University of Colorado; Geoffrey O. Seltzer, Syracuse University.
Recent findings indicate that climate change during the last deglaciation in the Americas was regionally dissimilar. This session will focus on continuous paleoclimatic time series (lake sediment cores, ice cores, tree rings) and semi-continuous records (moraine and lake-level chronologies) to identify patterns and mechanisms of regional climate change. ORAL
Quaternary Geology/Geomorphology [26], Paleoceanography/Paleoclimatology [17]

T35 ■ HOLOCENE CLIMATE CHANGE ON THE GREAT PLAINS.
GSA Quaternary Geology and Geomorphology; Terrain Sciences Division, Geological Survey of Canada; Global Change and Climate History Program, U.S. Geological Survey. Donald Lemmen, Geological Survey of Canada, Calgary.
In this presentation of Holocene paleoecologic and morphostratigraphic records of the Great Plains of North America, the focus will be on the role of both climatic and nonclimatic controls, based upon regional and site-specific studies, and relevant to contemporary issues of climate change, land-use management, water resources, and regional sustainability. ORAL
Quaternary Geology/Geomorphology [26], Paleoceanography/Paleoclimatology [17], Stratigraphy [30]

T36 ■ SURFICIAL PROCESSES AND LANDSCAPE DYNAMICS WITHIN ARID AND DESERT ENVIRONMENTS.
U.S. Army Research Office; Desert Research Institute. Russell Harmon, U.S. Army Research Office, Research Triangle Park, North Carolina; Steve Wells, Desert Research Institute, Reno, Nevada; Valerie Morrill, Conservation Program, U.S. Army, Yuma, Arizona.
Arid and desert environments are common across North America. Commonly occuring within zones of geologic, climatic, or ecosystem transition, they are particularly sensitive to human activities. This session will provide an interdisciplinary forum for the discussion of current research on surficial processes and landscape dynamics within arid and desert environments. ORAL
Quaternary Geology/Geomorphology [26], Environmental Geology [6]

T37 ■ PALEONTOLOGY SOLVES GEOLOGIC PROBLEMS.
Paleontological Society; Society of Vertebrate Paleontologists. Michael Woodburne and Nigel Hughes, University of California, Riverside.
As a result of their complexity, abundance, and morphological variation, fossils provide powerful constraints on the age, paleoenvironment, biogeographic province, and diagenetic and tectonic histories of a wide variety of sedimentary rocks. This theme session will illustrate how a broad spectrum of paleontological studies are critical to a diverse range of geological questions. ORAL
Paleontology/Paleobotany [18], Stratigraphy [30], Structural Geology [31]

T38 ■ THE END-PERMIAN MASS EXTINCTION: PALEOZOIC NEMESIS.
Paul B. Wignall and Richard J. Twitchett, University of Leeds, Leeds, United Kingdom.
The end-Permian mass extinction is increasingly contested; marine anoxia, volcanic winter, and meteorite impact have all been proposed as kill mechanisms. This session will include discussion of timing of extinction, associated facies, geochemical changes, and paleoceanographic events of this, the greatest biotic crisis of all time. ORAL
Paleontology/Paleobotany [18], Stratigraphy [30], Geochemistry, Other [8]

ABSTRACT DEADLINE JULY 13

T39 ■ PALEONTOLOGICAL DATABASES AND TAXONOMIC DECISIONS.
Paleontological Society. Colin Stearn, McGill University, Montreal.
In this decade, the possibility of rapid data retrieval from computer databases to a worldwide constituency has become a reality. Many groups of paleontologists are compiling databases at the generic and specific level. In this session, we will discuss the problems and possibilities of such compilations. ORAL
Paleontology/Paleobotany [18]

T40 ■ SEQUENCE STRATIGRAPHIC CONTROLS ON ORGANIC FACIES.
Bradley B. Sageman, Northwestern University; Thomas J. Algeo, University of Cincinnati.
The quantity and quality of preserved organic matter vary predictably among systems tracts because production and preservation of hydrocarbon-prone organic matter are influenced by factors (water-column stratification, dissolved oxygen and nutrient levels, sedimentation rates) that depend on relative sea level. Analysis of organic facies within sequence stratigraphic contexts promotes understanding of both ancient carbon cycling and source rock accumulation. ORAL
Stratigraphy [30], Geochemistry, Aqueous/Organic [7], Petroleum Geology [19]

T41 ■ GEOLOGICAL EVOLUTION OF MEXICO: ITS RELATION TO CONTERMINOUS NORTH AMERICA.
José F. Longoria, Jr., Florida International University, Miami; Dante Moran Centeno, Universidad Nacional Autónoma de México, Mexico City; Rogelio Monreal, Universidad de Sonora, Hermosillo, México.
For this session on the paleogeographic reconstruction of Mexico and its relation to the dynamic evolution of the rest of North America, we seek contributions on the paleogeographic development of any segment of Mexico, with special emphasis on tectonostratigraphic terranes, their paleogeographic reconstruction, and their relation to coeval successions across North America. ORAL
Stratigraphy [30], Tectonics [32], Paleontology/Paleobotany [18]

T42 ■ ONSHORE-OFFSHORE CORRELATION OF CENOZOIC STRATA, WESTERN MARGIN OF NORTH ATLANTIC.
W. Burleigh Harris, University of North Carolina, Wilmington; Marylin Segall, Bountiful, Utah.
Correlation of onshore-offshore Cenozoic strata along the western margin of the North Atlantic is complicated by differences in techniques of study, databases and stratigraphic terminology. This interdisciplinary theme session will focus on techniques of correlation and recent advances. ORAL and POSTER
Stratigraphy [30], Sediments, Clastic [29], Sediments, Carbonates [28]

T43 ■ INTERPRETING FOSSIL EARTHQUAKES FROM THE STRATIGRAPHIC RECORD.
Frank R. Ettensohn and Nicholas Rast, University of Kentucky.
Seismically generated structures in the older Phanerozoic stratigraphic record of the craton

GSA's Institute for Environmental Education and the John F. Mann Institute for Applied Geoscience

For the seventh year in a row, GSA's Institute for Environmental Education (IEE) is sponsoring the Annual Environmental Forum. This year's forum, "The Sustainability Challenge I: Energy for the 21st Century," will offer thought-provoking presentations and productive dialogue on one of the most controversial and pressing environmental issues of our time—dependence on nonrenewable fossil fuel resources. How can geoscientists contribute to public understanding of the economic realities and environmental consequences of this dependence and contribute to resolution of this problem?

IEE is an issue-driven, nonadvocacy, outreach program of GSA; its primary goal is enhancing the effective contribution of geoscientists and the geosciences to a wide array of environmental issues. Other IEE-sponsored sessions, indicated on these pages, include topics such as communicating geosciences to the public, and in the classroom; interdisciplinary discussions on ecosystems, hydrogeology, and environmental assessments; the ethical responsibilities of geoscientists in conducting and sharing scientific research; and sustainability.

interior are largely absent, primarily because of misinterpretation. This theme session will demonstrate the significance of such phenomena, how they can be distinguished, and how they enhance understanding of mid-continental earthquake hazards. ORAL

Stratigraphy [30], Engineering Geology [5]

T44 ■ GROUNDWATER SUSTAINABILITY.

GSA Hydrogeology Division; Institute for Environmental Education. Abe Springer, Northern Arizona University; Scott Bair, Ohio State University.

The concepts of safe yield and conjunctive use of groundwater have found new life under the term "sustainability." Research presentations will document the sustainability of local or regional aquifers and models for groundwater monitoring. ORAL and POSTER

Hydrogeology [13], Environmental Geology [6], Engineering Geology [5]

T45 ■ CAPTURE ZONES IN FRACTURED ROCK.

Kent Novakowski, National Water Research Institute, Burlington, Ontario; Ed Sudicky, University of Waterloo, Ontario.

This session will bring together hydrogeologists and engineers who are developing and applying new techniques for the definition and design of capture zones in fractured rock. Papers will describe the development and/or application of accurate models that are easily applied to represent transport in the fractured domain. ORAL

Hydrogeology [13]

T46 ■ SOLUTE TRANSPORT IN AQUITARDS: FIELD STUDIES.

GSA Hydrogeology Division. Vicki Remenda, Queen's University, Kingston, Ontario; Garth van de Kamp, Environment Canada, Saskatoon, Saskatchewan.

Solute movement in aquitards, whether by diffusion or advection, can have a major influence on water quality in adjoining aquifers. Laboratory experiments provide information on transport processes, but they may miss the effects of large-scale features and may not reflect in situ conditions. This session will focus on field studies of flow and solute transport in fractured and intact aquitards. ORAL

Hydrogeology [13], Environmental Geology [6]

T47 ■ GROUNDWATER FLOW AND SOLUTE TRANSPORT INTO THE GREAT LAKES.

GSA Hydrogeology Division. F. Edwin Harvey, University of Nebraska; Shaun K. Frape, University of Waterloo, Ontario.

Growing concern over the quality of Great Lakes waters has prompted this session, which focuses on determining and characterizing groundwater inputs to the Great Lakes. Topics include: techniques for locating and measuring groundwater flow, characterization of groundwater quantity and quality, solute transport through bottom sediments, and regional-scale groundwater-flow modeling. ORAL

Hydrogeology [13], Quaternary Geology/Geomorphology [26], Geochemistry, Aqueous/Organic [7]

T48 ■ RADIONUCLIDE TRANSPORT EXPERIMENTS AT UNDERGROUND RESEARCH LABORATORIES.

U.S. Department of Energy/Yucca Mountain Project. Robert A. Levich and Russell L. Patterson, Las Vegas; Ronald M. Linden, Henderson, Nevada.

This session will comprise papers on experiments investigating radionuclide transport, as related to waste disposal, including colloidal transport, thermal effects, microbial interaction, fracture, and matrix flow. ORAL

Hydrogeology [13], Geochemistry, Aqueous/Organic [7], Environmental Geology [6]

T49 ■ HYDROGEOLOGIC CONTROLS ON ECOSYSTEMS.

GSA Hydrogeology Division; Institute for Environmental Education. Edwin A. Romanowicz, Duke University; Andrew Reeve, University of Maine, Orono.

This session will focus on how hydrogeological processes and the geologic setting control biological, biogeochemical, and physical processes and the distribution and composition of plant and animal communities in many ecosystems. ORAL

Hydrogeology [13], Quaternary Geology/Geomorphology [26], Geochemistry, Aqueous/Organic [7]

T50 ■ FROM CONTINENTAL SHELF TO ABYSSAL PLAIN—LINKS BETWEEN SEDIMENT TRANSPORT AND MORPHOLOGY.

William W. Hay, GEOMAR, Kiel, Germany.

What are the processes that mobilize shelf and slope sediments and transport them to the deep sea? What is the relative importance of continuous vs. periodic transport? How do these processes respond to changes in sea level and climate? How do different processes affect the morphology of shelf, slope, and rise? ORAL

Marine Geology [14], Sediments, Clastic [29], Paleoceanography/Paleoclimatology [17]

T51 ■ PALEOECOLOGICAL AND GEOCHEMICAL SIGNATURE OF CRETACEOUS ANOXIC EVENTS: A MEMORIAL TO WILLIAM V. SLITER.

Cushman Foundation. Timothy J. Bralower, University of North Carolina, Chapel Hill; Brian Huber, Smithsonian Institution, Washington D.C.; R. Mark Keckie, University of Massachusetts.

The late William V. Sliter was a branch chief of paleontology and stratigraphy at the U.S. Geological Survey and Director, Editor, and President of the Cushman Foundation. Sliter devoted his career to the study of Cretaceous organic-rich sediments, source rocks for much of the world's petroleum; these are the subject of the session. POSTER

Paleoceanography/Paleoclimatology [17], Marine Geology [14], Micropaleontology [15]

T52 ■ THE LAC DE GRAS DIAMONDIFEROUS KIMBERLITE FIELD, NORTHWEST TERRITORIES, CANADA.

Society of Economic Geologists. A. Lee Barker, Southern Era Resources Ltd., Toronto; Buddy Doyle, Kennecott Canada Exploration, Ltd., Toronto; Jon Carlson, BHP Diamonds, Inc., Kelowna, British Columbia.

The discovery of the Lac de Gras diamondiferous kimberlite field in Canada's Northwest Territories in late 1991 was one of the most significant new mineral discoveries in North America, and worldwide. Exploration and academic studies will highlight the regional framework, descriptions of deposits, and the nature of the Earth's mantle in the area. POSTER

Economic Geology [4]

T53 ■ ORIGIN AND TRANSPORT OF NON-HYDROCARBON GASES IN SEDIMENTARY BASINS.

Chris Ballentine, University of Michigan; Barbara Sherwood Lollar, University of Toronto.

This session will focus on isotopic and geochemical techniques which address the origin and transport of non-hydrocarbon gases such as nitrogen, carbon dioxide, and noble gases within sedimentary basins. Studies that resolve the multiple origin of these gases, set constraints on the controls and timing of inputs, and identify modes of transport are of particular interest. ORAL

Geochemistry, Other [8], Petroleum Geology [19], Geochemistry, Aqueous/Organic [7]

T54 ■ ASSEMBLING A NEW UNDERSTANDING OF MARS.

GSA Planetary Geology Division. James R. Zimbelman, Smithsonian Institution; Kenneth S. Edgett, Arizona State University, Tempe.

Mars Pathfinder and Mars Global Surveyor are providing data that expand upon, and sometimes challenge, the post-Viking view of the Red Planet. Volunteered abstracts are solicited for presentation of new results and interpretations stimulated by (but not limited to) these new geological and geophysical data. ORAL

Planetary Geology [23], Quaternary Geology/Geomorphology [26], Geophysics/Tectonophysics [10]

The 1998 GSA Annual Meeting in Toronto will provide a very special opportunity for many American visitors to learn about the geology of southern Ontario and southern Quebec, as well as that of the northeastern United States.

Professionals and students attending the meeting are strongly encouraged to take advantage of the lower airfares for Saturday night stay-overs. This significantly reduces the costs associated with premeeting field trip participation.

The theme of the meeting, *Assembly of a Continent*, is, in part, a reference to its focus on the Canadian Lithoprobe program. Two geological transects and two other excursions through the Grenville province of the Precambrian Shield will in fact be directly related to Lithoprobe seismic transects. *Assembly of a Continent* is also a reference to the fact that the Geological Society of America has a continental, not just U.S., scope. Many of the trips will offer an opportunity to explore southern Ontario, southeastern Quebec, northern Pennsylvania, and New York State. Several trips will feature very recent results from studies of Paleozoic paleontology and stratigraphy. Some of the trips will provide an opportunity to discuss results of work done in response to public as well as scientific concerns about hydrology, environmental geology, Quaternary geology, and geomorphology in southern Ontario. Other trips will focus on the Oak Ridges moraine, a massive accumulation of mid-continental glacial sediments that dominate the north shore of Lake Ontario; the Niagara escarpment, another spectacular geomorphologic feature of southern Ontario; and Niagara Falls. Most trips, but not all, will start and end in Toronto.

FOR MORE INFORMATION

Contact the trip leader or the 1998 Field Trip Co-Chairs: Pierre-Yves F. Robin, (905) 828-5419, and Henry C. Halls, (905) 828-5363, Dept. of Geology Erindale College, University of Toronto, 3359 Mississauga Road, Mississauga, ON L5L 1C6, Canada, fax 905-828-3717, probin@erin.utoronto.ca or halls@erin.utoronto.ca.

The following list is tentative and subject to change. Further details will be given when registration for the meeting begins in June.

Costs are given in U.S. dollars.

PREMEETING TRIPS

FROM FRONT TO INTERIOR: A SOUTHERN ONTARIO TRANSECT OF THE GRENVILLE PROVINCE FROM SUDBURY, ONTARIO, TO THE ADIRONDACKS, NEW YORK.
Wednesday, October 21 through Sunday, October 25. Cosponsored by *GSA Structural Geology and Tectonics Division.* J. A. "Tony" Davidson, Geological Survey of Canada, 601 Booth St., Ottawa, ON, K1A 0E8, Canada, (613) 995-4793, fax 613-996-8059, tdavidson@gsc.nrcan.gc.ca; Mike Easton. Maximum: 35. Cost: $505.

A WESTERN QUEBEC GRENVILLE TRANSECT.
Thursday, October 22 through Saturday, October 24. Cosponsored by *GSA Structural Geology and Tectonics Division.* Jacques Martignole, Dept. de Géologie, Université de Montréal, Montréal, PQ, H3C 3J7, Canada, (514) 343-7734, fax 514-343-5782, martigno@ere.umontreal.ca. This trip starts in Val-d'Or, Quebec (one-hour flight from Montreal) and ends at the Montreal International Airport. Maximum: 25. Cost: $335.

POSTGLACIAL SURFACE PROCESSES OF NORTHERN NEW ENGLAND.
Thursday, October 22 through Sunday, October 25. Cosponsored by *GSA Quaternary Geology and Geomorphology Division.* Paul Bierman, Dept. of Geology, University of Vermont, Burlington, VT 05405-0122, (802) 656-4411, fax 802-656-0045, pbierman@zoo.uvm.edu. Will start in Burlington, Vermont, and end in Toronto. Maximum: 25. Cost: $270.

STRATIGRAPHY, SEDIMENTOLOGY, AND PALEOCOMMUNITIES OF THE BLACK RIVER AND TRENTON LIMESTONE GROUPS (ORDOVICIAN), EAST OF LAKE SIMCOE, ONTARIO.
Friday, October 23 through Sunday, October 25. Mike Brookfield, Dept. of Land Resource Science, University of Guelph, Guelph, ON, N1G 2W1, Canada, (519) 824-4120, ext. 2654, fax 519-824-5730, mbrookfi@lrs.uoguelph.ca; El Gadi, Derek Armstrong, Dave Rudkin, and Carl Brett. Maximum: 28. Cost: $330.

TECTONIC, EUSTATIC, AND CLIMATIC CONTROLS ON COAL DEPOSITION, FROM LATE MISSISSIPPIAN TO LATE PENNSYLVANIAN.
Friday, October 23 through Sunday, October 25. Cosponsored by *GSA Coal Geology Division.* Cortland Eble, Kentucky Geological Survey, 228 Mining and Minerals Bldg., University of Kentucky, Lexington, KY 40506, (606) 257-5500, fax 606-257-1147, eble@kgs.mm.uky.edu; Blaine Cecil. Maximum: 40. Cost: $350.

FENITES, CARBONATITES, AND OTHER ALKALIC ROCKS IN THE BANCROFT-HALIBURTON-MUSKOKA REGIONS, GRENVILLE PROVINCE, ONTARIO.
Saturday, October 24 and Sunday, October 25. Sid B. Lumbers, 7 Calle Alejandra, Santa Fe, NM 87505, (505) 466-1233, fax 505-466-1236; Vince Vertolli. Maximum: 22. Cost: $160.

REGIONAL QUATERNARY GEOLOGY AND HYDROGEOLOGY OF THE OAK RIDGES MORAINE AND GREATER TORONTO AREAS, SOUTHERN ONTARIO.
Saturday, October 24 and Sunday, October 25. Cosponsored by *GSA Quaternary Geology and Geomorphology Division.* David Sharpe, Geological Survey of Canada, 601 Booth St., Ottawa, ON, K1A 0E8, Canada, (613) 992-3059, fax 613-992-0190, sharpe@NRCan.gc.ca; P. Barnett, H. Russel, L. Dyke, M. Hinton, R. Gerber, and T. Brennand. Maximum: 35. Cost: $125.

Horseshoe Falls, Niagara Falls — Photo by E. B. Freeman

HYDROGEOLOGY OF THE NIAGARA FALLS AREA.
Saturday, October 24. Cosponsored by *GSA Engineering Geology Division.* Kent S. Novakowski, Canada National Water Research Institute, CCIW, Environment Canada, 867 Lakeshore Rd., P.O. Box 5050, Burlington, ON, L7R 4A6, Canada, (905) 336-4610, fax 905-336-4972, Kent.Novakowski@cciw.ca; P. Lapcevic. Maximum: 30. Cost: $70.

CLASSIC QUATERNARY GEOLOGY SITES OF TORONTO.
Sunday, October 25. Nick Eyles, Sciences Dept., Scarborough College, University of Toronto, 1265 Military Trail, Toronto, ON, M1C 1A4, Canada, (416) 287-7231, fax 416-287-7204, eyles@lake.scar.utoronto.ca. Maximum 60. Cost: $55.

HISTORY OF GEOLOGY FIELD TRIP TO NIAGARA FALLS.
Sunday, October 25. Cosponsored by *GSA History of Geology Division.* Keith Tinkler, Dept. of Geography, Brock University, St. Catharines, ON, L2S 3A1, Canada, (905) 688-5550, ext. 3486, fax 905-688-6369, ktinkler@spartan.ac.brocku.ca; Gerard Middleton. Maximum: 50. Cost: $80.

POSTMEETING TRIPS

CLASSIC QUATERNARY GEOLOGY SITES OF TORONTO.
Friday, October 30. Nick Eyles, Sciences Dept., Scarborough College, University of Toronto, 1265 Military Trail, Toronto, ON, M1C 1A4, Canada, (416) 287-7231, fax 416-287-7204, eyles@lake.scar.utoronto.ca. Maximum: 60. Cost: $55.

GROUNDWATER EXPERIMENTAL FIELD SITES AT THE BASE BORDEN RESEARCH SITE AND OTHER SITES IN THE WATERLOO AREA.
Friday, October 30. Cosponsored by *GSA Engineering Geology Division.* Dave Rudolph, Dept. of Earth Sciences, University of Waterloo, Waterloo, ON, N2L 3G1, Canada, (519) 888-4567, ext. 6778, fax 519-883-0220, drudolph@sciborg.uwaterloo.ca. Maximum: 40. Cost: $70.

CHERT, CORN, ENVIRONMENTAL CHANGE AND PREHISTORIC LAND CLEARANCE: THREE GEOARCHAEOLOGICAL STUDIES ON THE NIAGARA ESCARPMENT.
Friday, October 30 and Saturday, October 31. Cosponsored by *GSA Archaeological Geology Division.* Ronald F. Williamson, Archaeological Services Inc., 528 Bathurst St., Toronto, ON, M5S 2P9, Canada, (416) 966-1069, fax 416-966-9723, archaeology@sympatico.ca; Peter L. Storck and Robert I. MacDonald. Maximum: 20. Cost: $195.

HYDROGEOLOGY AND LATE QUATERNARY HISTORY OF POINT PELEE NATIONAL PARK, ONTARIO.
Friday, October 30 and Saturday, October 31. Cosponsored by *GSA Engineering Geology Division.* Allan Crowe, Canada National Water Research Institute, CCIW, Environment Canada, 867 Lakeshore Rd., P.O. Box 5050, Burlington, ON, L7R 4A6, Canada, (905) 336-4585, fax 905-336-4400, Allan.Crowe@CCIW.ca; John Coakley, C. J. Ptacek. Maximum: 30. Cost: $170.

LATE GRENVILLIAN HORIZONTAL EXTENSION AND VERTICAL THINNING OF PROTEROZOIC GNEISSES, CENTRAL ONTARIO.
Friday, October 30 and Saturday, October 31. Cosponsored by *GSA Structural Geology and Tectonics Division.* Walfried M. Schwerdtner, Dept. of Geology, University of Toronto, Toronto, ON, M5S 3B1, Canada, (416) 978-2062, fax 416-978-3938, fried@quartz.geology.utoronto.ca. Maximum: 22. Cost: $150.

SILURIAN-DEVONIAN STRATIGRAPHY OF THE NIAGARA ESCARPMENT.
Friday, October 30 and Saturday, October 31. Carlton Brett, Dept. of Earth and Environmental Sciences, University of Rochester, Rochester, NY 14627, (716) 275-5713, fax 716-244-5689, cebh@db1.cc.rochester.edu; Brian Pratt. Maximum: 28. Cost: $210.

SPONSORED BY SOCIETY OF ECONOMIC GEOLOGISTS

GOLD DEPOSITS OF NORTHERN SONORA, MEXICO.
Monday, October 19 through Friday, October 23. Kenneth F. Clark, Dept. of Geological Sciences, University of Texas at El Paso, El Paso, TX 79968-0555, (915) 747-5843, fax 915-747-5073, clark@geo.utep.edu. This trip begins and ends in Tucson, Arizona. Maximum: 45. Cost: $670, includes field trip transportation, all meals, accommodations (double occupancy), and guidebook.

Professional Horizons: GSA Short Courses

GSA-SPONSORED SHORT COURSES

Registration information and course descriptions will be published in the June issue of *GSA Today.* For additional information, contact Edna Collis, Continuing Education Coordinator, GSA headquarters, ecollis@geosociety.org, or see GSA's Web site, www.geosociety.org.

Fees are given in U.S. dollars

PREREGISTRATION DEADLINE: SEPTEMBER 18

ANALYSIS OF VEINS IN SEDIMENTARY ROCKS—AN INTRODUCTION FOR STRUCTURAL GEOLOGISTS.
Saturday, October 24 and Sunday, October 25. Cosponsored by *GSA Structural Geology and Tectonics Division.* David V. Wiltschko, John W. Morse, and Will Lamb, Texas A&M University; Zachary Sharp, University of New Mexico. Fee: $290, students $270. C.E.U. 1.6.

DEFORMATION MECHANISMS AND MICROSTRUCTURES.
Saturday, October 24 and Sunday, October 25. Cosponsored by *GSA Structural Geology and Tectonics Division.* Jan Tullis, Brown University; Christian Teyssier, University of Minnesota; Holger Stunitz, Geology and Paleontology Institute of Basel University, Switzerland. Fee: $250, students $230. C.E.U. 1.6.

PHASE I ENVIRONMENTAL SITE ASSESSMENTS.
Saturday, October 24 and Sunday, October 25. Cosponsored by *GSA Engineering Geology Division.* Raymond C. Kimbrough, Tom Joiner & Associates, Tuscaloosa, Alabama. Fee: $245, students $225. C.E.U. 1.6.

3-D SEISMIC INTERPRETATION: A PRIMER FOR GEOLOGISTS.
Saturday, October 24 and Sunday, October 25. Bruce S. Hart, New Mexico Bureau of Mines and Mineral Resources. Fee: $240, students $220. C.E.U. 1.6.

ANALYTICAL METHODS AND APPLICATIONS IN PROVENANCE STUDIES OF LITHIC ARTIFACTS.
Sunday, October 25. Cosponsored by *GSA Archaeological Geology Division.* Patrick J. Julig, Darrel G. F. Long, Laurentian University, Sudbury, Ontario. Fee: $220, students $200. C.E.U. 0.8.

APPLICATIONS OF ENVIRONMENTAL ISOTOPES IN GROUNDWATER STUDIES TO SOLVING HYDROLOGIC AND GEOCHEMICAL PROBLEMS.
Sunday, October 25. Cosponsored by *GSA Hydrogeology Division.* Ramon Aravena, University of Waterloo; Ian D. Clark, University of Ottawa. Fee: $190, students $170. C.E.U. 0.8.

BUCK ROGERS, FIELD GEOLOGIST: 21ST CENTURY ELECTRONIC WIZARDRY FOR MAPPING AND FIELD DATA COLLECTION.
Sunday, October 25. John H. Kramer, Condor Earth Technologies, Inc., Sonora, California; Todd Fitzgibbon, U.S. Geological Survey, Menlo Park. Fee: $240, students $220. C.E.U. 0.8.

DESIGN AND CREATION OF STATE-OF-THE ART, INTERACTIVE, MULTIMEDIA CD-ROMS FOR USE IN TEACHING GEOLOGY.
Sunday, October 25. Parvinder S. Sethi, Radford University, Radford, Virginia. Fee: $230, students $210. C.E.U. 0.8.

DETECTING ENVIRONMENTAL EFFECTS USING BENTHIC FORAMINIFERA AND THECAMOEBIANS.
Sunday, October 25. Cosponsored by *Cushman Foundation.* David B. Scott, and Eduard G. Reinhardt, Dalhousie University, Halifax, Nova Scotia; Francine M. G. McCarthy, Brock University, St. Catharines, Ontario; R. Timothy Patterson, Carleton University, Ottawa, Ontario. Fee: $230, students $210. C.E.U. 0.8.

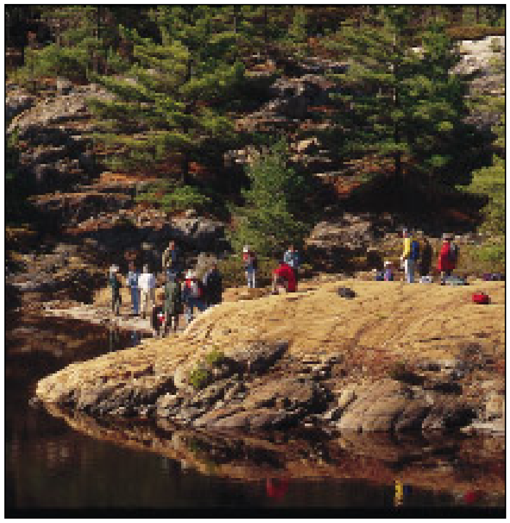
GEOTECHNICAL AND ENVIRONMENTAL APPLICATIONS OF TIME DOMAIN REFLECTOMETRY.
Sunday, October 25. Cosponsored by *GSA Engineering Geology Division.* Kevin M. O'Connor, GeoTDR, Inc., Apple Valley, Minnesota; Charles H. Dowding, Dept. of Civil Engineering, Northwestern University, Evanston, Illinois. Fee: $190, students $170. C.E.U. 0.8.

TEACHING PRACTICAL HYDROGEOLOGY: HOW TO MAKE DO WITH SCANT "REAL WORLD" DATA.
Sunday, October 25. Cosponsored by *GSA Hydrogeology Division.* Donald I. Siegel, Syracuse University. Fee: $170, students $150. C.E.U. 0.8.

OTHER COURSES, WORKSHOPS, AND FORUMS

Registration and information can be obtained from the contact person listed for each course.

TECHNIQUES IN HYDROTHERMAL ORE DEPOSITS.
Saturday, October 24 and Sunday, October 25. Sponsored by *Society of Economic Geologists.* Information: Peter Larson, Washington State University, Department of Geology, Pullman, WA 99164-2812, (509) 335-3095, fax 509-335-7816, plarson@wsu.edu, or Jeremy Richards, Dept. of Earth and Atmospheric Sciences, University of Alberta, Edmonton, AB, T6G 2E3, Canada, (403) 492-3430, fax 403-492-2030, Jeremy.Richards@ualberta.ca.



Whitefish Falls Field Camp, Manitoulin Isle, Sudbury Area — Photo by Karyn Gorra. Courtesy of University of Toronto, Dept. of Geology

NATIONAL ASSOCIATION OF GEOSCIENCE TEACHERS WORKSHOP ON INNOVATIVE AND EFFECTIVE TECHNIQUES FOR TEACHING GEOSCIENCE.
Saturday, October 24. Sponsored by *National Association of Geoscience Teachers, GSA SAGE Program,* with partial support from *National Science Foundation.* Information: R. Heather Macdonald, Dept. of Geology, College of William and Mary, Williamsburg, VA 23187-8795, (757) 221-2443, fax 757-221-2093, rhmacd@facstaff.wm.edu.

NATIONAL ASSOCIATION OF GEOSCIENCE TEACHERS WORKSHOP, MORE ON INNOVATIVE TEACHING TECHNIQUES: SHARING WHAT YOU'RE DOING.
Sunday, October 25. Sponsored by *National Association of Geoscience Teachers, GSA SAGE Program,* with partial support from *National Science Foundation.* Information: R. Heather Macdonald, Dept. of Geology, College of William and Mary, Williamsburg, VA 23187-8795, (757) 221-2443, fax 757-221-2093, rhmacd@facstaff.wm.edu.

CLASTIC FACIES AND SEQUENCE STRATIGRAPHY FOR GRADUATE STUDENTS *ONLY.*
Saturday, October 24 and Sunday, October 25. Sponsored by *Exxon Production Research Company.* Information: Morgan Sullivan, Exxon Production Research Company, 3120 Buffalo Spdwy., Houston, TX 77098, (713) 966-6396, fax 713-965-4114, or Art Donovan, Exxon Production Research Company, (713) 965-7608.

ISOTOPE PALEOBIOLOGY AND PALEOECOLOGY.
Sponsored by *Paleontological Society.* Information: Richard Norris, Clark 117, MS-23, Woods Hole Oceanographic Institution, Woods Hole, MA 02543-1541, (503) 289-2839, RNorris@whoi.edu.

FORUMS

DIGITAL DATABASE FORUM.
Sunday, October 25. Sponsored by *Geoscience Information Society.* Information: Adonna Fleming, Owen Science & Engineering Library, #3200, Washington State University, Pullman, WA 99164-3200, (509) 335-7601, afleming@wsu.edu.

GEOLOGY AND PUBLIC POLICY FORUM: GEOSCIENCE ETHICS IN ENVIRONMENTAL AND NATURAL RESOURCE ISSUES.
Wednesday, October 28. Sponsored by *GSA Geology and Public Policy Committee and Institute for Environmental Education.*
What is the appropriate role for the geosciences in a democratic society struggling with the ever-changing, symbiotic relationship between humans and Earth? How do the goals of democracy, science, and sustainability shape our personal and professional ethics? How can geoscientists be effective researchers and problem-solvers in conflicts that are often enmeshed with politics and power? How do the geosciences respond when the issues transcend political boundaries and governing systems? Special guest panelists will offer perspectives from both within and outside the geosciences, setting the stage for open discussion among the forum attendees and beyond.

GSA's SAGE Program for K–16

GSA Educational Programs invite you to join us in Toronto for an exciting K–16 Education Program, with something for everyone—geoscientists, undergraduate and graduate students, and K–16 teachers. Workshops begin on Saturday and Sunday, so plan to preregister and come early if you want to participate. There will be workshops on "Directing Undergraduate Research," "Innovative and Effective Teaching," "Exploring the Solar System," and "Exploring Plate Tectonics." We will also offer a workshop on "Learning from the Fossil Record," and a session on the *PROMISE project* will round out the schedule. Monday also marks the beginning of a great series of technical sessions, symposia, and forums on a variety of education topics. We will also have our annual Earth Science Educators Reception, complete with the always popular Rock Raffle and an Earth Science Information Share-a-thon.

Special Events

EVENING HIGHLIGHTS

Some very special events will introduce 1998 Annual Meeting attendees to Toronto's ambiance and unique attractions. Look for detailed descriptions and pricing information in the June issue of *GSA Today.*

SATURDAY, OCTOBER 24

Dinner and the Toronto PATH

The PATH is Toronto's downtown walkway linking 10 kilometers of underground services, restaurants, shopping, and entertainment. Join us for a geological and historical tour of Toronto's underground, culminating with dinner at a Toronto landmark restaurant. The tour begins at the Sheraton Centre Hotel. Finish with dinner and drinks at the intriguing Old Ed's Restaurant, with its museum of antiques, art objects, and theatrical memorabilia.

SUNDAY, OCTOBER 25

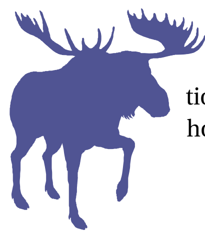
PATH Walking Tour

Walk the PATH to the GSA Welcoming Party. This guided tour will help you get acquainted with Toronto's amazing underground. The PATH and its labryinth of paths offer hundreds of restaurants, shops, and extraordinary geologic features.

Welcoming Party

(meeting registration required)

Celebrate the grand opening of the 1998 GSA Annual Meeting and Exposition at the Metro Toronto Convention Centre. Join colleagues and exhibitors at a reception brimming with international flavor and Toronto hospitality.



MONDAY, OCTOBER 26

Alumni Receptions

Plan to join your former classmates for an evening of memories and renewed connections.

TUESDAY, OCTOBER 27

Royal Ontario Museum Wine and Cheese Reception

Explore the treasures of the fabulous Royal Ontario Museum (ROM). The evening begins with a wine and cheese reception in Eaton Hall, where you'll meet the curators of the various exhibits and get an *inside* look at this world-renowned facility.

WEDNESDAY, OCTOBER 28

Pub Crawl

Visit some of Toronto's finest pubs. Guides, familiar with various brews as well as the fascinating history of the area, will lead the way in this fun-filled evening.

Registration, Travel, and Lodging

REGISTRATION

Preregistration Deadline:
September 18

Cancellation Deadline:
September 25

Registration materials will be available in June *GSA Today.* That will be the only complete registration issue.

Make plans now to take advantage of the June registration opportunity. Registration is required for events, which will fill quickly. There are considerable savings on registration fees if you register early. One-day registration is available on-site Sunday through Thursday. Guest and spouse registrations do not include technical session access. GSA members will automatically receive registration information and forms during the first weeks of June. If you are not a member and would like registration forms and further information, contact the Registration Coordinator, GSA headquarters, meetings@geosociety.org.

Meeting registration fees have not been established as we go to print. However, for your budgeting and travel authorization requests, please use the estimated preregistration fees below (U.S. dollars). Final fees will be published in the June issue of *GSA Today.*

MEMBERS PAY LESS … JOIN NOW!

If you are not yet a GSA member, NOW is the time to join. Nonmembers who become GSA members by October 1, 1998, can preregister at the member rate. You will save a substantial amount on your registration fee by paying the member rate—almost exactly the amount you would pay to join GSA. That's like joining GSA for free! For further information, contact Membership Services at GSA headquarters, member@geosociety.org.

ACCESSIBILITY FOR REGISTRANTS WITH SPECIAL NEEDS

GSA is committed to making every event at the 1998 Annual Meeting accessible to all people interested in attending. If you have special requirements, such as hearing-aided equipment or wheelchair accessibility, indicate them on the meeting registration form, or contact Kathy Lynch, GSA headquarters, ext. 114, klynch@geosociety.org. Please let us know your needs by September 25.

ESTIMATED REGISTRATION FEES

Costs in U.S. dollars	ADVANCE Full Meeting	ON-SITE Full Meeting	ON-SITE One Day
Professional Member	$210	$255	$128
Professional GSA Member 70 or older	$160	$205	$ 78
Professional Nonmember	$255	$300	$148
Student Associate Member	$ 75	$100	$ 51
Student Nonmember	$100	$125	$ 61
Guest or Spouse (no technical session access)	$ 75	$ 75	n/a
K–12 Professional	$ 25	$ 35	n/a
Cont. Ed. or Field Trip Only	$ 35	$ 35	n/a

Skydome Stadium and CN Tower — Photo courtesy of Metropolitan Toronto Convention & Visitors Association

TRAVEL

GSA's official travel agent (to be listed in June *GSA Today*), is committed to obtaining the best possible fares for GSA Annual Meeting travelers. Advance bookings with Saturday night stay-over are the best route to lowest fares. However, as with all airline reservations, please use caution regarding change and cancellation penalties that accompany low-fare tickets. This applies especially to field trip and continuing education participants, whose trip or course may be canceled after the September 18 preregistration deadline.

The Lester B. Pearson International Airport is located in the northwestern corner of Toronto and is about 30 to 40 minutes from downtown. Airport shuttle services are provided from the airport to downtown hotels for a small fee. For further information on Ontario contact the Canadian Tourism Commission, 235 Queen St., Ottawa, ON, K1A 0H6, Canada, (613) 954-1900. Their Web site is www./info.ic.gc.ca/tourism. For local Toronto information contact Tourism Toronto, P.O. Box 126, 207 Queens Quay W., Suite 590, Toronto, ON, M5J 1A7, Canada (416) 203-2600. Their Web site is www.tourism-toronto.com.

"We're not in Kansas anymore, …"

And crossing the border is EASY—thousands of people do it every day. There are just a few basic things to remember. Visit the GSA Toronto Web site for links to travel information: www/geosociety.org/meetings/98, then e-mail us if you have questions: meetings@geosociety.org.

FEDERAL AND STATE EMPLOYEES

Please put your request in NOW for foreign travel. Canada is still regarded as foreign travel by the federal government as well as many state governments. Be sure the GSA Annual Meeting in Toronto is on the "approved" travel list.

U.S. VISA HOLDERS

Please get in touch with your consulate NOW. You may travel easily into Canada, but you may encounter some questions when returning into the United States. Citizens or permanent residents of other countries must have a valid passport and/or a valid visitors visa and should contact their local Canadian Embassy, Consulate, or High Commission Office for further qualification.

TRAVEL AND IMMIGRATION INFORMATION FOR CONVENTION DELEGATES

Citizens or permanent residents of the United States can usually cross the border without difficulty or delay. However, certain types of identification are required by both Canada and U.S. Immigration. For native-born Americans and/or U.S. citizens, Canadian Immigration requires either a passport or a **birth certificate, supported by photo I.D.** For return entry, U.S. Immigration officials also suggest that you have one of these items with you, in addition to your normal identification. A permanent resident who is not a citizen is required to possess a 1551 or 1151 form ("Green Card") by both U.S. and Canadian Immigration.

"KNOW BEFORE YOU GO" BROCHURE—U.S.

This brochure informs travelers of applicable exemptions, restrictions, etc. It can be obtained by contacting any local Customs office, some federal bookstores, and many travel agents.

GSA STUDENT ASSOCIATE MEMBER TRAVEL GRANTS

The GSA Foundation has awarded matching grants to the six GSA Sections. The money, when combined with equal funds from the Sections, is used to assist GSA Student Associates traveling to GSA meetings. The following sections offer assistance to the Annual Meeting in Toronto. The remaining two sections, Cordilleran and Rocky Mountain, offer assistance to their section meetings. For information and deadlines, contact your Section Secretary.

- ***North-Central:*** Robert F. Diffendal, Jr. (402) 472-7546, rfd@unlinfo.unl.edu
- ***Northeastern:*** Kenneth N. Weaver (410) 554-5532, kweaver438@aol.com
- ***South-Central:*** Rena M. Bonem (254) 710-2361, bonemr@baylor.edu
- ***Southeastern:*** Harold H. Stowell (205) 348-5098, hstowell@wgs.geo.ua.edu

LODGING

GSA has booked rooms at eight properties that offer special convention rates ranging from CAN$86 (US$60) to CAN$155 (US$109) single, and CAN$86 (US$60) to CAN$177 (US$124) double. A block of 600 rooms is reserved at the Sheraton Centre, which is the headquarters for the meeting, and will host most social and business events. Other participating hotels include the Royal York, Marriott Eaton Centre, Days Inn Toronto, Delta Chelsea Inn, Bond Place, Strathcona Hotel, and Toronto Colony Hotel. In addition, several lower cost properties will be available to student registrants.

Most activities will take place at the Metro Toronto Convention Centre, the Sheraton, and the Delta Chelsea Inn.

GSA SHUTTLE

Only two of the Toronto hotels are within easy walking distance from the Convention Centre; however, GSA will provide daytime shuttle service between the other GSA-selected hotels and the Convention Centre throughout the week. Service will be extended to all GSA hotels during the evening hours.

EMPLOYMENT INTERVIEW SERVICE

GSA will again be offering its Employment Interview Service. Each year, this program provides valuable job-matching opportunities in the geosciences. At the 1997 meeting, in Salt Lake City, participating employers conducted over 504 interviews with nearly 211 applicants seeking employment!

As in the past, booths will be provided for employers to interview applicants registered with the Employment Service, and GSA staff will be on hand to coordinate the scheduling of interviews. In particular, students completing doctoral and master's theses during 1998 are encouraged to check the job offerings.

See the July 1998 issue of *GSA Today* for applicant and employer forms and further information, or contact Terry Moreland, Employment Service Manager, GSA headquarters, tmorelan@geosociety.org. Information is also available on GSA's Web site, www.geosociety.org, in the Membership Services section.

GRADUATE SCHOOL INFORMATION FORUM

This forum provides an opportunity for undergraduate students planning to obtain advanced degrees to meet one-on-one with representatives of graduate schools. This informal setting provides a unique opportunity to discuss interests and explore programs. A list of participating schools will appear in the June and September issues of *GSA Today.*

If your school is interested in participating, contact GSA headquarters, meetings@geosociety.org. The reservation deadline is August 15.

STUDENTS! FREE BREAKFAST

GSA President, Vic Baker, invites all the students registered for the meeting to join him and many other GSA officers for a free buffet breakfast hosted by Exxon early on Monday morning, October 26. Put this one on your calendar now!

GUEST PROGRAM

A hospitality room will be provided in the Sheraton Centre Hotel for registered guests to meet, enjoy refreshments, and obtain information on Toronto and surrounding areas. Formal and informal tour information will also be available. Guest registration includes an exhibit hall pass, but does not give access to technical sessions. (A guest can obtain a temporary pass to see a spouse or friend present his/her paper.)

PRELIMINARY LIST OF ORGANIZED TOURS

Open to All GSA Registrants

Look for detailed tour descriptions and prices in the June issue of *GSA Today.*

- Bird watching
- City tour
- Niagara Falls tour, including Butterfly Museum and lunch at a winery
- McMichael Gallery, Kleinburg—guided tour
- Festival Theatre Trip
- Cooking class
- Art Gallery of Ontario—guided tour
- High Tea at the King Edward Hotel
- Don Valley Brick Works Museum and Park tour, and walk along the stream to Mount Pleasant Cemetery

DEMO THEATER

The GSA Demo Theater offers individual demonstrations of geoscience products, services, and new technologies. Also included are shareware and freeware opportunities. The presentation schedule will appear on GSA's Web site in August and in the on-site *Program.* If you are interested in showcasing your product, service, or shareware/freeware, contact the Exhibits Manager by e-mail: meetings@geosociety.org.

Exhibits

The 3½ day 275-booth exposition will showcase more than 170 organizations representing the latest geological publications; geological software; scientific instrumentation; microanalysis and photographic equipment; geoscience educational supplies; gems, minerals, and fossils; resource information from environmental, national, and state agencies; field supplies and gear; geoscience associations, laboratory services, miscellaneous services, and information on earth science programs at major institutions. Find out more about our current 1998 exhibitors by visiting our on-line Product and Service Guide. www.geosociety.org/meetings/98.

Exhibitors can reach more than 6,000 influential and key decision-makers from the geoscience community, meeting face-to-face with attendees and developing new customers, increasing sales, and educating current customers on your organization's benefits. For information on becoming an exhibitor and taking advantage of this highly cost-effective marketing opportunity, contact the Exhibits Manager, GSA headquarters, meetings@geosociety.org.

1997 PRESIDENTIAL ADDRESS

Deep Mantle Plumes and Geoscience Vision

George A. Thompson, *GSA President, 1997*

Joy and amazement at the beauty and grandeur of this World of which Man can just form a faint notion

—Albert Einstein

INTRODUCTION

Humans, perhaps alone in the animal world, have a basic spiritual hunger to soar beyond the mundane. This has led to superstition and magic, but more importantly to a serious awe and reverence for the nighttime sky and a hunger for understanding Nature in all its variety. This spiritual hunger was a theme of Eldridge Moores in his address to you a year ago, and I carry on the theme. Einstein may have been a geologist at heart. Geoscience, along with astronomy, provides a far more fantastic reality than magic, of our tiny place in the immense span of time and space—in the case of geoscience we enjoy a full range from the spiritual to useful applications. We geoscientists are lucky to be able to enjoy that vision and also to find oil, manage groundwater, mitigate landslides, and predict volcanic eruptions. Most important, we need to learn, and to help our fellow humans learn, to interact with Earth without degrading it irretrievably, to live sustainably beyond our individual tiny niche in space and time.

I am pleased to report that your Society is doing an excellent job of reaching out, in education and in public policy, through two programs that are largely self-sustaining. A glance through the program of this meeting [the 1997 GSA Annual Meeting] will demonstrate that a large fraction of the program is devoted to GSA's efforts to educate at all levels.

Now, what does all this have to do with deep mantle plumes?

GEOSCIENCE CONCEPTS

Great unifying concepts or models, sometimes called paradigms to make them more mysterious, not only cut through the barriers of specialization and jargon among ourselves but also allow us to communicate the beauty and challenge of science to nonscientists, a goal advocated by Richard Feynman: *"The world looks so different after learning science. For example, trees are made of air, primarily. When they are burned, they go back to air, and in the flaming heat is released the flaming heat of the sun which was bound in to convert the air into tree. [A]nd in the ash is the small remnant of the part which did not come from air, that came from the solid earth, instead. These are beautiful things, and the content of science is wonderfully full of them. They are very inspiring, and they can be used to inspire others."* [Quoted in *National Science Education Standards,* National Academy Press, 1996.]

Clearly, the theory of plate tectonics, now about 30 years old, tops the list of great unifying concepts in earth sciences. To illustrate its power for communication with the public: Anita and I, who are weekend tree farmers, discovered that a logger friend with an abbreviated high school education knows all about plate tectonics—mostly learned from public television and popular reading, but not far from the accurate scientific mark (Fig. 1). And besides the *fun* of plate tectonics, no exploration program can afford to ignore it!

A second great unifying concept is that of biological mass extinctions and the role of asteroid impacts. The resulting fits and starts of evolution are responsible for the rise of mammals like us. Despite erosion and subduction, impact structures are abundant on Earth. The Manicouagan impact crater on the Canadian shield, for example, (Fig. 2) is 70 km in diameter and is 210 m.y. old. Meteor Crater, Arizona (Fig. 3), is 1.2 km in diameter and has an age of only 25 ka. I show Meteor Crater in memory of Gene Shoemaker, who studied it so well. The implications of *larger*

Presidential Address *continued on p. 18*

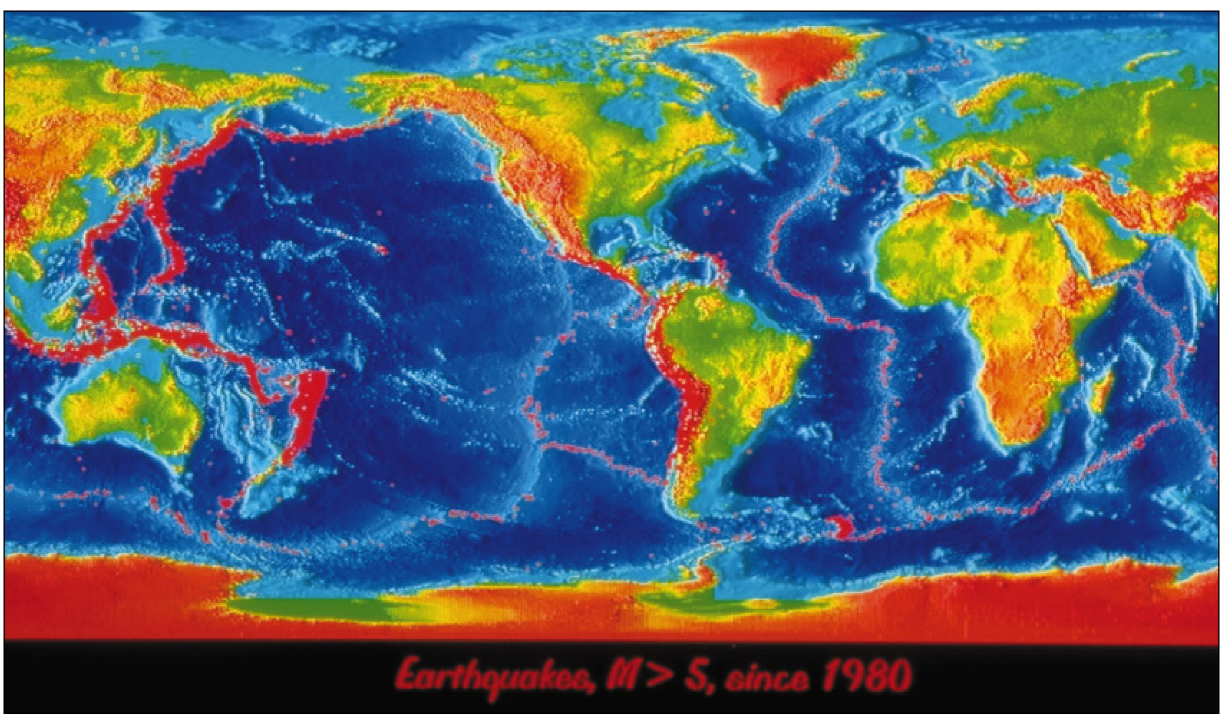


Figure 1. Tectonic plates on Earth. The Hawaiian seamount chain is near the upper left. From NASA.

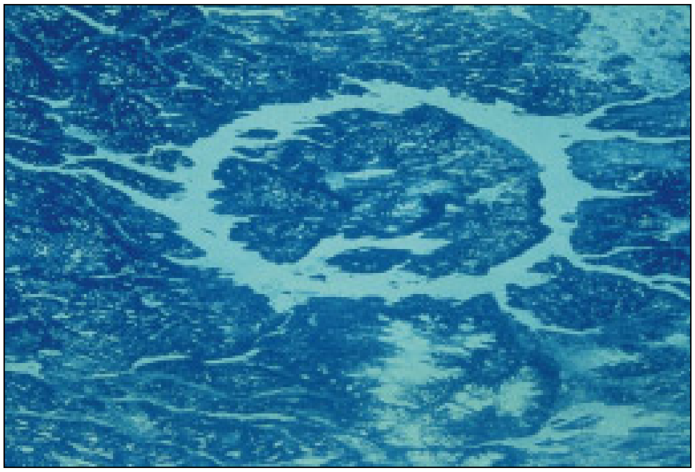


Figure 2. The Manicouagan impact crater on the Canadian shield, 70 km in diameter and 210 m.y. old. From NASA.

Figure 3. Meteor Crater, Arizona, 1.2 km in diameter and 25 ka. From NASA.

Presidential Address *continued from p. 17*

impacts for life and for evolution are staggering. They include the confirmation of impact splashes from Mars onto Earth and intense speculative interest in the possibility of transfer of fossils or even of primitive life among the planets.

Third are the extremophiles, life forms that live in extremes of boiling water and in rocks at depths and temperatures that seem like pure fantasy. They are an abundant biomass, unsuspected until recently, and their implications for evolution, for chemical changes, and for applications are barely imagined.

Finally, my own current fascination with an important unifying concept is with deep mantle plumes. Tuzo Wilson (1993) did not live to deliver his talk on the neglect of deep mantle plumes, but he would be excited to learn of progress since 1993. I focus here on the geophysical and tectonic aspects, and outline without much qualification models that in some cases are quite speculative. By adopting the simplest interpretation of present evidence—the criterion of Occam's razor—I'll be at the risk illustrated in a cartoon of Jack Oliver's showing Occam accidentally cutting his own throat.

CONCEPT OF DEEP MANTLE PLUMES

Mantle plumes are the mothers of flood basalts and of the greatest dike swarms on Earth (e.g., Ernst and Buchan, 1997); they help to drive tectonic processes and to deposit ores. Their surface expression, long-lived *hotspots,* such as Hawaii, Iceland, and Yellowstone, form a comparatively stationary reference frame over which the tectonic plates perform their slow dance, making volcanic tracks such as the Hawaii-Emperor seamount chain, which tracks the differential movement between the hotspot and the Pacific plate (e.g., Tarduno and Cothrell, 1997). Even at the world scale of Figure 1 one can make out this chain. About 40 hotspots are usually identified worldwide; a compilation for the western hemisphere is shown in Figure 4. Some of these are almost certainly secondary, produced by sublithospheric buoyant flow from major plume heads (e.g., Ebinger and Sleep, 1998). In contrast to plumes, ordinary convection expressed at ocean ridges cools the mantle, and, as pointed out to me about 30 years ago by Tanya Atwater, the ridges move about with respect to each other. This is easily seen in the ridges surrounding Africa (Fig. 1), where the

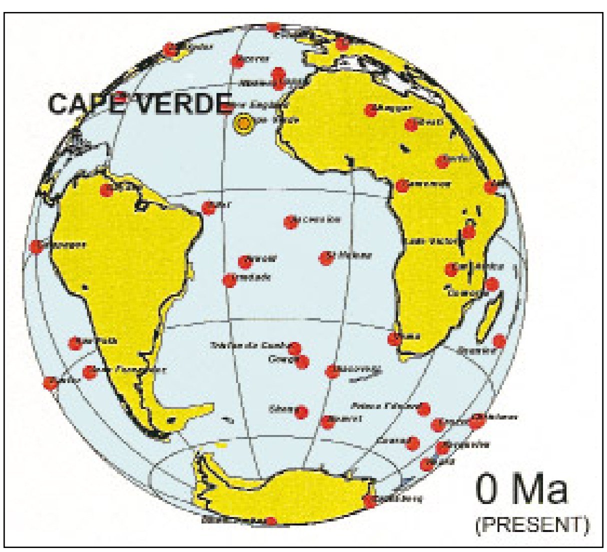


Figure 4. A compilation of hotspots in the western hemisphere; the Cape Verde hotspot is highlighted for this paper. From unpublished work by Stephen Gardoll (University of Western Australia) and Andrew Long (Stanford University).

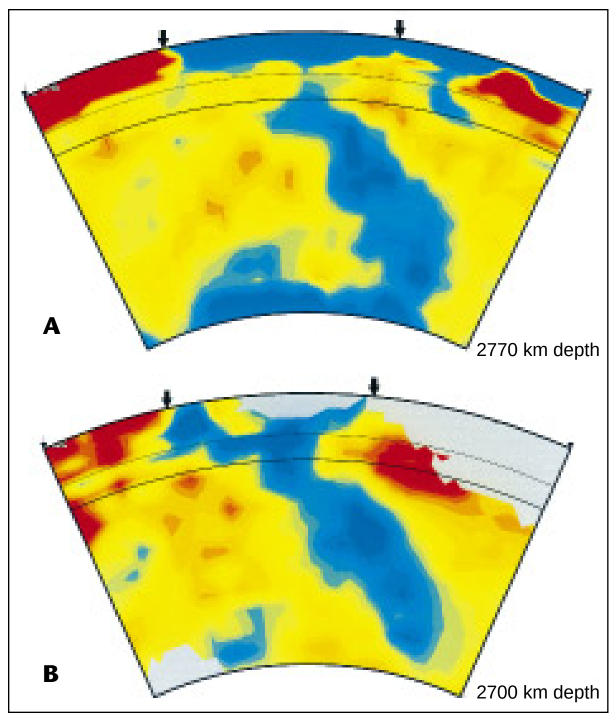


Figure 5. The Farallon subducted slab independently imaged by P and S waves (A and B, respectively) in a section across North America. Blue represents seismically slower and therefore cooler regions. The base of each section is near the thin D" layer, transitional from the mantle to the liquid core. From Grand et al. (1997).

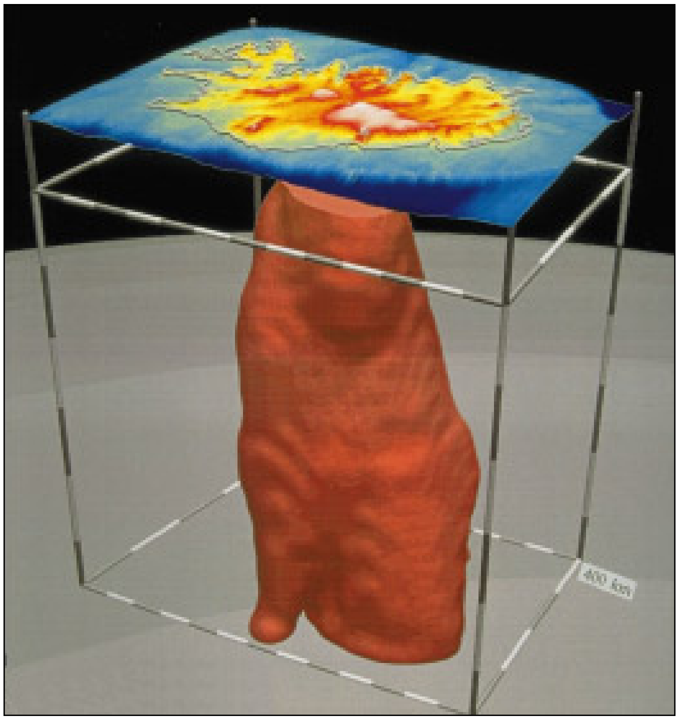


Figure 6. Earthquake tomographic image of the Iceland plume column to a depth of about 400 km. From C. Wolfe (Wolfe et al., 1997).

ridges must move apart because there is no subduction within the African plate. Deep mantle plumes, on the other hand, supply the cooling mechanism for Earth's liquid core.

Improved earthquake tomography shows that at least some subducted slabs plunge all the way to the core-mantle transition zone, the D'' layer of seismology (Fig. 5). The Central America and Japan subducted slabs are similar (van der Hilst et al., 1997) to the Farallon slab. Earthquake tomography also demonstrates a surprisingly low velocity and lateral heterogeneity in the thin (200 km) core-mantle transition zone (e.g., Kuo and Wu, 1997; Wysession et al., 1992), an unstable situation that leads to buoyant rise of incipient plumes, which are too small to be clearly imaged at these depths.

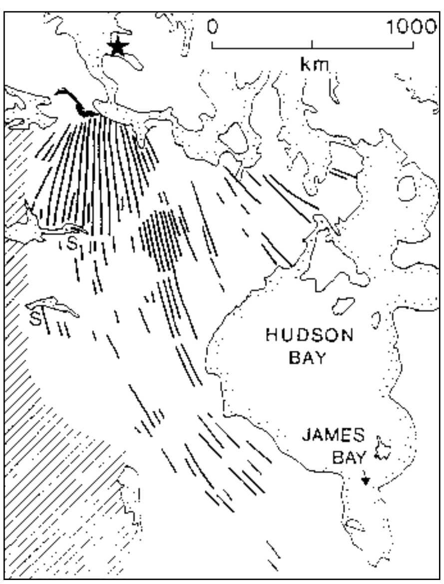


Figure 7. Simplified map of the Mackenzie giant radiating dike swarm (1.265 Ga) of northern Canada. S marks coeval sills: black area indicates coeval Coppermine volcanics. From Ernst et al. (1995).

Plumes in laboratory models (e.g., Whitehead and Luther, 1975) develop a rising viscous column topped by a voluminous head several times as large—imagine a mushy golf ball on a mushy tee. In nature, the rising column is perhaps as thin as 100 km in diameter, and the head is many times larger. When the head reaches the base of the lithosphere, a geologic drama begins. The column of the Iceland plume is shown to a depth of about 400 km in the earthquake tomographic image of Figure 6. The plume head (the golf ball) has already dispersed from the Iceland plume by buoyant flow into and along the rift, as computationally modeled by Sleep (1997).

The starting plume head, hundreds of degrees hotter than normal mantle, spreads laterally beneath the comparatively refractory lithosphere, incorporates surrounding mantle, and buoyantly uplifts a region roughly 1000 km in diameter to produce a topographic bulge about 1 km high (Sleep, 1997, and references therein). Decompression melting in *and around* the plume head can produce immense volumes of magma rapidly, generating huge dike swarms and erupting as flood basalts, whose volumes are typically several million cubic kilometers. The plume tail (the tee under the golf ball) lives on as a rising convective column for tens to hundreds of millions of years and produces a track of volcanism such as the Hawaii-Emperor seamount chain if the overlying plate is moving relative to the plume. It is important to emphasize that the starting head and the presumed flood basalts that signaled the first emergence of the Hawaiian plume are long gone—probably subducted at the Aleutian trench. Hawaii and its hotspot track, as well as Yellowstone and Iceland, are solely manifestations of plume tails.

Mackenzie Dike Swarm and Intrusive Sheets

Giant, radiating dike swarms are key to recognizing ancient mantle plumes even where tell-tale flood basalts have been tectonically or erosionally removed (e.g., Ernst and Buchan, 1997). A striking example is the 1.265 Ga Mackenzie swarm of northern Canada (Fahrig and West, 1986) (Fig. 7) with an extent of about 2000 km! Dikes make their own fractures in the brittle crust, inflate to widths of tens of meters, and propagate, at about the rate a person can walk, for hundreds of kilometers.

In addition to dike swarms, which are usually mapped aeromagnetically, seismic reflection imaging has discovered extensive subhorizontal intrusive sheets in the mid-crust. Some are connected with the Mackenzie dikes (Mandler and Clowes, 1997). The Winagami reflection sequence, of an age bracketed between 1.89 and 1.76 Ma, has been found over an area of 120,000 km^2 in western Canada (Ross and Eaton, 1997). The intrusive sheets, typically about 10–300 m thick, usually cut

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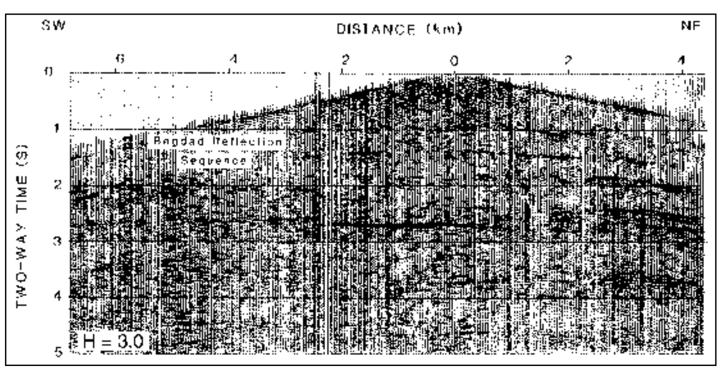

Figure 8. Subhorizontal intrusive sheets in the Precambrian crust of Arizona, imaged from a single large explosion (Goodwin et al., 1989).

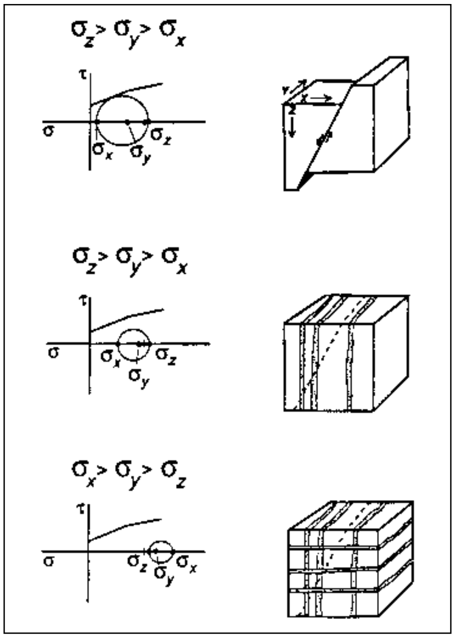

Figure 9. Progressive (from top to bottom) effect of dike injection on stress relations in an extending (normal faulting) environment. The Mohr diagrams show how dike inflation tends to increase the least horizontal stress, diminish the stress difference (shown by the diameter of the Mohr circle), suppress normal faulting, make the vertical stress least, and lead to injection of horizontal sheets. From Parsons and Thompson (1991).

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across rock fabric and reside at a range of mid-crustal depths. Similar subhorizontal intrusions are common the world over. Figure 8 shows a seismically imaged example from Arizona (Goodwin et al., 1989). The explanation for the process of subhorizontal sheet intrusion is intriguing (e.g., McCarthy and Thompson, 1988; Parsons and Thompson, 1991). As shown in Figure 9, dikes inject perpendicular to the least horizontal stress, as in artificial hydraulic fracturing, but unlike the hydrofrac process, magma chills against the fracture walls, inflates the dike, and in so doing increases the horizontal stress until the vertical stress becomes least. Melt then shoots off in horizontal sheets, again perpendicular to the least stress, lifting the crust above. Injection of a 5-m-thick dike is equivalent to a very large normal-fault earthquake in its effect on the elastic stress in the crust. Dike injection always tends to decrease the stress difference and therefore to suppress faulting and earthquakes.

Deep crustal reflection imaging now has the resolution to illuminate tectonic events and processes in three dimensions.

YELLOWSTONE MANTLE PLUME

The Yellowstone plume first emerged at the McDermitt caldera along the Oregon-Nevada border about 16–17 m.y. ago (Fig. 10), although it may have had ancestral expressions (Geist and Richards, 1993; Opplinger et al., 1997). From this center, dikes raced southward for hundreds of kilometers, forming the northern Nevada rift, and northward to feed the Columbia River flood basalts (Pierce and Morgan, 1992; Zoback and Thompson, 1978; Zoback et al., 1994). The Nevada aeromagnetic map (Fig. 11) shows the expression of the northern Nevada rift and subparallel or radiating rifts to the west. A map of exposed dikes in part of the rift is shown in Figure 12. A region perhaps 1000 km in diameter was buoyantly elevated perhaps 1 km by the starting plume head and has now tectonically extended and subsided. The effects of the plume in the northern Basin and Range province and eastern Sierra Nevada were dramatic and profound.

The extended crust is only half as thick as needed to support the elevation, and the excess buoyancy is in the upper mantle (Fig. 13). The relic of the Yellowstone plume head is a mass deficiency cal-

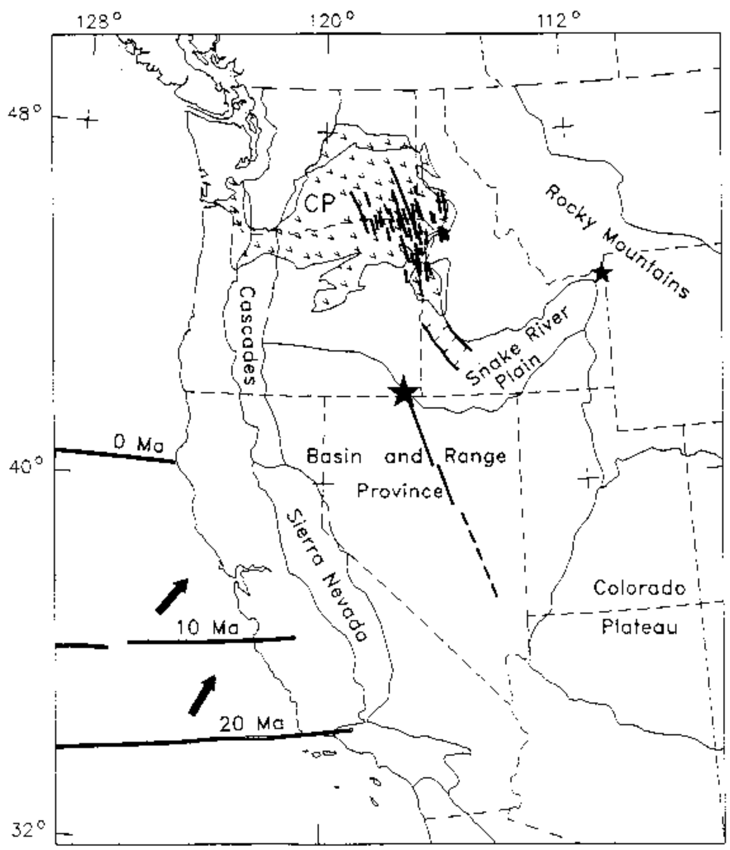

Figure 10. Emergence point of Yellowstone plume (large star), its track on the Snake River Plain, and its present position at Yellowstone (small star). The line extending south from the large star indicates dike swarms of the northern Nevada rift. To the north are shown the Columbia River flood basalts (CP) and their feeder dikes. Heavy lines at left indicate the position of the Mendocino fracture zone at three time intervals. From Zoback et al. (1994).

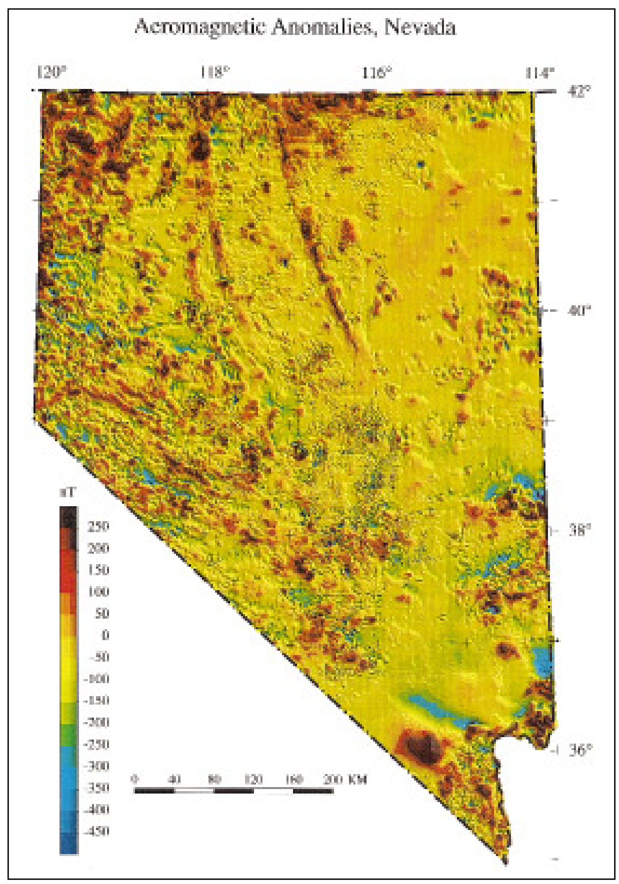

Figure 11. Aeromagnetic map of Nevada; the most prominent anomaly is associated with the dike swarms of the northern Nevada rift. Smaller subparallel anomalies west of the rift probably indicate concealed dikes radiating from the emergence point of the Yellowstone plume. From Blakely (1988).

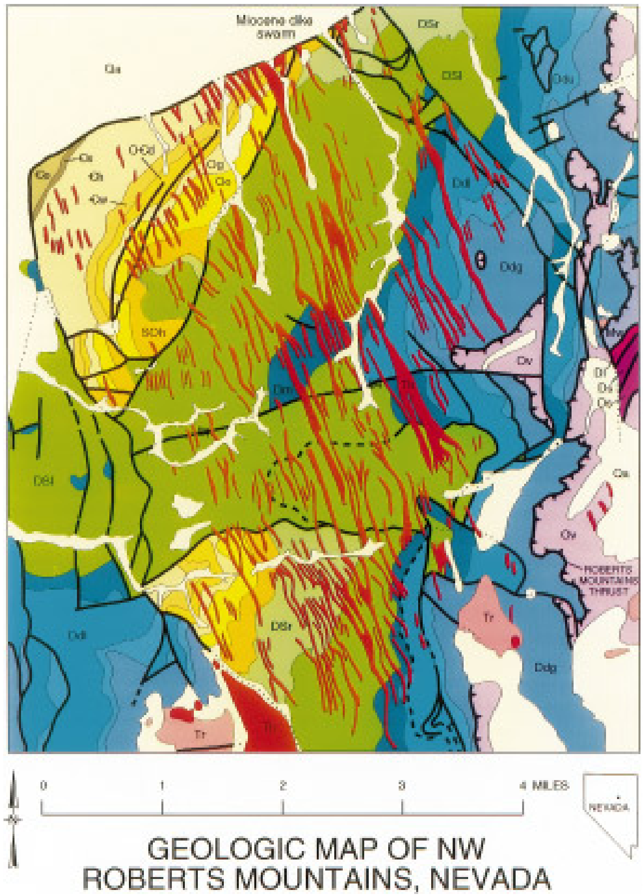

Figure 12. Dikes of the northern Nevada rift exposed in the Roberts Mountains. From Zoback et al. (1994).

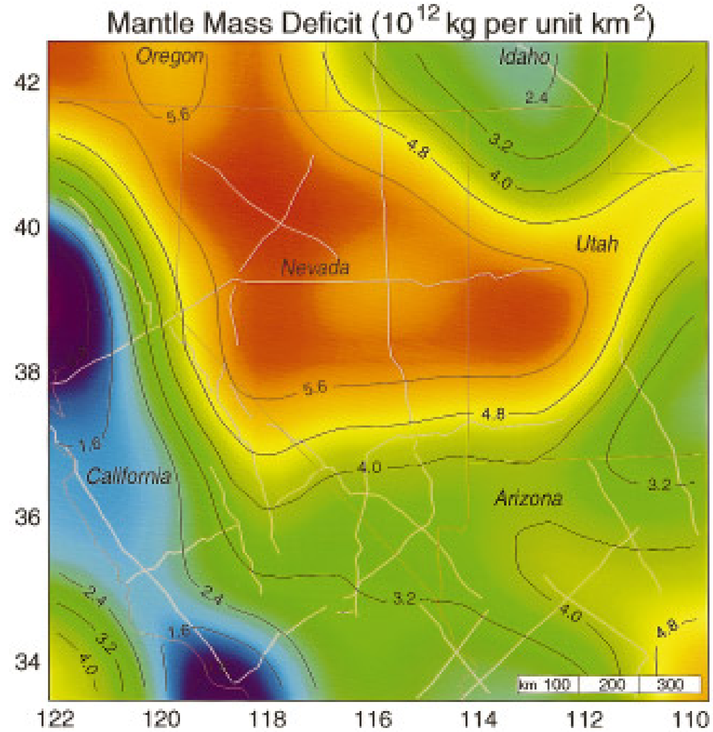

Figure 13. Probable location of the plume head of the Yellowstone hotspot, expressed as mantle mass deficiency (or excess buoyancy) per unit area, as calculated from crustal seismic data and gravity constraints. From Parsons et al. (1994).

culated by Parsons (Parsons et al., 1994) from seismic and gravity data. Meanwhile, the North American plate was moving southwestward, carrying much of the material of the plume head with it, while the plume tail or stem produced a remarkable volcanic track along the eastern Snake River Plain to its present location beneath the Yellowstone Plateau (Fig. 14; topographic track is 100 km wide).

Remarkably, as the Basin and Range terrane extended southwestward in this region, breaking into large normal-faulted blocks and producing large earthquakes, the Snake River Plain somehow extended along with the surrounding mountains but without large normal faults or earthquakes. The key to this puzzle is revealed by lines of basaltic vents and minor rifts, marking dike swarms that extend across the plain (Fig. 15). The plain stretched by dike injections in a process akin to ocean-ridge spreading (Fig. 16).

The Yellowstone mantle plume, in summary, powered much of the late Cenozoic tectonic and magmatic activity in a broad region.

CENTRAL ATLANTIC (CAPE VERDE) PLUME

Primary evidence for the giant Central Atlantic, or Cape Verde, plume (Fig. 17) is an extraordinary system of Jurassic diabase dikes (Fig. 18) that radiated from approximately the Blake Plateau off the southeastern U.S. coast for thousands of kilometers into North America, South America, and Africa at a time when these continents were still joined. May (1971) recognized the unity of this dike system in a paper, published, I'm happy to say, in the *GSA Bulletin*. Corresponding flood basalts are seismically imaged offshore (Lizarralde and Holbrook, 1997; Kelemen and Holbrook, 1995; Fig. 19 here), and along with intrusive rocks

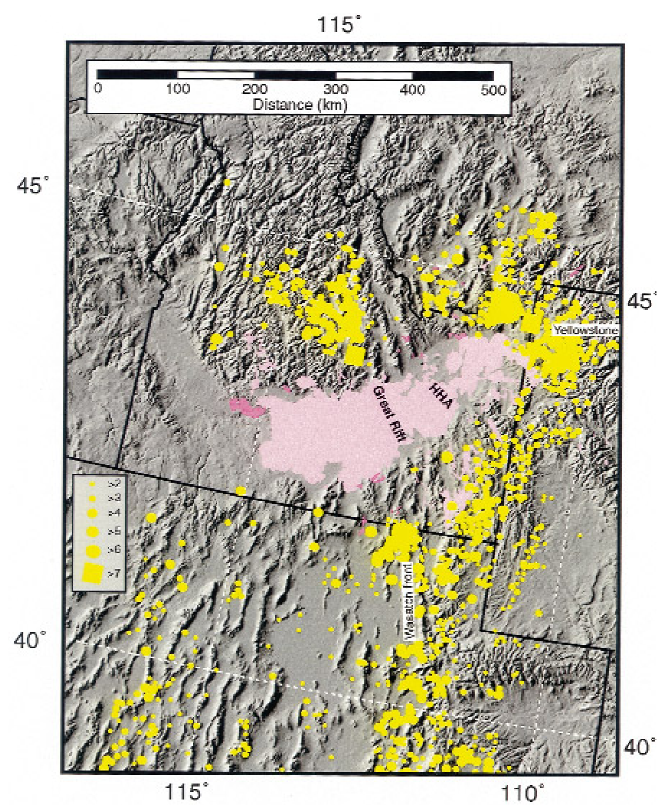

Figure 14. Plume track of the Yellowstone hotspot, forming the eastern Snake River Plain, and Basin and Range fault blocks to the north and south of the plain. Yellow marks earthquakes. From Parsons and Thompson (1991).

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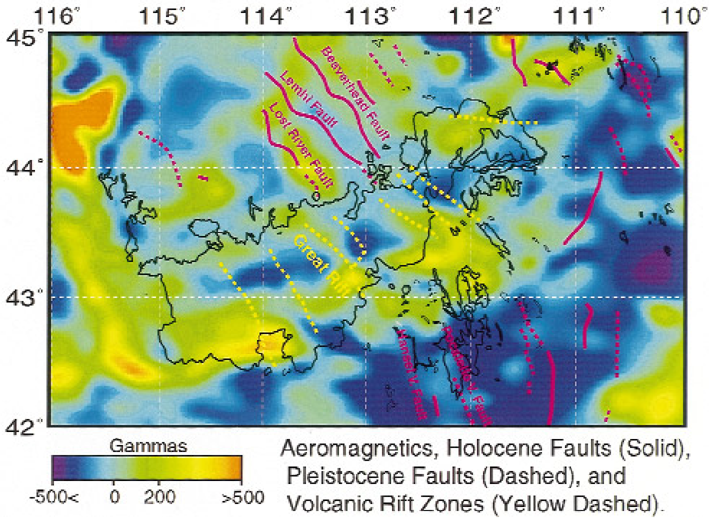

Figure 15. Lines of basaltic vents and minor rifts (dashed yellow lines) extending across the eastern Snake River Plain. From Parsons et al. (1998).

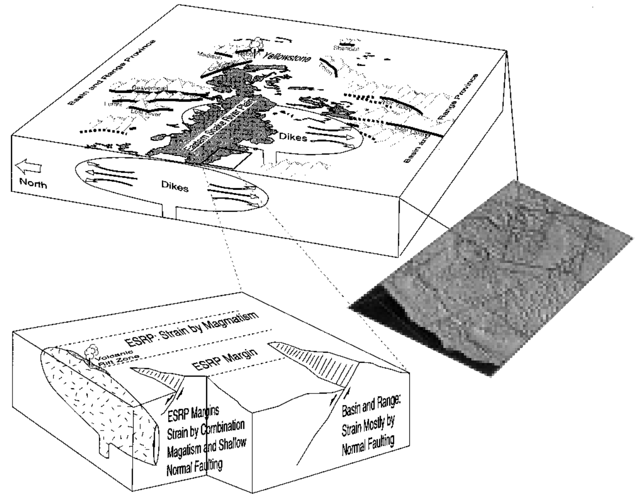

Figure 16. Model for aseismic strain by dike injection in the eastern Snake River Plain (ESRP) and transition to block faulting off the plain. From Parsons et al. (1998).

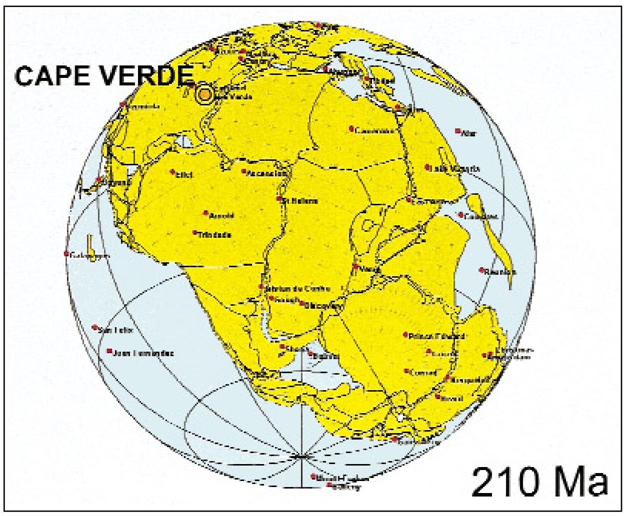

Figure 17. Location of the Cape Verde and other plumes at 210 Ma. From unpublished work of Stephen Gardoll (University of Western Australia) and Andrew Long (Stanford University).

201 Ma, Early Jurassic (e.g., Deckart et al., 1997; Weems and Olsen, 1997, p. 199). But well before the magmatic activity broke out, eastern North America began to pull apart in the extensive system of Triassic, sediment-filled rifts roughly parallel with the coast and with the earlier Paleozoic structures. The plume head underlay this region (Fig. 17). When magma broke through the lithosphere, radial and then rift-parallel dikes were injected for thousands of kilometers. The pattern is complex in detail; for example, in North America a pulse of magma generated a prominent subcenter of dikes radiating from near the coast of South Carolina (Ragland et al., 1983).

In the hard Paleozoic and older rocks, the pressurized magma fractured and injected the rocks as dikes. Figure 21 shows a part of the Virginia geologic map (Virginia Division of Mineral Resources, 1993) with generally straight dikes cutting the older rocks. But in the softer sedimentary rocks of the Triassic Culpeper Basin in Virginia (Fig. 22), the magma ballooned into huge irregular dikes, sills, and blobs. Similarly, in the Gettysburg Basin in Penn-

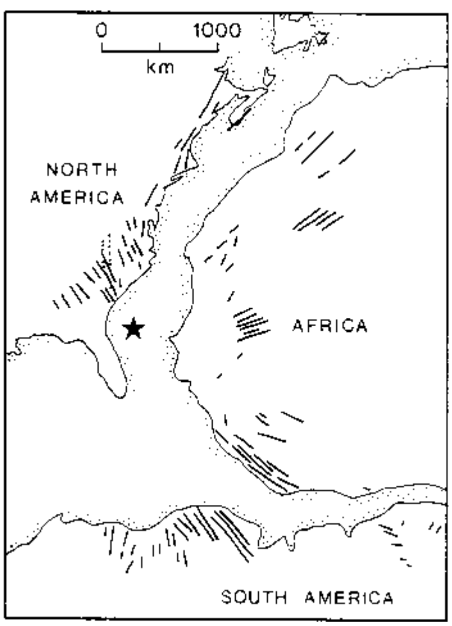

Figure 18. Giant swarm of Early Jurassic dikes radiating from offshore eastern North America (star) into the three continents before breakup. From Ernst et al. (1995).

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that inflated the crust, they are responsible for the East Coast magnetic anomaly (Fig 20). Here are the missing flood basalts! Modern, high-quality radiometric dates on dikes and flows on the three continents cluster around a starting time of about

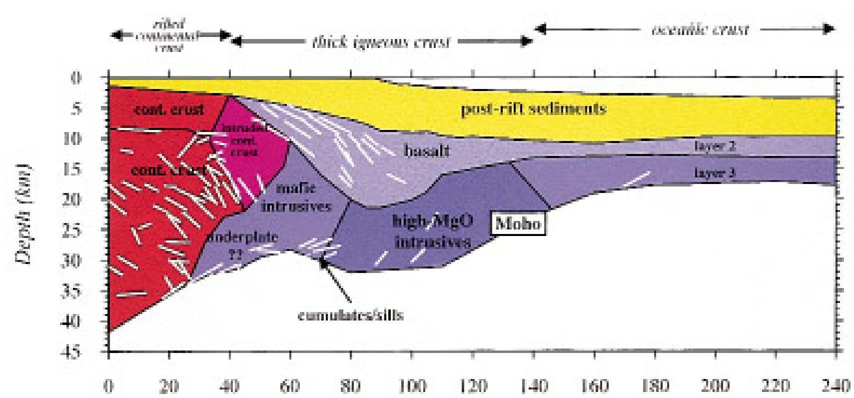

Figure 19. Cross section of the Atlantic margin of North America constructed from seismic images. From W. S. Holbrook (Lizarralde and Holbrook, 1997).

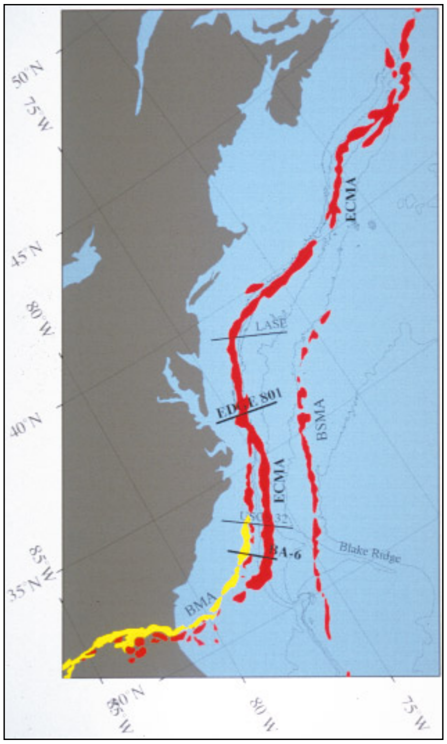

Figure 20. East Coast magnetic anomaly (ECMA), produced by the flood basalts and intrusions shown in Figure 19. From W. S. Holbrook (Lizarralde and Holbrook, 1997).

Figure 21. Part of the geologic map of Virginia (Virginia Division of Mineral Resources, 1993), showing the diabase dikes (red) cutting hard Paleozoic rocks. Width of area shown is 40 km.

sylvania, shown at a larger scale in Figure 23 (Pennsylvania Department of Environmental Resources, 1980), one sees the ballooning of the diabase intrusions. Here the master fault of the half-graben is on the north side and is now almost obliterated by the intrusive diabase. Also on the north side is the location of the great Cornwall magnetite deposit, which operated from well before the Revolutionary War until 1972, when a hurricane shorted out the power supply to the electric pumps. Ore deposits like Cornwall derived their iron and copper, as well as the heat for hydrothermal circulation, from the diabase intrusions, and

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Figure 22. Another part of the geologic map of Virginia, also an area 40 km wide, showing the diabase ballooning in the Triassic sedimentary rocks of the Culpeper Basin.

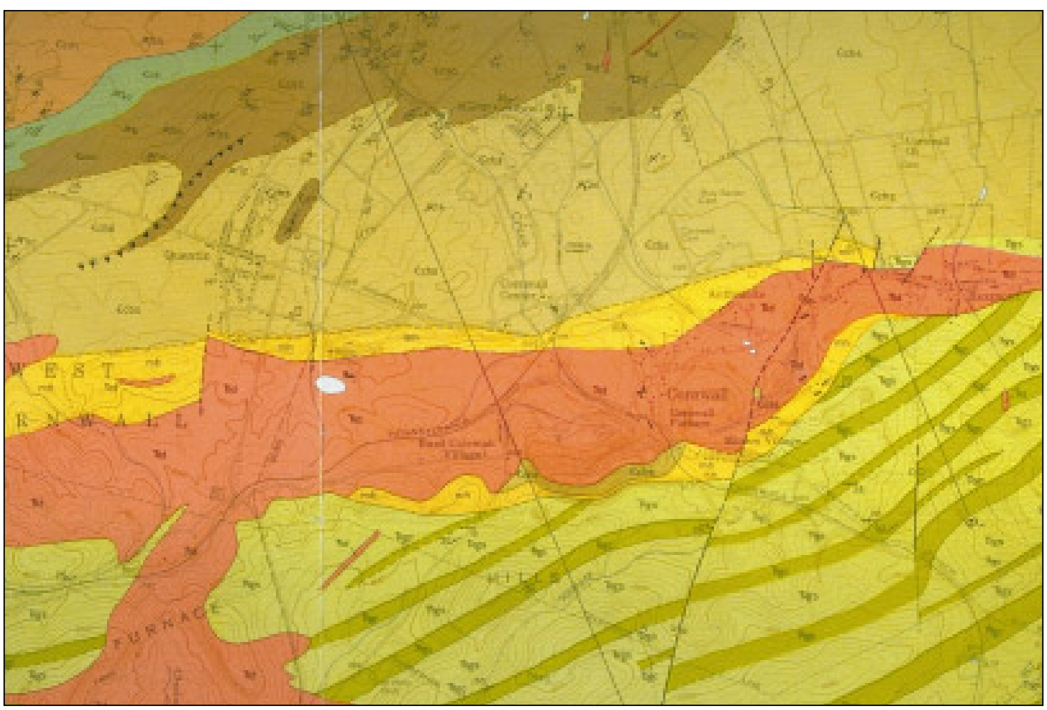

Figure 23. Part of the geologic map of Pennsylvania (Pennsylvania Department of Environmental Resources, 1980), 8-km-wide area, showing the northwest-dipping bands of Triassic sedimentary rocks (lower right) in the Gettysburg Basin. The huge irregular diabase intrusions (orange) balloon in the Triassic sedimentary rocks and mask the northern boundary fault of the half-graben. The northern boundary is the site of the historical Cornwall iron mine.

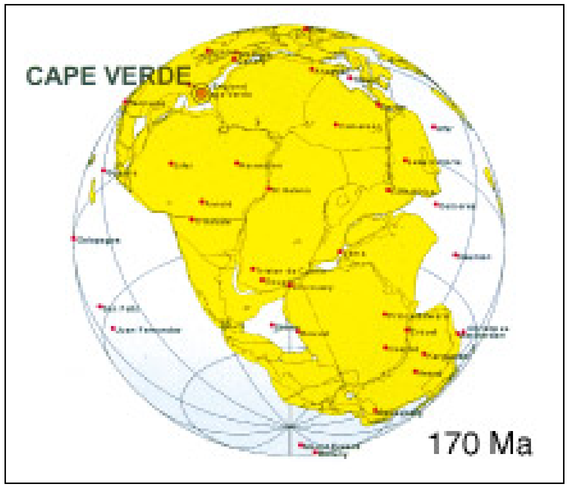

Figure 24. Location of the Cape Verde plume at 170 Ma, after initial opening of the Atlantic Ocean. From unpublished work by Stephen Gardoll (University of Western Australia) and Andrew Long (Stanford University).

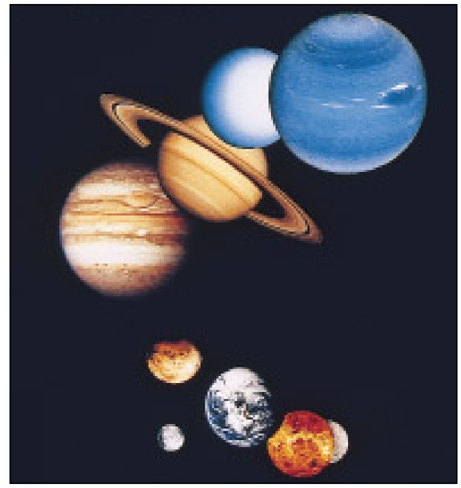

Figure 26. Earth, the blue-green water planet, is uniquely beautiful. From the National Academy of Sciences.

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Paleozoic carbonates precipitated the ore. Thus, a convective plume originating at the core-mantle boundary shaped our landscape and history in this region!

Meanwhile, the Atlantic had begun to open (Fig. 24). We can trace the path of the Central Atlantic plume and identify it clearly as the Cape Verde plume (Fig. 25). The Atlantic fracture zones (e.g., Kane; see Fig. 25) show the path of opening. The oldest magnetic stripes preserved in the ocean floor on both sides of the Atlantic date to about 170 Ma. As the African plate held nearly stationary in the hotspot frame of reference, North America sailed slowly away to the northwest at about the rate a fingernail grows. And the early Mid-Atlantic Ridge also moved northwest at half the North American rate, quickly advancing across and beyond the Cape Verde plume. Thus, the plume was captured by the nearly stationary African plate around 150 Ma and remains on the African plate today.

CONCLUSIONS

The immense volume of the hot plume head, and the lesser ongoing flow of the Cape Verde plume column, profoundly influenced the tectono-magmatic events on three continents. In western North America, the Yellowstone plume head spread widely, burped out the Columbia River basalts, and reactivated Basin-and-Range uplift and extension. The Yellowstone plume column, or tail, left a spectacular track, the eastern Snake River Plain, on the moving plate, and on the way revealed to us another mechanical process besides normal faulting for the continental crust to stretch, namely by emplacement of dikes, like the stretching at oceanic ridges.

These dramatic tectono-magmatic events are not mere passive consequences of the Atlantic opening or, in the west, passive consequences of older compression and subduction, but resulted from powerful new inputs of plume energy.

The paradigm of deep mantle plumes, like plate tectonics or asteroid impacts, supplies a wonderful unifying concept for geoscientists and for communicating our science to the world at large. Walter Sullivan said it well: "The discovery that there is order and logic in the seeming randomness of nature can be a quasi-religious experience. There is great beauty to be found there, and the succesful teachers and writers who, having glimpsed it, are driven to share it with others." [Quoted by Bruce Alberts in address to National Academy of Sciences, April 1996]

Earth, our beautiful blue-green water planet (Fig. 26), is clearly the best of the lot and deserves all the care that we can give to it!

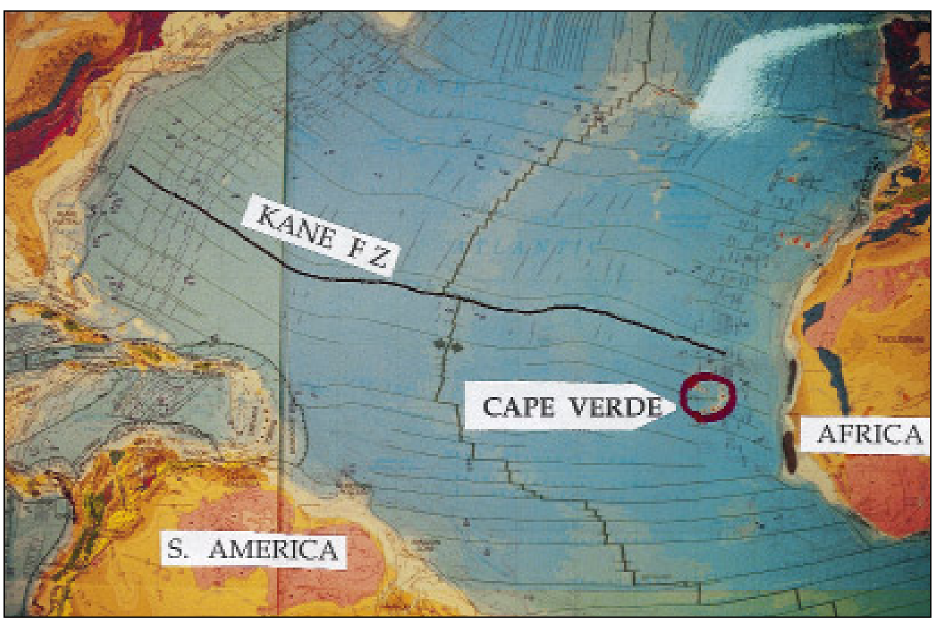

Figure 25. The present-day Atlantic ocean, showing fracture zones and magnetic chrons in relation to the Cape Verde hotspot. The fracture zones, marking the path of opening, lead clearly from the center of the Jurassic radial dike swarm (approximately at the Blake Plateau) to the Cape Verde hotspot. See text for further explanation. From Exxon Production Research (1985).

ACKNOWLEDGMENTS

I am indebted to many colleagues who, sometimes unknowingly, served as inspiring teachers. I am especially indebted to Norm Sleep and Tom Parsons for illuminating discussions of the growing knowledge about mantle plumes. The support of a talented and generous GSA staff made my year as president enjoyable and, I hope, productive.

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LETTER

The recent article by Eugenie Scott on "Creationism and Evolution" in the January *GSA Today* (SAGE Remarks) prompts this comment. As one who has been teaching for many years an undergraduate course on Darwin and the *Origin of Species*, I would like to provide another, rather different perspective on the creationism and evolution debate.

The approach I have found most useful for my students is to make clear the distinct epistemological differences between the rival claims of creationists and evolutionists. The epistemology of each side is diametrically opposed: what they know, how they know it, and the limits of their knowledge. The creationist is unequivocally committed to textual *content,* namely the literal meaning of Biblical Genesis, and disbelieves anything that contradicts that content. The evolutionist, by contrast, is thoroughly committed to *method,* namely drawing logical inferences from reproducible observations. Whereas the evolutionist will revise current content if the results of the method so dictate, the creationist has no method and simply relies on an inerrant text.

It is not rational, therefore, for the well-meaning evolutionist to expect that there is some critical body of evidence, external to literally interpreted Biblical claims, that will win over a creationist, because there is none, for the rules by which one assesses "truth" are fundamentally different for each side of the debate.

I have found that focusing on the underlying epistemologies of different realms of knowledge—science, religion, the arts—is more instructive for students as a way for their discovering what is more likely credible and useful with respect to certain aspects of human experience. Thus, one should rely on the epistemology of science for the removal of a cancer; religious belief might console after the death of a loved one; and the arts can enrich aesthetic experience.

This emphasis on an epistemological approach to knowledge will win over many more adherents to evolution in particular, and science more generally, than the fruitless debates about creationism that too often degenerate into "is"/"isn't."

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Geologic Field Trip Access to National Forests

John Dragonetti and David Applegate, American Geological Institute Government Affairs Program, 4220 King Street, Alexandria, VA 22302-1502, govt@agiweb.org

Among geoscientists, there is no activity quite so cherished as the geologic field trip. For students and professionals, the opportunity to get out on the outcrop and experience the natural laboratory is for many the defining experience of our occupation. Likewise, summer field camp remains a key component of undergraduate geoscience curricula. Many of these field trips and camps take place in the western United States, much of which is federal land managed principally by the Department of the Interior's National Park Service and Bureau of Land Management, and the U.S. Department of Agriculture's Forest Service. Although field trip leaders are accustomed to restrictions on access and sample collecting at national parks, they are used to minimal contact with other land managers. Within that context, GSA and other professional societies have received several complaints this past year from geologic field trip leaders concerning entry onto Forest Service lands—specifically, incidents in which they were told that they were considered to be outfitters or guides and would need to obtain proper permits to conduct their field trips.

Because of the importance of these activities to our community, these societies asked the American Geological Institute's Government Affairs Program to look into this matter. AGI then initiated contact with Forest Service geologists in an attempt to determine the extent of the problem. At present, the incidents appear to be isolated, and both we and the Forest Service hope that further incidents can be avoided through improved communication at all levels. Such improvement will have the added effect of increasing land managers' awareness and understanding of geoscience activities, which can lead in time to the improved use of science in public land-management decision making.

Brief History of Access to Public Lands

Procedures regarding the use of federal lands have changed dramatically over time, for the most part tracking changes in public perception of what (and whom) these lands are for. Many still share a philosophy that there should be unobstructed access to properties designated as public lands, a way of thinking that dates back to earlier days when there was essentially no management of the public domain, much of which was perceived as an uninhabited wasteland. In the days when the Homestead Act of 1862 prevailed, government land would frequently pass into private ownership, with forests cleared for farming and other purposes. This situation changed dramatically when the first national forests were established with passage of the Forest Reserve Act of 1891. This Act allowed the President to set aside lands containing forests as "public reservations." Subsequent legislation, such as the Organic Administration Act of 1897, the Mineral Leasing Act of 1920, and the Taylor Grazing Act, have broadened the original authority and extended similar rule to other public lands.

The large-scale disposal of public lands ended in 1976 with the passage of the Federal Land Policy and Management Act that mandated the public ownership of government lands in perpetuity. Lands administered by the Forest Service and the Bureau of Land Management after 1976 are managed under the concept of multiple use, and regulations have been adopted to govern timber sales, grazing, recreation, mineral development, and other uses. Although the nation's citizens can gain admittance to almost all federal lands, the agencies responsible for monitoring activities on lands under their jurisdiction have been mandated to protect resources, prevent degradation of the land, assure public health and safety of those occupying such lands, confirm that accessibility responds to the overall public need and provide for a fair-market return to the public from commercial uses.

It appears that the current situation of heightened enforcement of permitting regulations has evolved over time for a number of reasons, including increased sensitivity for the protection of government-owned vertebrate fossils and archeological remains and sites, and an ever-growing concern for the environment, particularly through the protection of various sites designated as Wilderness areas. There has also been a dramatic increase in public use of Forest Service lands. Whereas visits to the National Park System have remained nearly constant in recent years, the number of visitors to national forests has risen rapidly in part due to the less stringent use restrictions on these lands. Ironically, the volume of people seeking to get away from National Park Service regulations is forcing Forest Service managers to adopt more stringent controls.

One factor making interaction with National Park Service personnel more common is the sheer size of the lands overseen by the Forest Service—three times that of the National Park System. Currently, the National Park Service manages 78 million acres, the Forest Service manages 191 million acres, and the Bureau of Land Management manages 266 million acres. It is anticipated that these acreages will increase as the public seeks to expand its ownership of lands containing cultural, historical, or other unique features as well as locations of environmental sensitivity or scenic attraction.

Access Restrictions

In the National Park System, geological field work requires permits for any kind of sample collection (not just fossils), and fairly stringent reporting specifications are in force. Special-use permits for groups and other restrictions go with the territory. But several field trip leaders have been surprised to find out that special-use permits are also required for their visits to national forests. In the Shoshone National Forest in Montana, for example, a document has been designed specifically to make it clear that forest managers consider course work on public lands to be an institutional use for which a special-use permit must be obtained.

Forest Service regulations broadly define outfitting or guiding as the provision of virtually any sort of services, including "education, research, training, [or] interpretation." Consider the following determining factors: (1) Is there an entry or participant fee charged? (2) Is the primary purpose to sell goods or services? (3) Is the field trip leader compensated in any way (even just expenses) for the trip? (4) Is the institution reimbursed for costs related to the trip? If the answer to any one of these questions is affirmative, then the trip could be considered outfitting or guiding. But the regulations draw an important distinction between commercial outfitting, "in which outfitting services are provided as a business," and institutional outfitting, "in which outfitting services are provided by an established organization or institution having significance to society (e.g., church, university) in order to contribute to the cause of the organization." Permits are required for both categories, and issuance of a permit is not automatic. Factors such as party

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Natural Hazards: Mitigation, Not Litigation

David J. Verardo, *1997–1998 GSA Congressional Science Fellow*

Against the backdrop of one of the most developed El Niño events recognized to date, natural hazards are receiving a great deal of attention at the National Academy of Sciences, by an innovative consortium of public and private groups called Public Private Partnership 2000 (PPP 2000), and in the U.S. Congress.

The National Research Council (NRC) Board on Natural Disasters appointed a new committee on Assessing the Costs of Natural Disasters and held its first meeting December 15–16, 1997. The two-year study was initiated by the Federal Emergency Management Agency (FEMA) and was motivated by increasing national exposure, over the past 30 years, to losses from a broad spectrum of natural hazards. This increased exposure results from several factors, including continued population growth and development in disaster-prone areas. The goal of the NRC study is to create standard economic measures to estimate losses. Currently, the economic costs of natural disasters vary widely because there are no consistent measures for estimating losses. Although mitigation costs are known, it is often unclear how best to implement mitigation or preventive measures. Consequently, the response to natural hazards has been less than satisfying from a technical and policy standpoint. Without standard and accurate measures of loss, mitigation is hampered and public safety is jeopardized.

In a 1996 report to the NRC, "Understanding Risk: Informing Decisions in a Democratic Society," the Committee on Risk Characterization outlined several

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size and land-use allocation may be considered in the decision to issue a permit. Geoscientists leading business-related trips could fall under the commercial definition and face stiffer requirements.

Special Cases

Land managers have a particular sensitivity for behavior within Wilderness areas and other specially designated areas such as sites where vertebrate fossils exist. At such locations, the removal of material is highly regulated. In Wilderness areas, removal of specimens can be accomplished only with written permission or under a special-use permit, and commercial activities are essentially prohibited. Therefore, field trips not specifically designed for scientific investigation might not be able to gain access to those properties.

With respect to vertebrate fossils, there is an existing permit process that allows the collection and removal of fossils for placement in an accredited institution on permanent loan. In such instances, the government retains ownership, and such materials may only be transferred from the authorized establishment with the written permission of a certified Forest Service officer. The Forest Service is particularly interested in protecting rare and unique vertebrate fossil sites from deterioration by overuse. As a result, certain national forests reserve the right to require that information on particular fossil localities or specimens collected be kept confidential. Such a requirement runs counter to normal scientific reporting practices, and efforts must be made to limit the exercise of this requirement to only the most sensitive cases.

Bridging the Gap

For field trip leaders accustomed to bringing groups onto public lands without obtaining a permit or notifying the land managers, being told that they need to do so may come as a shock. Questions such as cost, number of permits issued, time it takes to obtain a permit, and the paperwork involved all leap to mind. The logistics of organizing a field trip or field camp may seem daunting enough without the litany of regulations and designations described above. Ensuring that the laws designed to protect public lands do not interfere unduly with those who seek to study and learn from those lands will take a concerted effort by individual geoscientists as well as the societies that represent them.

For an individual trip, the borders for national parks and forests are generally clearly marked, and boundary information is also readily available at each of the nine Forest Service regional offices where there is a staff geologist in residence who, along with the regional special-use manager, may provide help. Permits for entry onto Forest Service lands may be applied for at the forest headquarters. Many of the national forests also have a geologist on staff. When planning field trips, the earliest possible communication with the Forest Supervisor, District Ranger, or any of the geologists on the national forest staff is highly recommended. Not only will this provide the field trip leader with the permit conditions that might apply to geological investigations within a specific forest, it may provide valuable insights as to the existence and location of little-known geological features. Contact information can be obtained from the Forest Service Web site, http://www.fs.fed.us.

For the geoscience community, the concerns raised by field trip leaders over Forest Service policy present an opportunity to work with the geoscientists and land managers at this agency to develop a better understanding of how scientific field trips should be treated. Establishing a national precedent for this type of use could provide guidance to individual forests that might otherwise develop their own standards.

In the long run, the geoscience community is better served by increased communication between field trip leaders and participants, field camp personnel, and individual researchers with the people who are responsible for managing public lands. A growing concern within our profession is the lack of attention paid to geoscience input when it comes to land-management decisions. Although contacts made at the level of an individual forest or regional headquarters may seem inconsequential to some, the nature of agencies such as the Forest Service is that a great deal of the decision-making authority and power are distributed at precisely those levels, not concentrated in Washington.

Although such a view is undoubtedly optimistic, we hope that it will put the concerns of field trip leaders into a broader context. AGI and GSA will continue to look into this matter to determine whether unduly burdensome requirements are being placed on geological field trips that might hamper our colleagues' ability to enjoy and participate in these tremendous learning opportunities. In order to improve our own understanding, we particularly welcome comments from geoscientists reading this article who have had experience with the U.S. Forest Service or other land management agencies.

The AGI Government Affairs Program is supported by AGI's 31 member societies, including GSA. For information on environmental, energy, resource, and science policy issues, visit the program's Web site at www.agiweb.org. ■

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guiding principles for examining risks that have direct application to natural hazards. First, risk characterization should be a decision-driven activity directed toward informed choices and problem solving. To be of value to decision makers, risk characterization should follow a phased approach beginning with scientific studies that provide baseline information. This is followed by analysis that must be conveyed in a manner meaningful to the nonspecialist. Evaluating a risk situation requires a broad understanding of the relevant losses, harms, or consequences to the interested and affected parties. The committee further described risk characterization as an analytic-deliberative process wherein early and explicit attention to problem formulation yields substantial benefits. Furthermore, flexibility in analysis and deliberation by interested and affected parties allows a problem to be shaped and redefined as the circumstances of data collection and analyses evolve over time.

The importance of embracing such tenets is echoed by participants in PPP 2000. PPP 2000 is a coalition of 19 agencies, comprising the Subcommittee on Natural Disaster Reduction (SNDR), part of the National Science and Technology Council's Committee on the Environment and Natural Resources, the Institute for Business and Home Safety (IBHS), and several nonprofit organizations. The goal of PPP 2000 is to "seek new opportunities for government and nonprofit, private sector organizations to work together to reduce vulnerability to and losses from natural hazards in communities throughout the Nation." Meeting these goals centers around fostering an open dialogue between public and private groups through a series of fourteen forums offered in Washington, D.C., and organized by William H. Hooke, chairman of SNDR, and Harvey G. Ryland, president of IBHS. The first forum, convened in September 1997, focused on initiatives in the insurance sector. Of great concern were state laws that guarantee insurance, at subsidized rates to all citizens, with the effect of creating unintentional incentives to build or rebuild in disaster-prone areas. As noted by Tim Cohn of the U.S. Geological Survey, forum participants discussed several ideas, such as making natural disaster reduction a public value, disaster impact statements, structural and nonstructural mitigation, establishing effective warning systems, examining mitigation financing, creating databases containing disaster information using standardized classifications and formats, and including all stakeholders in discussions on natural-disaster reduction.

At the second forum, in November, the emphasis was on the uncertainty of managing catastrophic risks. An interactive session focused on the actuarial aspects of risk and described a national situation in which insurance premiums and risks from natural disasters were decoupled. Forum participants questioned whether insurance rate regulation was justified and if catastrophe insurance could be expanded. Participants also discussed the role of science and modeling in guiding hazard policy and mitigation. At the core of the discussion was the role that government and the private sector could play in providing hazard awareness to the public and affected industries.

The third forum in the series, in January 1998, centered on the problems of "Cities and Megacities at Risk" from natural hazards. The issue of natural disasters is of importance to Oregonians and in an opening statement, Senator Ron Wyden (D—OR) remarked, "In my home state of Oregon, we are keenly aware of the dangers posed by natural disasters and are following a comprehensive strategy of earthquake and tsunami risk reduction.… Following flooding in Oregon during the spring of 1997, several policy issues came to light including the need for flexible funding for disaster relief projects and federal recognition of the benefit of land use plans and regulations that prevent settlement in disaster prone areas and remove people from vulnerable areas."

The Oregon viewpoint on natural hazards was further illuminated by the shared experiences of Oregon State Geologist Don Hull and Deputy State Geologist John Beaulieu. Hazards in Oregon result principally from geologic processes such as earthquakes, tsunamis, and volcanic eruptions. Oregon's strategy for coping with such risks centers on the systematic mapping of hazards, assessment of risk posed by future hazard events, land-use planning, safer new buildings, strengthening older buildings, and public education and training in schools. Systematic mapping of hazards provides the basis for broad public understanding and, in turn, subsequent steps to reduce risk. Some highlights from the Oregon perspective included the FEMA-guided development of a new model for calculating risk, the HAZUS model, which used Portland, Oregon, as the initial prototype for model design; Oregon state legislation that was passed in 1995 to limit the construction of critical buildings such as schools, hospitals, and fire stations in coastal areas that have been mapped as vulnerable to tsunami impacts; improved building codes that have led to construction of safer new buildings; and hazard-awareness education in Oregon schools in grades K–12 that includes earthquake drills and training and evacuation drills for tsunamis.

In Congress, the U.S. House of Representatives Water Resources and Environment Subcommittee met on January 28, 1998, to hear testimony on disaster mitigation. The hearings began with impassioned testimony by Representatives Joe Skeen (R—NM), Howard McKeon (R—CA), and Ted Strickland (D—OH) describing devastation in their districts from natural hazards. Although those present at the hearing understood that natural disasters cannot be fully prevented and had praise for FEMA's handling of recent emergencies, it was apparent that no one wanted the nation to lurch from one disaster project to another within a patchwork of "fail and fix." There is a burgeoning sense in Congress to develop a comprehensive policy for dealing with natural disasters that aids the public through cooperative mitigation and legislation rather than adversarial litigation. This effort, however, requires advice from geoscientists if it is to succeed.

Natural-hazard risk assessment is a passionless diversion of mathematical models with natural processes and responses as variables and fatalities and property damage as output. The reality of a natural disaster is no abstraction; lives are lost, communities are disrupted, and people are changed. It is incumbent upon geoscientists to work with legislators so that those with an intimate knowledge of earth processes and natural forces can guide the legislative process.

Conceptually, public policy is like geologic time and the national debt. Few can fully comprehend the significance of billions of years or trillions of dollars because the numbers are beyond everyday experiences. Likewise, developing public policy often seems daunting because of the vast range of possibilities and opinions throughout America. In a practical sense, formulating public policy hinges on communication within a relatively small group of people who trust one another. It does not follow from some theoretical abstraction of an issue or the people's will.

The bottom line is that until people embrace disaster reduction as a public value, human and organizational behaviors will not change and society will repeat its mistakes until it appears as though, as baseball-great Yogi Berra once quipped, "It's déjà vu all over again." ■

Dave Verardo, 1997–1998 GSA Congressional Science Fellow, serves on the staff of Senator Ron Wyden (D—OR). This one-year fellowship is supported by GSA and by the U.S. Geological Survey, Department of the Interior, under Assistance Award No. 1434-HQ-97-GR-03188. The views and conclusions contained in this article are those of the author and should not be interpreted as necessarily representing the official policies, either expressed or implied, of the U.S. government or GSA. You can contact Verardo by mail at 717 Hart Senate Building, Washington, DC 20510, by phone at (202) 224-3430, or by e-mail at david_verardo@wyden.senate.gov.

GSA ANNUAL MEETING — 1999

Denver, Colorado
October 25–28
Colorado Convention Center

GENERAL CO-CHAIRS

Mary J. Kraus, David Budd, *University of Colorado*

TECHNICAL PROGRAM CHAIRS

Craig Jones, G. Lang Farmer, *University of Colorado*

Due date for symposia and theme proposals: ***January 6, 1999***

CALL FOR FIELD TRIP PROPOSALS

We are interested in proposals for single-day and multi-day field trips beginning or ending in Denver, and dealing with all aspects of the geosciences. Please contact the Field Trip Co-Chairs:

Alan Lester
Dept. of Geological Sciences
University of Colorado
Campus Box 399
Boulder, CO 80309-0399
(303) 492-6172
fax 303-492-2606
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GSA SECTION MEETINGS—1998

CORDILLERAN SECTION, April 7–9, California State University, Long Beach, California. Information: Stan Finney, Dept. of Geological Sciences, California State University, Long Beach, CA 90840, (562) 985-8637, scfinney@csulb.edu.

ROCKY MOUNTAIN SECTION, May 25–26, Northern Arizona University, Flagstaff, Arizona. Information: Larry Middleton, Dept of Geology, Box 4099, Northern Arizona University, Flagstaff, AZ 86011, (520) 523-2492, Larry.Middleton@nau.edu. *Preregistration Deadline: April 24, 1998.*

Call for Symposium and Field Trip Proposals, 1999 Cordilleran Section Centennial Meeting

The GSA Cordilleran Section Centennial meeting will be at the University of California, Berkeley, June 2–4, 1999. The theme is **Century of the Pacific Rim: The Past as Prologue to the Future.** Hosts will be the Department of Geology and Geophysics, the Museum of Paleontology and the Earth Resources Center of the University of California at Berkeley. Sponsors will be the Association for Women Geoscientists (San Francisco Bay Area chapter), the Paleontological Society, the Seismological Society of America, and the Society of Engineering Geologists.

The focus for this meeting is the impact of Cordilleran geology and paleontology on the global geological framework. Symposia and field trips will highlight the many geological, geophysical and paleontological studies that have originated with Cordilleran geoscientists, and the contributions these scientists and Cordilleran sites have made to the advancement of the field over the past 100 years. We will also look to future contributions that geoscientists and educators can make to the global environment in the next 100 years. The invited program and field trips are listed below. Suggestions for additional technical sessions and field trips are welcome.

Proposed Invited Symposia and Technical Sessions:

- Cordilleran Geology, Past and Future: Impact on Global Geological Framework
- History of the Cordilleran Section, Its Geologists and Paleontologists
- Pacific Rim Symposium on Mine Restoration
- Pacific Rim Symposium on Ore Deposits
- Earthquake Source Mechanisms
- Sedimentary Record of Cordilleran Tectonics and Earthquakes
- Evolutionary History of Pacific Rim Biota
- Paleoceanography of the Eastern Pacific Ocean
- Geochronology from the Cordilleran Perspective: Pioneering Methods and Applications
- The Role of Hydrogeologic Uncertainty in Subsurface Remediation

To suggest other symposia or technical sessions, contact, by **June 1, 1998,** one of the program co-chairs: George Brimhall, Dept. of Geology and Geophysics, University of California, Berkeley, CA 94720; (510) 642-5868, brimhall@socrates.berkeley.edu; or Eldridge Moores, Dept. of Geology, University of California, Davis, CA 95616, (916) 752-0352; moores@geology.ucdavis.edu.

Proposed Invited Field Trips:

- Sierra Nevada Foothills Accretionary Belt
- Franciscan Metamorphics at Panoche Pass
- Franciscan of the San Francisco Bay Area
- Coast Range Ophiolite
- High Sierra Glacial Geomorphology
- San Andreas Fault
- Long Valley Caldera
- Environmental Geology of the Homestake Mine
- Gold Deposits of the Mother Lode
- The Salinian Block
- Geology of the Hayward Fault
- Mining History of Diablo Range, Black Diamond to New Idria
- Cenozoic Volcanism at the Sutter Buttes
- Transect Across California (via train; private car on AMTRAK)
- Accretionary Tectonics of the Klamaths and Trinity Alps
- The Geysers
- Geology of the Wine Country
- The Monterey Formation
- Bodega Bay, San Andreas Fault
- Mesozoic Paleontology and Stratigraphy in Southern San Joaquin Valley

To suggest other field trips, contact, by **May 15, 1998,** Field Trip Chair Steve Graham, Dept. of Geological and Environmental Sciences, Stanford University, Stanford, CA 94305-2115, (650) 723-0507, graham@pangea.Stanford.edu.

For further information, contact General Chair Doris Sloan, Dept. of Geology and Geophysics, University of California, Berkeley, CA 94720, (510) 642-3703, dsloan@socrates.berkeley.edu. The Web site is at http://socrates.berkeley.edu/~earthres/GSApage.html ■

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Positions Open

CONCORD COLLEGE

Needed — Assistant Professor of Physical Sciences at Concord College to teach a wide range of subjects in geology, serve as academic advisor for an Interdisciplinary Degree program in Environmental Geoscience and serve as Interim Department Chair for a small Physical Science Department (chair may become permanent). Salary $30,000 to $35,000 based on qualifications and experience with additional pay for summer/overload teaching. Earned doctorate in geology. Teaching experience and knowledge of Appalachian geology desirable. The candidate should have strong written and oral communication skills. Concord College is a four year, liberal arts state supported college with an enrollment of about 2,600 students in southern West Virginia. Please send letter of interest, vitae, and three letters of reference to the Human Resources Office, Concord College, P.O. Box 1000, Athens, WV 24712. Application review began 3/15/98 and will continue until position is filled. Concord College is an affirmative action/equal opportunity employer.

HYDROGEOLOGIST

Kansas Geological Survey, University of Kansas, Lawrence. Full-time position on KU staff at faculty-equiv. rank of assistant or associate scientist depending on qualifications. Requires Ph.D. (or expected within 6 months) with hydrogeology emphasis. Research/publications on simulation of physical/biochemical processes affecting transport in porous media supplemented with practical experience. Background in stochastic applications to gw flow/transport is desirable. The Geohydrology Section has 9 full-time professionals with additional support personnel. Emphasis on state-of-the-art field studies and complementary theoretical research. Opportunity to pursue individual and cooperative research of relevance to Kansas and teach/advise students at KU. Complete announcement available from S. Cox, Personnel Services (785) 864-3965 or from http://www.kgs.ukans.edu. Ref: 98W0189. Application deadline: June 1, 1998, postmark. For further information contact Jim Butler at jbutler@kgs.ukans.edu. KU is an EO/AA employer.

QUATERNARY GEOLOGIST
DESERT RESEARCH INSTITUTE
QUATERNARY SCIENCES CENTER
POSITION #P-30-027

The Quaternary Sciences Center (QSC) of the Desert Research Institute (DRI) has an opening for a geologist specializing in the study of earth surface hazards and Latin America Business Development. The preferred level of appointment is Assistant Research Professor. Applicants must have a Ph.D. and demonstrated experience in the application of geomorphology and/or Quaternary geology toward the evaluation and identification of natural hazards, such as but not limited to earthquakes, landslides, debris flows, volcanic and anthropogenic disturbances to fluvial systems. Fluency in Spanish and/or Portuguese; good communication skills including the ability to work with scientists from diverse fields, as well as representatives from government agencies and private businesses in Latin America; and demonstrated ability to develop and

CALENDAR

Only new or changed information is published in *GSA Today*. A complete listing can be found in the **Calendar** section on the Internet: **http://www.geosociety.org.**

1998 Penrose Conferences

May

May 14–18, **Linking Spatial and Temporal Scales in Paleoecology and Ecology,** Solomons, Maryland. Information: Andrew S. Cohen, Dept. of Geosciences, University of Arizona, Tucson, AZ 85721, (520) 621-4691, fax 520-621-2672, acohen@geo.arizona.edu.

June

June 4–12, **Evolution of Ocean Island Volcanoes,** Galápagos Islands, Ecuador. Information: Dennis Geist, Dept. of Geology, University of Idaho, Moscow, ID 83844, (208) 885-6491, fax 208-885-5724, dgeist@uidaho.edu.

July

July 4–11, **Processes of Crustal Differentiation: Crust-Mantle Interactions, Melting, and Granite Migration Through the Crust,** Verbania, Italy. Information: Tracy Rushmer, Dept. of Geology, University of Vermont, Burlington, VT 05405, (802) 656-8136, fax 802-656-0045, trushmer@zoo.uvm.edu.

September

September 13–17, **Ophiolites and Oceanic Crust: New Insights from Field Studies and Ocean Drilling Program,** Marshall, California. Information: Yildirim Dilek, Dept. of Geology, Miami University, Oxford, OH 45056, (513) 529-2212, fax 513-529-1542, dileky@muohio.edu.

1998 Meetings

May

May 2–6, **34th Forum on the Geology of Industrial Minerals,** Norman, Oklahoma. Information: Oklahoma Geological Survey, 100 E. Boyd, Room N-131, Norman, OK 73019, (405) 325-3031, fax 405-325-7069, jlcoleman@ou.edu.

May 22–23, **Recent History of the Illinois-Kentucky Fluorspar District** symposium and field trip. Information: Alan Goldstein, Falls of the Ohio State Park, P.O. Box 1327, Jeffersonville, IN 47131-1327 (812) 280-9970, ext. 403, falls3@aye.net, http://www.cismall.com/fallsoftheohio/symposium.html.

June

June 25–27, **Council on Undergraduate Research 7th National Conference,** Los Angeles, California. Information: Council on Undergraduate Research, 734 15th St., NW, Suite 550, Washington, DC 20005, (202) 783-4810, fax 202-783-4811, cur@cur.org, http://www.cur.org.

July

July 13–17, **Society for Industrial and Applied Mathematics (SIAM) Annual Meeting,** Toronto, Ontario. Information: SIAM Conference Coordinator, 3600 University City Science Ctr., Philadelphia, PA 19104-2688, (215) 382-9800, fax 215-386-7999, meetings@siam.org.

September

September 9–14, **6th International Conference on Geoscience Information (GeoInfo VI),** Washington, D.C. Information: Science Editing & Information Management, 1998 International Meeting, American Geophysical Union, 2000 Florida Ave. NW, Washington, DC 20009, edinfo98@kosmos.agu.org, http://earth.agu.org/editorinfo98.

September 14–17, **Environmental and Engineering Geophysical Society, European Section,** Barcelona, Spain. Information: Victor Pinto Miguel, Fac. Geol., University of Barcelona, G.P.P.G. c/Marti Franques s/n, Barcelona 08071, Spain, victor@natura.geo.ub.es, phone 34 3 4021396, fax 34 3 4021340, www.geo.ub.es/~eegs4/index.html.

September 15–17, **Fourth International Symposium and Exhibition on Environmental Contamination in Central and Eastern Europe,** Warsaw, Poland. Information: Warsaw '98 Symposium, Florida State University, 2035 East Paul Dirac Dr., 226 HMB, Tallahassee, FL 32310-3700, (850) 644-7211, fax 850-574-6704, Warsaw98@mailer.fsu.edu.

September 18–20, **National Association of Geoscience Teachers—Far West Section Fall Field Conference:** Geology of Yosemite National Park and Pinnacles National Monument, California. Information and registration: Garry Hayes, Modesto Junior College, 435 College Ave., Modesto, CA 95350; garry.hayes@ccc-infonet.edu, http://virtual.yosemite.cc.ca.us/ghayes/nagt.htm.

September 27–Oct. 2, **AIH-IAH Joint Conference,** Gambling with Groundwater, Las Vegas, Nevada. Information: AIH/IAH Conference, 2499 Rice St., Suite 135, St. Paul, MN 55113-3724, fax 612-484-8357, AIHydro@aol.com.

October

October 8–13, **Dust Aerosols, Loess & Global Change:** Interdisciplinary Conference and Field Tour on Dust in Ancient Environments and Contemporary Environmental Management, Seattle, Washington. Information: Alan Busacca, Crop and Soil Sciences, Washington State University, Pullman, WA 99164-6420, (509) 335-1859, fax 509-335-8674, busacca@wsu.edu, http://www.eus.wsu.edu/c&i/programs/dust.htm.

October 19–20, **Seismological Society of America Eastern Section 70th Annual Meeting,** Millersville, Pennsylvania. Information: Charles K. Scharnberger, Dept. of Earth Sciences, Millersville University, P.O. Box 1002, Millersville, PA 17551, (717) 872-3295, fax (717) 871-4725, cscharnb@marauder.millersv.edu, http://www.millersv.edu/~esci/esssa98. *(Abstract deadline: September 18, 1998.)*

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promote opportunities for applied and basic research in Latin America. In addition, this position will be responsible for the Institute-wide development of the business, applied research, and basic research opportunities in Latin America. Candidates must also demonstrate abilities in quantitative geomorphologic analyses of landscapes; Quaternary geologic field methods including geologic mapping, stratigraphic analyses, and dating of Quaternary deposits; experience in the application of these Quaternary geologic field methods in investigations of problems related to earth surface hazards, landscape stability, landscape reclamation, and/or environmental assessments; and experience working with geotechnical firms. This position will be located either in Reno or Las Vegas, Nevada. To Apply: Submit (a) curriculum vitae; (b) statement describing research interests and goals; and (c) the names, addresses, and telephone numbers of four references to: Recruitment Office, Desert Research Institute, P.O. Box 19040, Las Vegas, NV 89132-0040. Application Deadline: To ensure full consideration, applicants are encouraged to have all information on file by May 1, 1998. The date for assumption of this position is July 1, 1998. For additional information regarding this position, contact Dr. Eric Mcdonald, at emcdonald@dri.edu, Search Committee Chair. For complete position description visit our web site at www.dri.edu.

LECTURER/RESEARCH ASSOCIATE IN GEOLOGY

A non-tenure track teaching/research position to teach two courses and conduct research during the academic year 1998–99. One of the courses will be an introductory course in Earth Systems Science and the other either geomorphology or geochemistry. The successful applicant will be expected to conduct research in his/her specialty. Collaborative research with members of the department is encouraged if possible.

The Ph.D. is required. Applicants should send letter stating research interests, a resume, and three letters of recommendation to: Leonard Alberstadt, Geology Department, Box 1805, Station B, Vanderbilt University, Nashville, TN 37235 USA. Deadline for receiving applications is May 1.

For additional information about the department and the university see our WEB site: http://geo.cas.vanderbilt.edu.

Vanderbilt University is an equal opportunity educational institution.

CLASTIC SEDIMENTARY GEOLOGY
UNIVERSITY OF ALASKA FAIRBANKS

The Department of Geology and Geophysics and the Geophysical Institute of the University of Alaska invite applications for a tenure-track Assistant Professor position to begin fall, 1998 or spring, 1999. We seek a creative, field-oriented clastic geologist with broad interests in tectonics and basin analysis. The position will carry significant responsibilities in both teaching and research.

Requirements include a Ph.D. in geology, with expertise in clastic stratigraphy, sedimentology, and/or petrology. Teaching responsibilities will include historical geology, sedimentology, physical geology, and other sedimentary geology courses. The successful candidate is expected to develop an externally funded research program, supervise M.S. and Ph.D. students, and collaborate with existing faculty with interests in structural geology and tectonics, carbonate stratigraphy and sedimentology, and reservoir modeling. Experience and interest in petroleum-relevant research are essential, and petroleum industry experience is desirable.

Applicants should send a résumé and publication list, statement of research and teaching interests, copies of key publications, and names, addresses, telephone numbers, and e-mail addresses of three references. Send applications or requests for further information to: Clastic Geologist Search Committee, Department of Geology and Geophysics, University of Alaska—Fairbanks, Fairbanks, AK 99775-5780. Screening of applications will begin on May 15, 1998, and continue until the position is filled. A more complete position description is available at: http://www.uaf.edu/geology/jobs.

The University of Alaska is an equal opportunity/affirmative action employer and educational institution. Women and minorities are encouraged to apply. Your application for employment with the University of Alaska is subject to public disclosure under the Alaska Public Records Act. Persons hired by the University of Alaska must comply with provisions of the 1986 Immigration Control Act and are expected to possess a valid social security number.

GEOMORPHOLOGY POSITION

The University of Arizona Department of Geosciences invites applications for a tenure-track appointment in geomorphology, preferably at the assistant professor level. A Ph.D. or equivalent degree is required.

We seek applicants with a strong background in geomorphology, with expertise in one of several sub-disciplinary areas, including, but not confined to, tectonic, fluvial or glacial geomorphology. Preference will be given to candidates with a strong record of publication and potential for obtaining research funding. Commitment to undergraduate and graduate education is essential, and preference will be given to candidates with demonstrated teaching ability.

The Department of Geosciences is strongly committed to excellence in surface process studies, partly through collaborations with allied units on campus, including Hydrology, and Soils, Water, and Environmental Sciences, where searches in fields closely related to geomorphology are being developed, the Tree-Ring Laboratory, and the U.S. Geological Survey.

The selection processes will begin July 1, 1998 and will continue until the position is filled. Interested applicants should submit a curriculum vitae, a statement of research and teaching interests, and a list of at least three references with addresses, e-mail, phone and fax numbers to: Joaquin Ruiz, Chair, Department of Geosciences, University of Arizona, Tucson, AZ 85721, phone: (520) 621-6024, fax 520-621-2672, chair@geo.arizona.edu.

The University of Arizona is an EEO/AA Employer. M/W/D/V.

FACULTY POSITION IN SURFICIAL PROCESSES
FRANKLIN & MARSHALL COLLEGE

The Department of Geosciences invites applications for an entry-level visiting faculty appointment for the academic years 1998-99 and 1999–2000. The successful candidate will teach undergraduate courses in geomorphology, hydrology, introductory environmental geology, and a seminar in environmental problems. Expertise and the ability to teach a course in GIS are also desirable.

A Ph.D. in the geosciences, an ongoing program of research and some teaching experience are required. Women and members of minority groups are particularly encouraged to apply. Please send letter of application including a statement of teaching and research interests, curriculum vitae, graduate transcripts, and three letters of recommendation to: Rob Sternberg, Chair, Department of Geosciences, Franklin & Marshall College, Lancaster, PA 17604-3003 (R_Sternberg@FandM.edu). Review of applications will begin March 16 and continue until the position is filled.

Franklin & Marshall is a highly selective liberal arts college with a commitment to the integration of teaching and research. For additional departmental information, see our web page at http://www.fandm.edu/departments/Geosciences/Geosciences.html EOE/AA.

DEPARTMENT OF PHYSICAL SCIENCES
KUTZTOWN UNIVERSITY
HARD-ROCK GEOLOGIST (TEMPORARY)

Applications are invited for a full-time, temporary faculty position in Hard-Rock Geology beginning August, 1998. A Ph.D. in Hard-Rock Geology is required along with a commitment to undergraduate teaching. Primary responsibilities include: Igneous and Metamorphic Petrology, Structural Geology, and Physical Geology. The teaching load consists of twenty-four contact hours per academic year. Submit a letter of application, curriculum vitae, undergraduate and graduate transcripts, a brief statement of teaching philosophy, and three current letters of recommendation to: Chairperson of Hard-Rock Geology Search Committee, Department of Physical Sciences, P.O. Box 730, Kutztown University, Kutztown, PA 19530 by April 21, 1998. Kutztown University is an AA/EEO employer. Also on World-Wide Web at http://www.kutztown.edu/acad/geol.

DEPARTMENT OF PHYSICAL SCIENCES
KUTZTOWN UNIVERSITY
SOFT-ROCK GEOLOGIST (TEMPORARY)

Applications are invited for a full-time, temporary faculty position in Soft-Rock Geology beginning August, 1998. A Ph.D. in Soft-Rock Geology is required along with a commitment to undergraduate teaching. Primary responsibilities include: Paleontology, Sedimentation, and Physical Geology. The teaching load consists of twenty-four contact hours per academic year. Successful interview and demonstration of ability are required qualifications. Submit a letter of application, curriculum vitae, undergraduate and graduate transcripts, a brief statement of teaching philosophy, and three current letters of recommendation to: Chairperson of Soft-Rock Geology Search Committee, Department of Physical Sciences, P.O. Box 730, Kutztown University, Kutztown, PA 19530 by April 21, 1998. Kutztown University is an AA/EEO employer. Also on World-Wide Web at http://www.kutztown.edu/acad/geol.

TECTONIC GEODESY:
PROFESSOR AND DIRECTOR OF THE
INSTITUTE FOR CRUSTAL STUDIES

The Department of Geological Sciences at the University of California at Santa Barbara invites applications for a senior faculty position in Tectonic Geodesy. The appointment will be at the full professor level, with 50% in Geological Sciences and 50% as full-time Director of the Institute for Crustal Studies (ICS), commencing July 1, 1999, for a nominal period of 5 years. After that time the appointment will become 100% in Geological Sciences.

We seek an individual who conducts internationally recognized research in the fields of quantitative crustal deformation and plate tectonics. The appointee to this position will develop and teach undergraduate and graduate courses about the continuing tectonic evolution of the Earth in general and of southern California in particular. The appointee will also supervise graduate student research in these topics.

The ICS Director leads an organization with about eight staff members and about 40 Principal Investigators whose research activities focus on seismology, neotectonics, petrology, tectonic evolution of the Earth, and vadose zone monitoring of contaminants. The ICS portfolio includes approximately 55 research projects totaling about $6M. Administrative or project leadership experience is desirable.

The preferred deadline for applicaitons is June 1, 1998; however, applications will be considered until the position is filled. Please submit a curriculum vitae, statement of research, teaching, and administrative experience, along with the names of three references to: Professor Arthur G. Sylvester, Search Committee Chairman, and Associate Director, Institute for Crustal Studies Department of Geological Sciences, University of California, Santa Barbara, CA 93106-9630.

UCSB is an equal opportunity/affirmative action employer.

Services & Supplies

LEATHER FIELD CASES. Free brochure, SHERER CUSTOM SADDLES, INC., P.O. Box 385, Dept. GN, Franktown, CO 80116.

Opportunities for Students

Graduate Research Assistantships in Earth Surface Processes. Research assistantships are available at Iowa State University for motivated Ph.D. and M.S. students with interests in glaciology, geomorphology, or environmental geology. Research opportunities include field experiments on glaciers in Norway, laboratory and field studies of sediment deformation beneath glaciers and on hillslopes, and field studies of gully development in loess soils. For more information, contact Dr. Neal Iverson, Department of Geological and Atmospheric Sciences, Iowa State University, Ames, IA 50011. (515) 294-8048. e-mail: niverson@iastate.edu. Departmental web site: http://www.geology.iastate.edu.

Teaching Assistantships. Geology Department at California State University has teaching assistantships available for students wishing to pursue a M.S. in geology. Appointment carries tuition waiver and $10,000 salary for academic year. Department strengths are in the areas of sedimentary geology, petroleum geology, geophysics, hydrogeology and geochemistry, structural geology, and environmental geology. Bakersfield is located in the heart of California's petroleum and agricultural areas and abundant opportunities exist for industry-supported thesis projects. For additional information and application materials contact: Robert Horton, Graduate Coordinator, Department of Geology, California State University, Bakersfield, CA 93311-1099, (805) 664-3059, or visit the department's web site at http://www.geol.csubak.edu/Geology/.

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Abstracts Due
July 13

Preregistration Due
September 18

Registration and Housing Information
June *GSA Today*

Program Schedule
September *GSA Today* and the Web

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1998 ANNUAL MEETING AND EXPOSITION October 26–29, 1998

Tectonics and Geochemistry of the Northeastern Caribbean

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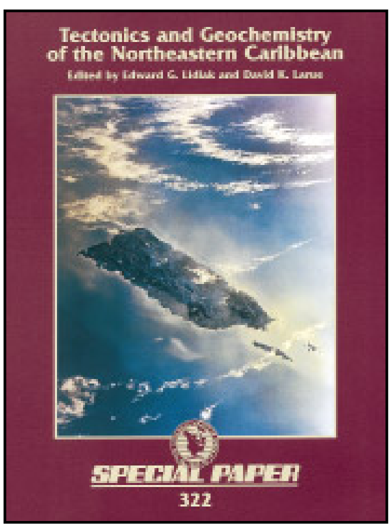

This up-to-date account of the geology of the northeastern Caribbean plate boundary region is the first general summation of this region since the publication of the DNAG series volume (H) on the Caribbean region (1990). The primary focus of this Special Paper is on the tectonics and geochemistry of the plate boundary, with emphasis on the island of Puerto Rico, the Puerto Rico trench, and adjacent areas. Following an introductory chapter on tectonic setting and stratigraphic correlations of the volcanic strata in Puerto Rico, five papers deal with geochemical aspects of these and related igneous rocks. A second group of three papers deal primarily with the tectonics and stratigraphy of Tertiary and younger rocks along the north coast of Puerto Rico and in the adjacent Puerto Rico trench. This is essentially a companion to GSA Special Papers 262 and 295; all three concern the circum-Caribbean plate margins.

SPE322, 222 p., indexed, ISBN 0-8137-2322-1, $68.00, Member price $54.50

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